AN ASSESSMENT OF THE HYDROLOGIC IMPACT RESULTING FROM DEVELOPMENT IN REGIONAL GROWTH AREAS IN HAMILTON TOWNSHIP, ATLANTIC COUNTY

**Prepared by the Staff of
the New Jersey Pinelands Commission**

August 1990

**New Jersey Pinelands Commission
P.O. Box 7, New Lisbon, N.J. 08064**

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ERRATA SHEET, DECEMBER 1990

The Total Outflows figure for Cedar Brook in Table 8 is incorrect and should read 3.18 MGD.

The TDS (Total dissolved solids) and TSS (Total suspended solids) data entries on Tables **9b** and **9d** (Hamilton Study Water Quality Data) for the dates 07/11/89 and 07/12/89 should be transposed to read accurately. That is, the TDS value is actually the TSS value, and vice versa.

The word, withdrawals, is misspelled in the legend at the bottom of Table 11 on page 33.

ACKNOWLEDGMENTS

This project was a collaborative venture that utilized the talents, expertise and sheer effort of many present and former Pinelands staff and that of several other agencies. Thanks are due to Robert Schopp and Pierre LaCombe at USGS for their help in the formative stages of study development and in providing us with essential data in a timely fashion. Paul Morton and Julia Spiritosanto of the Bureau of Monitoring Management (NJDEP) were essential in carrying out the water quality aspects of the study. Howard Bratcher of the HTMUA and Joseph Pantalone, the executive director of HTMUA, also must be thanked for their expeditious responses to our requests for information. The same to Keith Buch of the Federal Aviation Administration Technical Center.

David A. Schock,
Hydrogeologist
August, 1990

TABLE OF CONTENTS

	PAGE
ABSTRACT	1
INTRODUCTION	
DESCRIPTION OF THE STUDY AREA	3
Definition of the Study Basins	3
Land Use Analysis of the Study Basins	6
Existing Unit Counts	7
Local Hydrogeology	8
Water Supply and Sewage Treatment Counts	12
HYDROLOGIC SYSTEM	14
Hydrologic Budget. Existing Conditions (1988)	14
Water Quality Assessment	17
PROJECTED DEVELOPMENT AND HYDROLOGIC IMPACT ANALYSES	23
Buildout Estimates	23
Hydrologic Impact Analyses	26
Conclusions of the Analyses	33
Alternative Sources of Water Supply	34
APPENDICES	37
A: Methods for Streamflow Estimation	37
B: Hydrologic Budget Methods and Assumptions	39
C: Assumptions of the Hydrologic Impact Analyses	42
REFERENCES	43

ABSTRACT

This report delineates the findings and recommendations of a New Jersey Pinelands Commission study of the potential hydrologic effects of ground water supply development in several stream basins in Hamilton Township, Atlantic County, and in small adjacent portions of Galloway and Egg Harbor Townships. The study was carried out during the period 1988 to 1989.

The study findings suggest that projected buildout of the Regional Growth Areas in Hamilton Township and portions of Galloway Township, where wastewater will be exported via sewers, cannot be supplied with water derived from the Kirkwood-Cohansey water table aquifer in the regions of the study basins without significantly depleting streamflows. The study also suggests that plans of the Hamilton Township Municipal Utilities Authority (HTMUA) to export 5.825 million gallons per day (MGD) of wastewater via the Atlantic County Utilities Authority Coastal Interceptor, will deplete streamflows in all of the study basins if Kirkwood-Cohansey ground water sources are used.

The report recommends an investigation into the feasibility and environmental impact of using several water supply alternatives.

1) Deeper confined aquifers, such as the Atlantic City 800 Foot Sand.

2) Wellfields in hydraulic connection with the mainstem of the Great Egg Harbor River or Lake Lenape.

3) Surface flows from the Great Egg Harbor River.

INTRODUCTION

This study of Hamilton Township water supply alternatives for the Pinelands Regional Growth Areas was begun in **1988** to provide a quantitative basis upon which to assess future water supply and wastewater treatment options in a rapidly developing area of the Pinelands. Recent actions affecting the Hamilton Township Municipal Utilities Authority (HTMUA), including approval for an increase in their NJDEP water allocation permit to **2.5** million gallons per day (MGD), approval to implement a new **1500** gallon per minute public supply well in the Kirkwood-Cohansey water table aquifer, and actions to merge with the Atlantic County Utilities Authority (ACUA) Coastal Interceptor sewer project, were recognized as the first steps in a much larger future expansion of water and sewer services to meet the needs of potential development.

All of the aforementioned water and sewer system actions and plans involve the use of the Kirkwood-Cohansey water table aquifer for public supply and the interbasin transfer of the wastewater for treatment. Such a system tends to remove significant volumes of water from the local hydrologic system that, in turn, maintains streamflows, ground water levels, recharge to deeper aquifers and wetland habitats.

The purpose of this study is to provide a quantitative analysis of the existing hydrologic system, the existing water supply and wastewater treatment systems, and the existing distribution of land use and development in order to provide a basis for assessing present conditions and a baseline against which to assess the hydrologic effect of future development. In addition, future water utilization was projected on the basis of a **buildout** analysis of the area. This information was then used to assess the hydrologic effects of future development. Finally, alternatives for future water supply were identified.

DESCRIPTION OF THE STUDY AREA

Hamilton Township is located in central Atlantic County. It is traversed by several major auto routes that link the metropolitan areas around Philadelphia to Atlantic City and the shore regions. The township is undergoing residential, commercial, and industrial development in its Pinelands designated Regional Growth Areas, from just west of May's Landing east to the border of Hamilton with Egg Harbor Township (see Map 1).

The township is located in the Coastal Plain province, a geologic unit consisting of unconsolidated sediments (dominated by sands). Elevations range from less than 10 feet above sea level to just over 100 feet at the far northwest corner of the township. Relief, as is the case in most of the Coastal Plain, is low, and the area is most aptly described as flat. The total area of the township is 109 square miles, of which 1.5 square miles are located outside of the Pinelands Area.

