PATUXENT RESERVOIRS:

"NATURAL" DAILY INFLOW DEVELOPMENT

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Abstract

The prior ICPRB set of daily inflows to the Patuxent reservoirs was examined and revised as necessary.

The prior ICPRB inflow data set for the Patuxent reservoirs was developed in three sections for water years 1913-1941, 1942-1944, and 1944-1997 using the area-adjustment method. Each section of the inflow data set was based on flow measurements from different gages in the watershed. These inflows were examined and discrepancies were noted during periods when gages used to develop the inflows overlapped.

Reference inflows were developed that represented the best available estimate of inflow to the reservoir. The reference inflows were based on gages that were located close to the site of the existing dam, or on gages that measured flow from all of the major tributaries to the reservoirs. Reference inflows thus incorporated measured flow information from the widest possible portion of the reservoir watershed. Reference flows were used as a yardstick against which the reservoir inflows could be compared.

The following changes were made:

1. Starting in October of 1939, there were out-of-basin diversions above Burtonsville gage. The prior inflow record did not account for the out-of-basin transfers. The Burtonsville-based inflow record was adjusted to account for the diversions between October of 1939 through September 1941. The adjusted record was **2.8 percent** higher than the prior ICPRB record, on average.

2. The prior inflow for October 1, 1941 through September 30, 1944 was based on the Little Patuxent River near Guilford gage. An alternative inflow was developed that was based on the Little Patuxent River near Savage gage. The Savage-based inflow was found to be closer to the reference inflow than the Guilford-based inflow. Therefore, Savage gage was selected for use during the period 1941-1944. The Savage-based inflow was **5.1 percent less** than the prior ICPRB record, on average.

3. From October 1, 1944 through June 6, 1978 the prior inflow record to the Patuxent reservoirs was based on gage flows on the Patuxent River at Unity (Unity gage). The prior Unity-based inflow was **decreased by 1.2 percent** to develop an inflow record that better represents the reference inflow, per the comparison described below.

4. From June 7, 1978 through September 30, 1997 the prior inflow record was based on Unity gage. An inflow based on the Patuxent River at Unity, Hawlings River near Sandy Spring, and Cattail Creek near Glenwood gages was instead developed. The average Unity-Hawlings-Cattail-based inflow **was 1.2 percent less** than the Unity-based inflow.

1. Introduction

The Patuxent reservoir system consists of Brighton Dam, which impounds Triadelphia Reservoir, and T. Howard Duckett Dam and Reservoir. The 132 square-mile watershed spans Howard, Montgomery, and Prince George's counties in Maryland (Figure 1), and is about 14 miles north of the northernmost tip of Washington D.C. The reservoirs are owned and operated by the Washington Suburban Sanitary Commission (WSSC). The two reservoirs have a combined usable capacity of approximately 9.1 billion gallons. Triadelphia reservoir is located upstream of T. Howard Duckett Reservoir, but the reservoirs were treated as a single reservoir system so that a single inflow data record could be developed.

The Co-op Section of the Interstate Commission on the Potomac River Basin (ICPRB) maintains inflow records for the reservoir as part of its mission for efficient utilization of all available water supply facilities for the Washington Metropolitan Area, particularly during drought periods.

Throughout the historical gage-record there were no gages directly measuring the inflow to the Patuxent reservoirs. However, a record of "natural" daily inflows was constructed for the period from August 1, 1913 through September 30, 1997 using the area-adjustment method. The inflow record that was developed is called "natural" because it represents those inflows to the reservoir that would have occurred without upstream withdrawals, diversions, or reservoir regulation.

Area-adjustment factors were applied when a gage located within the reservoir watershed measured flow from a smaller drainage area than that of the reservoir watershed. Measured flow from the gaged drainage area was increased by an amount equal to the area of the larger reservoir watershed divided by the area of the gage station watershed:

$$\frac{(Gaged\ flow) * (Area\ of\ reservoir\ watershed)}{(Area\ of\ gage\ station\ watershed)}$$

The area-adjustment method tends to over-predict peak flows and under-predict recession flows because of differences in the time-of-concentration between the smaller gaged watershed and the reservoir watershed. Over a longer interval (i.e., weeks) differences cancel when the runoff produced per unit area is equivalent. (An underlying assumption of the area-adjustment procedure is that each part of the reservoir watershed is equally productive.) Although the area-adjustment method is appropriate for predicting the total volume of inflow to the reservoir over time, this technique is not appropriate for estimating the timing and magnitude of *peak* flows into the reservoir. Therefore, the inflow record created using this method should not be used to analyze the magnitude or frequency of peak daily flow events (e.g., as for flood risk analysis). This inflow record was instead developed and validated for use in simulation models that perform volumetric accounting of reservoir contents, for water supply planning purposes.

