

**A Study of Spatial Patterns in the East Branch of the Waterbury Reservoir,  
in Waterbury, Vermont.**

**Research Paper Presented By:  
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**May 2003**

**In partial fulfillment of a Bachelor of Science in Environmental Science,  
Geology Concentration.**

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**ABSTRACT:** This study looks at the spatial pattern of sediment deposition in the East Branch of the Waterbury Reservoir. This research is part of a larger project incorporating the entire Waterbury reservoir in a study of land-use change and the effect on sedimentation. Sedimentation information is useful because construction within the watershed could cause significant impact to the area. Reservoirs contain a record of land-use change and storm events within the sediment. The study of this sediment can determine information about the area. 76 sediment cores were taken in transects along the East Branch of the Waterbury Reservoir. Using field information and computer analysis, a pattern of sediment thickening downstream was seen. Bulk density information was also taken from nine sample sites along the reservoir. However, no pattern was found in the bulk density information. Sand layers were evident in a majority of the cores, which means there was a large hydrologic event that occurred after the construction of the dam. The information found in this study contains information about how sediment deposition affects the watershed of the Waterbury Reservoir.

## **INTRODUCTION:**

The construction of a dam for storage, power, or recreation can cause significant effects to the downstream area as well as to the flow conditions of natural streams inside and downstream of the artificial lake (Johnson, 2002). Flow regulation by dams has disrupted the natural current of most rivers and has altered the processes that sustain biodiversity (Johnson, 2002). The construction of dams has reduced the transport of nutrients resulting in severe affects to food web structures (Conley et al, 2000). The dam itself often blocks sediment, resulting in a diminishing storage capacity. If the reservoir fills with sediment, flooding can occur and further affect the area. The land-use and environmental history of the drainage basin influences the rate of erosion, which leads to sedimentation in reservoirs. Several methods, such as coring and stratigraphic analysis. Cesium-127 dating, and mineral magnetic techniques can help date the sediment and determine how fast the reservoir is filling. The reservoir itself acts as a sediment yield record for determining the erosion rates of the area.

Thousands of dams have been constructed all over the United States for flood control, storage, and power. The New England water resources region has the highest density of dams in the country, which is a legacy of the regions long history of mill-dams (Graf, 1999). The reservoirs behind the dams provide a record of sediment yield for the impounded basin. Sediment cores taken within semi-enclosed aquatic basins can provide a historical record of land-use within the watershed (McCray et al, 2001). The sediment record can be studied in order to gain an understanding of how sediment yield has varied over time (Ambers, 2001).

My research project explored the patterns of sediment deposition in a flood control reservoir located in northwestern Vermont. This paper reviews relevant literature on sedimentation studies in lakes, ponds and reservoirs and outlines the methodologies and results of my study.

## **FACTORS AFFECTING EROSION RATES:**

Sediment deposits in lakes, ponds or reservoirs can be used to estimate sediment yields and reconstruct changing patterns of sediment sources in response to environmental changes. There is a relationship between land-use change, soil erosion, and sediment yield. The sediment deposits accumulating in lakes contain both the material that originated in the water body and the material derived from external sources, such as sediment eroding from the surrounding drainage basin. A variety of techniques can be used to trace the origins of the eroded materials and that information can be used to interpret recent environmental changes. Other methods can be used to date the material to coincide with environmental changes (Foster and Walling, 1994).

The land-use history of an area, such as agriculture, grazing, or forestry practices can affect the rate of erosion within the watershed and quantity of sediment deposited in a lake, pond or reservoir (Foster and Walling, 1994). In a study in England, Foster and Walling (1994) found that surface material from pasture areas represented the dominant source of deposited sediment in a reservoir. They attributed sediment deposition to an increase in livestock and grazing intensity after World War II. Because of this, a pattern of sediment yield for the life of the reservoir can be constructed and a clear trend of increasing sediment yield is apparent in the reservoir. It was found that the sediment was predominantly from the slopes of the basin and had been mobilized from pasture areas

(Foster and Walling, 1994). Walling (1999) determined that forest clearing after 1968 accounted for a 1.8 fold increase in the sediment load of a reservoir. In small basin studies, it has been found that there is an increase in sediment production after clearcutting, and road building. Unpaved logging roads are also significant sediment sources (Ambers, 2001). The relationship between land-use and sedimentation can significantly impact the storage capacity of a basin.

Sediment data may also be used to confirm evidence of past disturbances and to determine whether the rate of erosion is “normal” or “accelerated.” Sediment qualities can be linked to specific events in the basin such as deforestation or early farming (Dearing, 1991). “Accelerated” erosion can occur because of the way the surrounding land was used in the past. For example, increased livestock and grazing intensity can increase erosion and runoff into the reservoir (Foster and Walling, 1994). Present day sediment loads are 21.6 times higher than in the recent geological past and human activity is one explanation for this increase (Walling 1999). A study by Owens and Walling (2002) concluded that land clearance, cultivation, population growth, and technological advances have accelerated erosion. The rates of soil erosion on agricultural land in the United Kingdom have increased over the past 100 years. This reflects the growth in the amount of land under cultivation and the intensification of farming practices (Owens and Walling, 2002). In a study by McIntyre (1993), long term land-use and reservoir sedimentation were quantified and linked. In this case, reservoir sedimentation had decreased over time because of the conversion of fields to perennial pastures. When the abandoned fields with bare soil areas were reduced by natural vegetation it caused a decrease in sediment yield. 70% of the sediment was deposited in

the first 20 year period of the reservoir and then rapidly decreased over time as the land use changed (McIntyre, 1993).

Lake sediments preserve a record not only of land-use history but also of hydrological events. Several studies have shown that sediment yield changes recorded in lake sediments were related primarily to precipitation history, rather than gradual environmental change (Royall, 2000; Ambers, 2001). Lake sediments have also been used to interpret long-term storm history of a region. Several studies in New England have indicated that the condition of a watershed at the time of a storm may strongly influence the amount of erosion that occurs (Brown et al, 2000). It was determined in a study by Brown et al (2000) that the cause for deposition of the coarser, more terrestrial inputs to a basin in northern Vermont is runoff triggered by hydrologic events.

