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Memorandum

To: Aaron Silver and Grace Kane, DMJM Harris

From: Bob Elliot and Sam Gould, **Northwest Hydraulic Consultants**

Date: May 10, 2007

Re: Hydraulics for Woodinville SR202 Bridge

This technical memorandum outlines the hydraulic analysis conducted by Northwest Hydraulic Consultants (**nhc**) for the Sammamish Bridge and Road (SR202) project. The work carried out by **nhc** included fieldwork to set current and high water marks, developing and calibrating an updated hydraulic model of the study area, and calculating the water surface elevation at the highway bridge. Each of these items is discussed below.

Field Work

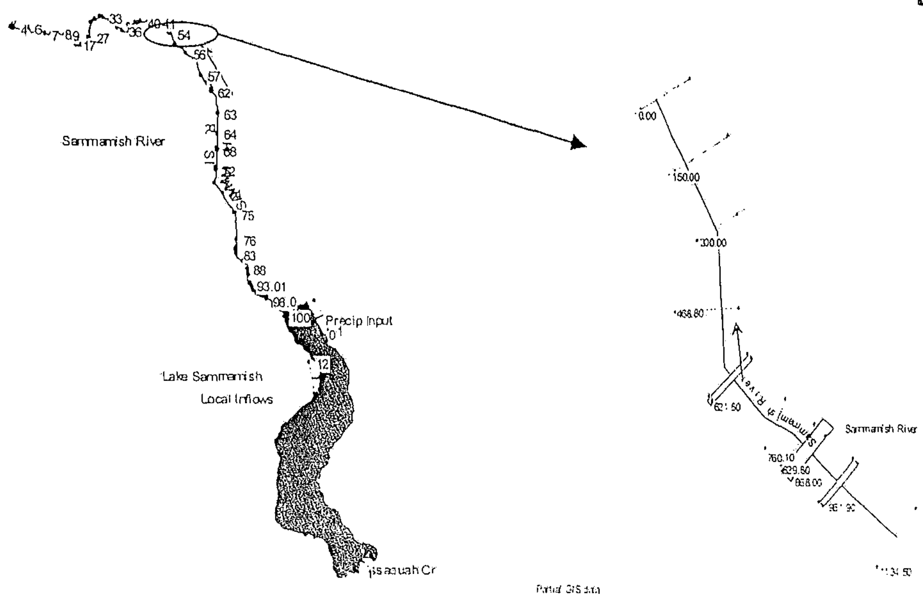
On November 9th 2006 field investigations were carried out by **nhc** to review the site, and set high water and current water level marks in the study area. Streams within the region had become swollen due to high rainfall, and the intent was to obtain useful data for calibrating the hydraulic model. River stages had already dropped by November 9th but not by too much. Compared to an extreme flood such as the 100-year, however, this event turned out to be relatively minor. Details on the acquisition of the high water and current water level marks, including their approximate locations, are given in Appendix A.

HEC-RAS Model

All hydraulic modeling was carried out using HEC-RAS 3.1.3. Two steady flow HEC-RAS models were used during this study, a full Sammamish River model and a site model shown in Figure 1. The full Sammamish River model was originally developed by **nhc** in HEC-2 and was later converted to HEC-RAS by the Corps of Engineers. It contains 126 cross sections representing the Sammamish River from the outlet of Lake Sammamish to Lake Washington. This model was used to generate downstream tailwater conditions for the site model.

The site model consisted of 12 cross sections and represents a 1200 ft reach of the Sammamish River surrounding the Woodinville SR202 bridge project. The model was constructed using 7 cross sections located by **nhc** and surveyed by Roth Hill for this project (see Appendix A), and 3 cross sections from the Full Sammamish River model. The SR202 bridge geometry was developed using the WSDOT bridge drawings. The geometry of the upstream and downstream railroad bridges were defined using data from the full Sammamish River model.