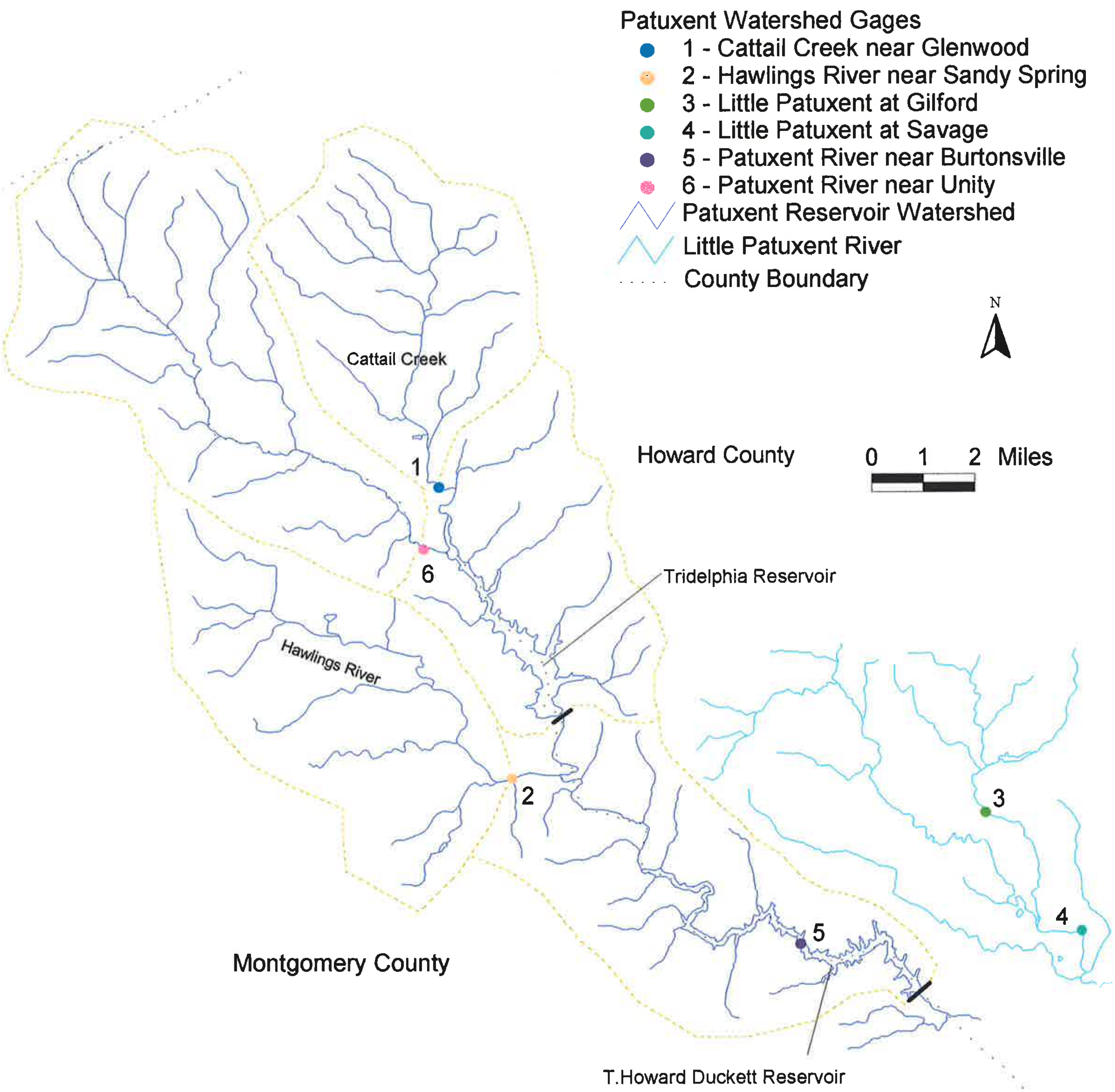

Figure 1: Patuxent reservoir watershed and neighboring tributaries, USGS gaging stations, county boundaries, and sub-watersheds

2. Examination of prior inflow data set

The prior ICPRB inflow data set for the Patuxent reservoirs was developed in three sections for years 1913-1941, 1941-1944, and 1944-1996 using the area-adjustment method. Each section of the inflow data set was based on flow measurements from different gages in the watershed. These inflows were examined and discrepancies were noted during periods when gages used to develop the inflows overlapped.

1913-1941

The 1913-1941 inflow was based on area-adjustment applied to the Patuxent River near Burtonsville (Burtonsville gage). Natural flows at Burtonsville gage after September 1941 were corrupted by the influence of the newly constructed Triadelphia Reservoir upstream, so a different gage was used to develop inflows after September 1941.

Starting in October of 1939, there were small out-of-basin diversions above Burtonsville gage. The average out-of-basin transfer was 2.4 cfs (2.8 percent of total flow) during the period October 1939 through September 1941. The prior inflow record did not account for the out-of-basin transfers. The Burtonsville-based inflow record was increased by the average monthly values as listed in Appendix A to account for the diversions.

1941-1944

The 1941-1944 inflow was based on area-adjustment applied to Little Patuxent River at Guilford gage (Guilford gage), which measures flow from a tributary of the Patuxent River that is outside of the reservoir watershed and that drains an area of 38.0 square miles. The Guilford-based inflow was compared with the Burtonsville-based inflow during the period October 1939 through October 1941. The average Burtonsville-based inflow was 14.9 percent lower than the average Guilford-based inflow. (Note that the out-of-basin diversions were added to the Burtonsville flow record prior to this comparison.) Figure 2 shows an example hydrograph of the Guilford-based and Burtonsville-based inflows. The Guilford-based inflow tracks well with the Burtonsville-based inflow but is nearly always higher.

1944-1996

The 1944-1996 inflow was based on flows recorded at Patuxent River near Unity, Maryland gage (Unity gage). The Unity-based inflow was compared with the Guilford-based inflow during the period July 1944 through September 1996. The average Guilford-based inflow was 3.1 percent higher than the average Unity-based inflow.

Summary of comparisons

The Guilford-based inflow was 14.9 percent higher than the Burtonsville-based inflow, and 3.1 percent higher than the Unity-based inflow. Ideally, these independent calculations of inflows would have matched exactly during overlapping periods. These differences were a cause for concern and led to changes in how the inflow data set was calculated, as detailed in the *Inflow Development* section, following.

