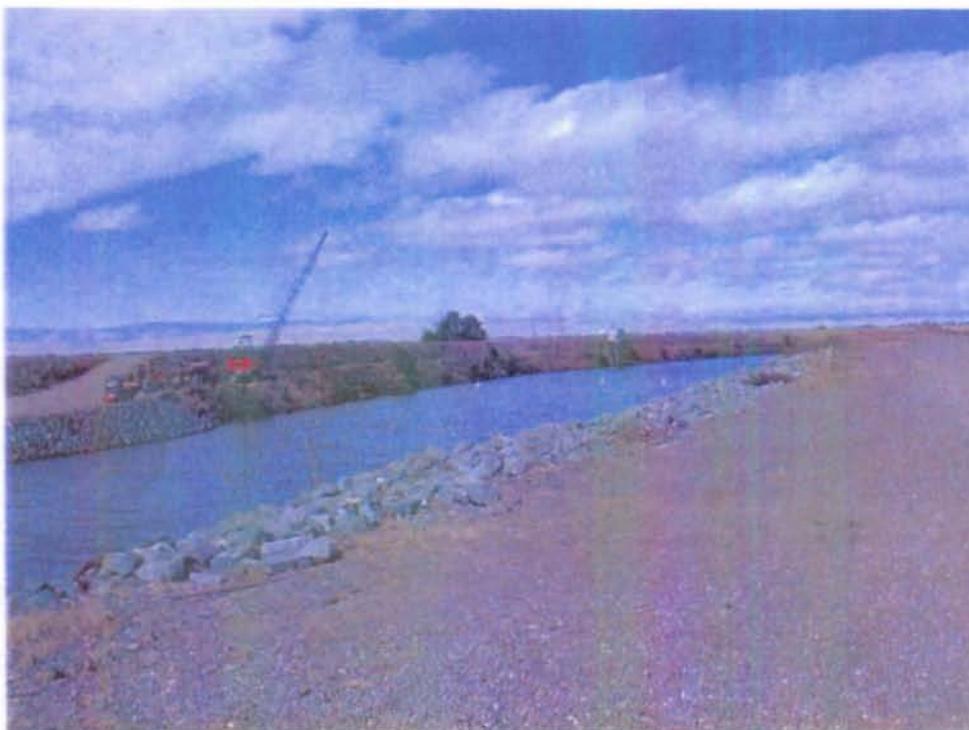


State of California  
The Resources Agency  
DEPARTMENT OF WATER RESOURCES  
Division of Planning and Local Assistance  
Central District

**Bed Sediment Monitoring in the South Delta**



**Memorandum Report**  
**September 2004**

# Memorandum

Date :

To : Mike Ford  
Bay-Delta OfficeKarl Winkler  
Central District

From : Department of Water Resources

Subject: Bed Sediment Monitoring in the South Delta

The results of bed sediment monitoring conducted by Central District from fall 1998 through the fall of 2002 are presented in this report. Planning for this monitoring program was initiated in the fall of 1997 in response to comments on the Interim South Delta Program Draft Environmental Impact Report/Environmental Impact Statement.

Monitoring was conducted twice a year, once in the fall and once in the spring, at 17 sites to observe the effects of temporary barrier placement and seasonal flow variations on bed sediment grain size and streambed elevation.

In general, streambed elevation rose between the fall and spring monitoring surveys and streambed elevation fell between the spring and fall monitoring surveys.

Monitoring results for 2003 and 2004 will be included in future reports.

If you have any questions regarding this report, please contact Bob Niblack at (916) 227-7590.

Attachment

SURNAME

DWR 155 (Rev. 2/86)

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## **Executive Summary**

Central District (CD) has monitored streambed sediment accumulation in South Delta channels since 1998. The monitoring program has two components, streambed elevation surveys and bed sediment sampling. Seventeen monumented sites were established and then surveyed twice a year to collect data to make bathymetric maps of the streambed. Bed sediment samples were also collected twice a year from the 17 sites.

Bathymetric maps made from survey data collected in the spring and fall of 2000, 2001, and 2002 were compared to detect changes in streambed elevation. The comparisons showed that sediment usually accumulated at the monitoring sites between the spring and subsequent fall survey events. The comparisons also showed that sediment was usually eroded from the monitoring sites between the fall and subsequent spring survey events. During these years the temporary flow barriers were constructed in the spring and removed in the fall. Although the study demonstrated the ability to effectively measure streambed changes, the period of record was insufficient to make a long-term projection.

Bed sediment characteristics were compared using mean grain size of sediment samples calculated from grain-size distribution curves. Over a five-year period, the mean grain size of bed sediment samples collected in the spring samples increased relative to the previous fall samples in 60 percent of the comparisons. The mean grain size of fall samples decreased relative to the samples collected in the spring in 65 percent of the comparisons. In general, the distribution of sand and silt showed little change over the five-year monitoring period.

## **Background**

Planning for this monitoring program was initiated in 1997 in response to comments on the Interim South Delta Program EIR/EIS. The Interim South Delta Program released a draft EIR/EIS in 1996 describing a project to construct three flow control structures and one fish control structure in South Delta channels. Comments on the EIR/EIS expressed concern that the structures would increase sedimentation in the channels and create problems for navigation and recreation. The streambed elevation and bed sediment monitoring conducted since spring 1998 has helped to estimate the timing, location, and amount of sedimentation in South Delta channels. This information can help determine if Delta flow and fish control structures will impact the Delta sedimentation conditions.

## **Purpose of Monitoring**

The monitoring program described in this report was designed to provide data to address concerns regarding sedimentation and its effects in the South Delta. The data collected in the implementation of this monitoring program has been used in this report to determine the following:

- The volume of sediment that was deposited on or eroded from monitoring sites in the project area
- The period of the year that sediment was deposited at the monitoring sites
- The period of the year that sediment was eroded from the monitoring sites
- The grain size and changes in grain size of the sediment on the streambed at the monitoring sites

The sediment monitoring sites and the monitoring schedule were coordinated with the location and installation of the temporary barriers in the South Delta. Monitoring sites were established upstream and downstream near the temporary barriers where practical. Bed elevations were surveyed and bed sediment samples were collected in the spring before temporary barriers were placed and in the fall before temporary barriers were removed.

## **Study Area Description**

The general study area is in the San Joaquin-Sacramento River Delta in San Joaquin County north of the City of Tracy, west of the City of Manteca, and southwest of the City of Stockton. It includes the following channel reaches:

- Old River downstream of the San Joaquin River to the West Canal
- Middle River downstream of the Old River to the Victoria Canal
- Grant Line Canal
- Fabian and Bell Canals
- Doughty Cut

The sediment monitoring activities use waterways, roads, and levees within the South Delta region for site access and surveying. The specific areas of study are 17 sites within the river channels and canals listed above.

## **Study Methods**

This study was based on a monitoring plan that was designed to determine the change in bed sediment accumulation and the change in bed sediment grain size over two seasonal periods. One period, between spring and fall, roughly coincided with the time the temporary flow barriers were in operation. The other period, between the fall and subsequent spring, coincided with the period when the temporary barriers were absent.

Bed elevation surveys and bed sediment sampling for grain-size analyses were conducted twice a year. One survey/sampling event was conducted in April or May of each year before the temporary barriers were installed. The other survey/sampling event was conducted in September before the temporary barriers were removed.

The survey and sediment sample data were compared to data from previous survey/sampling events to evaluate changes that occurred. The contoured surfaces that

were created from data collected in subsequent surveys were compared to determine sediment volume changes at each monitoring site. Mean grain sizes calculated from grain-size analyses were compared to determine changes in grain size at each site over time.

## **Site Selection**

Seventeen bed sediment monitoring sites were selected to observe conditions in the wide variety of channels and settings found in the South Delta. Site locations are shown on Figure 1. The initial sites were chosen near the temporary barriers, both upstream and downstream of the barriers, where effects of their operation might be most noticeable. At the suggestion of U.S. Bureau of Reclamation (USBR) Technical Service Center, Sedimentation and Hydraulics Group staff, other monitoring sites were added to reaches in Old River and Grant Line Canal.

Monitoring sites were initially selected on topographic maps. Then the proposed locations were identified in the field. At that point, some of the sites were relocated to improve access and avoid vegetation, primarily blackberry thickets, and other obstacles. Each site was chosen to be accessible by boat and truck, initially to install monuments, and thereafter to make repeated survey measurements. To establish the monitoring sites, it was necessary to establish line-of-sight between the two monuments and at a right angle to the line defined by the monuments at each site. Additional criteria for selecting the sites is listed below in the section of this report titled "Monument Installation."

USBR Sedimentation and Hydraulics Group engineers suggested that each monitoring site encompass a length of channel at least as great as the width of the channel. This goal was met by establishing a monitoring section 200 feet long at most sites and a monitoring section 300 feet long at site GLC2.

## **Site Preparation**

At each of the 17 monitoring sites, two permanent monuments were installed on one side of the channel. The monuments provide site-specific horizontal and vertical control for channel cross section measurements and they identify each bed sediment sampling site.

## ***Temporary Entry Permits***

Temporary entry permits were required to access sites on private property to install monuments and visit the sites for semiannual surveys. Reclamation Districts 1, 2, 544, 773, 1007, and 2089 required that right-of-entry to the levees be obtained from the Reclamation Districts. Temporary entry permit forms were delivered to the Reclamation Districts on April 13, 1998, and the Division of Land and Right-of-way later finalized the permits.

One condition of the permits is that survey results will be transmitted to the Reclamation Districts. This report will be delivered to the participating Reclamation Districts.

## ***Monument Installation***

Monitoring site monuments were installed according to the following criteria:

- Monuments at each site were spaced at a distance equal to or greater than the channel width. In most cases, this was about 200 feet.
- Monuments were built approximately eight feet downslope of the waterside hinge point of the levee to prevent them from being damaged by levee road maintenance.
- Monuments at each site defined a line parallel to the channel.
- The ground surface around the monuments can accommodate survey instruments positioned over the monument.
- Monuments were installed so that lines-of-sight across the channel at right angles to the line defined by the monuments was clear at each monument, and at 50-foot intervals between the monuments, with minimum disturbance to vegetation.

The monuments were constructed by driving a 5/8-inch copper-clad rod vertically into the levee bank until refusal, typically 10 to 30 feet. The rod was then cut off above grade. A two-foot section of four-inch diameter PVC pipe was then placed around the rod into an 18-inch deep hole and filled with concrete. The ground outside the PVC pipe was backfilled and compacted with a tamper. A brass cap stamped with the words "California Department of Water Resources" (DWR) and the station designation was crimped onto the top of the primary monument at each site.

## **Bed Elevation Surveys**

Bed elevation surveys were conducted once each spring before the temporary barriers were emplaced and once in late summer or early fall before the temporary barriers were removed. The surveys began in the fall of 1998 at each of the 17 monitoring sites. Table 1 lists the date that each survey was conducted.

## ***Survey Activities***

The surveys were completed with the following steps:

- Collect sounding data at each of the 17 sites
- Create a bathymetric map based on the sounding data from each survey
- Compare subsequent maps from each site
- Calculate the volume change between the two contour surfaces

Surveys conducted in fall 1998, spring 1999, and fall 1999 collected sounding data along five lines at right angles to the line defined by the monuments and at 50-foot intervals

along the monument line to create bathymetric maps. In the spring of 2000, we changed the survey method to use a global positioning system (GPS) synchronized with a single-beam acoustic sounder with digital output.

In all of the surveys, streambed elevation was determined by collecting data with an acoustic sounder that measured the depth from a reference point below the water's surface to the streambed. The surveys also determined the elevations of the water surface relative to the primary monuments at each site. The primary monument was designated by a brass cap. The water surface elevation value was applied to each sounding value to calculate the spot elevations that were used to create a bathymetric map.

A crew of up to five people was required for about five days to conduct the first three survey events with the initial surveying methods. During those surveys, a lot of time was spent aligning the boat along each profile. Extensive preliminary work for the initial surveys included resurveying the profile location at 50-foot intervals along the line defined by two monuments. Sounding data was collected with a Raytheon DE 719 analog sounder along five transects perpendicular to the line defined by the monuments.

The method used to collect sounding data was modified for the spring 2000 survey event to reduce costs, increase accuracy, and increase efficiency. With the change, staff spent less time in the field, fewer people were required to do the work, and less processing was required in the office to prepare the data and create maps. Survey techniques are continually being refined.

The updated hydrographic survey method used a GPS receiver synchronized with a digital output acoustic sounder. The GPS unit and sounder were deployed on a boat that traversed the monitoring site while collecting data points at one-second intervals. Typically, over 2,000 points were collected at each site during the survey. Figure 2 shows the distribution of data points collected in a typical site survey and the area over which the analysis of streambed change was conducted.

Routine procedures were developed to minimize sources of survey error. The boat traversed the monitoring site parallel and perpendicular to the shoreline and turned outside of the boundary of a site's area of analysis to minimize the effects of heave, pitch, roll, and yaw on the depth soundings. The speed of the boat was maintained at a steady and slow rate to minimize boat motion and velocity effects on the soundings. The sounding unit was calibrated once a day by comparing the sounder to streambed depth displayed by the acoustic sounder to the value measured by a survey rod. The depth sounding measurement had a precision of plus or minus 0.1 foot, according to the sounder specifications.

The following equipment was used to collect the soundings:

- GPS: Trimble Pro XR
- Narrow-beam acoustic sounder: Raytheon DE 719D MK2

- Laptop computer
- 16-foot Klamath aluminum boat with a V-hull.

Sounding data were collected upstream and downstream of the site boundaries and as close to shore as possible. Since many data points were gathered outside of the area of volume change analysis, the contours within the area of analysis were well-defined. The area of analysis was a rectangular area in the middle of the channel defined at each site by four coordinate pairs which were the same for each survey. They are shown on each contour map in Appendix 1.

At each site during the survey, a two-person crew determined the water surface elevation relative to the primary monument at the site using a total station surveying instrument. The measurement of the water surface height relative to the site monument was typically measured several times during the period that the boat crew collected sounding data.

### ***Survey Output and Analysis***

The maps developed in the first three surveys, from fall 1998 through fall 1999, were not as accurate as the maps created later using GPS technology. The methods to quantify changes in the streambed, described below, were only applied to the surveys conducted after fall 1999. However, bathymetric maps of all surveys were created. The maps created from surveys conducted in 2000 through 2002 are included in Appendix 1. The maps for earlier surveys are in Appendix 2.

The updated hydrographic survey method generated a data file for each site with the following four fields:

- Time of measurement
- Northing
- Easting
- Depth

Each depth reading was adjusted to account for the depth of the sounder below the water surface and the water surface elevation relative to the site monument as measured by the land-based survey crew.

In the office, bed elevation data points were reviewed to remove apparent outliers that may have resulted from objects in the water above the streambed. The data points were then used in a contouring software program to create contour surfaces. Finally, contour surfaces developed from consecutive surveys at each site were compared and changes in volume were calculated.

The first survey conducted with the sounder coupled to the GPS unit in the spring of 2000 was used as the baseline for volume change analysis. Subsequent surveys were compared to this initial survey. The difference in the volume between the two surfaces was

computed using AutoCAD Land Development Desktop® computer program. The values of volume change were plotted on graphs that are included as Appendix 3.

### ***Discussion of Survey Results***

Sediment loss or accumulation at each monitoring site was determined by comparing maps of streambed surfaces generated from the six survey events conducted from spring 2000 to fall 2002. The bed sediment volume change that occurred between subsequent surveys at a site was calculated by subtracting modeled surfaces from each other. The comparison was limited to the streambed within an area of analysis which is indicated by a rectangle drawn on each site map. The bed sediment volume change between subsequent surveys at each of the 17 sites is shown graphically on figures in Appendix 3.

There were 102 individual spring and fall site surveys conducted over the study period. The spring survey at a site was compared to the subsequent fall survey at the same site in 51 cases. Of those 51 comparisons, 45 showed that sediment had accumulated and six showed that sediment had eroded. In 34 comparisons, the fall survey was compared to the following spring survey. Of this group, 32 of the comparisons showed that sediment eroded over the period and two comparisons showed that sediment had accumulated over the period.

The volume change calculated in the comparisons ranged from a gain of 1,040 cubic yards to a loss of 844 cubic yards. The comparisons between subsequent modeled surfaces, in units of cubic yards, are summarized in the following table:

Period of Comparison	Maximum <sup>a</sup>	Minimum <sup>b</sup>	Median <sup>c</sup>	Mean <sup>d</sup>
spring 2000 to fall 2000	1040	-27	249	289
fall 2000 to spring 2001	5	-835	-171	-281
spring 2001 to fall 2001	763	-211	182	150
fall 2001 to spring 2002	47	-460	-115	-147
spring 2002 to fall 2002	420	-71	206	208

Note: Values are in cubic yards.

- a maximum sediment volume gain of the 17 sites
- b minimum sediment volume gain of the 17 sites
- c median of sediment volume gain values
- d average of sediment volume gain values

The analysis of mapped streambed surfaces showed that, in general, sediment accumulated during the period between the spring survey and the following fall survey, which generally coincided with the time that the flow barriers were in place. The analysis also showed that, in general, sediment was eroded from the streambed monitoring sites during the period between the fall survey and the following spring survey, which generally coincided with the period when the flow barriers were absent.

Exceptions to the trends occurred at monitoring sites OR8 and OR9, upstream of the area near Little Hawaii Island that was dredged in the fall of 2000. Both sites appeared to have lost some sediment during the summer of 2001. Of the 51 comparisons between the fall and spring measurements over the period of record, the comparisons at these sites accounted for two of the six cases where sediment was lost in the period between the spring and fall survey.

The magnitude of flow through Delta channels is one variable that determines how much sediment is deposited or scoured. For reference, the record of flow at the Vernalis gage on the San Joaquin River is included as Figure 3. The flow was significantly higher in 1998 than at any other time during the monitoring period. Over the period of analysis, the greatest flow occurred during the spring of 2000.

## **Bed Sediment Sampling**

The properties of the streambed sediment at each monitoring site were determined through the following steps:

- Collect sediment samples at three points along a transect perpendicular to and in line with one monument at each site.
- Submit samples to the DWR Soils and Concrete Laboratory at Bryte for grain-size analysis.
- Develop a grain-size distribution curve for each sample.
- Calculate the mean grain size for each sample.
- Evaluate data for trends and changes.

### ***Sediment Sample Collection***

Bed sediment samples were collected twice each year at each of the 17 monitoring sites beginning in spring of 1998. Sampling locations were identified by lining the sampler up between a monument on one bank and a marker placed on the other bank across from the monument and at a right angle to the line defined by the two site monuments. Samples were collected at the center of the channel, midway between the center and the left bank, and midway between the center and the right bank. Either the upstream or downstream monument at a site was chosen to reference the sampling location on the first sampling event depending on channel obstructions and ease of boat operation. The same locations were sampled in each sampling event.

Samples were collected with a US BMH-60 sampler that was lowered from a boat with a hand-operated crane. The sampler was purchased from the Federal Interagency Sedimentation Project, a federal consortium formed in 1939 that developed sediment samplers and sampling techniques. The US BMH-60 sampler collected samples from the streambed with a spring-driven scoop that was released as the sampler rested on the streambed and the line suspending it from the crane went slack. In optimum conditions, the scoop enveloped a 175 cubic centimeter sample. After a sample was retrieved, a

geologist described the material, logged the description in a notebook, and emptied the sample into a labeled Ziploc® bag for transport to the lab for grain-size analysis.

Bed sediment samples were labeled with the station name and an abbreviation that indicated their relative placement in the channel. For instance, the samples from station OR5 were labeled OR5lt on the sample collected between the left bank and the center of the channel, OR5cl on the sample from the center of the channel, and OR5rt on the sample from between the right bank and the center of the channel.

Clams, clamshells, and pieces of wood, which were often found in fine-grained samples, were removed from the samples by hand. That ensured that the grain-size distribution curves reflected only sediment grain size.

### ***Grain-Size Analysis***

Sediment samples were analyzed using the method specified by ASTM D 422, Standard Test Method for Particle-Size Analysis of Soils, at the DWR Soils and Concrete Laboratory at Bryte.

In addition to the sieve sizes specified by ASTM D 422, a 63- $\mu\text{m}$  (No. 230) pore diameter sieve was added to the series. This smaller sieve size was added in order to further separate the fine fraction of sediments and allowed the results to be related to the results of other studies that use a No. 230 sieve.

Selected fine-grained sediment samples were also submitted for hydrometer analysis (by ASTM D 422) to obtain a further distribution of grain sizes between the 63- $\mu\text{m}$  and 1- $\mu\text{m}$  particle size range.

Grain-size analyses were plotted on cumulative grain-size distribution curves. A total of 510 grain-size distribution curves were plotted. (These are available on compact disc upon request.)

### ***Calculation of Grain-Size Statistics and Parameters***

Mean grain size and mean grain-size classification were determined for each sediment sample and were used to compare the samples and analyze the trends in bed sediment changes. Values used in the calculation of mean grain size were picked from the grain-size distribution curves.

Data parameters for each sample are presented in both millimeter (mm) and phi units in Appendix 4. The phi unit ( $\phi$ ) is a logarithmic transformation of millimeters into whole integers, according to the formula:

$$(\phi)\phi = -\text{Log}_2 d \quad \text{where } d = \text{grain diameter in millimeters}$$

Phi units were used so that the grain-size distribution data could be plotted easily on arithmetic (as opposed to log) graphs.

Mean grain size of a sediment sample has been calculated by others in several ways. The following two formulas use values that were graphically derived from the cumulative grain-size distribution curves and were used to calculate the mean grain-size values presented in this report:

Equation 1 (Folk and Ward, 1957):  $\text{mean} = (\phi_{16} + \phi_{50} + \phi_{84})/3$

Equation 2 (Trask, 1932):  $\text{mean} = (D_{25} + D_{75})/2$

The values  $\phi_{16}$ ,  $\phi_{50}$ , and  $\phi_{84}$  represent the sediment size (in phi) for which 16, 50, and 84 percent of a sediment sample (by weight) is finer. Similarly,  $D_{25}$  and  $D_{75}$  represent the sediment size (in mm) for which 25 and 75 percent of the sediment sample (by weight) is finer.

The method by which mean grain sizes were calculated varied because many samples were fine-grained, but hydrometer analyses were not conducted on all of them. Equation 1 was used when the 16<sup>th</sup>, 50<sup>th</sup>, and 84<sup>th</sup> percentile values could all be read from the cumulative distribution curve. Equation 2 was used when the 16<sup>th</sup> percentile value could not be determined from the cumulative distribution curve, and the 25<sup>th</sup> percentile value could be determined. When neither the 16<sup>th</sup> nor the 25<sup>th</sup> percentile value could be directly read, the values were estimated, and Equation 1 was used to calculate an estimated mean grain-size value.

The calculated mean grain-size values were used to classify the dominant grain-size fraction present in each sample, such as "coarse sand," "silt," etc., using the Wentworth Classification Scale.

Grain-size analysis data including cumulative grain-size distribution, calculated mean grain size, and sediment classification are summarized in Appendix 4.

### ***Discussion of Bed Sediment Sampling Results***

Bed sediment at each sampling site was classified using the Wentworth Classification Scale. The most common sediment classifications (based on mean grain size) found at each site was as follows:

#### Old River

- OR1 and OR2: medium and coarse sands
- OR3: silt and medium and coarse sands
- OR4, OR6, and OR8: fine and medium sands
- OR5: silt or finer
- OR7 and OR9: silt and fine and medium sands

### Grant Line Canal

- GLC1a, GLC1b, and GLC5: silt and very fine to fine sands
- GLC2 and GLC3: fine sands and silts and finer
- GLC4: medium and coarse sands, with a few samples classified as fine sands

### Middle River

- MR1: silt and finer sediments

### Doughty Cut

- DC1: fine and medium sands

In general, the distribution of sand and fines in the bed sediment samples collected at all monitoring sites showed very little change over the 5-year monitoring period. Notable exceptions occurred at OR1 It at various monitoring events, and at OR3 It in the spring 2001 sample. Samples with mean grain sizes in the range of coarse sand, the coarsest samples from the 17 monitoring sites, were occasionally found at these sites. (See graphs in Appendix 5 for mean grain-size trends.)

### ***Grain-size Trends***

The mean grain size of pairs of consecutive sediment samples from each site was compared to determine if mean grain size increased or decreased over the period between sample collection events. Samples collected in the spring monitoring event were compared to samples collected in the next fall sampling event, and samples collected in the fall were compared to those collected in the next spring sampling event. The results of these comparisons are summarized below.

<b>SPRING SAMPLES COMPARED TO FOLLOWING FALL SAMPLES</b>			
<b>Monitoring Location</b>	<b>Number of sample pairs available for comparison</b>	<b>Number of Sample pairs with increased mean grain size in fall</b>	<b>Number of Sample pairs with decreased mean grain size in fall</b>
Old River	110	39	69 (63%)
Grant Line Canal	52	18	34 (65%)
Middle River	5	1	3 (60%)
Doughty Cut	11	2	9 (82%)
Totals:	178	60	115 (65%)

Sample comparisons were made as follows: spring 1998 to fall 1998, spring 1999 to fall 1999, spring 2000 to fall 2000, spring 2001 to fall 2001, and spring 2002 to fall 2002. Two sample pairs from Old River had no change in mean grain-size values. One sample pair from Middle River had no change in mean grain-size values.

In most cases, 60 to 82 percent depending on location, the mean grain size of bed sediment samples collected in the spring was larger than that for the samples collected in the following fall sampling event.

<b>FALL SAMPLES COMPARED TO FOLLOWING SPRING SAMPLES</b>			
<b>Monitoring Location</b>	<b>Number of sample pairs available for comparison</b>	<b>Number of sample pairs with increased mean grain size in spring</b>	<b>Number of sample pairs with decreased mean grain size in spring</b>
Old River	81	46 (57%)	33
Grant Line Canal	33	20 (61%)	13
Middle River	4	3 (75%)	0
Doughty Cut	10	8 (80%)	2
Totals:	128	77 (60%)	48

Sample comparisons were made as follows: fall 1998 to spring 1999, fall 1999 to spring 2000, fall 2000 to spring 2001, and fall 2001 to spring 2002. Two sample pairs from Old River had no change in mean grain-size values. One sample pair from Middle River had no change in mean grain-size values.

In most cases, 57 to 80 percent depending on location, the mean grain size of bed sediment samples collected in the fall was smaller than that for the samples collected in the following spring sampling event.

The mean grain-size values calculated for each sediment sample (and discussed above) are also shown plotted as a function of time (over the monitoring period of spring 1998 through fall 2002) on Graphs in Appendix 5. The graphs suggest that there appears to be only minor seasonal, or “barrier-in” versus “barrier-out,” differences in grain-size distribution at all bed sediment sampling locations.

## **Findings**

### ***Findings Regarding Bed Elevation Surveys***

- During the period of this study, there were no extraordinary hydrologic events.
- Of the 34 spring surveys, two showed deposition and 32 showed erosion when compared to the previous fall survey.
- Of the 51 fall surveys, 45 showed deposition and six showed erosion when compared to the previous spring survey.

The following findings are for the two complete years (spring 2000 to spring 2002 or fall 2000 to fall 2002) of this study.

- Of the three sites directly upstream of the barriers, OR8, GLC5, and MR1, two showed deposition and one showed erosion.
- The three sites directly downstream of the barriers, OR1, GLC4, and OR9, showed erosion.
- Of the 11 sites that are distant from the barriers, four showed deposition, two showed erosion, and five showed erosion over one two-year period and deposition over the other two-year period.

### ***Findings Regarding Bed Sediment Sampling***

The bed sediment samples collected at each monitoring site can be characterized as follows:

- OR1 - medium to coarse sand
- OR2 - medium to coarse sand
- OR3 - silt to medium and coarse sand
- OR4 - fine to medium sand
- OR5 - silt or finer
- OR6 - fine to medium sand
- OR7 - silt and fine to medium sand
- OR8 - fine to medium sand
- OR9 - silt and fine to medium sand
- GLC1a - silt and very fine to fine sand
- GLC1b - silt and very fine to fine sand
- GLC2 - fine sand
- GLC3 - silt to fine sand
- GLC4 - medium to coarse sand, with lesser amounts of fine sand
- GLC5 - silt and very fine to fine sand
- MR1 - silt and finer sediment
- DC1 - fine to medium sand

In general, the distribution of sand and silt showed little change over the 5-year monitoring period.

The greatest variation in grain size was found at OR1 It and OR3 It. The range of grain size was from medium to coarse sand at OR1 It and silt to coarse sand at OR3 It.

A majority (60 to 82 percent) of comparisons of bed sediment samples shows decreased mean grain-size values when comparing samples collected in the spring to those later collected in the fall.

## Conclusions

- In general, the bed sediment monitoring sites representatively exhibit erosion loss for the period between fall and the following spring (characterized as winter). For the period between spring and the following fall (characterized as summer), the sites representatively exhibit sediment accumulation.
- For the sites directly upstream of the temporary barriers, evaluation of the data for collective trends is inconclusive.
- For the sites directly downstream of the temporary barriers, evaluation of the data indicates a slight collective trend for erosion.
- For the sites distant from the temporary barriers, no collective long-term trends are apparent.
- The period of record of this study is insufficient to make an evaluation of the long-term effects of the temporary barriers on bed sediment volume changes.
- The mean grain size of bed sediment samples showed minor, but detectable, change over the monitoring period. In most cases, sediment samples collected in the fall sampling event had a smaller mean grain size than sediment samples collected in the spring sampling event.

## Recommendations

Monitoring should be continued to obtain a record sufficiently long to determine the following:

- trends in erosion or deposition at the monitoring sites
- the effects of a high flow event
- changes that may occur upon completion of the permanent flow control structures

Surveying methods should continue to be refined. The precision of the surveys may be improved by the use of GPS equipment that employs a base station. The base station would be deployed on site monuments during the surveys.

Frequency of sediment sampling for grain-size analysis should be reduced to a frequency of one time per year from its current frequency of two times per year. Although there seems to be some correlation between grain size and season, the difference is slight. Sediment samples should still be collected one time per year to detect changes that occur when the permanent flow control structures are completed.

## Acknowledgements

This Memorandum Report was prepared under the direction of Emil Calzascia, Chief, Water Management Branch, CD, by Bob Niblack, Chief, Geology and Groundwater Section, CD, with assistance from Tanya Meeth, Solomon Mesghina, and Bill Brewster.

Since the monitoring program's inception in 1997, many individuals within DWR have provided assistance in the collection and/or analysis of data. Appreciation is expressed to the following DWR personnel for providing information presented in this report:

Richard Allen, Chris Bonds, Pam Casselman, Dorothy Dahl, John Ho, Howard Mann (retired), Bob Nozuka, Jay Patel, Richard Pendleton, David Schaap, Randal Smith, Mark Souverville, John Tingle, and Alex Vasquez (retired).

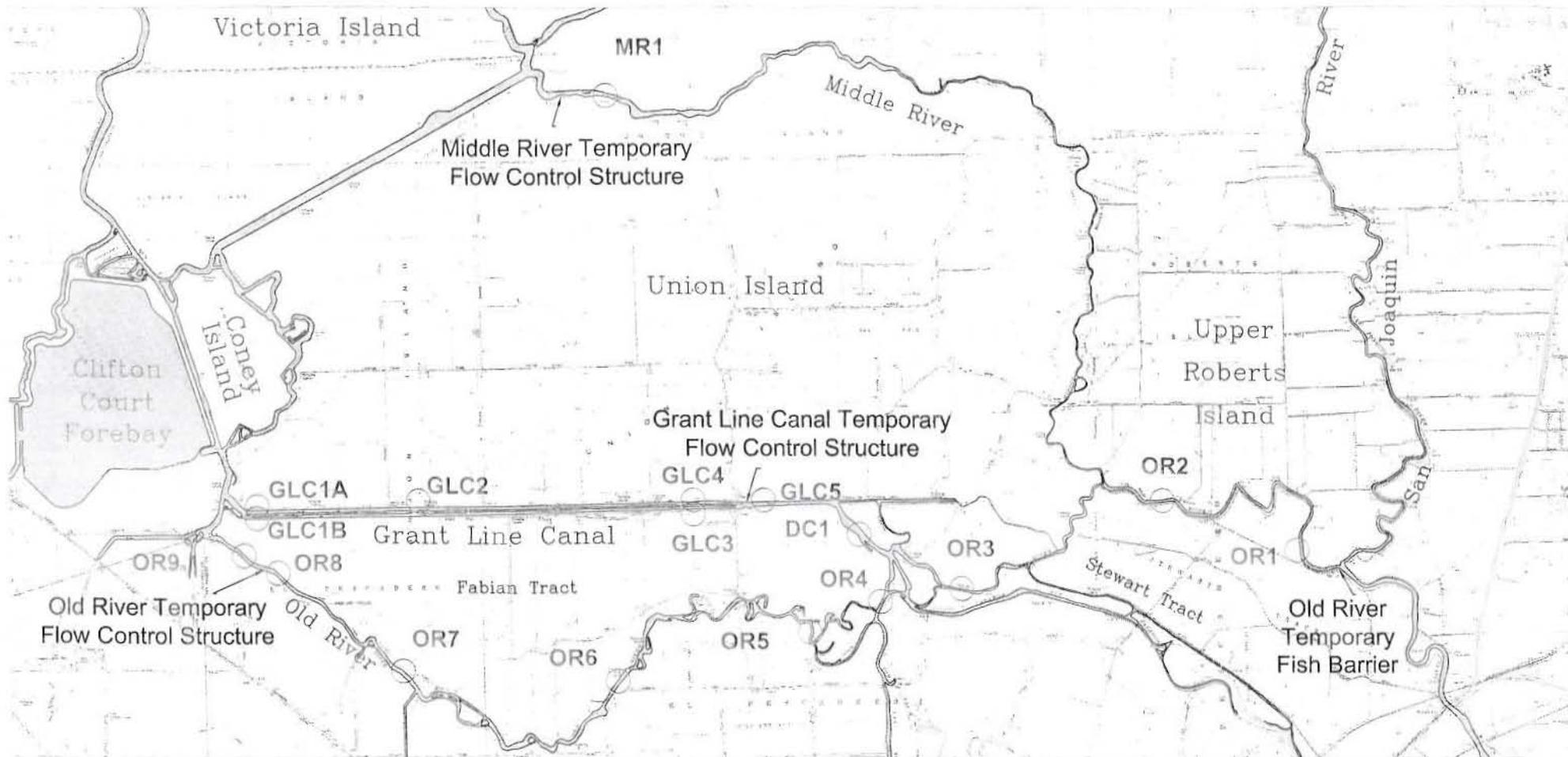
## References Cited

U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-74, May 2001, *Sampling Surface and Subsurface Particle Size Distributions in Wadable Gravel- and Cobble-Bed Streams for Analyses in Sediment Transport, Hydraulics, and Streambed Monitoring*, Bunte, Kristin, et al.

Folk R.L., Ward W.C., 1957, *Brazos River Bar: A Study of Significant Grain Size Parameters*, *Journal of Sedimentary Petrology* 27: 3-26.

Trask, P.D., 1932, *Origin and Environment of Source Sediments of Petroleum: Houston*, Gulf Publishing Co., p. 323.

# Figures



○ SDIP Sediment Monitoring Sites

SCALE



Prepared By:  
 Department of Water Resources  
 Groundwater and Geology Section  
 Central District  
 December, 2003



South Delta Improvement Program  
 Sediment Monitoring

**Figure 1**

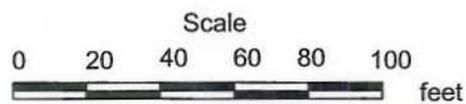
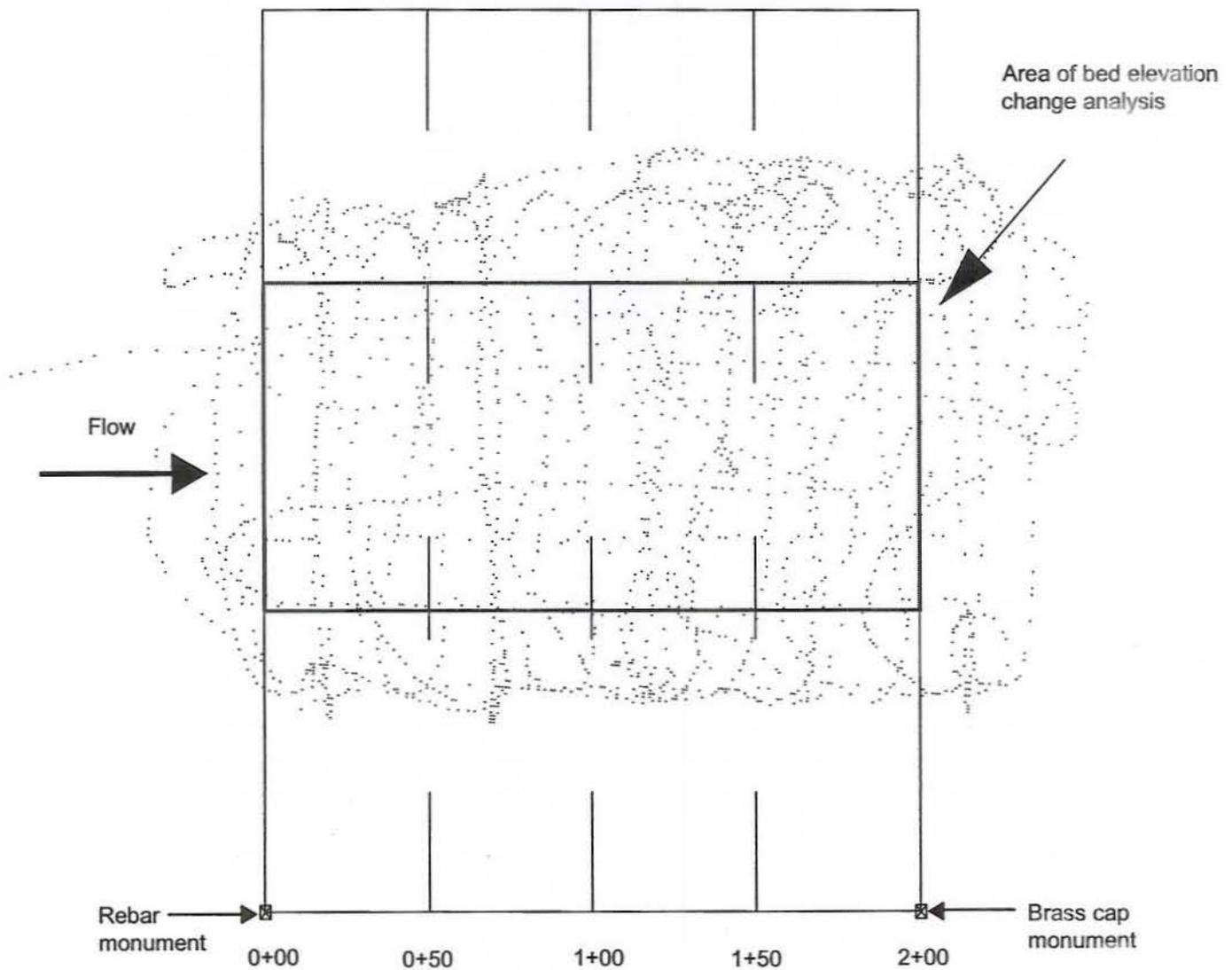
**Bed Elevation Survey  
 and  
 Bed Sediment Monitoring Sites**



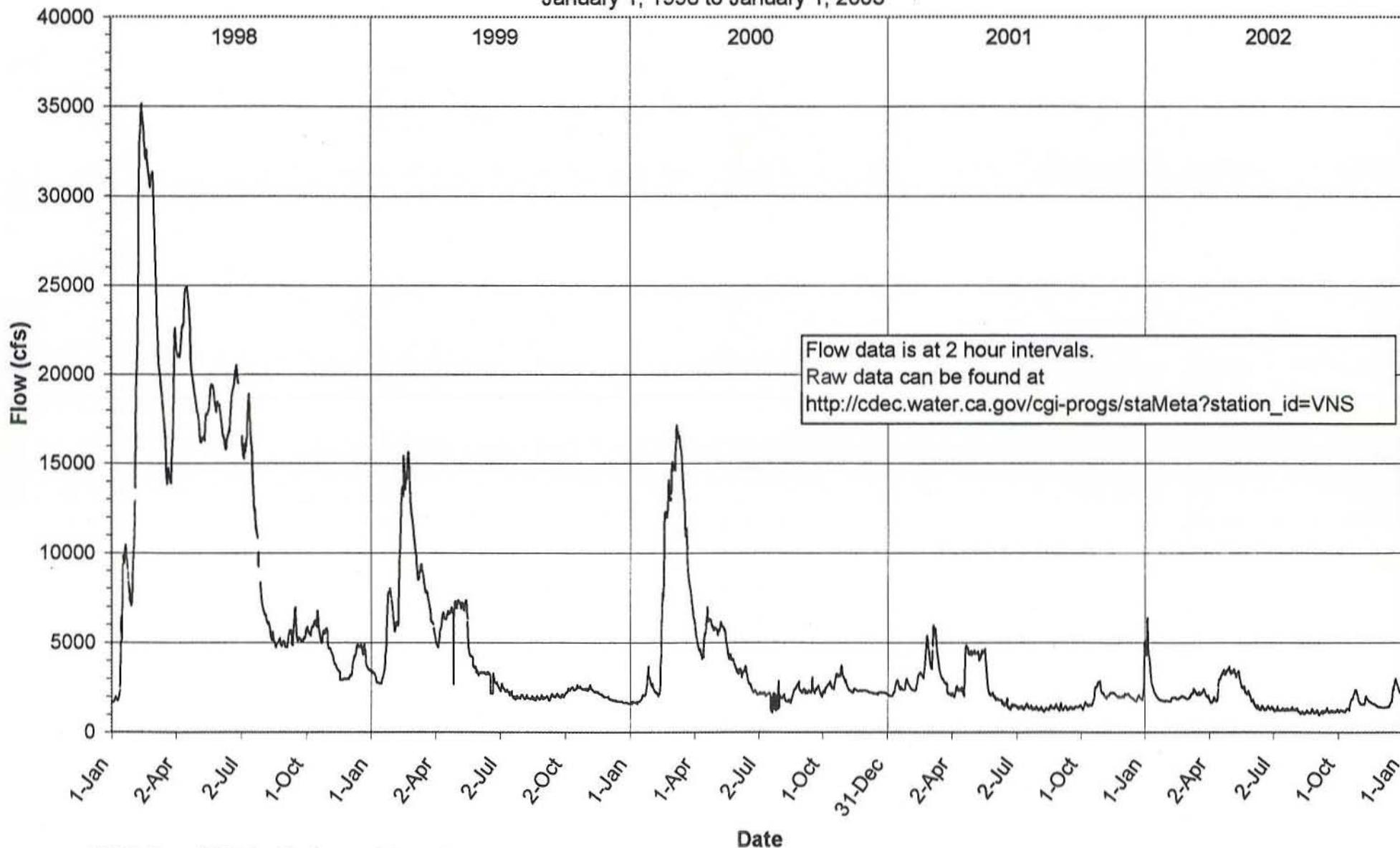
# Figure 2 Distribution of Data Points Collected With Linked GPS and Acoustic Sounder

OR1 4/10/2000

(Approximately 2156 data points collected)



**Figure 3**  
**San Joaquin River Flow at Vernalis**  
January 1, 1998 to January 1, 2003



# Table

**Table 1**  
**Dates of South Delta Bed Elevation Surveys**

	Fall 1998	Spring 1999	Fall 1999	Spring 2000	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring2003
Monitoring Site	survey date									
OR1	9/24/1998	4/9/1999	9/14/1999	4/10/2000	9/19/2000	3/20/2001	9/10/2001	4/2/2002	9/11/2002	4/8/2003
OR2	9/24/1998	4/9/1999	9/14/1999	4/10/2000	9/19/2000	3/20/2001	9/10/2001	4/2/2002	9/11/2002	4/8/2003
OR3	9/25/1998	4/15/1999	9/14/1999	4/10/2000	9/19/2000	3/26/2001	9/10/2001	4/2/2002	9/11/2002	4/8/2003
OR4	9/28/1998	4/15/1999	9/14/1999	4/10/2000	9/19/2000	3/27/2001	9/21/2001	4/2/2002	9/11/2002	4/8/2003
OR5	9/28/1998	4/12/1999	9/15/1999	4/12/2000	9/19/2000	3/26/2001	9/21/2001	4/2/2002	9/11/2002	4/8/2003
OR6	9/29/1998	4/13/1999	9/15/1999	4/12/2000	9/20/2000	3/27/2001	9/21/2001	4/3/2002	9/11/2002	4/9/2003
OR7	9/29/1998	4/13/1999	9/15/1999	4/12/2000	9/20/2000	3/27/2001	9/11/2001	4/3/2002	9/11/2002	4/9/2003
OR8	9/29/1998	4/12/1999	9/15/1999	4/12/2000	9/20/2000	3/27/2001	9/11/2001	4/3/2002	9/12/2002	4/9/2003
OR9	9/29/1998	4/12/1999	9/15/1999	4/12/2000	9/20/2000	3/27/2001	9/10/2001	4/4/2002	9/12/2002	4/9/2003
MR1	10/13/1998	4/12/1999	9/16/1999	4/19/2000	9/20/2000	3/27/2001	9/7/2001	4/4/2002		4/10/2003
GLC1A	10/13/1998	4/12/1999	9/13/1999	4/11/2000	9/20/2000	3/26/2001	9/7/2001	4/3/2002	9/12/2002	4/9/2003
GLC1B	9/29/1998	4/14/1999	9/15/1999	4/11/2000	9/19/2000	3/27/2001	9/7/2001	4/4/2002	9/12/2002	4/9/2003
DC1	9/28/1998	4/15/1999	9/16/1999	4/10/2000	9/19/2000	3/27/2001	9/10/2001	4/2/2002	9/11/2002	4/8/2003
GLC2	9/30/1998	4/14/1999	9/13/1999	4/11/2000	9/20/2000	3/26/2001	9/7/2001	4/3/2002	9/7/2002	4/9/2003
GLC3	9/30/1998	4/14/1999	9/16/1999	4/11/2000	9/19/2000	3/26/2001	9/10/2001	4/4/2002	9/12/2002	4/9/2003
GLC4	9/30/1998	4/14/1999	9/16/1999	4/11/2000	9/19/2000	3/26/2001	9/7/2001	4/3/2002	9/12/2002	4/9/2003
GLC5	9/30/1998	4/15/1999	9/16/1999	4/11/2000	9/19/2000	3/26/2001	9/10/2001	4/3/2002	9/12/2002	4/8/2003

Note:Mr1 survey in Fall 2002 could not be conducted due to the thick growth of aquatic vegetation at the site.