Definition of the Study Basins

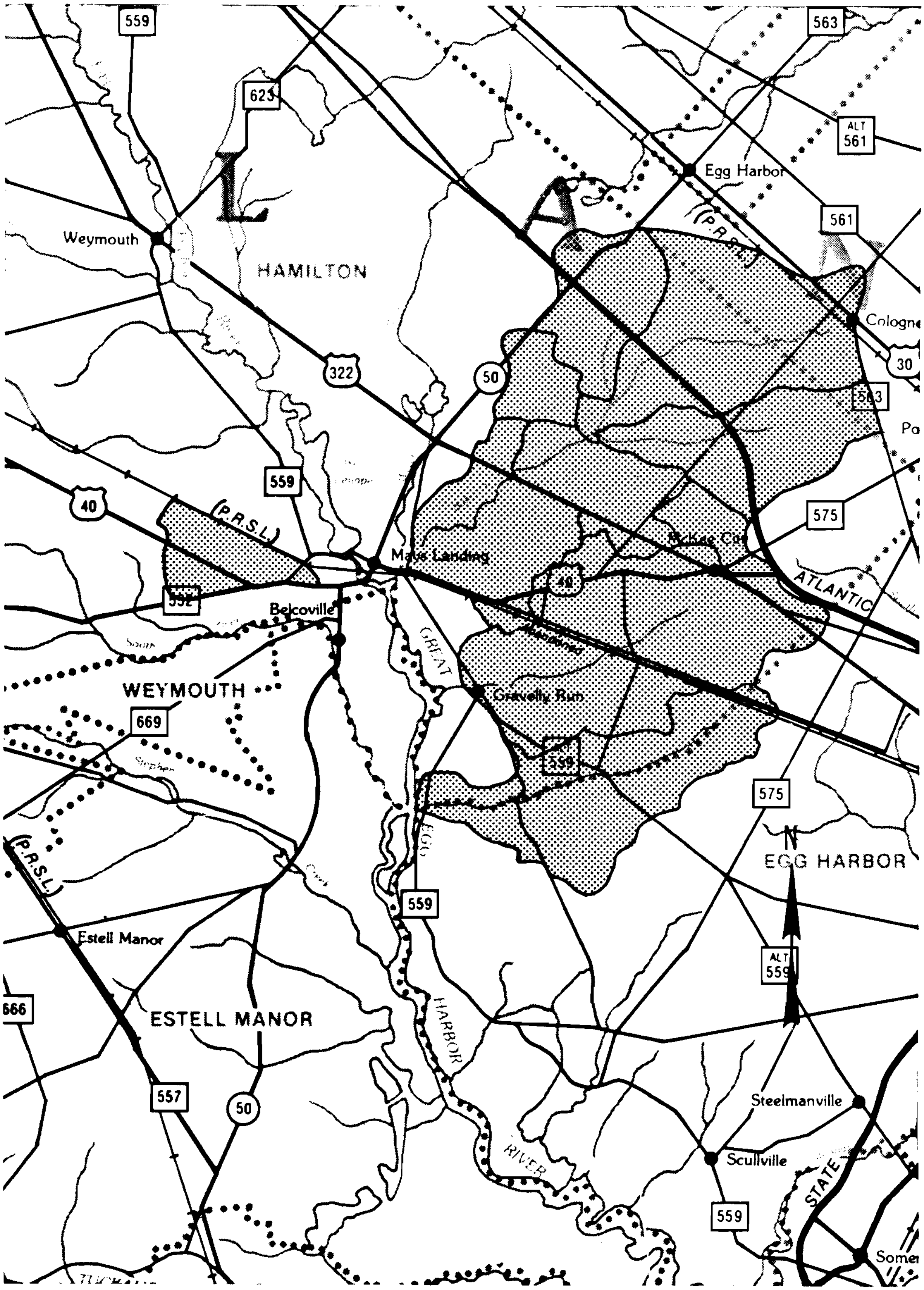
For purposes of analysis, the township was broken down into several discrete, hydrologically defined study areas. These primary study areas were several stream basins, defined by their surface drainage divides, that contained large areas of Regional Growth Area (RGA) zoning, which allows the most concentrated development. These study basins are listed in Table 1 below and are shown on Map 2, which also shows the locations of the Hamilton Township Municipal Utilities Authority (HTMUA) three (3) public supply wells.

Table 1: LIST OF STUDY BASINS

STREAM	STUDY BASIN	SUBBASIN TRIBUTARY	AREA (ACRES)	PERCENT RGA ZONE
BABCOCK CREEK	Lower Babcock		2285	91.3
	Babcock Swamp		1489	34.3
		Adams Branch	471	
		North Babcock	732	
	Upper Babcock		3748	12.4
		Jack Pudding Br	2302	
		Man Killer Br	1593	
GRAVELLY RUN	Lower Gravelly Run		2523	23.0
	Upper Gravelly Run		3213	100.0
CEDAR BROOK	Cedar Brook		996	63.1

PERCENT RGA ZONE = sum of RGA area in the study basin and its tributaries divided by the sum of the total area of the study basin and its tributaries.

