# HydroQuest

414 E. Kerley Corners Rd.
Tivoli, New York, 12583
845-657-8111
hydroquest@yahoo.com

**Consistency Review of the US Army Corps of Engineers New York District January 2016 report titled Mamaroneck & Sheldrake Rivers, New York Flood Risk Management - General Reevaluation Report (GRR) for the Village of Mamaroneck (Draft Main Report).**

**Submitted to:** Richard Slingerland, Village Manager
Daniel Sarnoff, Asst. Village Manager
123 Mamaroneck Avenue
Mamaroneck, NY 10543

Cindy Goldstein, Chair
Harbor Coastal Zone Management Commission
Mamaroneck, NY 10543

**March 20, 2016**

**Prepared by:** HydroQuest
414 E. Kerley Corners Rd.
Tivoli, New York 12583-5211
E-mail: hydroquest@yahoo.com

414 E. Kerley
Corners Rd.
Tivoli, New
York, 12583
845-657-8111
hydroquest@yahoo.com

**Consistency Review**

HydroQuest performed an independent technical hydrologic review and consistency evaluation of the US Army Corps of Engineers (ACE) New York District January 2016 feasibility-level investigation conducted to analyze and formulate a Flood Risk Management (FRM) project for the Village of Mamaroneck, Westchester County, New York. This US ACE work product is presented in a report titled Mamaroneck & Sheldrake Rivers, New York Flood Risk Management - General Reevaluation Report (GRR) for the Village of Mamaroneck (Draft Main Report).

HydroQuest project work was designed to provide technical assistance to the Harbor Coastal Zone Management Commission (HCZMC) relative to their major concerns of flooding, the flow of water, and environmental concerns in the Village of Mamaroneck. The HCZMC is tasked with providing consistency determinations based on their Local Waterfront Revitalization Program (LWRP). Emphasis was placed on assessing if the project, as proposed, is consistent with the HCZMCs LWRP. As discussed at the HCZMC meeting of March 16, 2016, and below, portions of the project were determined to not be consistent with a number of listed LWRP policies. Some of these policies and information related to them will be examined in the context of the ACE project as it is currently proposed.

It is important to recognize that concerns raised in this report are not designed to stop advancement of a flood mitigation project. Instead, discussion is provided that is oriented towards improving important aspects of the project so that it protects and preserves the environment, stream habitat, water quality, and the character of the community.

Review of LWRP policies raises two important questions. The first focuses on the likely effectiveness of the mitigation measures proposed, with emphasis on the issue of exactly how massive quantities of floodwater will be reduced with no clear plan detailing how floodwaters will not continue to back up behind anthropogenic channel constrictions downriver of the confluence of the Mamaroneck and Sheldrake rivers without their removal or alteration (e.g., Halstead Avenue bridge). Overall, there is public concern that the plan selected may not greatly reduce the flood risk in the Village of Mamaroneck consistent with Federal and local planning objectives.

The Army Corps of Engineers acknowledges the existing channel constriction problem:

> *"The area just downstream of the confluence between the Mamaroneck and the Sheldrake River, which includes the Station Avenue Bridge, Metro North Railroad Bridge and the Halstead Avenue Bridge, is causing considerable losses and high water surface elevations. The small flow capacity of the channel bends through the bridges and the*

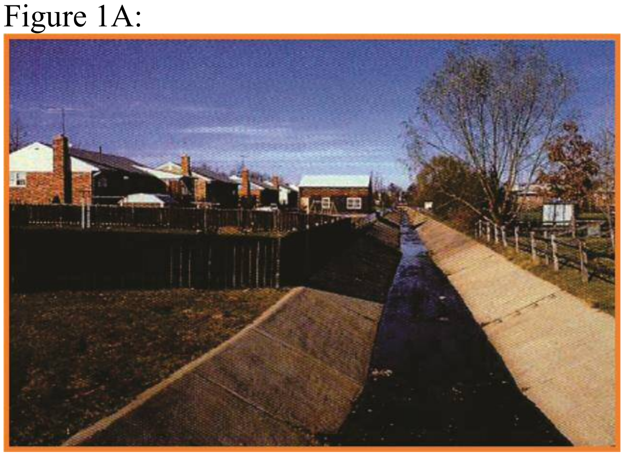
*small size of the Halstead Avenue Bridge are key reasons for the frequent flooding in the Village of Mamaroneck. ... Primary causes of flooding include small bridge openings, poor channel flow capacity and channel constrictions/bends and high velocities due to steep channels."*

The second very important issue focuses on the ACE design to alter miles of river channels using hard structural channel modification means that are not only long outdated (by some quarter century or more) but have been superseded by modern fluvial geomorphic methods that have been, in significant part, developed by the Army Corps of Engineers along with numerous other Federal agencies and world-leading river hydrologists. As planned, project design will degrade aquatic ecosystems, wildlife habitat, water quality, and fishing and recreational opportunities while diminishing river access, enjoyment, and pride in what should be envisioned as a protected and preserved Village natural resource available for all to enjoy - one that brings a sense of pride to the community. Notably, the Village of Mamaroneck has already led the community in soft engineered channel restoration project that has resulted in a healthy, viable, river reach throughout Columbus Park. This project work was conducted in 1995 and now serves as a Village centerpiece, enjoyed by all. The current ACE project, as proposed, would result in a very long riprapped and cement-walled sluiceway devoid of healthy ecosystems and any aesthetic quality. Its construction would be a very large step backward in time - to the old school channelization methods invoked by the Army Corps back in the 1930s. The community would benefit from a functioning flood mitigation plan that protects and preserves the environment.

**NED Plan Alternate 1Z (modified alternative 1M) calls for:**

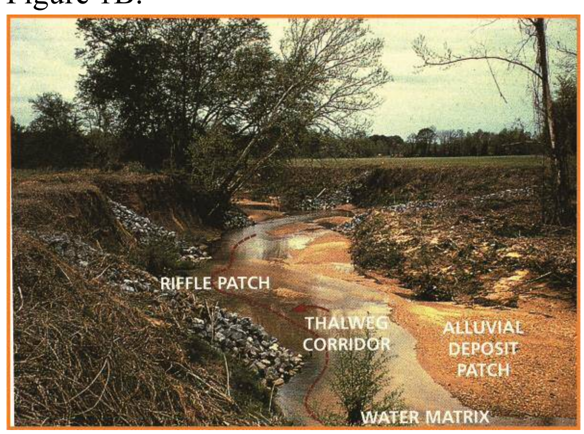
Channel modifications, retaining walls, some bridge removal and replacement, a culvert under the railroad parking lot, and trapezoidal cuts along the Mamaroneck and Sheldrake rivers, **including approximately 1.82 miles of channel work in the Mamaroneck and Sheldrake rivers with new 8.5 ft high riprap and concrete channel retaining walls would be 8.5 ft over 4,360$^{+}$ ft.**

Figure 1A:



Stream channelization. Instream modifications, such as uniform cross section and armoring, result in ecological decline (Fig. 3.10 FISRWG, 1998). **US ACE is a contributor to an extensive publication that strives to avoid what is depicted**. Contrast this with the photo to the right.

Figure 1B:




Fluvial elements of a stream reach where patches were applied. A low floodplain borders the stream depicted above. Riffles, pools and a thalweg corridor are important components of a healthy stream. Figure 1.9 from FISRWG, 1998.

**LWRP Policies**

To further ACE project evaluation relative to the Local Waterfront Revitalization Program, HydroQuest provides input relative to five LWRP policies. Summaries of these policies are provided below along with some discussion. Additional discussion is provided below this policy summary report section.

*LWRP POLICY 12*

*Activities or development in the coastal area will be undertaken so as to minimize damage to natural resources and property from flooding and erosion by protecting natural protective features.*

*Explanation: Natural protective features …help safeguard coastal lands and property from damage, as well as reduce danger to human life, resulting from flooding and erosion. Excavation of coastal features, improperly designed structures, inadequate site planning, or other similar actions which fail to recognize their high protective values lead to diminishing or destruction of those values. Activities or development in, or in proximity to, natural protective features must ensure that all such adverse effects are minimized.*

**Non-consistent issue:** Miles of hard structural channel modification faced or armored with riprap and cement would degrade ecosystems, water quality, and river functions. Alternate 1Z, as currently planned, would **maximize damage** to natural resources and would irreparably harm the environment. Similarly, the design of Alternate 1Z channel structures does not incorporate modern fluvial geomorphic restoration methods.

*LWRP POLICY 44*

*Preserve and protect tidal and freshwater wetlands and preserve the benefits derived from these areas.*

**Non-consistent issue:** Alternative 1Z will alter the integrity of the wetland situated at the confluence of the Mamaroneck and Sheldrake rivers (see Figure 2).

*LWRP POLICY 17*

*Whenever possible, use nonstructural measures to minimize damage to natural resources and property from flooding and erosion. Such measures shall include …*

*Explanation: This policy recognizes both the potential adverse impacts of coastal and riverine flooding on and erosion on development and natural protective features which may occur in the coastal area as well as the costs of protection against those hazards which structural measures entail.*

*Nonstructural measures include the use of … It also applies to the planning, siting and design of proposed development,* ***including measures to protect existing activities and development****. It applies to nonstructural measures to minimize damage to natural resources and property from* *flooding and erosion from riverine flooding. ... Westchester County and the Village of Mamaroneck have determined that these include a policy of "zero increase" in peak rates of stormwater discharge. This policy means that building projects* ***and other development*** *shall not result in increased peak rates of stormwater discharge beyond predevelopment levels.*

**Non-consistent issue:** It is questionable as to whether Alternate 1Z planners have demonstrated a specific, workable, means of dealing with all channel constrictions down river of the Mamaroneck/Sheldrake river confluence such that back flooding will no longer occur in the lower Village of Mamaroneck. As such, it is not clear how the "*culvert*" planned in the railroad parking area will achieve any active flow during times when floodwaters are backed up behind existing and remaining downriver channel constrictions. Furthermore, the planned riprapped and concrete retaining walls will result is increased river velocities, far in excess of Westchester County' and the Village of Mamaroneck's policy of "*zero increase*".

*LWRP POLICY 18*

***To safeguard the vital economic, social and environmental interests*** *of the State and the Village of Mamaroneck, proposed major actions in the coastal area must give full consideration to those interests, and to the safeguards which the State and Village have established to protect valuable coastal resource areas.*

*Explanation: Proposed major actions may be undertaken in the coastal area* ***if they will not significantly impair valuable*** *coastal waters and* ***resources****. This policy applies to actions which would* ***affect natural resources*** *identified in this Program, water levels and flows (both saltwater and riverine), and* ***recreation****.*

**Non-consistent issue:** Converting miles of the Mamaroneck and Sheldrake rivers to riprapped and concrete-walled sluiceways will impair and degrade valuable natural resources and will adversely affect fishing and other recreational activities. The many adverse environmental impacts of advancing Alternate 1Z include increased surface runoff, stream power and flow velocity; decreased river capacity to accumulate, store and filter materials; reduced river capacity to assimilate nutrients and pesticides; adverse ecosystem impacts; and increased exposure to solar radiation, weather and temperature extremes. These are among many potential adverse environmental impacts associated with implementation of Alternate 1Z. These impacts and others that are associated with Alternate 1Z river modification, as planned, are listed in a Table provided in Chapter 3 (Table 3.3) of a major 1998 publication titled *Stream corridor restoration: Principles, processes, and practices* and authored by a Federal Interagency Stream Restoration Working Group (FISRWG). Stream hydrology experts and numerous Federal agencies participated in producing this important work including the U.S. Department of Agriculture, U.S. Environmental Protection Agency, Tennessee Valley Authority, Federal Emergency Management Agency, U.S. Department of Commerce, the **U.S. Department of Defense - Army Corps of Engineers**, U.S. Department of Housing and Urban Development, and the U.S. Department of the Interior. The many contributors to this document included:

Hollis Allen - U.S. Army Corps of Engineers, Waterways Experiment Station; Vicksburg, MS
Mary Landin - U.S. Army Corps of Engineers, Waterways Experiment Station; Vicksburg, MS
Dave Hewitt - U.S. Army Corps of Engineers; Washington, DC
Tom Munsey - U.S. Army Corps of Engineers; Washington, DC

Meg J. Burns - U.S. Army Corps of Engineers; Baltimore, MD
Richard DiBuono - U.S. Army Corps of Engineers; Washington, DC
Beverly Getzen - U.S. Army Corps of Engineers; Washington, DC
Darrell Nolton - U.S. Army Corps of Engineers; Alexandria, VA
Kyle Schilling - U.S. Army Corps of Engineers; Ft. Belvoir, VA
David Biedenharn - U.S. Army Corps of Engineers; Vicksburg, MS
Ronald Copeland - U.S. Army Corps of Engineers; Vicksburg, MS
Craig Fischenich - U.S. Army Corps of Engineers; Vicksburg, MS