Figure 1 – Full Sammamish River Model and Site Model



a) Full Sammamish River Model b) Site Model

Calibration to the November 9th Current Water Level Marks

The HEC-RAS hydraulic models were calibrated using the current water marks from the November 2006 field work. The calibration process occurred in two steps. First the full Sammamish River model was run using the flow data shown in Table 1. These flow data were developed using provisional flow data from the King County gage at Sammamish River at USGS gage 12125200. The flow for each location was computed from the gage records by applying a drainage basin area ratio. The Manning's n coefficient in the full Sammamish River model was then adjusted until the current water level marks at all three bridges could be reproduced with reasonable accuracy. The final Manning's coefficient determined from this process was n = 0.028, which is reasonable for this river and comparable to **nhc**'s original calibration of the HEC-2 model that resulted in Manning's coefficients ranging from n = 0.026 to 0.031.

Table 1 – November 9 2006 Flow Data

Location	Flow [cfs]
Sammamish Lake Outlet to Bear Creek Confluence	485
Bear Creek Confluence to Little Bear Creek Confluence	855
Little Bear Creek Confluence to North Creek Confluence	936
North Creek Confluence to Swamp Creek Confluence	1080
Swamp Creek Confluence to Lake Washington	1195

Cross section 42 from the full Sammamish River model coincides with the downstream cross section of the site model, and thus provided the water level to be used as the tailwater boundary condition for the site model. The flows for the "Bear Creek Confluence to Little Bear Creek Confluence" and "Little Bear Creek confluence to North Creek Confluence" shown in Table 1 were used in the site model. The site model was then run using a Manning's coefficient of n = 0.028. The water surface elevations calculated at the SR202 highway bridge compared with the current water marks can be found in Table 2. The site model predicts slightly lower water levels than the full model, but still within 0.2 ft of the measured marks.

Table 2 – Water surface elevations

	Upstream RR Bridge [ft NAVD]	Highway Bridge [ft NAVD]	Downstream RR Bridge [ft NAVD]
Surveyed Current Water Mark	21.58	21.60	21.43
Calculated Water Surface Elevations Full Model	21.59	21.51	21.49
Calculated Water Surface Elevations Site Model	21.45	21.40	21.39

Water Surface Elevation with 100 Year Flow

After calibrating the models to the November 9th event they were used to calculate the water surface elevation at the highway bridge for the 100-year flow. The models were run with two different sets of flow boundary conditions: the 100-year flow quantiles from the existing FEMA flood insurance study (FIS); and, a more conservative set of 100-year flow quantiles developed by **nhc** as part of a hydrology study on the Sammamish River basin for the Washington State Department of Transportation (WSDOT) regarding stormwater flow control exemptions. Quantiles in this study were determined using the HEC-FFA flood frequency program to fit a Log-Pearson Type III distribution to peak annual flow data at gage 12125200, with drainage basin area subsequently used to adjust the frequency curve at the gage to characterize flood quantiles for different locations on the river[1]. The two sets of flow boundary conditions along the river are shown in Table 3.

Table 3 – 100-Year Flow Quantiles

Location	FIS 100-yr Flow [cfs]	NHC 100-yr Flow [cfs]
Sammamish Lake Outlet to Bear Creek Confluence	1202	1401
Bear Creek Confluence to Little Bear Creek Confluence	2830	3299
Little Bear Creek Confluence to North Creek Confluence	3099	3612
North Creek Confluence to North Creek Confluence	3576	4169
Swamp Creek Confluence to Lake Washington	4300	4613

As in the calibration procedure the full Sammamish River model was first run to generate the tailwater condition for the site model for each set of flow data. Next the site model was run to calculate the water elevation at the bridge. This was done for both sets of flow quantiles and the resulting water surface elevations at the highway bridge (upstream face) are shown in Table 4.