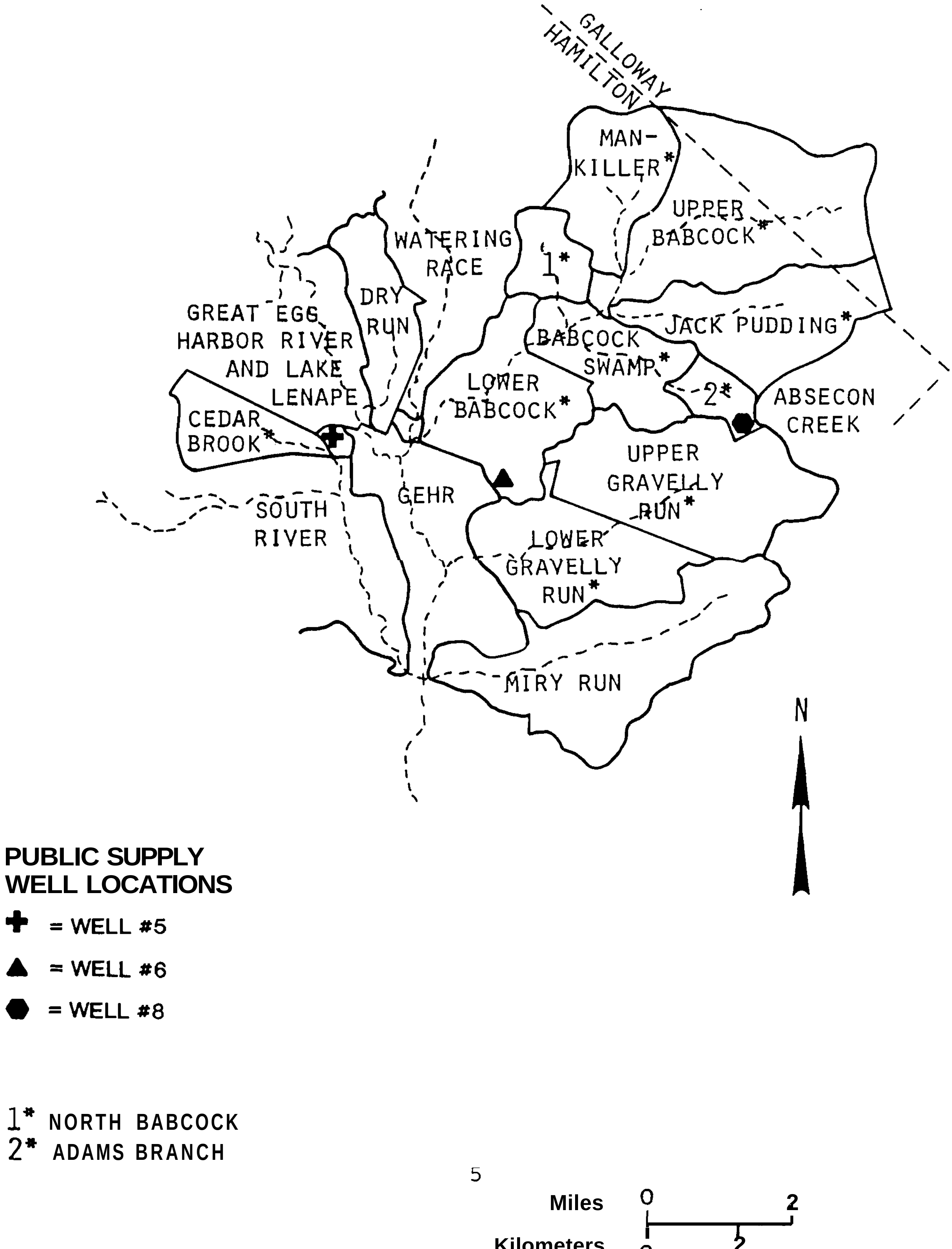
MAP 1: GENERAL GEOGRAPHY OF STUDY AREA



4 Miles 0 2

Kilometers 0 2

MAP 2: STUDY BASINS (*) AND OTHER STREAM BASINS



In addition to the study basins, several other stream basins were found either to be affected by actual or projected water use in the township or were selected as potential sources of water supply. These stream basins and other proximal stream basins are shown on Map 2, and include the mainstem of the Great Egg Harbor River, Absecon Creek, South River, Dry Run, Watering Race and Miry Run. With the exception of Miry Run, the hydrologic systems of these basins were interpreted only on the basis of published data. Geographic analysis, such as land use assessment, zoning analysis and buildout estimation, was not carried out for these stream basins.

Land Use Analysis of the Study Basins

The study basins were subjected to land use analysis on the basis of land cover maps prepared using New Jersey Department of Environmental Protection March 1986 photoquad map information. In addition, soil types (wetland vs upland) were determined on the basis of United States Department of Agriculture soil survey data. Vegetation types were determined from Pinelands Commission vegetation maps. All of the maps used are at a scale of 1:24000. Existing unit counts (residential and other) were made from Real Estate Data, Inc., (REDI) tax books and tax maps (1988 and 1989). It should be noted that the difference in the dates of publication between the photoquads (1986) and the tax book and tax map information (1988 & 1989) may have produced a discrepancy between the land use information, from the former source, and the existing unit counts, from the latter source. In an attempt to address this potential discrepancy, land use data were verified in the field by Pinelands staff. As such, the discrepancy should be small, if not negligible.

TABLE 2: LAND USE (ACRES) IN THE STUDY BASINS

BASIN/SUB-BASIN	TOTAL ACRES IN BASIN	UNDEVELOPED UPLAND	UETLAND	DEVELOPED LAND
LOVER BABCOCK	2285	844	903	538
BABCOCK SWAMP	1489	674	739	76
ADAMS BRANCH	471	121	27	323
NORTH BABCOCK	732	583	74	74
UPPER BABCOCK	3748	2201	1314	233
JACK PUDDING BRANCH	2302	1480	607	214
MAN KILLER BRANCH	1593	807	654	132
L M R GRAVELLY RUN	2523	1383	1051	89
UPPER GRAVELLY RUN	3213	1625	871	717
CEDAR BROOK	996	486	249	261
TOTALS	19350	10204	6490	2657

Table 2 shows the acreage of each study basin (and selected sub-basins within the study basins), as well as 1) developed acreage, 2) undeveloped upland acreage (which is subject to development under the Pinelands Comprehensive Management Plan and Hamilton Township zoning regulations), and 3) wetland acreage (in which development is prohibited or severely restricted). Only 12% of the total 19,350 acres of the study basins was developed as of 1988, and just over 10,000 acres of developable land is to be found in the study basins. In comparison with other areas in the Pinelands, agricultural activity is minimal in the study basins.

Thirty-three percent of the total study basin area is covered by wetlands. Table 3 denotes the wetland community or type as a percentage of the total study basin area.

TABLE 3: WETLAND TYPE IN STUDY BASINS

BASIN/SUB-BASIN	TOTAL ACRES IN BASIN	CEDAR SWAMP	HARDWOOD SWAMP	PITCH PINE LOWLAND	BOG	WATER	UNTYPED
			(UNITS = PERCENT OF TOTAL ACRES)				
LOWER BABCOCK	2285	0	13	24	2	0	0
BABCOCK SWAMP	1489	0	24	25	0	0	0
ADAMS BRANCH	471	0	3	3	0	0	0
NORTH BABCOCK	732	0	3	7	0	0	0
UPPER BABCOCK	3748	1	5	20	9	0	0
JACK PUDDING BRANCH	2302	0	9	15	1	0	1
MAN KILLER BRANCH	1593	0	8	29	2	0	1
LOWER GRAVELLY RUN	2523	2	21	9	6	0	2
UPPER GRAVELLY RUN	3213	0	13	14	0	0	0
CEDAR BROOK	996	2	5	16	0	1	0

Existinq Unit Counts

Table 4 denotes the number of residential and non-residential units in each of the study basins. In general, Adams Branch, Upper Gravelly Run, Cedar Brook, Lower Babcock Swamp and a small portion of Babcock Swamp have zoning designations that allow intense, mixed development. At present, Lower Gravelly Run, North Babcock, Upper Babcock, Man Killer Branch and Jack Pudding Branch are zoned for low density residential development, except for portions of Upper Babcock in Galloway Township which are designated as Regional Growth Areas and Pinelands Villages.

TABLE 4: EXISTING DEVELOPMENT UNIT COUNTS AND DENSITIES (1988)

BASIN/SUBBASIN	BASIN AREA (ACRES)	BASIN AREA (SQ MI)	SINGLE/ MULTI- FAMILY (UNITS)	COMM/ IND/ INST (UNITS)	RESIDENTIAL DENSITIES (NO/ACRE)	RESIDENTIAL DENSITIES (NO/SQ MI)
LOVER BABCOCK	2285	3.57	251	8	0.11	70.3
BABCOCK SWAMP	1489	2.33	281	5	0.19	120.8
ADAMS BRANCH	471	0.74	430	143	0.91	584.4
NORTH BABCOCK	732	1.14	92	1	0.13	80.5
UPPER BABCOCK (GALLOWAY TOWNSHIP COUNT)	3748	5.86	225 (179)	24 (24)	0.06	38.4
JACK PUDDING BRANCH (GALLOWAY TOWNSHIP COUNT)	2302	3.60	72 (0)	1 (0)	0.03	20.0
MAN KILLER BRANCH	1593	2.49	100	3	0.06	40.2
LOWER GRAVELLY RUN	2523	3.94	31	2	0.01	7.9
UPPER GRAVELLY RUN (EGG HARBOR TOWNSHIP COUNT)	3213	5.02	527 (4)	73	0.16	105.0
CEDAR BROOK	996	1.56	617	11	0.62	396.6
TOTALS	19350	30.23	2626	271	0.14	86.9

Numbers in parenthesis indicate portions of total outside of Hamilton Township.