### **APPROACHES TO STUDYING DEPOSITION IN RESERVOIRS:**

There are several different methods to document and analyze sediment deposition in lakes, ponds, and reservoirs. Coring methods are widely employed to study lake sediments. Cores were taken from basins and visually studied in projects by Ambers (2001) and Parris (2001). In a study by Ambers (2001), eight sediment cores were collected and subjected to detailed study in order to obtain information about variations in the sediment yield of the watershed. Each core represented the total thickness of the lake sediment at its sampling location, as determined by the presence of either pre-lake soil or an impenetrable rock layer at the base of the cores. The stratigraphy was described in detail. Another 40 cores were taken from a variety of locations to determine the average density and organic matter content. A study by Parris (2001) used 23 sediment cores from small basins in order to determine the history of storms and hillslope

erosion in New England. The cores contained discreet, terrestrially derived, inorganic deposits identified by physical changes in the sediment including visual observation, loss-on-ignition, and grain size analysis.

In a study by Souch and Sloymaker (1986), methods for the assessment of the variability of sediment accumulation in small ponds were done without measuring chemical attributes of the cores. The cores were extracted and the stratigraphy was studied. The volume of the sediment accumulated was determined through a combination of core, probe, and survey data. Total sediment volume in the ponds was calculated by using different grid sizes and offsets and comparing values calculated with those determined for the 2x2 meter grid. Assumptions were also made about the geometric shape of the accumulated sediment body. This method both under and overestimated the volume in order to fall somewhere in the middle. It also avoids error because the shallow, elliptical nature of the sediment body in the lake has no regular pattern of accumulation about a single center of deposition (Souch and Sloymaker, 1986). This method shows the importance of the determination of the three dimensional geometry of lake sediments, volume, density, and mass calculation. A study by Dearing (1991) has also employed a different method to determine the amount of accumulation of sediment in reservoirs. However, Dearing used chemical, radiometric, magnetic, and microfossil properties to determine the quality of sediment in order to infer the source of the deposited materials. After doing this, sediment qualities can be linked to particular events in the basin such as deforestation or early farming (Dearing 1991).

One of the most widely used methods is Cesium-137 dating to measure soil erosion and sediment accumulation rates. Cs-137 is a unique tracer for studying erosion

and sedimentation. Radioactive fallout in the form of Cs-137 has been deposited across the landscape from atmospheric nuclear tests and has absorbed onto soil particles (Ritchie and McHenry 1990). However, the Cs-137 technique can only be used with sediment deposited since 1954, the year that fallout was first deposited in measurable amounts. Dating with Cesium is also useful because periods of higher fallout can be related to dates during aboveground testing and periods of lower fallout can be related to moratoriums on testing and the Test Ban Treaty (Ritchie and McHenry 1990).

Magnetic susceptibility is another common method used for dating. It is a measure of the concentration of magnetic minerals in a substance. These correlate sediment sequences from different parts of the lake by visual comparison of the magnetic profiles (Royall 2000). Mineral magnetic signatures can also be used to distinguish topsoil and subsoil material (Foster and Walling 1994).

Collectively, these studies show that lakes, ponds and reservoirs can be used as a record of basin sediment yield. This record can detect land-use change over time or the presence of any past hydrologic events. The purpose of this project is to document the deposits of sediments in the East Branch of the Waterbury Reservoir. My analysis explores the stratigraphy and spatial patterns evident in the deposits and looks for evidence of storm events in the deposits. A companion study (Janow, 2003) estimates basin sediment yield from the same data set. This research is part of a larger project incorporating the entire Waterbury reservoir in a study of land-use change and the effect on sedimentation.

## **METHODS:**

### ***STUDY AREA:***

The study area consisted of the East Branch of the Waterbury Reservoir in Waterbury, Vermont. It is located a quarter mile west of State Route 100. The Waterbury Reservoir is the ninth largest water body in the state of Vermont (Waterbury Reservoir, 2003) with a drainage area of 16.9 km<sup>2</sup> (Green Mountain Power Corporation, 1999). The reservoir was formed by an earth fill dam completed by the United States Army Corps of Engineers in the summer of 1937 for flood control and storage of water for power (USGS, 1997). From late spring to early fall the reservoir is maintained to a surface area of 860 acres and a maximum depth of 100 feet. The surface area is reduced to between 250 and 300 acres in the winter to prepare for spring snowmelt (Waterbury Reservoir, 2003). During the collection of data (summer and fall 2002), the reservoir was drained to allow work to be done on the dam. The bottom was exposed and a stream was running through it. The reservoir sediment was a deep brown, saturated, clayey material.

***FIELD SAMPLING AND LAB ANALYSIS:***

Sediment cores were taken from 76 sites in the East Branch of the Waterbury Reservoir. Each of the 76 cores taken were visually studied and logged. Each core represented a complete thickness of lake sediment, either by hitting pre-reservoir sediment or the presence of the old streambed. Cores were taken from the approximate center of the reservoir off Reservoir Road in transects ranging from 1 to 295 meters. The coring process involved using a one-meter gauge auger with a one-meter handle and pushing it down into the sediment. The core was open on one side in order to see the material. A GPS was used to record the location of each site. Once the core was extracted, the stratigraphy of the sediment was visually described and logged. To the best of our knowledge, evidence of significant sand layers were noted. The smallest was

approximately 4cm so anything thicker was considered significant. Each core represented a complete thickness of the reservoir sediment, as determined by the presence of pre-lake material or a rock layer. The thickness of the post reservoir sediment was determined by visual character and noted

Nine sediment samples from random sites were preserved in bags and taken to the lab in order to perform a bulk density analysis. The samples were baked at 105 degrees Celsius overnight and then weighed in a pre-tared pan to determine dry mass (m) of the sample. Core volume (v) was determined by multiplying length of the post-reservoir sediments in the core by the cross-sectional area of the auger. Bulk density ( $\rho$ ) of each sample was calculated as  $\rho = m/v$ .

#### ***COMPUTER ANALYSIS:***

A geographic information system and statistical analysis software were used to analyze the sediment data. A location map of the study area was created on ArcMap, a PC-based GIS software, using orthophotos as a basemap. Points from an excel spreadsheet containing the location of the cores were imported into ArcMap to create a point layer of sampling locations. Maps of core locations and cores with sand layers were made using attribute data contained in the point layer. Streamflow data from a nearby gauging station on the White River, in West Hartford, Vermont was used for information on annual peak flows from 1938 (the construction of the dam) to the present (Peak Streamflow for Vermont, 2003). This station was used because it contains the largest data record in Vermont on an undamed river. Points from an excel spreadsheet containing the streamflow data were used to create a graph showing annual peak flow. A three-dimensional map showing the thickness of the post reservoir sediment was

constructed to visually examine any pattern of thickening sediment. MiniTab, a statistical program, was used in order to determine if there was a relationship between distance and sediment thickness or bulk density using a regression analysis

## **RESULTS:**

This survey covered an area in the East Branch of the Waterbury Reservoir approximately 12,000 meters long; using 23 transects (Table 1) that ranged from 1 meter to 295 meters wide (Figure 1). Thickness of the post reservoir sediment varied from 8cm to 162cm. Most cores contained the reservoir sediment along with sand clay-couplets of varying sizes (Figure 2a-c). These signify the seasonal changes in the movement of water within the reservoir and are usually attributed to deposition from turbidity currents (Ambers, 2001). Significant sand layers were found in 45 out of the 76 cores (Figure 3) Any core containing a coarse sand layer thicker than 4cm was considered significant. These layers ranged in thickness and color but stood out among the fine-grained reservoir sediment. More than half of these samples contained sand layers, which were spread out in different locations along the study area. After the construction of the reservoir, several large storm events occurred but the most influential one occurred in 1974 and can be contributed to the ubiquitous sand layer seen in 59% of the cores (Table 2) (Figure 4).

