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ASSESSMENT OF IMPACTS OF INCREASED WEED GROWTH ON DETROIT RIVER FLOWS

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Assessment of Impacts of Increased Weed Growth on Detroit River Flows

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BACKGROUND

Detroit River flows are important to the Great Lakes water resources. Changes in these flows affect hydropower usage, navigational activities, and shoreline profiles to name a few. The spread of zebra mussels into the Great Lakes system led to increased clarity of the water in Lakes St. Clair and Erie and the Detroit River due to their filter feeding habits. This increased clarity could amplify aquatic weed growth since light is able to penetrate deeper into the water column and increase the photosynthetic process. Increased weed growth acts to increase the hydraulic roughness of the Detroit River during the growing season, thus changing the river's hydraulic properties. As Detroit River flows are used in a wide variety of water resource studies, it is important to quantify both the amount and the seasonal distribution of the weeds and the increase in roughness due to the impact of the zebra mussel.

APPROACH

The approach will be to assess changes in Manning's roughness coefficient (Henderson, 1966) corresponding to the zebra mussel invasion using a series of velocity measurements coupled with water level data. A time series of velocity profiles was measured with an Acoustic Doppler Current Profiler (ADCP) deployed in the Detroit River at Fort Wayne. The data was collected from September 1996 through September 2000. This data set is equivalent to a set collected prior to the zebra mussel invasion at the same site from 12 November 1986 to 12 December 1989. Two reaches will be analyzed: the upper reach (Ft. Wayne to Wyandotte), and the lower reach (Wyandotte to Gibraltar). This data will be used in conjunction with recorded water level data (NOS, 2000) along the river to develop stage-fall-velocity equations for the upper and lower reaches. The equation's roughness coefficients will be analyzed to determine the change in the hydraulic flow regime due to the weed growth for both measurement periods. These coefficients will subsequently be available for use in Detroit River stage-fall-discharge equations and mathematical flow models.

METHODS

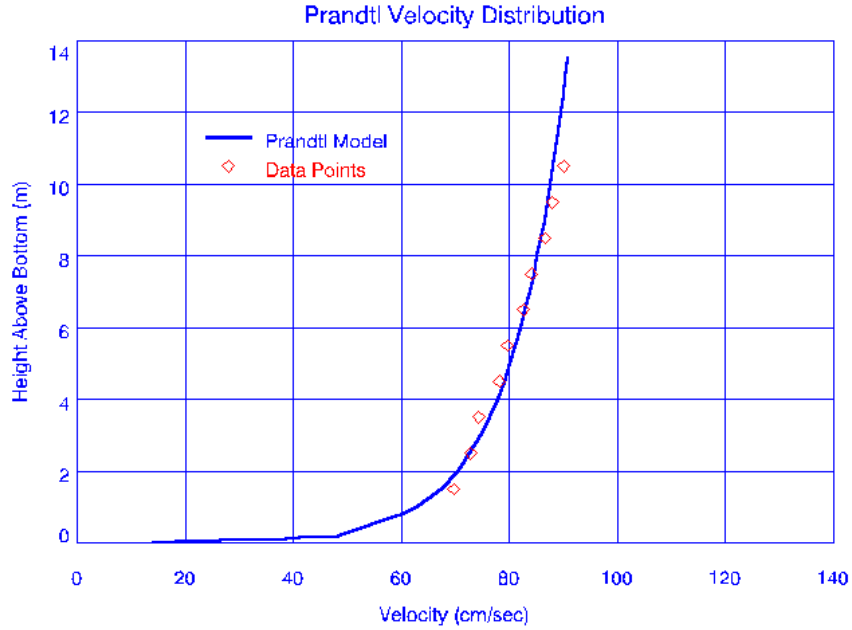
In order to compute an average velocity from the ADCP measured data, a curve must be fit through the measured points. The reason for a curve fit is twofold. First, velocity measurements at the boundaries are unreliable, and second, an integral of the curve is a better approximation of the average velocity. Each velocity measurement consists of data collected at ten 1-meter spaced bins that were then fit to the Prandtl's curves (Figure 1).

Average vertical velocities were calculated using the raw ADCP data. Prandtl's equation of turbulent flow (equation 1) was applied to both data sets to produce a smooth velocity profile that includes the top and bottom of the water column (not measurable).

$$U = C_1 \times 1n\frac{y}{D} + C_2 \qquad (1)$$

Where U is the resultant velocity; C_1 and C_2 are the slope and intercept regression coefficients; y is the roughness length; and D is the depth at which the velocity is recorded. An averaged vertical velocity (V) will be computed for this by evaluating V over the interval the elevation (y_o) to depth of the stream (d) (equation 2).