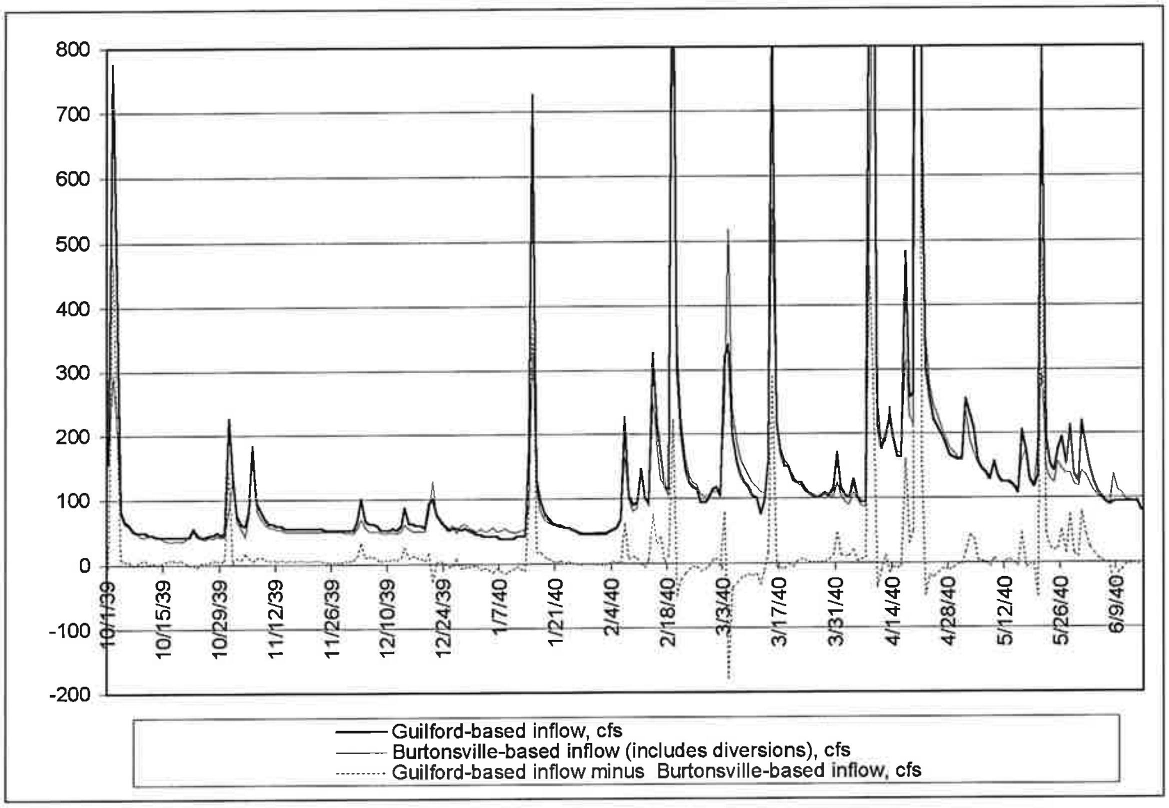

Figure 2: Example hydrograph comparing Guilford- and Burtonsville-based flow

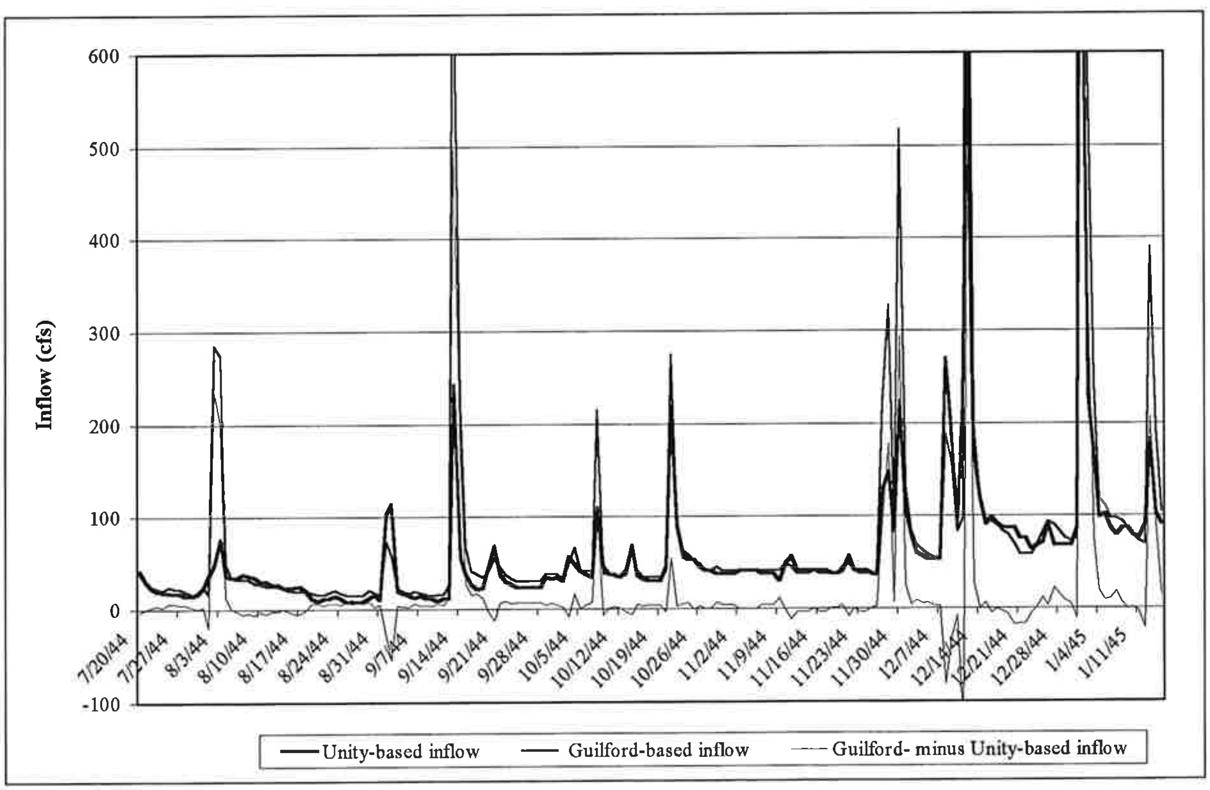

Figure 3: Example hydrograph comparing Guilford- and Unity-based flow

3. Inflow development

Table 1 summarizes the different stream gages and time periods used in the development of each segment of the Patuxent reservoir inflow record.

Table 1: Stream gages used to develop the Patuxent reservoir inflow record

Inflow period of record	U.S.G.S. stream gages used for record generation	Gage number	Drainage Area (Sq. miles)
8/1/1913 - 9/30/1941	Patuxent River near Burtonsville	01592000	127
10/1/1941 - 9/30/1944	Little Patuxent River at Savage	01594000	98.4
10/1/1944 - 6/6/1978	Patuxent River near Unity	01591000	34.8
6/7/1978 - 9/30/1996	• Patuxent River near Unity • Hawlings River near Sandy Spring • Cattail Creek near Glenwood	01591000 01591700 01591400	34.8 27.0 22.9

Reference inflows

Reference inflows were used as a yardstick against which the reservoir inflows could be compared during overlapping gage periods. Reference inflows represented the best available estimate of inflow to the reservoir since they were either based on gages that were located close to the site of the existing dam, or that measured flow from all of the major tributaries to the reservoirs. Reference inflows thus incorporated gaged flow information from the widest possible portion of the reservoir watershed.

Two reference inflows were developed. The Burtonsville-based flow was selected as a reference inflow since it was located just above the site of the lower dam, T. Howard Duckett. Starting in June of 1978, three gages were active upstream of the Patuxent reservoirs (Patuxent River at Unity, Hawlings River near Sandy Spring, and Cattail Creek near Glenwood). The combined Unity-Hawlings-Cattail-based inflow was considered a reference inflow to the reservoirs because this inflow includes measurement of runoff from all major tributaries to the reservoirs.

The development of each component of the inflow record, throughout the simulation period, is described below.

1913-1941

The inflow record to the Patuxent reservoirs from August 1, 1913 to September 30, 1941 was developed based on the stream flows measured at the Burtonsville gage. The Patuxent reservoirs have a drainage area of 132 square miles, while the gage on the Patuxent River near Burtonsville has a drainage area of 127 square miles (all within the reservoir drainage area). Therefore, the record of estimated inflow to the Patuxent reservoirs was obtained by multiplying the gage flows by an area adjustment factor of 1.039 = (132 ÷ 127).

Before applying the area-adjustment to the Burtonsville gage record, the Burtonsville gage record was corrected to account for the out of basin transfers as described in the section, *Examination of prior inflow data set.*

1941-1944

The prior record for 1941-1944 was based on the Guilford gage, which is located outside of the reservoir watershed. As shown in the section above, *Examination of prior inflow data set*, the Guilford-based inflow was 14.9 percent higher than the Burtonsville-based inflow (the best available estimate of inflow). Therefore, an alternative gage site was explored as the basis for the 1941-1944 inflow.