Visual inspection of the sampled points shows a distinct pattern of thickening reservoir deposits in the downstream direction (Figure 5). This pattern is non-linear and statistically significant ( $p < 0.0005$ ) (Figure 6). Core thickness was highly variable, particularly among samples taken downstream. Some of this variability is likely due to varying core thickness across individual transects (Figure 2a-c). 35.6% of the variability of thickness can be explained by the cubic relationship between distance and thickness.

This is a weak regression equation, which shows that there must be something else affecting the variability (Figure 6).

Bulk densities of the nine samples analyzed ranged from 0.3 to 1.5 g/cm<sup>3</sup>, with a mean of 0.55 g/cm<sup>3</sup> (552.9 kg/m<sup>3</sup>) (Table 3). Only one sample had a bulk density greater than 1 g/cm<sup>3</sup>, and bulk density of the nine samples taken from East Branch differed little from two samples collected near Stevenson Brook, located on the western bank of the Waterbury reservoir. There was no spatial pattern in bulk density of the samples with distance upstream ( $p=0.376$ ) (Figure 7).

## **DISCUSSION:**

A spatial pattern of sediment deposition was found in the East Branch of the Waterbury Reservoir. The thickness of reservoir sediment was shown to be increasing downstream (Figure 4 and Figure 5). Although a clear pattern was visualized, a regression analysis of the data proved that only 35.6% of the variability of thickness could be explained by the cubic relationship between distance and thickness. This is a weak regression equation and means that there are other variables affecting the relationship. There was no relationship between distance and bulk density, which means that there is no spatial pattern based on the data. Since sand layers were found in a majority of the samples, a large hydrologic event must have affected the area since the construction of the dam. This storm event caused a flux of sediment to be deposited in the area. Based on the annual peak streamflow data for the White River, several large storm events occurred after the construction of the dam. 1973 contained the largest discharge (42,300 cfs) during the life of the reservoir. A good interpretation would be that this storm caused the sand layers found in a majority of the cores. This warrants

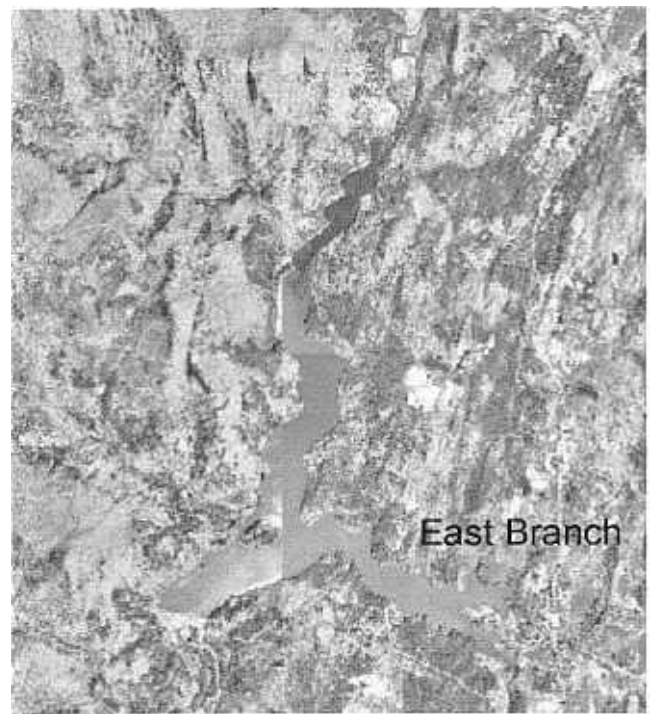
further research to determine if the date of the sand layers correlates with the 1973 storm. If major construction projects begin within the watershed of the Waterbury Reservoir, increased sedimentation might be expected. Further study on this subject would be extremely useful to uncover more information about possible effects on the Waterbury Reservoir.

Point Name	18t	utm	length of post res sed (cm)	sand layer
1.1	679839	4916789	29	
1.2	679849	4917001	35	
1.3	679840	4916803	94	*
1.4	679843	4916816	34.4	*
1.5	679848	4916826	37.4	*
2.1	679811	4916844	117	
2.2	679814	4916853	64	*
2.3	679803	4916830	98	*
2.4	679795	4916823	45	
2.5	679826	4917032	31	
2.6	679786	4916801	105	
3.1	679751	4916841	59	*
3.2	679763	4916863	61	*
3.3	679769	4916889	67	*
3.4	679775	4916902	94	*
3.5	679779	4916911	72	
3.6	679826	4917136	162	
4.1	679684	4916905	123	*
4.2	679679	4916894	153	*
4.3	679662	4916880	45.6	*
4.4	679684	4916942	129	
4.5	679679	4916904	58	
5.1	679597	4916998	93	
6.1	679594	4916966	88	
6.2	679606	4916978	80	
6.3	679608	4916976	105	
7.1	679620	4916961	141	
8.1	679643	4916951	117	
8.2	679654	4916952	50	*
9.1	679711	4916929	127	*
9.2	679723	4916938	132	*
10.1	679829	4916739	117	*
10.2	679930	4916750	8	
10.3	679937	4916759	73	*
10.4	679943	4916771	61	*
10.5	679950	4916786	72	*
11.1	680012	4916763	48	*
11.2	680011	4916755	23	
11.3	680009	4916750	42	
11.4	680000	4916741	80	*
11.5	679994	4916733	27	*
st1	679995	4916760	116	
st2	679992	4916758	109	
st3	679980	4916757	125	*
12.1	680037	4916689	62	*
12.2	680048	4916702	70	
12.3	680055	4916742	23	*
12.4	680059	4916713	32	
13.1	680084	4916674	62	*
13.2	680111	4916680	26	
13.3	680115	4916685	78	
13.4	680118	4916697	66	*
14.1	680208	4916650	38.3	*
15.1	680242	4916650	24	*
15.2	680240	4916665	28	*
16.1	680277	4916668	46	*
16.2	680275	4916656	33	*
17.1	680286	4916668	48	*
17.2	680283	4916657	26	*
18.1	680312	4916656	33	*
18.2	680308	4916657	53	
19.1	680342	4916673	48	*
19.2	680338	4916655	41.5	
20.1	680158	4916673	29	*
20.2	680166	4916684	27	*
21.1	680190	4916670	54	*
22.1	680950	4916798	28	*
22.2	680972	4916814	25	
22.4	680999	4916787	26	
22.5	680946	4916744	42	*
22.7	680865	4916783	38	*
23.1	680811	4916755	28	
23.2	680808	4916760	43	*
23.3	680740	4916743	31	*
23.5	680609	4916771	70	*
23.7	680432	4916828	62	

