Adirondack River Discharge During the Last Century

By JEFFREY R. CHIARENZELLI

Introduction

While the effects of climate change since the end of the last Ice Age are varied and imperfectly understood, one of the most fundamental changes in terms of the history of civilization is the variation in the amount of water available for human use. Indeed, the collapse of some civilizations appears to be directly related to diminished water resources, drought, and associated environmental change (Diamond 2005). Zhang et al. (2007) provide the first evidence of human-induced changes in global precipitation patterns. While models of global temperature and precipitation trends are becoming more sophisticated, the prediction of local, or even regional, changes from global climate models with coarse gridding[1] is problematic (Smith et al. 2006). While global climate models are important for examination of global trends in climate, they reduce the entire Adirondack region to a single data point or portion thereof.

The amount of water available for use by plants, animals, and humans in any given location depends upon many intra- and extra-basinal factors. These include climatic and meteorological (evaporation, precipitation, temperature, seasonality, sunlight, etc.), geological (elevation, slope, permeability, infiltration rates, storage, material properties, etc.), and biological (land cover, species, transpiration rates, etc.) factors, among others. Many of these factors are notoriously difficult to accurately measure or estimate. For example, evaporative loss in a given area is estimated by measuring evaporation rates from a metal pan and has a high uncertainty (Dingman 2002). In contrast, discharge is easily measured and has been monitored in many waterways in the United States for decades (Slack and Landwehr 1992; Wahl et al. 1995).

In many regions of the United States and the world humans have had a great impact on the hydrologic cycle (Lins 2005). In particular, the withdrawal of surface water and, especially, ground water for irrigation and domestic and industrial use can lower the water table by tens, or even hundreds, of feet, rapidly depleting water stored for hundreds or thousands of years. The Adirondack region has seen relatively little anthropogenic impact on the hydrologic cycle because rainfall and snow melt are plentiful, population is sparse, vast tracks of land are uninhabited, and there is minimal agriculture, industry (except logging), and manufacturing. The continued use of century-old, often hand dug, shallow wells and perennially damp basements confirm shallow water tables over many decades. Nonetheless the influence of flood control, water diversion, and hydroelectric dams on discharge may be locally important.

Previously in this journal Stager and Martin (2002) summarized trends in precipitation and temperature from select weather stations in the Adirondack region over a 75-year period (1926–2000). Their main finding is that the Adirondack region is not in lockstep with global climate trends, emphasizing the utility of empirical data, from specific sites, in order to accurately assess local conditions. They demonstrate that weather conditions in the Adirondacks, specifically at the Wanakena Ranger School, have changed relatively little thus far. Herein the variation in the discharge of Adirondack rivers is investigated. These trends are used to evaluate annual, seasonal, and monthly trends in discharge over half-century to century-long (62–101 years) time spans (Neuroth and Chiarenzelli 2007) and the last 30 years.

Methodology

The United States Geological Survey is charged with maintaining stream discharge records for the nation. This program began in 1889 and has grown to include more than 7000 stations (Wahl et al. 1995). Stream flow records have many uses including the management and prediction of floods, determination of contaminant and nutrient inputs, delineation of flood plains, reservoir and hydroelectric plant management, highway, culvert, and bridge design, and the allocation of water, among others. The uncertainty in discharge is a function of the variability of stream flow in a given area and the length of record keeping. Because natural cycles of precipitation longer than a decade have been observed, record lengths of greater than 30–50 years are required to detect trends related to human activity or global warming (Wahl et al. 1995; Lins 2005). Approximately 1650 stations in the United States Geological Survey database are suitable for trend analysis to determine the impact of climate change on the hydrologic cycle (Slack and Landwehr 1992).

The discharge gauging stations investigated (Figure 1) were selected based on the completeness of their records and geographic coverage of the Adirondack region (USGS 2008). Note that some rivers (Black, Mohawk, Sacandaga) include areas within their drainage basins

Jeffrey R. Chiarenzelli is an associate professor in the Department of Geology at St. Lawrence University. He may be reached at jchiaren@stlawu.edu.

---

[1] Typical grids cover 1° to 2.5° of latitude and longitude.