Discrepancies between the Last two columns result from rounding and significant figures.

Local Hydrogeology

Rhodehamel (1979) estimated that 22.5 inches of the 45 inches of average annual precipitation that falls in the Pinelands is split between direct stream runoff (11% of the 22.5 inches) and recharge to the ground water system (the remaining 89% of the 22.5 inches). The fact that runoff is such a small percentage of total captured precipitation is largely a consequence of the sedimentary texture of the soils and deeper stratigraphic units of the Coastal Plain. High porosities and permeabilities enable rainfall to move quickly through the upper unsaturated zones to the water table aquifer. In many bedrock terrains of New Jersey, runoff is greatly accentuated by the low porosity of the rock and the overlying soil units, and stream impoundments are virtually the only method of capturing large volumes of water for public use.

In the Coastal Plain, in general, and Hamilton Township, in particular, the hydraulic efficiency of the aquifers makes them an excellent source of water supply. In Hamilton Township two major aquifers may be reached in the subsurface. These are the uppermost water table and semi-confined Kirkwood-Cohansey and the deeper confined Atlantic City 800 Foot Sand.

Instantaneous streamflow data were collected by Pinelands staff at discrete points in these study basins (see Map 3) beginning in the summer of 1988 and up through August of 1989. These data, plus published hydrologic data, enabled us to interpret the surface water hydrologic regimes of these study basins.

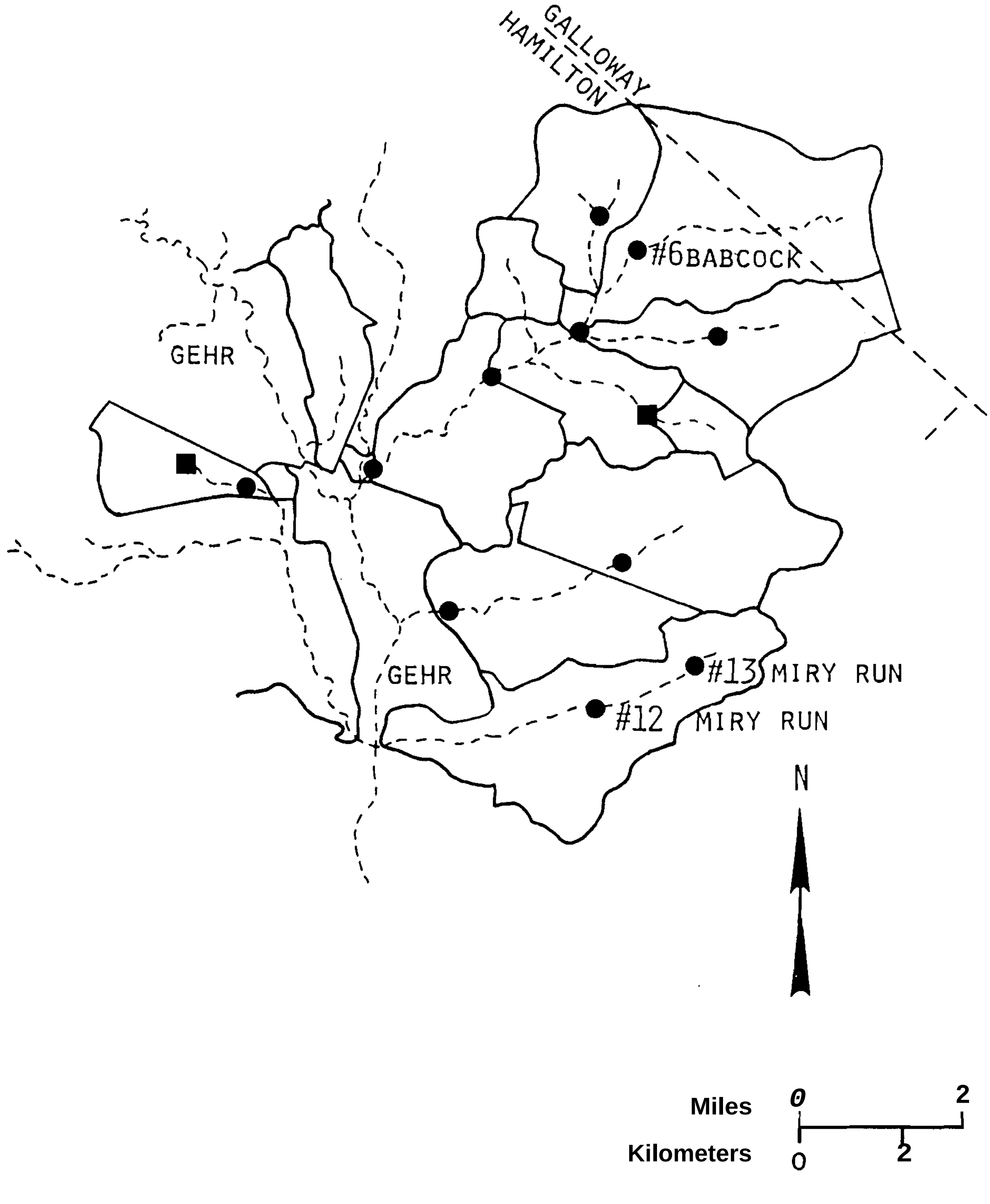
The sum total of average streamflows in the study basins is estimated to be relatively small (27 MGD) in comparison with the flow of the Great Egg Harbor River at the Lake Lenape Dam in May's Landing (estimated at 201 to 277 MGD: the former estimate based on an areal extrapolation of the USGS gage data at Folsom, and the latter based on the regional regression equation of Appendix A). All of the streams that flow into the Great Egg Harbor River below Lake Lenape have tidal effects over portions of their lower reaches.

Table 5 denotes the average flows and the 2-year and 10-year low flow estimates of the study basins. These estimates were determined from the streamflow and other data collected in the study program. Table 6 denotes average streamflows in the non-study basins, as determined by the regional regression equation method. Methodologies are discussed in Appendix A.

The low flow statistics denote an estimate of the average streamflow over seven days that will occur in a two year or ten year period (with a statistically defined recurrence interval of two or ten years). In general, they are an estimate of streamflow conditions during a summer drought -- the 10-year figure reflecting worse drought conditions than the 2-year. These estimates may be compared with the annual average streamflow to visualize the effects of drought on streamflow.