[1] *Sammamish River Case Study*, memorandum by David Hartley and Derek Stuart of Northwest Hydraulic Consultants, presented to Larry Schaffner and Rich Hovde of WSDOT. December 23, 2004.

Table 4 – 100-Year Water Surface Elevation

	Water Elevation at Highway Bridge [ft NAVD]
FIS 100yr Flow	26.51
NHC 100yr Flow	27.43

Sensitivity Analysis to Manning's Coefficient

A sensitivity analysis of the water surface elevation calculated by the site model to Manning's n was carried out. The site model was run with Manning's coefficients from 0.028 up to 0.045 with the NHC 100-year flow quantiles. The tailwater condition of the site model was fixed at 27.04 ft calculated by the full Sammamish River model with a Manning's coefficient of 0.028, as larger n values approaching 0.045 are not reasonable throughout the Sammamish River. The results from this analysis are shown in Table 5, indicating only a small change.

Table 5 – Sensitivity Analysis of Site Model to Manning's n

Manning's n	Water Elevation at Highway Bridge [ft NAVD]
0.028	27.47
0.035	27.52
0.040	27.59
0.045	27.67

Discussion of Model Results

The calibrated model is predicting a 100-year water surface elevation of about 27.5 ft NAVD. This is based in part upon calibration to the November 2006 event. However that flood was considerably smaller than 100-year conditions. The present (effective FIS) 100-year water surface elevation according to FEMA is about 27.7 ft (shifted to NAVD datum), approximately the same and matching the upper end of our sensitivity range to the calibrated channel roughness coefficients. Therefore, we recommend using the slightly higher 27.7 ft NAVD as the design water surface elevation for this project. This is about 12 ft below the low chord of the existing bridge. Clearance requirements for the existing Sammamish River trail located on the right bank are likely to be more restrictive than freeboard requirements for the new bridge above the 100-year water level.

Scour Analysis

Contraction scour is not an issue at this bridge. It is evident from the site visit and a longitudinal comparison of cross sections from upstream to downstream through the bridge that there is no narrowing of the channel nor does the bridge in any way constrict the waterway. Likewise, abutments are located well above the design water level so abutment scour is not of concern. Only local scour at the piers remains a possibility, however the preferred bridge design shows the intermediate piers remaining above the 100-year water surface elevation. Pier scour could only occur if, due to bank erosion and channel shifting, the pier(s) were to become exposed to the flow in the future. In our opinion this is unlikely. The bridge is located along a straight reach of the river. The channel is very stable, with velocities during the 100-year flood on the order of 3 to 4 ft/sec. Figure 2 compares the bridge cross section from the **nhc** HEC-2 model, taken from a Corps of Engineers survey from either 1984 or 1988 (it is uncertain which without further investigation), to the cross section in the present site model from the Roth Hill survey of December 2006. The figure shows that over the preceding 20-year period there has been no significant change in the channel shape or location. Note that the older survey included the

Sammamish River trail, whereas Roth Hill ended their cross section survey along the edge of the trail at the river bank. Though we did extend the section by adding one more point, details of the trail are not necessary as it lies above the 100-year design water surface.