Table 1: Table of point names, coordinates, and thicknesses of reservoir sediment from various locations at the Waterbury Reservoir in Waterbury, Vermont. Presence of a sand layer in the core is indicated by an asterisk.



Area of detail



East Branch

### Sampling Locations

- cores
- cores + bulk density

Waterbury Reservoir

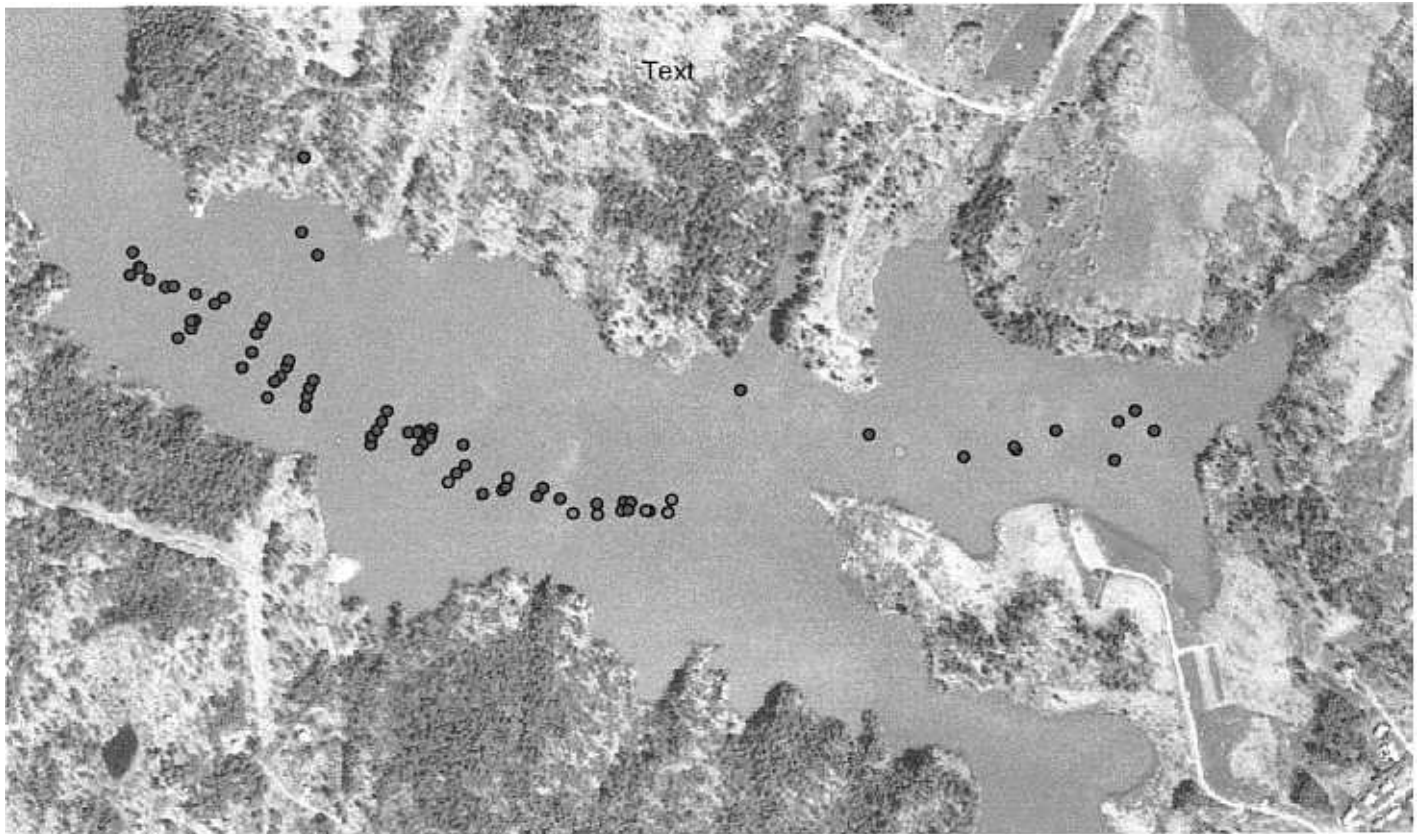
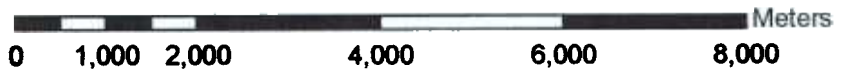


Figure 1: Location map of the East Branch of Waterbury Reservoir in Waterbury, Vermont. Sample points of coring locations are shown



Figure 2b: Transect of sediments that includes sites 6.2, 6.3, and 6.1 (from south to north).