Tables 5 and 6 point to the rather obvious fact that larger basins tend to have larger streamflows -- local streambed conductivities and ground water levels may alter this general rule. Well withdrawals from the water table aquifer in a basin will usually reduce streamflows and lower water table levels. These effects may be exacerbated if the used water is sewered out of the basin from which it is derived. In turn this may produce adverse effects on the local biota that relies on the maintenance of the natural hydrologic cycle. A prime consideration in the analysis of the water supply alternatives for Hamilton township is the effect of water table aquifer well withdrawals on streamflows and ground water levels.

MAP 3: STREAM GAGING AND WATER QUALITY SAMPLING POINTS



■ = STREAM, GAGING ONLY
● = STREAM GAGING AND WATER QUALITY SAMPLING
ALL STATIONS ARE DESIGNATED BY BASIN OF LOCATION
UNLESS OTHERWISE INDICATED,

TABLE 5: ESTIMATED STREAMFLOW CHARACTERISTICS

STREAM BASIN	AVERAGE FLOW (CFS)	AVERAGE FLOW (MGD)	METHOD	7Q2 (CFS)	7Q2 (MGD)	7Q10 (CFS)	7Q10 (MGD)	LOW FLOW METHOD
BABCOCK CREEK REACHES								
LOWER BABCOCK	28.80	18.62	1	8.26	5.34	4.91	3.17	1
BABCOCK SWAMP	19.00	12.28	1	5.02	3.24	3.03	1.96	1
ADAMS BRANCH	0.68	0.44	2	<.1	<.1	<.1	<.1	3
NORTH BABCOCK	1.09	0.70	2	0.14	0.09	0.12	0.08	2
UPPER BABCOCK	14.36	9.28	1	3.08	1.99	1.70	1.10	1
MAN KILLER BRANCH	2.74	1.77	2	0.42	0.27	0.33	0.21	3
JACK PUDDING BRANCH	4.09	2.64	2	0.68	0.44	0.50	0.32	3
BABCOCK #6	5.65	3.65	2	1.00	0.64	0.72	0.46	3
GRAVELLY RUN REACHES								
LOWER GRAVELLY RUN	11.52	7.45	2	2.32	1.50	1.55	1.00	2
UPPER GRAVELLY RUN	5.92	3.83	2	1.08	0.70	0.77	0.50	2
CEDAR BROOK	1.78	1.15	2	0.25	0.16	0.20	0.13	3
MIRY RUN	7.13	4.61	2	1.32	0.85	0.92	0.60	2

DEFINITION OF METHODS:
1 REGRESSION OF PARTIAL RECORD WITH CONTINUOUSLY GAGED STREAMS
2 BASIN AREA REGRESSION EQUATION BASED ON 112 COASTAL PLAIN STREAMS
3 BASIN AREA REGRESSION EQUATION BASED ON 112 COASTAL PLAIN STREAMS, NO FLOW CONDITIONS OBSERVED IN 1988 AT GAGING POINT. THUS, LOW FLOW CHARACTERISTICS MAY BE CONSIDERED ZERO.

Note that method 1 results were not used if correlation was poor.

TABLE 6: ESTIMATED AVERAGE STREAMFLOW IN NON-STUDY BASINS

STREAM	LOCATION	AREA (SQ MI)	FLOW (CFS)	FLOW (MGD)
ABSECON CREEK	Absecon Bay	26.4	40.6	26.2
GREAT EGG HARBOR RIVER	at Lake Lenape dam	205.0	311-428	201-277

Regional Regression Equation method used.
Areal method used for low estimate on GEHR.
Note that Absecon Creek is regulated by ACUA diversions.

In addition to the effects on the freshwater systems, streamflows may also be important to the brackish water communities of the river estuaries and the back bays behind the coastal barrier islands of New Jersey. While these issues are not specifically addressed in this study, the New Jersey Department of Environmental

Protection has instituted a three (3) year estuary study program in recognition of the importance of these natural systems and their relationship to water supply planning.

Estimated low-flows for the small study basins suggest that these basins will still have measurable flows in the 2-year and 10-year drought, but observations in the summer of 1988 showed some of them to be not flowing. While such intermittence of streamflow may be natural for these study basins, it may be assumed that substantial well withdrawals in these basins will increase the period of intermittence and alter the natural hydrologic regimes.

later Supply and Sewage Treatment Counts

Table 7 denotes the number of existing development units by type, water supply and sewage treatment system in the study basins.

TABLE 7: WATER AND SEWAGE TREATMENT SYSTEM BY DEVELOPMENT UNIT

	SINGLE FAMILY/MULTIFAMILY UNITS					COMMERCIAL/INDUSTRIAL/INSTITUTIONAL				
BASIN/SUBBASIN	TOTAL UNITS	PRIVATE WELL	PRIVATE SEPTIC	PUBLIC WATER	PUBLIC SEWER	TOTAL UNITS	PRIVATE WELL	PRIVATE SEPTIC	PUBLIC WATER	PUBLIC SEWER
LOWER BABCOCK	251	1	1	250	250	8	0	0	8	8
BABCOCK SWAMP	281	8	8	273	273	5	0	0	5	5
ADAMS BRANCH	430	0	0	430	430	143	0	0	143	143
NORTH BABCOCK	92	92	92	0	0	1	1	1	0	0
UPPER BABCOCK	46	46	46	0	0	0	0	0	0	0
(GALLOWAY TOWNSHIP COUNT)	179	179	94	0	85	24	24	14	0	10
JACK PUDDING BRANCH	72	72	72	0	0	1	1	1	0	0
(GALLOWAY TOWNSHIP COUNT)	0	0	0	0	0	0	0	0	0	0
MAN KILLER BRANCH	100	100	100	0	0	3	3	3	0	0
LOWER GRAVELLY RUN	31	30	30	1	1	2	1	1	1	1
UPPER GRAVELLY RUN	523	30	30	493	493	63	0	0	63	63
(EGG HARBOR TOWNSHIP COUNT)	4	4	4	0	0	10	10	10	0	0
CEDAR BROOK	617	3	3	614	614	11	0	0	11	11
TOTALS	2626	565	480	2061	2146	271	40	30	231	241

In general, private well water supplies in the study basins are drawn from the Kirkwood-Cohansey water table aquifer and returned to the same aquifer through a private in-ground septic system (minus a small percentage of evaporated water, roughly estimated at 44 GPD for each residential unit). As such, there is little net water loss to the hydrologic system when wells are combined with septic systems. However, the environmental drawback to the use of septic systems is a degradation of water quality in the form of increased nitrogen compounds (and other pollutants). Natural nitrate levels in the Pinelands are very low, a major cause of the unique biota of the Pinelands. Human introduced nitrates (and other nutrients from agricultural and lawn fertilizers) can disturb the existing natural balance.