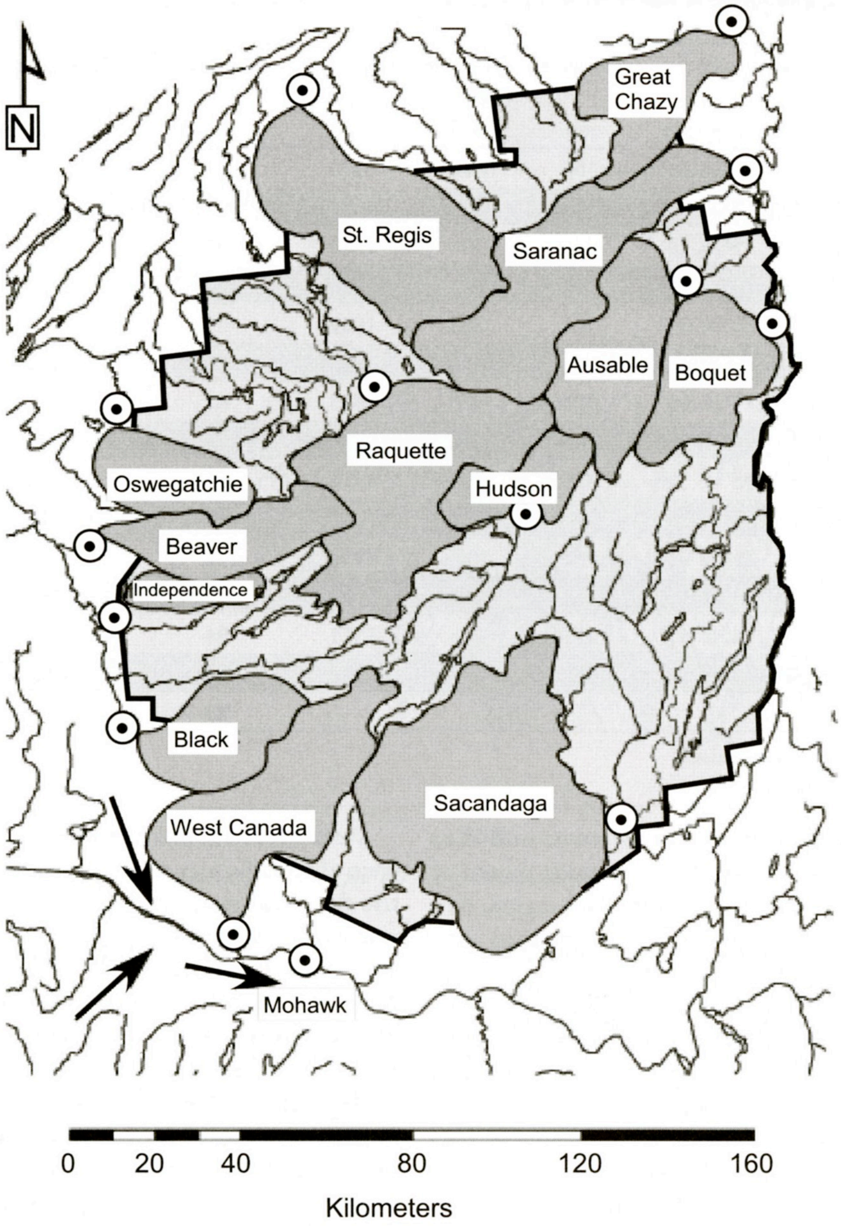


Figure 1. *Location of discharge gauging stations and associated drainage basins investigated during this study.*

that fall outside of the Adirondack Blueline. Figure 1 shows the location and size of each drainage basin analyzed during this study. Table 1 gives the location and elevation of gauging stations, the area of drainage basins, and the duration of record keeping for both long-term (62–101 years) and short-term (30 years) stations, respectively.[2]

Mean and standard deviation were calculated for annual, seasonal, and monthly discharge for long-term time spans and the last 30 years at each Adirondack gauging station using Excel.[3] The trends have been investigated by the use of correlation coefficients and trend lines on derived charts. Changes have been evaluated using both percent change and raw volume in cubic feet per second.

Quality Control

A number of quality control issues must be evaluated here including the overall quality, completeness, and representativeness of the data. Also, the statistical validity of any of the trends observed must be assessed. Given the long experience (Wahl et al. 1995) and internal quality control of the United States Geological Survey, it is assumed that the records used here accurately reflect river conditions.

A critical question is whether or not a sufficient period of record keeping is available for the evaluation of long-term trends. Five Adirondack gauging stations are included in the HydroClimatic Data Network[4] that includes rivers with continuous discharge records sufficiently long to be influenced by climatic fluctuations. Some Adirondack rivers with long discharge records were not selected as part of the HydroClimatic Data Network because of water regulation by hydroelectric dams. Here they are included so that discharge trends for most of the region, over an extended time period, can be evaluated. Despite the possible inaccuracies in some data sets, it is useful to evaluate long-term changes over the entire region.

A related question is whether the discharge measurements made are truly representative of the flow of the rivers in question. In other words, have large amounts of water been removed or

---

[2] Climatic variations depend on long-term records of at least 30–50 years (Wahl et al. 1995; Lins 2005) . The completeness of the annual discharge record is given in Table 1; calendar years were judged complete if data was available for each month. Note that several substantial gaps occur in the recent data at the Ausable, Boquet, Great Chazy, Hudson, and St. Regis stations, limiting their use for short-term trends.

[3] Data available from the United States Geological Survey at http://waterdata.usgs.gov/usa/nwis/sw.

[4] The United States Geological Survey has established the HydroClimatic Data Network consisting of over 1600 stream gages where discharge is primarily influenced by climatic variations (Slack and Landwehr 1992). Only 15 of these gages, however, have records that extend 90 years or more, thus limiting most estimates for stream flow to the last two-thirds of the previous century (Lins 2005).

Table 1. *Location, elevation, drainage basin area, and period of record keeping of discharge stations utilized in this study.*

River	Station Location	USGS	Coordinates		Elevation	Drainage Basin	Initiation	Duration	Completeness
		Station #	latitude	longitude	feet	mi^2	year*	years	%
Ausable	Ausable Forks	**4275500**	44°27′05″	73°38′35″	506	446	1916	89	74
Beaver	Croghan	4258000	44°53′50″	75°24′16″	806	291	1931	74	100
Black	Boonville	4252500	43°30′42″	75°18′25″	936	304	1912	93	100
Boquet	Willsboro	**4276500**	44°21′30″	73°23′50″	151	270	1924	81	72
Great Chazy	Perry Mills	4271500	45°00′00″	73°30′05″	165	243	1929	76	70
Hudson	Newcomb	1312000	43°57′58″	74°07′52″	1550	192	1926	79	77
Independence	Donnattsburg	**4255000**	43°44′50″	75°20′05″	973	89	1943	62	100
Mohawk	Little Falls	1347000	43°00′53″	74°46′47″	309	1342	1928	77	100
Oswegatchie	Harrisville	**4262500**	44°11′08″	75°19′52″	739	258	1917	88	100
Raquette	Piercefield	4266500	44°14′05″	74°34′20″	1502	721	1909	96	100
Sacandaga	Stewart's Bridge	1325000	43°18′41″	73°52′04″	582	1055	1931	74	100
Saranac	Plattsburgh	4273500	44°40′54″	73°28′18″	156	608	1904	101	86
St. Regis	Brasher Center	**4269000**	44°51′49″	74°46′45″	217	612	1911	94	96
West Canada	Kast Bridge	1346000	43°04′08″	74°59′19″	439	560	1921	84	100
Average								**83**	**91**