# Appendix 1

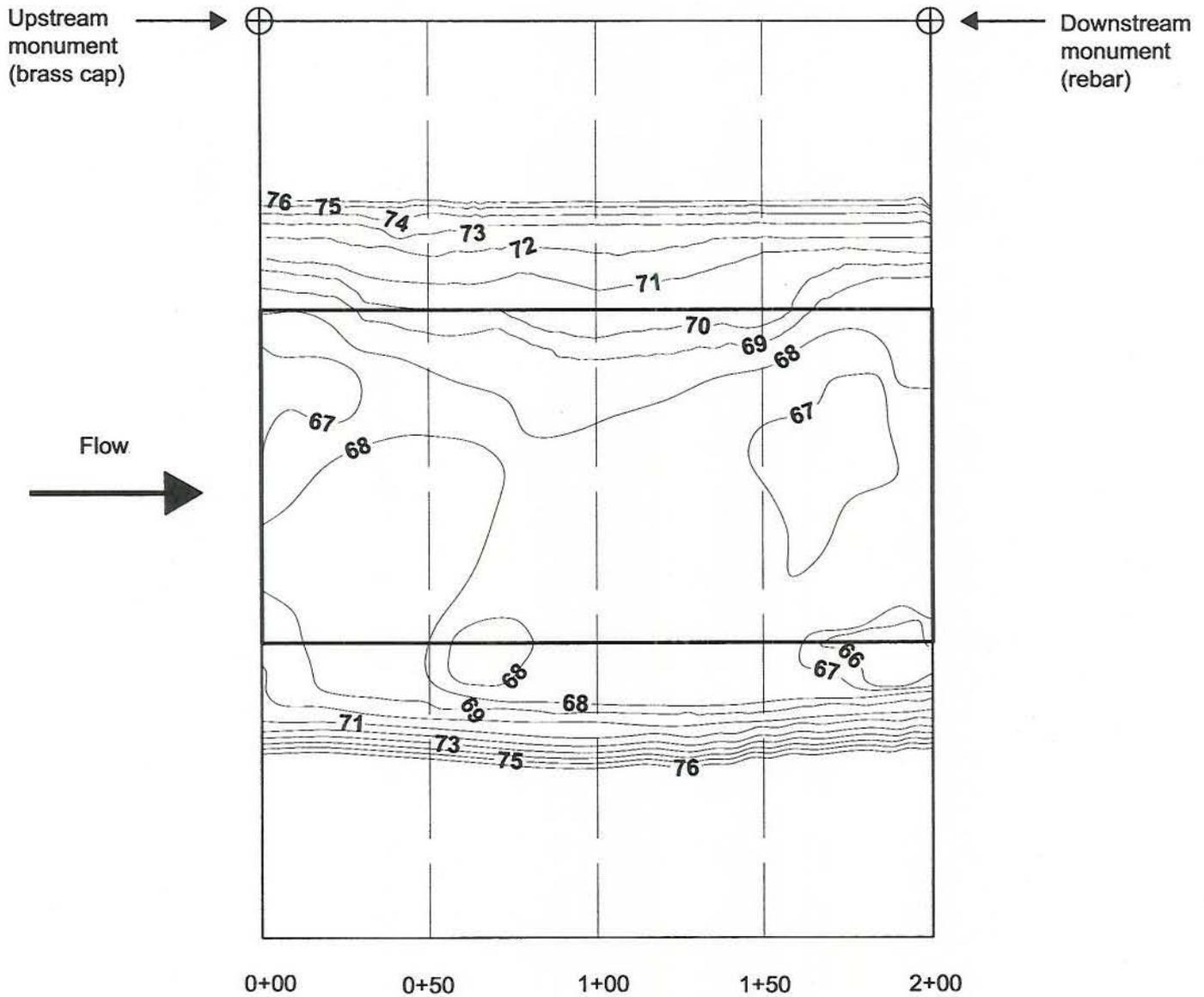
# APPENDIX 1

Appendix 1 includes bathymetric maps created from surveys conducted from spring 2000 to late summer 2002 at the following sites:

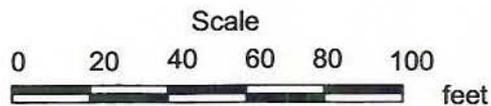
## Sample Location Name

<u>Old River:</u>	<u>Grant Line Canal:</u>	<u>Middle River:</u>	<u>Doughty Cut:</u>
OR1	GLC1a	MR1	DC1
OR2	GLC1b		
OR3	GLC2		
OR4	GLC3		
OR5	GLC4		
OR6	GLC5		
OR7			
OR8			
OR9			

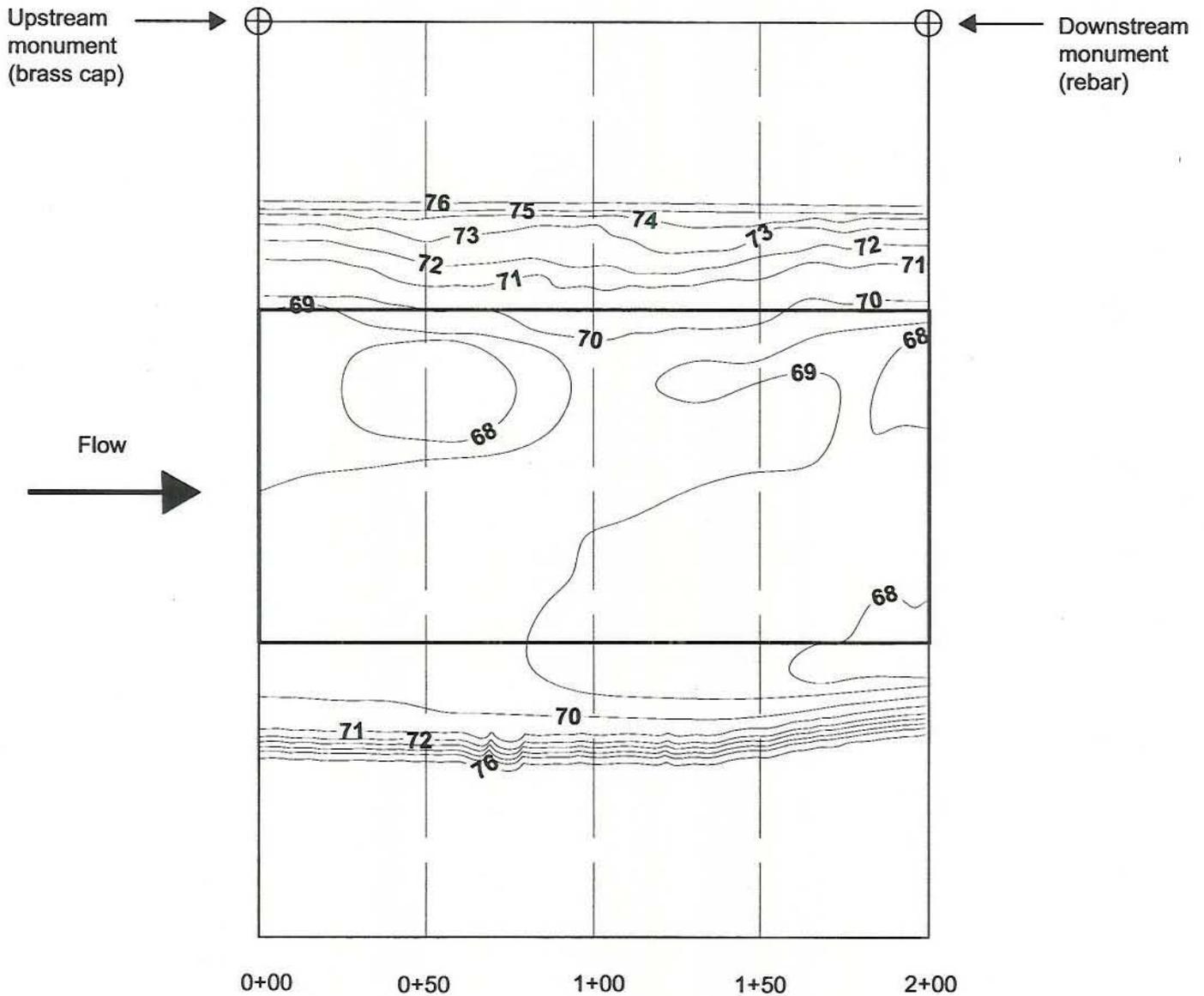
# Bathymetric Survey at OR1 Bed Sediment Contour Spring 2000



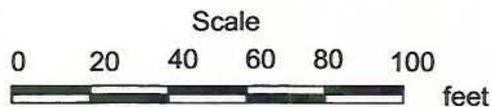
Note: Water surface elevation at the time of survey = 78.1 feet.  
Contours interpolated from soundings taken on April 10, 2000.  
Contour interval = 1 foot.



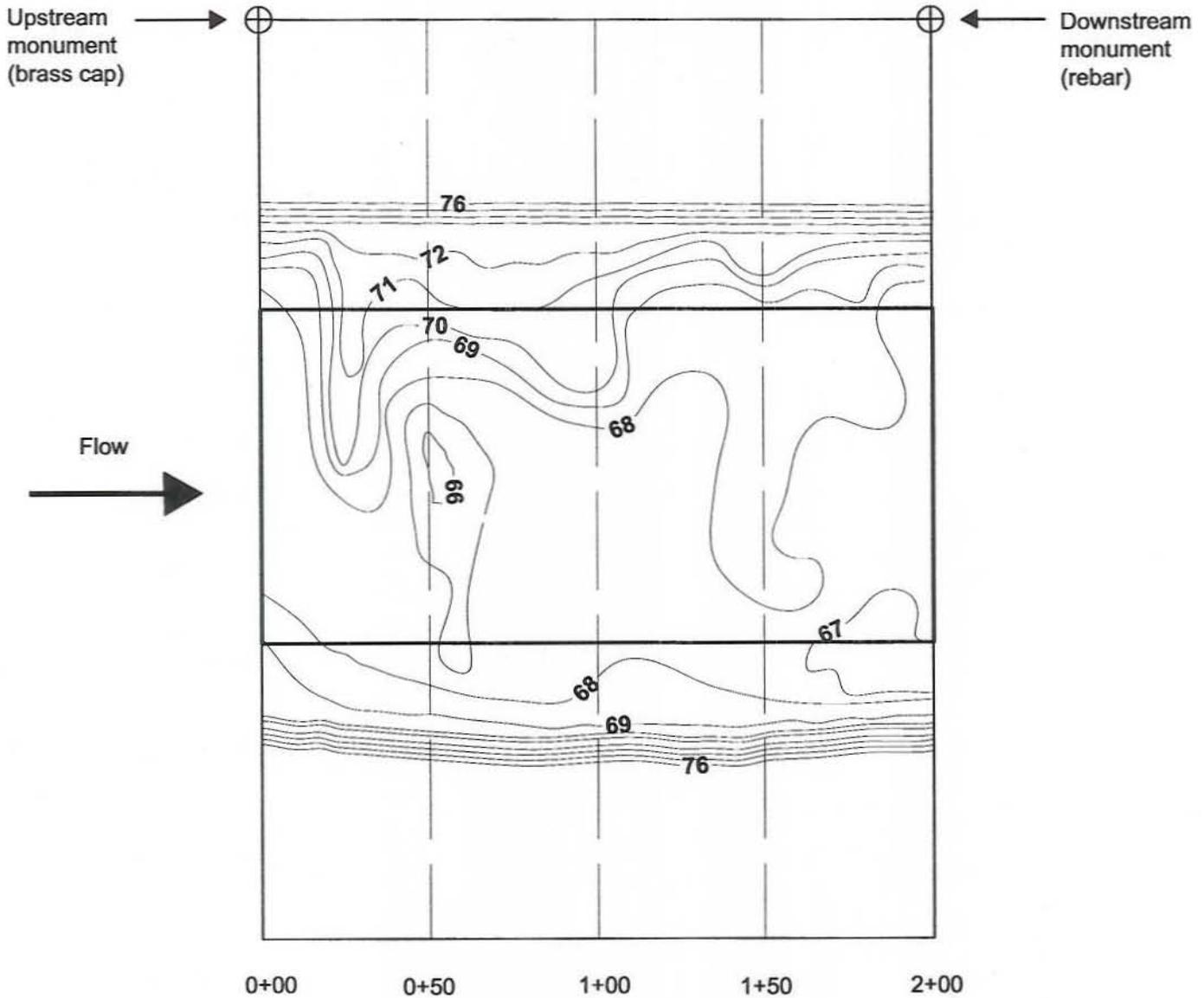
# Bathymetric Survey at OR1 Bed Sediment Contour Fall 2000



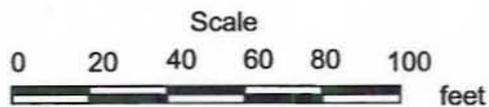
Note: Water surface elevation at the time of survey = 78.3 feet.  
Contours interpolated from soundings taken on September 19, 2000.  
Contour interval = 1 foot.



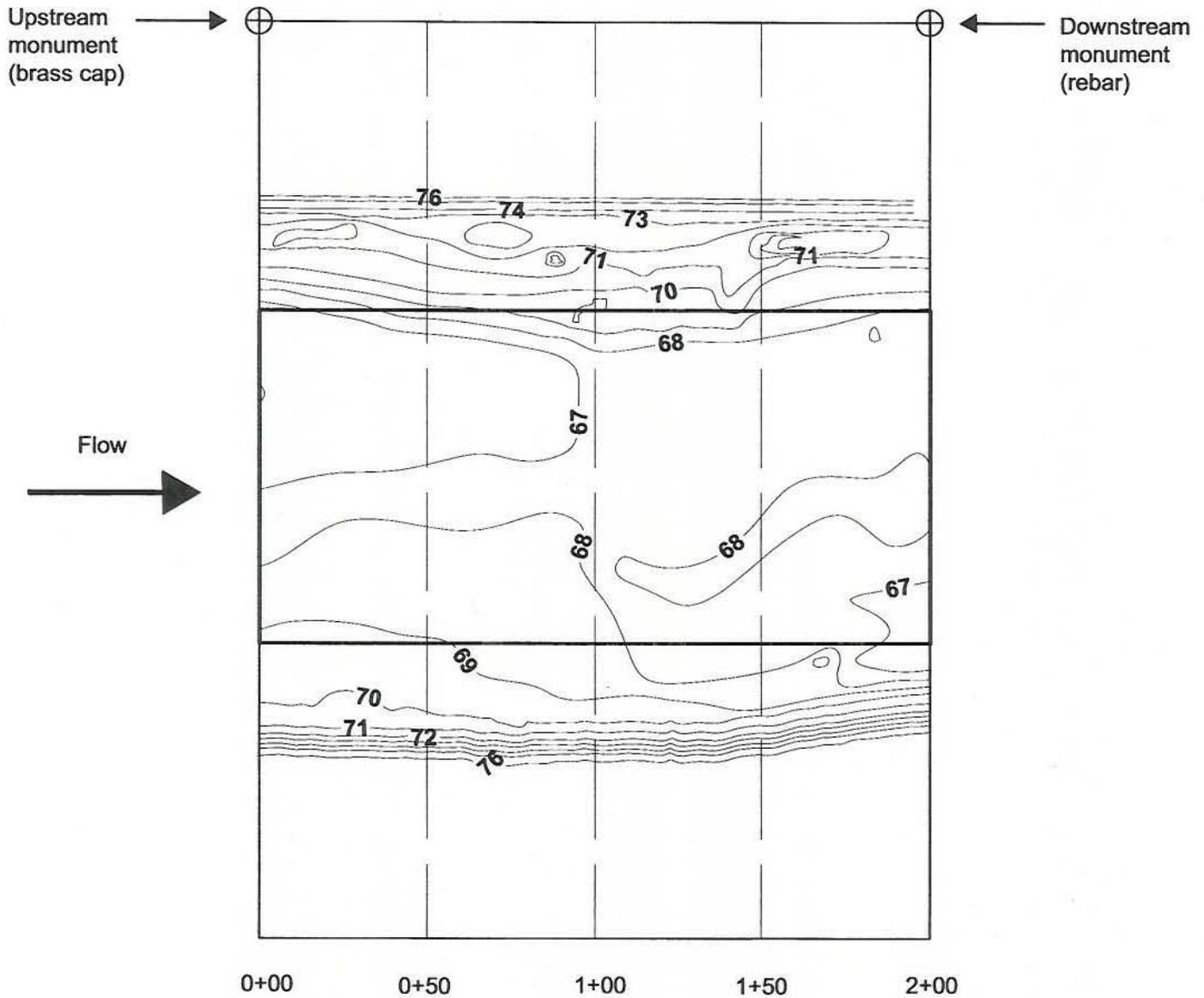
# Bathymetric Survey at OR1 Bed Sediment Contour Spring 2001



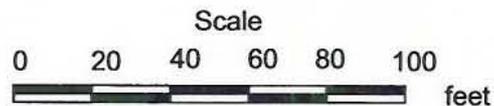
Note: Water surface elevation at the time of survey = 78.1 feet.  
Contours interpolated from soundings taken on March 20, 2001.  
Contour interval = 1 foot.



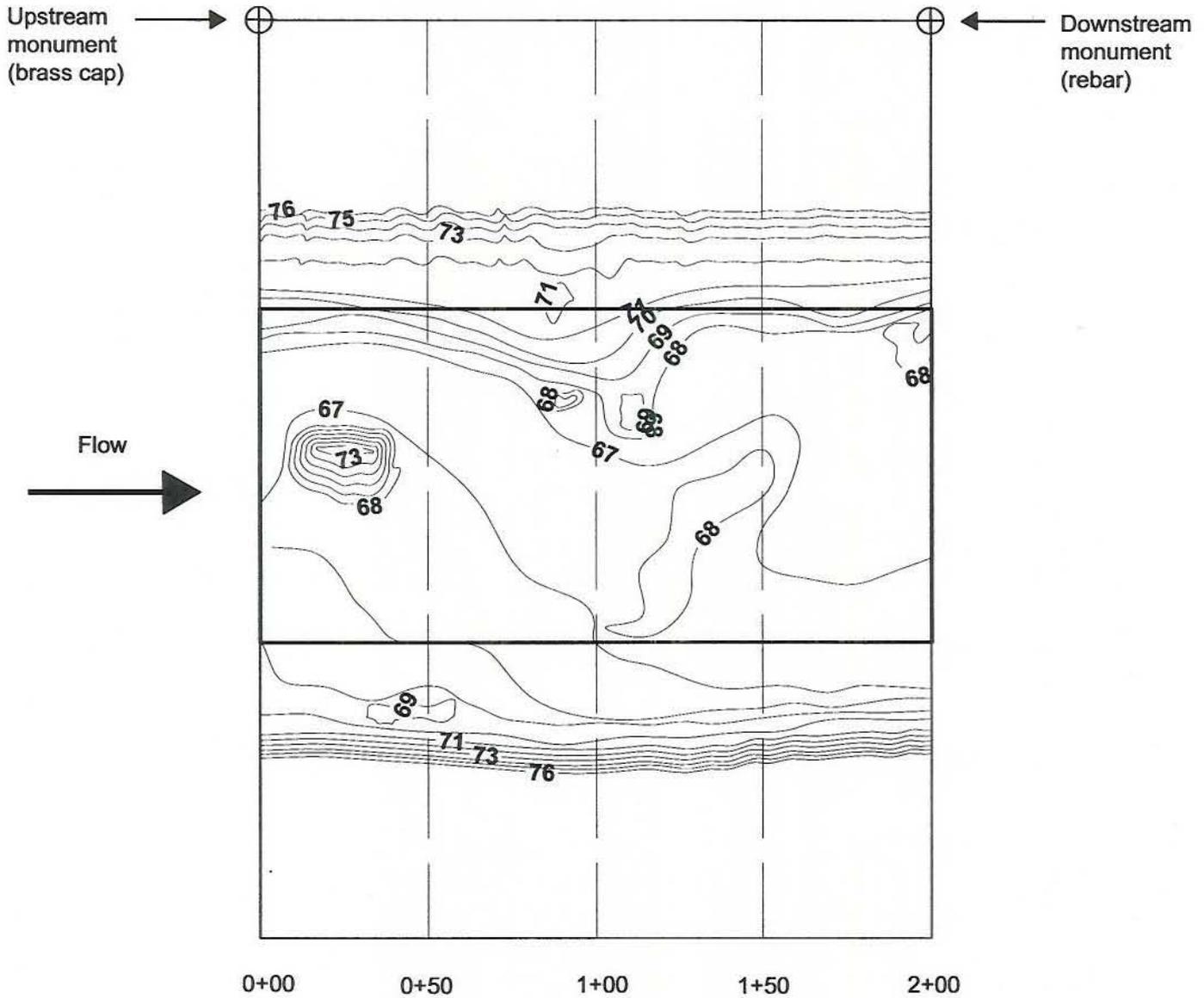
# Bathymetric Survey at OR1 Bed Sediment Contour Fall 2001



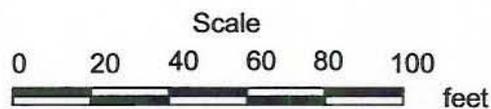
Note: Water surface elevation at the time of survey = 76.9 feet.  
Contours interpolated from soundings taken on September 10, 2001.  
Contour interval = 1 foot.



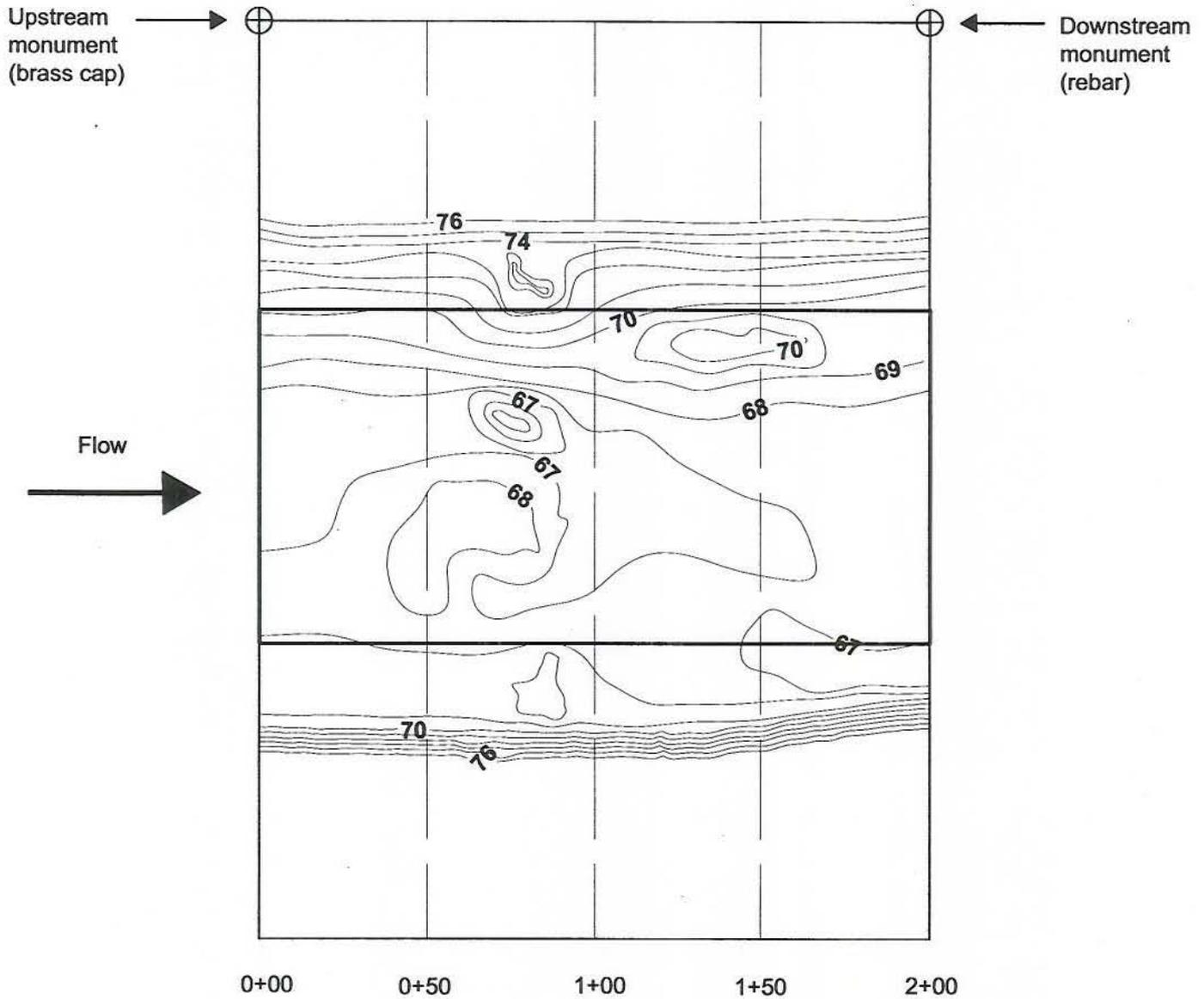
# Bathymetric Survey at OR1 Bed Sediment Contour Spring 2002



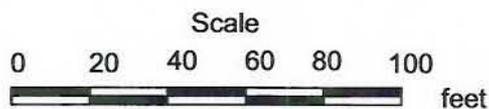
Note: Water surface elevation at the time of survey = 77.7 feet.  
Contours interpolated from soundings taken on April 2, 2002.  
Contour interval = 1 foot.

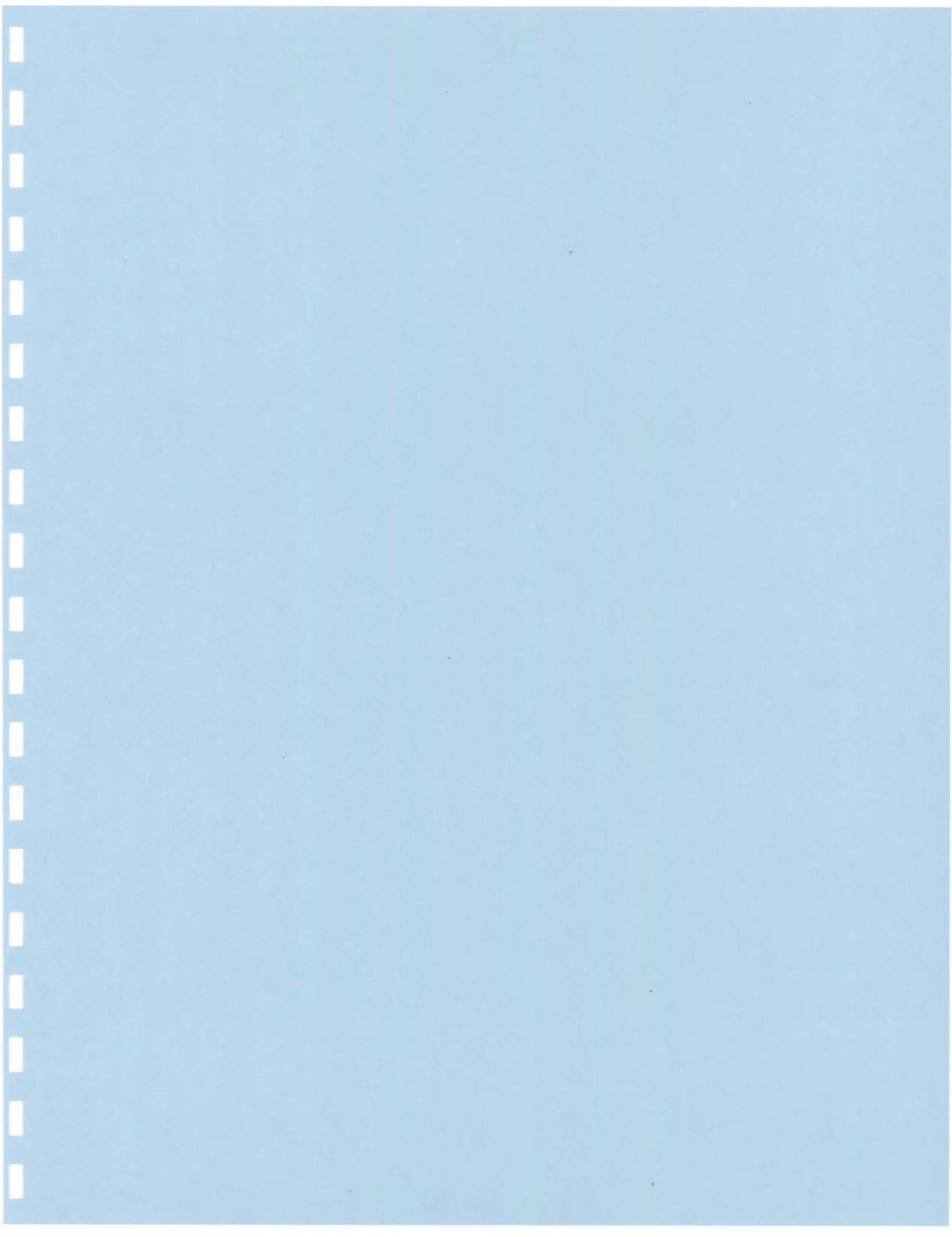


# Bathymetric Survey at OR1 Bed Sediment Contour Fall 2002

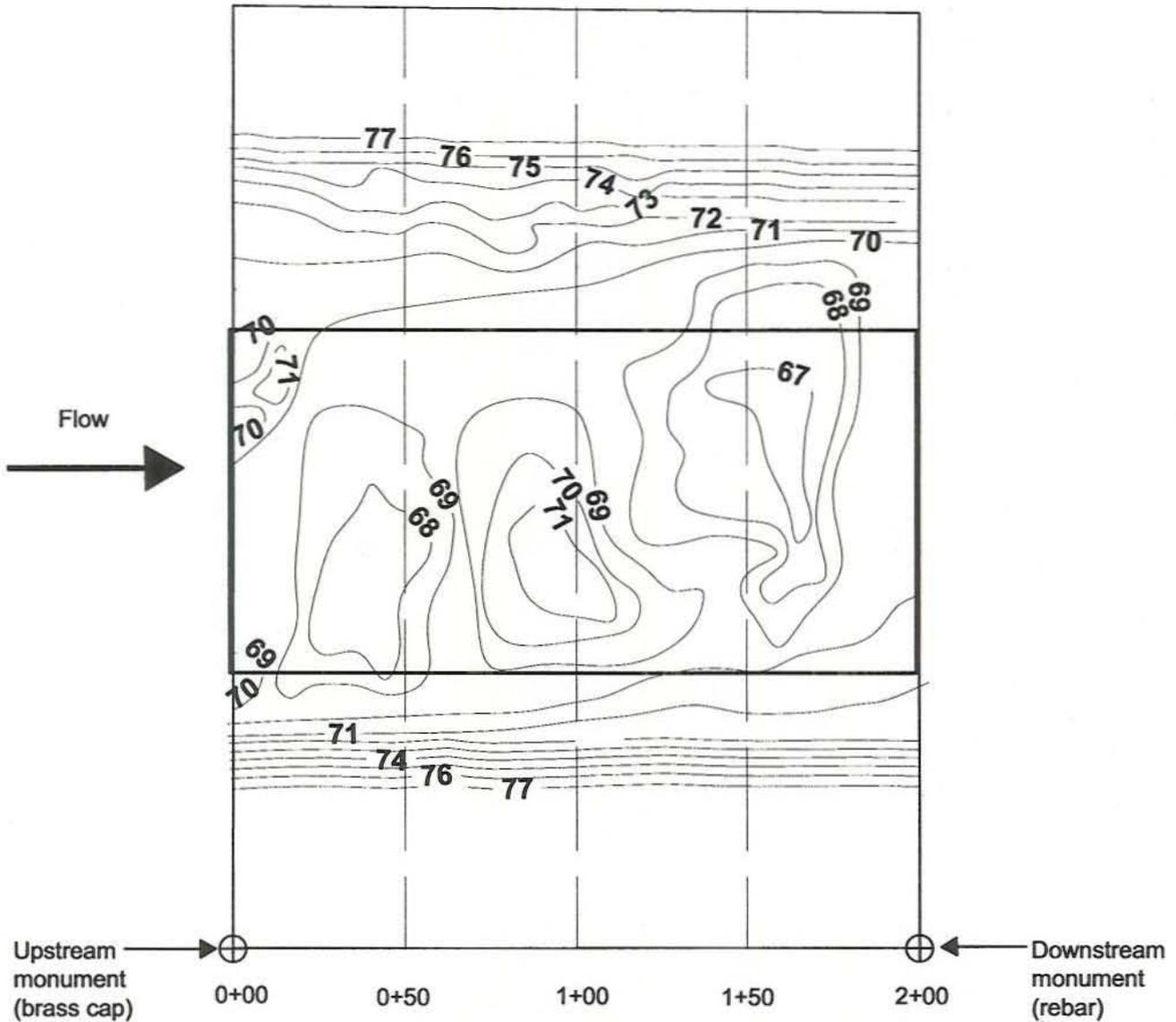


Note: Water surface elevation at the time of survey = 76.7 feet.  
Contours interpolated from soundings taken on September 11, 2002.  
Contour interval = 1 foot.

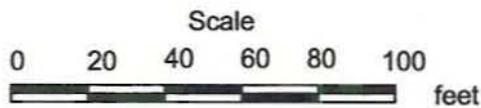




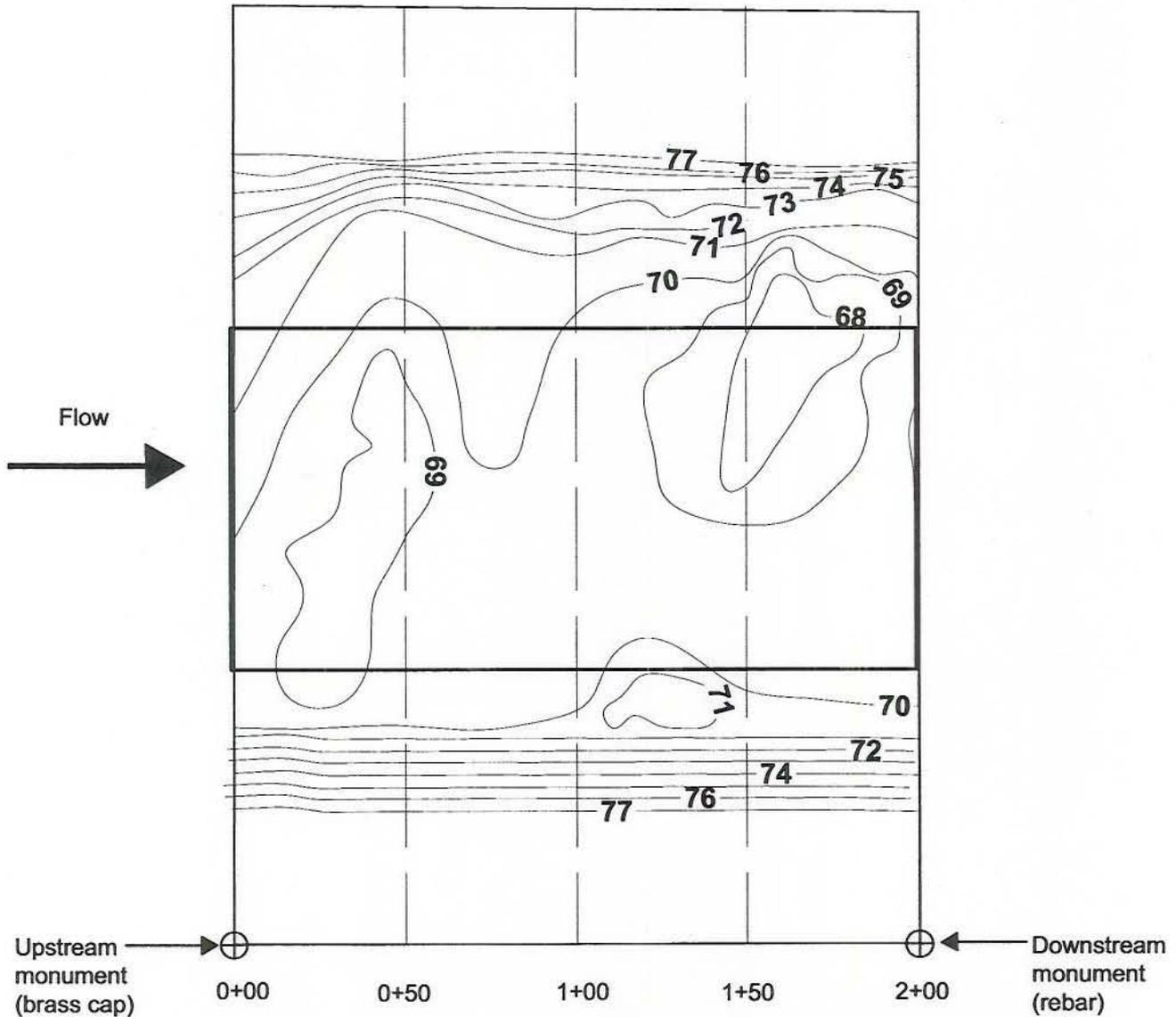
# Bathymetric Survey at OR2 Bed Sediment Contour Spring 2000



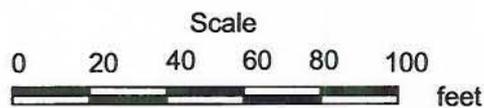
Note: Water surface elevation at the time of survey = 81.0 feet.  
Contours interpolated from soundings taken on April 10, 200.  
Contour interval = 1 foot.



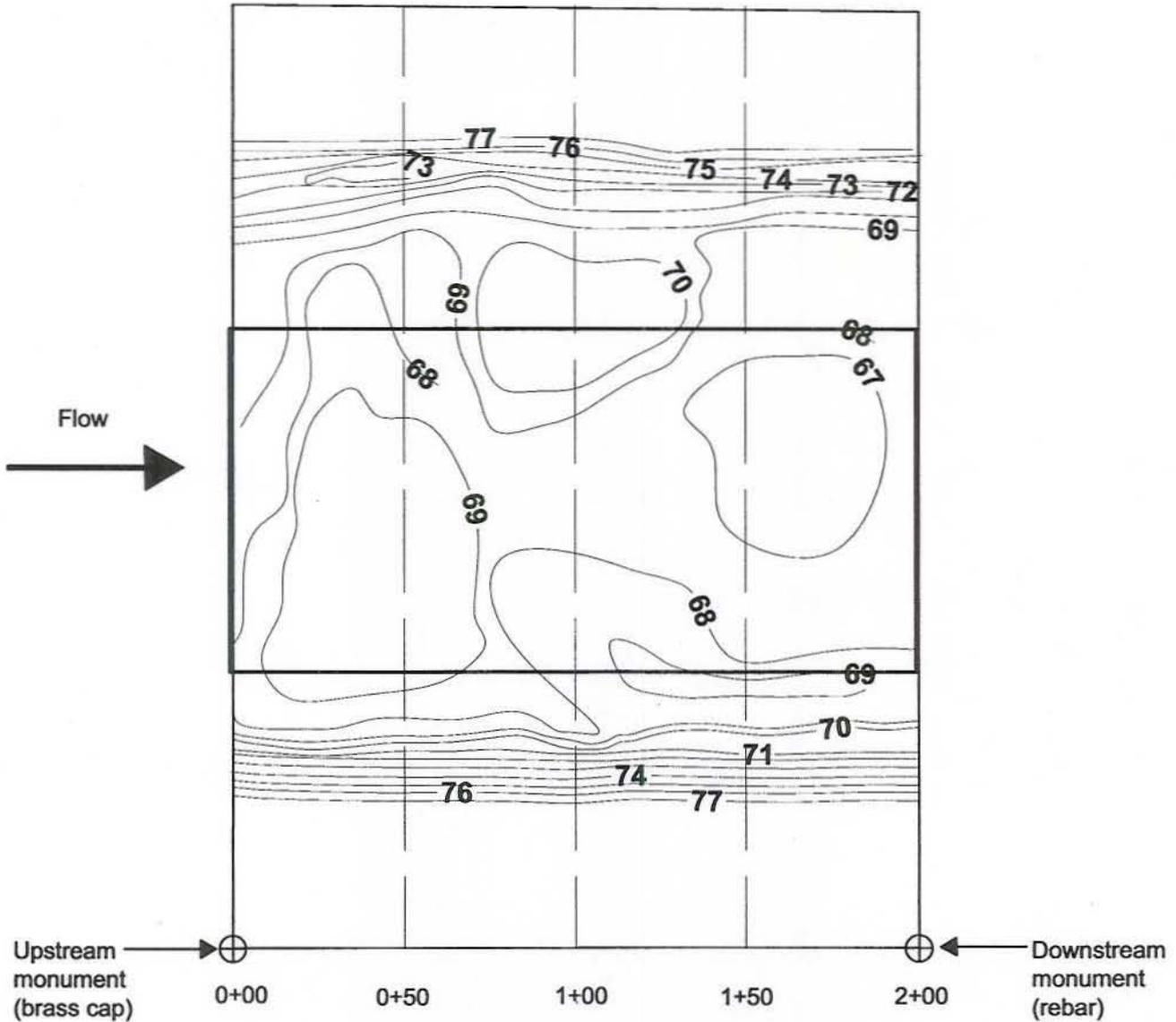
# Bathymetric Survey at OR2 Bed Sediment Contour Fall 2000



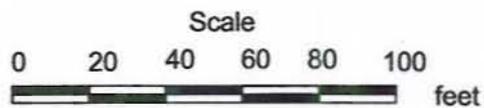
Note: Water surface elevation at the time of survey = 81.4 feet.  
Contours interpolated from soundings taken on September 19, 2000.  
Contour interval = 1 foot.