The many adverse environmental impacts associated with implementing Alternate 1Z are listed on this 1998 publication table. **This table (3.3 Potential effects of land use activities) should be carefully examined and is provided here as Appendix B. HydroQuest recommends that this table and its related publication material be used as a guide when evaluating project consistency with the LWRP.** There were many U. S. Army Corps of Engineer individuals who contributed to the environmentally healthy material in this publication which is **not at all consistent** with river modification work proposed in Alternate 1Z. An excerpt block from the 1998 publication follows:

**USACE Channel Restoration Design Procedure**

*A systematic design methodology has been developed for use in designing restoration projects that involve channel reconstruction (USACE, WES). The methodology includes use of hydraulic geometry relationships, analytical determination of stable channel dimensions, and a sediment impact assessment. The preferred geometry is a compound channel with a primary channel designed to carry the effective or "channel forming" discharge and an overbank area designed to carry the additional flow for a specified flood discharge. Channel width may be determined by analogy methods, hydraulic geometry predictors, or analytically. Currently under development are hydraulic geometry predictors for various stream types. Once a width is determined for the effective discharge, depth and channel slope are determined analytically by balancing sediment inflow from upstream with sediment transport capacity through the restored channel. Meander wavelength is determined by analogy or hydraulic geometry relationships. Assumption of a sine-generated curve then allows calculation of channel planform. The stability of the channel design is then evaluated for the full range of expected discharges by conducting a sediment impact assessment. Refinements to the design include variation of channel widths at crossings and pools, variable lateral depths in pools, coarsening of the channel bed in riffles, and bank protection.*

*LWRP POLICY 38*

*The **quality** and quantity **of surface water** and groundwater supplies **will be** conserved and **protected**, particularly where such waters constitute the primary or sole source of water supply.*

*Explanation: A few private wells exist in the Village, and for this reason the quality and quantity of groundwater supplies should be protected.*

**Non-consistent issue:** Maintaining surface water quality is important from an ecologic, groundwater, and coastal perspective. Armored concrete-walled sluiceways, even if they have nearby natural material in channel inverts, reduce natural tree cover and woody debris presence, and thermal protection. Refer to table 3.3 (FISRWG, 1998; Potential effects of land use activities) provided here as Appendix B.

## Background and Flood Mitigation Project Importance

Flood risk, flood damage and public safety have been issues in the Village of Mamaroneck since at least 1877 when a flood event was recorded. They remain major issues today. An historic map of the Village documents that the Railroad bridge and Halstead Avenue bridge were constructed on or before 1868. Assorted studies have been conducted through time, all of which document that channel constrictions at bridges situated downriver of the confluence of the Sheldrake and Mamaroneck rivers have resulted in back flooding upriver of constriction points (e.g., ACE, Furey Engineering, Leonard Jackson Associates, HydroQuest). Figure 2 below depicts the broad floodplain backed up behind the river constriction beneath the Halstead Avenue bridge (pink area).

Without question, flood mitigation work in the Village of Mamaroneck is needed. The issue at hand is how to best achieve flood reduction. It is important that the flood mitigation project that is advanced fully considers 1) all possible alternative remedial/restoration options with emphasis on consistency with LWRP policies, and 2) whether the alternative advanced will actually reduce floodwater impacts. It is important to recognize that, in places, adverse flood impacts are compounded because floodwaters back flooded upriver of the Halstead Avenue area bottleneck become elevated above more normal floodwater stages.

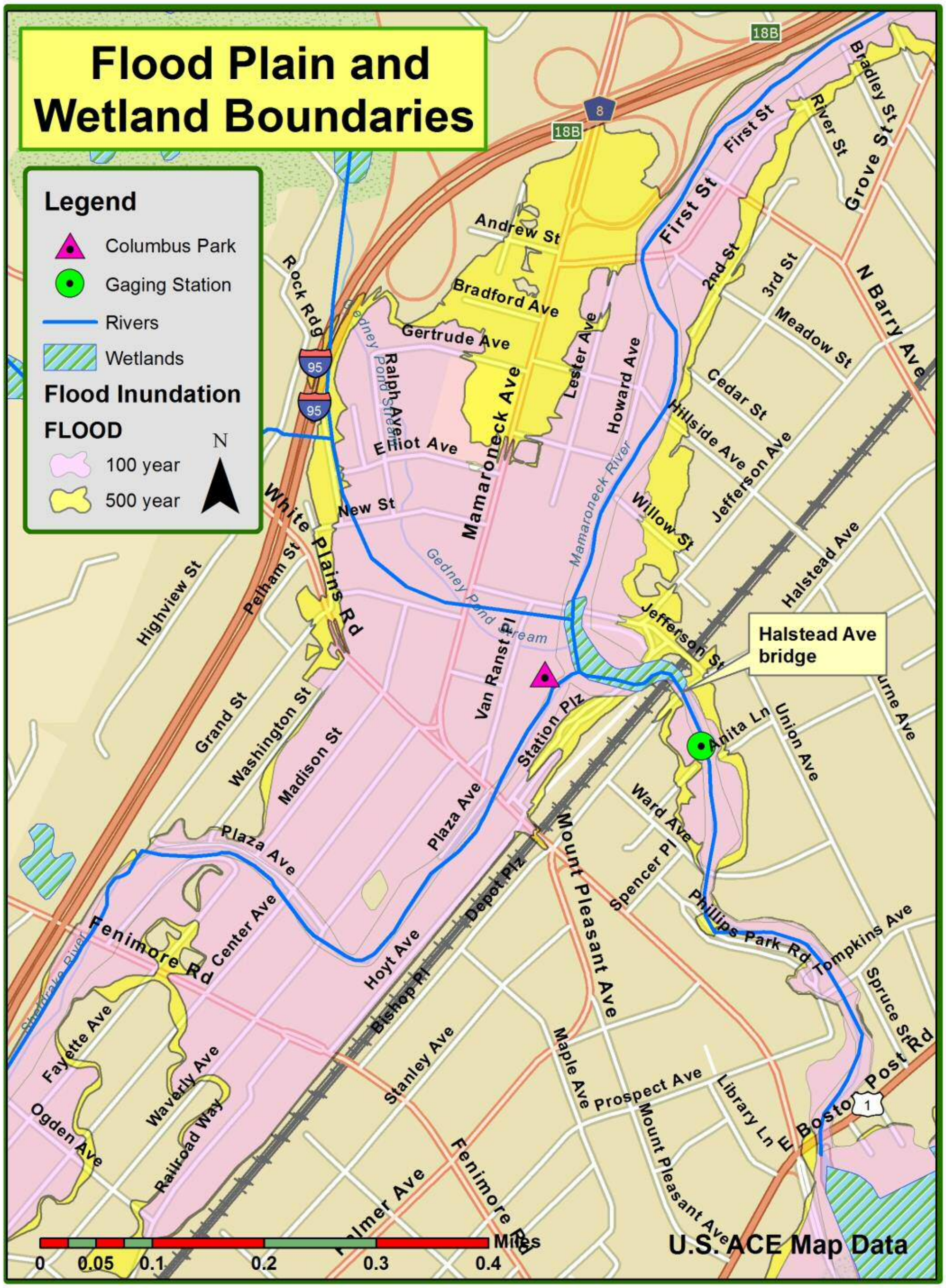



Figure 2. Limited channel cross-sectional areas beneath bridges situated down river of the confluence of Mamaroneck and Sheldrake rivers are not sufficient to convey major floodwaters. In response, floodwaters back up into the Village of Mamaroneck. Flooding dating back to at least 1877 results from these constrictions. Note the wetland that would be compromised with the current Alternative 1Z plan. This is not consistent with LWRP Policy 44.

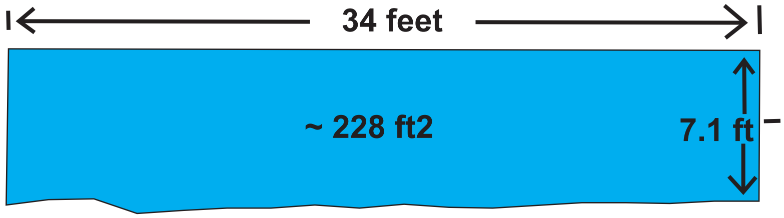
Whatever floodwater mitigation plan is ultimately selected, it must "*unplug*" the hydrologic bottleneck that occurs as floodwaters incident to channel constrictions at bridges back flood portions of the Village of Mamaroneck. There are three options that stand out as worthy of consideration. These are 1) bridge removal and/or bridge rebuilding designed to provide increased channel cross-sectional areas to accommodate 100-year floodwaters, 2) major channel deepening beneath constricting bridges conducted to not undermine structural integrity, and 3) some form of partial water diversion designed to reduce floodwater volume. [It is difficult to envision how the ACE-proposed culvert, model-optimized through the railroad parking area and ending upriver of the river bottleneck, will not be inundated by floodwaters.]

The most obvious immediate means to reduce floodwater volume at channel constriction points downriver of the confluence of Mamaroneck and Sheldrake rivers would require following option 1 above. If conducted without channel deepening, increased channel cross-sectional area could be achieved by raising bridges and/or expanding channel width. Depending on the area present beneath the Railroad bridge twin arches, this may or may not be possible. It is possible for all other bridges downriver of the Sheldrake/Mamaroneck confluence. This is not part of the ACE floodwater mitigation plan.

The second option (i.e., channel deepening and widening) would require an increase in channel cross-sectional area beneath the Halstead Avenue bridge of some $25^+$ percent greater than the current cross-sectional area (see Figure 3 below: *Channelization of Mamaroneck and Sheldrake Rivers: Lateral and Vertical Hydraulic Constraints*). While additional sub-bridge survey is required, this equates to about three feet of needed depth, assuming that the existing sub-bridge support walls are left intact. This appears to be the current Army Corps of Engineers approach to addressing large floodwater volumes that regularly back flood behind the Halstead Avenue bridge. Implementation of this option with continuous channel deepening and widening upriver of the bridges would result in a reduction/drop in river base level throughout all channel deepened reaches. As proposed, this would result in major disruption of upriver aquatic ecosystems, with a concurrent drop in local aquifer levels and river gradients.

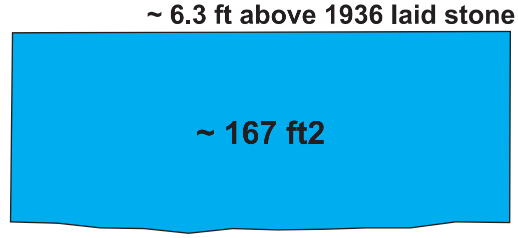
Assuming that 1) sufficient cross-sectional area is present beneath the twin Railroad bridge arches to accommodate 100-year floods, and 2) the Mamaroneck River invert (bottom) can be safely lowered beneath downriver bridges not slated for removal or replacement so as to not jeopardize their structural stability (e.g., Halstead Avenue bridge), there may be other viable engineered options that may be employed that will accommodate floodwater conveyance through a lowered downriver level without lowering river base level upriver of the Sheldrake/Mamaroneck confluence. One alternate option that could be explored is grade control structures anchored in the riverbanks and the river bottom to resist erosive forces and bed scour. This grade control measure is documented in a major document authored by the Federal Interagency Stream Restoration Working Group (*Stream corridor restoration: Principles, processes, and practices*; FISRWG, 1998). Some 12 individuals from various offices of the Army Corps of Engineers took part in the development of this excellent document which puts forth modern fluvial geomorphic-based, ecosystem-healthy, methods of channel restoration (vs. massive miles-long reaches of riprap and angled cement).

# Channelization of Mamaroneck and Sheldrake Rivers: Lateral and Vertical Hydraulic Constraints




Channel cross-section 59.5 ft upriver of the Hillside Ave bridge [Tr: Flood return interval]

2007 overbank floodwater height ~ 6.3 ft above 1936 laid stone wall




Channel cross-section beneath Columbus Park foot bridge deck

**Historic flooding in Mamaroneck dates back to at least 1877. A 1868 map shows both the railroad and Halstead (Railroad) Avenue bridges in place at that time.**


Channel cross-section beneath the Halstead Ave bridge

**Significant portions of both the Sheldrake and Mamaroneck rivers have been extensively channelized coincident with building and bridge construction. This has reduced the areal extent of the natural floodplain and increased river velocity. Riprap and cement walls now laterally constrain river flow until flood-water flows overbank into adjacent areas. Low bridges have served to both laterally and vertically constrain channel cross-sectional areas. The hydraulic response to this is back flooding upriver of low bridges, inclusive of the Halstead and Ward's avenues bridges. Calibration against flood levels depicted in 2011 and 2007 photographs reveal the damming effect of such bridges (e.g., Halstead Ave. above). Flood levels artificially elevated behind bridge dams compound upriver flooding impacts above normal flood levels. Flood level reduction requires increasing channel cross-sectional areas, especially under bridges, to accommodate flood flows. HydroQuest graphic.**

A third potential option for addressing the river bottleneck involves some other means of quickly diverting massive quantities of floodwater away from the bottleneck. One such option was explored and dismissed, apparently based on analysis of cost benefit ratios. ACE Alternate 5 briefly examined construction of a 1,050 foot long by 13 foot tunnel situated just downriver of the Sheldrake/Mamaroneck confluence. This is indeed one viable alternative means of shunting massive floodwater quantities around bridge bottlenecks. A properly-sized tunnel would have the capacity to quickly remove thousands of cubic feet per second (cfs) of water, thereby reducing or removing back flooded Columbus Park area flood waters. This relief tunnel, if considered, could be designed to permit low and moderate river flows along their existing flow route. As mentioned during the question and answer session on March 16, 2016, HydroQuest briefly looked into whether advances in horizontal directional drilling (HDD) technology (e.g., Hair, 2011) might make it possible to divert sufficient Mamaroneck River floodwater volume via twin large-diameter pipes placed between the railroad parking lot and Long Island Sound. This was investigated using the Hazen-Williams formula for gravity-fed pipe flow and was quickly dismissed due to limited conveyance capacity. Any water removal scenario must involve a large drainage opening.