The Savage gage on the Little Patuxent River (Savage gage) was downstream of the Guilford gage, and measured flow from a larger drainage area (98.4 square miles) than Guilford Gage (38 square miles). Because the Savage gage drainage-area is closer in size to the drainage area of the Patuxent reservoirs than Guilford gage's drainage area, the Savage gage was considered more likely to better represent Patuxent reservoir watershed inflow. An inflow based on the Savage gage was developed and compared to the Burtonsville-based reference inflow during the period October 1939 through September 1941. The average Savage-based inflow was 6.3 percent higher than the average Burtonsville-based reference inflow during this period. The Savage-based inflow was closer to the best estimate of inflow than the prior Guilford-based inflow, which was 14.9 percent higher. Therefore, Savage gage was selected for use during the period 1941-1944.

The Savage gage overlapped with the Burtonsville gage for a relatively short period of two years. Fortunately, the Savage gage record overlapped with the Unity-Hawlings-Cattail Creek gage records over a 22 year period, so the Savage-based inflow could be compared to the Unity-Hawlings-Cattail reference inflow over a longer time interval. Longer comparison intervals were considered likely to be a better basis for comparison (e.g., effects of local summertime thunderstorms would more likely cancel out over a longer time interval). The Savage-based inflow was compared to the Cattail-Unity-Hawlings reference inflow during the period May 16, 1975 through September 30, 1997. The average Savage-based inflow was within 0.6 percent of the average reference inflow during this period, indicating that there were no real differences in productivity between the two basins and thus no need to adjust the Savage-based inflow to account for differences in basin productivity.

The record of estimated inflow to the Patuxent reservoirs from October 1, 1941 to September 30, 1944 was obtained by multiplying the Savage gage flows by an area adjustment factor of 1.341 = (132 ÷ 98.4). Figure 4 shows an example hydrograph comparing the Savage-based inflow with the best available estimate of inflow (Cattail-Unity-Hawlings gage). Ideally, these independent calculations of inflow would match well. Figure 4 illustrates that the Savage-based flow well approximates the reference inflow.

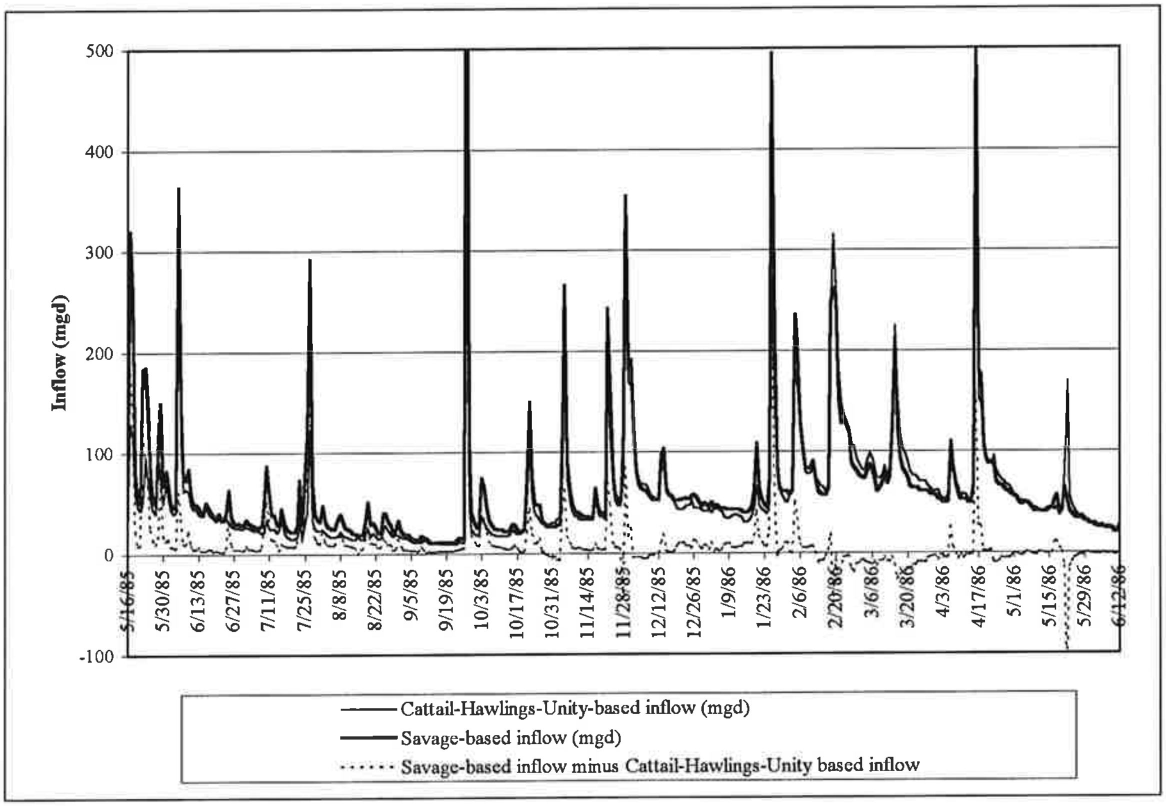

Figure 4: Example hydrograph comparing adjusted Savage-based inflow and Cattail-Unity-Hawlings-based inflow (best available estimate of inflow)

1944-1978

A stream gage on the Patuxent River at Unity began operating in 1944. This gage was upstream of Brighton and T. Howard Duckett Dams, and was unaffected by reservoir regulation. Therefore, from October 1, 1944 through June 6, 1978 the inflow record to the Patuxent reservoirs was based on gage flows on the Patuxent River at Unity, which has a drainage area of 34.8 square miles. The record of estimated inflow to the Patuxent reservoirs was obtained by multiplying the gage flows by an area adjustment factor of $3.793 = (132 \div 34.8)$.

The Unity gage did not overlap with the Burtonsville gage, so it was compared to the Unity-Hawlings-Cattail-based reference inflow. During the period June 1978 through September 1996, the average Unity-based inflow was 1.2 percent higher than the Unity-Hawlings-Cattail-based inflow. The Unity-based inflow was thus reduced by a factor of 1.2 percent to develop an inflow record that better represents the best available estimate of inflow. Figure 5 compares the adjusted Unity-based inflow with the Unity-Hawlings-Cattail-based inflow, and illustrates that the Unity-based inflow well approximates the Unity-Hawlings-Cattail-based inflow.