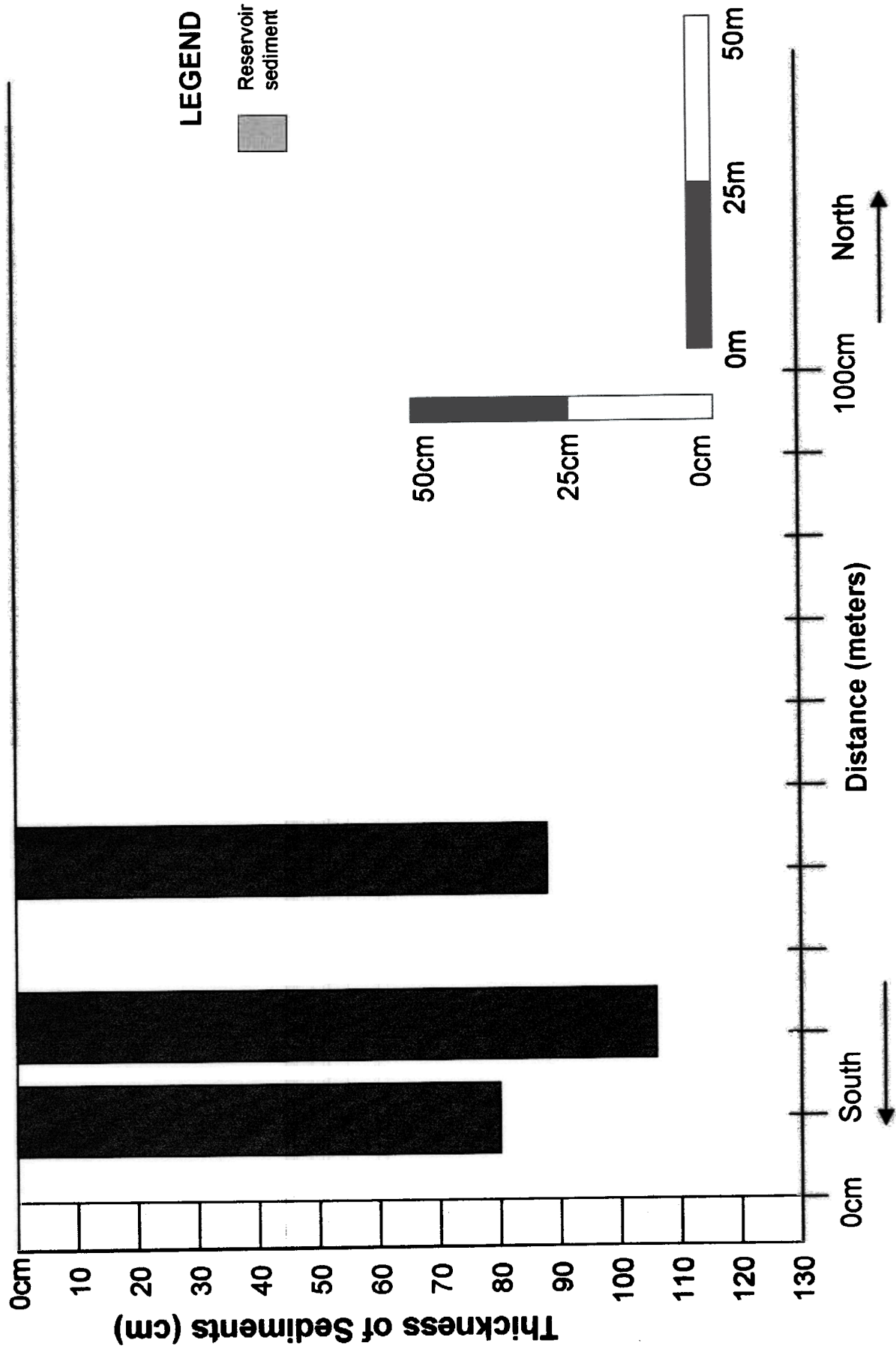
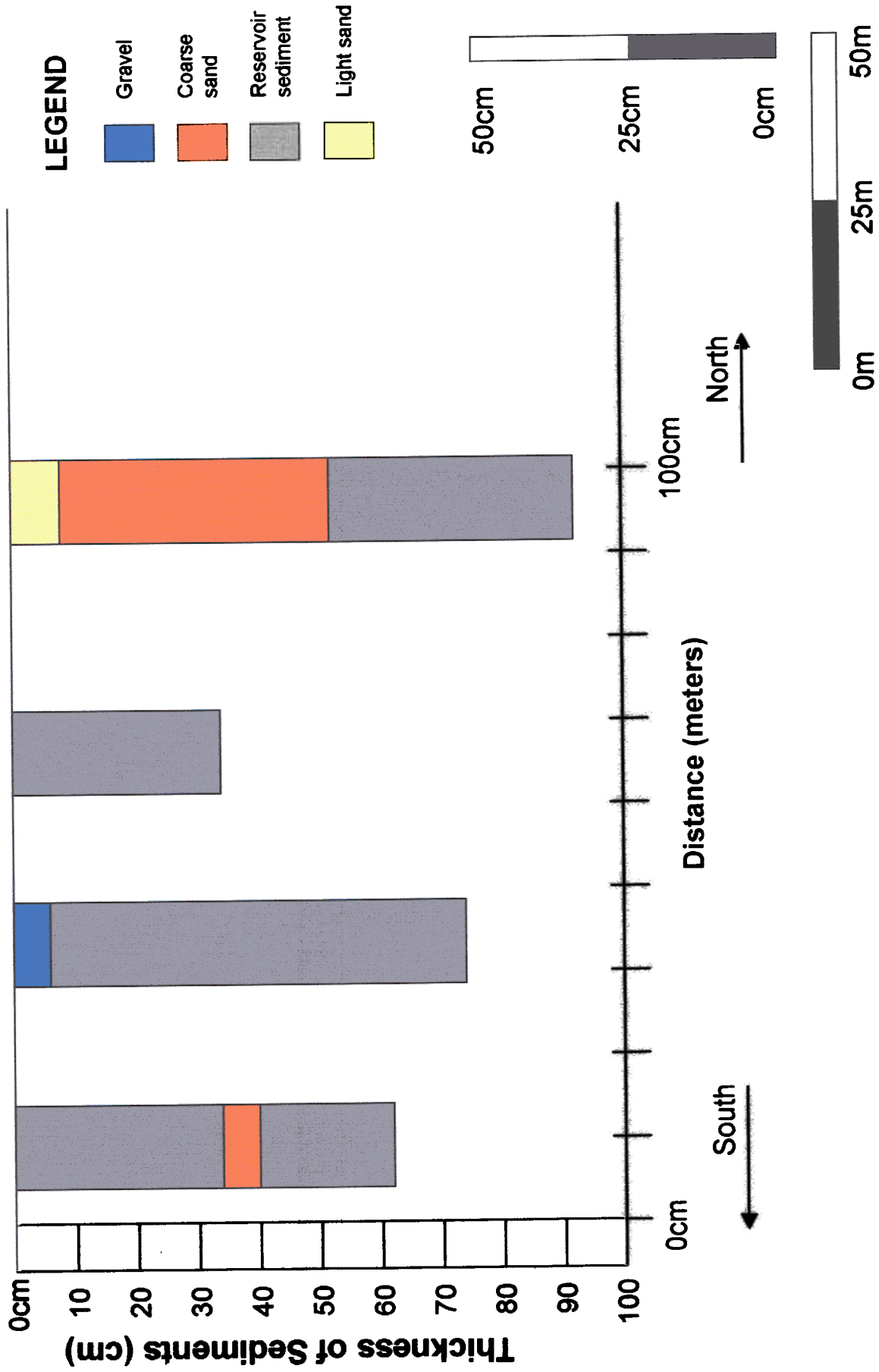
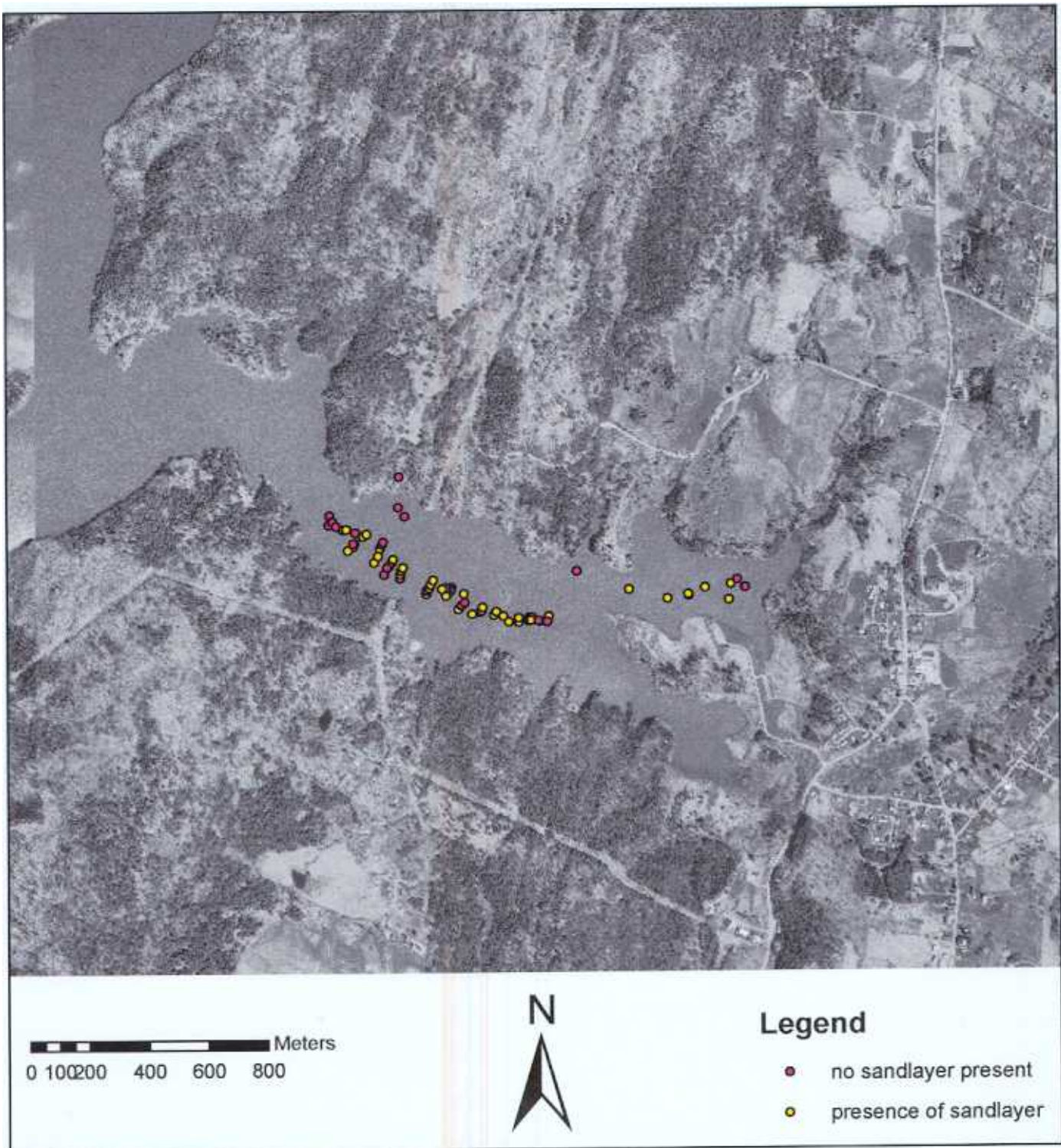