Public water supplies in the Hamilton Township portions of the study basins are also drawn from the Kirkwood-Cohansey water aquifer and from the Kirkwood 800 Foot Sand aquifer (Well #5). Map 2 shows the location of the public supply wells. However, the wastewater is presently collected by sewers and treated at the Hamilton Township MUA plant in May's Landing and discharged directly into Babcock Creek. While such a process negates the problem of increased nitrogen levels in the ground water and in streamflows (above the treatment plant discharge point), the export of the used water significantly reduces streamflows (at an estimated rate of 265 GPD for <u>each</u> sewered residential unit) in the stream basins from which the ground water is withdrawn.

Table 7 shows that roughly 75% of all users in the study basins are served by public water and sewers. These users are found only in the high development zones of Babcock Creek, Upper Gravelly Run, and Cedar Brook in Hamilton Township. Sewers are also present in Upper Babcock in Galloway Township. Outside of the study basins, May's Landing and several surrounding communities are also provided public water and sewer service by the HTMUA.

As of 1988, the Hamilton Township MUA water supply allocation was roughly 1.5 MGD (based on the average monthly limit). During the period of the study, HTMUA used roughly 1.0 MGD of this allocation -- well #5 and #6 were the two existing production wells over this period. In 1989 the HTMUA requested and received approval for an increase in its allocation permit to 2.5 MGD in anticipation of new development needs for increased water supply.

The existing design capacity of the Hamilton sewage treatment plant is 1.5 MGD. Rather than seek to increase the plant capacity, the HTMUA has made arrangements to connect with the Atlantic County utilities Authority sewage treatment system and to shut down their own plant. While still several years from implementation, this plan will lead ultimately to the export of all locally generated public water supply. The initial wastewater export limit on HTMUA to the ACUA system is 5.825 MGD. An additional 1.175 MGD is allocated to the Parkway Authority, FAATEC, Egg Harbor Township, and Galloway Township.

HYDROLOGIC SYSTEM

Hydrologic Buduet, Existinq Conditions (1988)

Table 8 is a hydrologic budget for the Hamilton study basins (and Miry Run) based on data gathered from various published sources and based on streamflow data collected by Pinelands staff during 1988 and 1989.

TABLE 8: HYDROLOGIC BUDGET FOR EXISTING CONDITIONS (1988-1989)

	UPPER BABCOCK	BABCOCK SWAMP	LOWER BABCOCK	UPPER GRAVELLY RUN	LOWER GRAVELLY RUN	CEDAR BROOK	MIRY RUN
			(UNITS = MGD)				
AREA (SQ MI):	11.98	4.32	3.70	4.95	3.88	1.74	5.82
PRECIPITATION	23.92	8.62	7.39	9.88	7.74	3.47	11.62
SEPTIC RECHARGE	0.07	0.02	0.00	0.01	0.01	0.00	*
TREATMENT PLANT DISCHARGE	0.00	0.00	0.00	0.15	0.00	0.00	0.00
UPSTREAM INFLOW	0.00	9.28	12.28	0.00	3.83	0.00	0.00
TOTAL INFLOWS	23.99	17.92	19.67	10.04	11.58	3.47	11.62
AVERAGE STREAMFLOV	9.28	12.28	18.62	3.83	7.45	1.15	4.61
EVAPOTRANSPIRATION	13.99	5.04	4.32	5.78	4.53	2.03	6.80
PUBLIC UITHDRAUALS	0.00	0.00	0.27	0.00	0.07	0.00	0.00
PRIVATE UITHDRAUALS	0.11	0.03	0.00	0.01	0.01	0.00	*
TOTAL OUTFLOWS	23.38	17.35	23.21	9.62	12.05	3.45	11.41
NET FLOV MAX ERROR (%)	2.61	3.31	17.98	4.39	4.13	9.09	1.85

* No value available for the Miry Run basin

Note that public withdrawals do not sun to 1.0 MGD. Remainder is allocated to other basins.

Hydrologic budgets delineate the inflows and outflows of water in some geographic region over some time period. Such budgets are useful in making a determination of the effect of changes in the natural system (e.g., the effect of a prolonged drought on streamflow and ground water levels) or of changes in human utilization and disposition of water resources (e.g., adding sewers to a region). More detailed information about hydrologic budget models may be found in Appendix B.

Table 8 is organized on the basis of the three major streams out of which the study basins were formed: 1)Babcock Creek, having a total area of 20.0 square miles, 2) Gravelly Run, having a total area of 8.83 square miles, and 3) Cedar Brook, with an area of 1.74 square miles. The Cedar Brook study basin, for purposes of determining the existing and projected development, was only 1.56 square miles. The additional 0.18 square miles used in the budget reflects a downstream portion of the basin.

It should be noted that the hydrologic budget also includes data on Miry Run. This stream basin was not subject to geographic analysis, but was subjected to hydrologic data collection and evaluation.

In the Babcock Creek portions of the budget, some of the study basins are combined. This was done in areas where small tributary streamflow data had a higher degree of uncertainty and/or development is and will be limited, given present zoning. Upper Babcock was combined with its two tributaries, Man Killer and Jack Pudding Branches. Babcock Swamp was combined with its two tributaries, Adams Branch and North Babcock. In the cases of the others streams, the study basins were kept separate in the budget analysis.

Inflows are defined as a hydrologic source with respect to a basin, that is, any system that provides water to a basin. In the case of the Hamilton study basins, major inflows are:

1) precipitation (41.93 inches per year),
2) septic recharge from development units that are not sewered,
3) sewage treatment plant discharge to Gravelly Run from FAATEC, and
4) streamflow from the upstream portion of the basin.

Other sources of inflow, such as irrigation return and ground water underflow were assumed to be negligible.

Outflows are defined as hydrologic sinks with respect to a basin, that is, any system that removes water from a basin. Outflows in the budget include:

1) average streamflow (found in Table 5),
2) evapotranspiration, which is the evaporative loss of water by plant transpiration and from undrained depressions.
3) public well withdrawals from the ground water system by the HTMUA, and
4) private well withdrawals from the ground water system.

Other potential outflows, such as irrigation evaporative loss, surface withdrawals and ground water underflow were considered to be negligible.

Aside from the magnitude of the various fluxes in the budget, what does the budget indicate about the study basins? A comparison of the total inflows and outflows shows that, with the exception of Lower Babcock, the totals are within five or ten percent of one another. Such a low degree of error or difference is excellent, given that the inflows and outflows are themselves subject to errors in measurement and in the analytical processes by which they are derived. As an example, instantaneous streamflow measurements are considered to have an error of +/-10% (R. Schopp, USGS, personal communication). The significant conclusion that may be drawn from the low degree of difference between inflows and outflows is that all of the assumptions, data and analysis that were used to define the hydrologic components of the study basins converge to produce flux values that are consistent with one another; therefore, values that may be considered to have a high degree of validity when used to describe how the real system works. In general, we may conclude that we have a valid quantitative model for evaluating existing and future hydrologic conditions in the study basins.