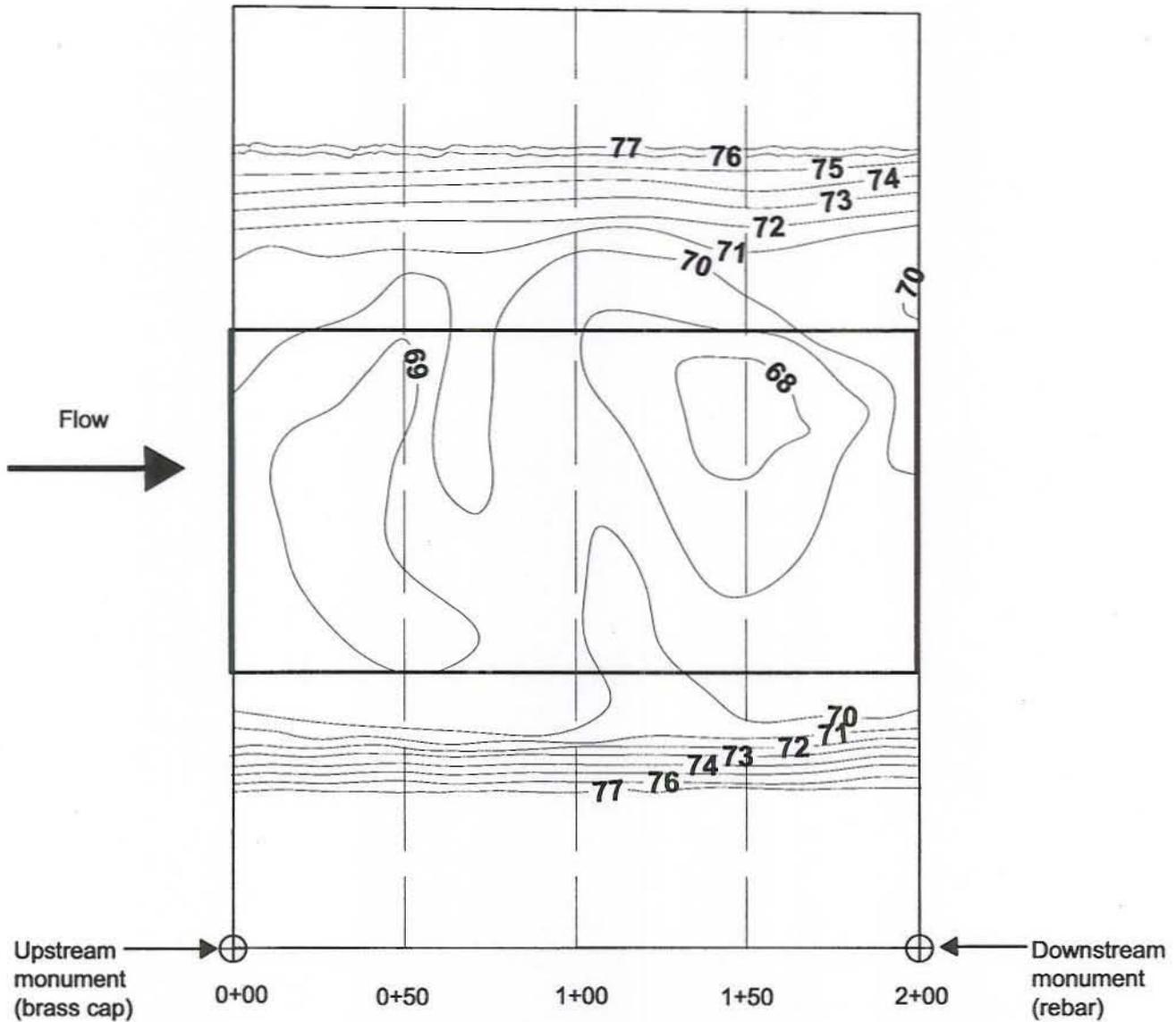
# Bathymetric Survey at OR2 Bed Sediment Contour Spring 2001



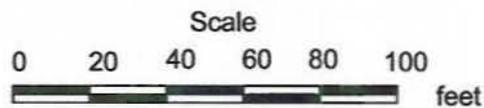
Note: Water surface elevation at the time of survey = 80.2 feet.  
Contours interpolated from soundings taken on March 20, 2001.  
Contour interval = 1 foot.



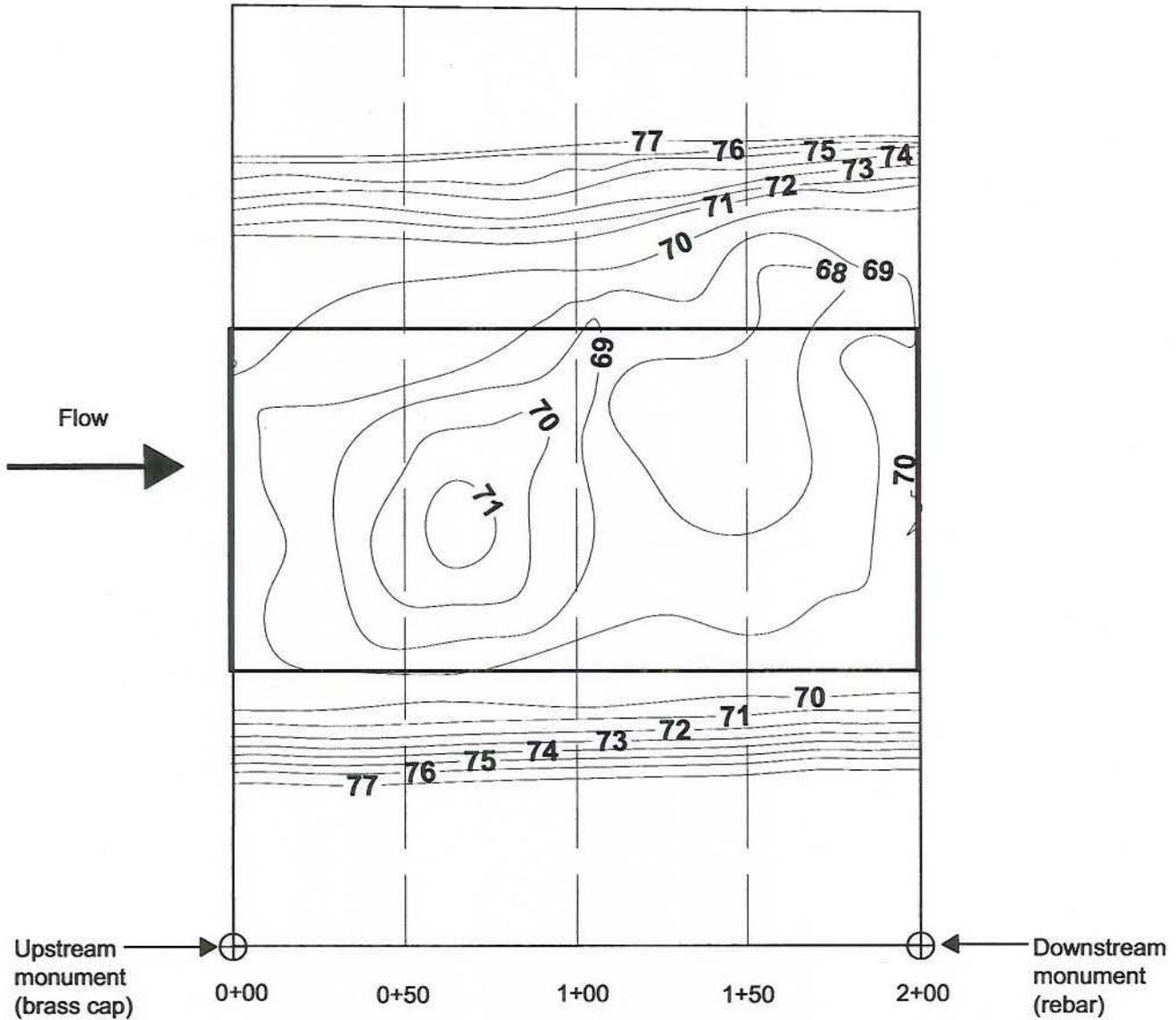
# Bathymetric Survey at OR2 Bed Sediment Contour Fall 2001



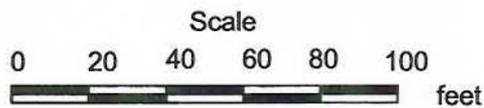
Note: Water surface elevation at the time of survey = 81.1 feet.  
Contours interpolated from soundings taken on September 10, 2001.  
Contour interval = 1 foot.



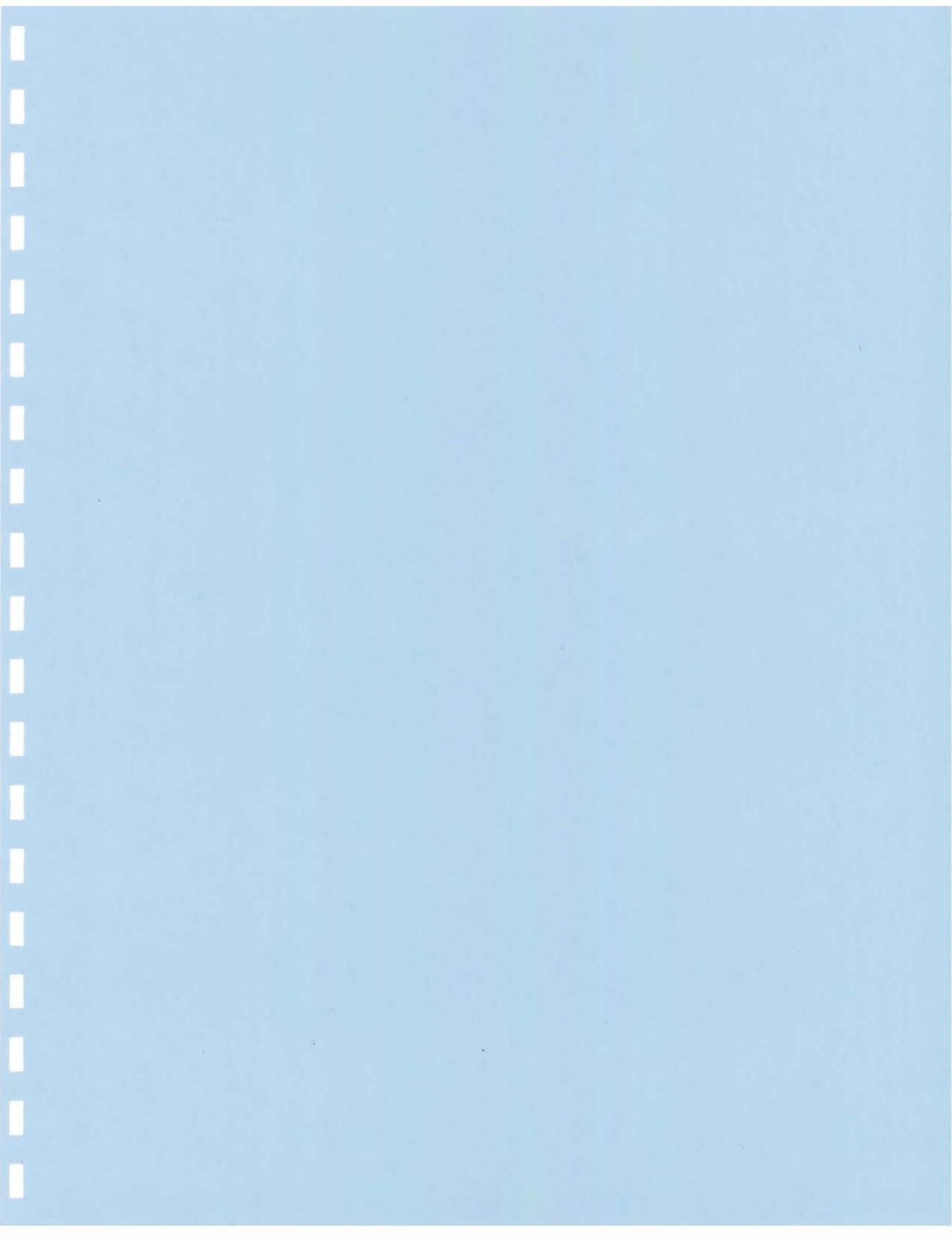
# Bathymetric Survey at OR2 Bed Sediment Contour Spring 2002



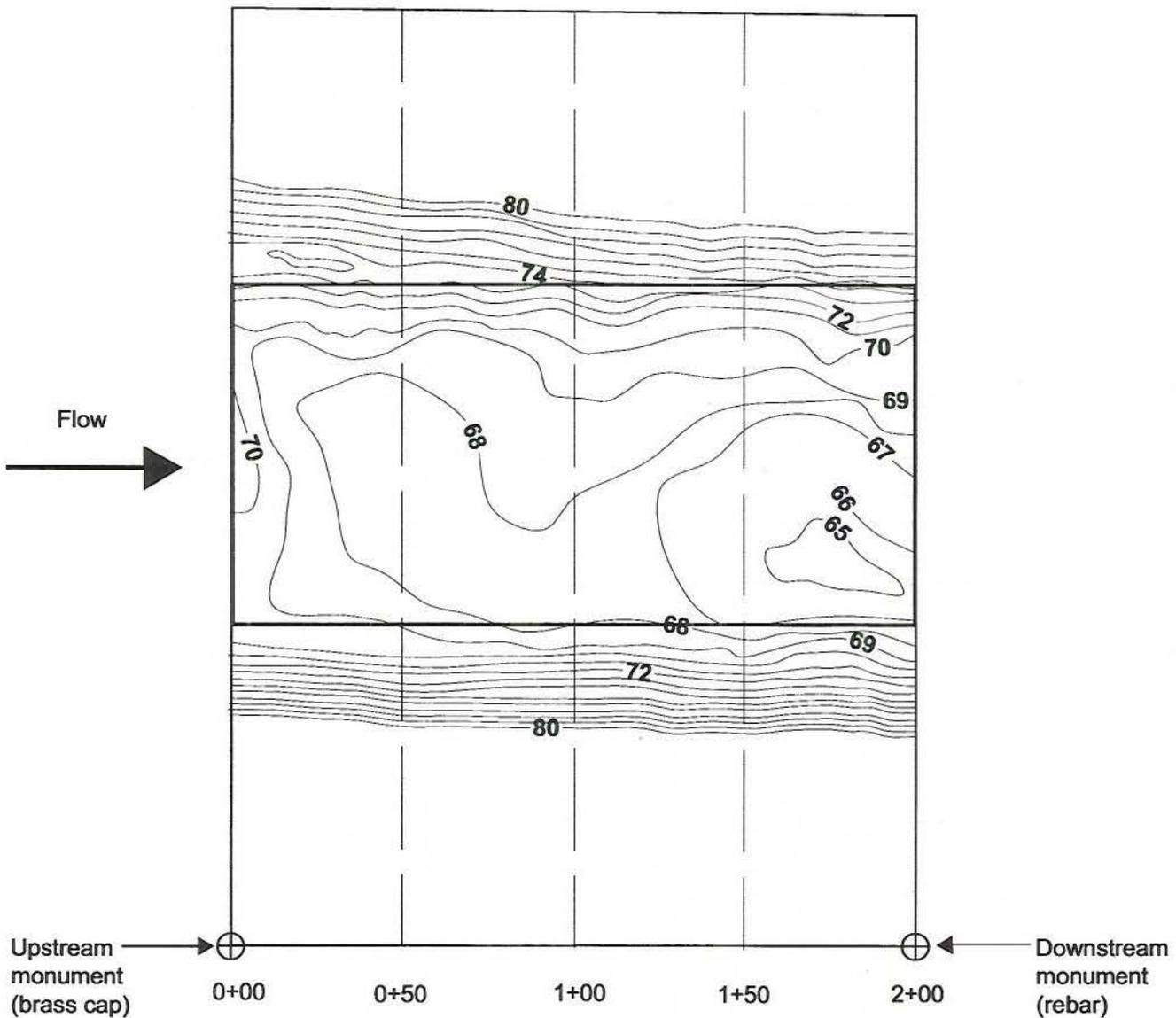
Note: Water surface elevation at the time of survey = 81.6 feet.  
Contours interpolated from soundings taken on April 2, 2002.  
Contour interval = 1 foot.



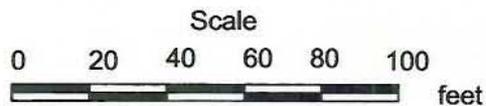




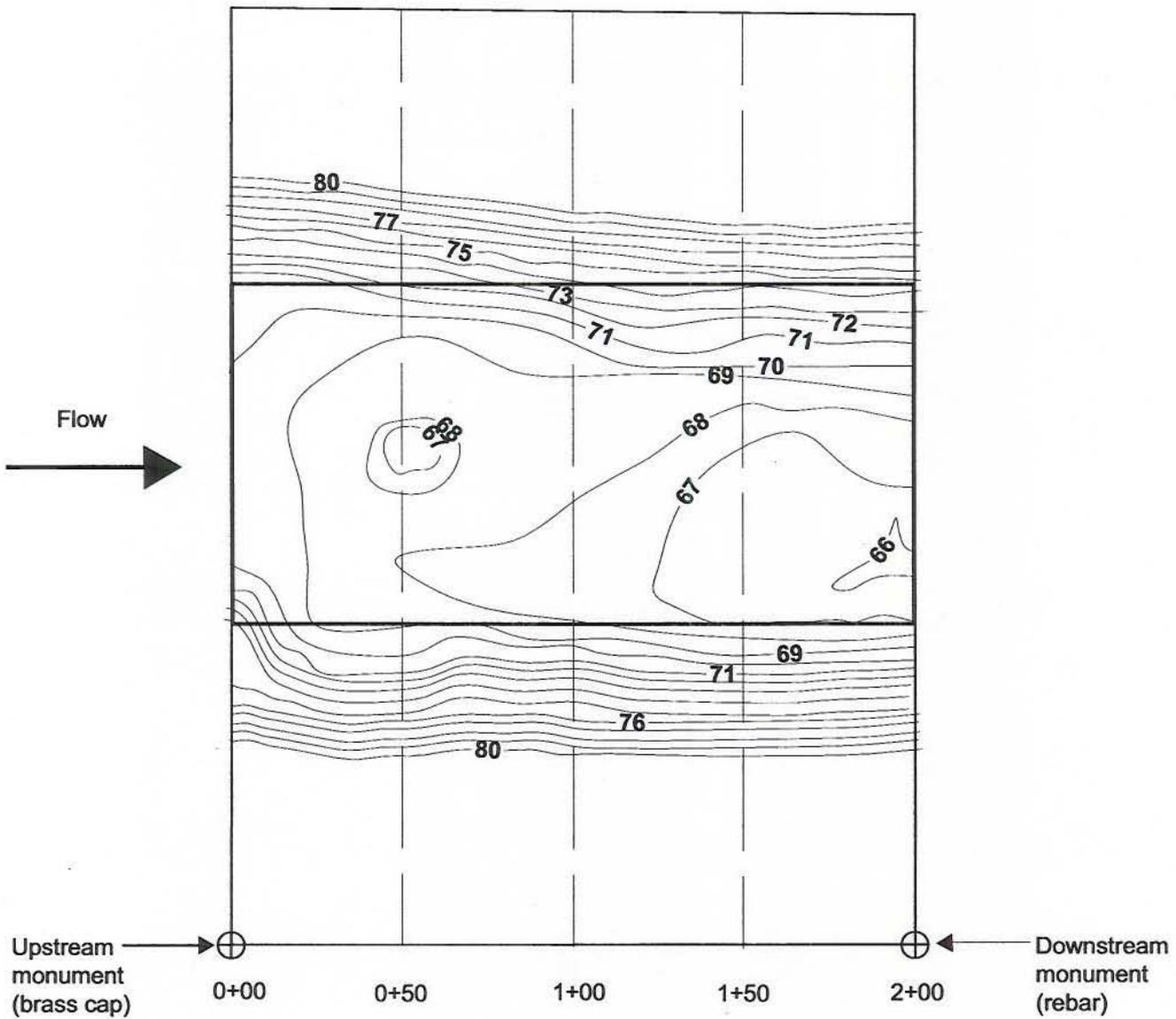
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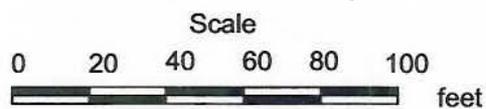
Notes: Water surface elevation at the time of survey = 86.2 feet.  
Contours interpolated from soundings taken on April 10, 2000.  
Contour interval = 1 foot.



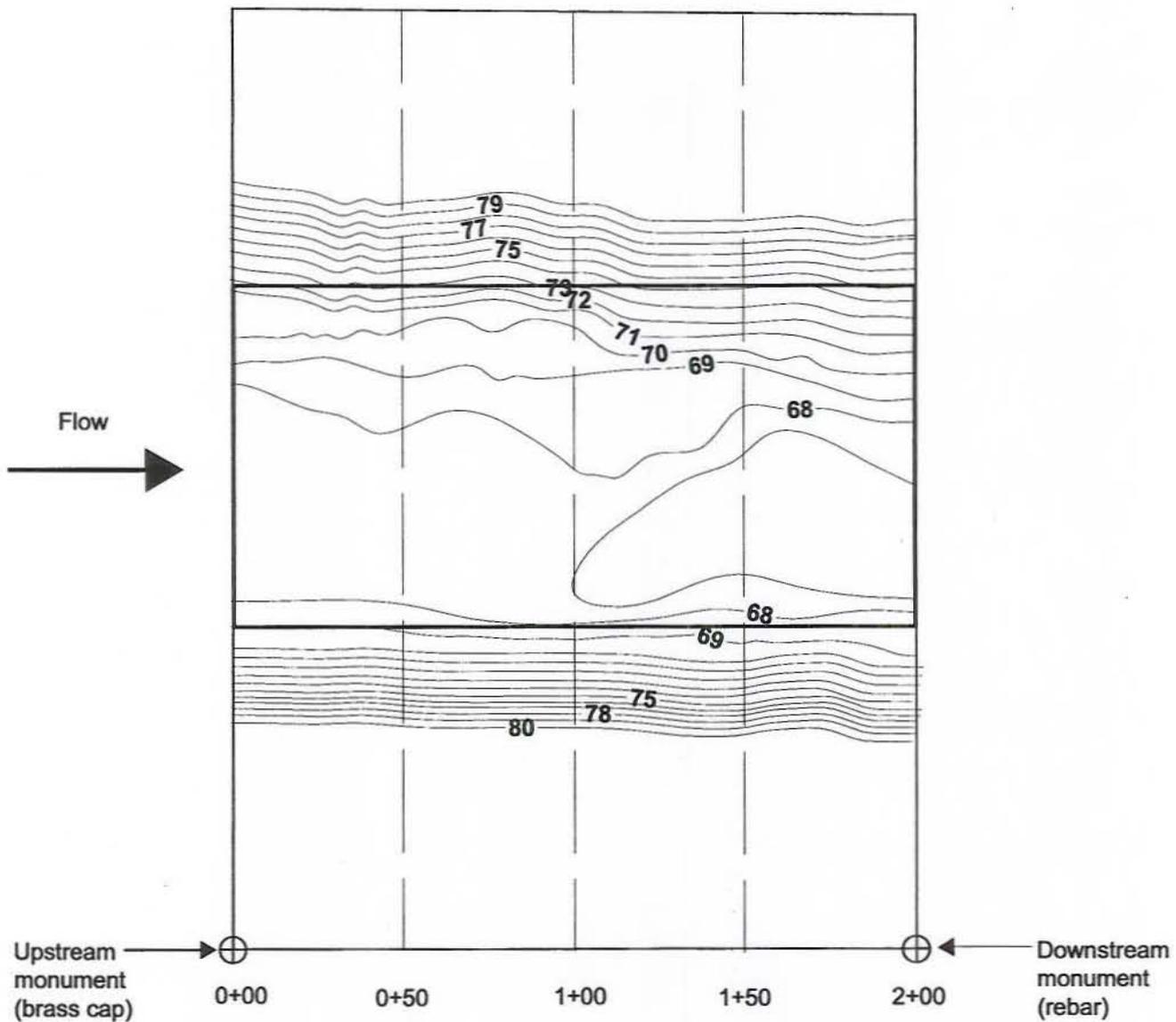
# Bathymetric Survey at OR3 Bed Sediment Contour Fall 2000



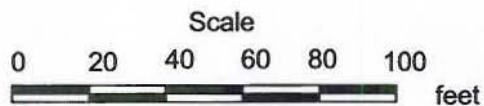
Note: Water surface elevation at the time of survey = 86.5 feet.  
Contours interpolated from soundings taken on September 19, 2000.  
Contour interval = 1 foot.



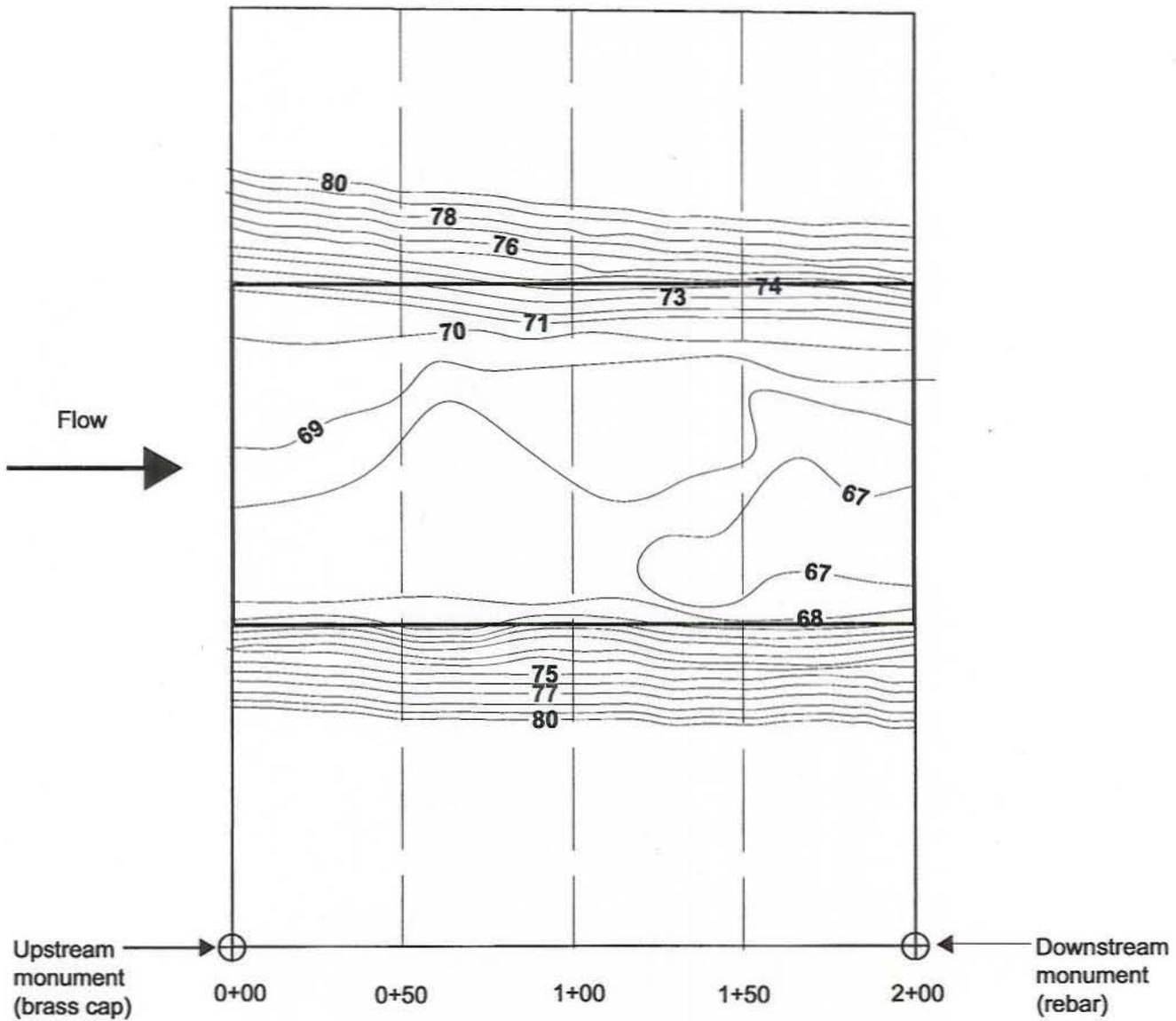
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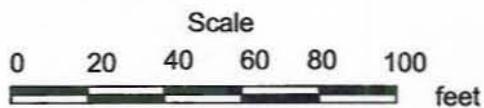
Note: Water surface elevation at the time of survey = 86.2 feet.  
Contours interpolated from soundings taken on March 26, 2001.  
Contour interval = 1 foot.



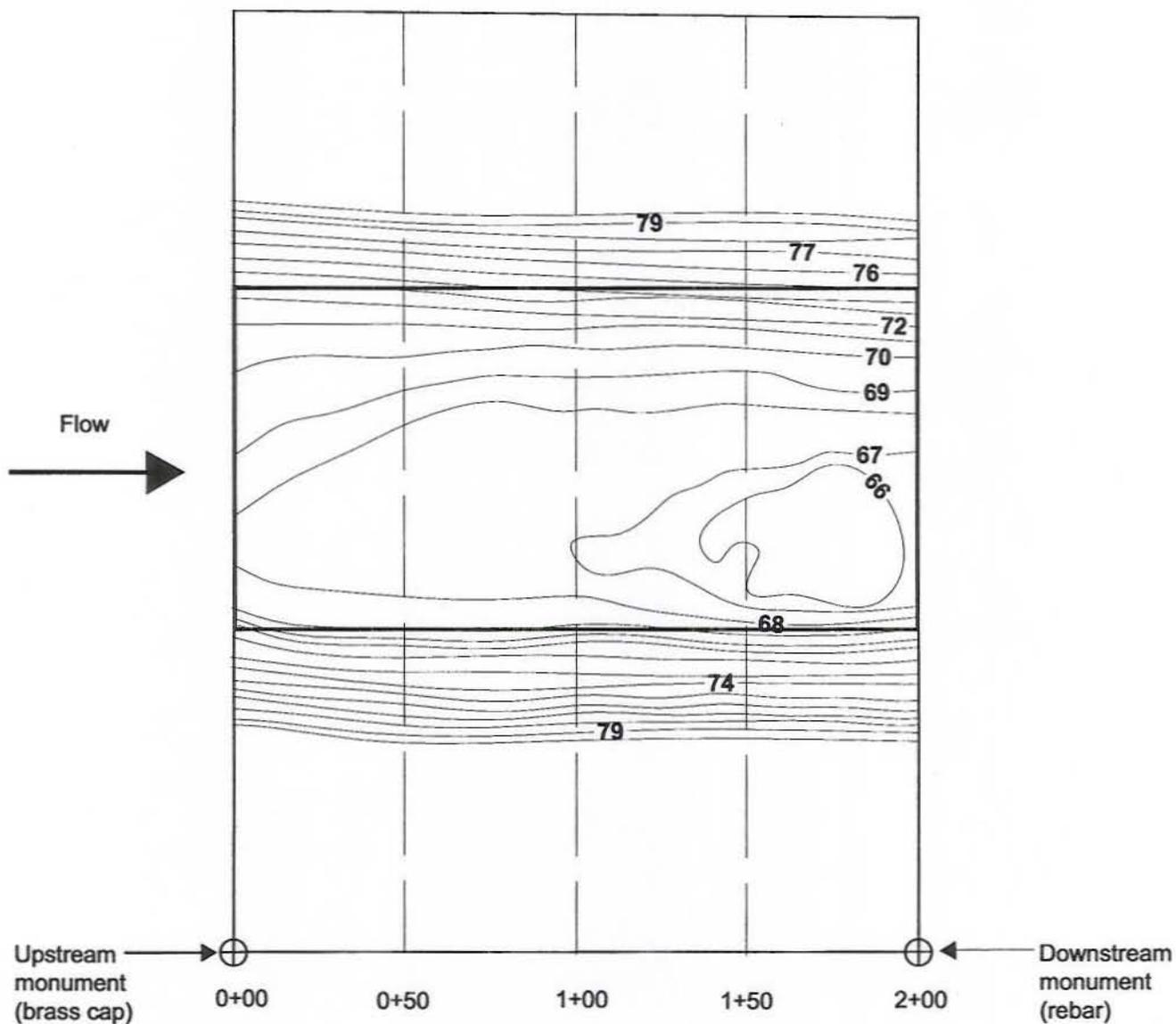
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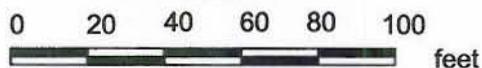
Note: Water surface elevation at the time of survey = 85.9 feet.  
Contours interpolated from soundings taken on September 10, 2001.  
Contour interval = 1 foot.



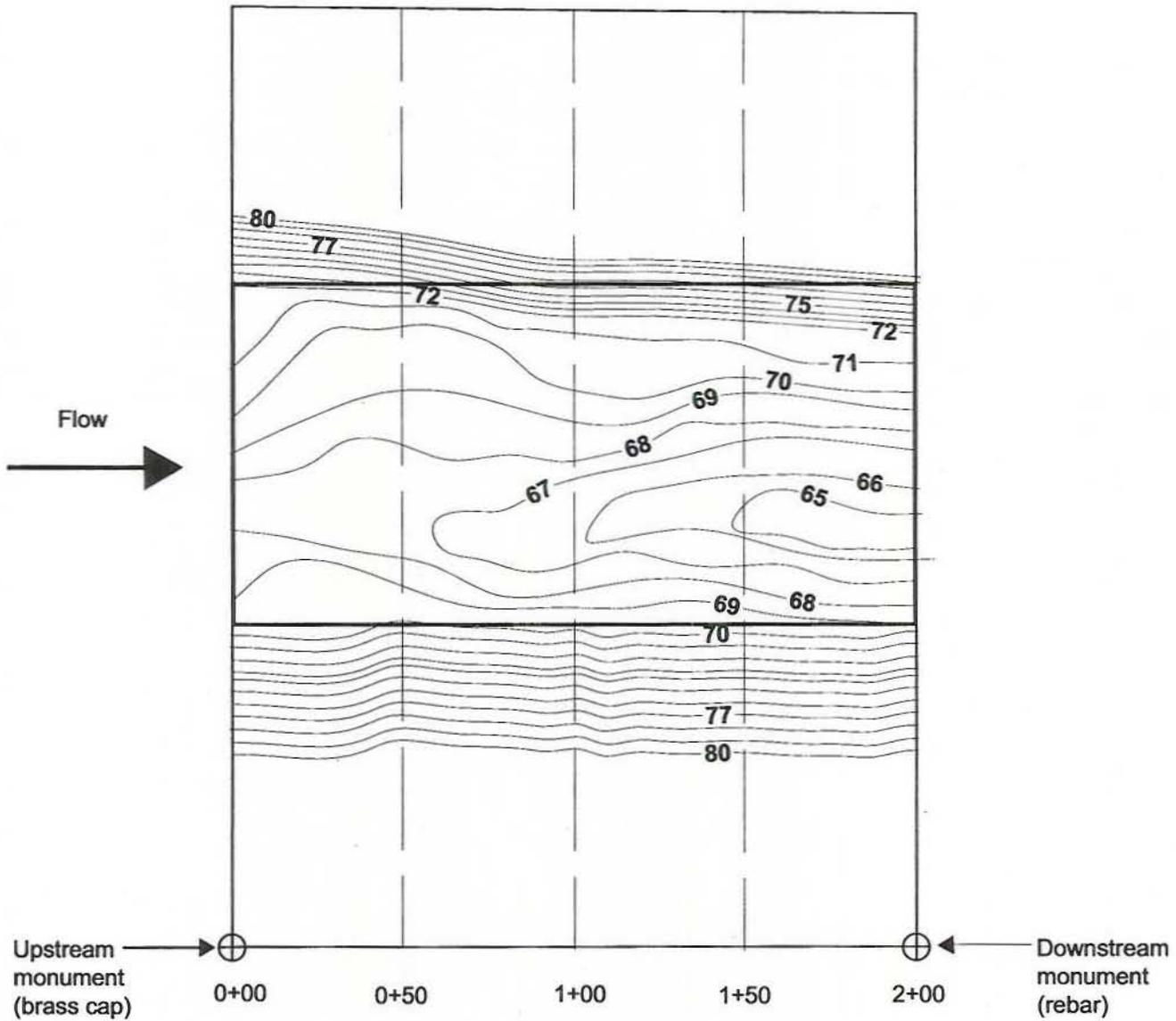
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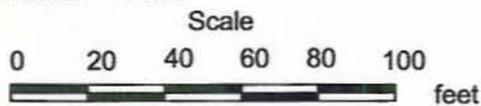
Note: Water surface elevation at the time of survey = 85.9 feet.  
Contours interpolated from soundings taken on April 2, 2002.  
Contour interval = 1 foot. Scale

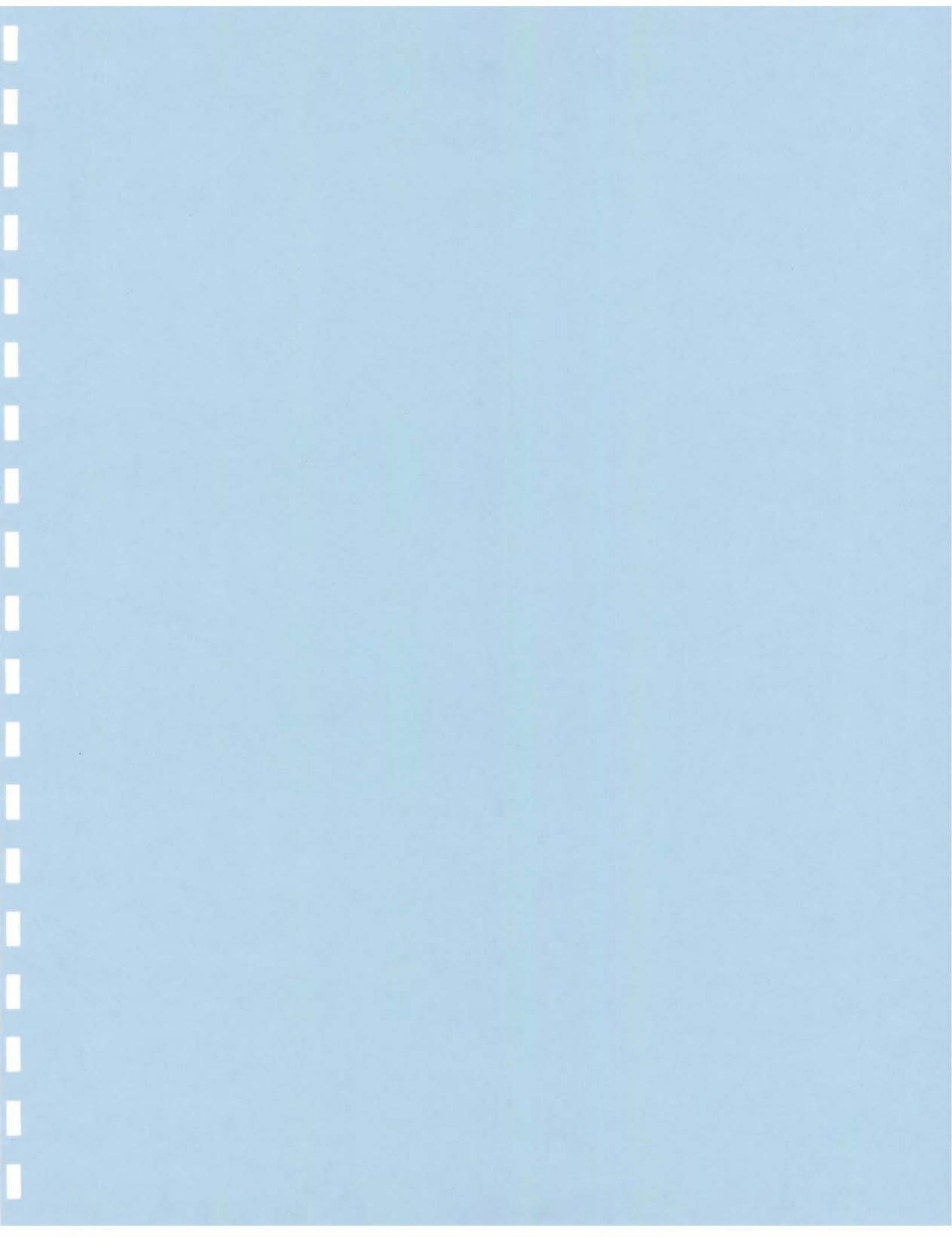


# Bathymetric Survey at OR3 Bed Sediment Contour Fall 2002

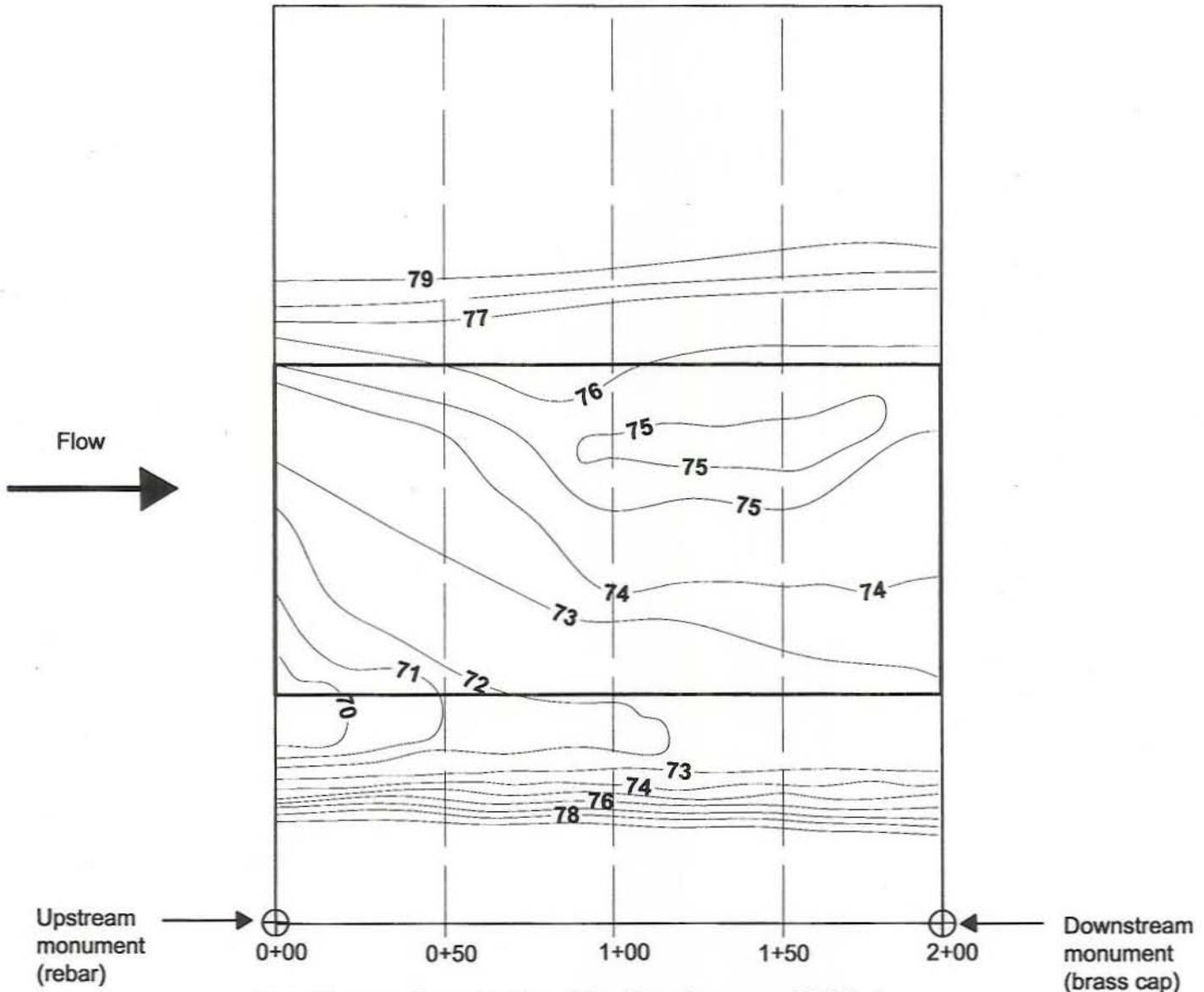


Note: Water surface elevation at the time of survey = 85.8 feet.  
Contours interpolated from soundings taken on September 11, 2002.  
Contour interval = 1 foot.