Figure 2c: Transect of sediments that includes sites 12.1, 12.2, 12.4, and 12.3 (from south to north).





**Figure 3: Map of study area on the East Branch of the Waterbury Reservoir. Location of sandlayers in the sediment stratigraphy is shown.**

Water Year	Annual Peak Discharge (cfs)	Rank (m)	Recurrence Interval (T= (n+1) / (m))	Water Year	Annual Peak Discharge (cfs)	Rank	Recurrence Interval (T= (n+1) / (m))
1938	47600	1	65	1986	17600	33	1.97
1973	42300	2	32.5	1990	17200	34	1.91
1998	34500	3	21.67	1950	16700	35	1.86
1976	34300	4	16.25	1981	16500	36	1.81
1987	32600	5	13	1991	16500	37	1.77
1947	31100	6	10.83	1956	16400	38	1.71
1949	31000	7	9.29	1968	16000	39	1.67
1952	29100	8	8.13	1939	15900	40	1.63
2001	28800	9	7.22	1979	15400	41	1.59
1953	26300	10	6.5	1988	15400	42	1.55
1996	25100	11	5.9	1945	15200	43	1.51
1982	24000	12	5.42	1962	15100	44	1.48
1964	23300	13	5	1983	15100	45	1.44
1977	23200	14	4.64	1997	15000	46	1.41
1972	22300	15	4.33	1955	14800	47	1.38
1992	21200	16	4.06	1942	14500	48	1.35
1984	21100	17	3.82	1971	14300	49	1.33
1969	21000	18	3.61	1993	14300	50	1.3
1974	20500	19	3.42	1975	14200	51	1.27
1989	20300	20	3.25	1954	13300	52	1.25
1960	20200	21	3.09	1999	13000	53	1.23
1958	20100	22	2.95	1980	12500	54	1.2
1994	20000	23	2.82	1961	11600	55	1.18
1948	19800	24	2.71	1959	11300	56	1.16
1967	19500	25	2.6	1957	11100	57	1.14
1940	19200	26	2.5	1985	10300	58	1.12
1946	19000	27	2.41	1943	9950	59	1.1
1944	18600	28	2.32	1941	9180	60	1.08
1970	18500	29	2.24	1963	8920	61	1.07
2000	18200	30	2.17	1966	6950	62	1.05
1951	18000	31	2.1	1995	6920	63	11.03
1978	17800	32	2.03	1965	4100	64	1.02

Table 2: Table of the annual peak discharge of the White River in Hartford, Vermont. The peak discharges are from 1938 to 2001.