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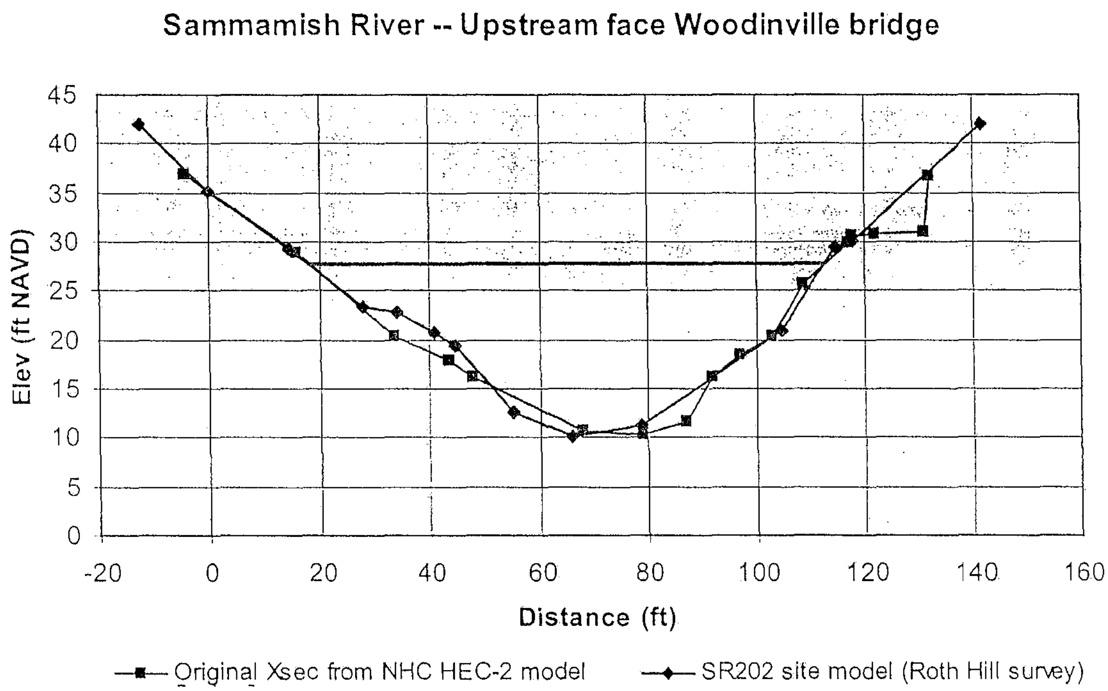
Figure 2 – Cross Section Comparison from 1984-88 to 2006



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Appendix A

Survey request for Woodinville Sammamish bridge project

November 22, 2006

DMJM Harris
10900 NE 8th Street, Suite 750
Bellevue, WA 98004

Attn: Grace Kane, P.E.

RE: Survey request for Woodinville Sammamish bridge project

Dear Ms. Kane:

This letter describes the locations of four high water marks (debris or silt lines, etc.) and five current water level marks (time of measurement) taken on November 9, 2006 along the Sammamish River that need to be surveyed for the hydraulic analysis of the Woodinville bridge replacement project. Figure 1 shows the approximate locations of the current level and high water marks, which are also depicted in attached Photos 1-5 and 6-9, respectively. Please note the following items when surveying the high water and current water level marks:

- Right bank and left bank are described looking in a downstream orientation.
- The high water mark and current water level stakes were driven where the mark met the ground. Survey to the base of the stake. Do not survey to the top of the stake.

In addition to the water level marks, we request surveys of seven river cross sections, as shown in Figure 2. For cross sections 2, 4, 5, and 6 soundings off of the bridge deck are fine. Please ensure that the following items are included in each cross section survey:

- Include a ground shot 10' to 20' beyond (landward of) the bank
- Top of bank
- Obvious break points along the bank slope
- Ordinary High Water bottom of vegetation
- Water surface at time of your survey
- Toe of bank
- At least five points across the channel bottom

Please don't hesitate to call me if you have any questions about this request.

Yours truly,
NORTHWEST HYDRAULIC CONSULTANTS, INC.

Robert C. Elliot, P.E.