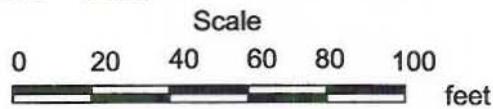




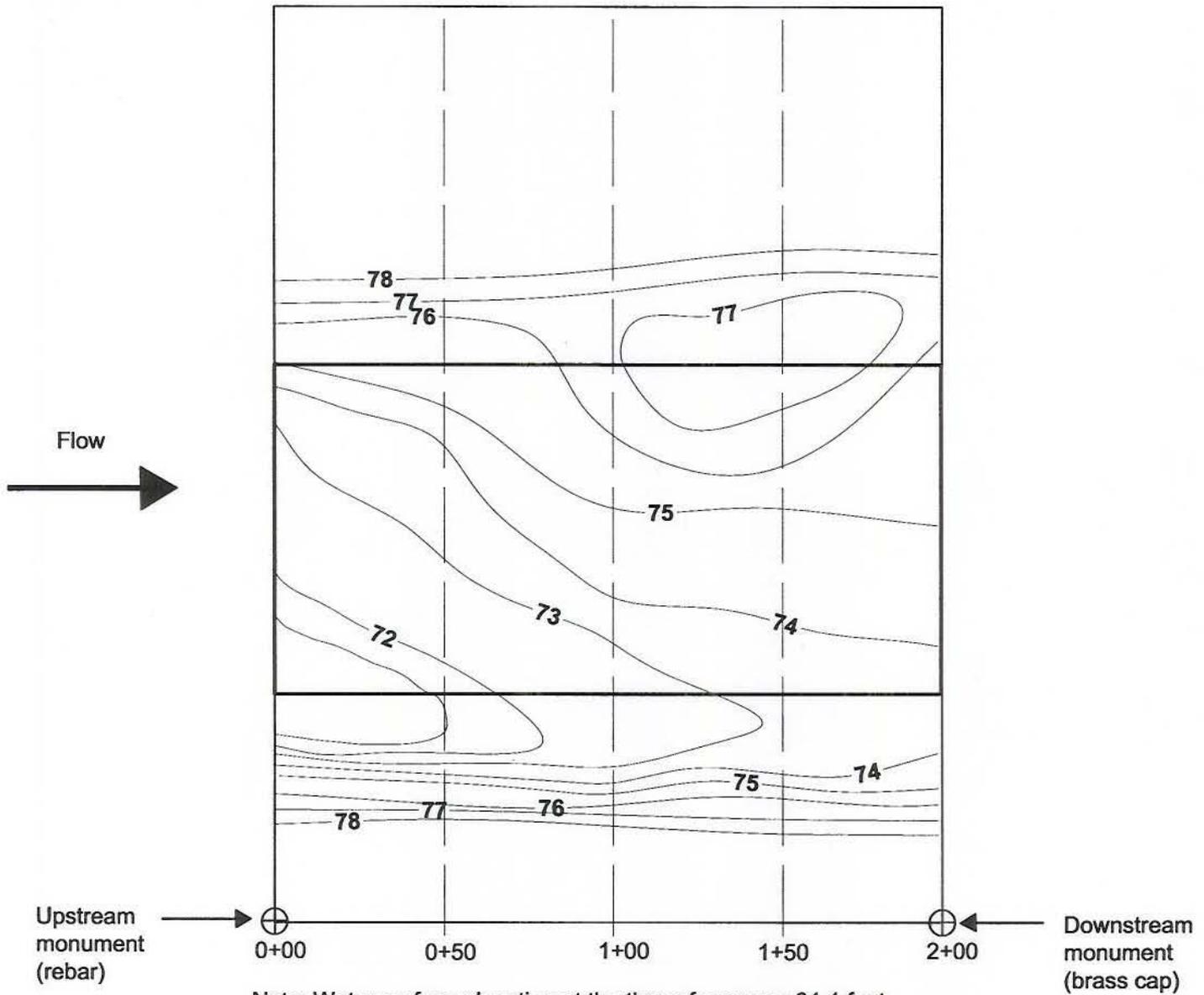
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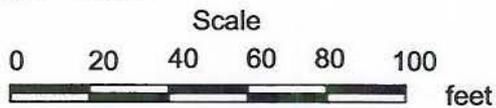
Note: Water surface elevation at the time of survey = 79.2 feet.  
Contours interpolated from soundings taken on April 10, 2000.  
Contour interval = 1 foot.



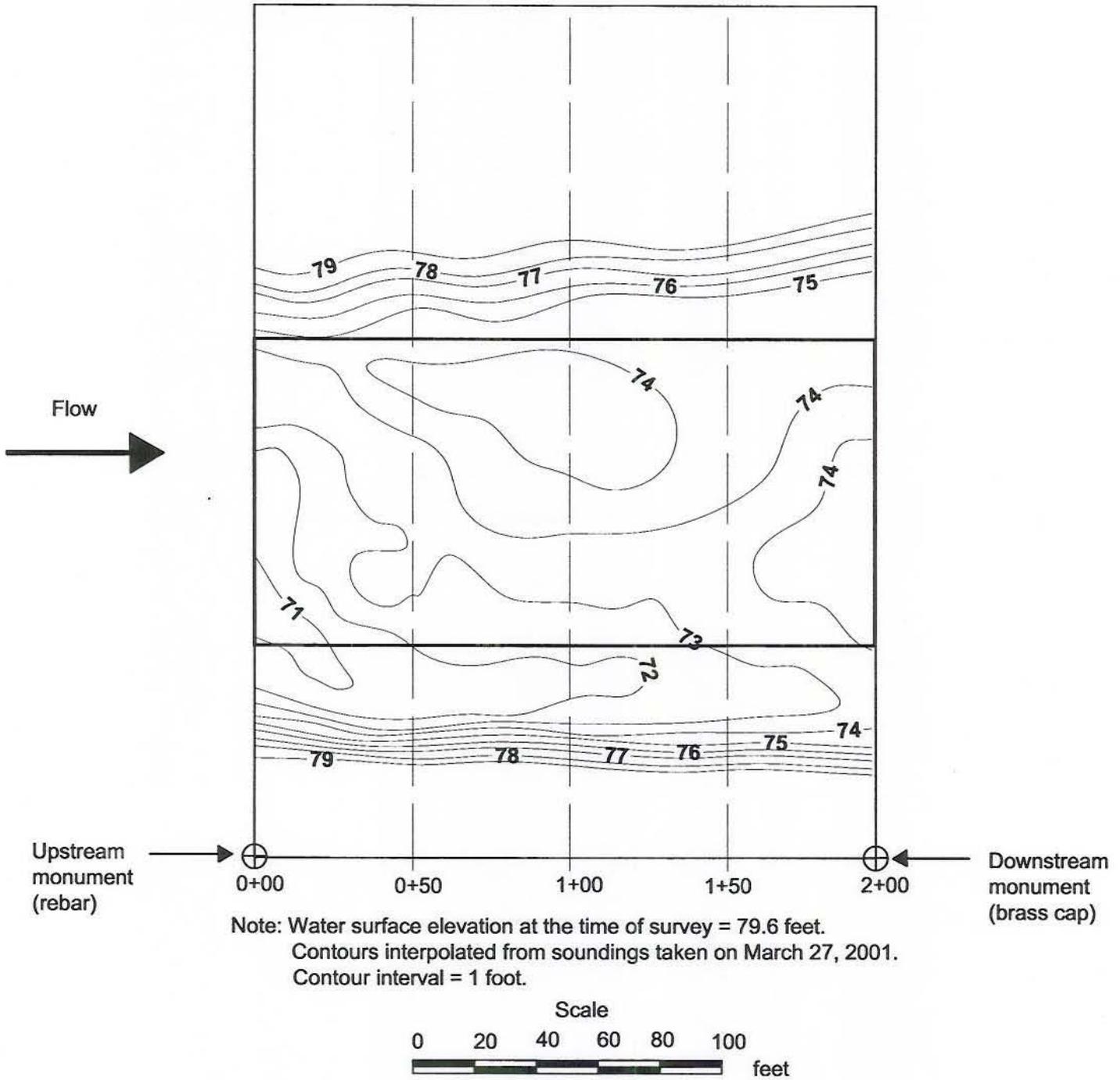
# Bathymetric Survey at OR4 Bed Sediment Contour Fall 2000



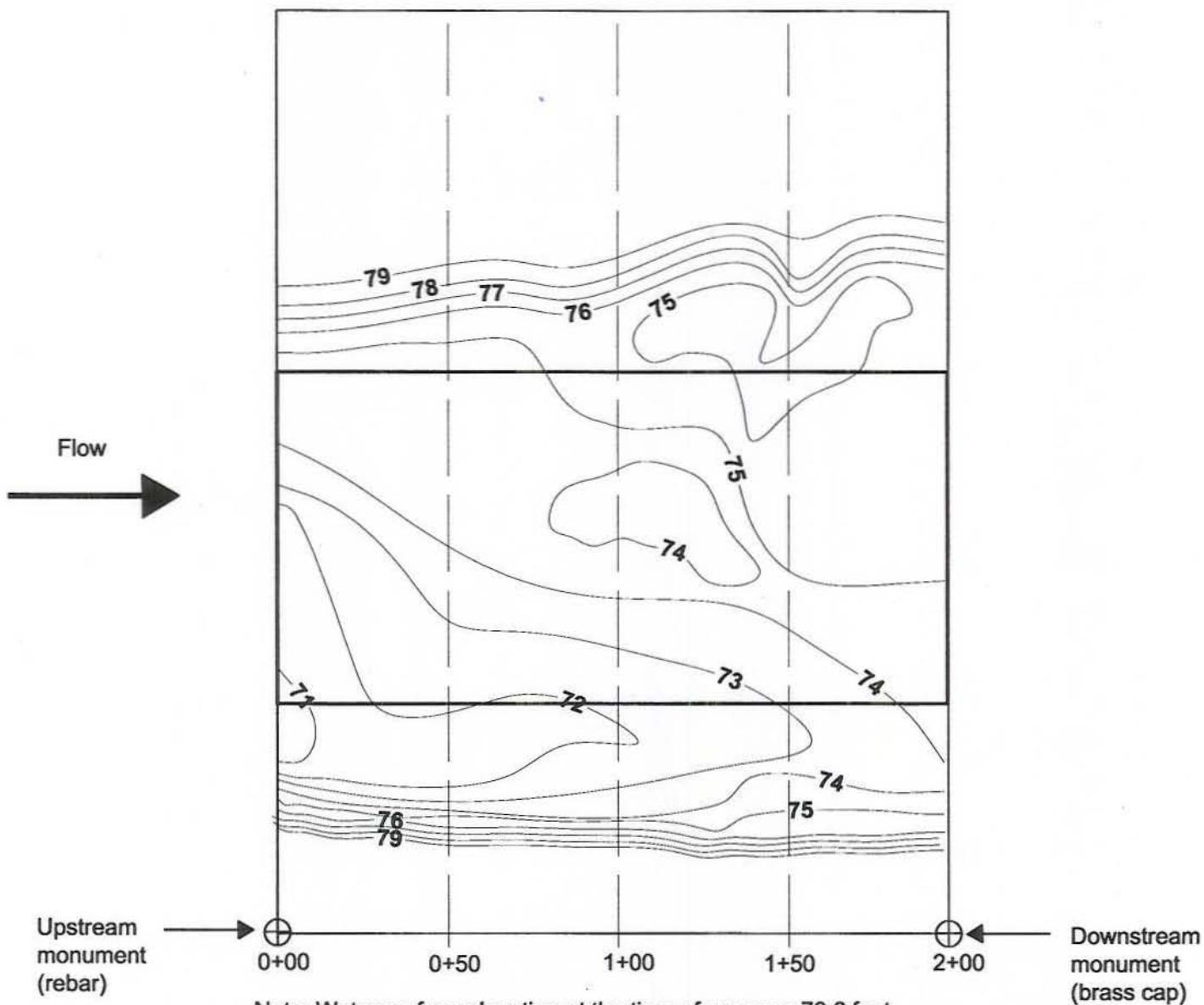
Note: Water surface elevation at the time of survey = 81.1 feet.  
Contours interpolated from soundings taken on September 19, 2000.  
Contour interval = 1 foot.



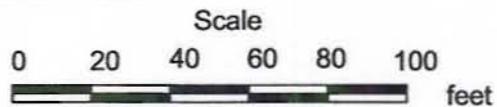
# Bathymetric Survey at OR4 Bed Sediment Contour Spring 2001



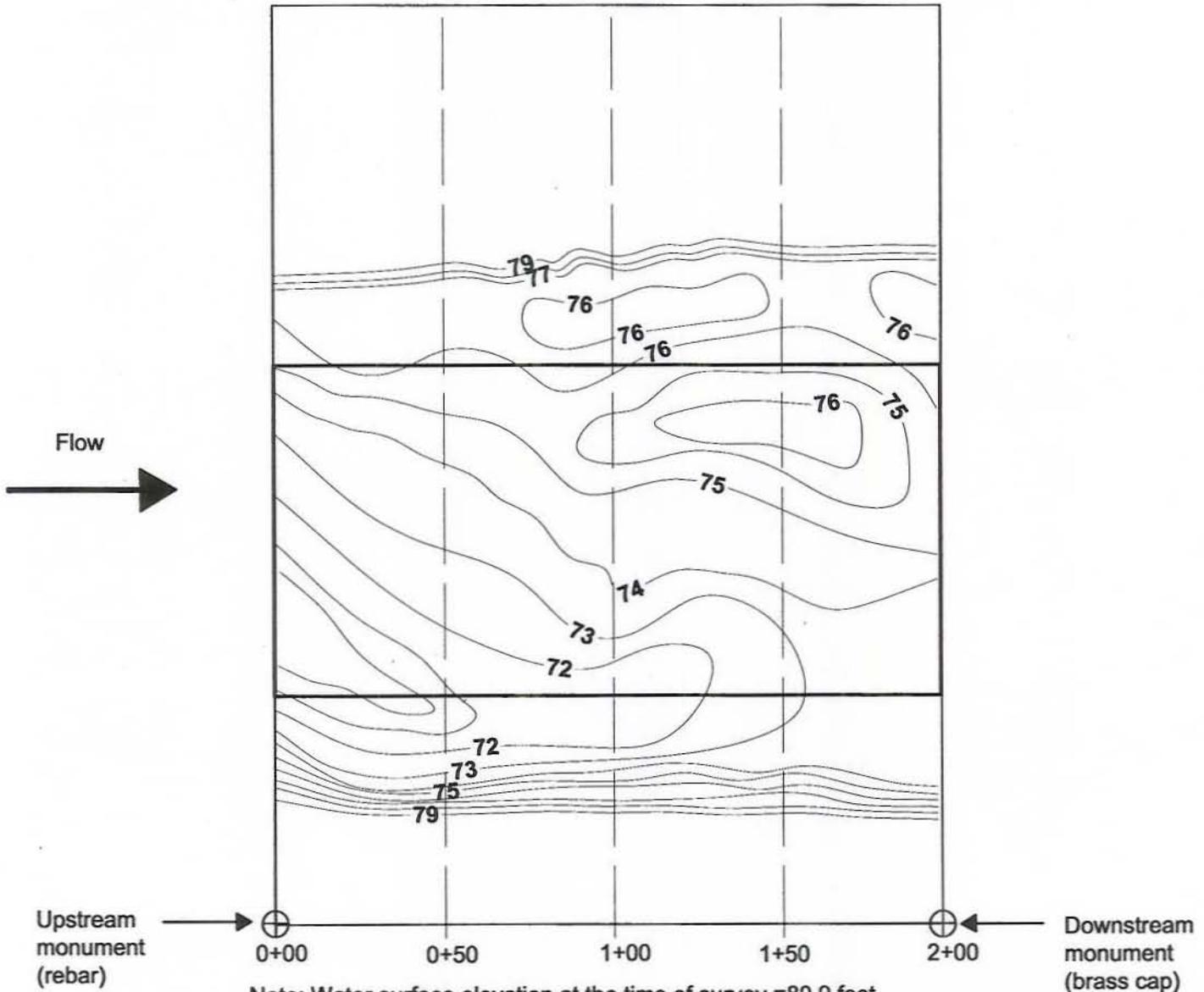
# Bathymetric Survey at OR4 Bed Sediment Contour Fall 2001



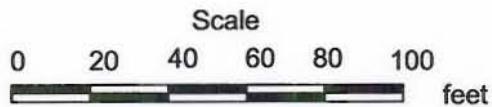
Note: Water surface elevation at the time of survey = 79.6 feet.  
Contours interpolated from soundings taken on September 21, 2001.  
Contour interval = 1 foot.



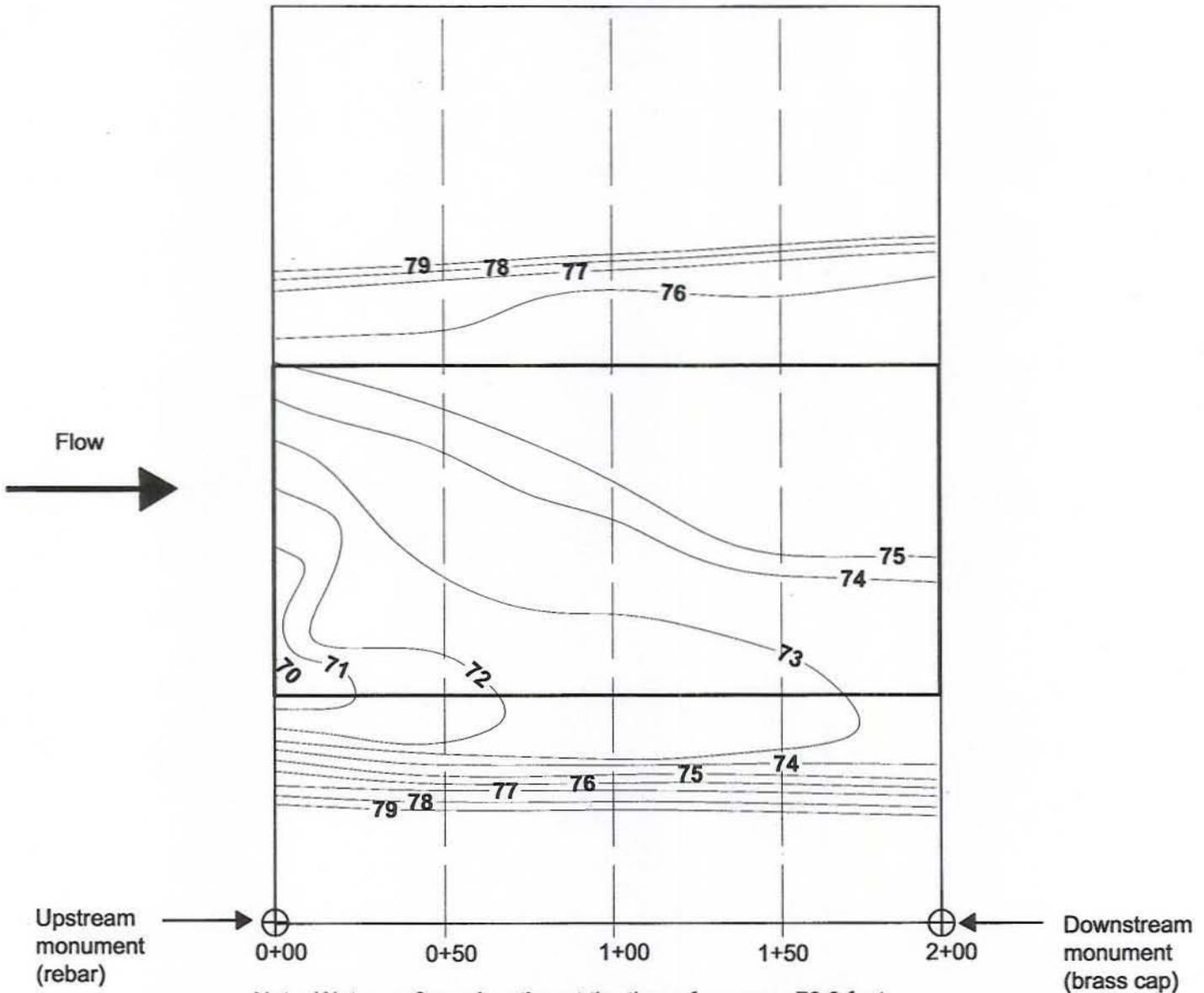
# Bathymetric Survey at OR4 Bed Sediment Contour Spring 2002



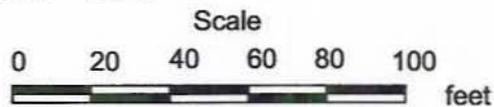
Note: Water surface elevation at the time of survey = 80.9 feet.  
Contours interpolated from soundings taken on April 2, 2002.  
Contour interval = 1 foot.

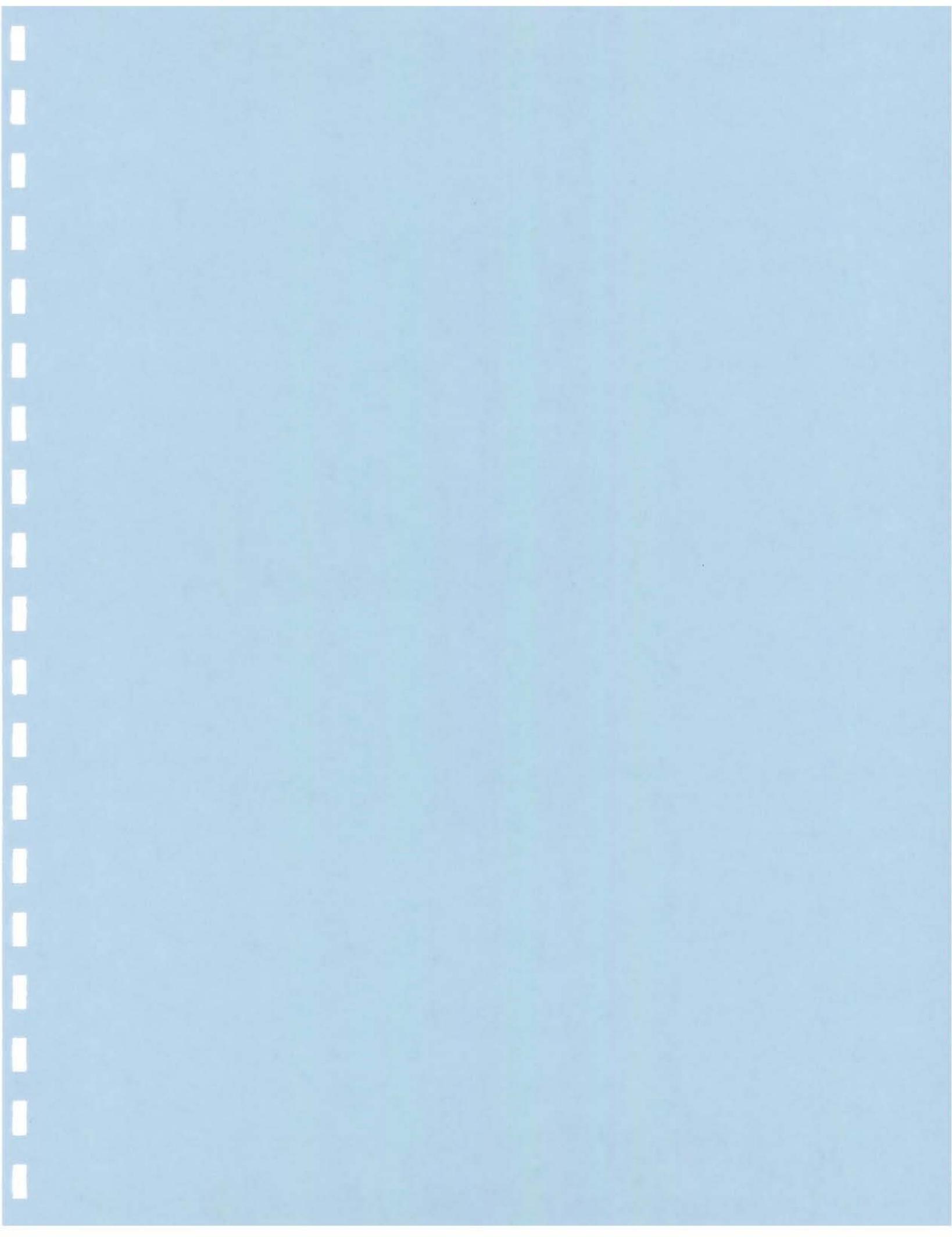


# Bathymetric Survey at OR4 Bed Sediment Contour Fall 2002

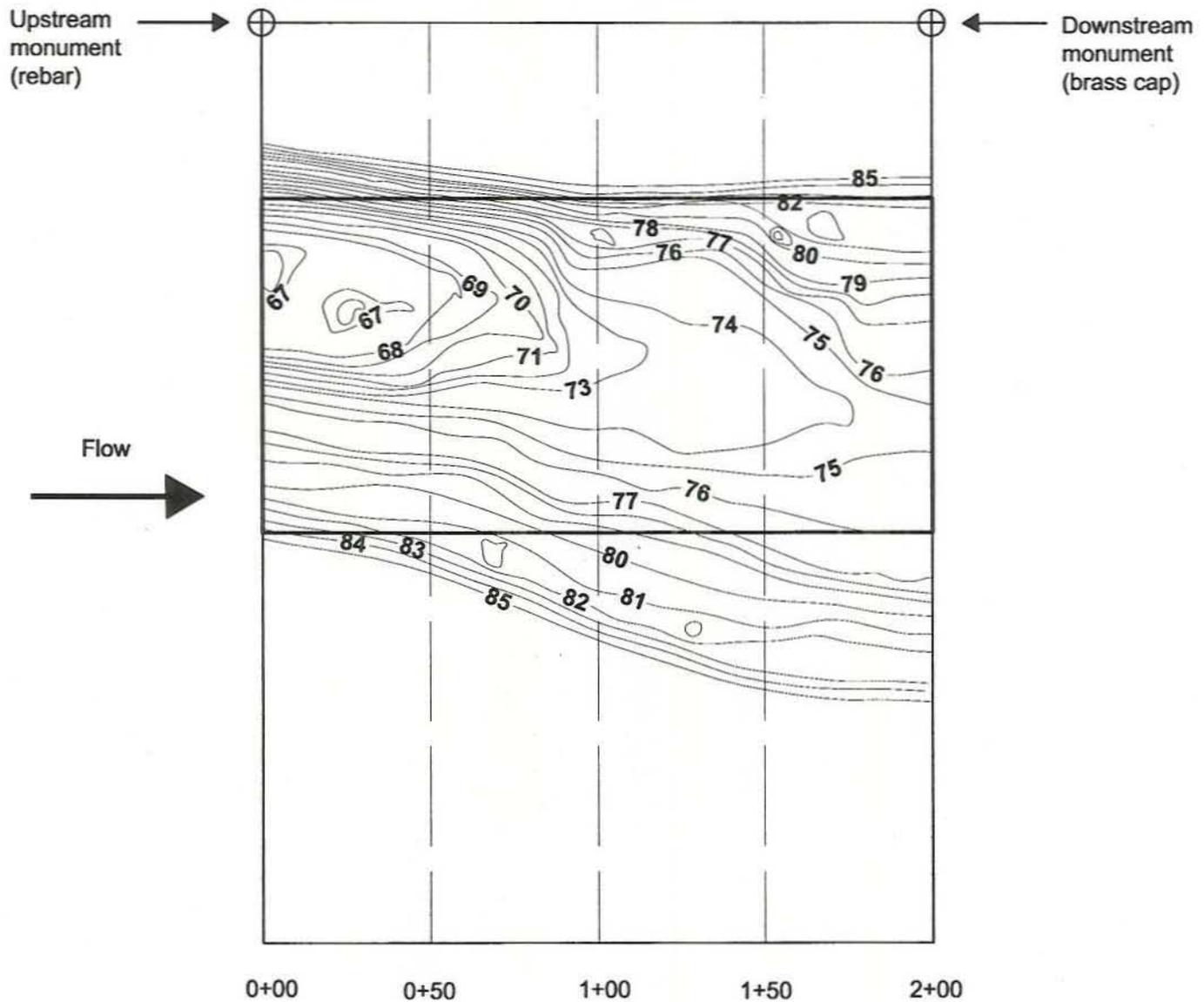


Note: Water surface elevation at the time of survey = 79.3 feet.  
Contours interpolated from soundings taken on September 11, 2002.  
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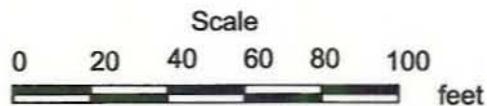




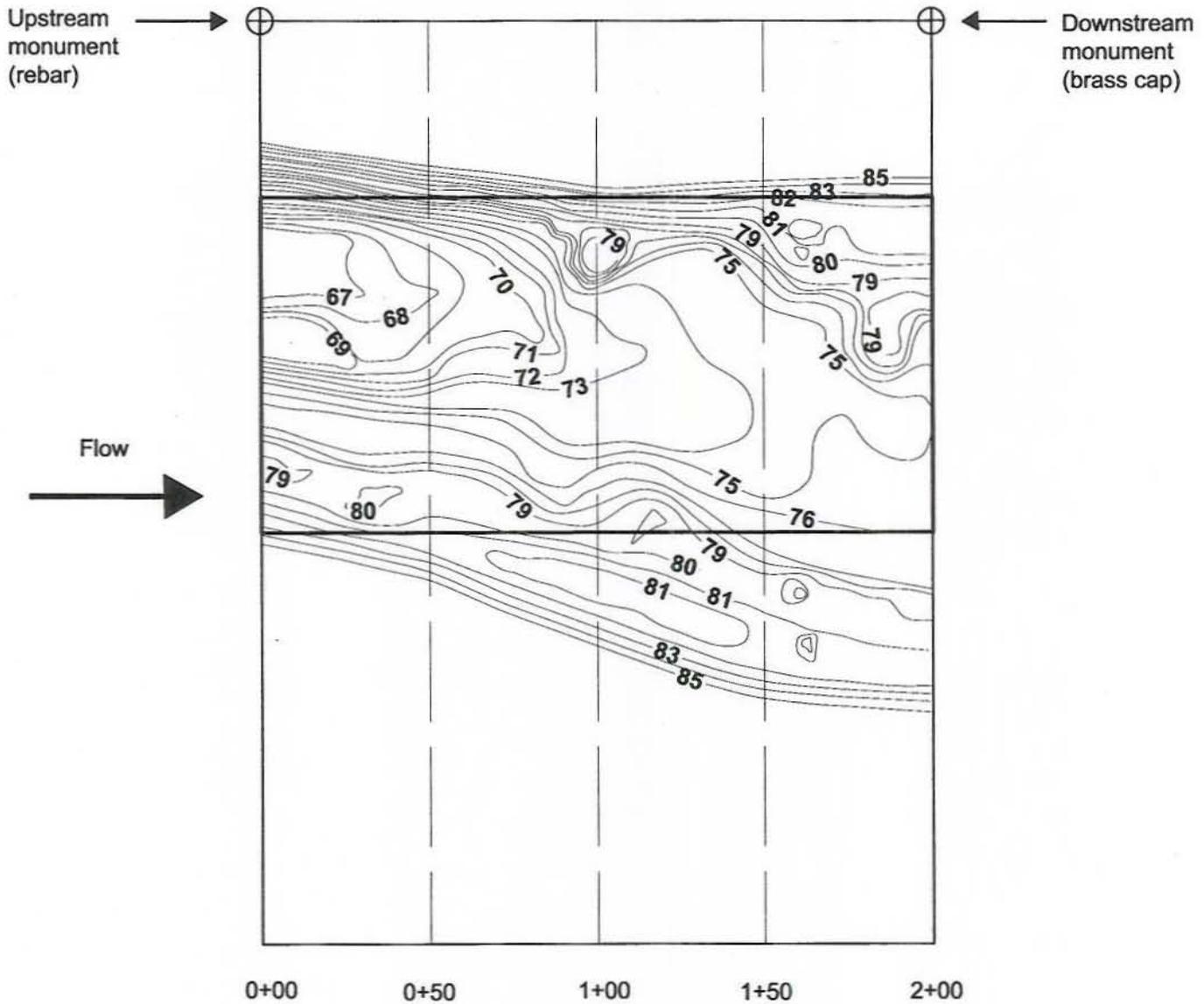
# Bathymetric Survey at OR5 Bed Sediment Contour Spring 2000



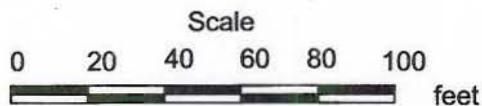
Note: Water surface elevation at the time of survey = 85.4 feet.  
Contours interpolated from soundings taken on April 12, 2000.  
Contour interval = 1 foot.



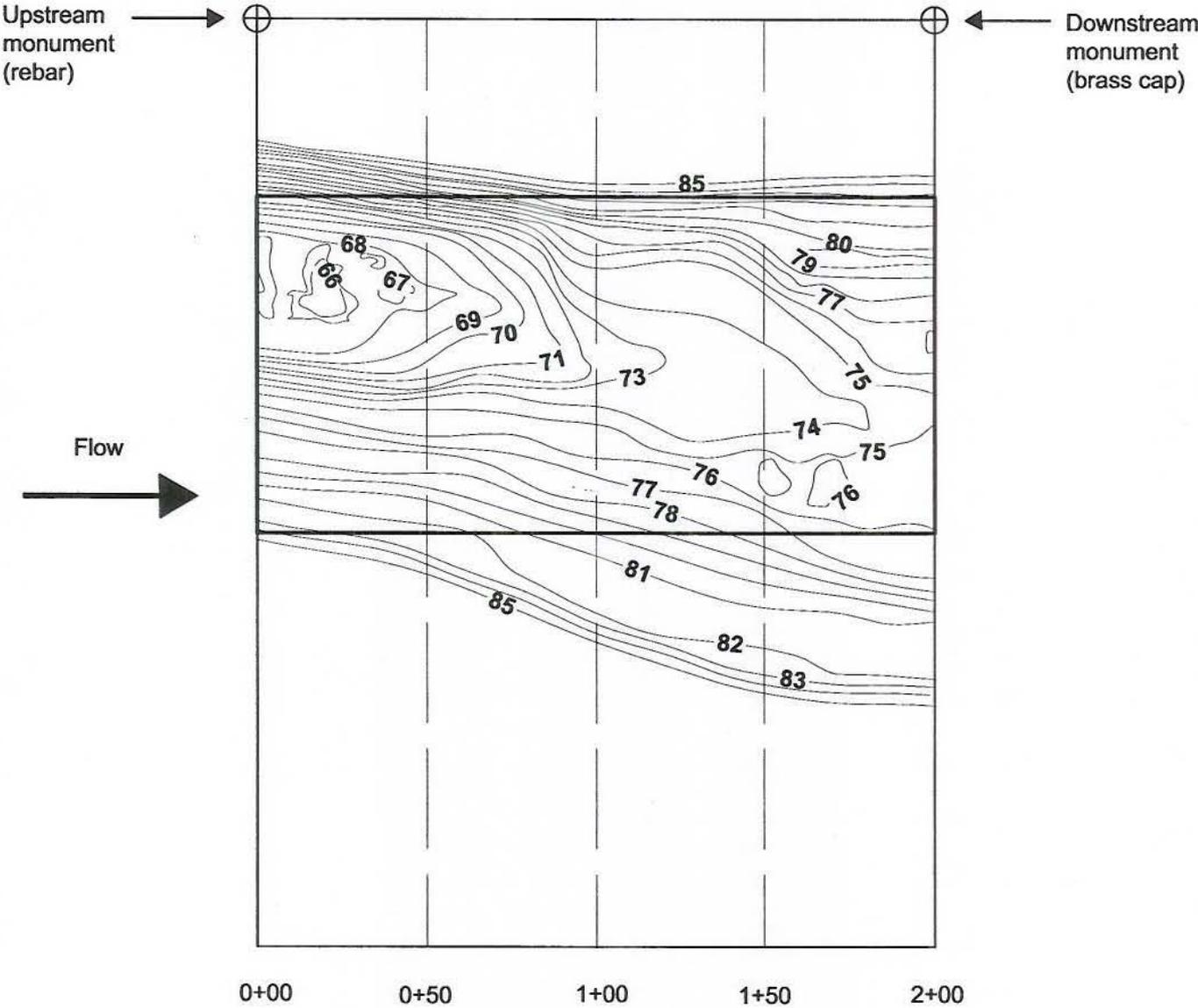
# Bathymetric Survey at OR5 Bed Sediment Contour Fall 2000



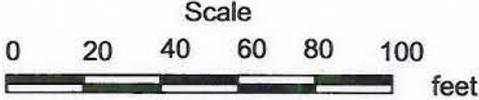
Note: Water surface elevation at the time of survey = 86.6 feet.  
Contours interpolated from soundings taken on September 19, 2000.  
Contour interval = 1 foot.



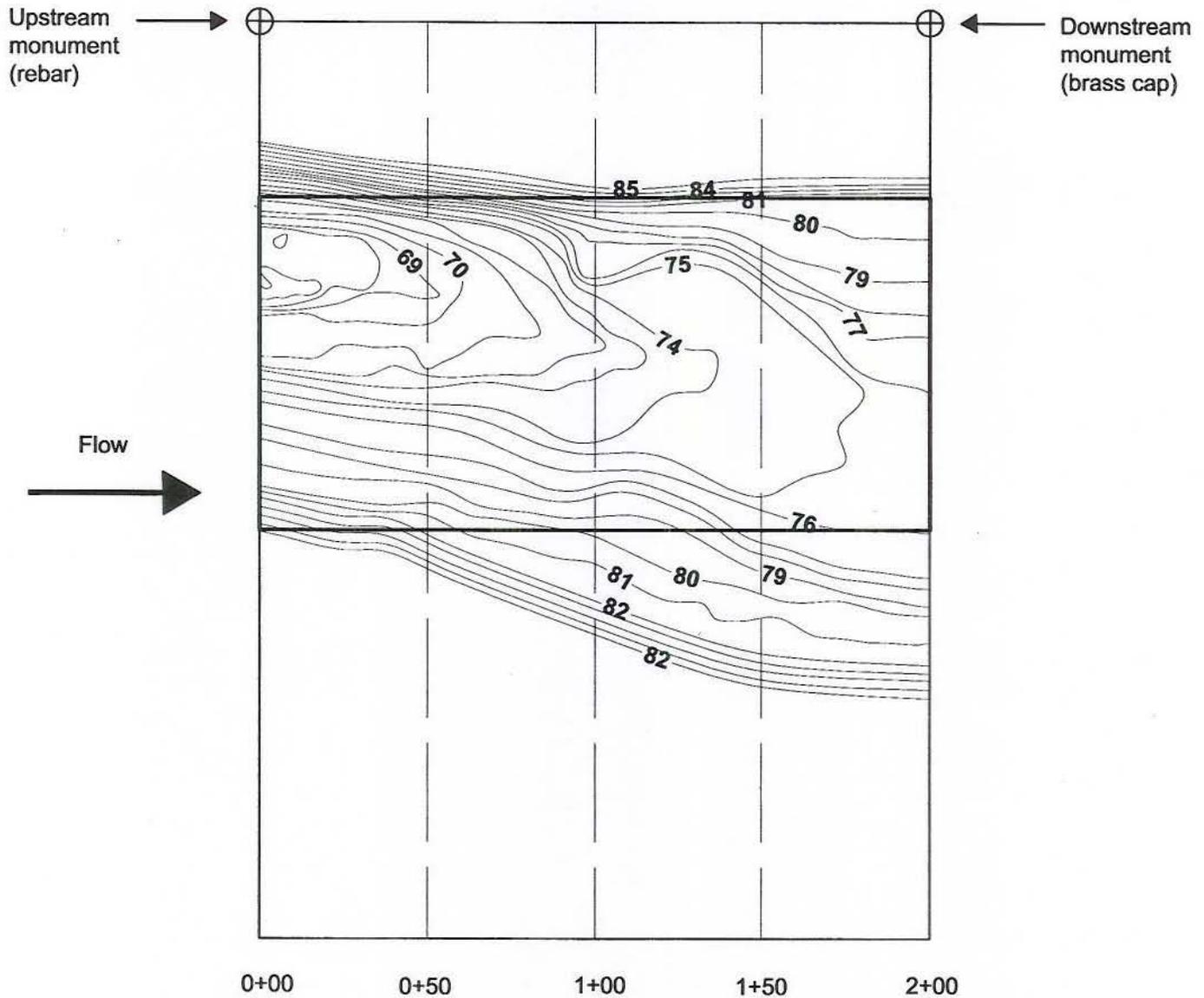
# Bathymetric Survey at OR5 Bed Sediment Contour Spring 2001



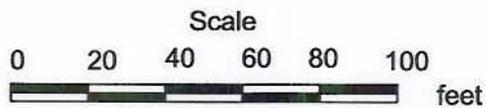
Note: Water surface elevation at the time of survey = 84.0 feet.  
Contours interpolated from soundings taken on March 26, 2001.  
Contour interval = 1 foot.