Figure 1. Prandtl distribution fit to collected velocity data.



$$V = \int_{\frac{y_o}{D}}^{1} \left(C_1 \ln \frac{y}{D} + C_2 \right) \frac{dy}{D} \tag{2}$$

This averaged vertical velocity is used along with water level measurements from the Fort Wayne (FW), Wyandott (WD), and Gibraltar (GB) gages to compute Manning's 'n' from Manning's equation (3).

$$\begin{aligned} V &= \frac{1}{n}\left(\frac{(FW+WD)}{2} - YM\right)^{2/3} * \left(\frac{(FW-WD)}{L}\right)^{1/2} \\ V &= \frac{1}{n}\left(\frac{(WD+GB)}{2} - YM\right)^{2/3} * \left(\frac{(WD-GB)}{L}\right)^{1/2} \end{aligned} \tag{3}$$

Where YM is the mean bottom elevation, L is the length of the Fort Wayne-Wyandotte and Wyandotte-Gibraltar reaches, and the constant n is the Manning's roughness. These roughness coefficients can then be analyzed for variance over time.

RESULTS

Data Collection

The U.S. Army Corps of Engineers and the Great Lakes Environmental Research Laboratory (GLERL) re-deployed the ADCP meter in the Detroit River on 5 September 1996. Precise locations of the meter were obtained with a Global Positioning System (GPS) provided by the Corps. The ADCP was deployed in approximately 14 meters of water located 90 meters from shore at a latitude of 42° 17' 88.81" and a longitude of 83° 05' 51.74" (Figure 2). Once deployed, the data link cable was secured to the river's bottom with chains, then connected to a

Figure 2. Location of the ADCP on the Detroit River.

lap-top computer used for data storage and transmission located at the National Ocean Survey (NOS) Ft. Wayne water level gage house.

Although the deployment went smoothly, divers couldn't secure the cable to the river's bottom with the same type of metal hooks that were used in the past. The divers said that the bottom was harder than before. During the first deployment in 1986, divers secured the cable by threading it through the metal hooks then pushing the 35-cm long spike part into the river's bottom with the stomp of the foot. This time, however, the bottom was harder, so they used hammers to secure the hook to the bottom. However, these hooks would not stay attached due to the swift current, so the cable was secured with chains.

Data has been collected since 9 September 1996. These data have been analyzed for their integrity by first ensuring that the ADCP was positioned correctly and by comparing it with previously collected data.

Although the data is received on a 15-minute sampling period, it was averaged to a daily velocity using the Prandtl's nonlinear velocity equation (Equation 2). Figures 3 - 6 show daily velocities collected for the 1986-2000 period.

Data Analysis

Water Level Analysis
An analysis of water levels was conducted for the upper reach to determine the reach's boundary. A student-standardized t-test at a level of significance of .05 was applied to Manning's roughness created for the reaches of Windmill Point-Wyandotte and Fort Wayne-Wyandotte. Results of the test showed that these roughness values have considerably different means, medians, and variances. This analysis suggests that Windmill Point levels may not be a true representation of Detroit River levels, but may also respond to events taking place in Lake St. Clair. Therefore, the reach of Fort Wayne and Wyandotte was used for computing roughness values for the upper reach.

Velocity Analysis
After analyzing all of the velocity data, the 1987 and 1997 data sets were selected for the final analysis. Velocity values for 1989 represent a year of a low flow regime. A comparison of the differences in Ft. Wayne water levels for years 1997, 1987, and 1989 indicates the data collected in 1989 is not an average water level year.