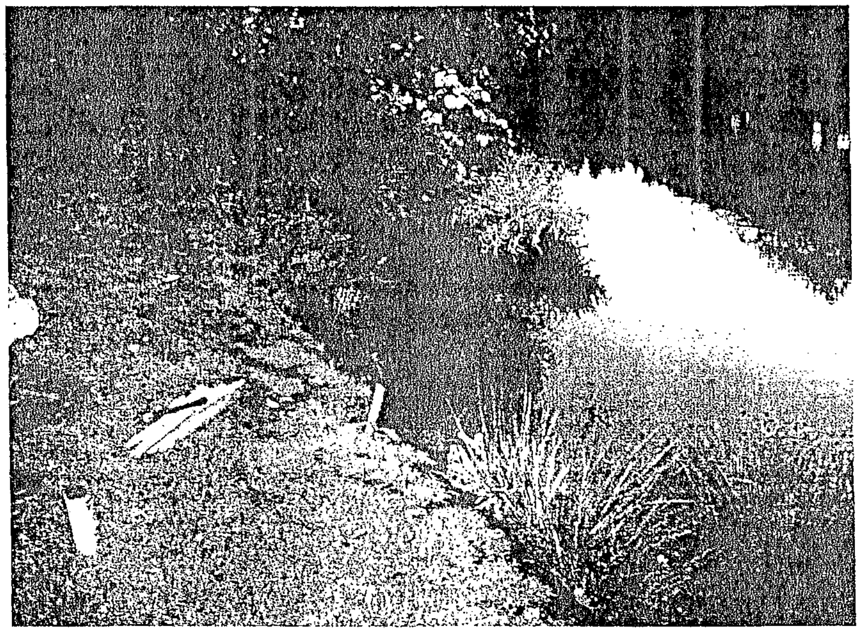
Attachments

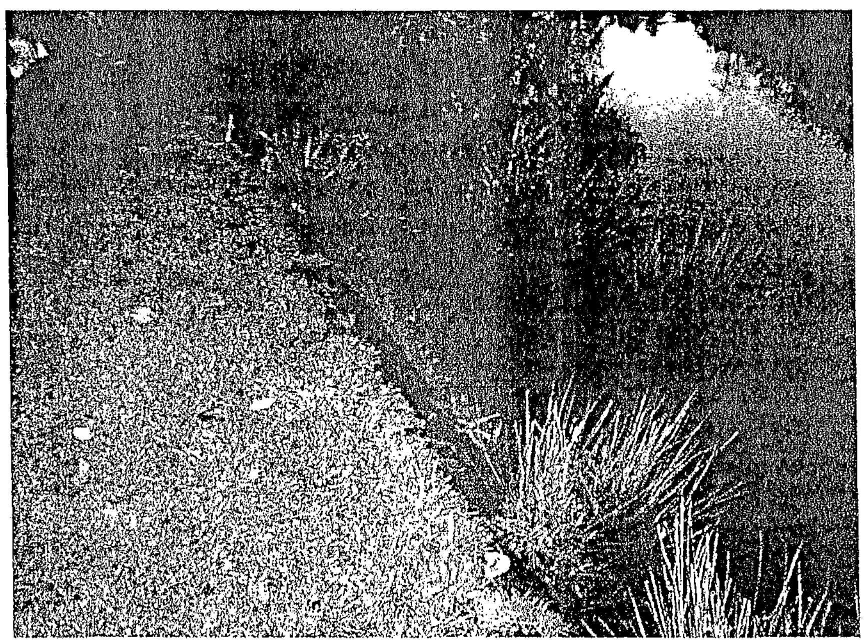
Current Water Level

Mark A

Mark A is located on the right bank upstream of the most upstream railroad bridge. The mark is located where the grass amphitheater meets the river bank. A stake is driven in ground at the current water level. In addition to the stake, orange paint was used to mark the current water level on a log located at the river bank.