* Year shown is first year for which annual discharge can be determined.
USGS stations in bold are part of the Hydroclimatic Data Network.

added to the rivers? The Adirondack region is sparsely populated[5] and does not provide substantial water for irrigation, industry, or agriculture. Nonetheless, temporary storage of water in reservoirs and small dams for hydropower, minor diversions for municipal and prison systems, and historic spring logging runs do occur and may impart trends in the discharge data not entirely reflective of natural "run of the river" conditions. Most important among these are diurnal variations due to fluctuation of power demands on hydrostations and storage or release of water to maintain reservoir water levels. While this imparts uncertainty to shorter-term records (particularly daily and diurnal records), longer records are less likely to be affected.

Perhaps the most serious quality control considerations are gaps in record keeping. Eight of the 14 stations investigated here have essentially complete coverage (100%) since their initiation (Table 1). Other stations generally have 70% or more completeness and thus provide a nearly continuous record of discharge in the Adirondack region. As a group, the entire data set analyzed has a completeness of 91%.

Another important question is the statistical validity of any trends identified in the discharge data. The approach taken is simplistic in terms of evaluating time-series trends; the discharge (y-axis) was plotted against calendar year (x-axis) for each river and the trend-line and correlation coefficient determined. Because the trends were relatively weak and corresponding squares of the correlation coefficient are low, confidence in the observed relations in any given river system is also low. The high correlation of discharge trends[6] observed among rivers in the same area suggests, however, that the long-term trends observed are meaningful.

Perhaps the ultimate test of the influence of local factors such as hydroelectric dams and reservoirs or diversion of water is whether or not rivers in the region show similar trends over extended time periods. This analysis assumes of course that the region in question has many similarities in terms of climate, geology, and biology. This similarity is broadly true for the Adirondack region that lies within the Blueline and shares a common climate, geology dominated by crystalline rocks and thin, glacially derived soils, and similar ecosystems. Figure 2 plots the discharge of all fourteen rivers during their period of measurement. Note that period of enhanced and low flows can easily be correlated over the 100-year measurement period. As can be seen, the resemblance between the patterns is striking. This suggests that across the greater Adirondack region, natural trends, rather than local factors such as reservoirs, dams, and water withdrawals, play the overwhelming role in determining discharge and the long-term trends observed are real.

---

[5] The full-time population of the 6 million acre park is less than 200,000 people (Jenkins and Keal 2004).

[6] The correlation coefficient of the annual discharge of Ausable River compared with nearby rivers also draining into Lake Champlain ranged from 0.96 (Boquet) to 0.93 (Saranac) over the period of data collection.