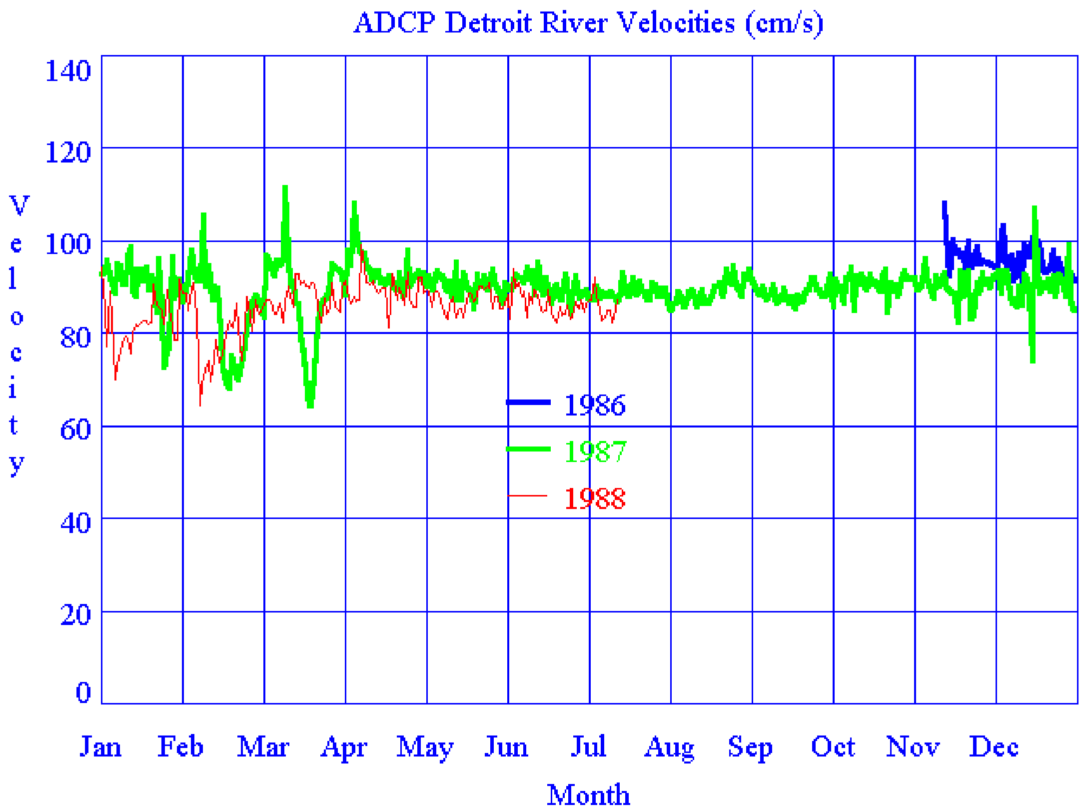


Figure 3.--Velocity data collected from 1986-1988.

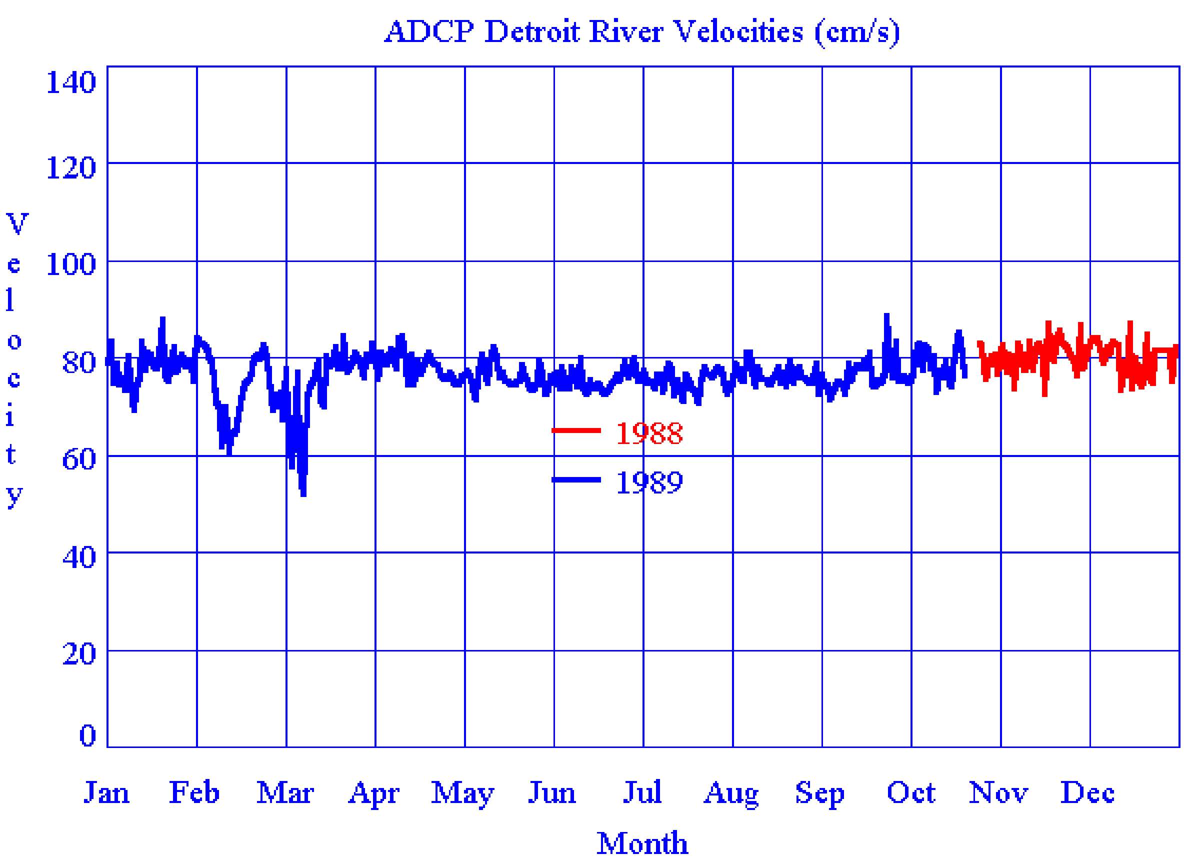


Figure 4.--Velocity data collected from 1988-1989.