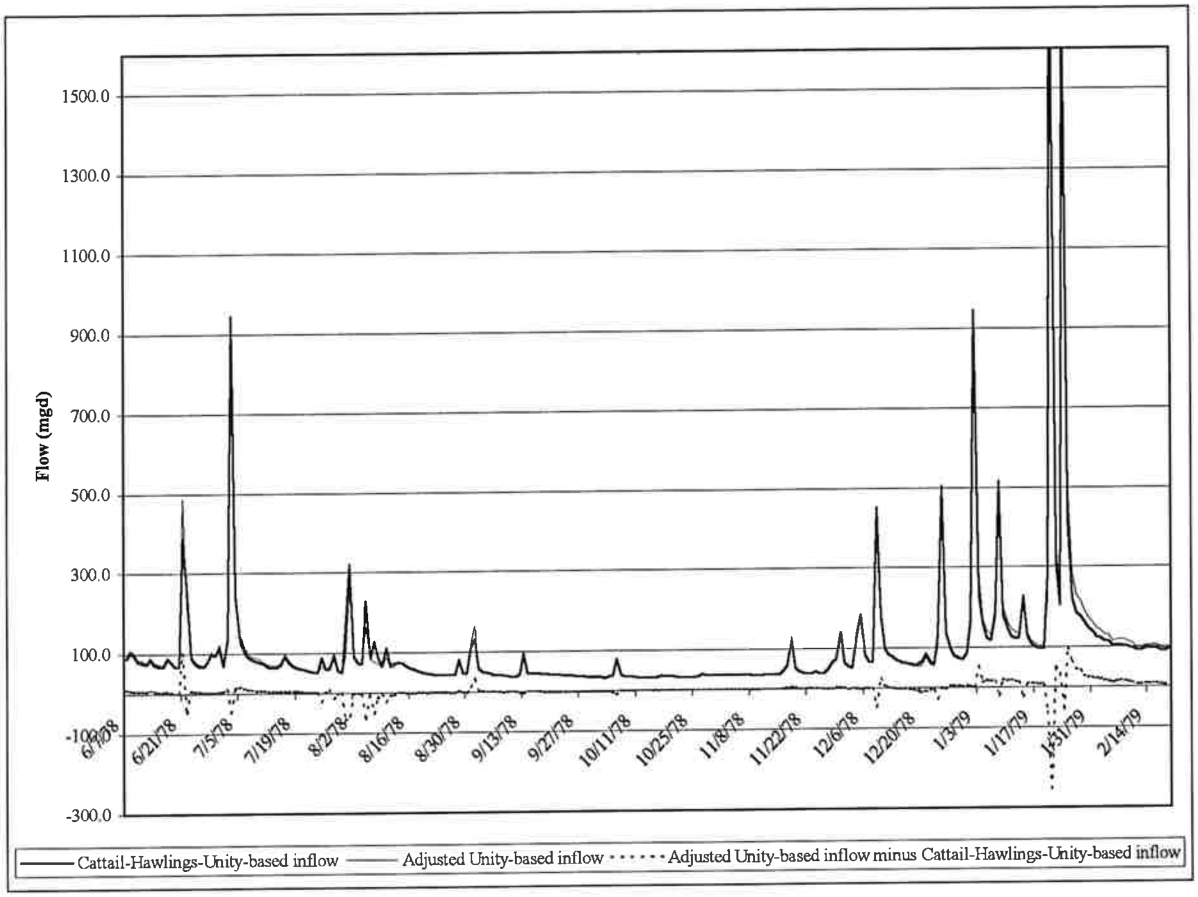

Figure 5: Example hydrograph comparing adjusted Unity-based flow and the best available estimate of inflow as measured at Unity-Cattail-Hawlings gages

1978-1996

From June 7, 1978 through September 30, 1996 the inflow record to the Patuxent reservoirs was based on gage flows on the Patuxent River at Unity, Hawlings River near Sandy Spring, and Cattail Creek near Glenwood. These gages have a combined drainage area of 84.7 square miles. No adjustment was made to this inflow since it was considered the best available estimate of inflow to the reservoir for this time period.

4. Effects of upstream regulation

Brighton dam impounds Triadelphia Lake and was built between 1941 and 1943. T. Howard Duckett Dam impounds T. Howard Duckett Reservoir and is located downstream of Triadelphia Lake. T. Howard Duckett Dam was started in the spring of 1952 and completed in the summer of 1954. All gages used to create the Patuxent reservoir inflow data set were unaffected by reservoir regulation.

5. Diversions and return flows

Mink Hollow raw water pumping station was finished in August of 1939 and was located above the Burtonsville gage. This station was active only during low flow periods and diverted water from the mainstem Patuxent to the Northwest Branch of the Anacostia River. The first diversions from the Patuxent basin began in October 1939, and ended in July of 1960 (Robert James, USGS, personal communication, August 25, 1998). Appendix A summarizes the diversions from October 1939 through September 1941. These diversions were added to the Burtonsville gage record before area-adjustment.

6. Storage loss due to sedimentation

WSSC contracted with Ocean Surveys, Inc., to develop estimates of the capacity and sedimentation rates of the reservoirs. Reservoir capacity and long-term sedimentation rates were determined by the following procedure. The original 5-foot contour interval topographic maps created prior to filling of the reservoirs were digitized. The current morphology of the reservoir basins was surveyed and digitized to create a data set comparable with that derived from the original topographic maps. Surface modeling techniques (QuickSurf Version 5.1) were used to compare the historic and current digitized maps. The results of the analysis are described below (Ocean Surveys, Inc., 1997).

Sedimentation rates

- Triadelphia Reservoir has lost approximately 0.69 billion gallons (bg) due to sedimentation over the 53 year period between 1942 to 1995. This is equivalent to an annual storage loss of 13.0 million gallons (mg).
- T. Howard Duckett Reservoir has lost approximately 0.44 bg during the 42 year period between 1954 to 1996. This is equivalent to an annual storage loss of 10.6 mg.

Current reservoir capacity

The current capacity of the Triadelphia Reservoir at the normal operating pool elevation of 363.4 feet is 5.59 billion gallons (as based on linear interpolation of the 1995 Triadelphia stage/volume curve). The volume of water in dead storage is 0.421 million gallons (1.29 acre feet), where dead storage is defined as that water volume stored below the lowest water intake structure at elevation 310.0 feet. The difference in these two volumes is the water available for water supply, **5.59 billion gallons**.

The usable capacity of T. Howard Duckett Reservoir can be better estimated when a revised stage/storage curve is developed for the reservoir as based on Ocean Surveys' 1996 survey. However, a rough estimate of the usable capacity was made using Ocean Surveys' (1997) estimate of the total capacity loss in T. Howard Duckett Reservoir (7.2 percent). Applying this percentage of total storage loss to the reservoir volumes predicted by older stage/storage curves provided a rough estimate of Duckett's total usable storage. The older stage/storage curves show that the volume at the normal operating pool elevation of 283.4 feet is 5.8 billion gallons and that the volume at the lowest water intake elevation of 242 feet is 2 billion gallons. The difference in these two volumes, 3.8 billion gallons, was reduced by 7.2 percent to account for sedimentation. Thus, the best available estimate of T. Howard Duckett's current water supply capacity is **3.5 billion gallons**.