### Annual Peak Discharge from 1938 to 2001 of the White River at West Hartford, Vermont

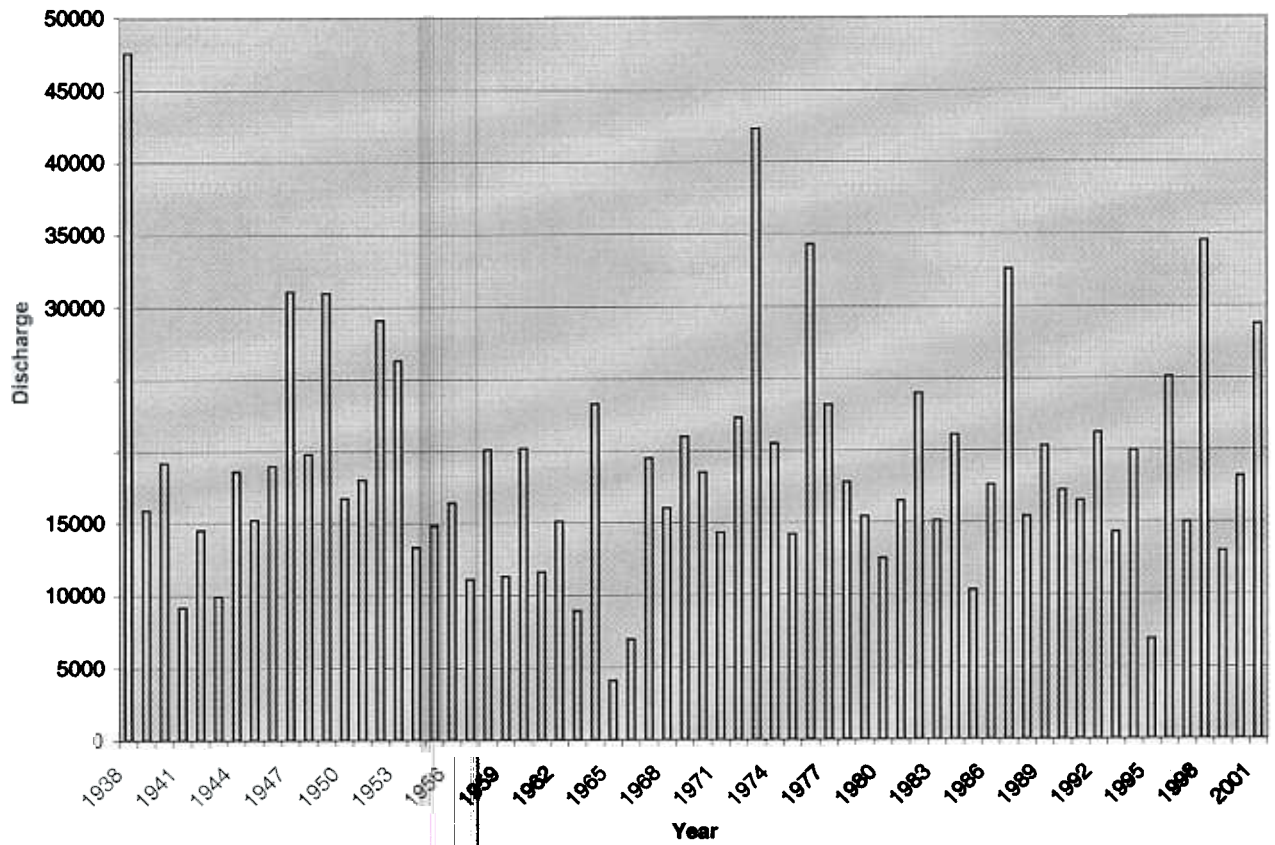


Figure 4: Graph showing the annual peak streamflow discharge by year. 1938 was the year the dam was built (after a large storm).

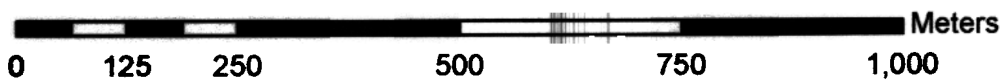


Figure 5: Map of the East Branch showing the thickness of reservoir sediment at each sampling location. Bars are displaced laterally from the sampling locations to prevent overlap (see Figure 1).

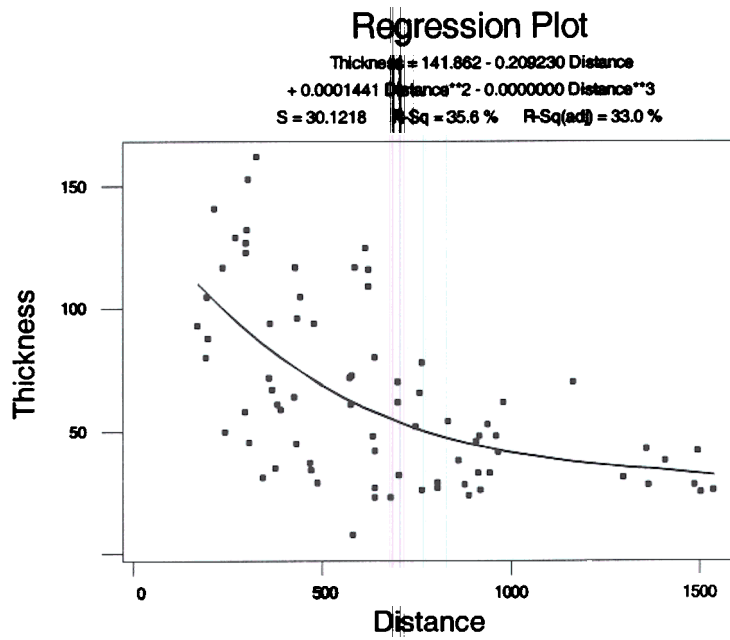


Figure 6: A regression plot of distance (meters) vs. core thickness with regression equation show. Distance increases in the upstream direction.

sample id	mass (g)	length (cm)	volume (cm <sup>3</sup> )	bulk density
13.4	455.4	55	922.9	0.49
12.1	280.4	35.2	590.7	0.47
n of steve	251.7	50	839	0.3
n of steve	330	50	839	0.39
15.1	165.4	21.5	360.8	0.46
19.2	241.8	29.1	488.3	0.5
16.2	461	57.2	959.8	0.48
18.2	328.1	39.8	667.8	0.49
19.1	637.9	25.4	426.2	1.5
18.1	240	27.6	463.1	0.52
14.1	313	38.8	651.1	0.48

Table 3: Table of core data used to determine bulk density for nine sites along the East Branch of the Waterbury Reservoir. Two samples were taken from Stevenson Brook. Mass and length are measured values. Volume is calculated as length \* the cross sectional area of the auger (16.78 cm<sup>2</sup>). The average bulk density is 0.55 g/cm<sup>3</sup> (552.9 kg/m<sup>3</sup>).