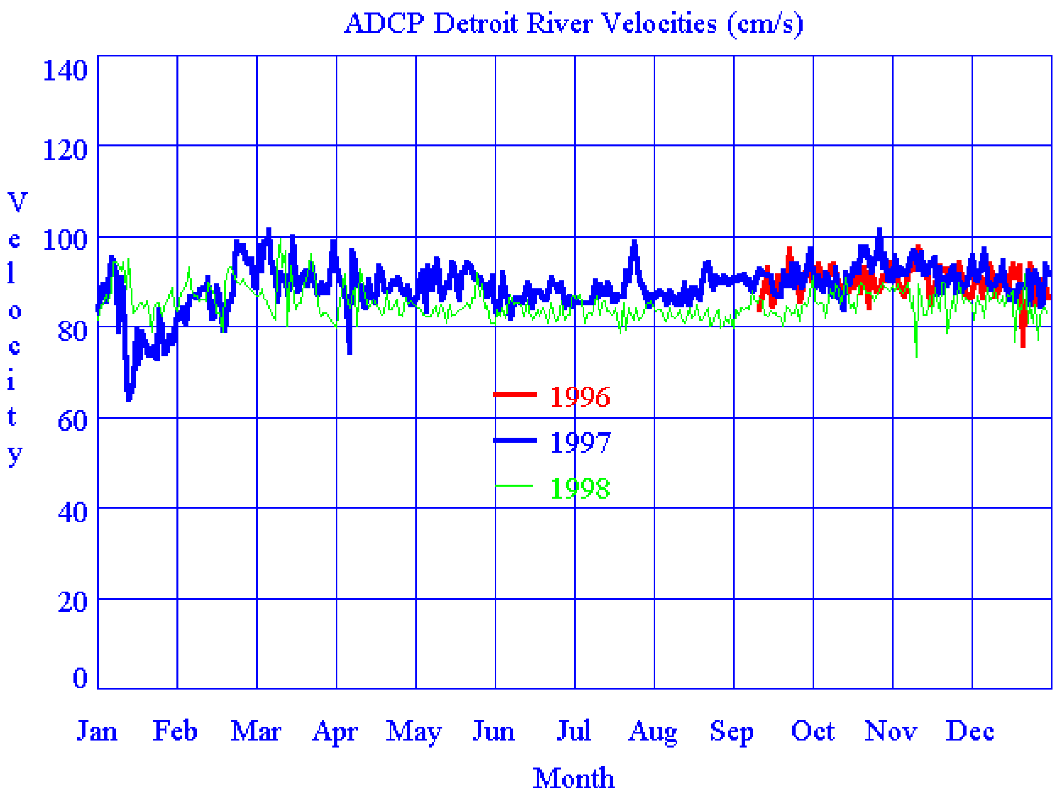


Figure 5.--Velocity data collected from 1996-1998.

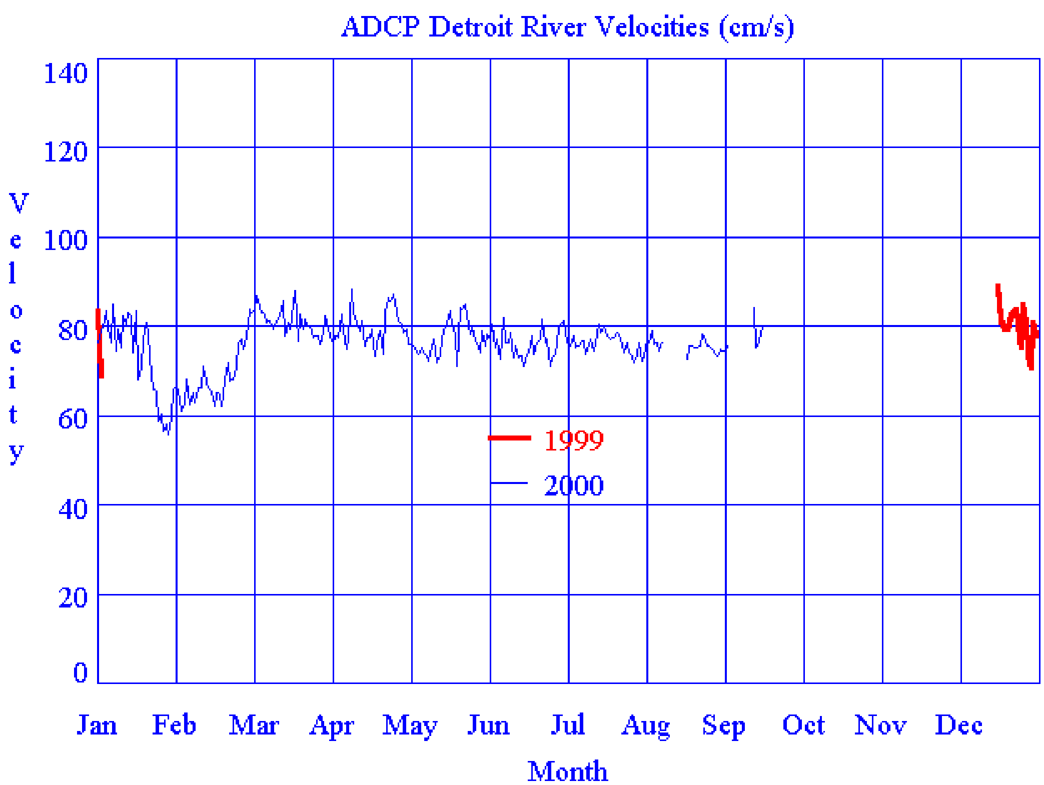


Figure 6.--Data collected from 1999-present.