The roughly eighteen percent (18%) error in the Lower Babcock figures is not unusually high in a hydrologic budget analysis, nor does it detract significantly from the usefulness of the values with respect to this study basin. The suspect value in this basin is average streamflow on the outflow side of the budget -- the increase in streamflow per square mile is much larger than that of any of the other study basins. There are several possible causes for a high value in this basin, but the diversions from Cloverleaf Lakes and Watering Race and tidal influence are the most likely. The surface diversions to this basin increase the total on the outflow side of the budget. However, the drainage area associated with this additional flow is unknown, and the areally computed factors on the inflow side of the budget (precipitation, upstream inflow) are, therefore, underestimated. With regard to tidal influence, the average streamflow value is based on the correlation of measured instantaneous streamflows with continuously gaged streams and shows good agreement. However, the measurements, made during low tide, could have picked up increased flow resulting from tidal back-up and release. Such an occurrence could tend to produce values greater than normal streamflow, just as streamflow measurements below a surface impoundment made during periods when stored water is being released are higher than normal streamflow.

Returning to the average streamflow values for the various study basins in the budget, the sum of these values (27.22 MGD) represents the total amount that could be physically withdrawn for public use; <u>except for the fact that such an action would dry up</u>

<u>the streams and wetlands in the study basins!</u> If we include Miry Run, the total streamflow becomes 31.83 MGD. As the Pinelands Commission is concerned with maintaining natural streamflows and wetlands and with providing water supply for planned development, a more reasonable estimate of available water supply is five to ten percent of the total average streamflow (1.3 to 3.2 MGD). While this range is arbitrary, it reflects a balance between the water supply needs associated with RGA development and the maintenance of natural hydrologic systems; but it should only be viewed as a basis for the preliminary evaluation of potential environmental impact and not as a regulatory standard.

Water Quality Assessment

Supplementary to the water supply elements of this study, a water quality sampling program was carried out by the Bureau of Monitoring Management of the New Jersey Department of Environmental Protection in cooperation with the Pinelands Commission. The purpose of this program was to evaluate surface water quality and ascertain disturbed conditions in any of the study basins. Water quality monitoring locations are shown on Map 3.

The period of sampling was between August 1988 to July 1989. Because several streams were dry during the latter portion of 1988, a complete data set (seven sampling dates) is available only for three (3) stations on Babcock Creek and two (2) stations on Gravelly Run. Comparisons among all streams was, therefore, limited to data collected during the latter part the study. Miry Run, while not a study basin for purposes of the demographic and buildout analysis, was included in the hydrologic aspects of the study.

In the discussion that follows, any characterization of chemical species (e.g., pH, nitrogen or phosphorous species) as having elevated concentrations or levels is indicative of disturbed conditions; i.e., chemical concentrations are higher than generally found in undisturbed Pinelands streams. It should be noted that phosphorous and nitrogen chemical species are nutrients that usually are found at very low concentrations in undisturbed Pineland streams. Sources of elevated nitrogen and phosphorous pollution include agricultural fertilizers and sewage. High pH values are also indicative of disturbed conditions.

The results of the water quality sampling program are given in Tables 9a through 9d. Parameters monitored were temperature, dissolved oxygen (DO), pH, nitrite-nitrogen (N02-N), nitrite+nitrate-nitrogen (NO2+NO3-N), ammonia+ammonium-nitrogen (NH3+NH4-N), total Kjehldahl-nitrogen (TKN), total dissolved solids (TDS), total suspended solids (TSS), alkalinity or acidity, and conductivity. Samples were analyzed by the New Jersey Department of Health's Environmental Chemistry Laboratory.

Cedar Brook was subjected to only one sampling (August 2, 1988), yet it showed elevated values for pH, total Kjehldahl-nitrogen, total phosphorous, and conductivity. Other nitrogen species concentrations were low in Cedar Brook for this one sample date.

With the exception of one elevated pH reading reported for Lower Babcock, pH levels throughout Babcock Creek were usually less than 5.5. The lowest pH values in Babcock Creek were found at Babcock Station #6 in the Upper Babcock study basin (3.8 to 4.5). All pH values greater than 5.0 in Babcock Creek were limited to the summer and fall during low flow conditions. The pH values for Gravelly Run, Miry Run and Man Killer Branch never exceeded 5.0, while those from Jack Pudding Branch ranged from 5.1 to 5.8.

Slightly to moderately elevated nitrite+nitrate-nitrogen concentrations were reported for all study basin streams. The lowest ranges were found in Man Killer Branch (0.15 to 0.19) and in Miry Run (0.16 to 0.18). In comparison, the highest range was found at Jack Pudding Branch (0.77 to 1.37). There was a notable decrease in concentration downstream in both Babcock Creek and Gravelly Run.

All other nitrogen species sampled exhibited low values of concentration. The only exception was the Kjehldahl-N reading for Cedar Brook in August of 1988 and Man Killer Branch in July of 1989.

Elevated phosphorous species (total phosphorous and orthophosphorous) concentrations were reported for Babcock Creek in August of 1988 and for Cedar Brook in the same month. All other stations showed low concentrations of phosphorous species.

TABLE 9a: HAMILTON STUDY WATER QUALITY DATA

Stream Station (Location)	Date	Temp deg.C	DO mg/l	pH field	NO2-N mg/l	NO2 + NO3-N mg/l	NH3 + NH4-N mg/l	TKN mg/l
Cedar Brook (Harding Lake)	08/02/88	32	8.3	7.92	<0.003	0.04	0.08	1.09
Lower Babcock	08/02/88	19.5	6.7	5.32	<0.003	0.25	0.05	0.17
(Old Egg	08/23/88	15.0	10.2	6.17	<0.003	0.32	<0.05	0.23
Harbor Rd)	09/21/88	17.3	7.9	5.32	0.003	0.24	<0.05	0.17
	11/16/88	10.5	8.9	5.48	<0.003	0.23	<0.05	0.11
	02/07/89	5.0	11.0	4.53	0.005	0.39	0.07	0.23
	05/31/89	17.5	9.7	4.58	0.008	0.32	0.12	0.04
	07/11/89	19.5	7.6	4.90	0.006	0.40	<0.05	0.53
Babcock Swamp	08/03/88	19.1	6.9	4.83	<0.003	0.42	0.07	0.22
(Rt. 322)	08/24/88	19.0	7.7	6.4*	0.021	0.51	0.08	0.71
	09/22/88	16.0	7.7	5.55	0.003	0.43	<0.05	0.17
	11/15/88	8.5	8.8	5.31	<0.003	0.36	0.06	0.16
	02/08/89	3.5	10.4	4.56	0.004	0.51	0.05	0.25
	06/01/89	20.0	7.9	4.43	0.01	0.36	<0.05	0.37
	07/11/89	20.0	7.4	4.19	0.012	0.40	0.11	0.64
Upper Babcock	08/03/88	18.5	7.2	5.22	<0.003	0.61	0.05	0.18
(Pine Street)	08/24/88	17.0	9.6	5.3*	<0.003	0.60	<0.05	0.14
	09/22/88	16.0	7.8	5.27	0.003	0.67	<0.05	0.16
	11/15/88	9.5	8.8	4.71	<0.003	0.62	<0.05	0.17
	02/08/89	4.0	10.6	4.50	0.004	0.67	<0.05	0.29
	06/01/89	18.5	7.0	4.32	0.01	0.36	<0.05	0.42
	07/12/89	18.0	7.1	4.63	0.01	0.48	0.14	0.63
Babcock #6	08/03/88	19.0	5.6	4.37	<0.003	1.23	<0.05	0.33
(Holly Street)	11/15/88	10.0	8.6	4.09	<0.003	1.10	0.05	0.20
	02/08/89	5.0	10.2	4.43	0.004	0.69	<.05	0.44
	06/01/89	20.0	7.0	4.50	0.014	0.39	0.06	0.53
	07/12/89	19.5	6.8	3.82	0.011	0.51	0.08	0.83