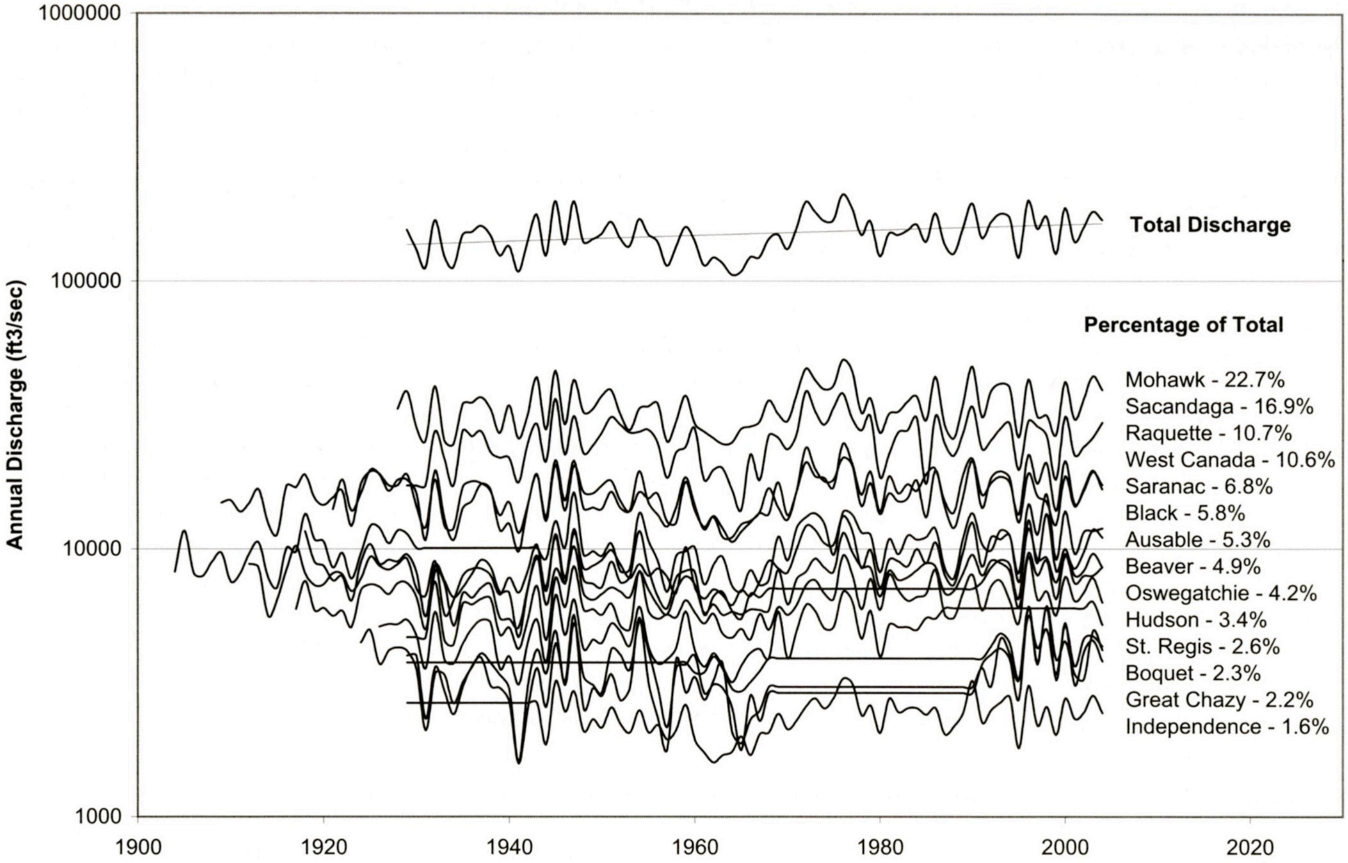


Figure 2. *Annual discharge trends for all 14 Adirondack rivers over their respective periods of measurements. Straight-line segments represent gaps in record keeping.*

Results and Discussion

Annual Trends in Discharge. Of the fourteen rivers investigated all show an increase (avg. 19.2 ± 10.5%; Table 2) in discharge over their period of observation (62–101 years). The Beaver, Black, and Great Chazy have greater increases (32.8–42.7%), while the increases shown by the Ausable, St. Regis, and West Canada are substantially less (4.9–7.9%) than average. Some of this variability is likely related to the different periods of observation at each station; nonetheless, the relatively low standard of deviation suggests the observed increase is real and significant over the long term. No significant correlation was found between drainage basin area, elevation, or location and annual discharge.

Conversely, over the last 30 years only three of 10 rivers have positive increases in discharge (0.4–8.8%), while the remainder have negative discharges (–14.8% to –5.1%). On the average, the decrease in discharge has been –4.6 ± 6.6% (Table 2). Note that the Sacandaga River in the southern Adirondacks showed the greatest loss (–14.8%) while the Saranac River in the northeast Adirondacks showed the greatest gain (8.8%). This hints at possible local differences in discharge over the last 30 years within the Adirondack region.

Despite an average decrease in discharge of approximately –4.6% during the last 30-year period (1975–2004), the Adirondack rivers examined in this study display, on the average, a 19.2 ± 10.5% increase in discharge over their period of measurement, and all rivers show an increase. Given that annual long-term discharge measurements have been estimated to have an error of 3–10% (Shiklomanov et al. 2004) and ±5% (Winter 1981), this trend is believed to represent a real and significant increase in annual discharge. Since runoff or discharge is a function of precipitation minus evapotranspiration, this increase must be tied to an increase in precipitation, a decrease

Table 2. *Annual discharge variation over period of record keeping and last thirty years (1974–2004).*

River	Duration %	30 years %
Ausable	8	nd
Beaver	33	–9.6
Black	33	1
Boquet	17	nd
Great Chazy	43	nd
Hudson	19	nd
Independence	15	–8.8
Mohawk	16	–5.5
Oswegatchie	19	–6.8
Raquette	21	–5.1
Sacandaga	14	–14.8
Saranac	21	9
St. Regis	5	0
West Canada	5	–5.6
Average	19	–4.6
Std. Dev.	11	7

"nd" means not determined.

in evapotranspiration, or both over the period of measurement. Given the relatively minor temperature variation (–0.20–0.14°F/decade) noted for the Adirondack region (Stager and Martin 2002), it is unlikely that decreases in evaporation have occurred. This suggests increases in discharge are a function of increased precipitation.

Review of hydrographs of individual rivers clearly shows abrupt increases in discharge in the early 1940s and 1970s. These trends are enhanced when a moving average is used to help smooth out some of the year-to-year variability (Figure 3). These abrupt changes are also seen in most monthly hydrographs that span the period of record keeping. This observation is not surprising, as annual increases in precipitation must be reflected in monthly discharge values. An abrupt increase in discharge around 1970 in the United States has been noted previously by McCabe and Wolock (2002) and Lins (2005) and is thought to indicate a shift in conditions likely to persist through a complete cycle. The rapid increase also seen in the 1940s in the Adirondack region may indicate 30-year cyclicity in discharge trends. If the trend continues, a new cycle (2000s) may have begun. Data from the Mohawk River, which drains parts of the Adirondacks, Tug Hill Plateau, and Central New York, are in good agreement with long-term and short-term discharge trends for the Adirondack region, suggesting such trends may also occur over wider areas.

Seasonal and Monthly Trends in Discharge. If annual precipitation has indeed increased throughout the Adirondack region, it would be instructive to know when during the year the increases have occurred. For example, increases in winter precipitation could result in a thicker snow pack and enhanced spring discharge. Pooling of the discharge data into three-month[7] seasonal periods (Figure 4) suggests long-term annual gains in discharge are apparent in the fall (32.4 ± 12.4%), winter (23.0 ± 9.1%), and summer (19.6 ± 15.8%), while little or no gain is apparent in the spring (3.3 ± 11.3%). Longer-term trends indicate more rainfall in the summer and fall; winter trends, however, are more difficult to interpret. Increased discharge could be a function of more precipitation falling as rain or enhanced intermittent melting of the snow pack or both. Either of these

---

[7] Seasonal trends were evaluated by pooling December, January, and February (winter), March, April, and May (spring), June, July, and August (summer), and September, October, and November (fall) for each river.