**Frequency of Flooding**

Numerous firms, including the Army Corps of Engineers (ACE), have recognized that flooding in the Village of Mamaroneck occurs regularly. As part of their recent hydrologic modeling effort, the ACE conducted a comparative analysis of historic Mamaroneck River stages near Halstead Avenue with other regional data (e.g., Norwalk, Yonkers) in an effort to reconstruct Mamaroneck annual peak flows during years when there was no stream gage present. The gage downriver of Halstead Avenue (the Mamaroneck gage) was discontinued at the end of water year 1989. Thus, no Mamaroneck River flow data was collected for major flood events (e.g., 1996, 2004, 2007, 2011) that occurred after 1989. As a result, all US ACE flow data for this location is based on HEC-RAS modeled data. This location is the calibration point of the hydrology of the ACE study which was is stated as being calibrated to high water marks for the largest historic flood.

As part of this hydrologic work, the ACE upwardly increased and updated 30 of the 50 recorded annual peak values recorded on the Mamaroneck River, upward by as much as an additional 150 percent. The remaining 18 of 68 annual peak flow values used by ACE in their flood return (Tr) analysis were obtained indirectly from other watersheds using hydrologic means. This new, largely modeled, data set was then used to reconstruct what the peak flow value (Q in cubic feet per second [cfs]) was for the April 16, 2007 flood event (5330 cfs) and then, in turn, assess what the discharge is of a 100-year flood event.

Based on this work, the ACE determined that the largest flood of record (April 2007) was, statistically, a one in 100 year flood event. To assess other Mamaroneck floods of record, HydroQuest used the ACE annual peak flood values discussed in the paragraph above and conducted a flood frequency analysis. Of the four statistical methods used (Gumbel, Log-Pearson Type III, Log-Normal, Normal), the Log-Normal Distribution provided the best fit of the ACE data (Figure 4). Appendix A (attached) presents this analysis.

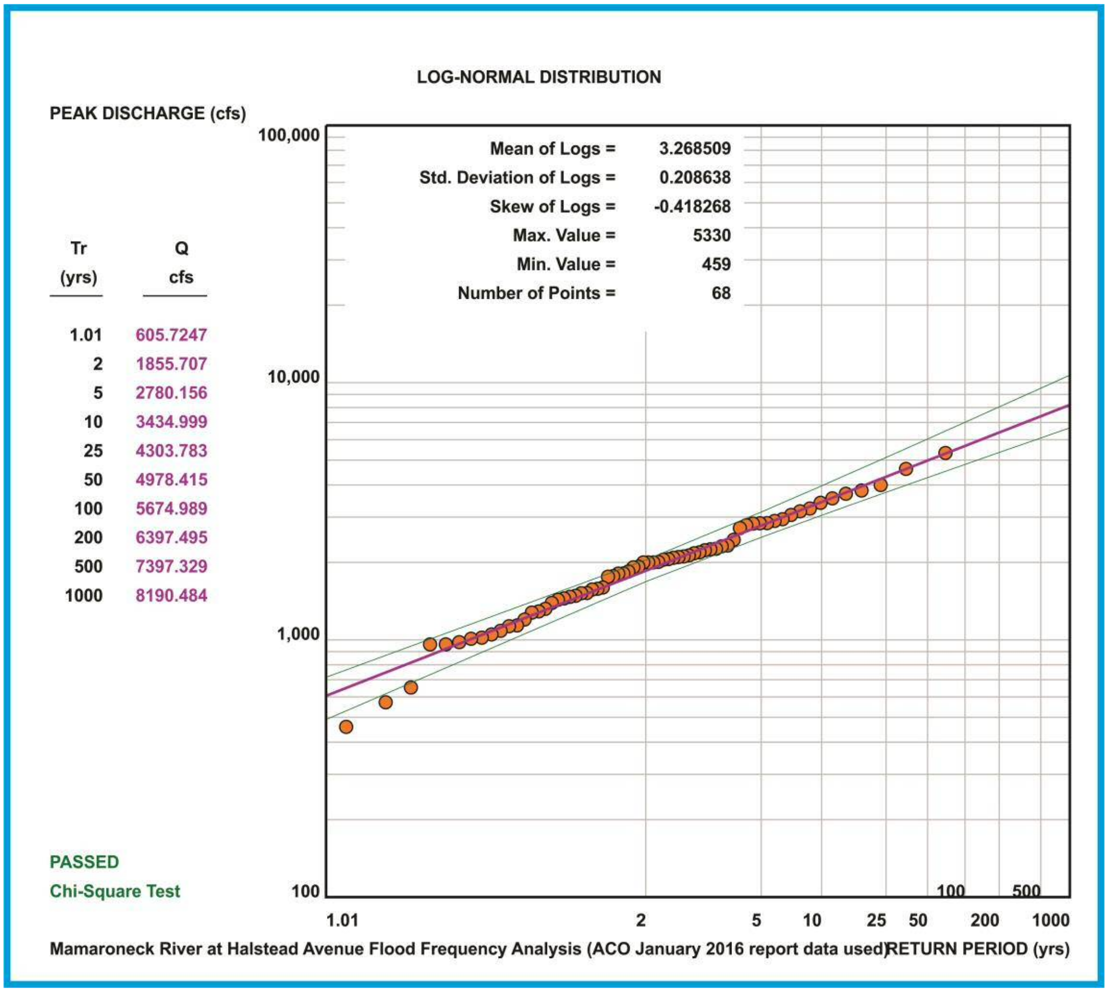



Figure 4. Log-Normal distribution provides the best fit of the ACE-based annual peak Flow values examined and generated for the Mamaroneck River near Halstead Avenue.

**Floods with Damage Information**

The ACE has identified the most damaging floods of record as those of October 1955, June 1972, September 1975 and April 2007. The table below shows that many damaging floods have a short flood return interval. Thus, engineered solutions to flood mitigation must be capable of efficiently handling both low and high flood return interval flows.

| Year | Damage | Estimated Peak Flow (cfs) | ~ Flood Return Interval (Tr in yrs)* |
|---|---|---|---|
| Oct. 1955 | ? | 3162 | 5-10 |
| June 1972 | $18M | 3550 | 10 |
| Sept. 1975 | $92M | 3700 | 10-20 |
| April 2007 | >$50M | 5330 | 50-100 |

*: Tr values based on HydroQuest flood frequency analysis (Appendix A) using modified ACE annual peak flow data.

**Floods of Record**

Reference to historic maps reveals that the railroad and Halstead Avenue bridges were present on or before 1868, well before the first noted flood of record (1877). With a reasonable degree of certainty, it is reasonable to conclude that the small cross-sectional areas beneath one or both of these bridges, as well as downriver bridges (e.g., Ward Avenue bridge), resulted in back flooding in Mamaroneck for the last century and a half. **Back flooding behind or upriver of "*bridge dams*" compounds adverse flooding impacts by forcing floodwaters to higher elevations atop back flooded waters.** Because little topographic/elevational difference occurs within the Mamaroneck flood zone, it is particularly important to maintain adequate drainage along stream reaches prone to flooding, especially at channel constriction points downriver of Columbus Park (e.g., laterally and vertically constricted channel cross section beneath the Halstead Avenue bridge). ACE reports list many floods of record (see below). It is possible that there were other floods that were not recorded (e.g., May 1990, April 1996, October 1996, September 2004, October 2005).

October 1877
September 1882
July 1889
October 1903
March 1936
July 1938
September 1938
July 1942
August 1942
September 1944
May 1946
March 1953
August 1955

October 1955
August 1960
April 1961
March 1962
August 1971
June 1972
September 1974
September 1975
April 1983
September 1999
March 2007
April 2007
August 2011

April 1980
April 1983
November 1977

While there is concern regarding flood impacts from the 100-year flood, it is clear that flooding in Mamaroneck occurs on a far more frequent basis. Sophisticated flood modeling is not needed to recognize that adverse flood impacts occur about once every five years. This can be calculated by simply taking the number of years of historic record (2015 - 1877 = 138 years) and dividing by the number of ACE mentioned flood events recorded above (29). This yields one recorded flood every 4.8 years. If other floods were not recorded, this value may be conservative. Thus, Mamaroneck flooding is a frequent event.

The 2008 KW Furey Engineering Flood Mitigation Status Report states that there were 95 floods events in the Village between 1877 and 2007. Addition of the 2011 flood event brings this total to 96 flood events between 1877 and 2015 (138 years). This equates to a flood event every 1.4 years. Clearly, flood events occur frequently in the Village of Mamaroneck and clearly something must be done to reduce flood levels, flood damage, and risk to life and property. All agree that a major project is needed to mitigate adverse flood impacts and risk. The issues at hand are what methods are best suited to 1) reduce flood impacts, and 2) maintain a healthy aquatic ecosystem suited to accessible recreational enjoyment and Village pride.

## Field Investigation

Because models are based on numerous assumptions and uncertainties, HydroQuest sought real-world data to determine to what extent floodwaters back up behind the Halstead Avenue bridge - thereby controlling floodwater elevations in Columbus Park and beyond into the Village of Mamaroneck. Photographs taken during the 2011 and 2007 floods were used to select high water elevations documented in Columbus Park, recognizing that the photos obtained may not represent somewhat higher peak flood levels. Survey work was conducted to determine that, at a minimum, floodwaters backed up behind the base of the I-beam support of Halstead Avenue bridge to 2.10 feet and 3.06 feet in 2011 and 2007, respectively. Figure 3 shows the results and approximate cross-sectional areas of river channel segments as measured by HydroQuest. The 2007 water depth in Columbus Park was determined to be $5.58^{+}$ feet deep in front of the Columbus monument.

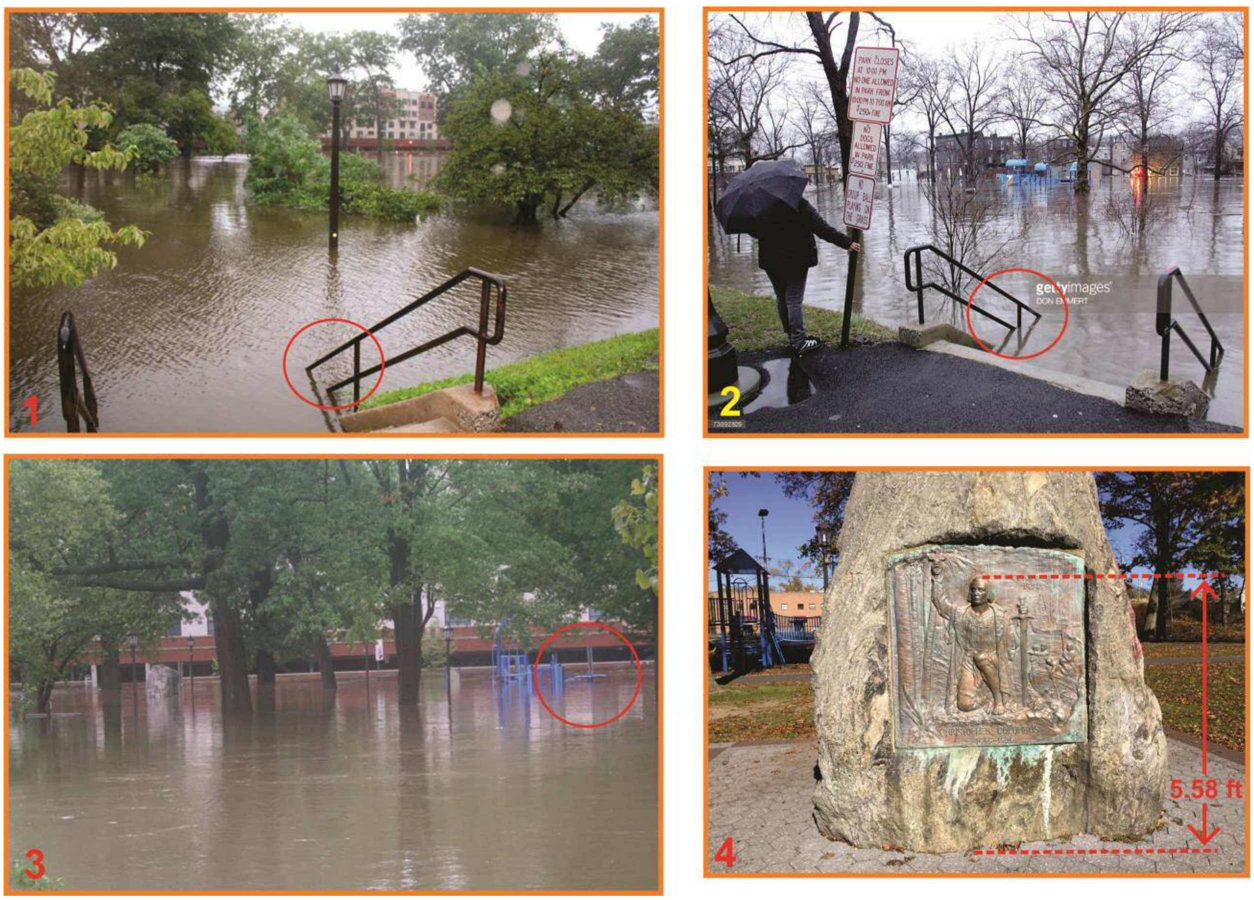



Figure 5. Columbus Park flooding. Photos 1 and 3 show August 27, 2011 flooding (W. Sutherland). Photo 2 shows April 16, 2007 flooding (D. Emmert). Photo 4 shows the April 16, 2007 flood level on the Columbus monument. HydroQuest survey work documented that the water level depicted on photo 2 (April 16, 2007) was back flooded behind the Halstead Avenue bridge to a level 3.06 feet above the base of the I-beam support. The flood level depicted on photo 3 was backed up some 2.10 feet above the base of the same I-beam support.