Roughness Analysis

Since the objective of this study is to quantify the change in the river's flow regime due to roughness changes, Manning's roughness values were compared on a monthly time scale for the upper Detroit River (Table 1) and the lower Detroit River (Table 2) an area of prominent weed growth.

A comparison of these values using a student-standardized t-test at a level of significance of 0.05 shows that there is a slight difference in the means and a greater difference in the population distributions (Figures 7-10) for the months of June and July. Corroborating data, particularly for the Fermi-Gibraltar reach where there is significant weed growth, shows a change in the water surface slope after 1988. Water level differences were computed for two reaches (Figures 11-12) for the weed-growth months of May-November. The significant negative change in slope at the Fermi-Gibraltar reach indicates a change in the river's hydraulic regime that might be attributed to increased weed growth.

CONCLUSIONS

Beginning with the presence of the zebra mussel in the late 1980's, the hydraulic flow regime of the Detroit River has changed. Although the amount of change is difficult to quantify, the analysis shows that different roughness populations exist for the June and July months of 1987 and 1997. Also, the corroborative data from the slope differences in the lower reach shows a different hydraulic regime after 1988.

REFERENCES

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Table 1. Manning's Roughness Values Comparison (Upper Reach).

Month	Pre-zebra mussel Manning's Roughness	Post zebra mussel Manning's Roughness
May	.0186	.0194
June	.0195	.0193
July	.0199	.0198
August	.0199	.0203
September	.0202	.0202
October	.0199	.0198
November	.0199	.0195

Table 2. Manning's Roughness Values Comparison (Lower Reach).

Month	Pre-zebra mussel Manning's Roughness	Post zebra mussel Manning's Roughness
May	.0278	.0274
June	.0286	.0276
July	.0291	.0289
August	.0284	.0280
September	.0288	.0284
October	.0287	.0274
November	.0288	.0284

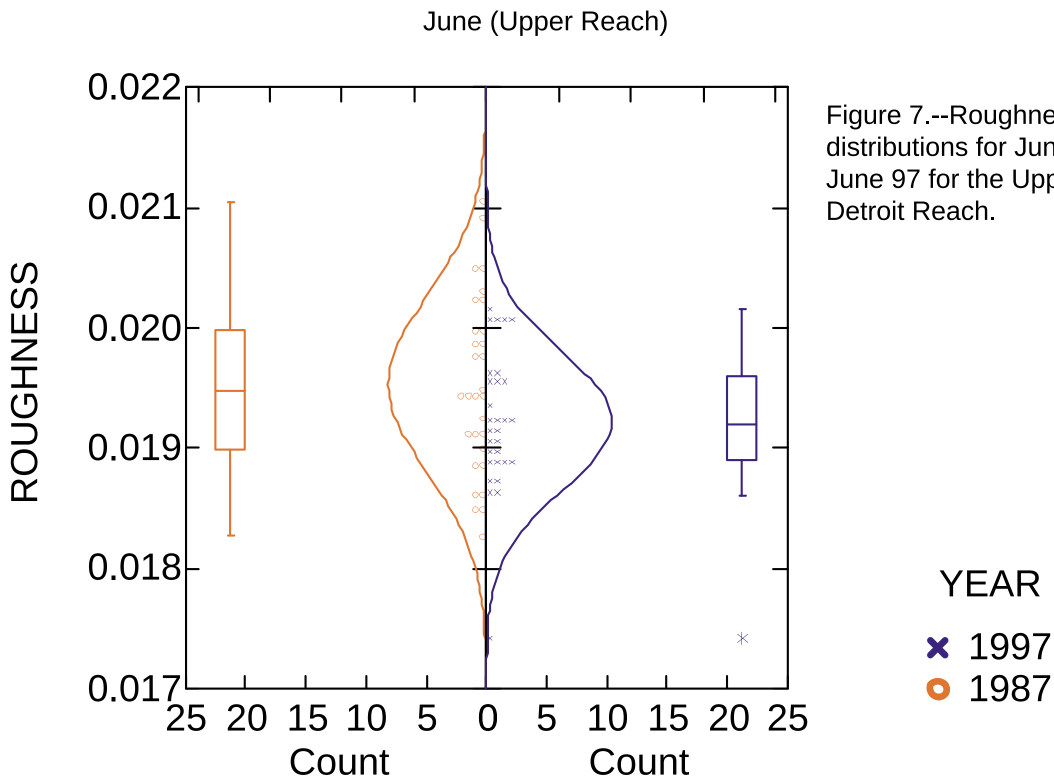

Figure 7.--Roughness distributions for June 87 vs. June 97 for the Upper Detroit Reach.