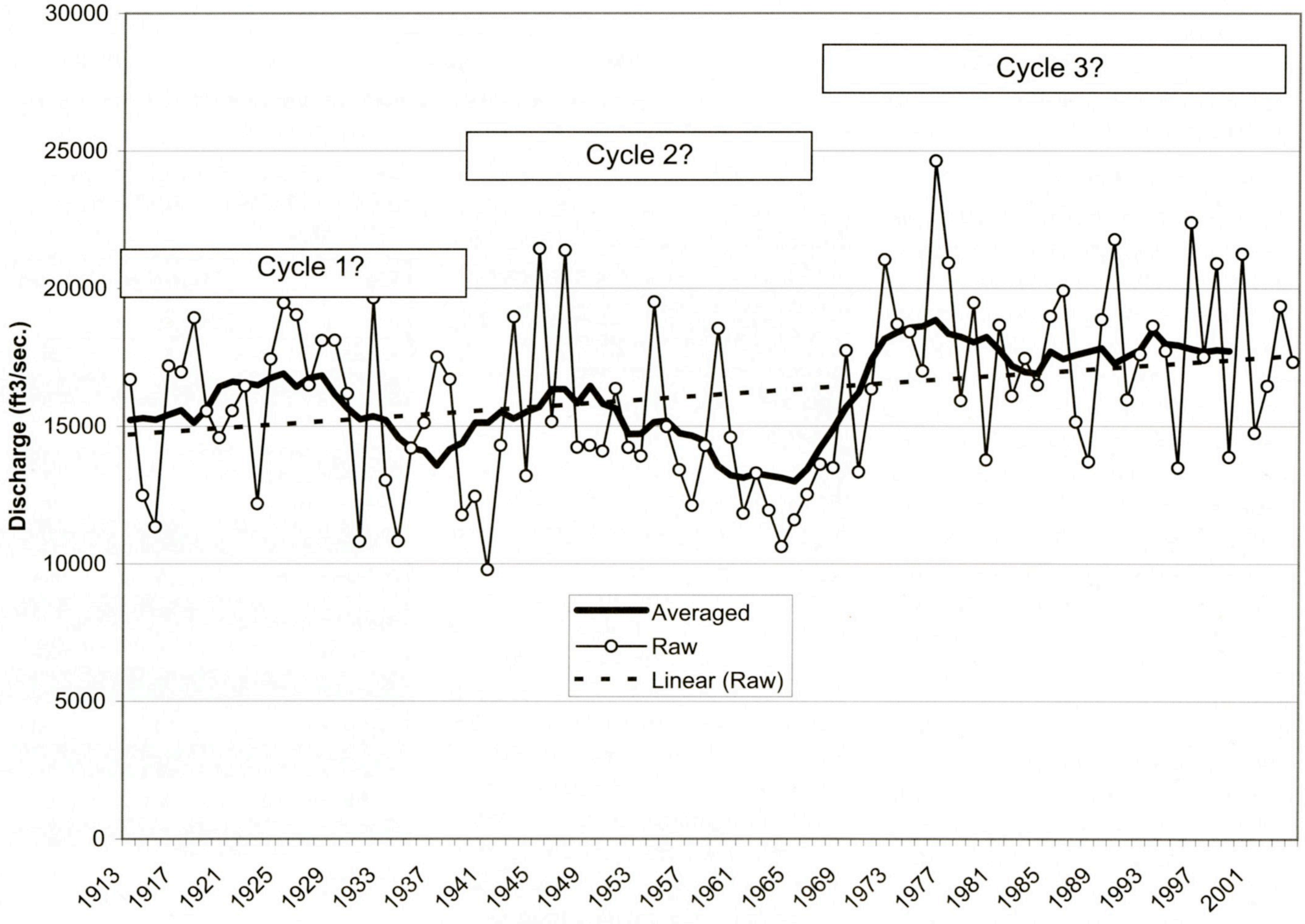


Figure 3. *Annual time series hydrograph for the Raquette River showing raw and time-averaged (10-year) data.*