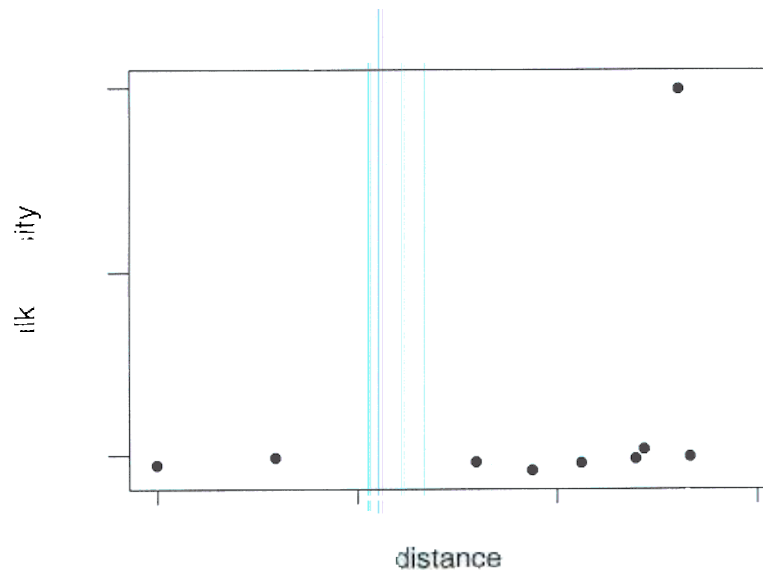


Figure Scatter plot distance (meters) Bulk Density

## **ACKNOWLEDGEMENTS:**

We are indebted to Beverley Wemple, Ph.D. professor at the University of Vermont, who directed the sampling and research processes that produced the data used for this paper. Dr. Wemple provided access to the computer lab and geography lab and also did revisions to the paper. Dr. Cliff and Dr. Rebecca Ambers, Sweet Briar College, gave us insight and instructions for sediment interpretation within core samples, which was used for analysis. We are grateful to Dr. Stephen Wright, University of Vermont, for very helpful comments and assistance in the field. Funding for this project was provided by a grant from the University of Vermont's Experimental Program to Stimulate Competitive Research (EPSCR) to Beverley Wemple.

## **REFERENCES:**

Ambers, Rebecca K.R., 2001. Using the Sediment Record in a Western Oregon Flood-Control Reservoir to Assess the Influence of Storm History and Logging on Sediment Yield. *Journal of Hydrology* 244: 181-200.

Ambers, Rebecca, personal communication, 2002-2003.

Ambers, Cliff, personal communication, 2002-2003.

Brown, Sarah L., P.R. Bierman, A. Lini, J. Southon, 2000. A 10,000-Year Record of Extreme Hydrologic Events. *Geology* 28(4): 335-338.

Dearing, J.A., 1991. Lake Sediment Records of Erosional Processes. *Hydrobiologia* 214: 99-106.

Foster, I.D.L and D. E. Walling, 1994. Using Reservoir Deposits to Reconstruct Changing Sediment Yields and Sources in the Catchment of the Old Mill Reservoir, South Devon, UK, Over the Past 50 Years. *Hydrological Sciences* 39(4): 347-368.

Graf, William L., 1999. Dam Nation: A Geographic Census of American Dams and their Large Scale Hydrologic Impacts. *Water Resources Research* 35(4): 1305-1311.

Green Mountain Power Corporation, 1999. Waterbury Hydroelectric Project FERC No. 2090. Volume 6.

Janow, J.N., 2003. Use of Reservoir Sedimentation to Determine Sediment Yield. Unpublished Research Paper. Department of Geology, University of Vermont.

Janow, Julie, personal communication, 2002-2003

McIntyre, Sherwood, 1993. Reservoir Sedimentation Rates Linked to Long-Term Changes in Agricultural Land Use. *Water Resources Bulletin* 29(3): 487-495.

McCray, Ellen L., J.W. King, P.G. Appleby, 2001. Historical Trace Metal Accumulation in The Sediment of an Urbanized Region of the Lake Champlain Watershed, Burlington, Vermont. *Water, Air, and Soil Pollution* 124(1-4): 201-230.

Owens, Phillip N. and D.E. Walling, 2002. Changes in Sediment Sources and Floodplain Deposition Rates in the Catchment of the River Tweed, Scotland, Over the Last 100 Years: The Impact of Climate and Land-use Change. *Earth Surface Processes and Landform* 27(4): 302-423.

Parris, Adam, A. Bosly, P. Bierman, A. Lini, A. Noren, A. Lord, A. Conlan, L. Morgan, 2001. Grain by Grain: Holocene Storms and Hillslope Erosion in New England. *The Geologic Society of America* 33(6): 314.

Peak Streamflow for Vermont, 2003.

[http://waterdata.usgs.gov/vt/nwis/peak?site\\_no=01144000&agency\\_cd=USGS&format=html](http://waterdata.usgs.gov/vt/nwis/peak?site_no=01144000&agency_cd=USGS&format=html). Accessed 2003.

Ritchie, Jerry C. and Roger J. McHenry, 1990. Application of Radioactive Fallout Cesium-137 for Measuring Soil Erosion and Sediment Accumulation Rates and Patterns: A Review. *Environmental Quality* 19: 215-233.

Royall, Dan, 2000. Lake Sediment-Based Evaluation of Recent Sediment Yield from a Small Appalachian Watershed, Thompson Lake, Virginia. *Physical Geography* 21(1): 68-88.

Souch C. and O. Sloymaker, 1986. Temporal Variability of Sediment Yield Using Accumulations in Small Ponds. *Physical Geography* 7(2): 140-153.

USGS, 1997. <http://nh.water.usgs.gov/WaterData/annual97/04288500.htm>. Accessed in 2003.

Walling, D.E., 1999. Linking Land Use, Erosion and Sediment Yields in River Basins. *Hydrobiologia* 410: 223-240.

Waterbury Reservoir, 2003. [www.central-vt.com/visit/attract/waterres](http://www.central-vt.com/visit/attract/waterres). Accessed in 2003.

Wemple, Beverley, personal communication, 2002-2003.

Wright, Stephen, personal communication, 2002-2003.