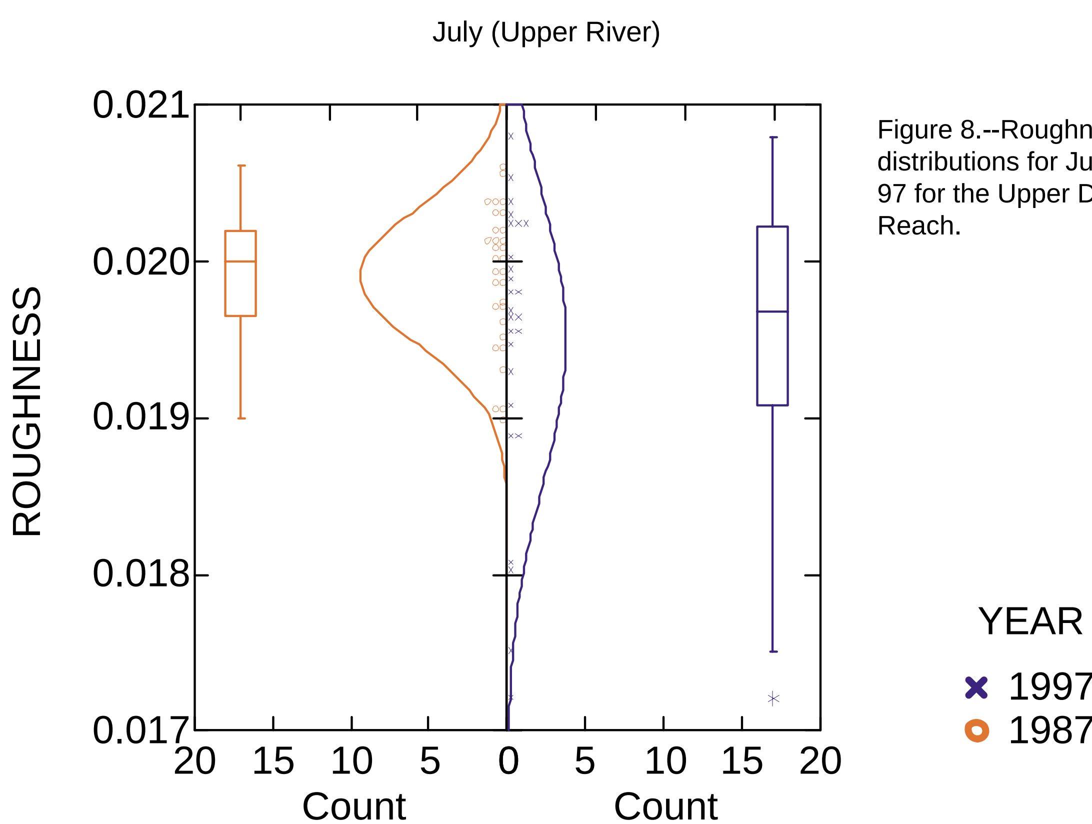

Figure 8.--Roughness distributions for July 87 vs. 97 for the Upper Detroit Reach.

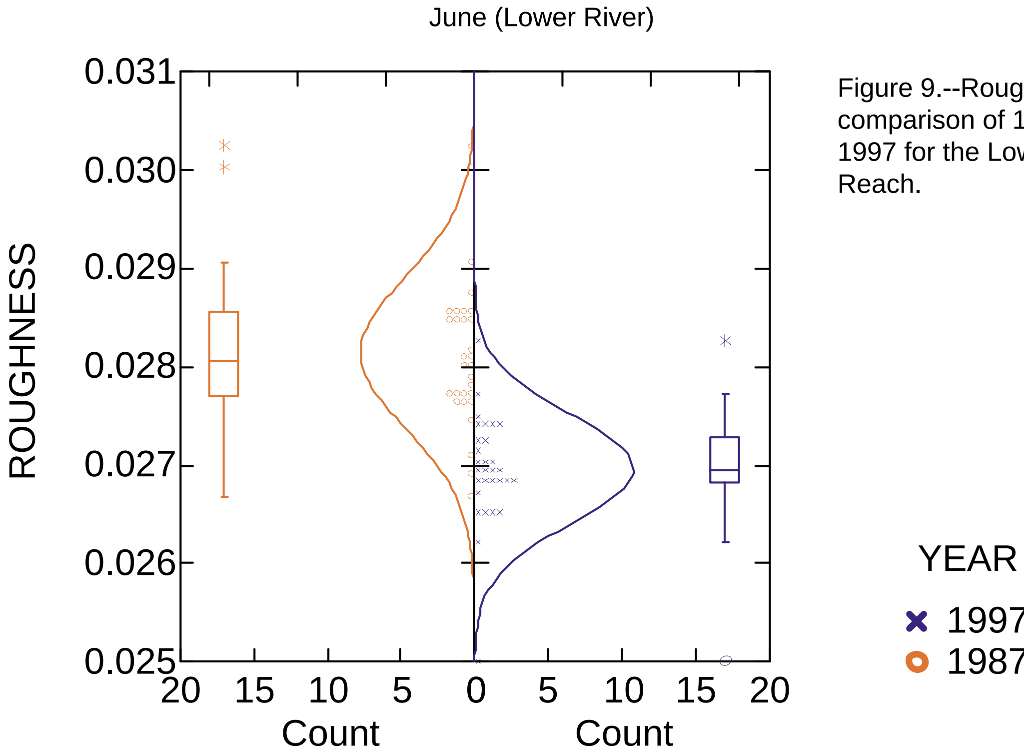

Figure 9.--Roughness comparison of 1987 vs. 1997 for the Lower Detroit Reach.