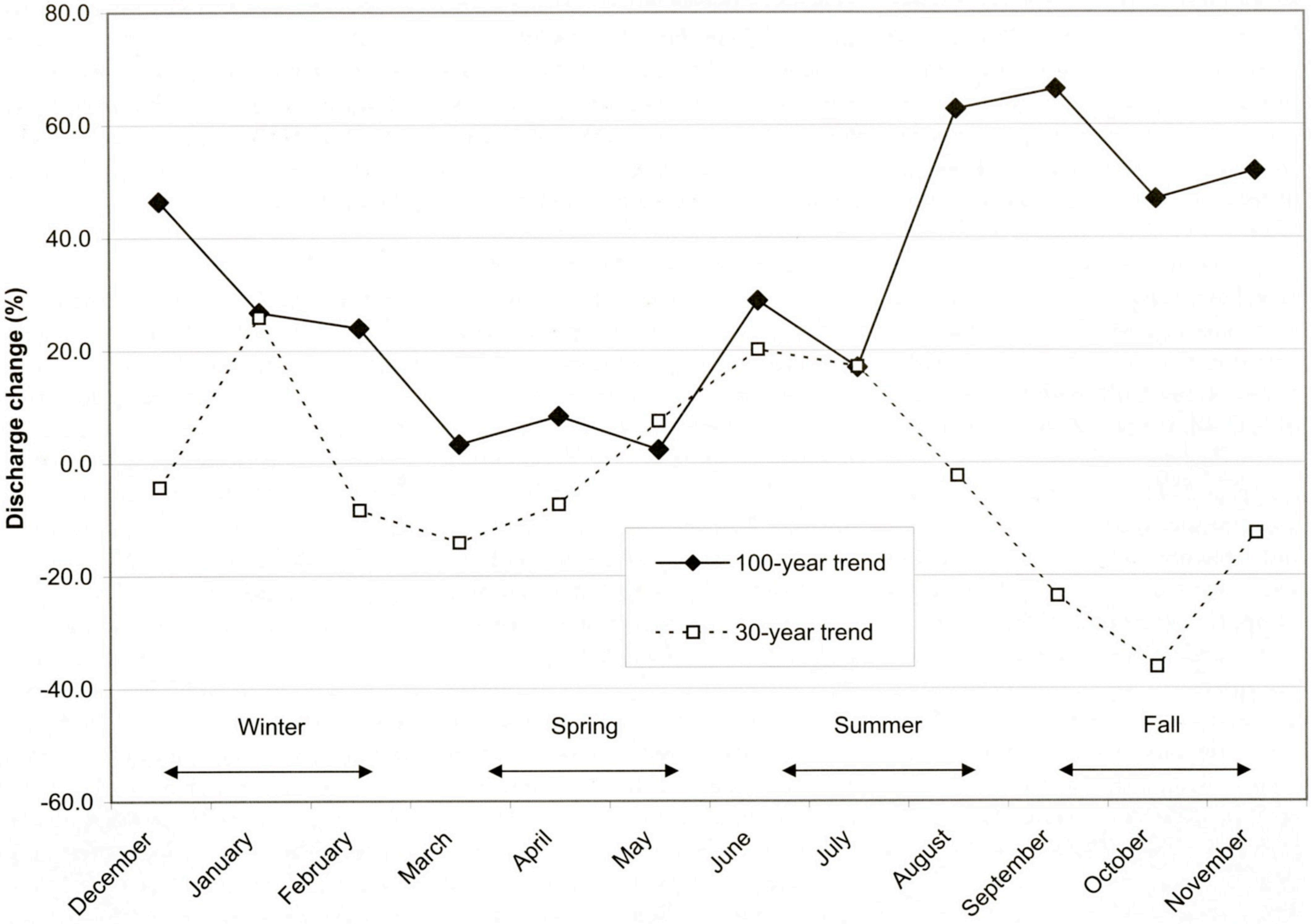


Figure 4. *Seasonal and monthly variations in Adirondack river discharge showing average long-term and short-term trends.*

options seems difficult to reconcile with the slight decline in temperature noted by Stager and Martin (2002).

Long-term monthly data suggest large gains in discharge for the fall months but smaller increases in winter and summer months (Figure 4). Spring month discharge has remained constant or has slightly increased. Although the variability among rivers is large, the average increase in discharge during the period of record keeping is greater than 40% for August–December and smaller than 7% for March–May. In general, gains in discharge are shown for 12 (out of 14) or more rivers during the fall and winter months but as few as six for the spring months (Neuroth and Chiarenzelli 2007).

Enhanced winter discharge without significant changes in mean winter temperatures could be caused by more extreme temperature variations. Available temperature data indicating little or no change in maximum and minimum temperatures (Stager and Martin 2002) do not support this possibility. Alternatively, water temporarily stored in aquifers, bank storage along rivers, and surface water bodies from enhanced precipitation in the fall could raise winter discharge volumes. The return of this water to rivers would be slowed and prolonged by freeze events and travel via groundwater pathways. This scenario would result in enhanced river base flow conditions during the winter months as precipitation stored during the fall is gradually released over time.

Given the relatively large increases in discharge apparent over the long term in the summer, fall, and winter, the relatively steady discharge of Adirondack rivers during the spring season is intriguing. Note that substantial gains in discharge (46–66%) have been measured for the months August–December over the period of recording keeping (Figure 4). Both January and February show increases of approximately 25%. While it is unlikely that these increases in discharge during the winter months are related to enhanced rainfall or snow pack melting, they may represent the hydrologic system's response to enhanced late summer and fall precipitation. Long-term trends indicate that discharge in March and April has remained nearly constant, despite enhanced winter discharge. Since peak discharge occurs in the spring, gains in long-term annual discharge have resulted in increases during times of low and moderate flow, primarily summer and fall.

Comparison of Local and Regional Trends. Numerous workers have noted changes in the hydrologic cycle over broad parts of the contiguous United States (Karl and Knight 1998; NERA 2001; Groisman et al. 2004; Lins 2005). As summarized by Lins (2005), in general, stream flow in the United States has been increasing since at least 1940 and in most instances it occurs in streams of low to moderate discharge. In most cases, stream minimum and median flows have increased, whereas maximum flows have not. Most increases have occurred in the Upper Mississippi, Ohio Valley, Texas Gulf, and Mid-Atlantic regions, while other regions experienced stream flow decreases. In the Upper Mississippi and Ohio Valley regions increases occur mostly during the late summer and September–December (Lins 2005). These trends appear to have begun as an abrupt change around 1970.