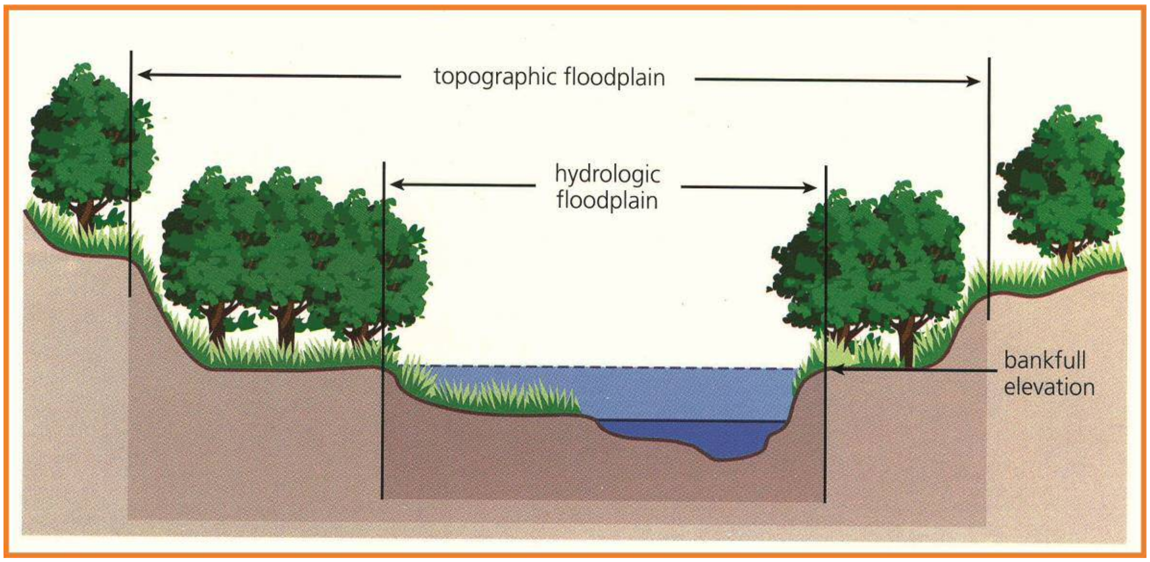
Based on the Army Corps of Engineers modeled hydrologic data for the Mamaroneck River near Halstead Avenue, the 100-year flood event is on the order of 5,330 cfs. Water backed up behind the Halstead Avenue bridge to a height of at least 3.06 feet above the base of the bridge's I-beam base filled a channel cross-sectional area on the order of 700ft$^2$. During major floods the sub-bridge and above-bridge area is hydraulically active. The hydraulic efficiency of the sub-bridge opening is almost certainly reduced in response to flood waters backed upriver of the Wards Avenue bridge and also by the small cross-sectional area present beneath the Halstead Avenue bridge, all being actively impacted by incoming floodwaters. Final determination of the cross-sectional area required to efficiently convey 5,330 cfs beneath bridges is needed. Exacting measurements of the cross-sectional areas present in and beneath all structures situated downriver of the Sheldrake/Mamaroneck rivers must be calculated and modeled using a combination of back flooded water levels, different flow rates, channel length, channel slope, roughness coefficients, turbulent flow conditions, and other factors. ACE peak flow data could be expanded to include the 2011 flood event (it currently ends at 2010). Then, model calibration could include 2007 and 2011 flow data and HydroQuest-obtained flood levels. All told, before any flood mitigation design work can be conducted, a rigorous evaluation of the minimum channel cross-sectional area is needed – if model-based, one that can reproduce observed back flooded levels. Alternately, with so many unknowns, a reasonable approach to assessing the channel size required to efficiently convey a 100-year flow of 5,330 cfs, and higher flood return interval flows (e.g., Tr of 250 and 500 years), might be to examine a variety of flow velocities, channel lengths, channel roughnesses, and gradients using the Hazen-Williams equation or suitable engineering formula. This is an important engineering determination.

**Overbank Flooding and River Meanders**

Whatever flood mitigation measures are ultimately agreed upon and utilized to increase river carrying capacity downriver of the confluence of Mamaroneck and Sheldrake rivers, it is important to recognize that historic channelization completed long ago will limit the nature of channel restoration in some upriver reaches. In places, full natural channel restoration that achieves natural channel configuration, such as that depicted in Figure 6 below, will not be possible. Urban infringement into natural floodplain areas provides a very challenging situation to deal with from both hydrologic and channel restoration standpoints. Reference to the top channel cross-section depicted in Figure 3 shows a channelized portion of the Mamaroneck River that regularly overbanks. While "*unplugging*" the channel constriction down river of the confluence of the Mamaroneck and Sheldrake rivers may reduce the frequency and magnitude of flooding upriver of the Hillside Avenue bridge (which must function as a dam during high flows), overbank flooding is likely to continue - requiring additional in and out-of-channel measures.

In non-urbanized settings, river restoration work seeks to restore channels to a hydrologically stable morphology (e.g., Rosgen 1996, 2009; FISRWG with Army Corps input, 1998). Restoration work uses detailed measurements of numerous fluvial geomorphic factors present in stable river reaches and then applies this information to develop working plans to restore destabilized and unhealthy river reaches. Simply adding meanders to a river in a random manner, if available space permits, has limited potential of resulting in stable river geometry or a healthy aquatic ecosystem. Many factors must be measured and evaluated first, including determination of watershed factors, stream type, erosion potential, channel stability, channel sinuosity, belt width, stream meander length, linear wavelength, arc length, and radius of curvature. Design opportunities for increasing river meandering must comprehensively and cumulatively evaluate these and other factors.

While increasing river meandering may be determined to be desirable based on completion of a comprehensive assessment of river and watershed hydrology factors, this may not be a viable option along many reaches of the Mamaroneck and Sheldrake rivers. The situation present in the Village of Mamaroneck has developed as a result of actions taken over the last 150 years. **It is a challenging situation, one that requires the expertise of some of the leading river hydrologists who have extensive river restoration experience.** Their successes throughout the United States and abroad can be brought to bear in the Village of Mamaroneck. Expense incurred to have experts from Wildland Hydrology assess the Mamaroneck/Sheldrake river channels and make recommendations would be well spent, will facilitate consistency with the LWRP, and may reduce overall project cost.




Hydrologic and topographic floodplains. The hydrologic floodplain is defined by bankfull elevation. The topographic floodplain includes the hydrologic floodplain and other lands up to a defined elevation. (Figure 1.20, FISRWG, 1998) Here, it is important to note the continuous lowest portion of the stream (i.e., thalweg) that in natural, healthy, streams provides critical habitat for fish and other species during times of low flow. Tree cover provides important thermal protection for fish and aquatic wildlife. Trapezoidal cement-walled (i.e., armored) channels are not part of healthy, non-structural streams. Figure 6.

**Village of Mamaroneck Channel Restoration (Case Example)**

Project design does not have to turn the Mamaroneck and Sheldrake river channels into riprapped and cement-walled sluiceways devoid of healthy aquatic ecosystems, fishing and recreational opportunities, protected water quality, and scenic value. This will be the end result of the proposed Alternate 1Z plan. These are reasons why Alternative 1Z is not consistent with the LWRP. Instead, even though Mamaroneck is heavily urbanized, it is possible to conduct river restoration and enhancement work that will conform with LWRP policies, will help to reduce flooding impacts, and will result in an environmentally healthy aquatic ecosystem in an aesthetically pleasing manner.

Project reexamination should include comprehensive assessment of modern fluvial geomorphic concepts consistent with the stream hydrology work of Rosgen, Silvey and Leopold. Their stream channel stability and restoration work is recognized and accepted throughout the United States and abroad (e.g., Rosgen 1996, 2009). Some of the concepts advanced by them have been employed along Sheldrake River within Columbus Park. Signage there illustrates the steps taken to achieve the aesthetically-pleasing natural productive habitat that encourages recreational activities. The figure below contrasts this natural approach with the unsightly channelized approach used upriver in the past and contemplated under current ACE project design, as well as with a worst case channelization project completed by the Army Corps of Engineers in the 1930s (Cole et al., 2009) (see photo 5).

In contrast to the 1930s ACE floodwater mitigation "*concrete flood chute*" design along the Hoosic River in North Adams, MA, the excellent 1995 aquifer buffer restoration project in Columbus Park completed by students of the Mamaroneck Ave. School and the Village of Mamaroneck is in keeping with the modern fluvial geomorphic approach used for: water quality protection, groundwater recharge and protection, flood control (an important hydrologic function), streambank stabilization, wildlife habitat, stream temperature moderation, source of organic matter, recreation and aesthetics. I recommend that Columbus Park be left intact as is and used as a visible reference by the community of the type of river restoration that can be incorporated into an Army Corps of Engineers flood mitigation project.

This completed Village of Mamaroneck project has shown that technological advances in fluvial geomorphology have made the possibility of reversing the ecological damage to these rivers feasible while still maintaining, and possibly enhancing, flood control capacity. As a result, the Columbus Park river restoration project had the effect of transforming the river into a source of pride for the community.


**Evolution of river channel modification through time. 1) Mamarock WPA channelization in 1936; 2) Mamaroneck with wetland raparian border; 3) Channelized Sheldrake River upstream of Columbus Park; 4 & 6) Healthy raparian and river ecosystem in Columbus Park; 5) ~ 1930s ACE Channelization of the Hoosic River in North Adams, MA (Clark Neuringer) - a worst case environmental scenario; 7 & 8) Signage praising the Mamaroneck Ave School and the Village of Mamaroneck for exemplary aquatic restoration work in Columbus Park. Contrast the unhealthy channelized reach of the Sheldrake River upstream of Columbus Park (3) with the 1995 down river restoration work (4 & 6). One river reach is suited to access, recreation, and enjoyment - one isn't.**

**Recommendations**

Local Waterfront Revitalization Program policies seek to protect and preserve fish and wildlife habitat, protect from flooding/erosion hazards, protect water resources and water quality, protect wetlands and scenic quality, and expand recreational use of fish and wildlife resources. The recommendations below seek to advance these policies to the broad benefit of the Village of Mamaroneck community.