Photo 1. Current water level mark A

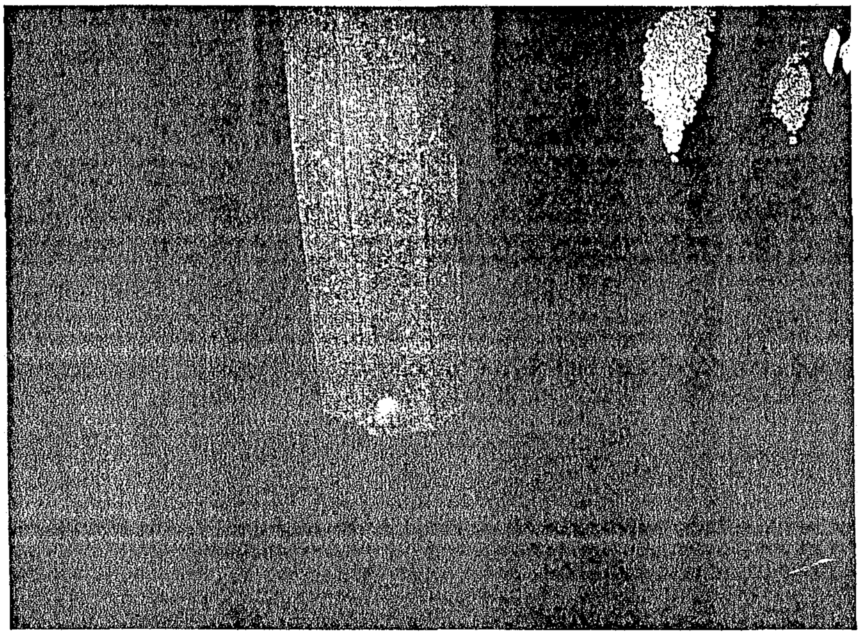




Mark B

Mark B is located on the right bank underneath the centerline of the 175th Street Bridge. The mark is horizontal paint strip (Orange color) around ½ of a bridge piling. The bottom of the paint line denotes current water level.

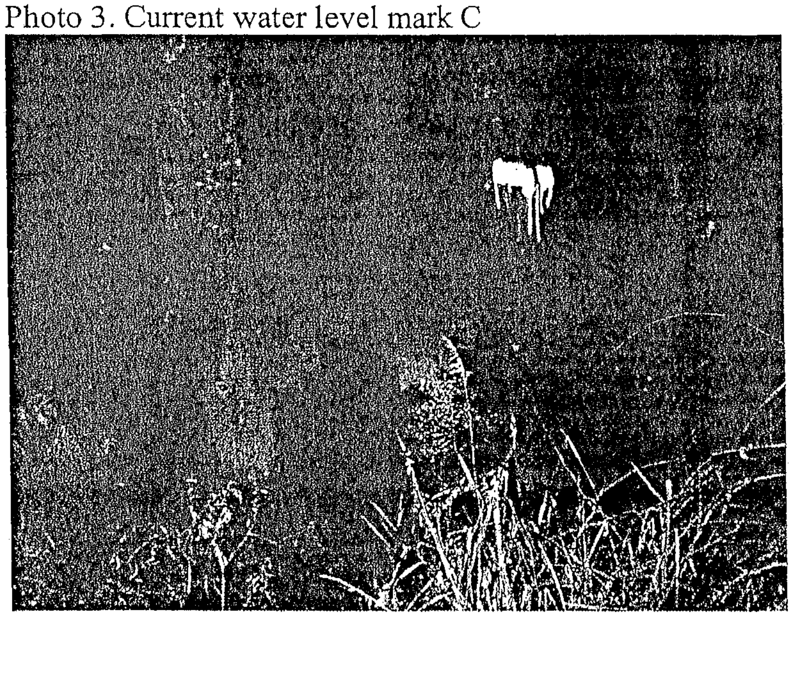
Photo 2. Current water level mark B



Mark C

Mark C is located on right bank on the pilings of the most downstream railroad bridge. The mark is a horizontal orange colored paint stripe on 2 steel pilings. The bottom of the stripe denotes current water levels.