Adirondack regional data is in excellent agreement with trends reported for the Ohio Valley region and large parts of the contiguous United States. It also appears likely that the increases began earlier than 1940. In the Adirondack region both 1940 and 1970 appear to be times of change resulting in discrete "steps" in discharge as reported by McGabe and Wolock (2002). Likewise, increases in discharge are most evident in the late summer and fall, as spring discharges have been relatively constant. The most likely explanation for these changes are enhanced precipitation in the Adirondack region during the late summer and fall, resulting in enhanced winter base flow in streams and rivers draining the Adirondacks. This change, in turn, is apparently related to climatic factors that affect large portions of the United States (Lins 2005) and perhaps the world (Zhang et al. 2007).

Forecasting Water Management Issues. The temptation to forecast climatic changes is hard to resist (McKibben 2002; Stager and Martin 2002). Here it is instructive to point out several possible changes in the Adirondacks related to water and its availability. If current trends continue, particularly the 30-year cycle of precipitation and discharge stepwise increases, Adirondack rivers will experience record historic stream flows, particularly in the fall and winter, providing more water for all uses. We already are benefiting from annual flows about 20% greater than 100 years ago, with monthly averages up to 50–60% greater. While some may welcome the abundance of water for recreation and hydropower purposes, the questions remain, When will enhanced precipitation and discharge result in negative consequences? And what will they be?

One legitimate question is whether enhanced discharge will lead to more frequent or more intense flood events. A direct link to increased flooding seems unlikely, however, because Adirondack monthly discharge histograms indicate that historically the greatest discharge volumes occur in spring, which has seen little or no increase in discharge over the duration of record keeping or the last 30 years. Even with the annual increases observed, spring flow still dominates the annual cycle and remains the time most prone to significant flooding events.

Indirectly, however, more rain and discharge at any period of time leads to saturation of the soil and a reduced capacity for infiltration and greater tendency for runoff and severe erosion events, including landslides. If discharge continues to increase, water tables will rise and valuable shorelines will retreat. Engineering charts, culverts, bridges, etc., for the region may need to be updated to handle greater flows. Wetlands and marshy areas may become inundated. With greater fall and winter discharges, less and less stable ice cover on lakes and rivers is likely. Eventually changes in vegetation and fauna may occur as the ecosystem adjusts to the new conditions.

Although little evidence exists for warming temperatures in the Adirondack region at the present time, warming would have a significant impact on the hydrologic cycle. For example, changes in the snow pack because of milder winter temperatures may lead to further increases in winter discharge and perhaps even shifting of stream discharge histograms. In particular, times of maximum flow may shift earlier in the spring season. Such shifts, combined with a spring and summer with low precipitation, and enhanced evaporation, could set the stage for lower summer discharge during dry years.

Summary

Adirondack rivers show an average increase of about 20% in their annual discharge over the last 100 years. These increases have occurred largely during the summer, fall, and winter months, while discharge during the spring months has remained steady. It is concluded that enhanced winter discharge (approximately 20%) is caused by the gradual release of water temporarily stored during the fall, which shows an average increase in discharge of approximately 32% over the same time period. These changes in discharge are driven by real changes in the amount of precipitation in the Adirondack region and beyond. The trends identified here are in agreement with regional discharge trends reported by the HydroClimatic Data Network for small rivers in the Upper Midwest and Northeast. In particular, 30-year cycles of precipitation, punctuated by abrupt increases in discharge, have been identified. In the Adirondack region these cycles appear to have operated since at least the 1940s.

Acknowledgments

I gratefully acknowledge the initial work of the Spring 2006 Hydrogeology Class at SUNY Potsdam, where the ideas for this study germinated. Mark Neuroth followed up on this work as an independent study project during January 2007. Carol Cady (St. Lawrence University) is gratefully acknowledged for assistance with preparation of GIS depictions utilized for this project. Precipitation and temperature data for Wanakena was provided by Curt Stager of Paul Smith's College and Michael Martin of Cedar Eden Environmental, LLC. Insightful editing by Jon Erickson and R. V. Chiarenzelli are greatly appreciated.

References

Diamond, J. M. 2005. Collapse: How Societies Choose to Fail or Succeed. Viking Press, New York, 576p.

Dingman, S. L. 2002. Physical Hydrology. Prentice Hall, Upper Saddle River, New Jersey, 646p.

Groisman, P. Y., Knight, R. W., Karl, T. R., Easterling, D. R., Sun, B., and Lawrimore, J. H. 2004. Contemporary changes of the hydrologic cycle over the contiguous United States: Trends derived from in situ observations. *Journal of Hydrometeorology* 5: 64–85.

Jenkins, J., and Keal, A. 2004. An Adirondack Atlas: A Geographic Portrait of the Adirondack Park. Syracuse University Press and The Adirondack Museum, Syracuse, New York, 274p.

Karl, T. R., and Knight, R. W. 1998. Secular trends of precipitation amount, frequency, and intensity in the United States. *Bulletin of the American Meteorological Society* 79: 231–241.

Lins, H. F. 2005. Streamflow trends in the United States. National Streamflow Information Program: U.S. Geological Survey Fact Sheet 2005-3017, 4p.

McCabe, G. J., and Wolock, D. M. 2002. A step increase in streamflow in the conterminous United States. *Geophysical Research Letters* 29: 2185–2188.

McKibben, B. 2002. Future shock: the coming Adirondack climate. *Adirondack Life* (March/April): 51–57.

NERA. 2001. How Will the New England Region Be Affected by Climate Change? http://www.necci.sr.unh.edu/Nera-products/ccfacts.pdf.

Neuroth, M., and Chiarenzelli, J. 2007. Adirondack River trends over the past one hundred years. Northeastern Section of the Geological Society of America Annual Meeting, Durham, New Hampshire, 12–14 October, p. 61.