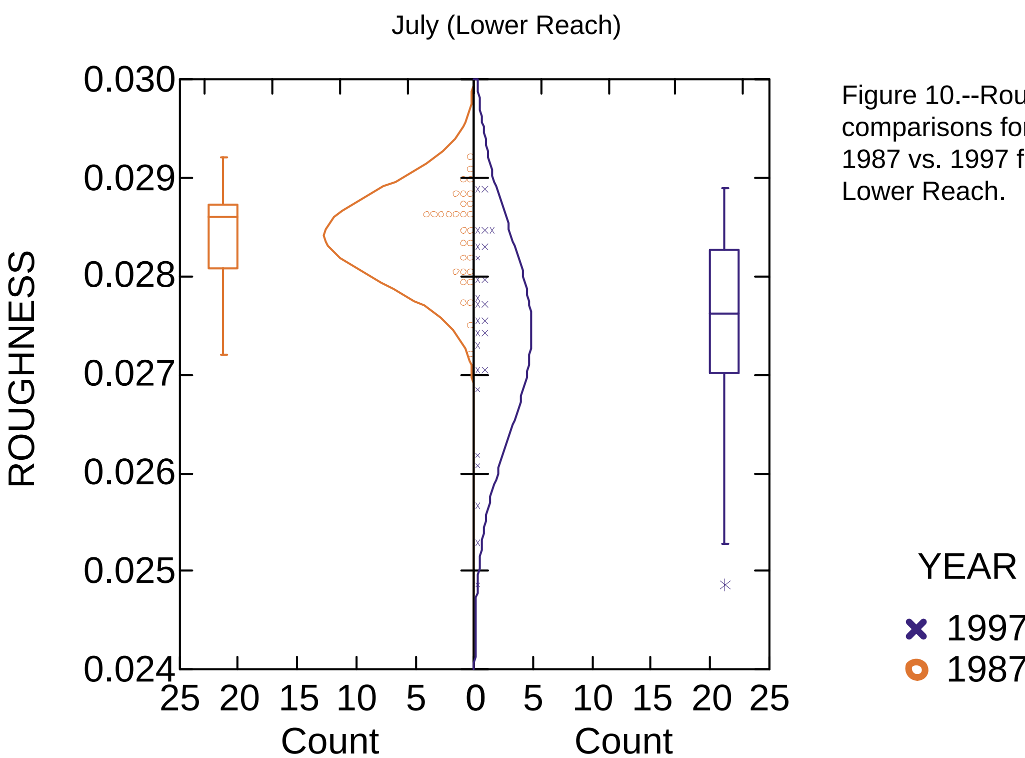

Figure 10.--Roughness comparisons for July 1987 vs. 1997 for the Lower Reach.