Photo 3. Current water level mark C

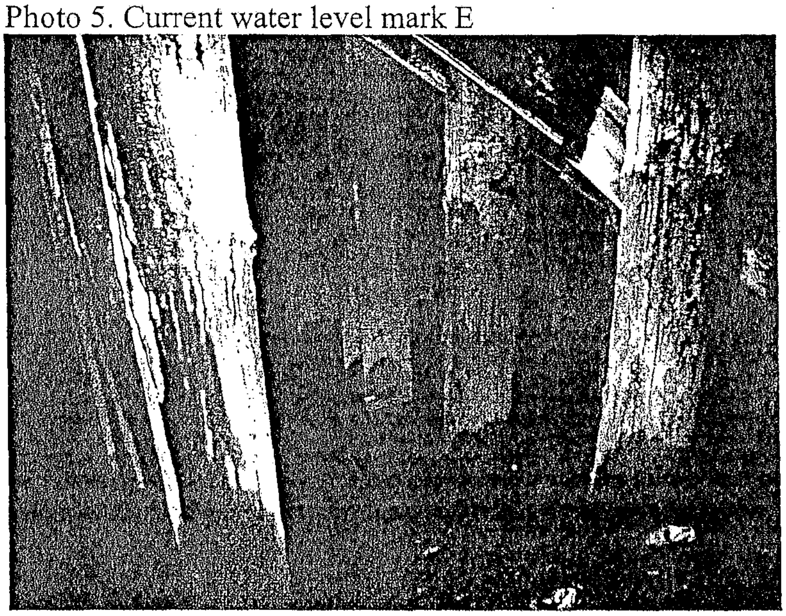


Mark D
Mark D is located on the right bank downstream of the most downstream railroad bridge. The mark is a stake driven in the ground at current water level. The stake is directly down the river bank slope from the North Creek Force Main Drain Structure #2 Sump Control Panel.

Photo 4. Current water level mark D

Mark E
Mark E is located on the left bank on the middle pilings of the most upstream railroad bridge. The mark is a horizontal orange paint stripe on 2 steel pilings. The bottom of the stripe denotes the current water level.

Photo 5. Current water level mark E

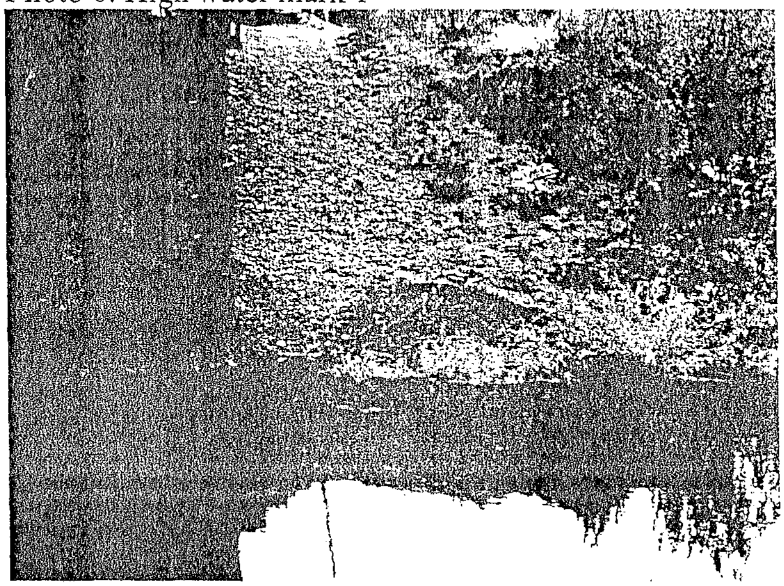


High Water Marks

Mark 1

Mark 1 is located on the left bank of the upstream railroad bridge. The stake is in the ground approximately 10' downstream of pilings. The mark is upper limit of settled reeds.