The total current usable capacity of Triadelphia and T. Howard Duckett Reservoirs is 5.59 + 3.5 billion gallons, or **9.1 billion gallons.** The total current usable capacity can be better estimated when the T. Howard Duckett Reservoir stage/storage curve is developed that is based on the 1996 survey.

7. Evaporation and precipitation

Evaporation can be a significant factor in the reservoir water balance equation, especially during summertime periods of drought. The National Climatic Data Center (NCDC) maintains pan evaporation and precipitation data for the Beltsville weather station located in Prince George's County, Maryland approximately 6 miles from the site of the Patuxent reservoirs. Pan evaporation for the Beltsville station is given in Table 2 for the years 1972 through 1996 (U.S. Department of Commerce, 1973-1997)., and monthly precipitation is given for the years 1941-1996 (U.S. Department of Commerce, 1998).

Actual evaporation from the reservoirs is likely to be less than the pan evaporation rates given in Table 2. A coefficient of 0.7 can be used to adjust pan evaporation to approximate reservoir evaporation rates (Linsley, 1949, 1982). Using the adjusted pan evaporation rate, evaporation could account for up to 1.4 billion gallons of water loss from the Patuxent reservoir during the months of April through October. (This calculation assumes no rainfall inputs, reservoir surface areas corresponding to the full-pool reservoir elevations, the maximum pan evaporation rates given in Table 2, and a pan adjustment coefficient of 0.7)

Table 2: Evaporation and precipitation for Beltsville station in Prince George's County, MD

Month	Average Pan Evaporation 1972-1996 (inches)	Maximum Pan Evaporation 1972-1996 (inches)	Average Precipitation 1941-1996 (inches)
January	1.3[a]	--	2.9
February	1.1[a]	--	2.6
March	1.5[a]	--	3.6
April	4.9	6.4	3.2
May	5.4	7.4	4.1
June	6.6	9.1	3.7
July	7.2	8.6	4.1
August	5.8	7.3	4.5
September	4.5	5.5	3.6
October	3.3	3.9	3.4
November	2.7[a]	--	3.2
December	1.8[a]	--	3.4

Note: [a] Evaporation at the Beltsville Research station was not measured during the months of November through March. Evaporation rates for these months from Hirsch (1978).

8. Summary

The prior ICPRB set of daily inflows to the Patuxent reservoirs was examined and revised as necessary. The following changes were made:

1. Starting in October of 1939, there were out-of-basin diversions above Burtonsville gage. The prior inflow record did not account for the out-of-basin transfers. The Burtonsville-based inflow record was increased by **2.8 percent** on average to account for the diversions between October of 1939 through September 1941.

2. The prior inflow for 1941-1944 was based on the Little Patuxent River near Guilford gage. An alternative inflow based on the Little Patuxent River near Savage gage was developed in the present analysis, and was found to be closer to the best estimate of inflow than the Guilford-based inflow. Therefore, the Savage gage was selected for use during the period 1941-1944. The average Savage-based inflow was **5.1 percent less** than the prior ICPRB inflow record for the years 1941-1944.

3. From October 1, 1944 through June 6, 1978 the prior inflow record to the Patuxent reservoirs was based on gage flows on the Patuxent River at Unity (Unity gage). The prior Unity-based inflow was **decreased by 1.2 percent** to develop an inflow record that better represents the reference inflow, per the comparison described below.

4. From June 7, 1978 through September 30, 1997 the prior inflow record to the Patuxent reservoirs was based on Unity gage. An inflow based on the Patuxent River at Unity, Hawlings River near Sandy Spring, and Cattail Creek near Glenwood gages was instead developed. The average Unity-Hawlings-Cattail-based inflow **was 1.2 percent less** than the Unity-based inflow.

Table 3 summarizes the calculated daily inflows to the Patuxent reservoirs by month from August 1913 through September 1997. Figure 6 summarizes annual inflow to the Patuxent reservoirs. Data are available in electronic format from ICPRB for both daily and monthly inflows.

Table 3: Monthly Patuxent Inflow (BG)

	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933
January	-	3.0	7.8	2.1	3.5	3.5	3.5	3.3	2.0	2.4	1.8	4.8	3.0	3.2	3.6	2.3	2.5	1.6	1.0	1.9	2.9
February	-	2.2	6.1	2.8	2.3	6.5	1.9	7.5	1.7	4.8	2.2	3.8	6.2	5.3	4.0	4.1	3.4	3.0	0.7	1.7	3.1
March	-	3.8	3.0	2.8	5.5	3.4	3.7	7.2	2.6	3.8	3.1	6.8	3.1	2.6	3.4	3.3	4.6	3.0	1.3	2.6	4.1
April	-	3.3	2.0	2.7	2.7	5.1	4.0	4.4	2.7	1.7	3.0	6.9	2.5	2.2	4.7	4.1	4.8	3.1	1.5	2.3	5.6
May	-	2.5	2.0	1.9	2.9	2.8	5.8	2.9	4.7	1.6	2.2	6.6	2.3	1.6	3.6	3.1	2.9	1.5	1.3	2.8	5.0
June	-	1.5	2.7	2.6	2.9	1.5	2.7	3.0	1.7	1.7	2.0	4.4	1.1	1.0	2.5	7.1	2.2	0.9	1.2	1.8	3.1
July	-	1.0	1.8	3.7	3.7	1.0	5.1	2.1	2.0	2.2	1.7	2.4	2.2	1.5	1.6	2.7	1.1	0.4	2.1	0.7	3.9
August	5.0	1.6	3.5	1.7	1.6	1.2	3.6	3.2	1.4	1.0	1.5	3.6	1.1	2.1	1.8	4.0	0.7	0.2	1.7	0.6	7.3
Septembe	1.4	0.8	1.5	1.3	1.2	1.1	2.4	1.2	0.6	1.0	2.1	4.2	1.3	4.5	1.1	2.6	0.7	0.2	0.4	0.4	2.3
October	1.4	0.7	2.0	1.4	2.2	0.9	2.3	1.1	0.6	1.1	1.4	2.3	1.8	2.4	3.2	1.9	2.3	0.2	0.3	2.2	1.9
Novembe	1.7	0.9	1.3	1.4	1.3	1.0	3.1	1.8	1.4	0.8	1.8	2.1	2.3	5.4	2.5	1.8	2.0	0.4	0.4	3.9	1.6
December	1.9	2.3	2.1	2.3	1.1	2.8	3.4	2.8	2.0	1.2	2.8	2.3	1.8	3.5	3.5	2.0	1.6	0.8	0.7	2.4	1.7
Grand Total		23.6	35.7	26.8	30.9	30.9	41.6	40.6	23.5	23.5	25.6	50.2	28.8	35.2	35.4	39.2	28.6	15.4	12.8	23.3	42.5