- Reevaluate the project, placing emphasis on maintaining consistency with all LWRP policies;

- Incorporate concepts and material provided on Table 3.3 from FISRWG (1998, *Stream corridor restoration: Principles, processes, and practices*; Potential effects of land use activities) into channel modification methods being considered as part of the flood mitigation strategy. Technology advocated in this and related publications should be incorporated into a modified project design so as to be consistent with the LWRP. Some of this material is provided in Appendix B;

- As part of the overall flood mitigation plan, incorporate stream improvements that promote healthy stream ecology and protect water quality. River improvements should utilize modern fluvial geomorphic methods to the maximum extent practicable (e.g., following practices promoted in Rosgen 1996, 2009; ACE in FISRWG, 1998). As contemplated now, project completion will compromise ecologic, water quality, recreational, and aesthetic qualities of Mamaroneck that should be protected and preserved;

- Maintain the present regional base level of the Mamaroneck and Sheldrake rivers. The Columbus Park aquatic restoration project, aquifer, and ecosystems are adjusted to this level. Determination to lower the regional base level along river reaches should be supported by documentation justifying that no alternate, non-hard structural means, will afford the needed flood protection;

- Maintain existing stream and wetland integrity throughout Columbus Park and the wetland present at the mouth of the Sheldrake River. Columbus Park provides an excellent example of quality stream restoration work that provides aquatic habitat, provides a valuable recreational resource, and serves an important hydrologic function - temporary storage of floodwaters;

- Leave the existing hydrologic, biologic and physical nature of Columbus Park intact, complete with footbridges and Village of Mamaroneck signage that detail the importance of aquatic restoration;

- Actively involve Trout Unlimited and the community in project direction and design. TU has extensive experience with factors affecting fish habitat and stream ecology;

- Issue a positive declaration and have the project formally reviewed via the SEQRA process, complete with full public comment and review. Changing the regional hydrologic base level and disturbing and modifying a river for miles are significant environmental actions;

- Fund the installation and long-term maintenance of a USGS gaging station at or near the former Halstead Ave. gaging station location. This is important for documenting hydrologic conditions and in formulating decisions. Additionally, it would have value in flood monitoring. **This should be advanced ASAP independent of other project aspects**;

- Review lessons learned from the Hoosic River flood control project in North Adams, MA, as well as other similar projects, with an eye towards preventing ecologic, recreational, aesthetic, and water quality degradation; and

- Hire stream hydrology experts from Wildland Hydrology (e.g., David Rosgen) to assess the channelized physical setting now present, provide hydraulic input, and assist in project redesign using modern fluvial geomorphic stream restoration concepts and methods (falling back to hard structural means only where absolutely necessary).

Sincerely yours,

Paul A. Rubin

Paul A. Rubin
Hydrologist
HydroQuest

**References Cited**

Cole, B., Dryzga, M., Gaidus, A. and Robbins, C., 2009, Revitalizing North Adams and its Concrete River, 60 p.

Federal Interagency Stream Restoration Working Group (FISRWG), 1998, *Stream corridor restoration: Principles, processes, and practices* (GPO Item No. 0120-A). Washington, DC: Author. Numerous Federal agencies participated in producing this important work including the U.S. Department of Agriculture, U.S. Environmental Protection Agency, Tennessee Valley Authority, Federal Emergency Management Agency, U.S. Department of Commerce, the **U.S. Department of Defense - Army Corps of Engineers**, U.S. Department of Housing and Urban Development, and the U.S. Department of the Interior. The many contributors to this document included:

Hollis Allen - U.S. Army Corps of Engineers, Waterways Experiment Station; Vicksburg, MS
Mary Landin - U.S. Army Corps of Engineers, Waterways Experiment Station; Vicksburg, MS
Dave Hewitt - U.S. Army Corps of Engineers; Washington, DC
Tom Munsey - U.S. Army Corps of Engineers; Washington, DC
Meg J. Burns - U.S. Army Corps of Engineers; Baltimore, MD
Richard DiBuono - U.S. Army Corps of Engineers; Washington, DC
Beverly Getzen - U.S. Army Corps of Engineers; Washington, DC
Darrell Nolton - U.S. Army Corps of Engineers; Alexandria, VA
Kyle Schilling - U.S. Army Corps of Engineers; Ft. Belvoir, VA
David Biedenharn - U.S. Army Corps of Engineers; Vicksburg, MS
Ronald Copeland - U.S. Army Corps of Engineers; Vicksburg, MS
Craig Fischenich - U.S. Army Corps of Engineers; Vicksburg, MS

Hair, J. D. (2011, January 1). Considerations in the Application of Horizontal Directional Drilling to Pipeline Construction in the Arctic. Offshore Technology Conference. doi:10.4043/22086-MS.

Rosgen, D., 1996, Applied River Morphology. Pagosa Springs, CO: Wildland Hydrology.

Rosgen, D., 2009, Watershed Assessment of River Stability and Sediment Supply (WARSSS) (2nd ed.). Fort Collins, CO: Wildland Hydrology.

# Appendix A

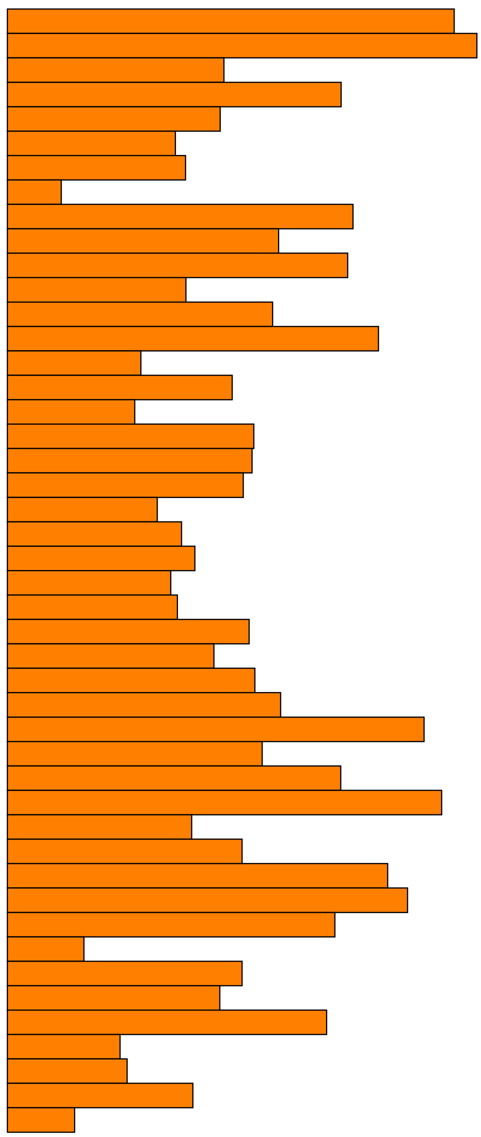
Computer-Aided Hydrology & Hydraulics
HydroStat Program
Version 3.00
www.cahh.com

| | |
|---|---|
| Project: | Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used) |
| User: | Paul A. Rubin - HydroQuest |
| Date: | 14 March 2016, Monday |
| Time: | 8:02 pm |
| Input: | C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF |
| Output: | C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT |

This data is an ANNUAL MAXIMUM series.

DATA ENTERED

| Water Year | PEAK DISCHARGE Q cfs |
|---|---|
| 1938 | 3807 |
| 1944 | 4000 |
| 1945 | 1845 |
| 1946 | 2844 |
| 1947 | 1813 |
| 1948 | 1432 |
| 1949 | 1518 |
| 1950 | 459 |
| 1951 | 2945 |
| 1952 | 2311 |
| 1953 | 2900 |
| 1954 | 1521 |
| 1955 | 2260 |
| 1956 | 3162 |
| 1957 | 1138 |
| 1958 | 1915 |
| 1959 | 1085 |
| 1960 | 2100 |
| 1961 | 2085 |
| 1962 | 2010 |
| 1963 | 1277 |
| 1964 | 1484 |
| 1965 | 1598 |
| 1966 | 1392 |
| 1967 | 1449 |
| 1968 | 2060 |
| 1969 | 1760 |
| 1970 | 2109 |
| 1971 | 2328 |
| 1972 | 3550 |
| 1973 | 2171 |
| 1974 | 2840 |
| 1975 | 3700 |
| 1976 | 1570 |
| 1977 | 2000 |
| 1978 | 3240 |
| 1979 | 3410 |
| 1980 | 2790 |
| 1981 | 653 |
| 1982 | 2000 |
| 1983 | 1810 |
| 1984 | 2720 |
| 1985 | 961 |
| 1986 | 1020 |
| 1987 | 1580 |
| 1988 | 572 |



(Listing continued on next page)

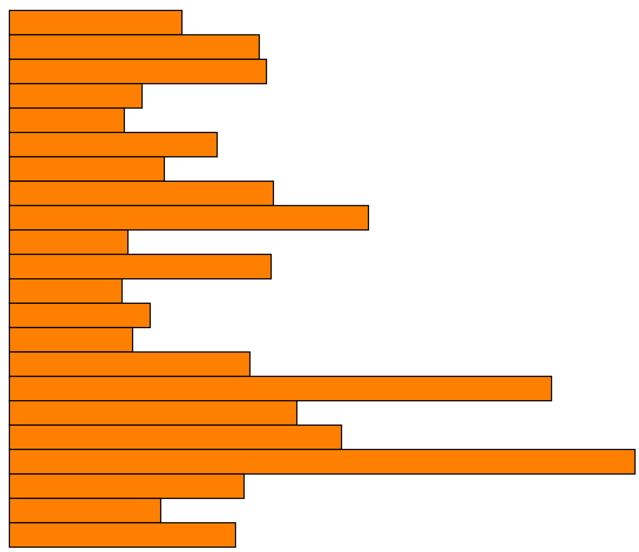
| | |
|---|---|
| Project: | Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used) |
| User: | Paul A. Rubin - HydroQuest |
| Date: | 14 March 2016, Monday |
| Time: | 8:02 pm |
| Input: | C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF |
| Output: | C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT |

This data is an ANNUAL MAXIMUM series.

DATA ENTERED

(Listing continued from previous page)

| Water Year | PEAK DISCHARGE Q cfs |
|---|---|
| 1989 | 1470 |
| 1990 | 2130 |
| 1991 | 2190 |
| 1992 | 1130 |
| 1993 | 980 |
| 1994 | 1770 |
| 1995 | 1320 |
| 1996 | 2250 |
| 1997 | 3060 |
| 1998 | 1010 |
| 1999 | 2230 |
| 2000 | 960 |
| 2001 | 1200 |
| 2002 | 1050 |
| 2003 | 2050 |
| 2004 | 4620 |
| 2005 | 2450 |
| 2006 | 2830 |
| 2007 | 5330 |
| 2008 | 2000 |
| 2009 | 1290 |
| 2010 | 1927 |



End of Data Series ==============================
This series contains 68 years of data.

Computer-Aided Hydrology & Hydraulics
HydroStat Program
www.cahh.com Version 3.00

Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

DATA AS CONTAINED IN: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE

| UNSORTED | | | | SORTED | | | |
|---|---|---|---|---|---|---|---|
| Q (cfs) | Rank | Plotting Position | Plotted Period (yrs) | Q (cfs) | Rank | Plotting Position | Plotted Period (yrs) |
| 3807 | 4 | .0580 | 17.250 | 5330 | 1 | .0145 | 69.000 |
| 4000 | 3 | .0435 | 23.000 | 4620 | 2 | .0290 | 34.500 |
| 1845 | 38 | .5507 | 1.816 | 4000 | 3 | .0435 | 23.000 |
| 2844 | 13 | .1884 | 5.308 | 3807 | 4 | .0580 | 17.250 |
| 1813 | 39 | .5652 | 1.769 | 3700 | 5 | .0725 | 13.800 |
| 1432 | 51 | .7391 | 1.353 | 3550 | 6 | .0870 | 11.500 |
| 1518 | 47 | .6812 | 1.468 | 3410 | 7 | .1014 | 9.857 |
| 459 | 68 | .9855 | 1.015 | 3240 | 8 | .1159 | 8.625 |
| 2945 | 11 | .1594 | 6.273 | 3162 | 9 | .1304 | 7.667 |
| 2311 | 20 | .2899 | 3.450 | 3060 | 10 | .1449 | 6.900 |
| 2900 | 12 | .1739 | 5.750 | 2945 | 11 | .1594 | 6.273 |
| 1521 | 46 | .6667 | 1.500 | 2900 | 12 | .1739 | 5.750 |
| 2260 | 21 | .3043 | 3.286 | 2844 | 13 | .1884 | 5.308 |
| 3162 | 9 | .1304 | 7.667 | 2840 | 14 | .2029 | 4.929 |
| 1138 | 57 | .8261 | 1.211 | 2830 | 15 | .2174 | 4.600 |
| 1915 | 37 | .5362 | 1.865 | 2790 | 16 | .2319 | 4.313 |
| 1085 | 59 | .8551 | 1.169 | 2720 | 17 | .2464 | 4.059 |
| 2100 | 28 | .4058 | 2.464 | 2450 | 18 | .2609 | 3.833 |
| 2085 | 29 | .4203 | 2.379 | 2328 | 19 | .2754 | 3.632 |
| 2010 | 32 | .4638 | 2.156 | 2311 | 20 | .2899 | 3.450 |
| 1277 | 55 | .7971 | 1.255 | 2260 | 21 | .3043 | 3.286 |
| 1484 | 48 | .6957 | 1.438 | 2250 | 22 | .3188 | 3.136 |
| 1598 | 43 | .6232 | 1.605 | 2230 | 23 | .3333 | 3.000 |
| 1392 | 52 | .7536 | 1.327 | 2190 | 24 | .3478 | 2.875 |
| 1449 | 50 | .7246 | 1.380 | 2171 | 25 | .3623 | 2.760 |
| 2060 | 30 | .4348 | 2.300 | 2130 | 26 | .3768 | 2.654 |
| 1760 | 42 | .6087 | 1.643 | 2109 | 27 | .3913 | 2.556 |
| 2109 | 27 | .3913 | 2.556 | 2100 | 28 | .4058 | 2.464 |
| 2328 | 19 | .2754 | 3.632 | 2085 | 29 | .4203 | 2.379 |
| 3550 | 6 | .0870 | 11.500 | 2060 | 30 | .4348 | 2.300 |
| 2171 | 25 | .3623 | 2.760 | 2050 | 31 | .4493 | 2.226 |
| 2840 | 14 | .2029 | 4.929 | 2010 | 32 | .4638 | 2.156 |
| 3700 | 5 | .0725 | 13.800 | 2000 | 33 | .4783 | 2.091 |
| 1570 | 45 | .6522 | 1.533 | 2000 | 34 | .4928 | 2.029 |
| 2000 | 33 | .4783 | 2.091 | 2000 | 35 | .5072 | 1.971 |
| 3240 | 8 | .1159 | 8.625 | 1927 | 36 | .5217 | 1.917 |
| 3410 | 7 | .1014 | 9.857 | 1915 | 37 | .5362 | 1.865 |
| 2790 | 16 | .2319 | 4.313 | 1845 | 38 | .5507 | 1.816 |
| 653 | 66 | .9565 | 1.045 | 1813 | 39 | .5652 | 1.769 |
| 2000 | 33 | .4783 | 2.091 | 1810 | 40 | .5797 | 1.725 |
| 1810 | 40 | .5797 | 1.725 | 1770 | 41 | .5942 | 1.683 |
| 2720 | 17 | .2464 | 4.059 | 1760 | 42 | .6087 | 1.643 |
| 961 | 64 | .9275 | 1.078 | 1598 | 43 | .6232 | 1.605 |
| 1020 | 61 | .8841 | 1.131 | 1580 | 44 | .6377 | 1.568 |
| 1580 | 44 | .6377 | 1.568 | 1570 | 45 | .6522 | 1.533 |
| 572 | 67 | .9710 | 1.030 | 1521 | 46 | .6667 | 1.500 |