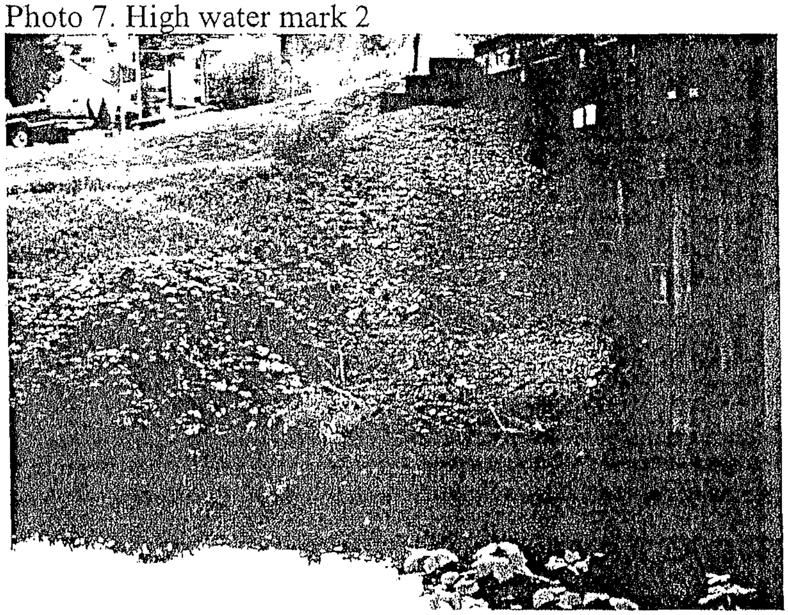
Photo 6. High water mark 1



Mark 2

Mark 2 is located on the left bank of the upstream railroad bridge. The stake is in the ground approximately 10' upstream of pilings. The mark is the upper limit of settled grasses and small reeds.

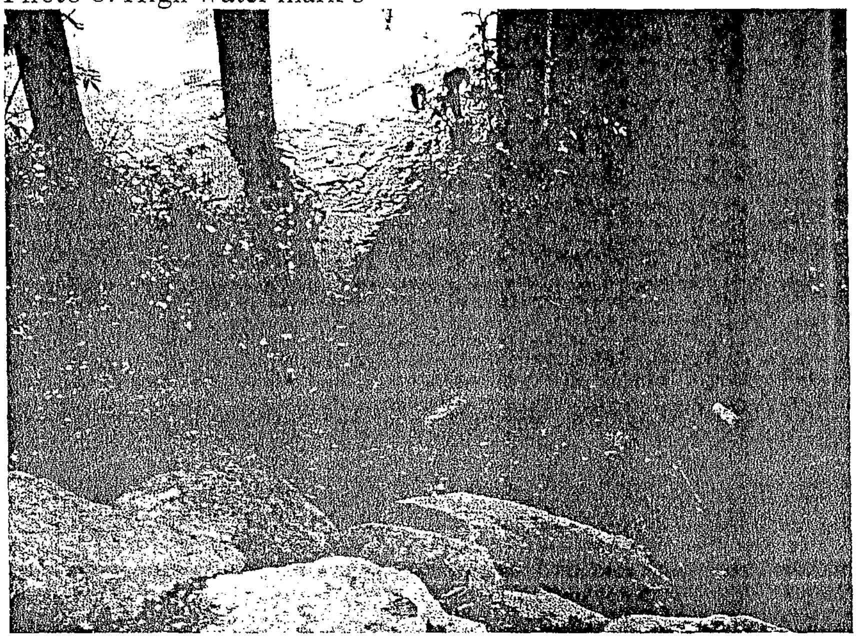
Photo 7. High water mark 2



Mark 3

Mark 3 is located on the right bank of 175th Street Bridge (middle bridge). The stake is directly under the middle center line of the bridge/roadway. The stake is driven at the location of grass/leaves that were caught in an adjacent bush.

Photo 8. High water mark 3



Mark 4

Mark 4 is located on the right bank downstream of the most downstream railroad bridge. An orange ribbon is located about 100' downstream of bridge pilings. The ribbon is tied on a branch of a tree on the bank adjacent to the river. The mark identifies debris that collected in branches.

Photo 9. High water mark 4