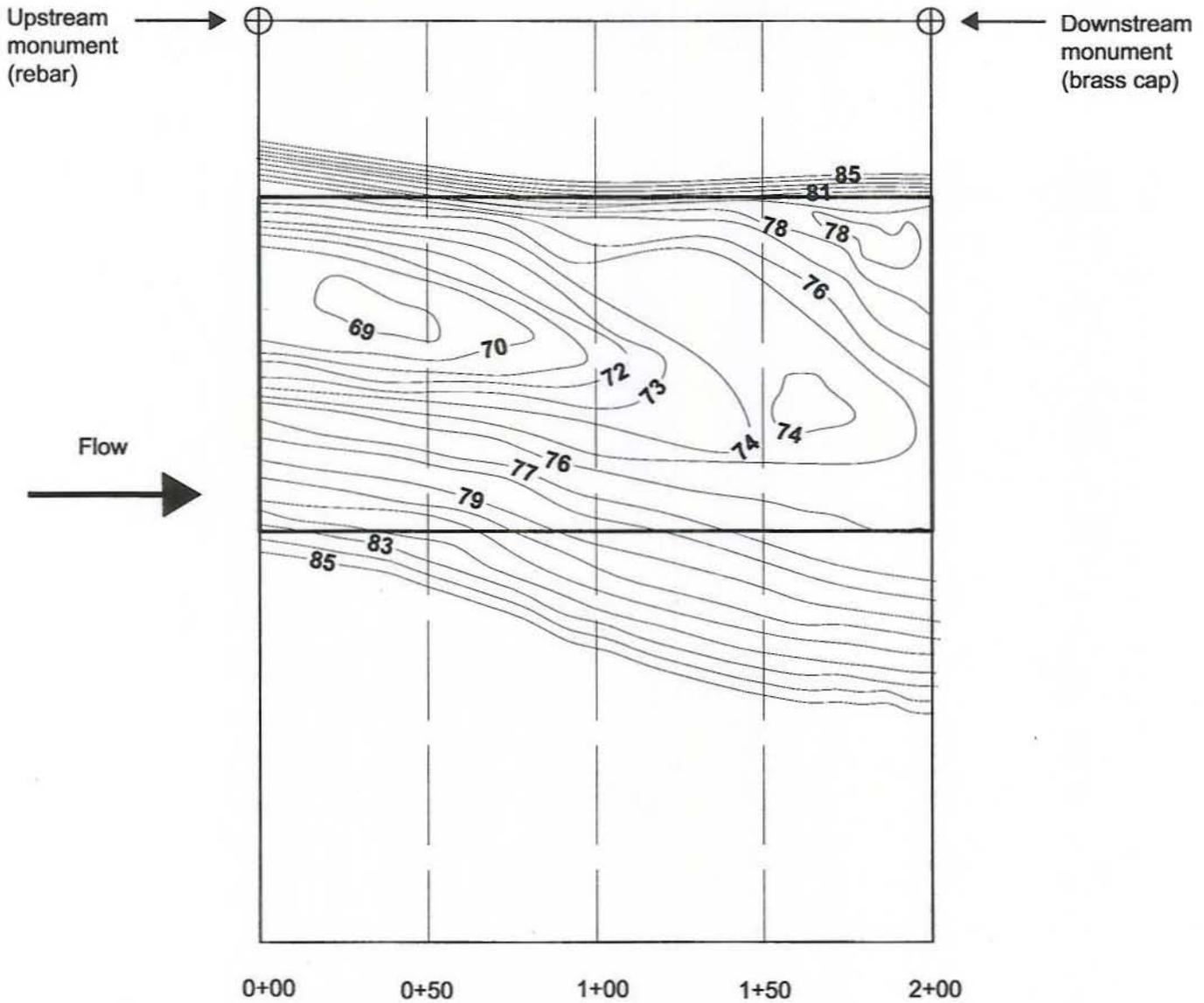
# Bathymetric Survey at OR5 Bed Sediment Contour Fall 2001



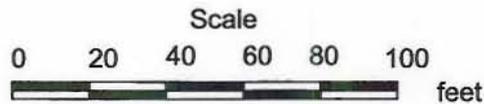
Note: Water surface elevation at the time of survey = 86.4 feet.  
Contours interpolated from soundings taken on September 21, 2001.  
Contour interval = 1 foot.



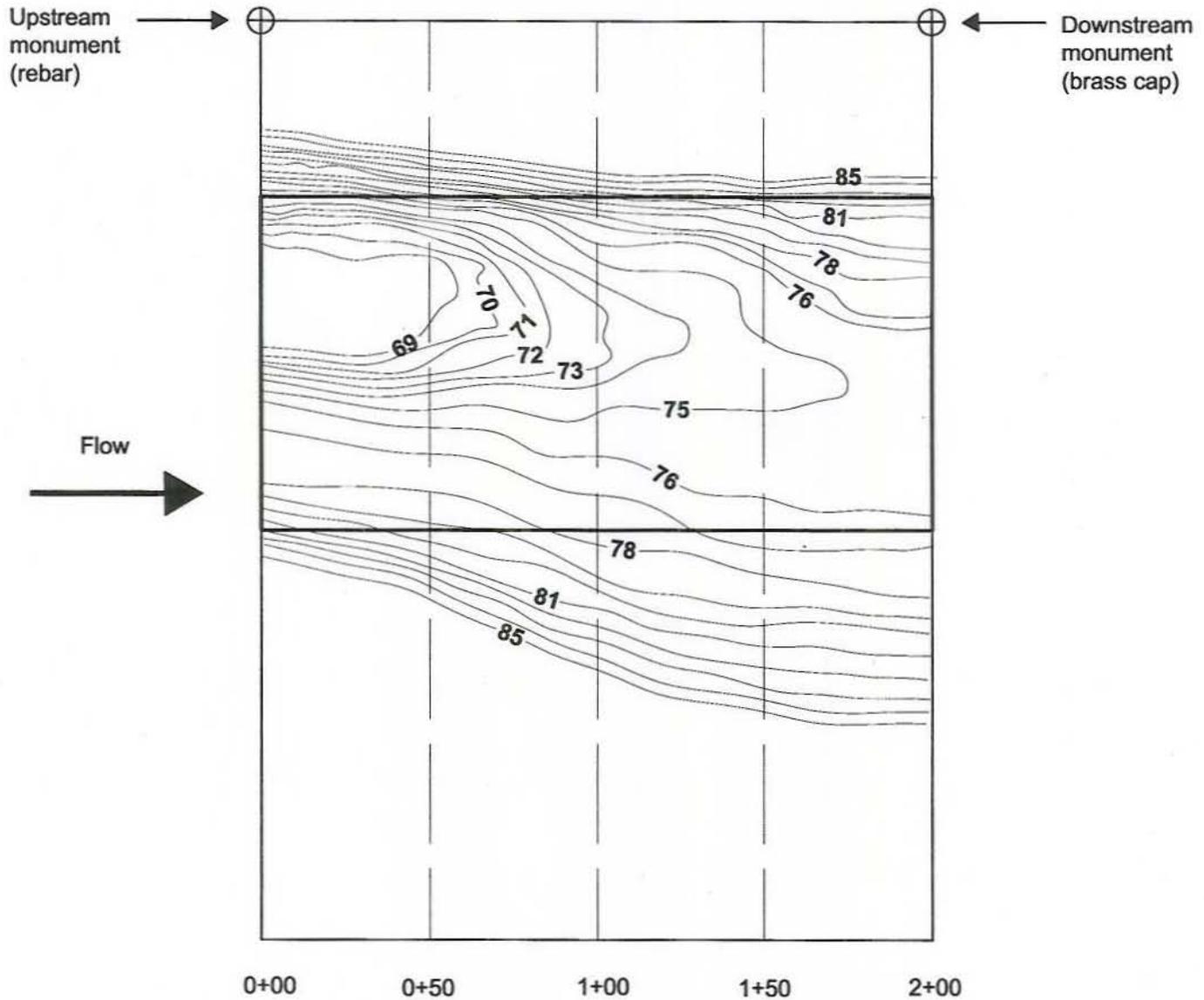
# Bathymetric Survey at OR5 Bed Sediment Contour Spring 2002



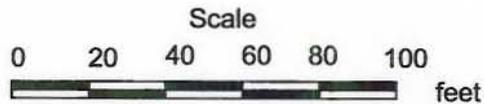
Note: Water surface elevation at the time of survey = 88.2 feet.  
Contours interpolated from soundings taken on April 2, 2002.  
Contour interval = 1 foot.

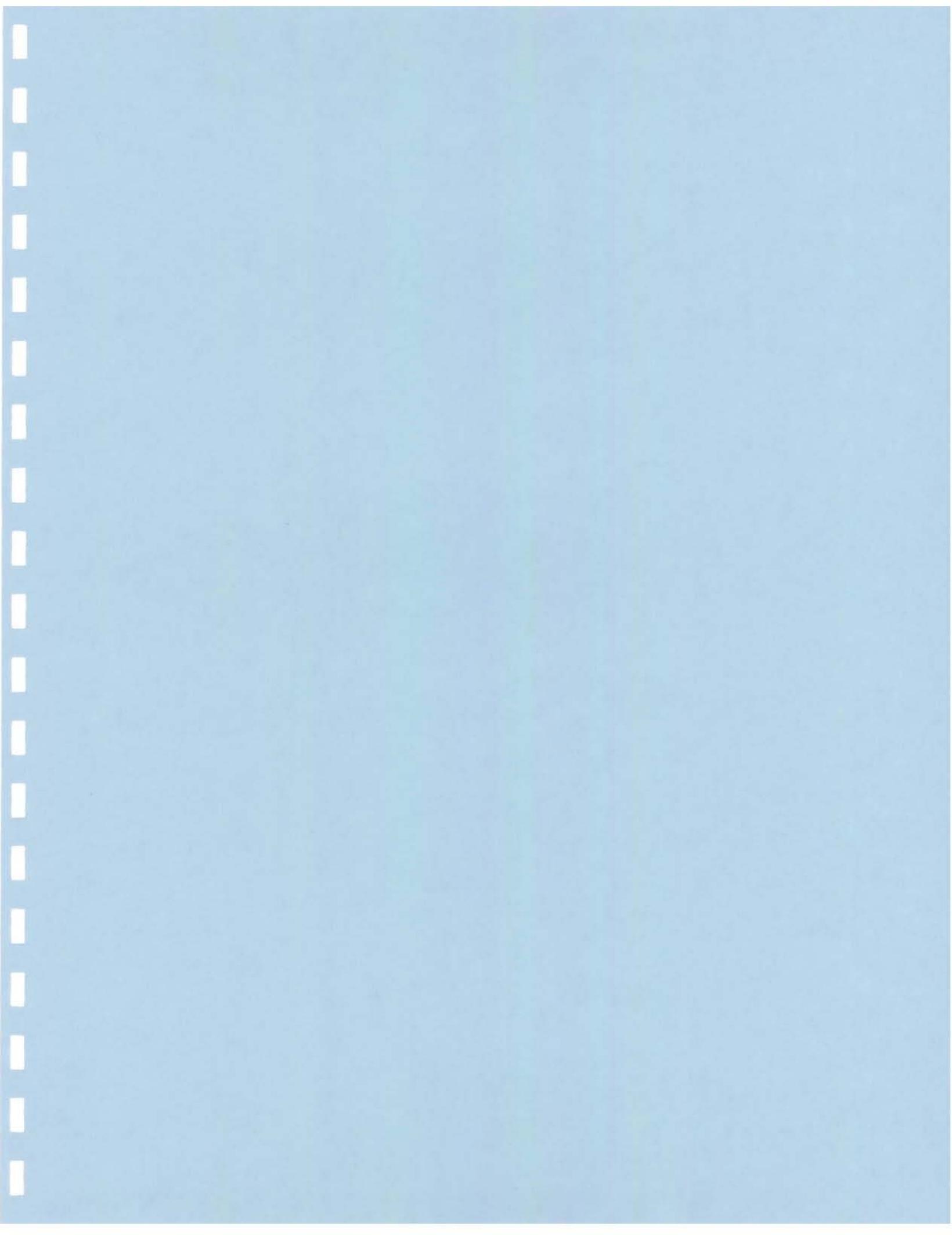


# Bathymetric Survey at OR5 Bed Sediment Contour Fall 2002

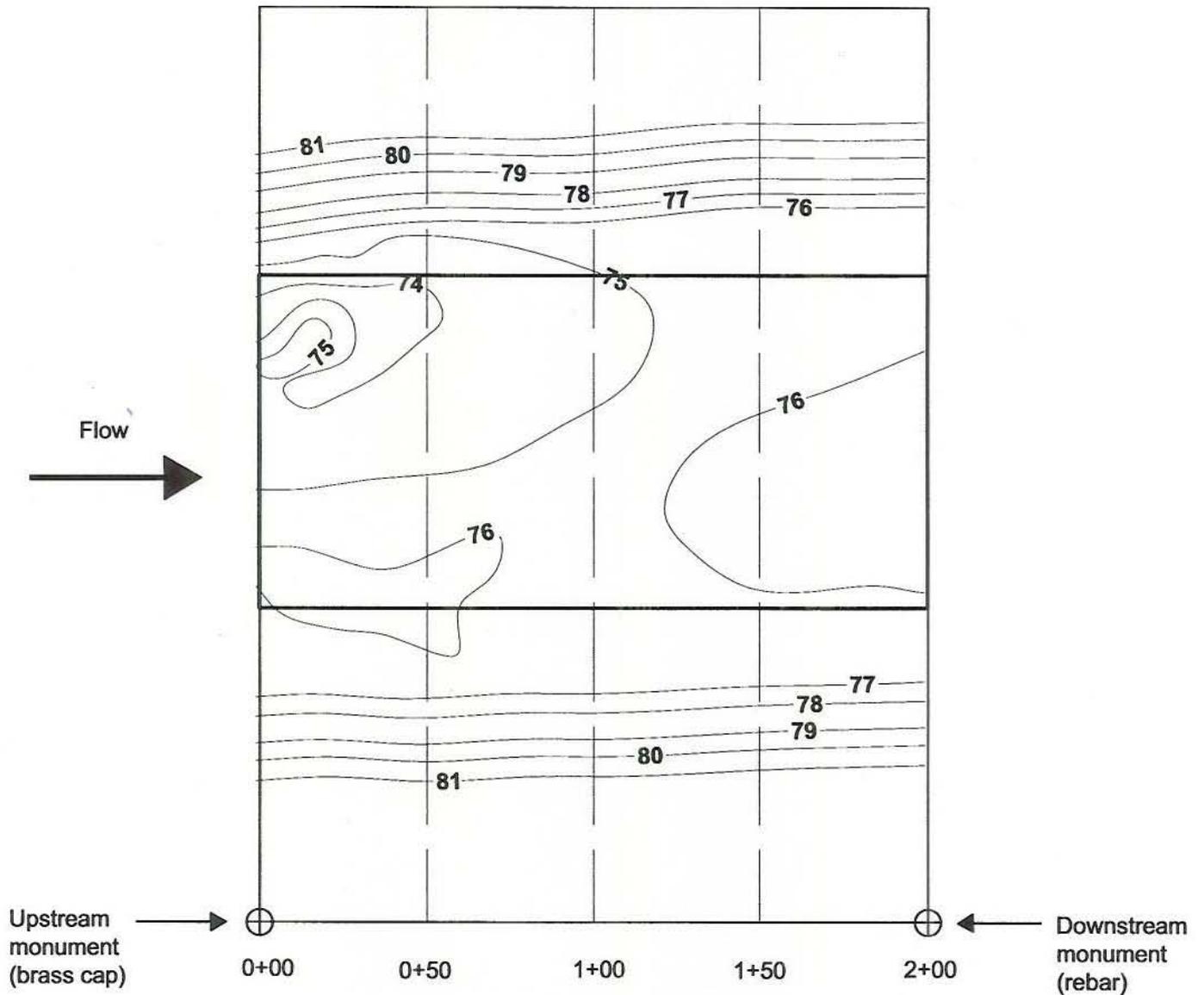


Note: Water surface elevation at the time of survey = 88.3 feet.  
Contours interpolated from soundings taken on September 11, 2002.  
Contour interval = 1 foot.

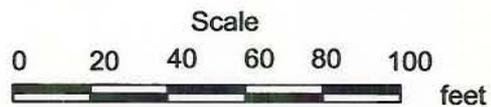




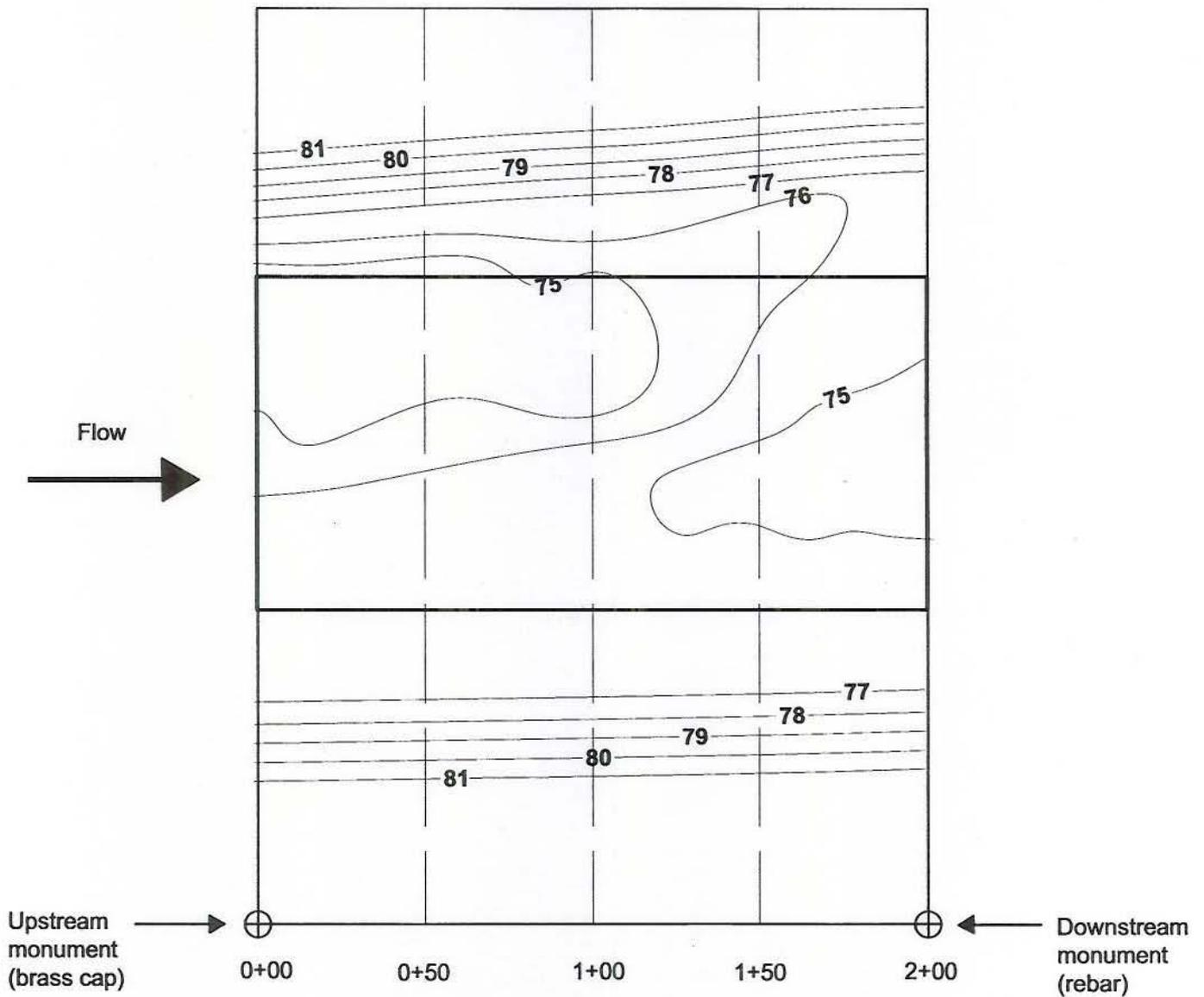
# Bathymetric Survey at OR6 Bed Sediment Contour Spring 2000



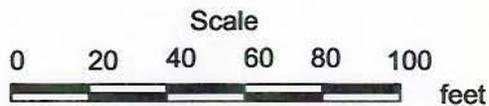
Note: Water surface elevation at the time of survey = 81.3 feet.  
Contours interpolated from soundings taken on April 12, 2000.  
Contour interval = 1 foot.



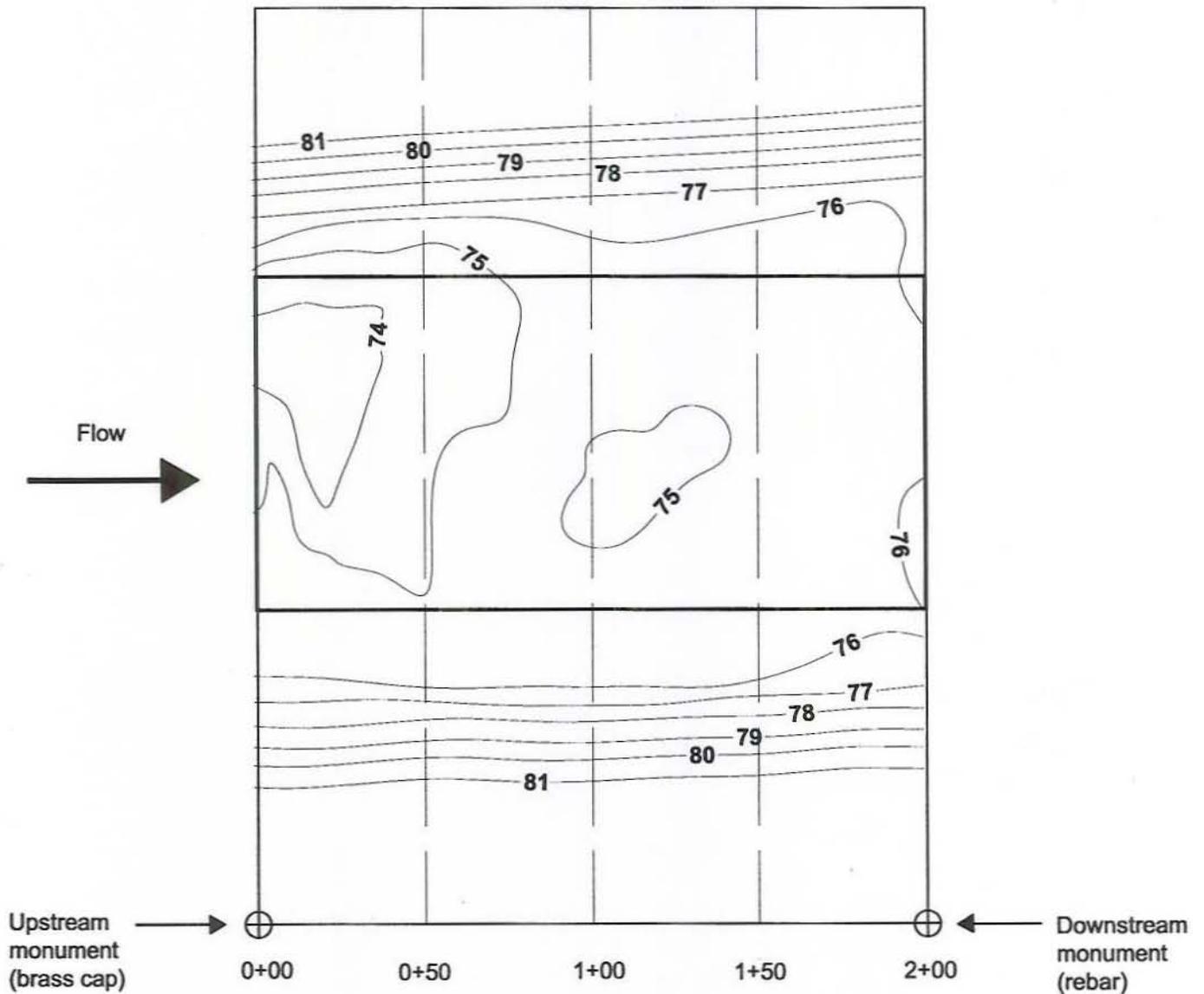
# Bathymetric Survey at OR6 Bed Sediment Contour Fall 2000



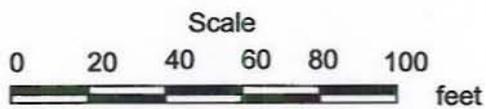
Note: Water surface elevation at the time of survey = 82.1 feet.  
Contours interpolated from soundings taken on September 20, 2000.  
Contour interval = 1 foot.



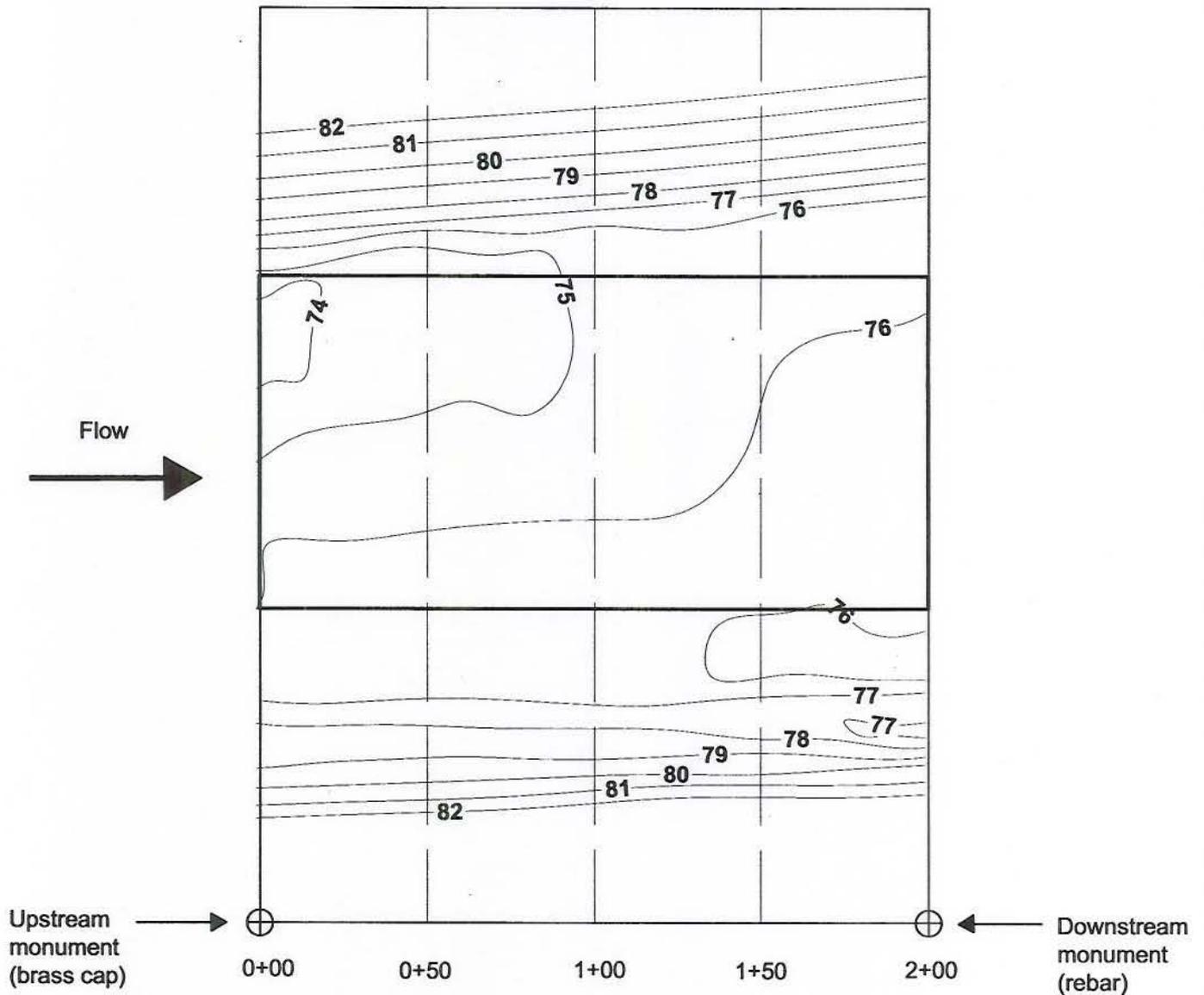
# Bathymetric Survey at OR6 Bed Sediment Contour Spring 2001



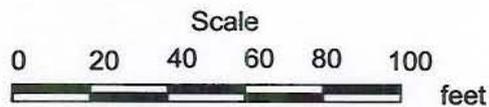
Note: Water surface elevation at the time of survey = 82.6 feet.  
Contours interpolated from soundings taken on March 27, 2001.  
Contour interval = 1 foot.



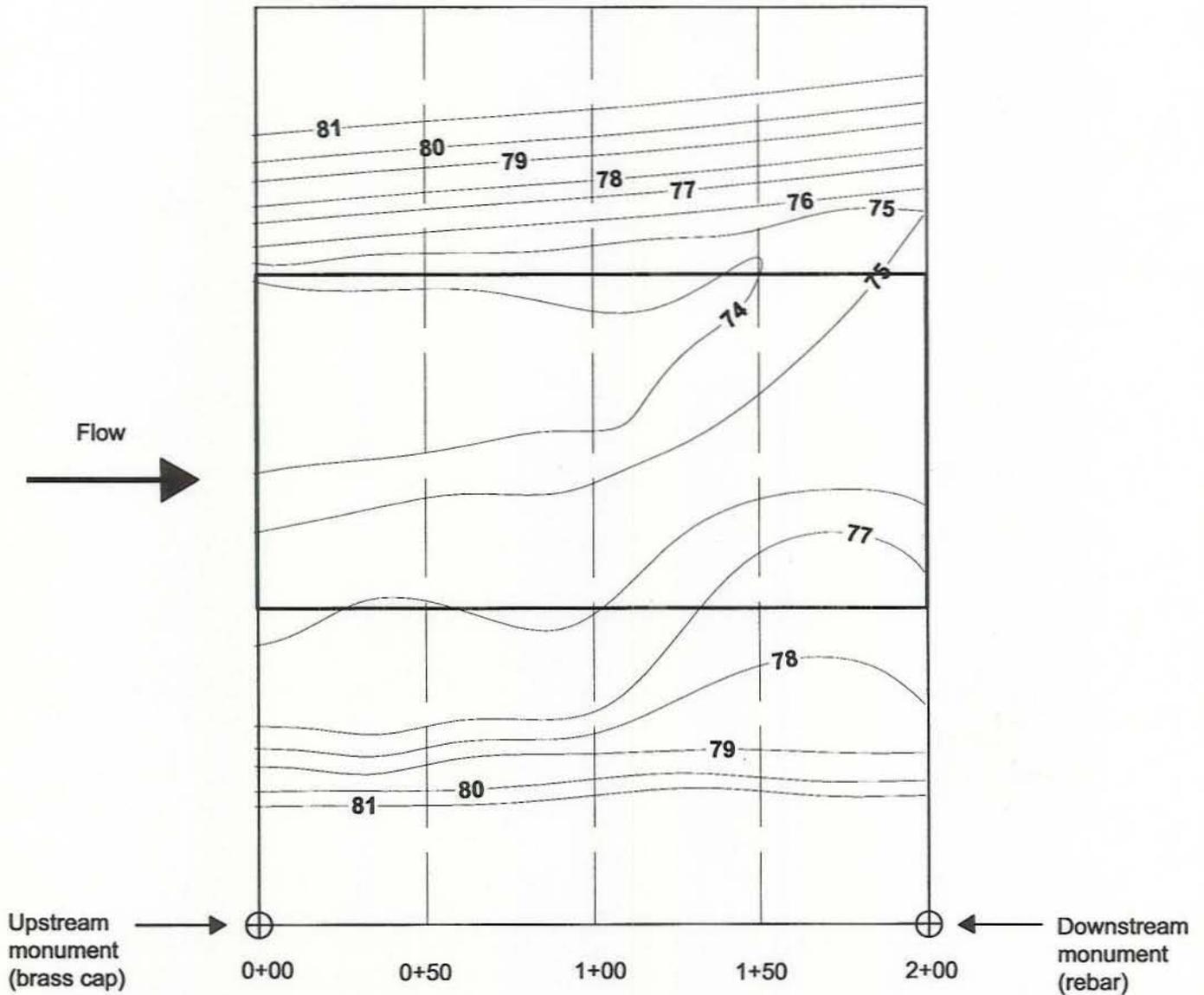
# Bathymetric Survey at OR6 Bed Sediment Contour Fall 2001



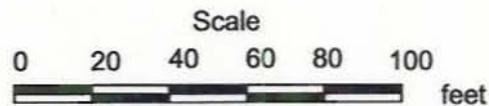
Note: Water surface elevation at the time of survey = 82.9 feet.  
Contours interpolated from soundings taken on September 21, 2001.  
Contour interval = 1 foot.



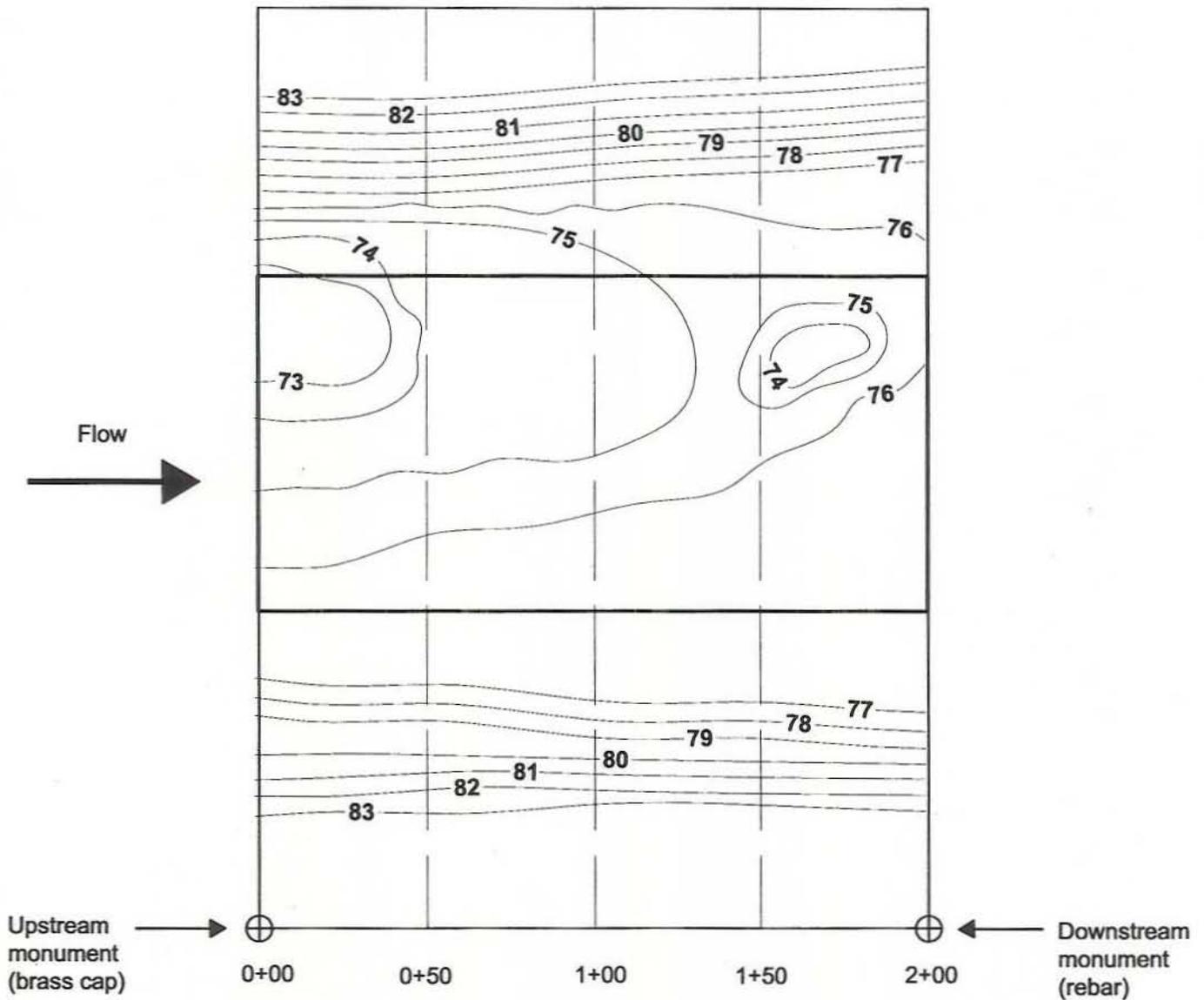
# Bathymetric Survey at OR6 Bed Sediment Contour Spring 2002



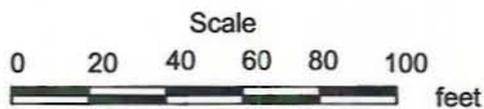
Note: Water surface elevation at the time of survey = 83.5 feet.  
Contours interpolated from soundings taken on April 3, 2002.  
Contour interval = 1 foot.

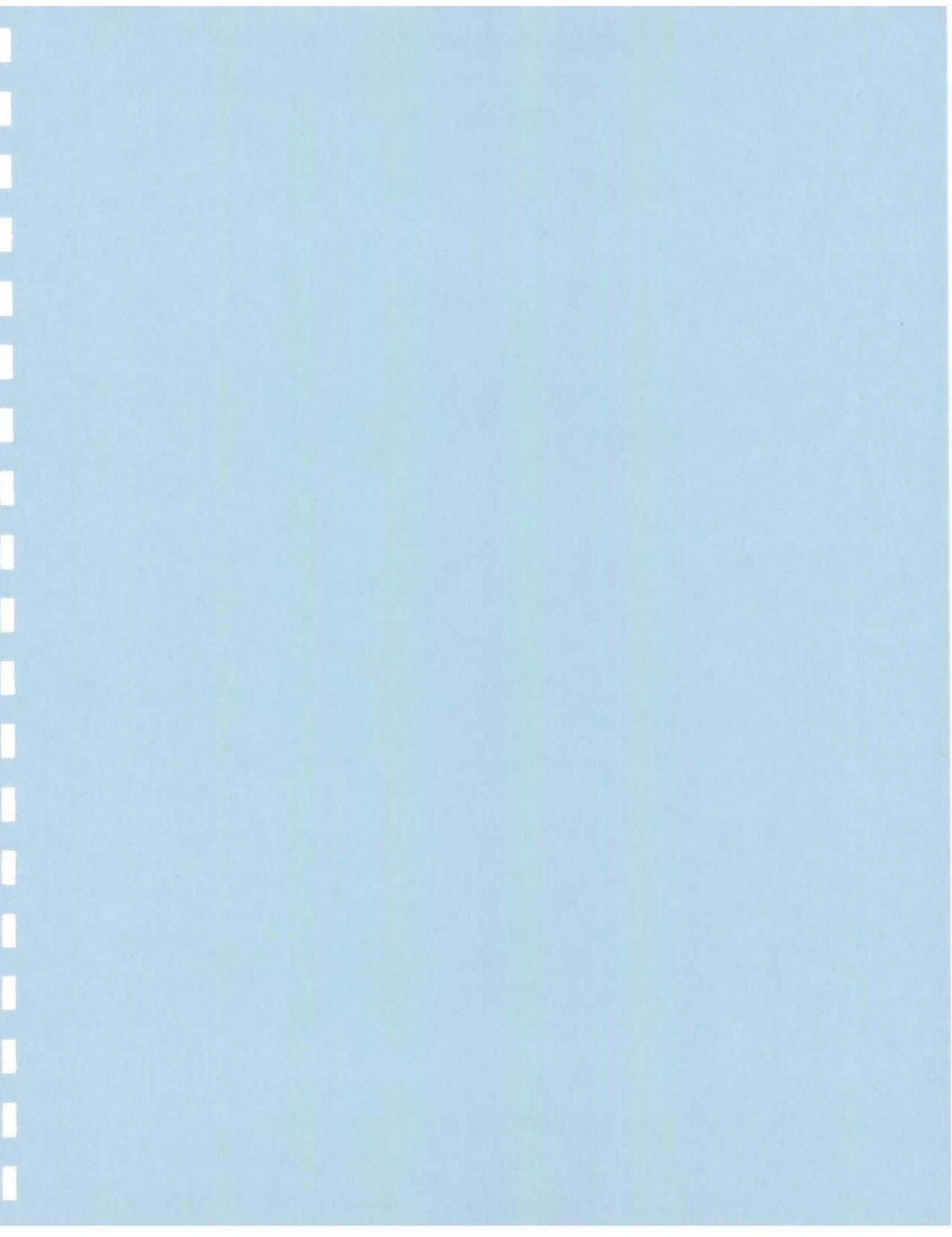


# Bathymetric Survey at OR6 Bed Sediment Contour Fall 2002

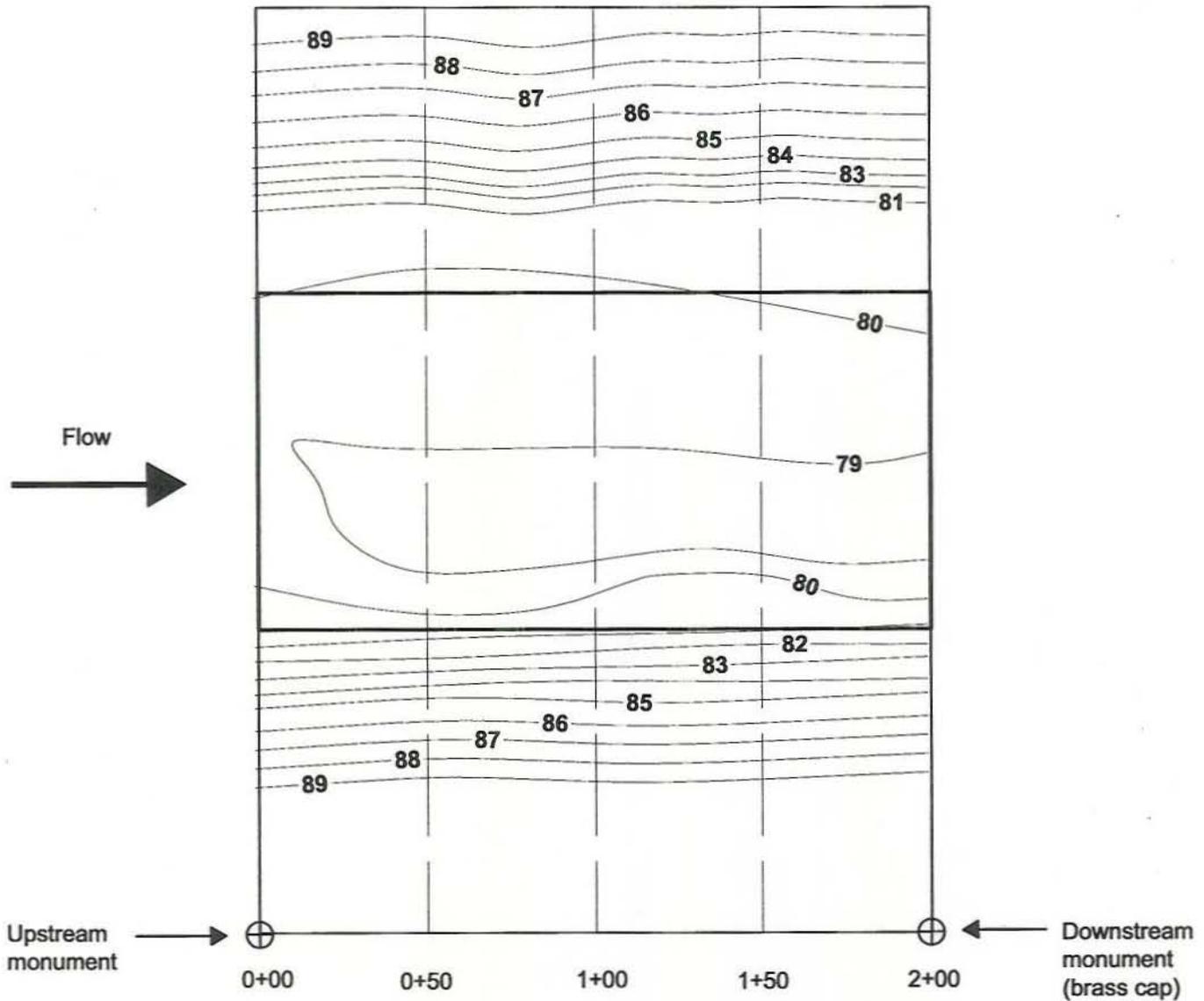


Note: Water surface elevation at the time of survey = 82.5 feet.  
Contours interpolated from soundings taken on September 11, 2002.  
Contour interval = 1 foot.