Shiklomanov, A., Lammers, R., Yakovleva, T., and Vorosmarty, C. 2004. Modeling the error of estimated river discharge in the Eurasian Pan-Arctic. American Geophysical Union Spring 2004 meeting, abstract H43A-01.

Slack, J. R., and Landwehr, J. M. 1992. Hydro-climatic data network: A U.S. Geological Survey streamflow data set for the United States for the study of climate variations, 1874–1988. United States Geological Survey Open File Report 92-129, 193p.

Smith, T. M., Yiu, X., and Gruber, A. 2006. Variations in annual global precipitation (1979–2004), based on the Global Precipitation Climatology Project 2.5° analysis. *Geophysical Research Letters* 33, L06705, doi:10.1029/2005GL025393.

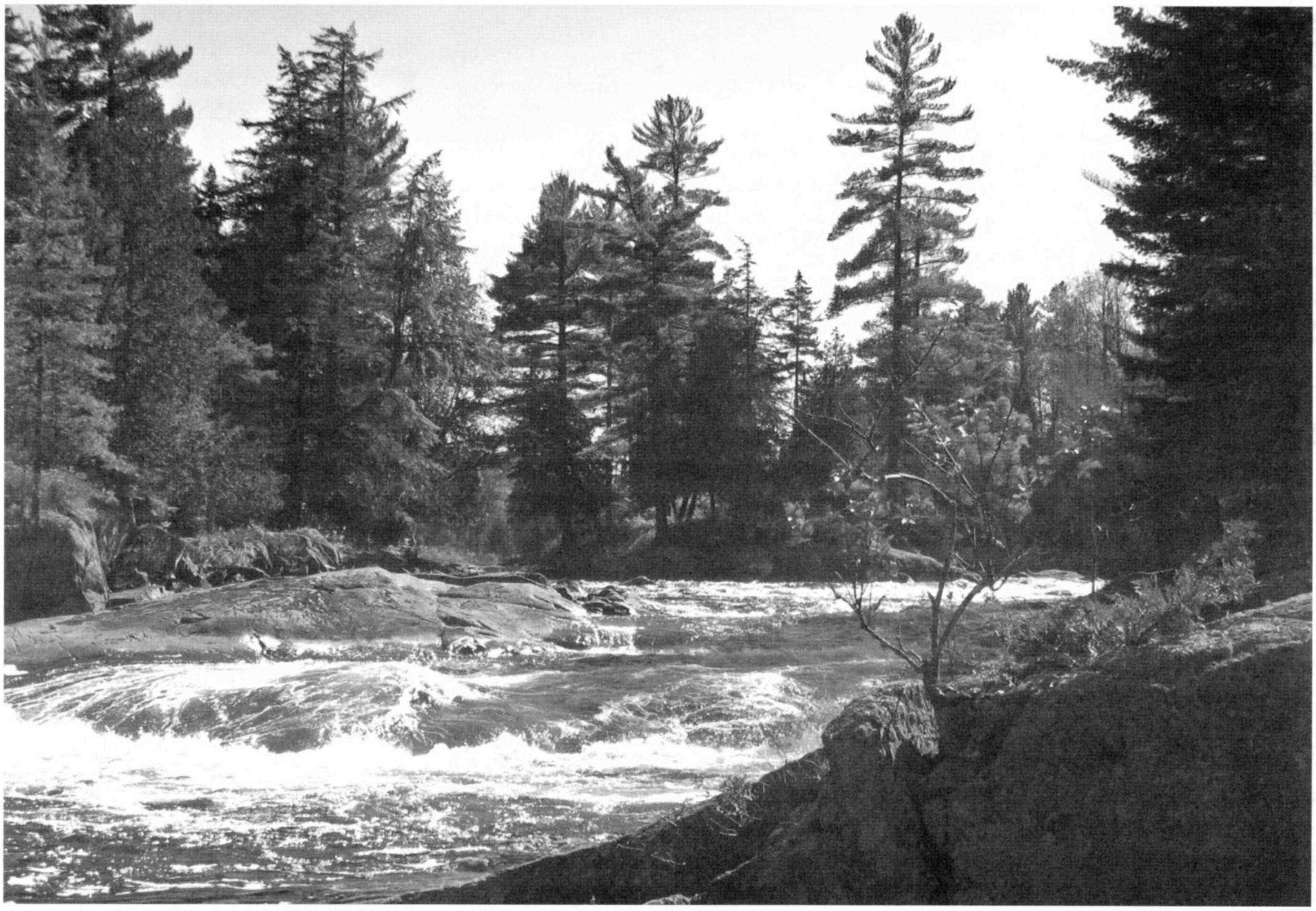
Stager, J. C., and Martin, M. R. 2002. Global climate change and the Adirondacks. *Adirondack Journal of Environmental Studies* 9: 6–13.

United States Geological Survey. 2008. National Water Information System: Web Interface, http://waterdata.usgs.gov/usa/nwis/sw/.

Wahl, K. L., Thomas, W. O., Jr., and Hirsch, R. M. 1995. Stream-Gaging Program of the U.S. Geological Survey, U.S. Geological Survey Circular 1123, Reston, Virginia.

Winter, T. C. 1981. Uncertainties in estimating the water balance of lakes. *Water Resources Bulletin* 17: 82–115.

Zhang, X., Zwiers, F. W., Hegerl, G. C., Lambert, F. H., Gillett, N. P., Solomon, S., Stott, P. A., and Nozawa, T. 2007. Detection of human influence on twentieth-century precipitation trends. *Nature* advance online publication 23 July 2007, doi:10.1038/nature06025.



Melissa J. Burchard

Raquette River at Jamestown Falls, some 15 miles downriver of the Piercefield USGS gaging station