(Listing continued on next page)

Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

DATA AS CONTAINED IN: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE

(Listing continued from previous page)

| UNSORTED Q (cfs) | UNSORTED Rank | UNSORTED Plotting Position | UNSORTED Plotted Period (yrs) | SORTED Q (cfs) | SORTED Rank | SORTED Plotting Position | SORTED Plotted Period (yrs) |
|---|---|---|---|---|---|---|---|
| 1470 | 49 | .7101 | 1.408 | 1518 | 47 | .6812 | 1.468 |
| 2130 | 26 | .3768 | 2.654 | 1484 | 48 | .6957 | 1.438 |
| 2190 | 24 | .3478 | 2.875 | 1470 | 49 | .7101 | 1.408 |
| 1130 | 58 | .8406 | 1.190 | 1449 | 50 | .7246 | 1.380 |
| 980 | 63 | .9130 | 1.095 | 1432 | 51 | .7391 | 1.353 |
| 1770 | 41 | .5942 | 1.683 | 1392 | 52 | .7536 | 1.327 |
| 1320 | 53 | .7681 | 1.302 | 1320 | 53 | .7681 | 1.302 |
| 2250 | 22 | .3188 | 3.136 | 1290 | 54 | .7826 | 1.278 |
| 3060 | 10 | .1449 | 6.900 | 1277 | 55 | .7971 | 1.255 |
| 1010 | 62 | .8986 | 1.113 | 1200 | 56 | .8116 | 1.232 |
| 2230 | 23 | .3333 | 3.000 | 1138 | 57 | .8261 | 1.211 |
| 960 | 65 | .9420 | 1.062 | 1130 | 58 | .8406 | 1.190 |
| 1200 | 56 | .8116 | 1.232 | 1085 | 59 | .8551 | 1.169 |
| 1050 | 60 | .8696 | 1.150 | 1050 | 60 | .8696 | 1.150 |
| 2050 | 31 | .4493 | 2.226 | 1020 | 61 | .8841 | 1.131 |
| 4620 | 2 | .0290 | 34.500 | 1010 | 62 | .8986 | 1.113 |
| 2450 | 18 | .2609 | 3.833 | 980 | 63 | .9130 | 1.095 |
| 2830 | 15 | .2174 | 4.600 | 961 | 64 | .9275 | 1.078 |
| 5330 | 1 | .0145 | 69.000 | 960 | 65 | .9420 | 1.062 |
| 2000 | 33 | .4783 | 2.091 | 653 | 66 | .9565 | 1.045 |
| 1290 | 54 | .7826 | 1.278 | 572 | 67 | .9710 | 1.030 |
| 1927 | 36 | .5217 | 1.917 | 459 | 68 | .9855 | 1.015 |

Note that the UNSORTED listing will give the same rank to identical values occuring in the input data file. The SORTED listing shows all ranks.

www.cahh.com

Computer-Aided Hydrology & Hydraulics

HydroStat Program

Version 3.00

| | |
|---|---|
| Project: | Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used) |
| User: | Paul A. Rubin - HydroQuest |
| Date: | 14 March 2016, Monday |
| Time: | 8:02 pm |
| Input: | C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF |
| Output: | C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT |

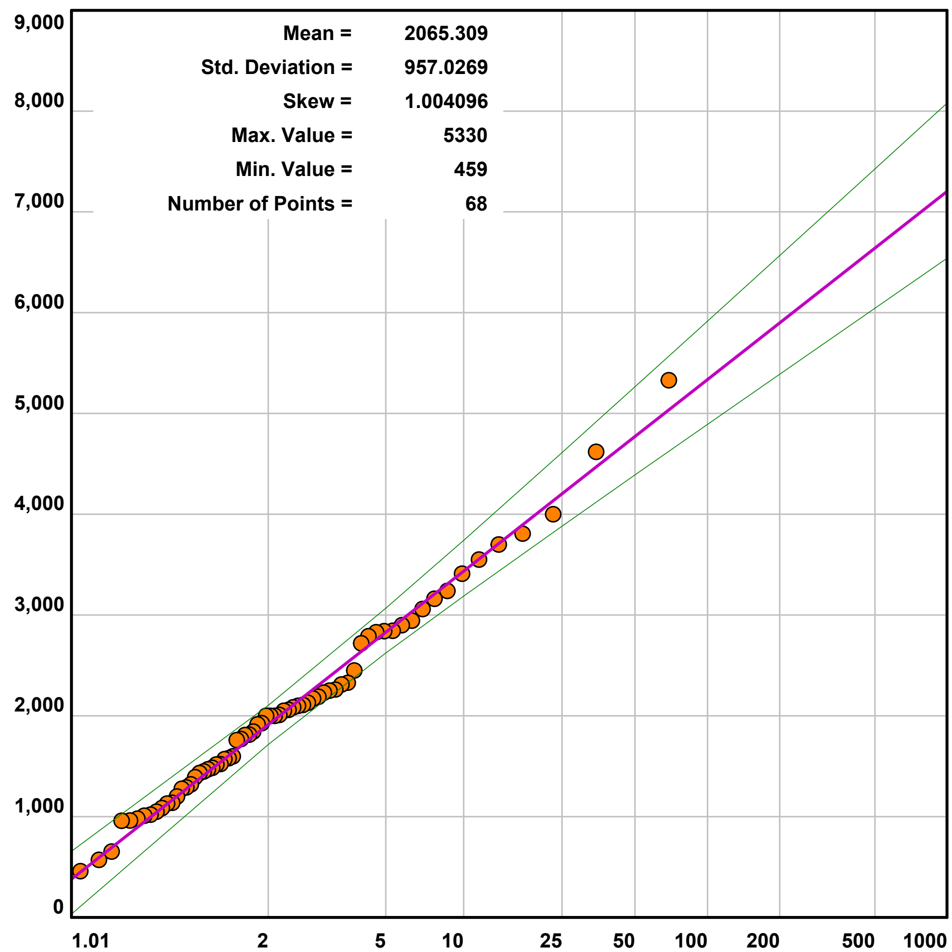
**EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION**

**PEAK DISCHARGE (cfs)**

| Tr (yrs) | Q cfs |
|---|---|
| 1.01 | 379.1319 |
| 2 | 1912.309 |
| 5 | 2828.92 |
| 10 | 3435.795 |
| 25 | 4202.583 |
| 50 | 4771.431 |
| 100 | 5336.078 |
| 200 | 5898.665 |
| 500 | 6640.891 |
| 1000 | 7201.849 |

**PASSED**

**Chi-Square Test**




**Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)RETURN PERIOD (yrs)**

| | |
|---|---|
| Project: | Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used) |
| User: | Paul A. Rubin - HydroQuest |
| Date: | 14 March 2016, Monday |
| Time: | 8:02 pm |
| Input: | C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF |
| Output: | C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT |

| | | | |
|---|---|---|---|
| Mean = | 2065.309 | Maximum Input Value = | 5330 |
| Std. Deviation = | 957.0269 | Minimum Input Value = | 459 |
| Skew = | 1.00409600 | Number of Points = | 68 |

EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION

| RETURN PERIOD (yrs) | Q (cfs) | FREQUENCY FACTOR | Q 90% CONFIDENCE LIMITS Lower (cfs) | Upper (cfs) |
|---|---|---|---|---|
| 1.01 | 379.1319 | -1.7619 | 32.92102 | 655.837 |
| 2 | 1912.309 | -0.1599 | 1715.012 | 2103.298 |
| 5 | 2828.92 | 0.7979 | 2622.252 | 3067.065 |
| 10 | 3435.795 | 1.4320 | 3187.079 | 3741.003 |
| 25 | 4202.583 | 2.2332 | 3881.549 | 4611.718 |
| 50 | 4771.431 | 2.8276 | 4389.893 | 5264.518 |
| 100 | 5336.078 | 3.4176 | 4891.403 | 5915.576 |
| 200 | 5898.665 | 4.0055 | 5389.196 | 6566.147 |
| 500 | 6640.891 | 4.7810 | 6044.116 | 7426.275 |
| 1,000 | 7201.849 | 5.3672 | 6538.173 | 8077.256 |

Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

| | | | |
|---|---|---|---|
| Mean = | 2065.309 | Maximum Input Value = | 5330 |
| Std. Deviation = | 957.0269 | Minimum Input Value = | 459 |
| Skew = | 1.00409600 | Number of Points = | 68 |

EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

| CLASS | CLASS LIMITS Lower (cfs) | Upper (cfs) | NUMBER OF VALUES Expected "Ei" | Observed "Oi" | $(Oi-Ei)^2$ / Ei |
|---|---|---|---|---|---|
| 1 | 0 | 1231.057 | 13.6000 | 13 | 0.0265 |
| 2 | 1231.057 | 1686.607 | 13.6000 | 13 | 0.0265 |
| 3 | 1686.607 | 2159.138 | 13.6000 | 17 | 0.8500 |
| 4 | 2159.138 | 2828.919 | 13.6000 | 10 | 0.9529 |
| 5 | 2828.919 | Infinity | 13.6000 | 15 | 0.1441 |

COMPUTED CHI-SQUARE = 2.0000
CHI-SQUARE FROM TABLE = 4.6100

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the EXTREME VALUE TYPE I (GUMBEL) DISTRIBUTION DOES apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

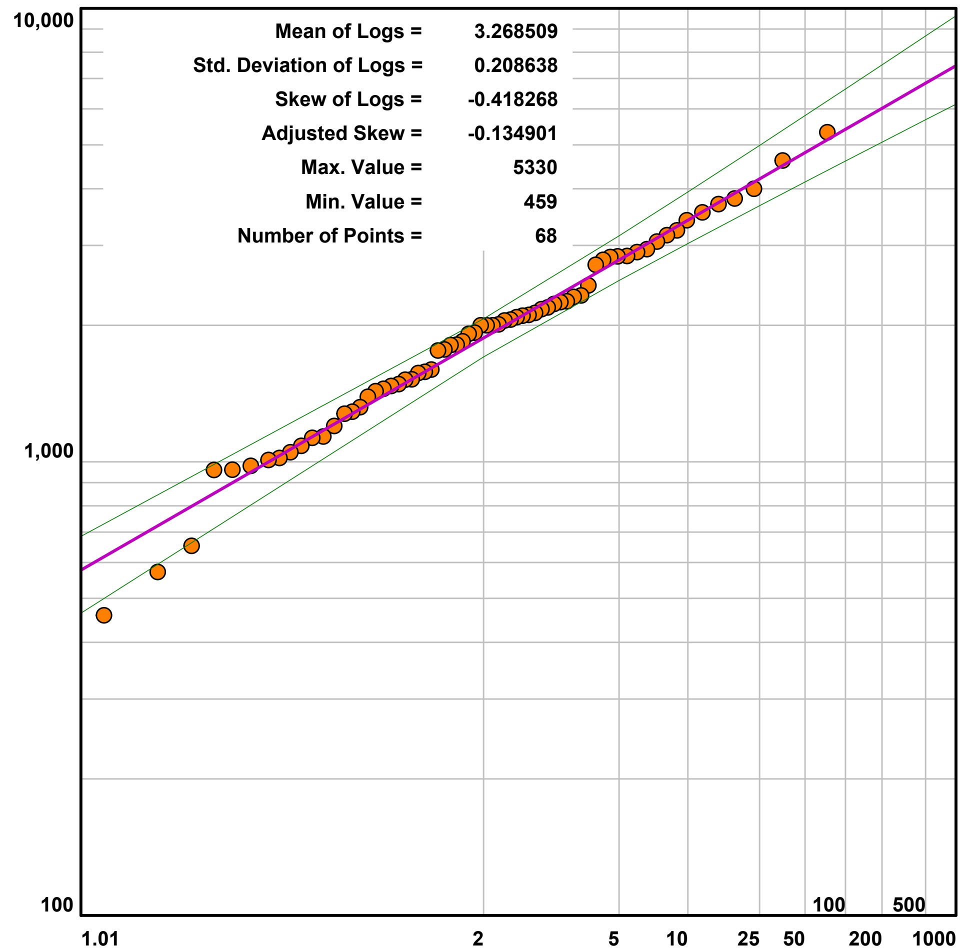
Computer-Aided Hydrology & Hydraulics
HydroStat Program
Version 3.00
www.cahh.com

Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

**LOG-PEARSON TYPE III DISTRIBUTION**

**PEAK DISCHARGE (cfs)**

| Tr (yrs) | Q cfs |
|---|---|
| 1.01 | 577.3265 |
| 2 | 1875.806 |
| 5 | 2788.13 |
| 10 | 3409.365 |
| 25 | 4206.111 |
| 50 | 4805.524 |
| 100 | 5408.54 |
| 200 | 6018.382 |
| 500 | 6838.484 |
| 1000 | 7471.633 |




**PASSED**
**Chi-Square Test**

**Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)RETURN PERIOD (yrs)**

Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

| | | | |
|---|---|---|---|
| Mean of Logs = | 3.268509 | Maximum Input Value = | 5330 |
| Std. Deviation of Logs = | 0.208638 | Minimum Input Value = | 459 |
| Skew of Logs = | -0.418268 | Number of Points = | 68 |
| Adjusted Skew = | -0.134901 | Generalized Map Skew = | 0.7 |

LOG-PEARSON TYPE III DISTRIBUTION

| RETURN PERIOD (yrs) | Q (cfs) | FREQUENCY FACTOR | Q 90% CONFIDENCE LIMITS Lower (cfs) | Upper (cfs) |
|---|---|---|---|---|
| 1.01 | 577.3265 | -2.4305 | 463.7177 | 684.9942 |
| 2 | 1875.806 | 0.0224 | 1703.068 | 2066.982 |
| 5 | 2788.13 | 0.8474 | 2510.197 | 3149.245 |
| 10 | 3409.365 | 1.2661 | 3028.542 | 3935.523 |
| 25 | 4206.111 | 1.7033 | 3670.189 | 4985.649 |
| 50 | 4805.524 | 1.9806 | 4140.437 | 5800.55 |
| 100 | 5408.54 | 2.2267 | 4605.034 | 6638.613 |
| 200 | 6018.382 | 2.4491 | 5067.633 | 7502.691 |
| 500 | 6838.484 | 2.7150 | 5679.951 | 8688.097 |
| 1,000 | 7471.633 | 2.8993 | 6146.032 | 9619.91 |

Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

| | | | |
|---|---|---|---|
| Mean of Logs = | 3.268509 | Maximum Input Value = | 5330 |
| Std. Deviation of Logs = | 0.208638 | Minimum Input Value = | 459 |
| Skew of Logs = | -0.418268 | Number of Points = | 68 |
| Adjusted Skew = | -0.134901 | Generalized Map Skew = | 0.7 |

LOG-PEARSON TYPE III DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

| CLASS | CLASS LIMITS Lower (cfs) | Upper (cfs) | NUMBER OF VALUES Expected "Ei" | Observed "Oi" | $\frac{(Oi-Ei)^2}{Ei}$ |
|---|---|---|---|---|---|
| 1 | 0 | 1242.911 | 13.6000 | 13 | 0.0265 |
| 2 | 1242.911 | 1659.939 | 13.6000 | 13 | 0.0265 |
| 3 | 1659.939 | 2116.913 | 13.6000 | 16 | 0.4235 |
| 4 | 2116.913 | 2788.131 | 13.6000 | 10 | 0.9529 |
| 5 | 2788.131 | Infinity | 13.6000 | 16 | 0.4235 |

COMPUTED CHI-SQUARE = 1.8529
CHI-SQUARE FROM TABLE = 2.7100

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the LOG-PEARSON TYPE III DISTRIBUTION DOES apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

Computer-Aided Hydrology & Hydraulics
HydroStat Program
www.cahh.com
Version 3.00

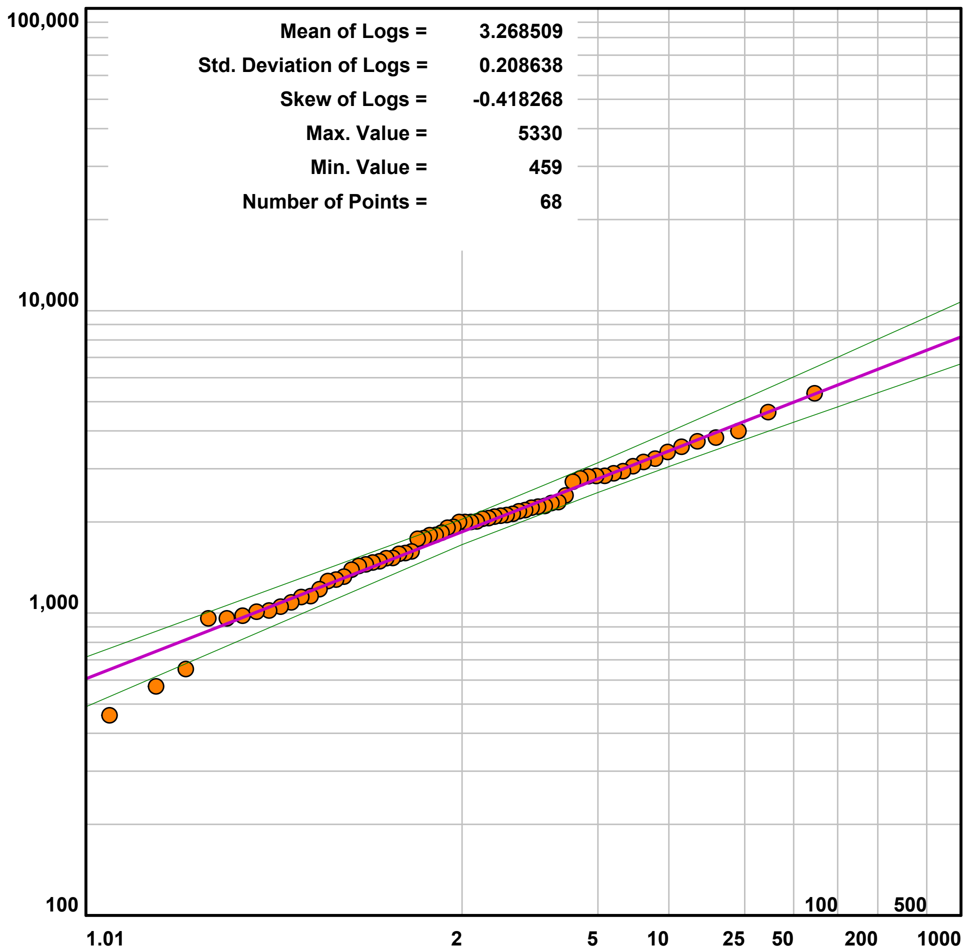
Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

**LOG-NORMAL DISTRIBUTION**

**PEAK DISCHARGE (cfs)**

| Tr (yrs) | Q cfs |
|---|---|
| 1.01 | 605.7247 |
| 2 | 1855.707 |
| 5 | 2780.156 |
| 10 | 3434.999 |
| 25 | 4303.783 |
| 50 | 4978.415 |
| 100 | 5674.989 |
| 200 | 6397.495 |
| 500 | 7397.329 |
| 1000 | 8190.484 |

**PASSED**
**Chi-Square Test**




**Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)RETURN PERIOD (yrs)**

Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

| | | | |
|---|---|---|---|
| Mean of Logs = | 3.268509 | Maximum Input Value = | 5330 |
| Std. Deviation of Logs = | 0.208638 | Minimum Input Value = | 459 |
| Skew of Logs = | -0.418268 | Number of Points = | 68 |

LOG-NORMAL DISTRIBUTION

| RETURN PERIOD (yrs) | Q (cfs) | FREQUENCY FACTOR | Q 90% CONFIDENCE LIMITS Lower (cfs) | Upper (cfs) |
|---|---|---|---|---|
| 1.01 | 605.7247 | -2.3305 | 489.9471 | 715.0862 |
| 2 | 1855.707 | 0.0000 | 1684.467 | 2044.355 |
| 5 | 2780.156 | 0.8415 | 2503.409 | 3139.375 |
| 10 | 3434.999 | 1.2817 | 3049.544 | 3968.638 |
| 25 | 4303.783 | 1.7511 | 3747.46 | 5117.094 |
| 50 | 4978.415 | 2.0542 | 4274.441 | 6039.06 |
| 100 | 5674.989 | 2.3268 | 4807.982 | 7014.202 |
| 200 | 6397.495 | 2.5762 | 5351.987 | 8047.503 |
| 500 | 7397.329 | 2.8785 | 6091.609 | 9509.853 |
| 1,000 | 8190.484 | 3.0905 | 6669.033 | 10693.89 |

Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

| | | | |
|---|---|---|---|
| Mean of Logs = | 3.268509 | Maximum Input Value = | 5330 |
| Std. Deviation of Logs = | 0.208638 | Minimum Input Value = | 459 |
| Skew of Logs = | -0.418268 | Number of Points = | 68 |

LOG-NORMAL DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

| CLASS | CLASS LIMITS Lower (cfs) | CLASS LIMITS Upper (cfs) | NUMBER OF VALUES Expected "Ei" | NUMBER OF VALUES Observed "Oi" | $(Oi-Ei)^2 / Ei$ |
|---|---|---|---|---|---|
| 1 | 0 | 1238.653 | 13.6000 | 13 | 0.0265 |
| 2 | 1238.653 | 1643.38 | 13.6000 | 13 | 0.0265 |
| 3 | 1643.38 | 2095.467 | 13.6000 | 14 | 0.0118 |
| 4 | 2095.467 | 2780.156 | 13.6000 | 12 | 0.1882 |
| 5 | 2780.156 | Infinity | 13.6000 | 16 | 0.4235 |

COMPUTED CHI-SQUARE = 0.6765
CHI-SQUARE FROM TABLE = 4.6100

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the LOG-NORMAL DISTRIBUTION DOES apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

Computer-Aided Hydrology & Hydraulics
HydroStat Program
Version 3.00
www.cahh.com

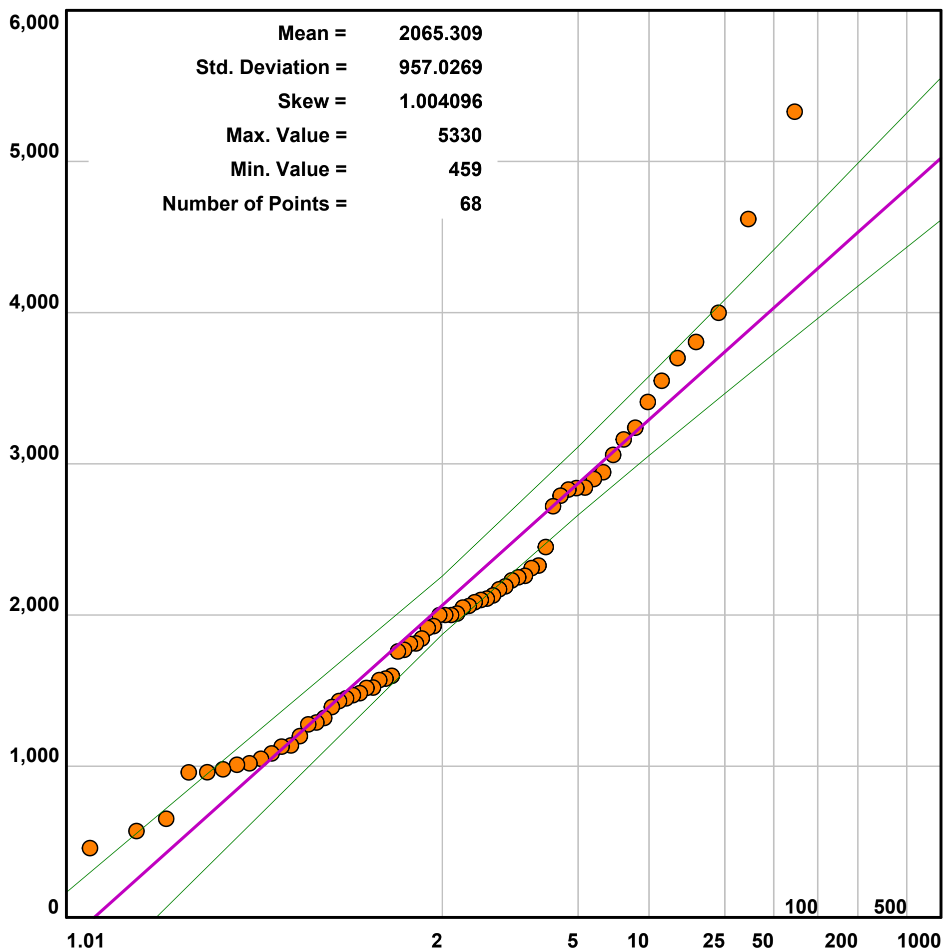
Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