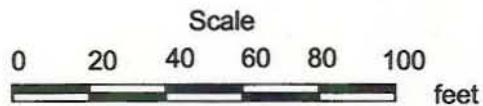




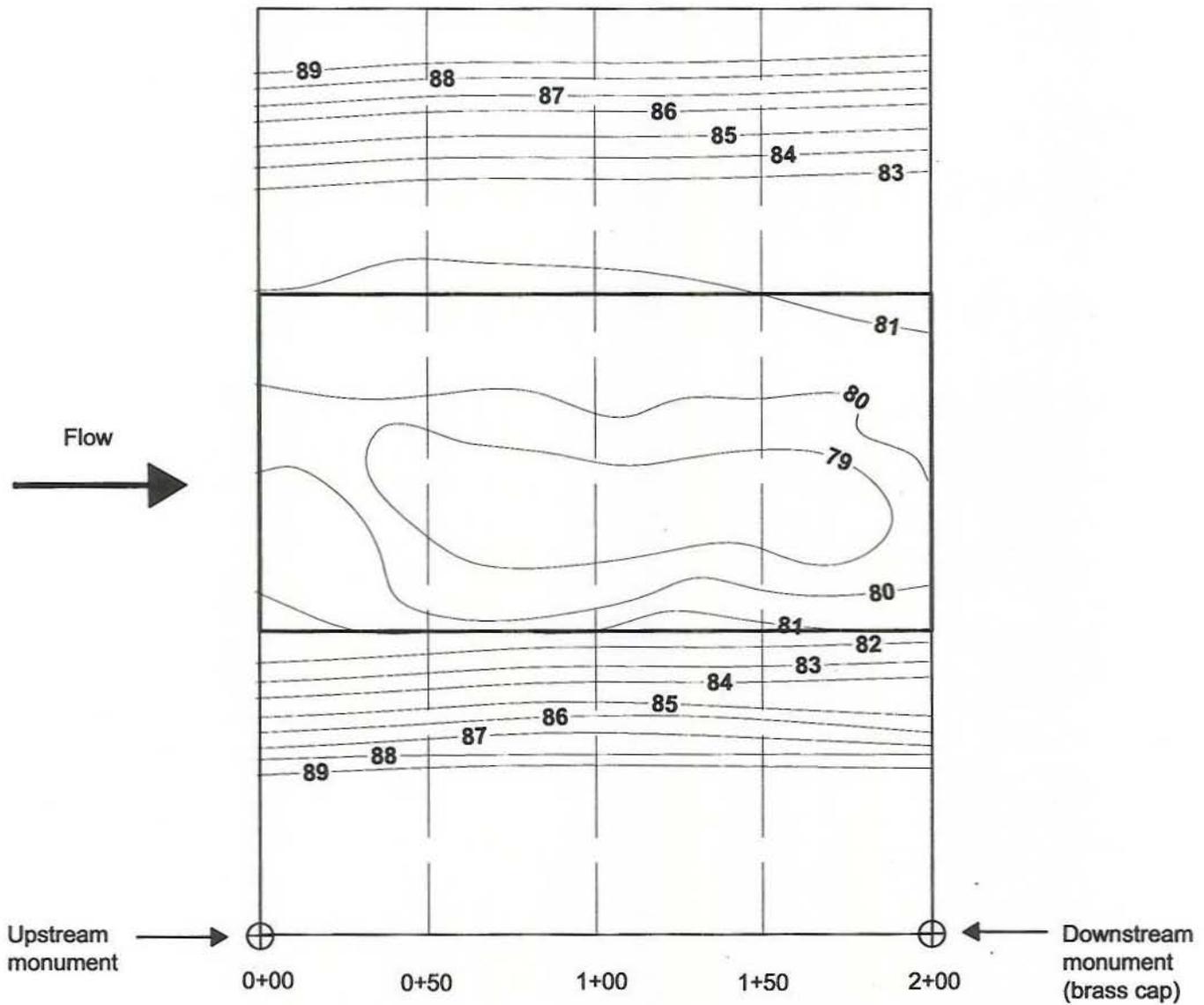
# Bathymetric Survey at OR7 Bed Sediment Contour Spring 2000



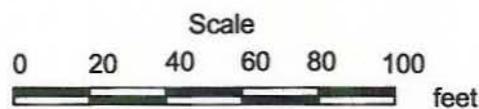
Note: Water surface elevation at the time of survey = 89.6 feet.  
Contours interpolated from soundings taken on April 12, 2000.  
Contour interval = 1 foot.



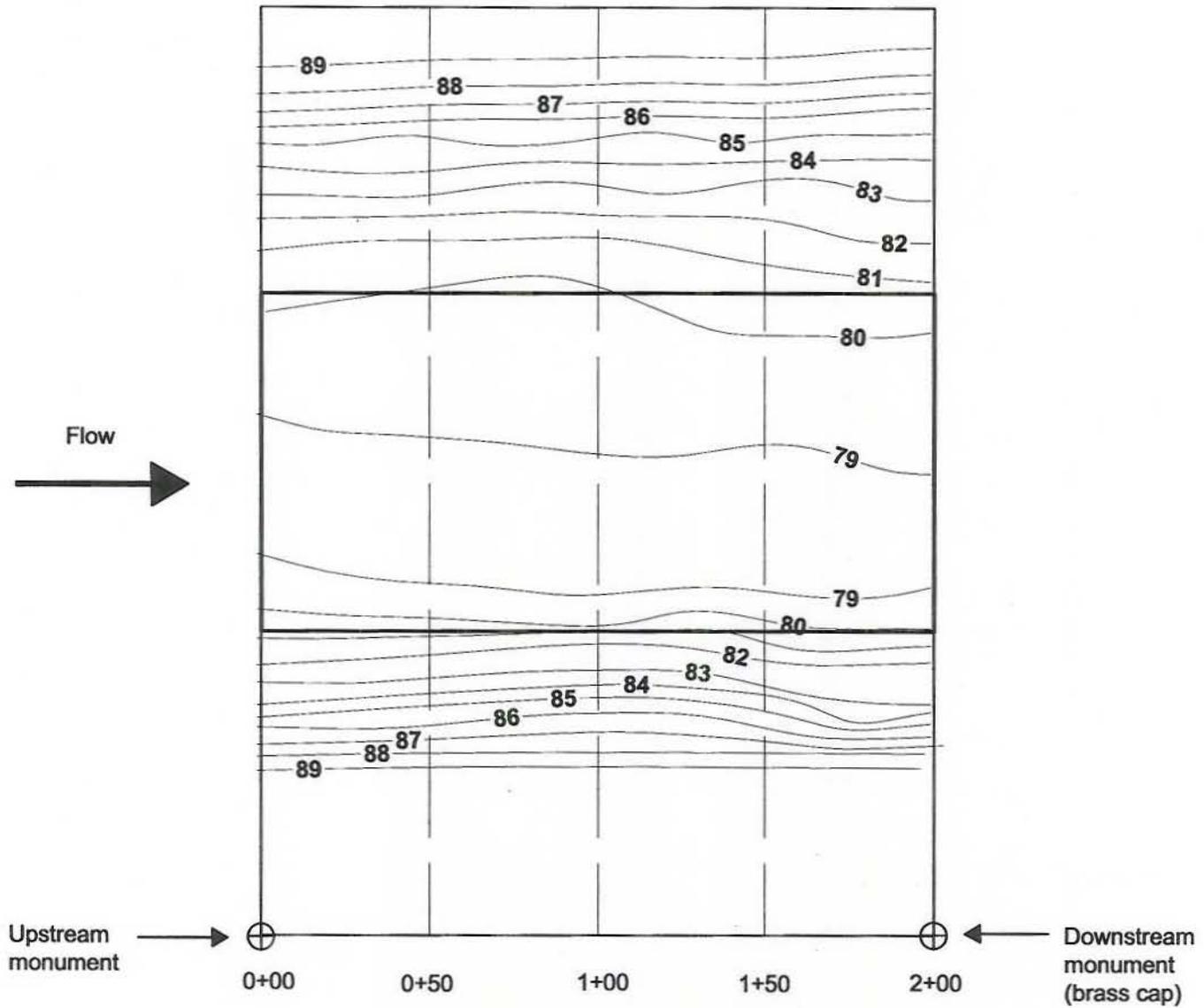
# Bathymetric Survey at OR7 Bed Sediment Contour Fall 2000



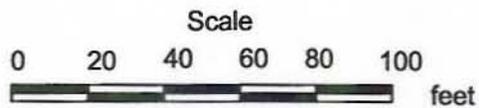
Note: Water surface elevation at the time of survey = 91.8 feet.  
Contours interpolated from soundings taken on September 20, 2000.  
Contour interval = 1 foot.



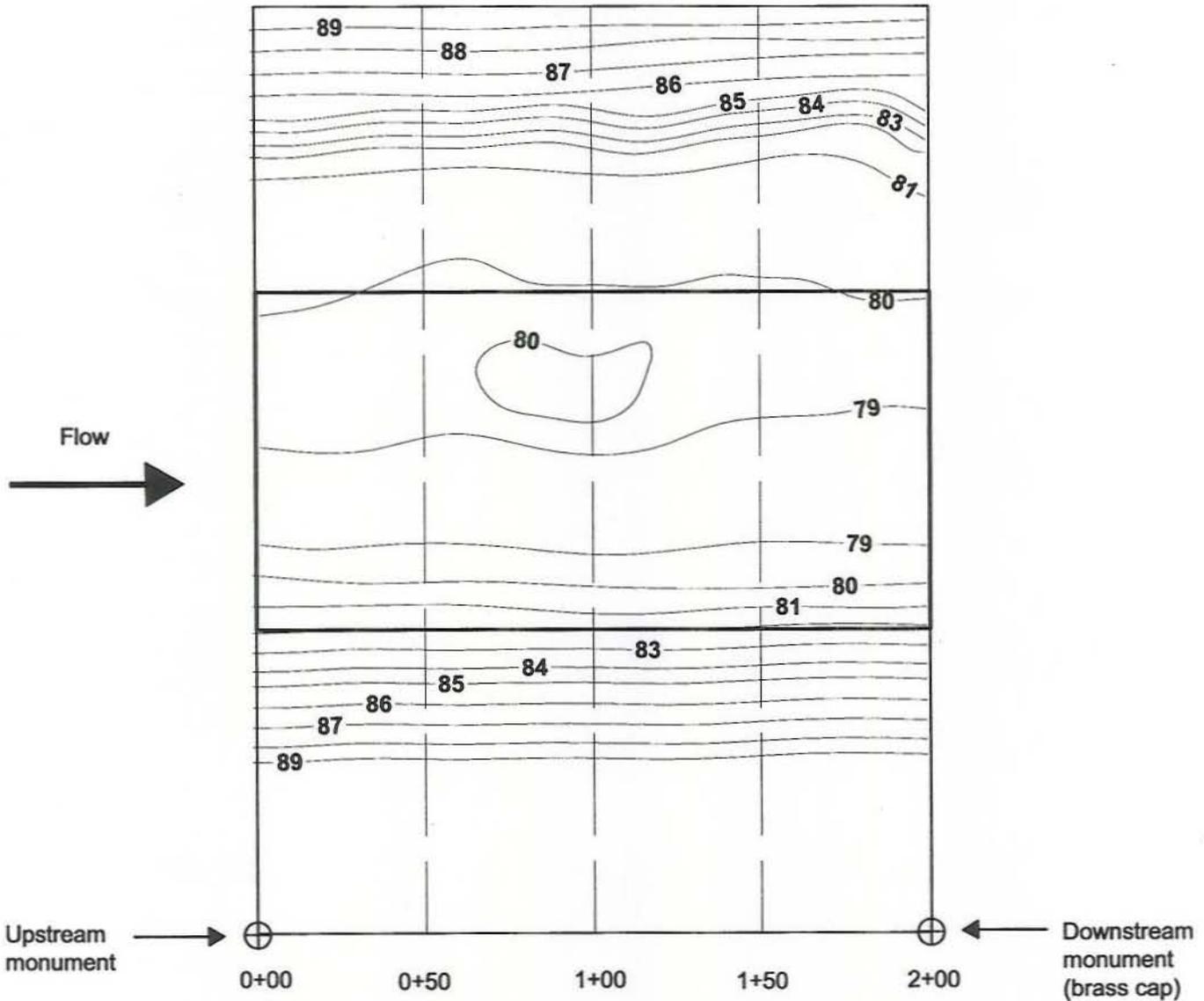
# Bathymetric Survey at OR7 Bed Sediment Contour Spring 2001



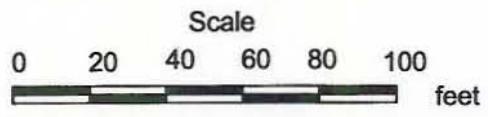
Note: Water surface elevation at the time of survey = 89.6 feet  
Contours interpolated from soundings taken on March 27, 2001  
contour interval = 1 foot



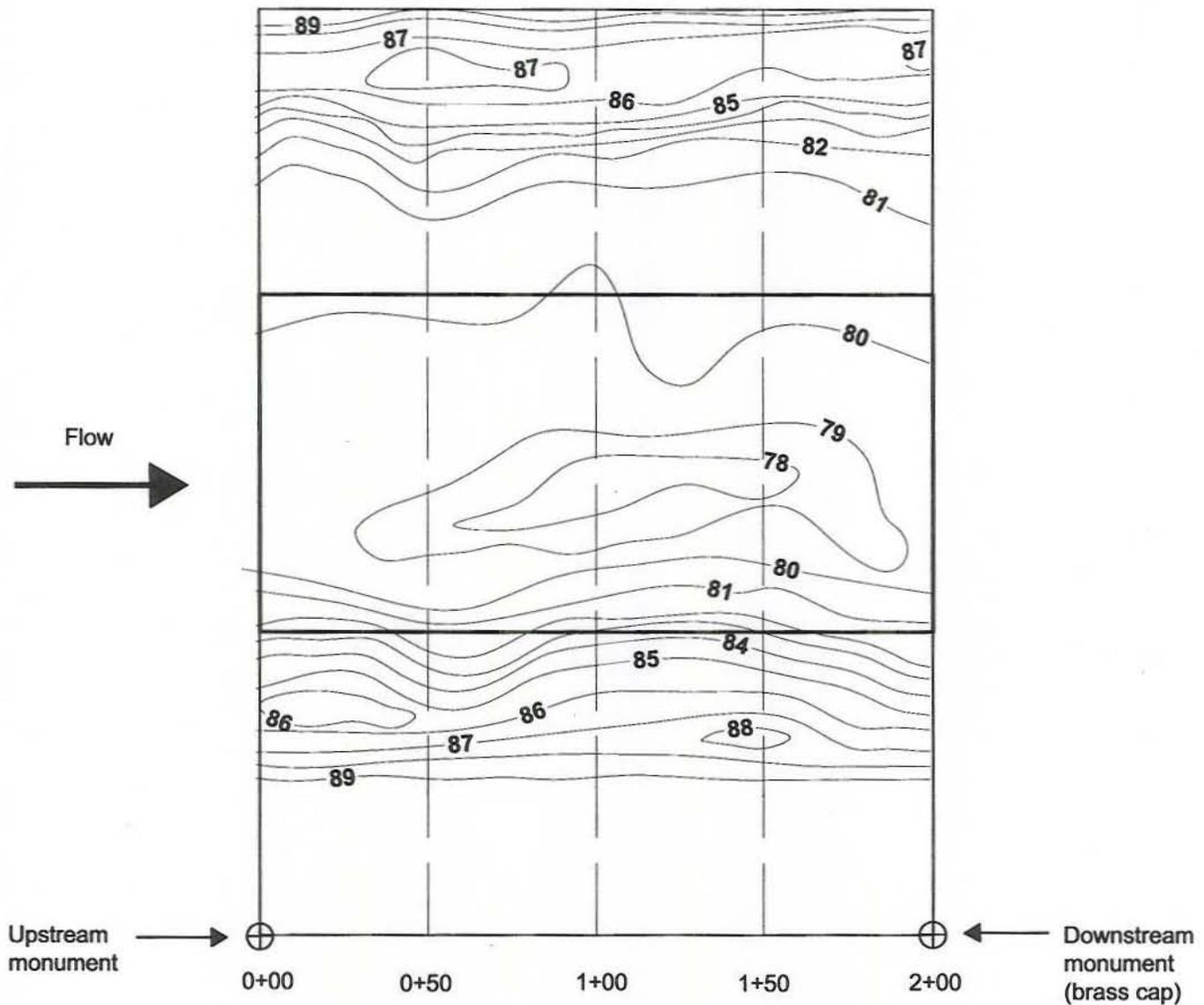
# Bathymetric Survey at OR7 Bed Sediment Contour Fall 2001



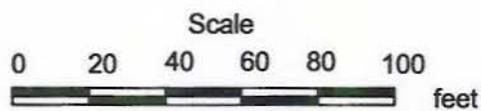
Note: Water surface elevation at the time of survey = 90.6 feet.  
 Contours interpolated from soundings taken on September 11, 2001.  
 Contour interval = 1 foot.



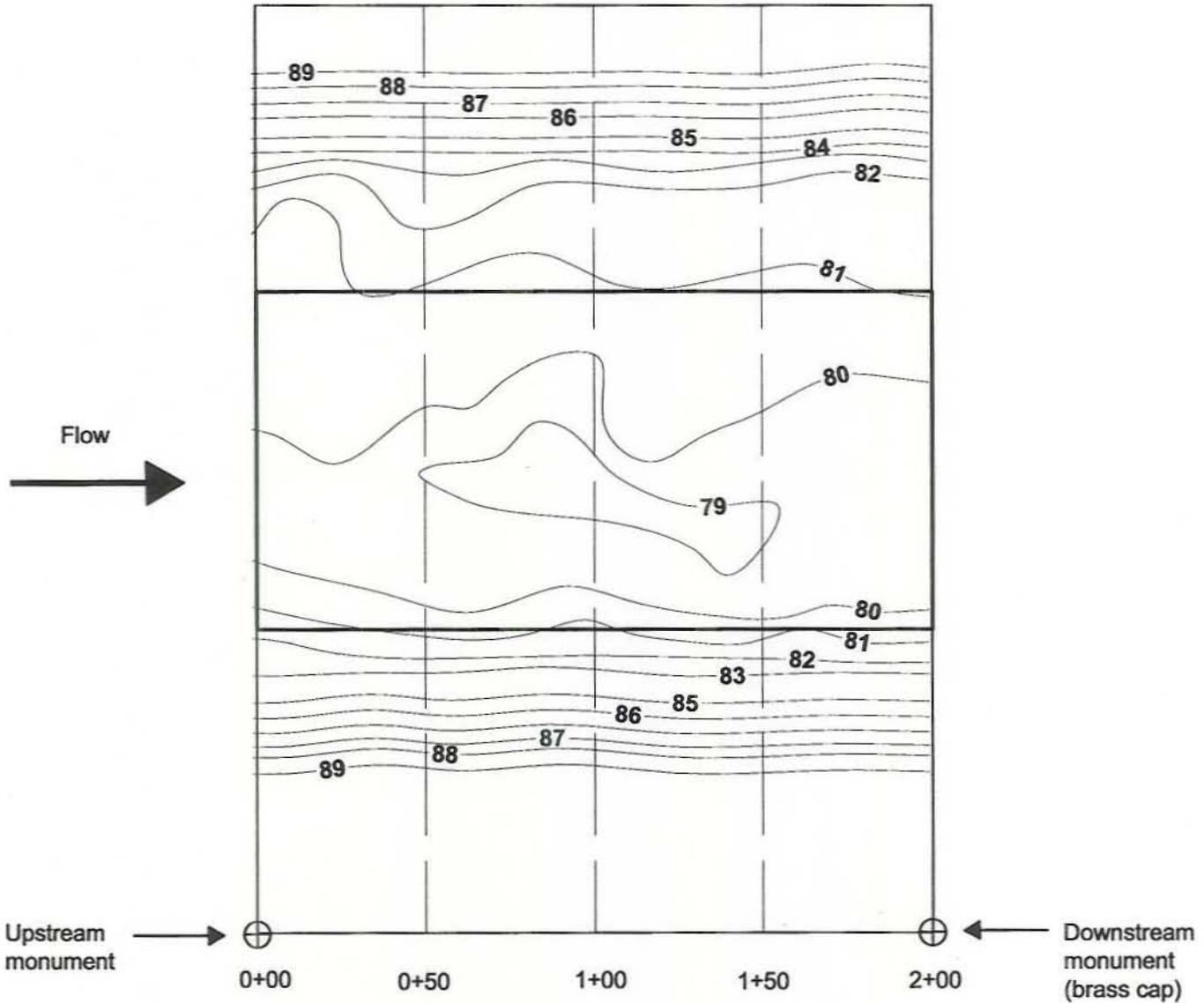
# Bathymetric Survey at OR7 Bed Sediment Contour Spring 2002



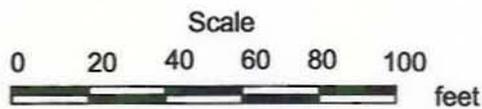
Note: Water surface elevation at the time of survey = 90.8 feet.  
Contours interpolated from soundings taken on April 3, 2002.  
Contour interval = 1 foot.

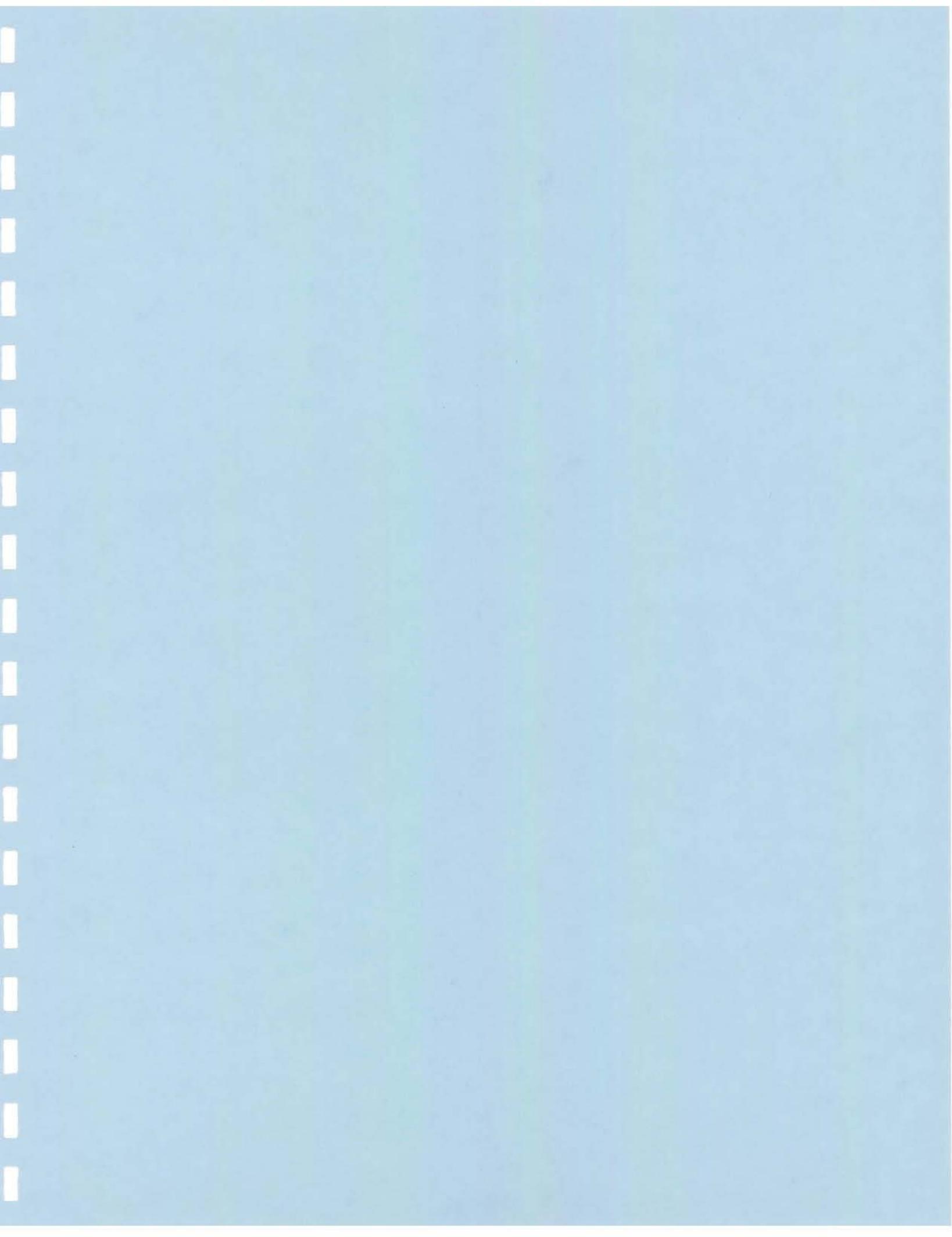


# Bathymetric Survey at OR7 Bed Sediment Contour Fall 2002

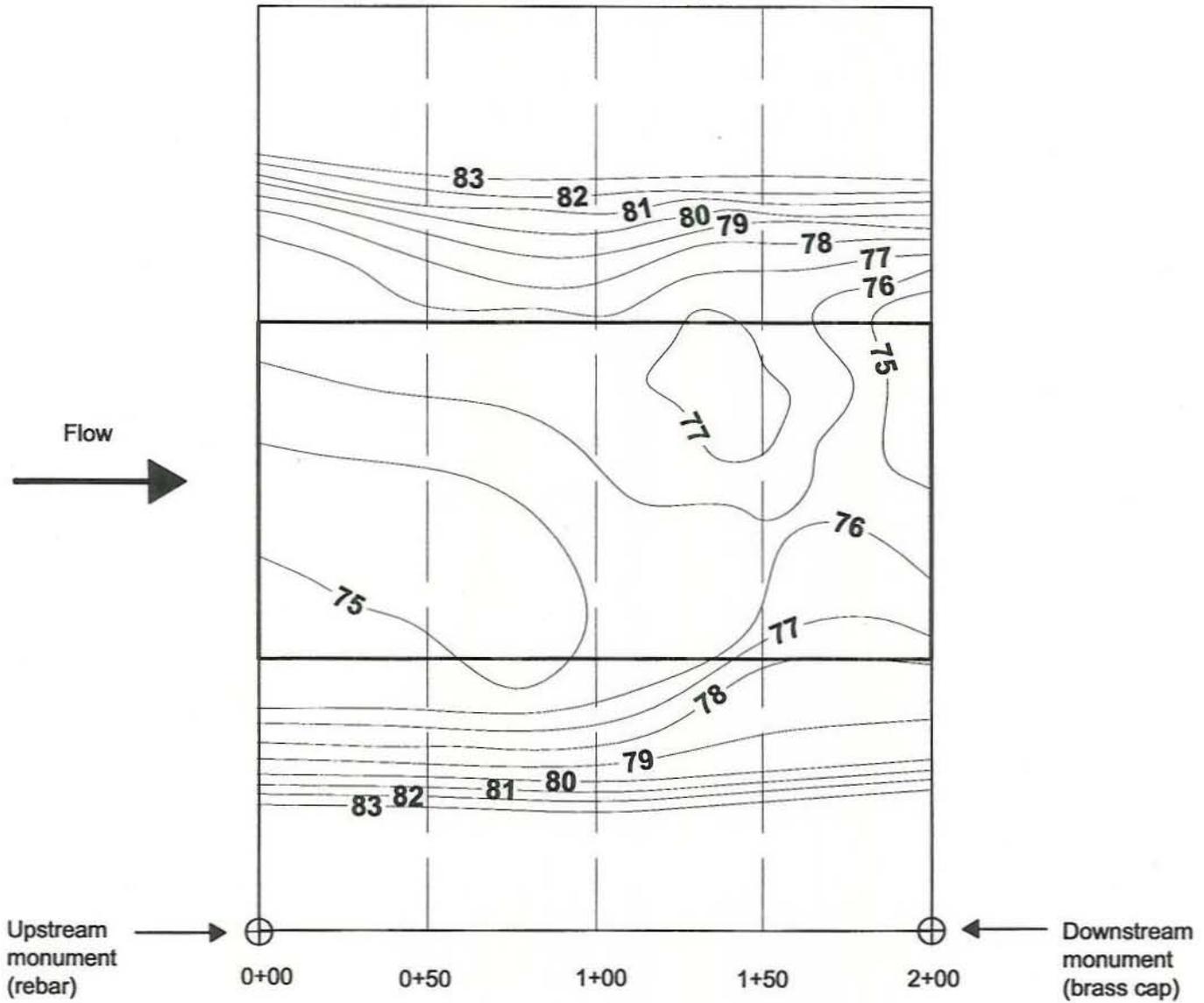


Note: Water surface elevation at the time of survey = 90.3 feet.  
 Contours interpolated from soundings taken on September 11, 2002.  
 Contour interval = 1 foot

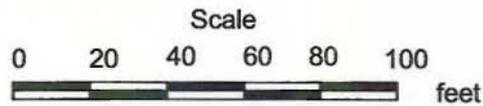




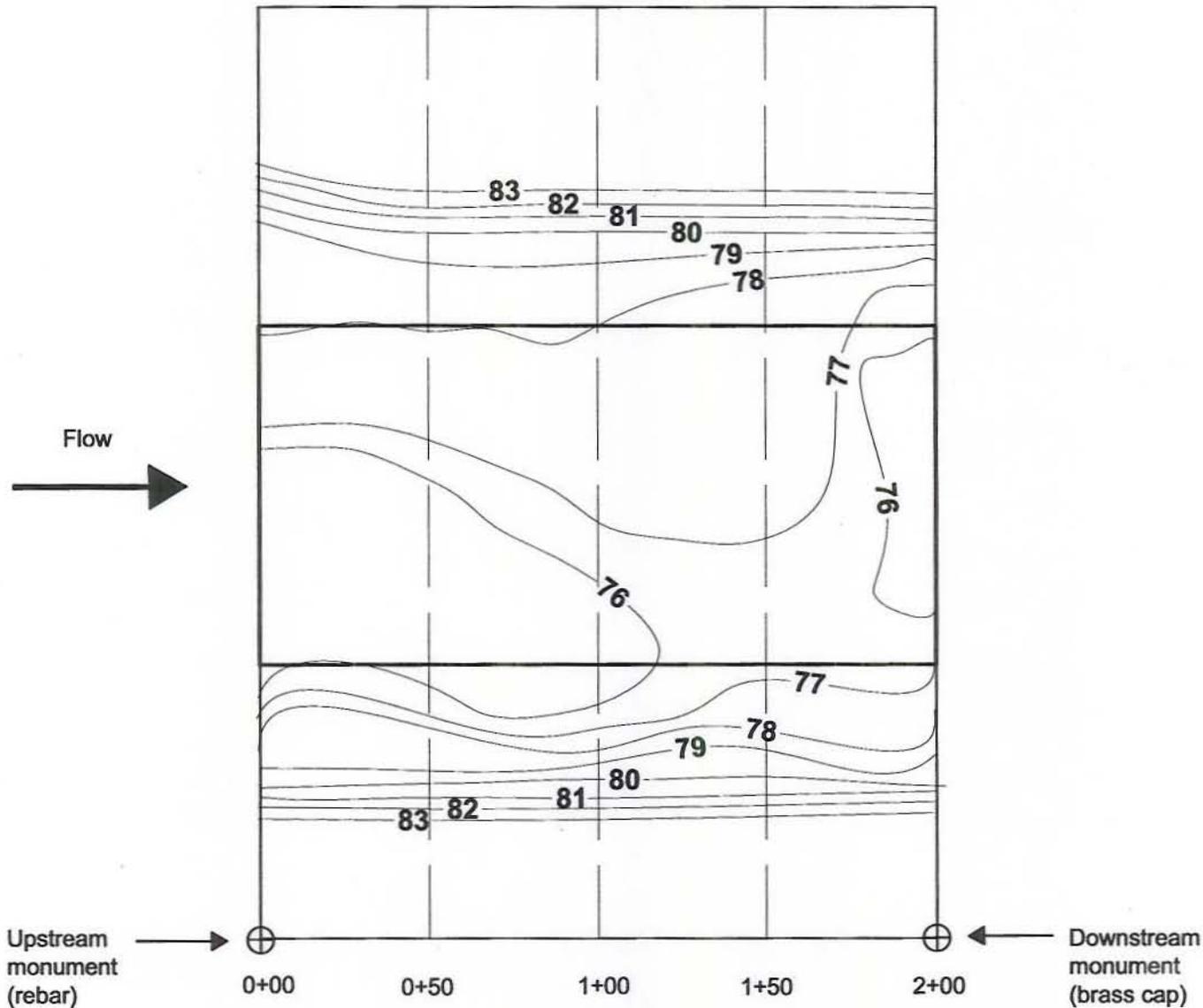
# Bathymetric Survey at OR8 Bed Sediment Contour Spring 2000



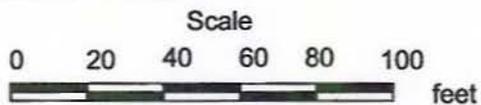
Note: Water surface elevation at the time of survey = 85.1 feet.  
Contours interpolated from soundings taken on April 12, 2000.  
Contour interval = 1 foot.



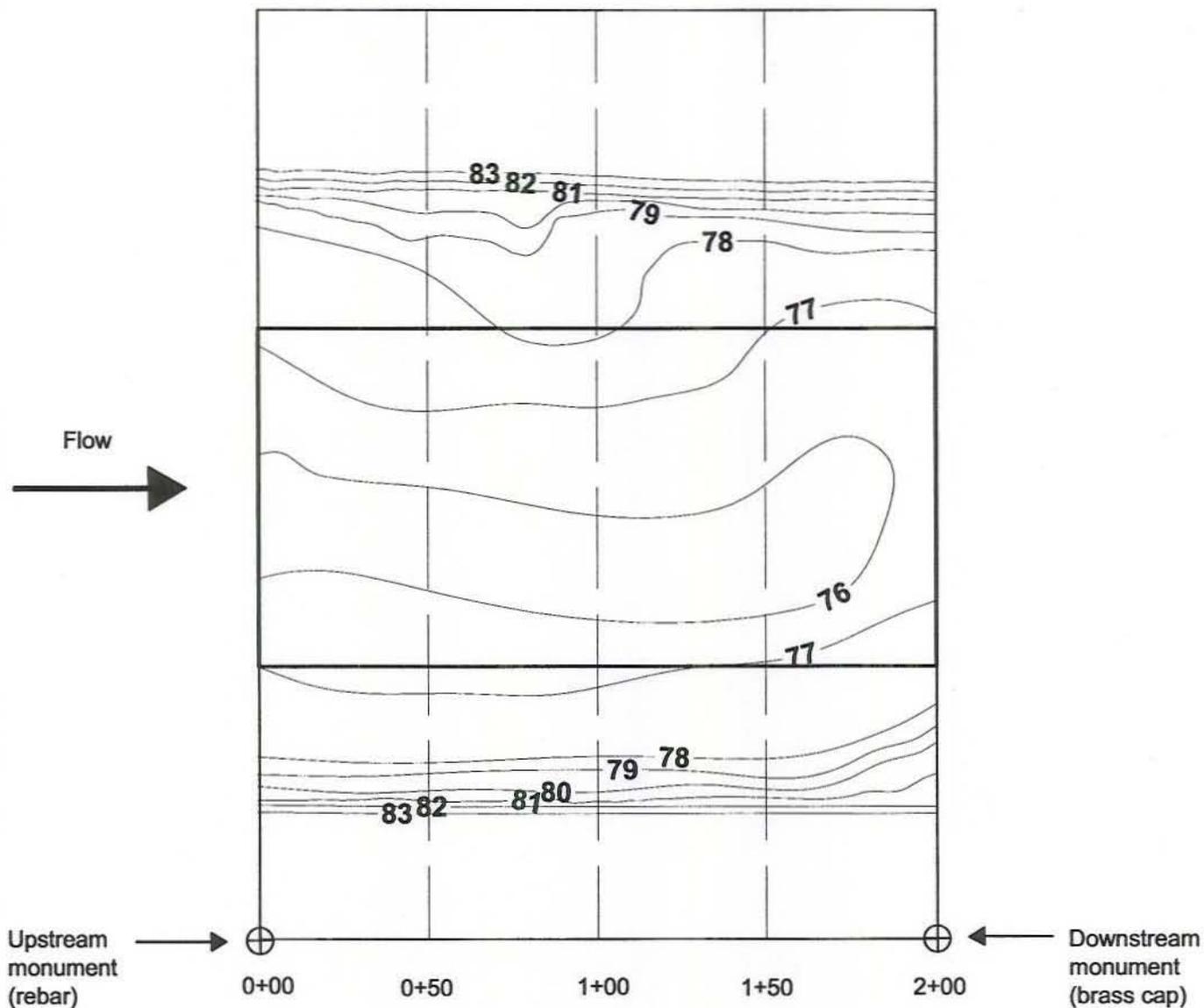
# Bathymetric Survey at OR8 Bed Sediment Contour Fall 2000



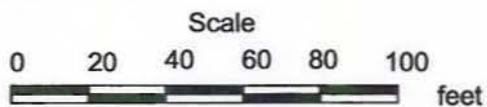
Note: Water surface elevation at the time of survey = 87.2 feet.  
Contours interpolated from soundings taken on September 20, 2000.  
Contour interval = 1 foot.



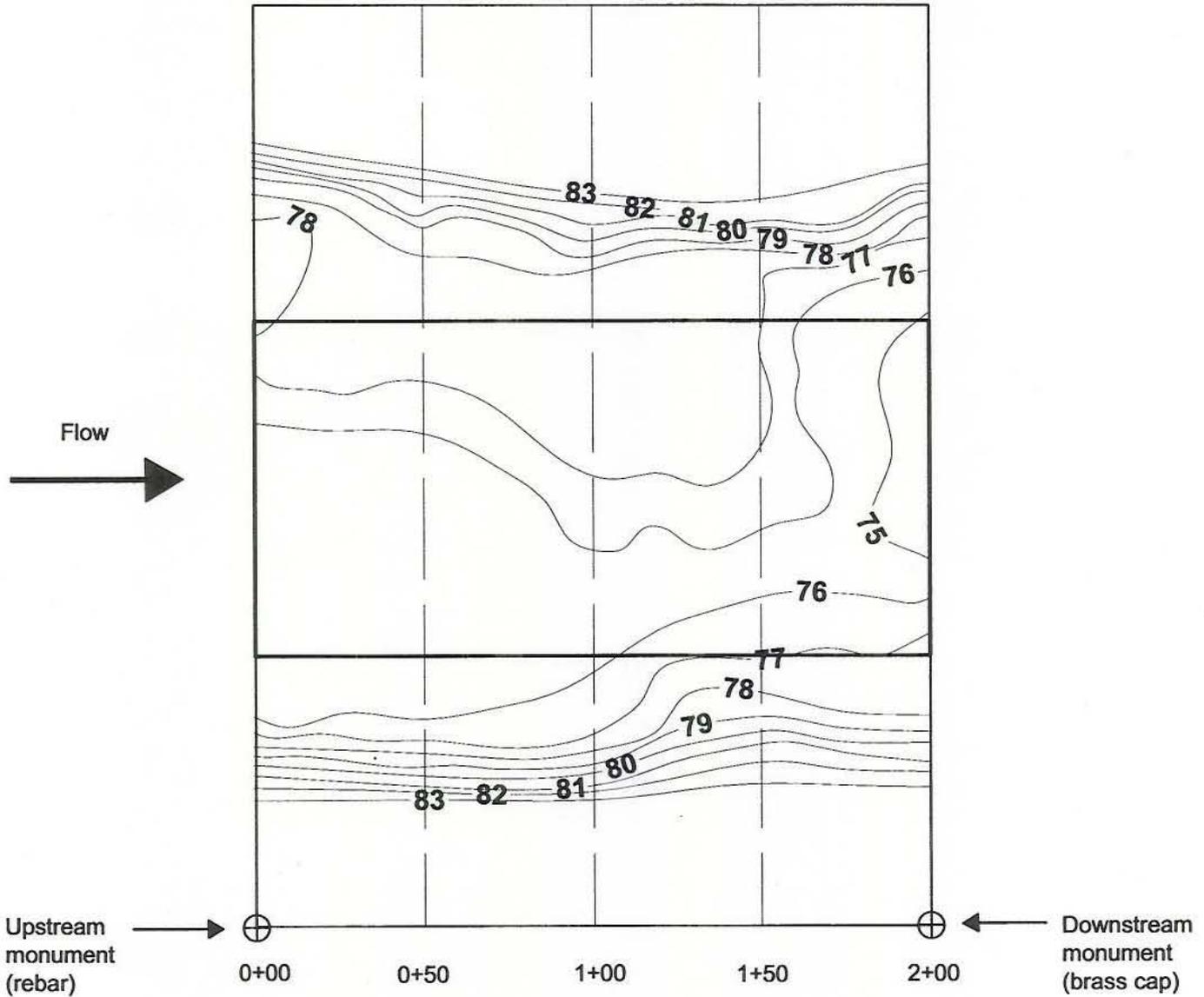
# Bathymetric Survey at OR8 Bed Sediment Contour Spring 2001



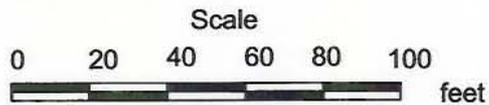
Note: Water surface elevation at the time of survey = 85.1 feet.  
Contours interpolated from soundings taken on March 27, 2001.  
Contour interval = 1 foot.