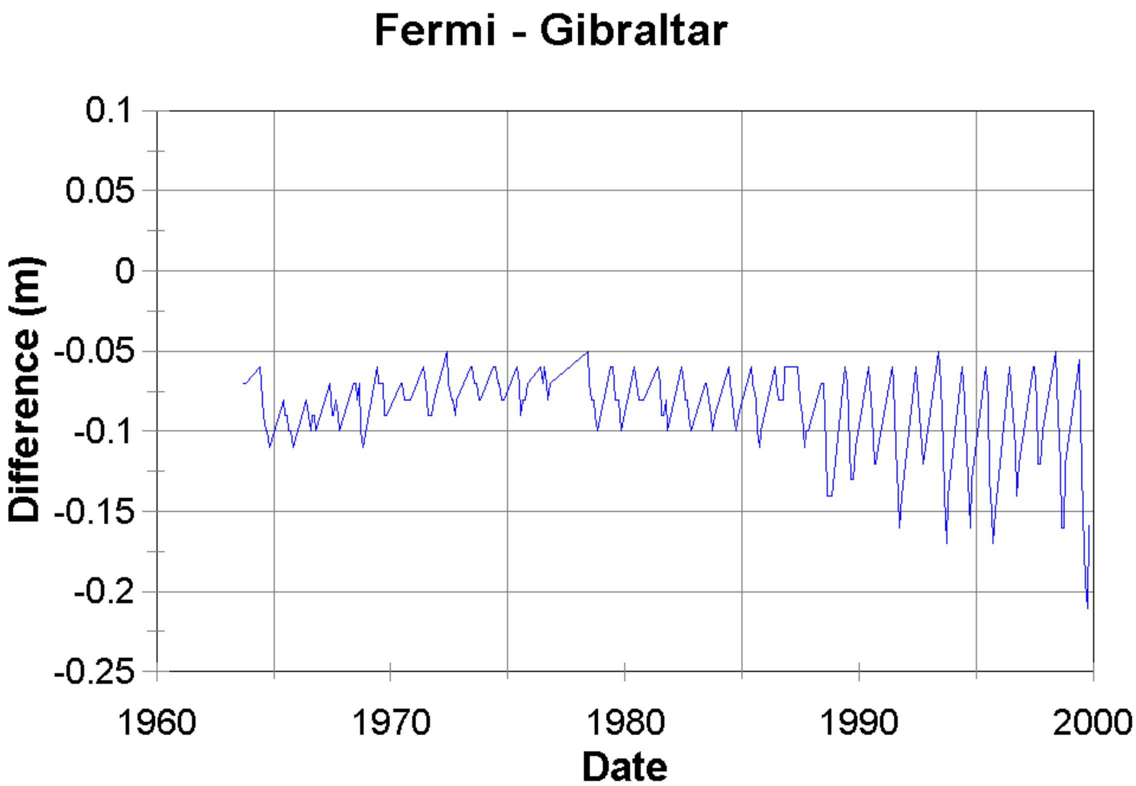

Figure 11.--Differences in water levels for months May to November.

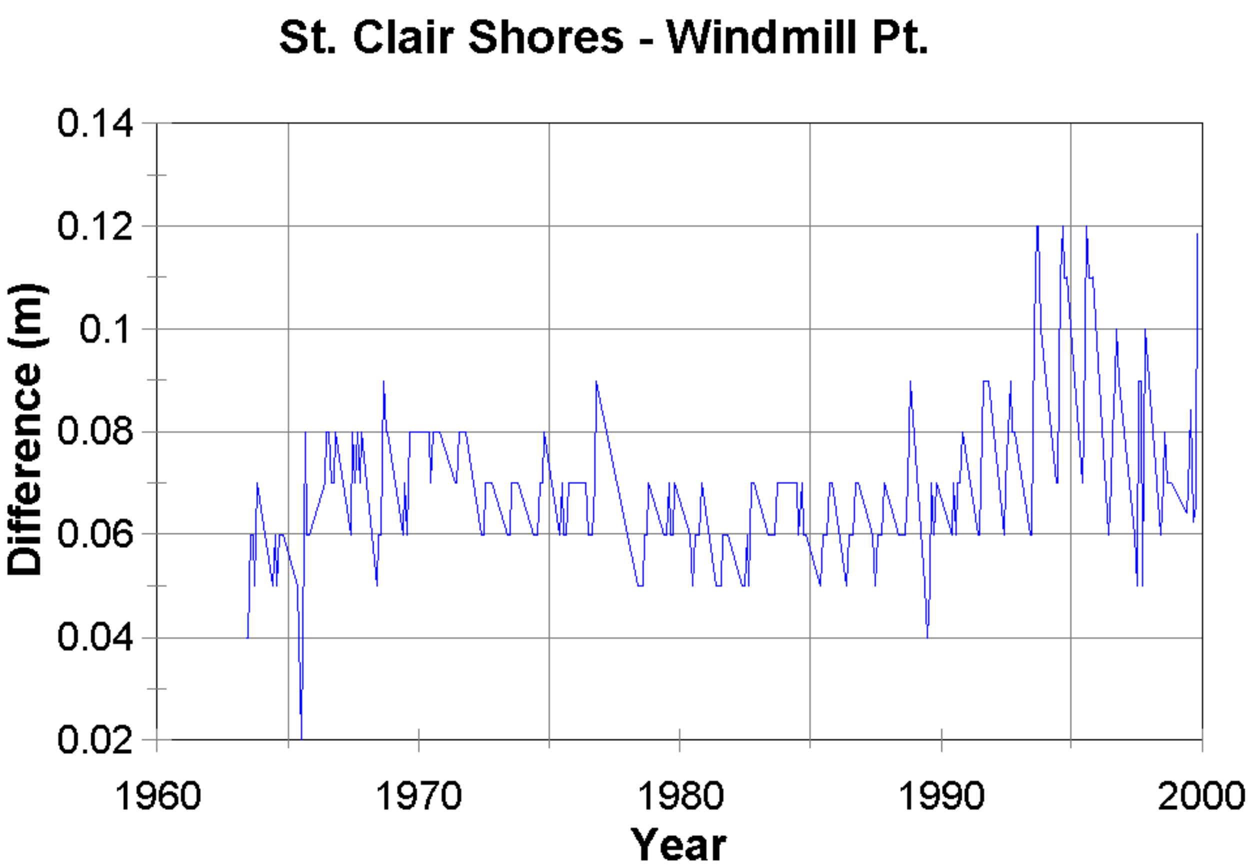

Figure 12.--Differences in water levels for May to November time period.