**NORMAL DISTRIBUTION**

**PEAK DISCHARGE (cfs)**

| Tr (yrs) | Q cfs |
|---|---|
| 1.01 | -165.0576 |
| 2 | 2065.309 |
| 5 | 2870.605 |
| 10 | 3291.958 |
| 25 | 3741.136 |
| 50 | 4031.223 |
| 100 | 4292.105 |
| 200 | 4530.836 |
| 500 | 4820.116 |
| 1000 | 5023.021 |

**FAILED**
**Chi-Square Test**




**Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)RETURN PERIOD (yrs)**

Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

| | | | |
|---|---|---|---|
| Mean = | 2065.309 | Maximum Input Value = | 5330 |
| Std. Deviation = | 957.0269 | Minimum Input Value = | 459 |
| Skew = | 1.00409600 | Number of Points = | 68 |

NORMAL DISTRIBUTION

| RETURN PERIOD (yrs) | Q (cfs) | FREQUENCY FACTOR | Q 90% CONFIDENCE LIMITS Lower (cfs) | Q 90% CONFIDENCE LIMITS Upper (cfs) |
|---|---|---|---|---|
| 1.01 | -165.0576 | -2.3305 | -587.6423 | 165.5892 |
| 2 | 2065.309 | 0.0000 | 1872.438 | 2258.179 |
| 5 | 2870.605 | 0.8415 | 2661.725 | 3112.681 |
| 10 | 3291.958 | 1.2817 | 3054.847 | 3579.632 |
| 25 | 3741.136 | 1.7511 | 3465.395 | 4085.957 |
| 50 | 4031.223 | 2.0542 | 3727.508 | 4415.974 |
| 100 | 4292.105 | 2.3268 | 3961.829 | 4714.171 |
| 200 | 4530.836 | 2.5762 | 4175.365 | 4987.938 |
| 500 | 4820.116 | 2.8785 | 4433.233 | 5320.555 |
| 1,000 | 5023.021 | 3.0905 | 4613.645 | 5554.318 |

NOTE: Negative values are shown for verification purposes only. Obviously, negative values will not occur. Frequently the lower return periods will have negative values resulting from the statistical fit.

Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

| | | | |
|---|---|---|---|
| Mean = | 2065.309 | Maximum Input Value = | 5330 |
| Std. Deviation = | 957.0269 | Minimum Input Value = | 459 |
| Skew = | 1.00409600 | Number of Points = | 68 |

NORMAL DISTRIBUTION
CHI-SQUARE TEST FOR GOODNESS-OF-FIT

| CLASS | CLASS LIMITS Lower (cfs) | Upper (cfs) | NUMBER OF VALUES Expected "Ei" | Observed "Oi" | $\frac{(Oi-Ei)^2}{Ei}$ |
|---|---|---|---|---|---|
| 1 | 0 | 1260.012 | 13.6000 | 13 | 0.0265 |
| 2 | 1260.012 | 1823.245 | 13.6000 | 17 | 0.8500 |
| 3 | 1823.245 | 2307.373 | 13.6000 | 18 | 1.4235 |
| 4 | 2307.373 | 2870.605 | 13.6000 | 8 | 2.3059 |
| 5 | 2870.605 | Infinity | 13.6000 | 12 | 0.1882 |
| | | | | COMPUTED CHI-SQUARE = | 4.7941 |
| | | | | CHI-SQUARE FROM TABLE = | 4.6100 |

CONCLUDE: Based on Chi-Square (Goodness-of-Fit) results,
the NORMAL DISTRIBUTION does NOT apply to the input data.
Note that Chi-Square results are dependent upon the number of class intervals used.

Computer-Aided Hydrology & Hydraulics
HydroStat Program
Version 3.00

www.cahh.com

Project: Mamaroneck River at Halstead Avenue Flood Frequency Analysis (ACO January 2016 report data used)
User: Paul A. Rubin - HydroQuest
Date: 14 March 2016, Monday
Time: 8:02 pm
Input: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECK_ACE.HDF
Output: C:\USERS\PAUL\DOCUMENTS\MY DOCUMENTS\FLOOD RETURN WORKING PROGRAM FOR USE\MAMARONECKACE.OUT

| | | | |
|---|---|---|---|
| Mean = | 2065.309 | Maximum Input Value = | 5330 |
| Std. Deviation = | 957.0269 | Minimum Input Value = | 459 |
| Skew = | 1.00409600 | Number of Points = | 68 |
| Mean of Logs = | 3.268509 | Generalized Map Skew = | 0.7 |
| Std. Deviation of Logs = | 0.208638 | | |
| Skew of Logs = | -0.418268 | | |
| Adjusted Skew = | -0.134901 | | |

## COMPARISON OF STATISTICAL DISTRIBUTIONS

Number of Chi-Square class intervals used = 5

| | CHI-SQUARE | | |
|---|---|---|---|
| DISTRIBUTION | COMPUTED | TABULATED | |
| EXTREME VALUE TYPE I (GUMBEL) | 2.000 | 4.610 | Passed |
| LOG-PEARSON TYPE III | 1.853 | 2.710 | Passed |
| LOG-NORMAL | 0.676 | 4.610 | Passed |
| NORMAL | 4.794 | 4.610 | FAILED |

BASED ON A 10-PERCENT SIGNIFICANCE LEVEL, THE
LOG-NORMAL
DISTRIBUTION RESULTS IN THE BEST FIT OF THE DATA.

# Appendix B

***Table 3.3: Potential effects of major land use activities.***

| Potential Effects | Vegetative Clearing | Channelization | Streambank Armoring | Streambed Disturbance | Withdrawal of Water | Dams | Levees | Soil Exposure or Compaction | Irrigation and Drainage | Contaminants | Hard Surfacing | Overgrazing | Roads and Railroads | Trails | Exotic Species | Utility Crossings | Reduction of Floodplain | Dredging for Mineral Extract. | Land Grading | Bridges | Woody Debris Removal | Piped Discharge/Cont.Outlets |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Disturbance Activities | | | | | | | | | | | | | | | | | | | | | |
| Homogenization of landscape elements | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ■ | ▒ | ▒ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ |
| Point source pollution | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ■ | ▒ | ▒ | ■ | ▒ | ■ | ▒ | ▒ | ▒ | ■ |
| Nonpoint source pollution | ■ | ■ | ▒ | ■ | ▒ | ▒ | ■ | ▒ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ▒ | ■ | ■ | ▒ | ■ | ■ |
| Dense compacted soil | ■ | ▒ | ■ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ |
| Increased upland surface runoff | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ |
| Increased sheetflow w/surface erosion rill and gully flow | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ |
| Increased levels of fine sediment and contaminants in stream corridor | ■ | ■ | ▒ | ■ | ▒ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Increased soil salinity | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ |
| Increased peak flood elevation | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ■ |
| Increased flood energy | ■ | ■ | ■ | ■ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ■ | ■ |
| Decreased infiltration of surface runoff | ■ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ■ |
| Decreased interflow and subsurface flow | ■ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ■ |
| Reduced ground water recharge and aquifer volumes | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ■ |
| Increased depth to ground water | ■ | ■ | ▒ | ▒ | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ |
| Decreased ground water inflow to stream | ■ | ■ | ■ | ▒ | ■ | ▒ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ■ |
| Increased flow velocities | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ■ | ■ |
| Reduced stream meander | ▒ | ■ | ■ | ■ | ▒ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ■ | ▒ | ■ | ■ |
| Increased or decreased stream stability | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ■ | ■ | ■ |
| Increased stream migration | ■ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ■ |
| Channel widening and downcutting | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ■ | ■ | ■ |
| Increased stream gradient and reduced energy dissipation | ▒ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ■ |
| Increased or decreased flow frequency | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ▒ | ■ | ▒ | ▒ | ■ |
| Reduced flow duration | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ■ | ■ |
| Decreased capacity of floodplain and upland to accumulate, store, and filter materials and energy | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ■ | ■ |
| Increased levels of sediment and contaminants reaching stream | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ■ | ▒ | ■ | ■ | ■ | ■ | ■ |
| Decreased capacity of stream to accumulate and store or filter materials and energy | ▒ | ■ | ■ | ■ | ▒ | ▒ | ■ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ■ | ■ |
| Reduced stream capacity to assimilate nutrients/pesticides | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ■ |
| Confined stream channel w/little opportunity for habitat development | ▒ | ■ | ■ | ■ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ |

■ Activity has potential for direct impact.

▒ Activity has potential for indirect impact.

***Table 3.3: Potential effects of major land use activities (continued)***

| Potential Effects | Disturbance Activities: Vegetative Clearing | Channelization | Streambank Armoring | Streambed Disturbance | Withdrawal of Water | Dams | Levees | Soil Exposure or Compaction | Irrigation and Drainage | Contaminants | Hard Surfacing | Overgrazing | Roads and Railroads | Trails | Exotic Species | Utility Crossings | Reduction of Floodplain | Dredging for Mineral Extract. | Land Grading | Bridges | Woody Debris Removal | Piped Discharge/Cont.Outlets |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Increased streambank erosion and channel scour | ■ | ■ | ▒ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ■ | ■ |
| Increased bank failure | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ■ | ■ |
| Loss of instream organic matter and related decomposition | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ▒ |
| Increased instream sediment, salinity, and turbidity | ■ | ■ | ▒ | ■ | ▒ | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ |
| Increased instream nutrient enrichment, siltation, and contaminants leading to eutrophication | ■ | ▒ | ▒ | ■ | ▒ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ■ | ■ |
| Highly fragmented stream corridor with reduced linear distribution of habitat and edge effect | ■ | ■ | ■ | ▒ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ■ | ■ | ▒ |
| Loss of edge and interior habitat | ■ | ■ | ■ | ■ | ▒ | ▒ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ▒ | ■ | ▒ | ■ | ■ | ■ | ▒ | ■ | ▒ |
| Decreased connectivity and width within the corridor and to associated ecosystems | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ |
| Decreased movement of flora and fauna species for seasonal migration, dispersal, and population | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ |
| Increase of opportunistic species, predators, and parasites | ■ | ■ | ■ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ▒ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ■ |
| Increased exposure to solar radiation, weather, and temperature extremes | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ▒ | ■ | ▒ |
| Magnified temperature and moisture extremes throughout the corridor | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ |
| Loss of riparian vegetation | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ▒ |
| Decreased source of instream shade, detritus, food, and cover | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ■ | ▒ |
| Loss of vegetative composition, structure, and height diversity | ■ | ■ | ■ | ▒ | ■ | ▒ | ■ | ▒ | ■ | ▒ | ■ | ■ | ■ | ▒ | ■ | ▒ | ■ | ■ | ▒ | ▒ | ▒ | ▒ |
| Increased water temperature | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ▒ |
| Impaired aquatic habitat diversity | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ▒ | ▒ | ■ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ■ |
| Reduced invertebrate population in stream | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ■ | ▒ | ▒ | ■ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ■ |
| Loss of associated wetland function including water storage, sediment trapping, recharge, and habitat | ▒ | ■ | ▒ | ■ | ■ | ■ | ■ | ▒ | ■ | ▒ | ■ | ■ | ■ | ▒ | ■ | ▒ | ■ | ■ | ■ | ▒ | ▒ | ▒ |
| Reduced instream oxygen concentration | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ■ |
| Invasion of exotic species | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ■ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ■ |
| Reduced gene pool of native species for dispersal and colonization | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ▒ | ▒ | ▒ | ▒ | ■ | ▒ | ▒ | ■ | ▒ | ■ | ▒ | ▒ | ▒ | ■ | ▒ |
| Reduced species diversity and biomass | ■ | ■ | ■ | ■ | ■ | ▒ | ■ | ■ | ■ | ▒ | ■ | ■ | ▒ | ▒ | ■ | ▒ | ■ | ▒ | ▒ | ▒ | ■ | ▒ |

■ Activity has potential for direct impact.

▒ Activity has potential for indirect impact.