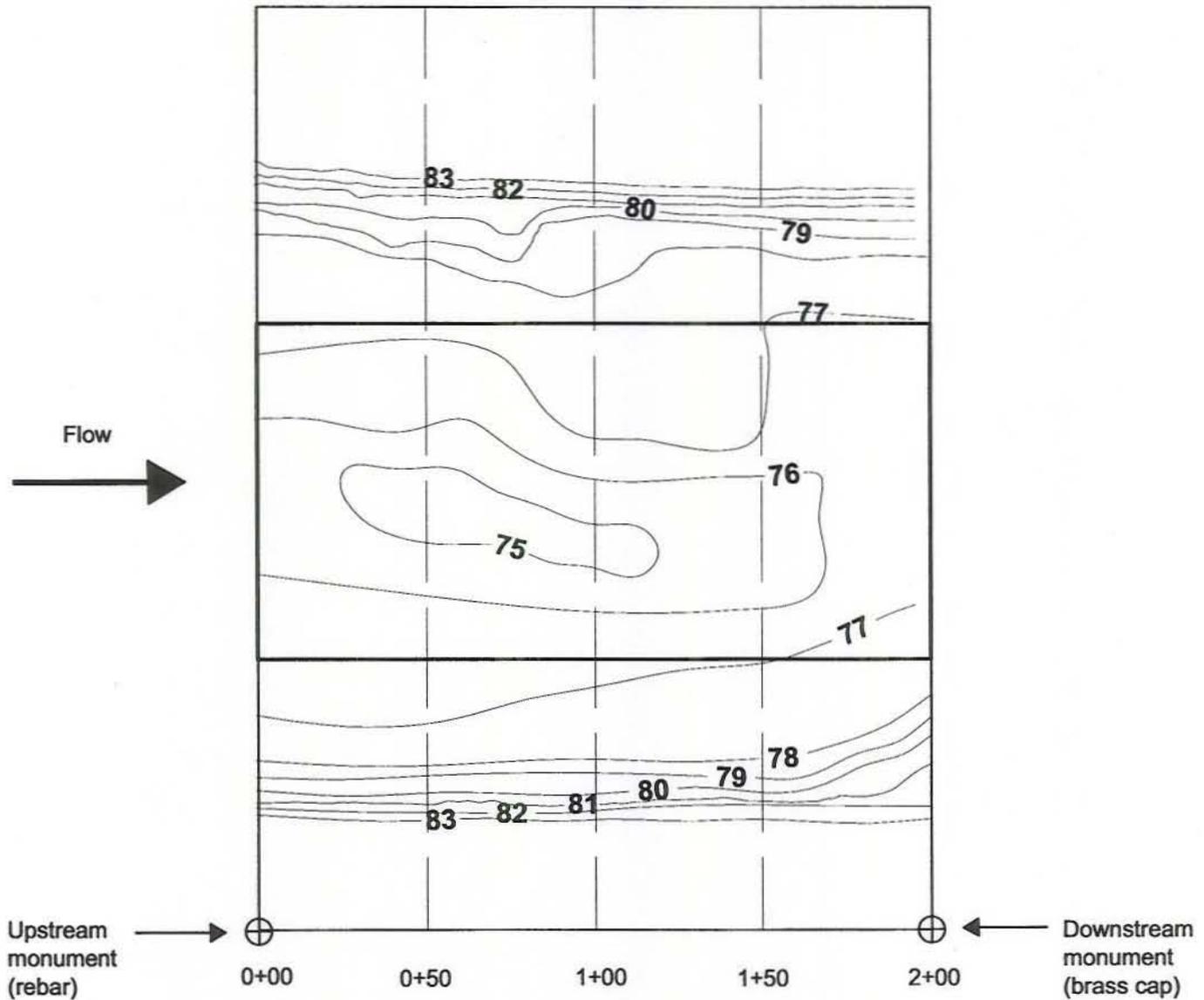
# Bathymetric Survey at OR8 Bed Sediment Contour Fall 2001



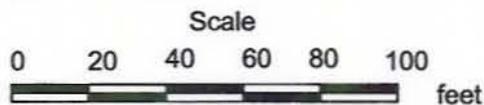
Note: Water surface elevation at the time of survey = 86.9 feet.  
Contours interpolated from soundings taken on September 11, 2001.  
Contour interval = 1 foot.



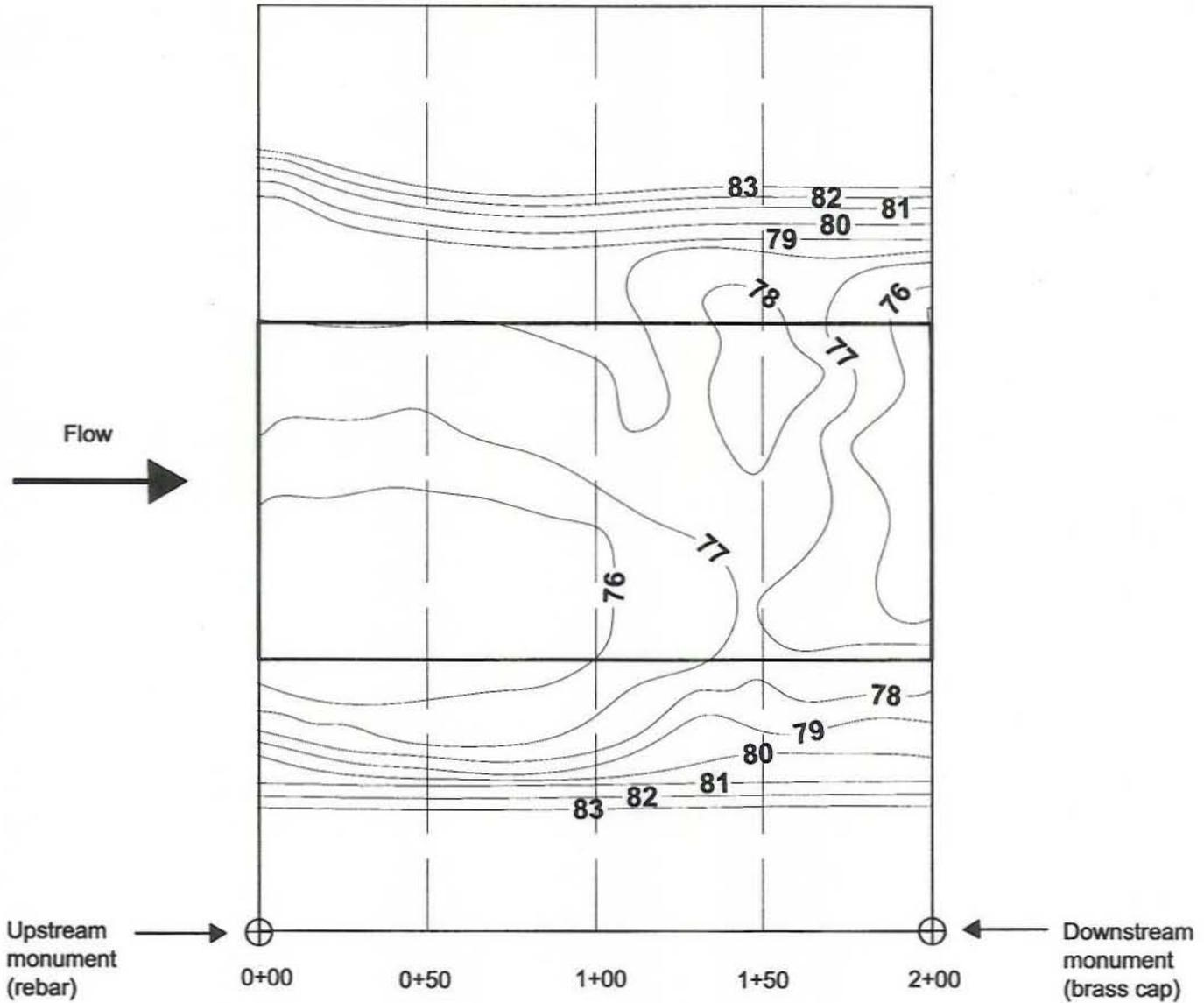
# Bathymetric Survey at OR8 Bed Sediment Contour Spring 2002



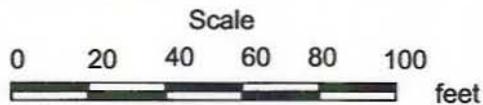
Note: Water surface elevation at the time of survey = 86.6 feet.  
Contours interpolated from soundings taken on April 3, 2002.  
Contour interval = 1 foot.

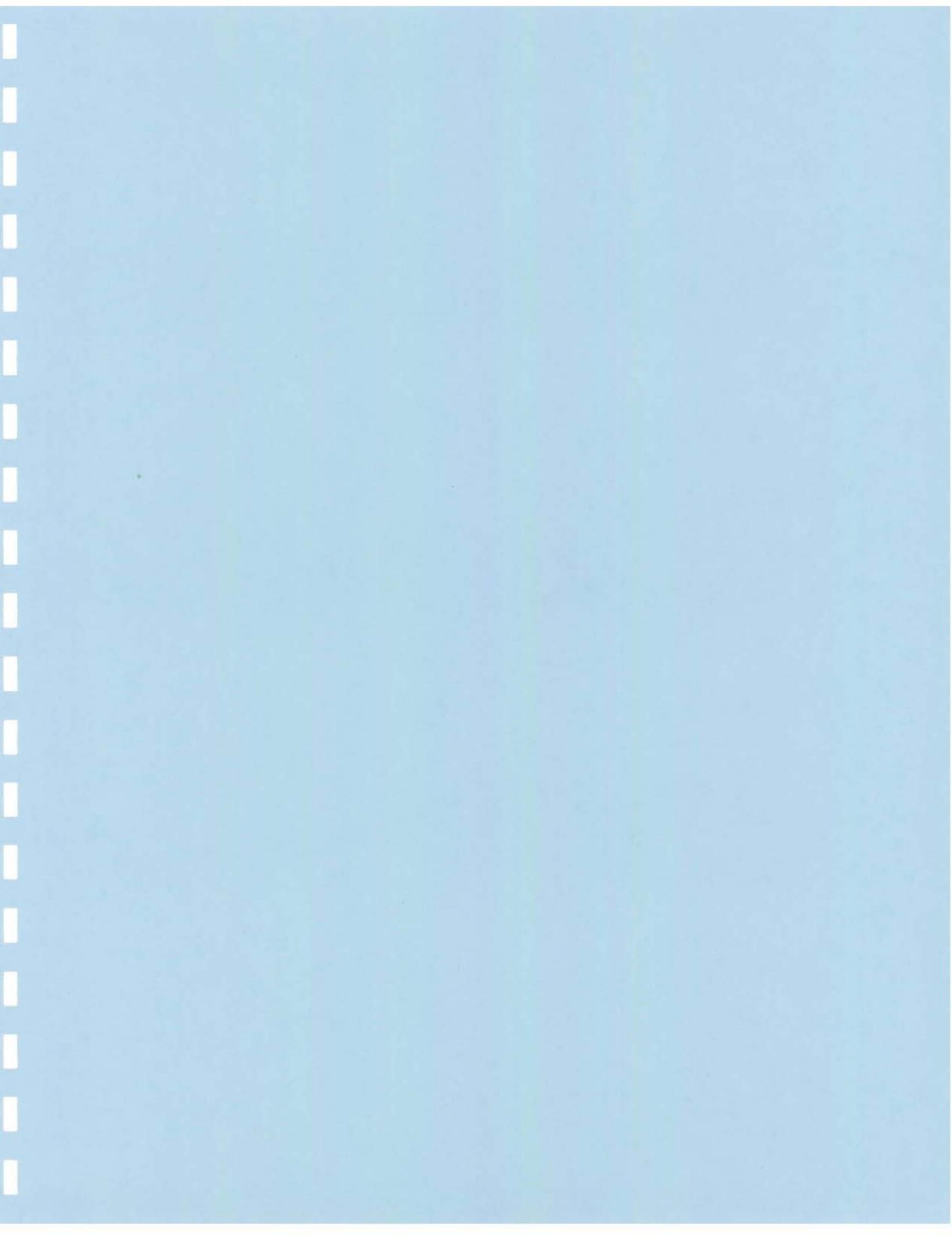


# Bathymetric Survey at OR8 Bed Sediment Contour Fall 2002

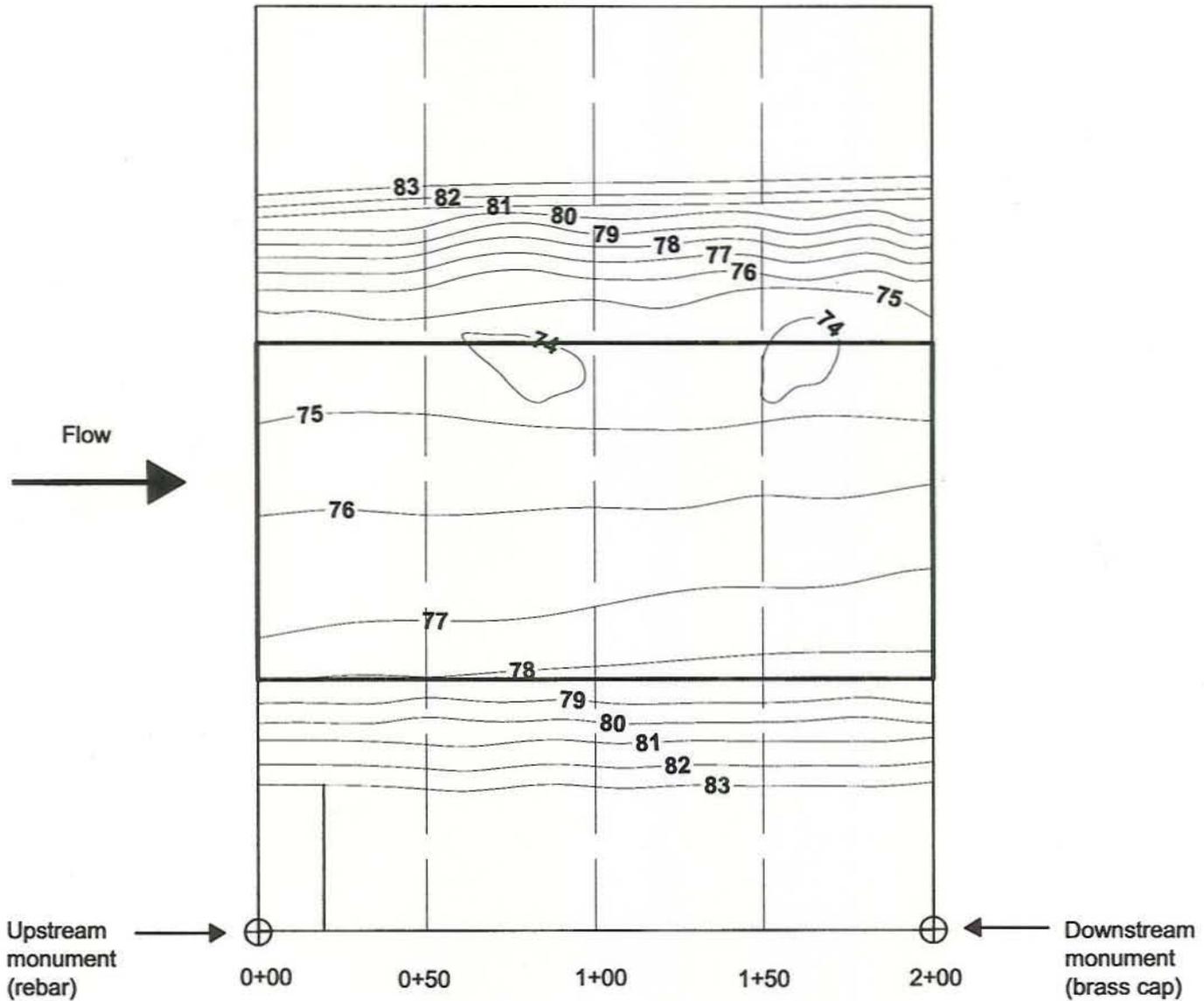


Note: Water surface elevation at the time of survey = 86.7 feet.  
Contours interpolated from soundings taken on September 12, 2002.  
Contour interval = 1 foot.

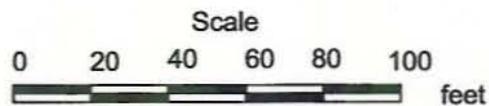




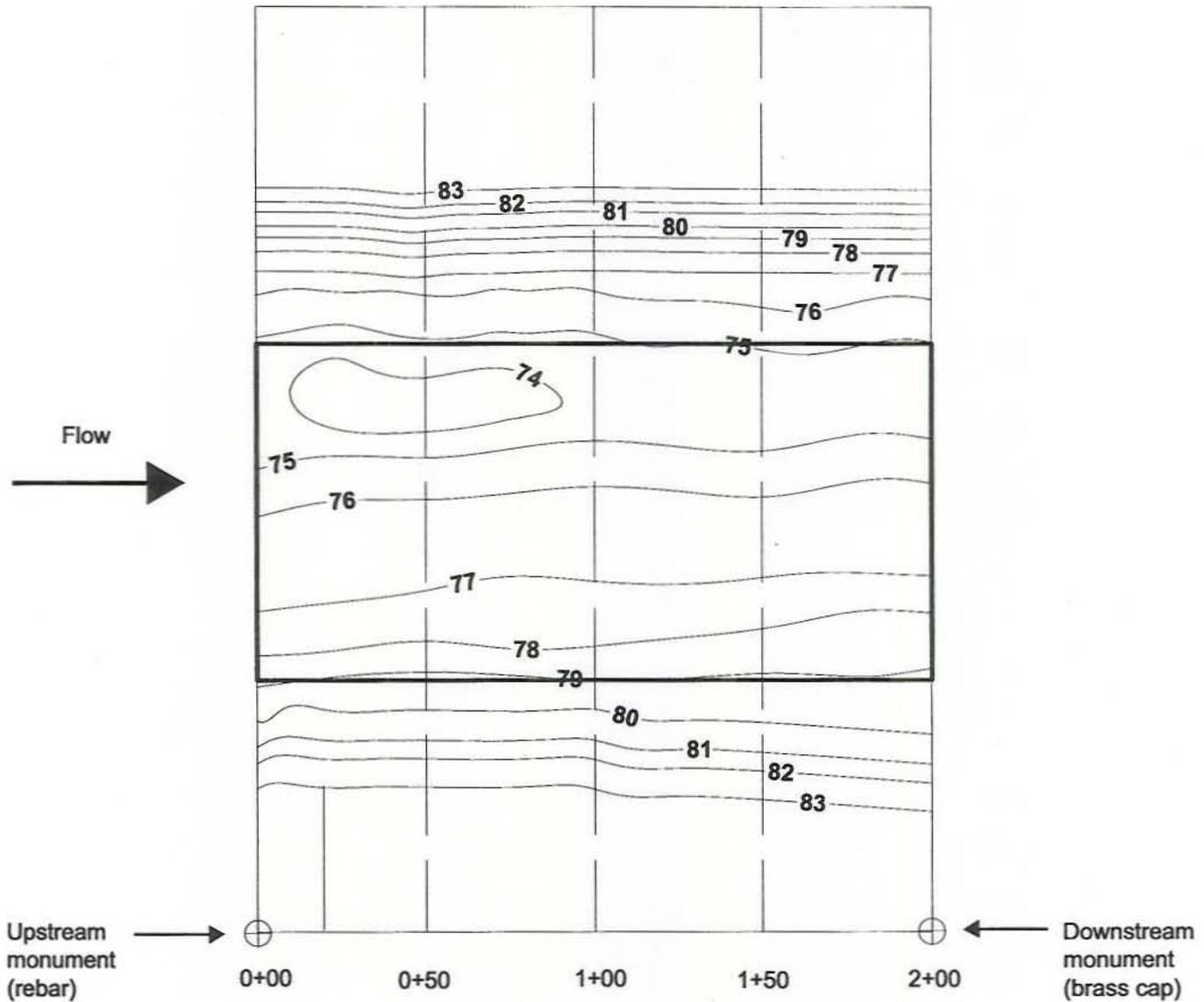
# Bathymetric Survey at OR9 Bed Sediment Contour Spring 2000



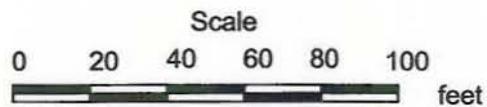
Note: Water surface elevation at the time of survey = 86.4 feet.  
Contours interpolated from soundings taken on April 12, 2000.  
Contour interval = 1 foot.



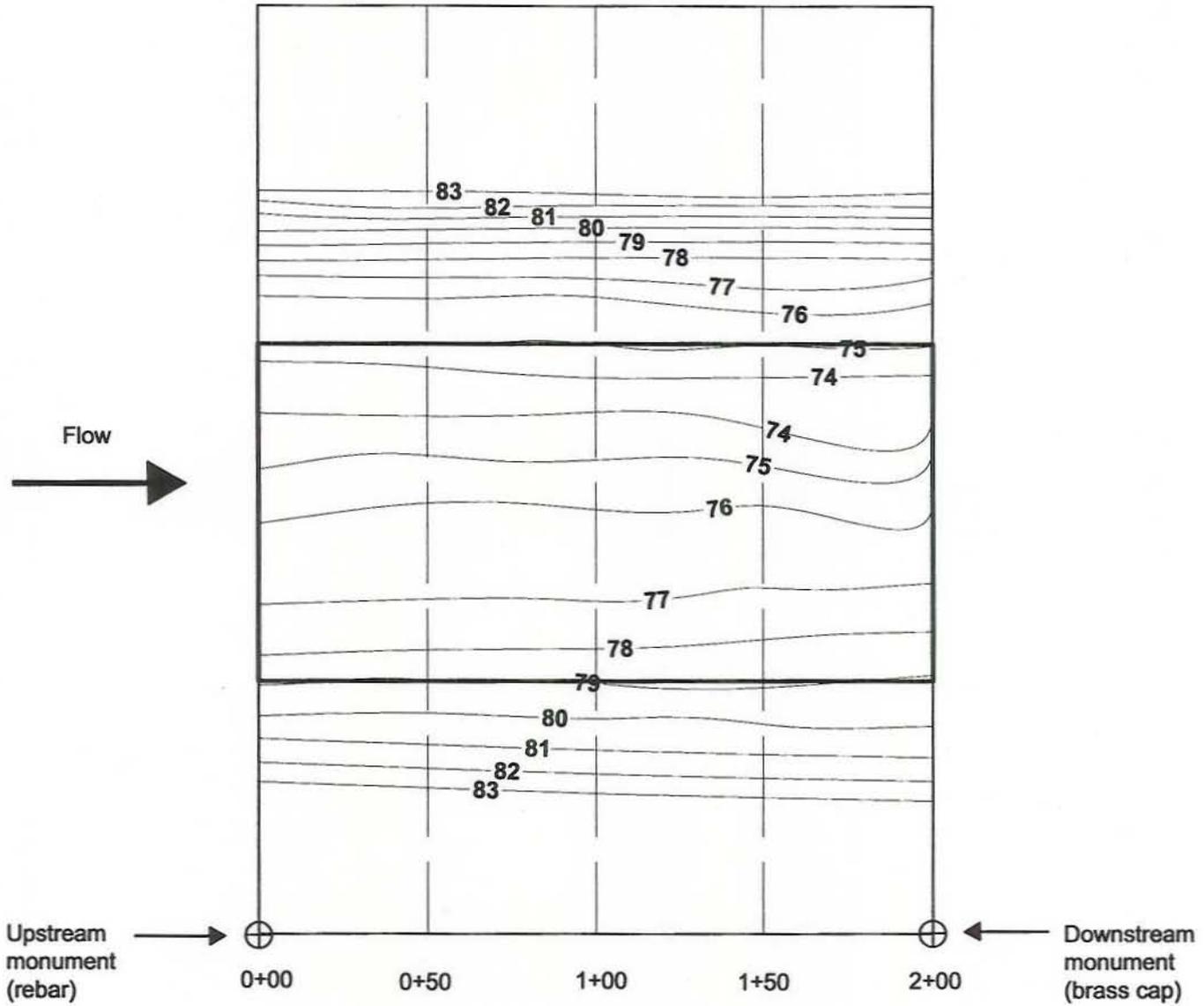
# Bathymetric Survey at OR9 Bed Sediment Contour Fall 2000



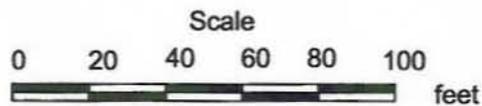
Note: Water surface elevation at the time of survey = 86.2 feet.  
Contours interpolated from soundings taken on September 20, 2000.  
Contour interval = 1 foot.



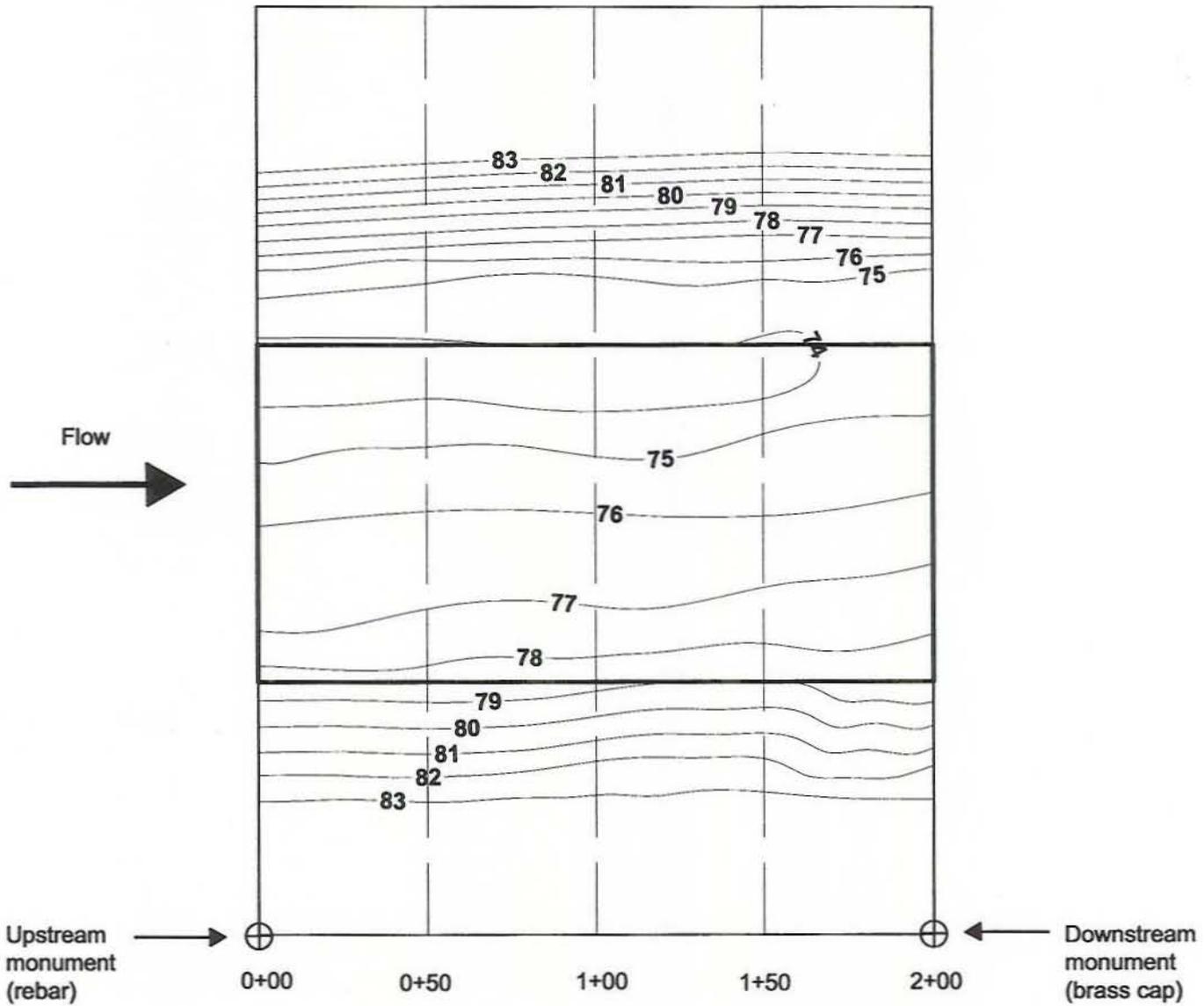
# Bathymetric Survey at OR9 Bed Sediment Contour Spring 2001



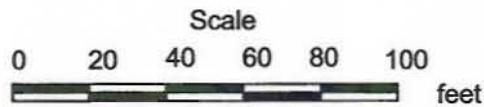
Note: Water surface elevation at the time of survey = 85.3 feet.  
Contours interpolated from soundings taken on March 27, 2001.  
Contour interval = 1 foot.



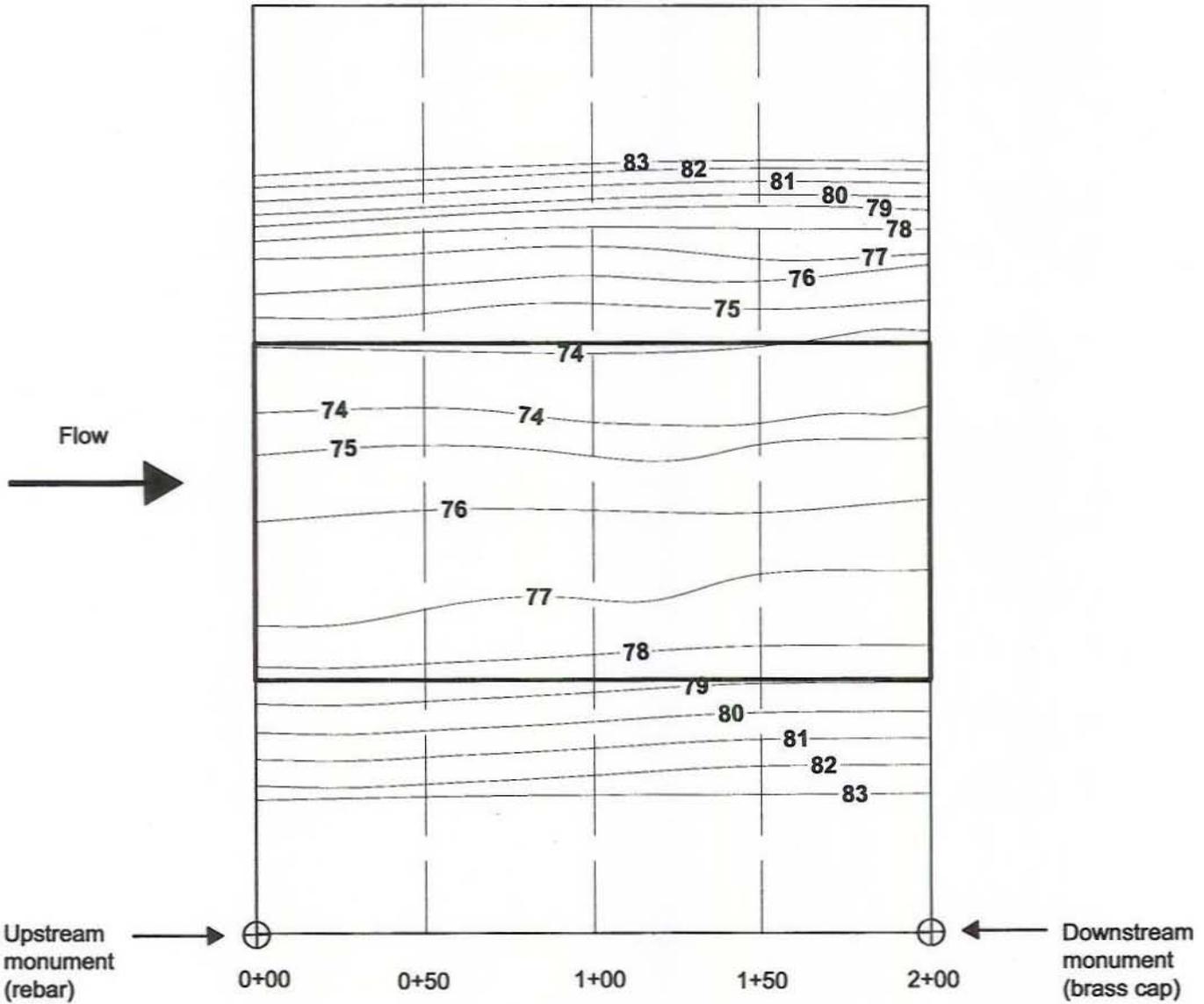
# Bathymetric Survey at OR9 Bed Sediment Contour Fall 2001



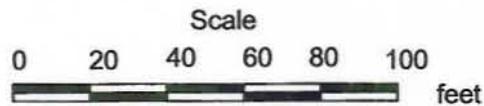
Note: Water surface elevation at the time of survey = 86.4 feet.  
Contours interpolated from soundings taken on September 10, 2001.  
Contour interval = 1 foot.



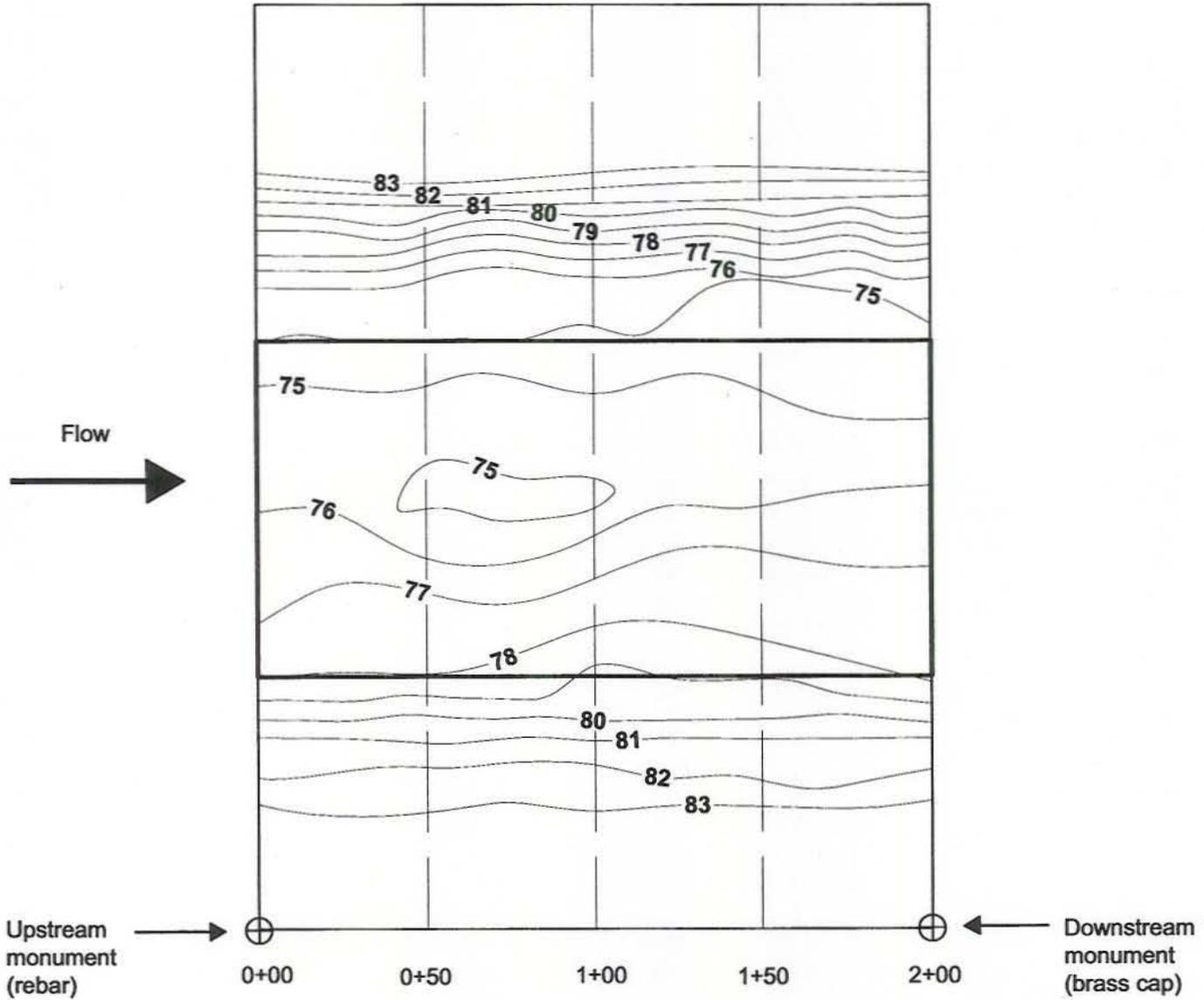
# Bathymetric Survey at OR9 Bed Sediment Contour Spring 2002



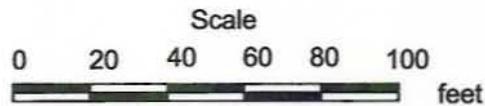
Note: Water surface elevation at the time of survey = 87.4 feet.  
Contours interpolated from soundings taken on April 4, 2002.  
Contour interval = 1 foot.

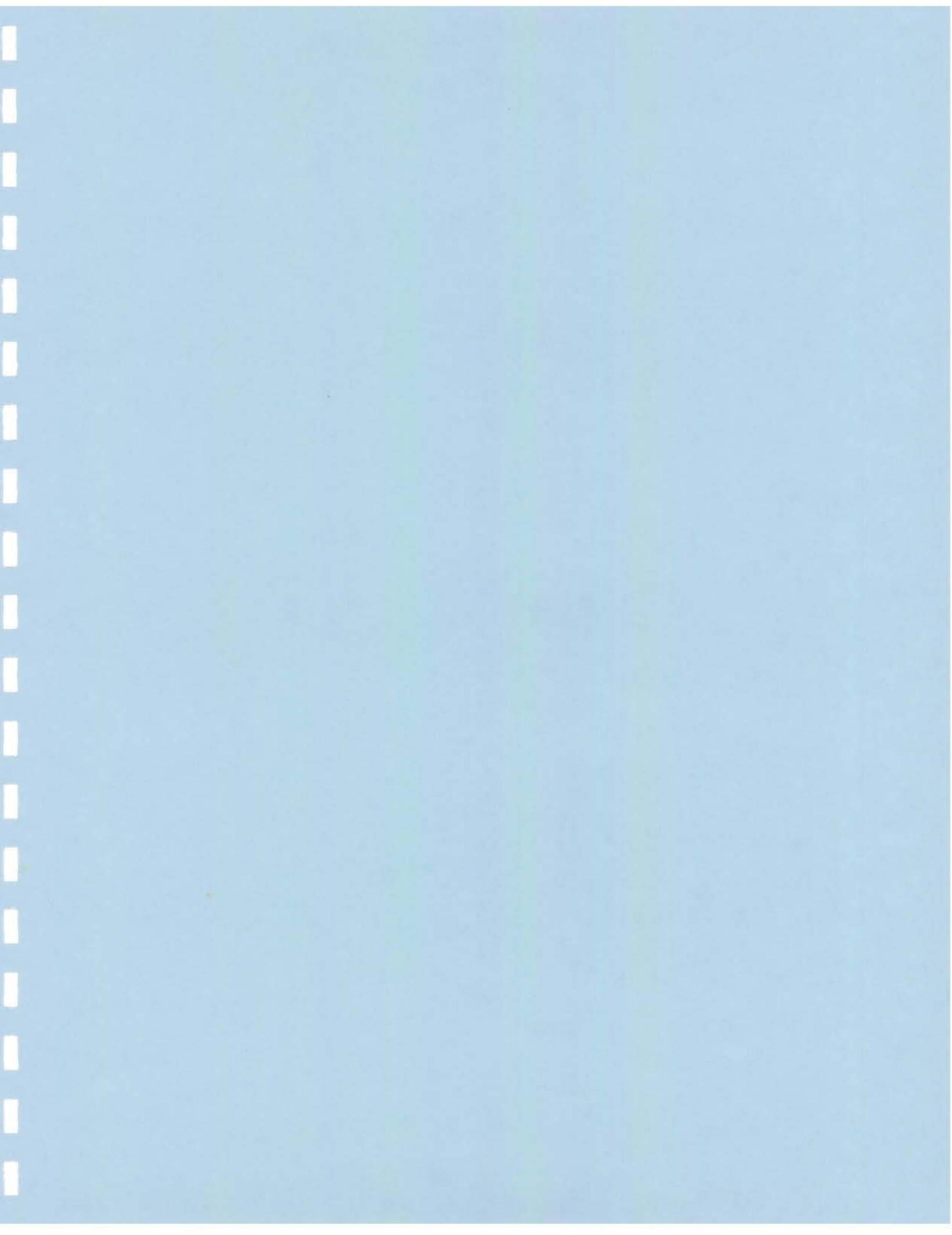


# Bathymetric Survey at OR9 Bed Sediment Contour Fall 2002

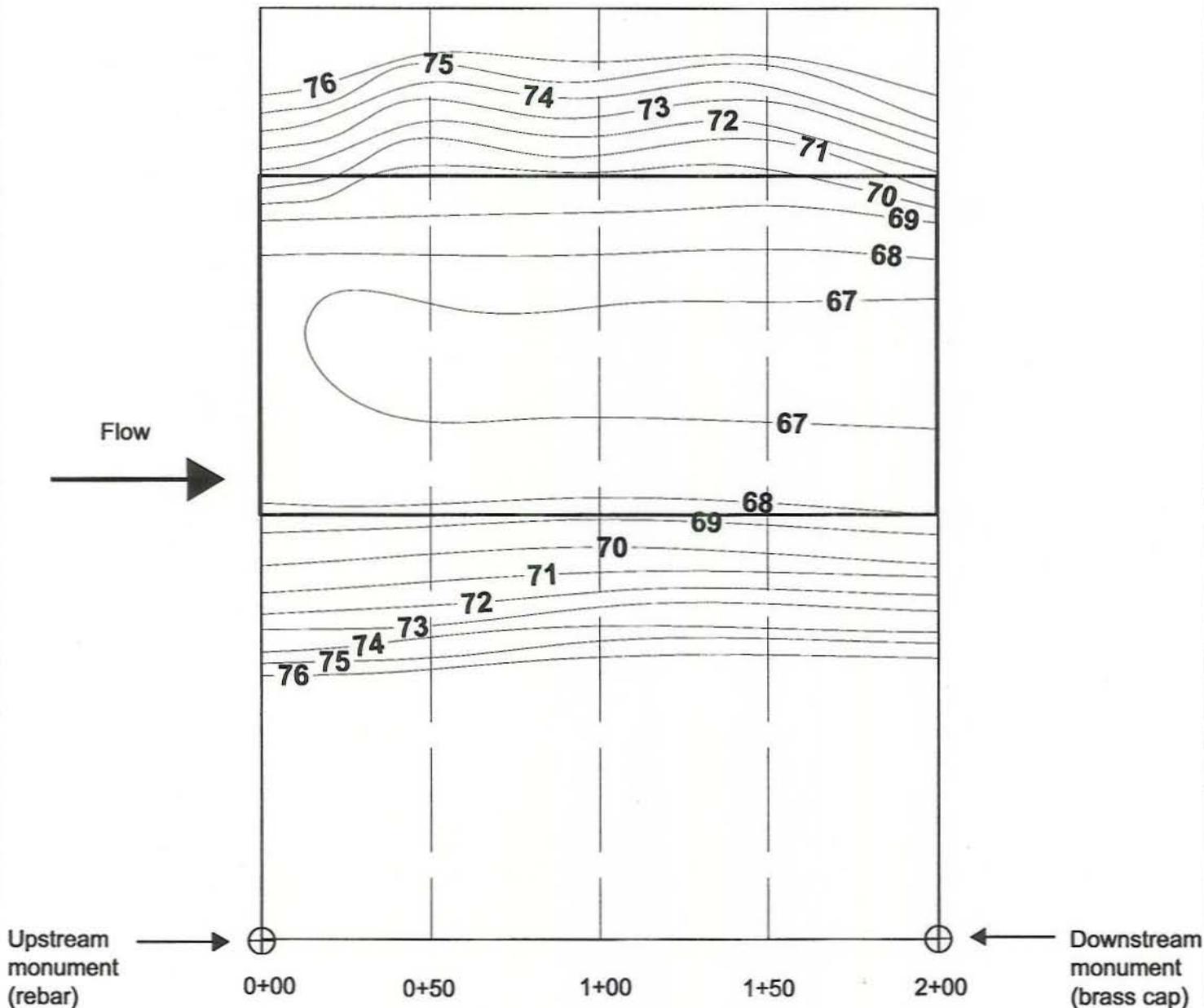


Note: Water surface elevation at the time of survey = 86.1 feet.  
Contours interpolated from soundings taken on September 12, 2002.  
Contour interval = 1 foot.