	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
January	2.6	3.5	6.5	4.9	3.0	3.0	1.3	2.9	0.9	2.6	4.1	2.7	4.3	2.3	3.4	8.6	2.0	2.9	4.4	5.9	1.8
February	1.6	4.7	8.1	4.7	3.2	5.1	2.8	2.6	1.4	3.9	1.5	3.7	3.6	1.3	4.6	6.5	4.5	6.1	3.6	4.0	1.6
March	5.1	4.7	6.7	3.8	3.2	4.2	3.3	3.0	2.4	4.4	4.2	3.3	3.8	2.5	3.9	5.4	5.4	4.1	4.3	7.7	3.0
April	3.4	5.5	4.2	6.2	2.7	4.1	5.4	3.2	3.1	3.3	3.2	2.6	2.5	1.6	3.9	4.5	2.9	3.6	10.9	5.5	2.5
May	3.3	4.4	2.6	4.1	2.4	2.5	3.0	1.6	1.8	4.3	2.0	1.9	3.1	3.3	3.9	4.0	3.2	3.0	10.6	5.8	2.2
June	2.1	2.4	1.8	3.7	1.5	1.9	1.8	1.4	2.0	1.8	1.5	2.0	4.8	2.0	2.9	1.9	2.2	6.9	5.3	3.9	1.0
July	1.0	2.1	1.5	2.2	1.7	1.3	1.3	1.4	1.9	1.1	0.6	6.1	1.9	1.6	1.8	2.3	1.4	2.7	4.7	1.8	0.6
August	1.0	1.1	2.1	5.1	1.3	0.8	1.1	0.7	2.6	0.5	0.7	6.4	1.2	1.8	2.1	1.9	0.8	1.2	2.5	1.8	0.7
Septembe	4.6	2.9	0.9	1.8	1.5	0.6	1.3	0.3	0.8	0.4	1.1	3.3	1.3	0.7	1.5	1.2	2.0	0.9	5.1	1.1	0.4
October	2.1	1.6	1.2	5.7	1.1	1.3	1.0	0.4	3.6	1.2	1.0	2.0	1.1	0.4	1.9	1.5	1.6	0.8	1.5	0.9	0.6
Novembe	2.1	2.8	1.0	5.2	1.3	1.2	2.8	0.6	2.0	3.1	1.1	3.3	1.0	2.2	3.1	1.4	3.2	2.0	6.0	1.3	0.7
December	3.5	2.2	3.1	3.0	2.3	1.1	2.5	1.0	3.3	1.5	2.2	5.7	1.3	1.4	8.0	2.5	4.7	2.5	4.6	2.7	1.4
Grand To	32.4	37.9	39.5	50.3	25.2	27.1	27.6	19.1	25.7	28.2	23.3	43.0	29.8	21.1	40.9	41.5	33.9	36.8	63.5	42.4	16.3

	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
January	1.0	1.9	2.3	5.5	2.1	2.6	2.3	1.8	1.7	5.3	2.5	0.8	2.8	4.0	1.7	2.8	2.9	4.4	4.8	4.5	2.9
February	2.7	4.6	3.6	3.4	1.9	3.7	6.5	2.7	1.7	2.9	3.1	3.1	2.5	2.1	1.9	3.7	7.5	6.4	5.6	2.5	3.2
March	3.6	4.6	3.2	7.2	2.0	3.5	5.4	5.6	5.2	5.2	5.2	2.3	6.0	4.0	2.4	3.2	4.1	6.8	4.4	3.4	5.9
April	2.0	3.2	3.5	6.4	2.3	4.3	5.9	3.9	1.6	4.0	3.2	2.2	2.7	2.3	1.8	6.0	2.9	7.8	8.5	4.5	3.7
May	1.2	2.0	1.8	4.5	1.5	3.4	3.8	2.7	1.1	2.5	2.0	2.7	2.8	2.7	1.2	4.3	4.5	6.1	5.9	2.7	5.1
June	1.5	1.4	1.3	3.3	0.9	1.8	2.4	1.3	2.1	1.2	1.2	0.9	1.0	2.6	0.7	2.6	2.8	15.0	3.7	2.3	2.4
July	0.5	7.7	0.5	3.2	0.5	1.2	1.9	0.9	0.6	0.8	0.7	0.3	1.4	1.2	2.7	2.8	3.1	5.6	2.6	1.2	2.6
August	7.3	1.4	0.4	2.0	0.6	1.2	1.0	0.6	0.6	0.6	0.5	0.2	4.0	0.7	1.6	1.1	9.0	2.6	1.7	1.1	1.6
Septembe	1.7	1.1	0.8	1.4	1.6	1.6	0.8	0.4	0.5	0.4	0.5	3.6	1.7	1.6	2.4	0.7	15.5	1.5	2.1	1.7	12.3
October	2.2	1.5	0.7	1.3	1.0	1.0	0.8	0.6	0.5	0.6	0.8	1.8	1.3	1.1	0.9	0.9	5.8	1.5	1.5	1.0	5.2
Novembe	1.8	1.7	1.0	1.4	1.2	1.2	1.0	1.3	1.8	0.7	0.7	1.4	1.2	2.2	1.1	2.5	5.8	3.8	1.3	1.2	3.9
December	1.4	2.2	4.6	1.4	2.1	1.1	1.3	1.1	1.5	1.9	0.6	1.8	4.0	2.0	2.4	2.2	5.4	7.0	4.7	5.0	3.5
Grand To	26.8	33.1	23.7	41.0	17.7	26.7	33.1	23.0	19.0	26.2	21.0	21.2	31.3	26.5	20.6	32.8	69.3	68.2	46.6	30.9	52.4

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Grand Total
January	8.1	1.4	9.1	9.9	3.7	0.9	1.7	1.4	3.8	1.8	1.7	2.9	4.0	2.5	3.8	5.1	1.5	3.4	5.3	4.5	11.5	5.3	287.1
February	3.9	2.0	3.1	10.3	2.4	3.3	5.2	2.4	6.5	5.8	3.3	2.3	3.6	2.3	3.0	2.5	1.7	2.6	8.3	2.3	4.2	4.3	313.4
March	3.4	3.4	7.2	6.9	5.5	1.8	2.8	6.1	7.0	2.0	2.8	4.2	3.2	4.0	2.8	4.6	2.8	12.4	9.5	2.9	4.6	6.4	361.8
April	4.3	4.9	3.6	4.2	5.4	2.0	3.3	9.4	7.3	1.8	2.6	4.3	2.9	2.8	4.1	3.3	2.5	10.9	5.3	1.9	4.8	3.7	331.9
May	3.6	2.3	7.7	3.7	6.0	1.9	1.9	6.5	5.4	1.8	1.5	2.3	6.8	10.1	3.8	2.0	2.1	4.3	3.8	2.4	4.7	2.4	284.1
June	2.3	1.5	3.1	3.9	3.3	2.0	3.2	4.9	2.5	1.5	0.7	1.7	2.0	5.1	2.0	1.1	1.4	2.6	1.7	1.3	5.7	1.7	210.1
July	2.0	0.9	3.4	1.9	2.0	1.6	1.4	1.7	2.0	0.9	0.5	2.5	1.7	2.7	1.4	0.7	2.0	1.2	1.5	1.0	5.5	0.8	165.0
August	1.1	0.7	2.5	2.4	1.2	0.7	0.9	1.1	2.6	0.6	0.6	0.5	0.9	1.7	1.9	0.5	1.1	1.2	2.4	0.8	4.3	0.7	156.0
Septembe	1.0	0.4	1.4	8.3	0.6	0.6	0.6	0.8	1.2	0.7	0.4	3.0	0.9	1.3	0.9	0.5	1.3	1.2	1.4	0.4	8.0	0.6	155.3
October	4.1	1.1	1.1	11.1	0.9	0.8	0.8	2.1	1.4	0.9	0.3	1.5	0.8	2.5	5.1	0.6	1.8	1.2	1.2	1.7	5.7	-	144.4
Novembe	2.2	2.3	1.4	4.4	1.4	0.7	1.3	3.4	1.9	2.1	1.5	3.0	1.8	3.0	3.1	0.8	3.2	5.8	1.5	3.6	6.0	-	178.7
December	2.2	6.0	3.4	3.3	1.1	1.1	1.6	8.4	2.0	1.9	4.1	2.7	1.3	1.8	3.9	1.9	5.3	5.6	2.2	2.5	11.3	-	236.7
Grand To	38.2	27.0	47.1	70.5	33.4	17.4	24.7	48.1	43.6	21.7	19.9	30.9	29.8	39.8	35.8	23.6	26.7	52.4	44.2	25.4	76.3	-	

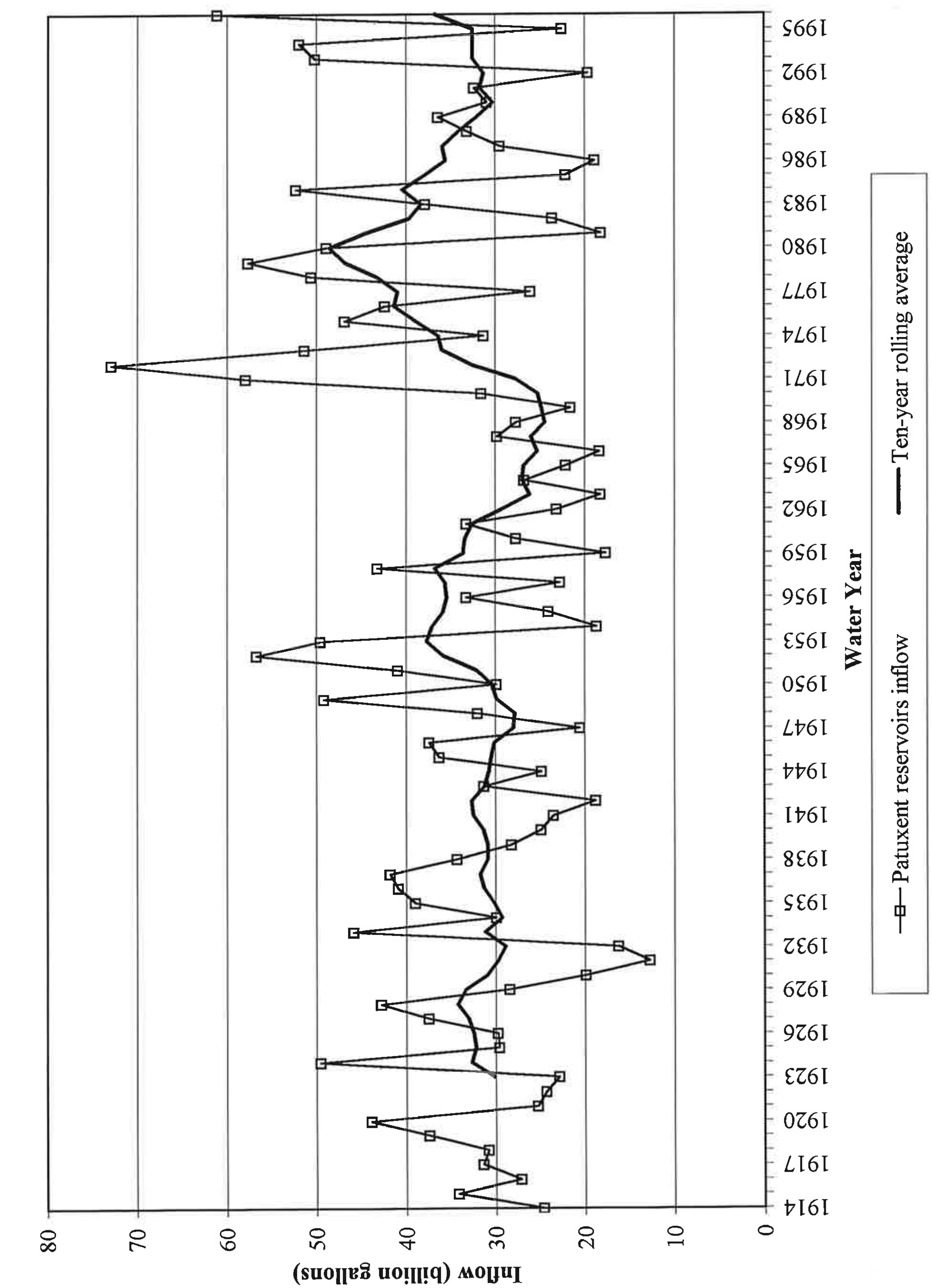

Figure 6: Annual Patuxent inflow by water year and ten-year rolling average inflow, 1913-1996

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10. Appendix A: Diversions above Burtonsville gage

Table I: Average monthly diversions from Patuxent to NW Branch of the Anacostia via Mink Hollow raw water pumping station, October 1939 through September 1941.

	Average diversions (cfs)
Oct-39	2.3
Nov-39	0
Dec-39	0
Jan-40	0
Feb-40	0
Mar-40	0
Apr-40	0
May-40	0
Jun-40	3.4
Jul-40	6.9
Aug-40	6.9
Sep-40	5.1
Oct-40	4.7

	Average diversions (cfs)
Nov-40	0.4
Dec-40	0.06
Jan-41	0.05
Feb-41	0.05
Mar-41	0.02
Apr-41	0.02
May-41	4.7
Jun-41	3.4
Jul-41	6.2
Aug-41	8.3
Sep-41	5.6
Average	2.4

Source: Robert James, USGS-Baltimore, personal communication, August 20, 1998.
As listed on 9192 monthly summary forms