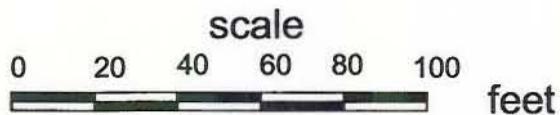




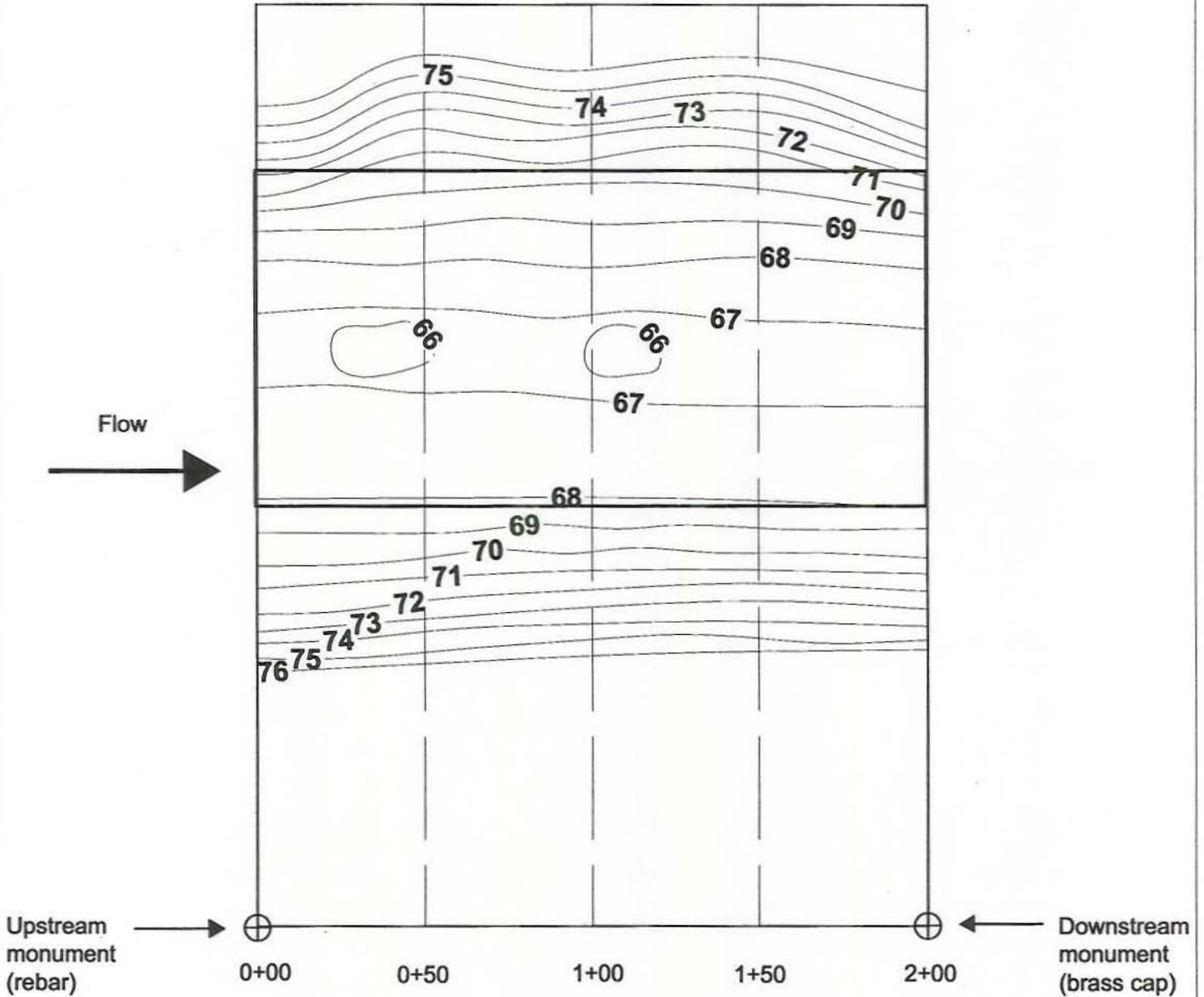
# Bathymetric Survey at GLC1A Bed Sediment Contour Spring 2000



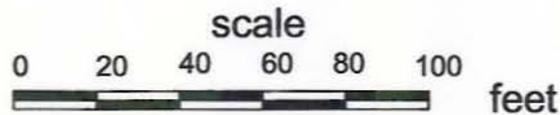
Note: Water surface elevation at the time of survey = 86.7 feet.  
Contours interpolated from soundings taken on April 11, 2000.  
Contour interval = 1 foot.



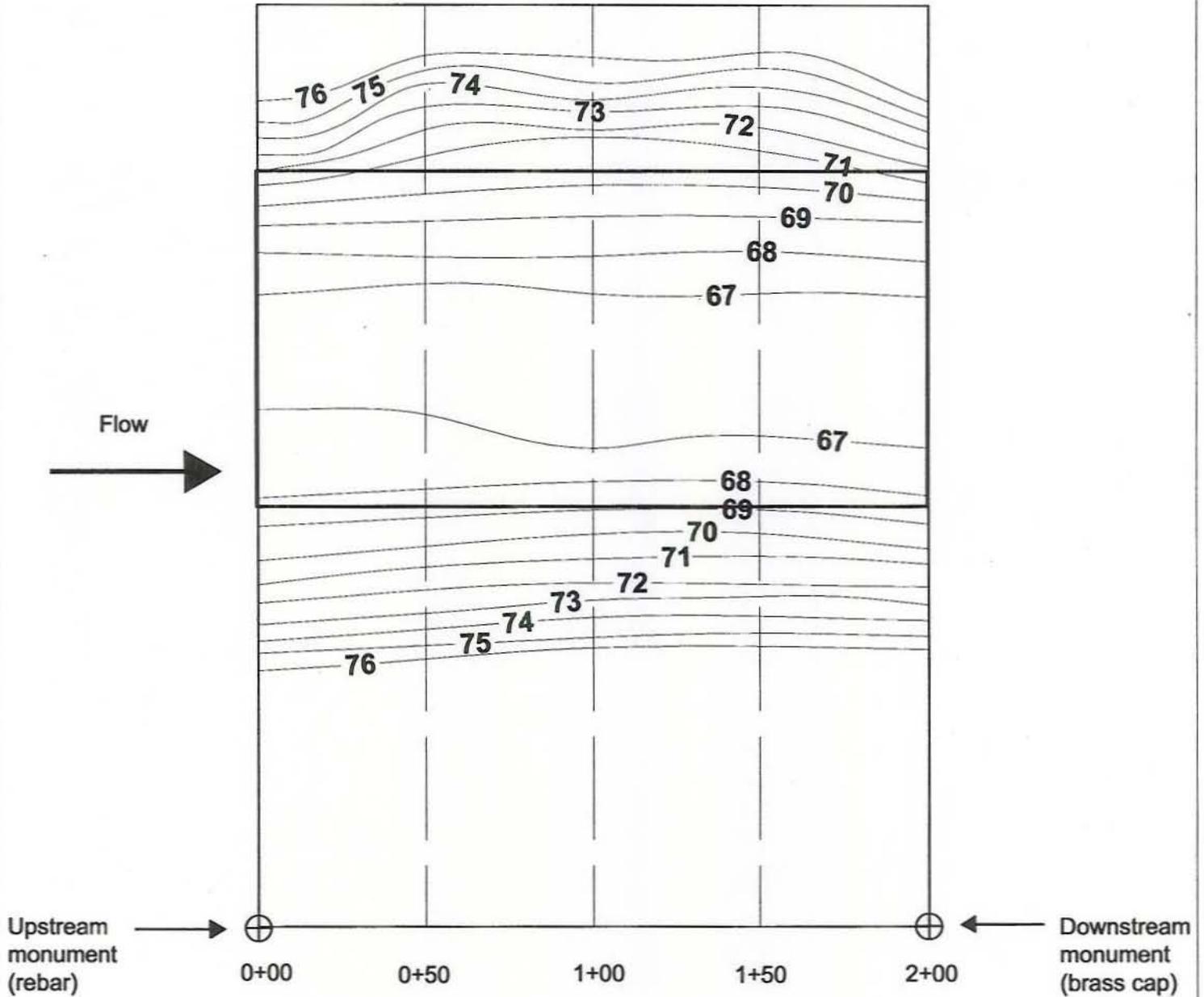
# Bathymetric Survey at GLC1A Bed Sediment Contour Fall 2000



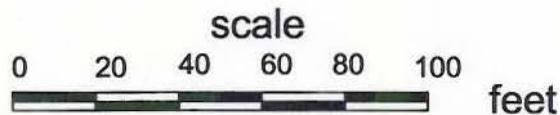
Note: Water surface elevation at the time of survey = 85.1 feet.  
Contours interpolated from soundings taken on September 20, 2000.  
Contour interval = 1 foot.



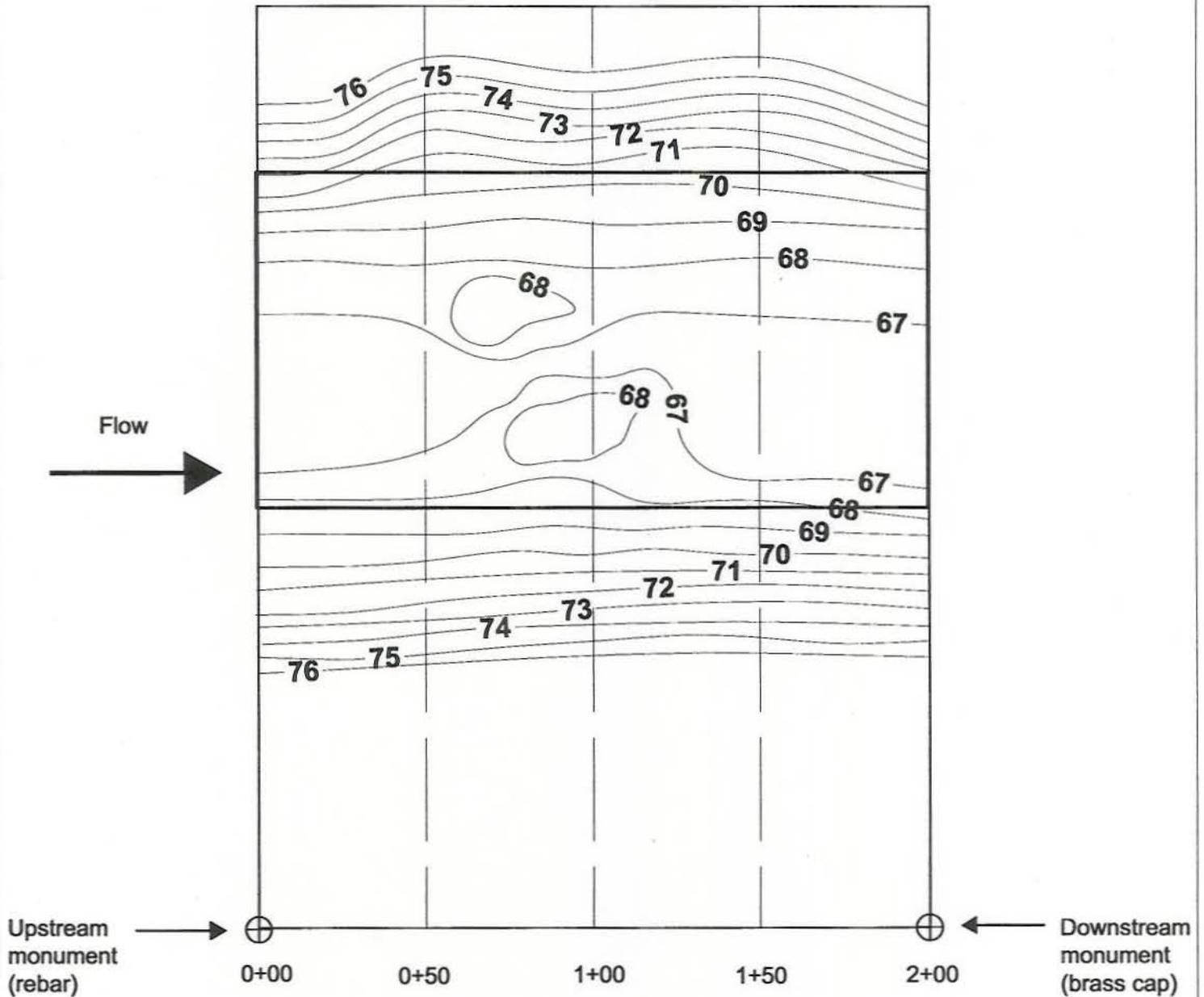
# Bathymetric Survey at GLC1A Bed Sediment Contour Spring 2001



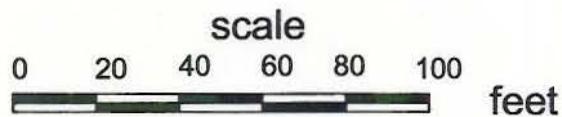
Note: Water surface elevation at the time of survey = 85.5 feet.  
Contours interpolated from soundings taken on March 26, 2001.  
Contour interval = 1 foot.



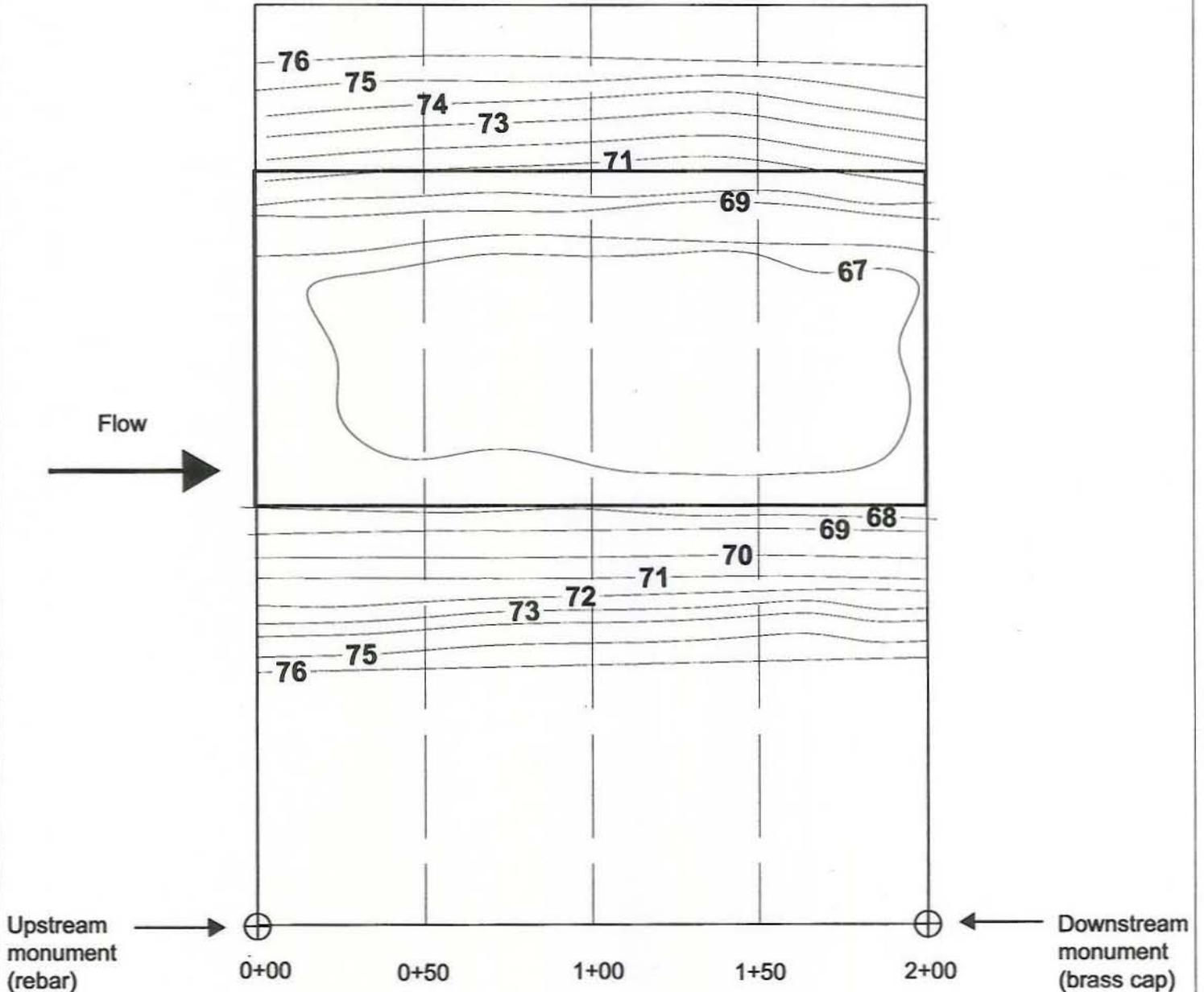
# Bathymetric Survey at GLC1A Bed Sediment Contour Fall 2001



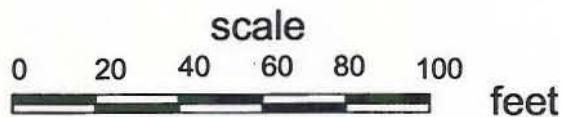
Note: Water surface elevation at the time of survey = 85.9 feet.  
Contours interpolated from soundings taken on September 7, 2001.  
Contour interval = 1 foot.



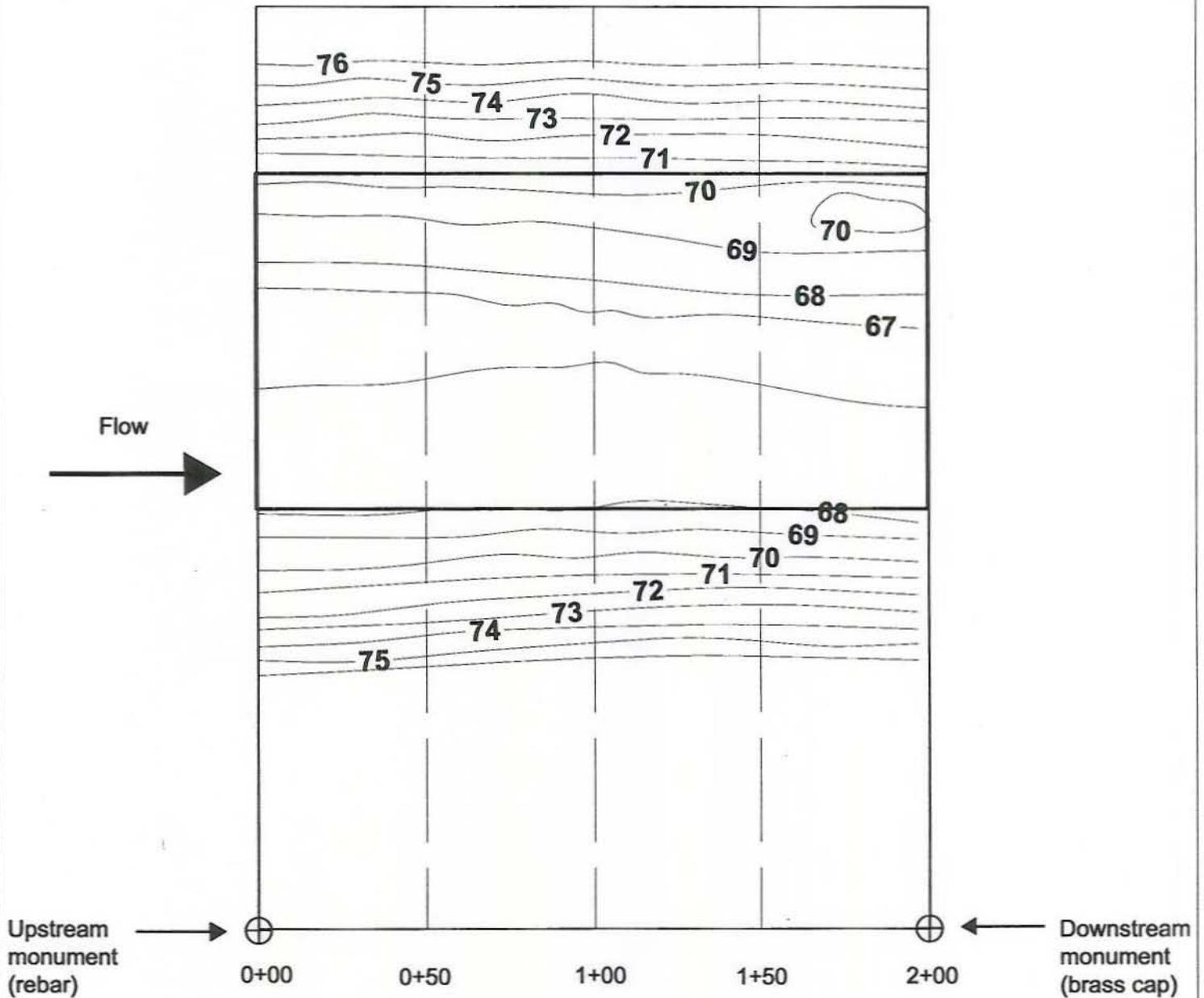
# Bathymetric Survey at GLC1A Bed Sediment Contour Spring 2002



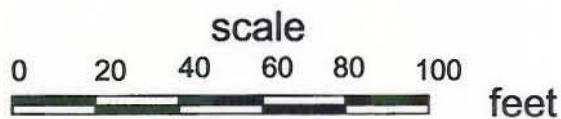
Note: Water surface elevation at the time of survey = 87.9 feet.  
Contours interpolated from soundings taken on April 3, 2002.  
Contour interval = 1 foot.

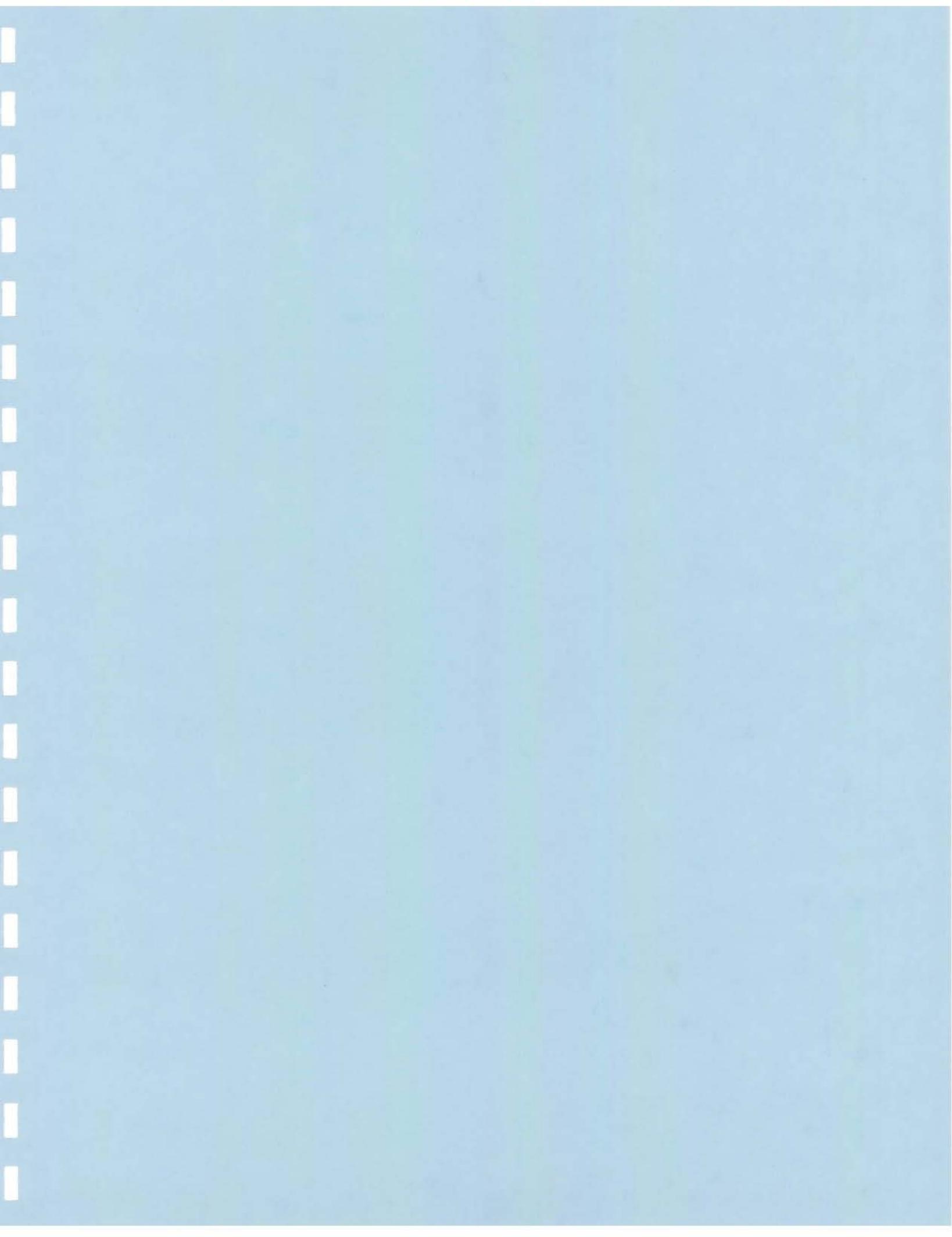


# Bathymetric Survey at GLC1A Bed Sediment Contour Fall 2002

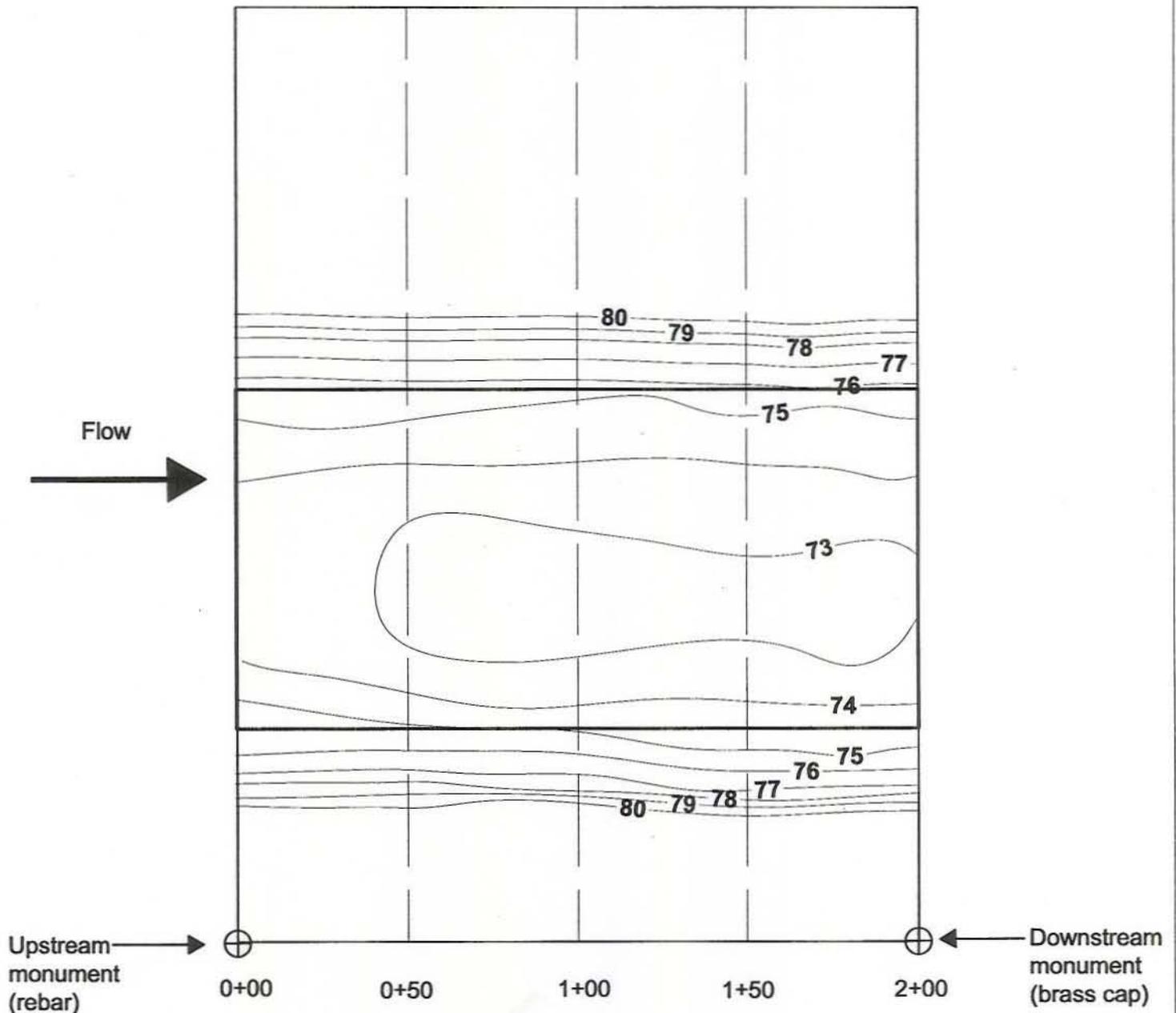


Note: Water surface elevation at the time of survey = 85.5 feet.  
Contours interpolated from soundings taken on September 12, 2002.  
Contour interval = 1 foot.

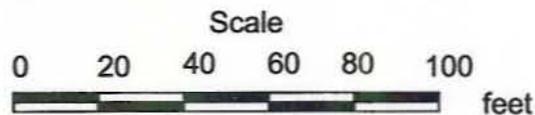




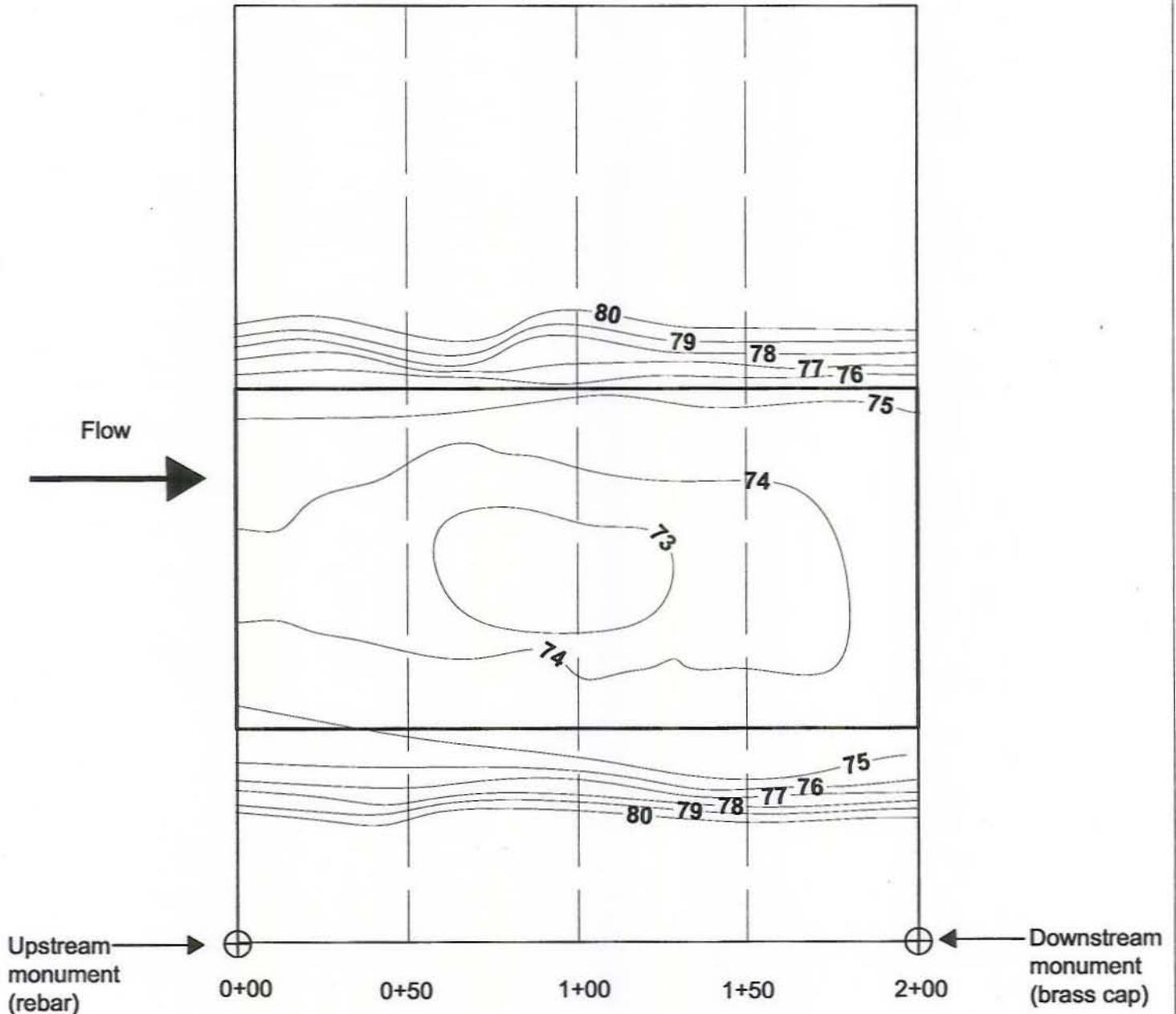
# Bathymetric Survey at GLC1B Bed Sediment Contour Spring 2000



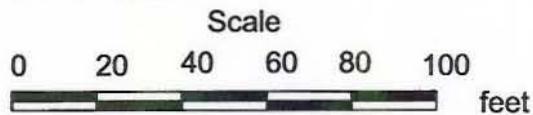
Note: Water surface elevation at the time of survey = 85.5 feet.  
Contours interpolated from soundings taken on April 11, 2000.  
Contour interval = 1 foot.



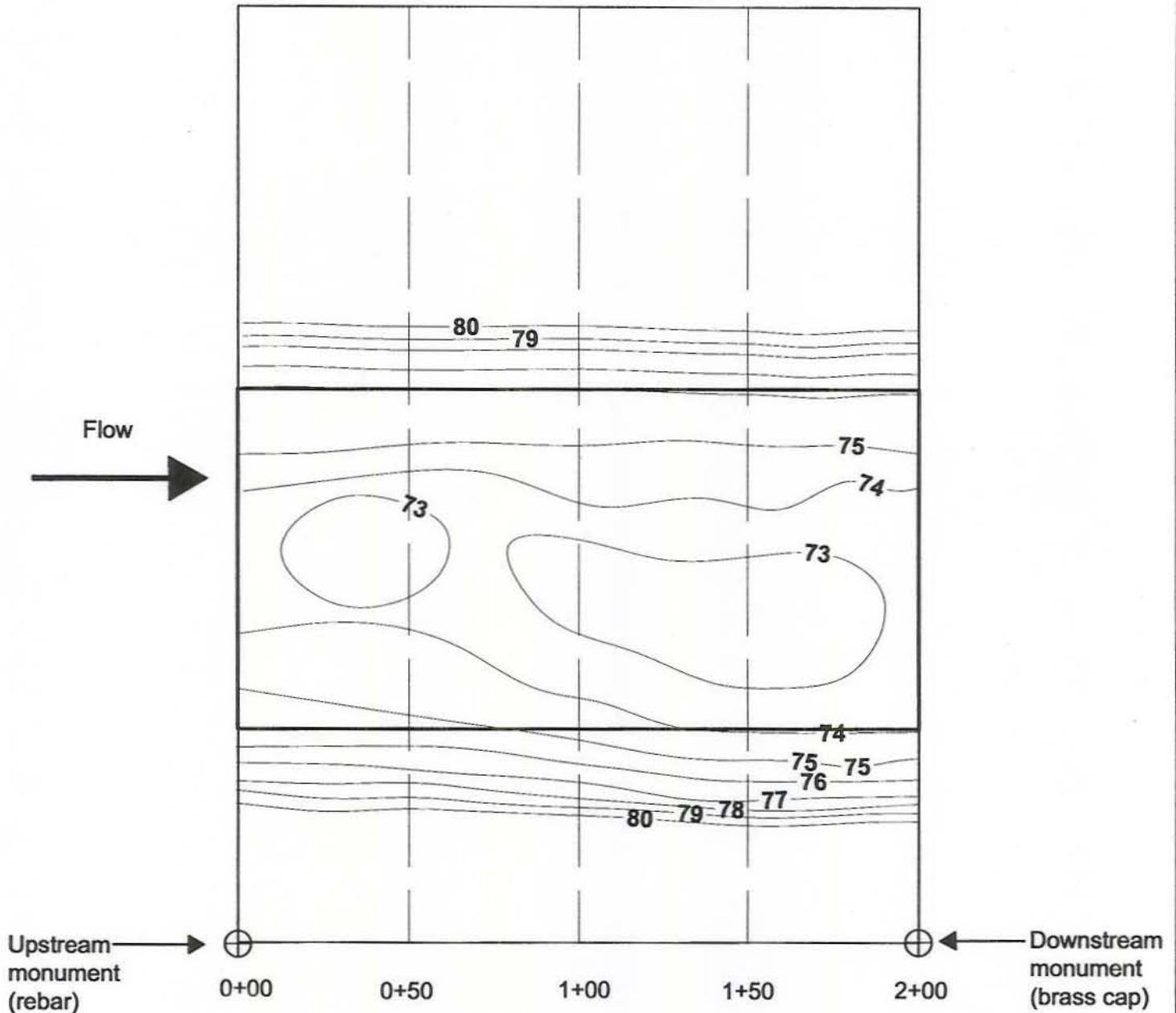
# Bathymetric Survey GLC1B Bed Sediment Contour Fall 2000



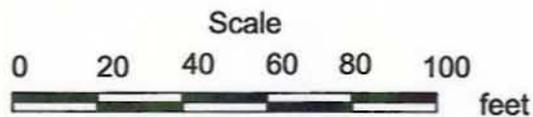
Note: Water surface elevation at the time of survey = 82.9 feet.  
Contours interpolated from soundings taken on September 19, 2000.  
Contour interval = 1 foot.



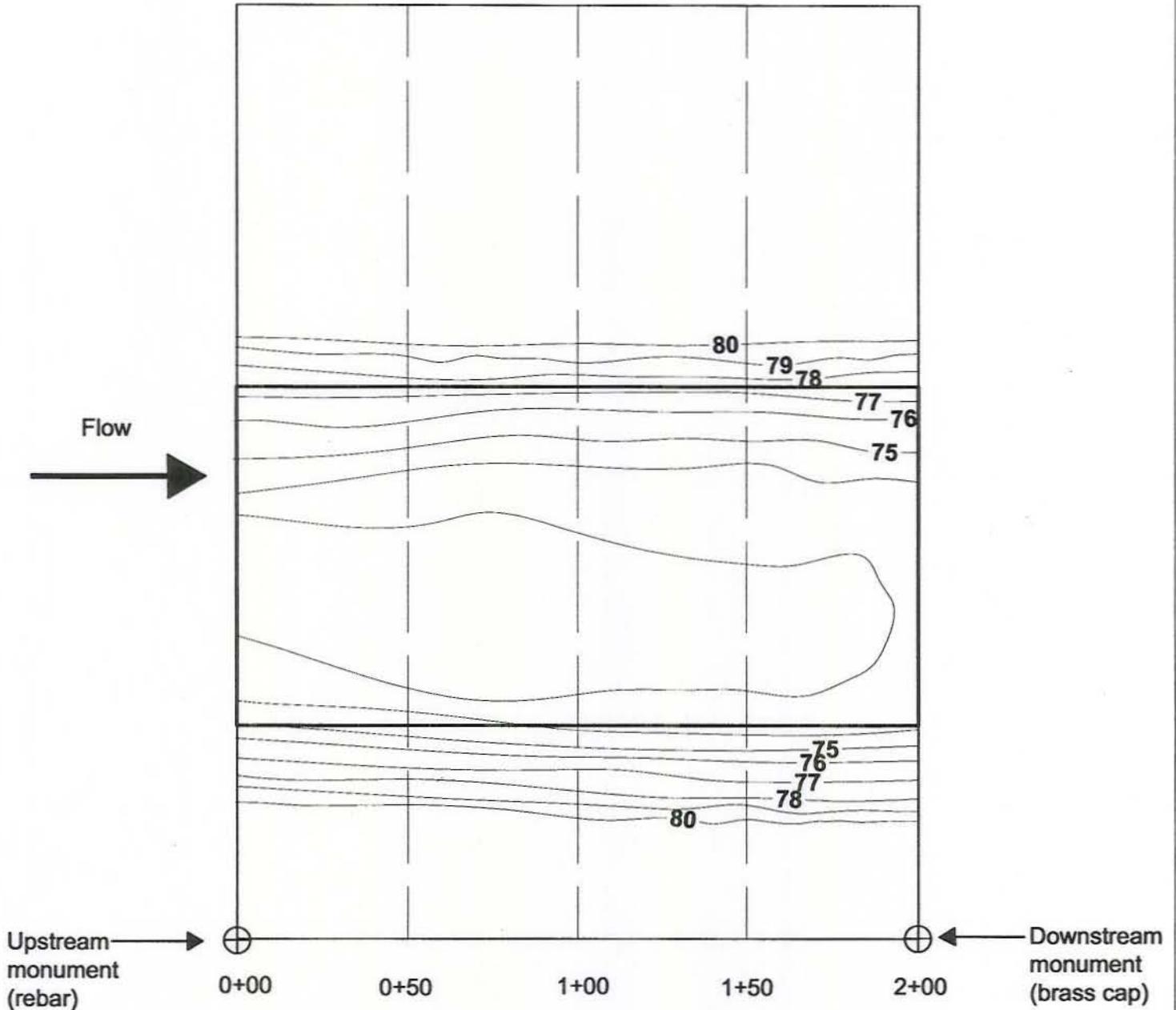
# Bathymetric Survey at GLC1B Bed Sediment Contour Spring 2001



Note: Water surface elevation at the time of survey = 84.4 feet.  
Contours interpolated from soundings taken on March 27, 2001.  
Contour interval = 1 foot.



# Bathymetric Survey at GLC1B Bed Sediment Contour Fall 2001



Note: Water surface elevation at the time of survey = 86.4 feet.  
Contours interpolated from soundings taken on September 10, 2001.  
Contour interval = 1 foot.