FOOTNOTES

* low quality control results

E estimated value; may not be accurate

TABLE 9b: HAMILTON STUDY WATER QUALITY DATA

Stream Station (Location)	Date	ORTHO P-P mg/l	TOTAL P-P mg/l	TDS mg/l	TSS mg/l	pH Lab	Alka-linity mg/l	Acid-ity mg/l	Cond umhos
Cedar Brook (Harding Lake)	08/02/88	<0.01	0.11	30*	13	6.15E	2		289.0
Lower Babcock	08/02/88	0.01	0.04	36*	1	5.78E	2		38.1
(Old Egg	08/23/88	0.01	0.03	37	1	5.9	4		39.0
Harbor Rd)	09/21/88	0.02	<0.02	39	6	5.7	3		33.2
	11/16/88	0.01	<0.02	36	2	5.8	3		40.4
	02/07/89	0.01	0.02	45	2	4.5	<1		62.1
	05/31/89	0.01	0.03	62	2	4.4		42	66.2
	07/11/89	<0.01	0.02	10	74	4.6	1		64.3
Babcock Swamp	08/03/88	0.01	0.03	32	<1	5.8	3		40.6
(Rt. 322)	08/24/88	0.07	0.28	54	16		11		64.7
	09/22/88	0.01	<0.02	3	16	5.7	3		33.4
	11/15/88	0.01	<0.02	36	<2	5.3	3		44.8
	02/08/89	<0.01	0.03	59	6	4.3		114	67.0
	06/01/89	0.01E	0.03	88	3	4.3		44	98.4
	07/11/89	<0.01	0.02	4	70	4.6	1		61.5
Upper Babcock	08/03/88	0.01	0.03	39	1	5.5	2		42.5
(Pine Street)	08/24/88	<0.01	0.04	41	3		2		47.0
	09/22/88	0.01	<0.02	25	3	5.5	2		39.9
	11/15/88	<0.01	<0.02	37	<2	4.9	1		52.2
	02/08/89	0.02	0.03	58	3	4.3		52	75.9
	06/01/89	0.0	0.04	80	6	4.3		40	78.7
	07/12/89	<0.01	0.02	7	74	4.4		44	68.9
Babcock #6	08/03/88	<0.01	0.02	40	<1	4.6	1		53.2
(Holly Street)	11/15/88	<0.01	<0.02	54	3	4.2		80	85.1
	02/08/89	0.02	0.02	38	2	3.8		122	109.6
	06/01/89	0.01E	<0.02	73	5	3.9		38	67.1
	07/12/89	0.01	<0.02	3	93	3.9		40	82.7

FOOTNOTES
- * low quality control results
- E estimated value; may not be accurate

TABLE 9c: HAMILTON STUDY WATER QUALITY DATA

Stream station (Location)	Date	Temp deg.C	DO mg/l	pH field	NO2-N mg/l	NO2 + NO3-N mg/l	NH3 + NH4-N mg/l	TKN mg/l
Gravelly Run #7	08/02/88	18.0	8.6	4.62	<0.003	0.17	0.05	0.16
(Rt. 559)	08/23/88	14.5	8.7	4.89	<0.003	0.16	<0.05	0.11
	09/21/88	17.0	8.8	4.70	0.003	0.13	<0.05	0.11
	11/16/88	11.0	9.6	4.12	0.003	0.12	<0.05	0.14
	02/07/89	6.0	11.0	4.23	0.003	0.26	<0.05	0.24
	05/31/89	17.0	9.1	4.40	0.004	0.34	0.13	0.48
	07/11/89	17.2	9.6	4.20	0.012	0.24	0.08	0.39
Gravelly Run #8	08/02/88	16.0	8.0	4.35	<0.003	0.46	0.05	0.17
(Neu York Ave.)	08/23/88	14.0	8.2	4.97	<0.003	0.43	<0.05	0.09
	09/21/88	15.0	7.3	4.85	<0.003	<0.05	<0.05	0.01
	11/16/88	14.0	7.6	4.50	<0.003	0.41	<0.05	0.10
	02/07/89	8.0	9.6	4.38	<0.003	0.54	<0.05	0.16
	06/01/89	17.5	6.2	4.65	0.01	0.45	0.11	0.43
	07/11/89	16.0	6.8	3.52	0.012	0.59	0.09	0.39
Jack Pudding Br	02/08/89	4.0	9.6	5.81	0.004	1.37	0.05	0.36
(Cologne Ave.)	06/01/89	23.0	5.7	5.05	0.01	0.91	0.10	0.39
	07/12/89	23.0	6.4	5.48	0.011	0.77	0.10	0.61
Man Killer Br	02/08/89	3.0	8.0	4.73	0.003	0.19	0.08	0.21
(Holly Street)	06/01/89	20.0	4.2	4.25	0.01	0.16	0.06	0.24
	07/12/89	20.0	3.2	4.73	0.016	0.15	0.07	1.05
Miry Run #12	02/07/89	3.0	9.04	4.09	<.003	0.18	<.05	0.27
(Alt. Rt. 559)	05/31/89	18.5	5.0	4.20	0.007	0.16	<.05	0.36
	07/11/89	20.0	4.4	4.30	0.015	0.20	<.05	0.45
Miry Run #13	05/31/89	17.0	5.5	4.70	0.004	0.27	<.05	0.16
(Pine Ave.)	07/11/89	18.5	4.6	3.77	0.011	0.22	0.05	0.18

FOOTNOTES

* Lou quality control results

E estimated value; may not be accurate

TABLE 9d: HAMILTON STUDY WATER QUALITY DATA

Stream Station (Location)	Date	ORTHO P-P mg/l	TOTAL P-P mg/l	TDS mg/l	TSS mg/l	pH lab	Alka-linity mg/l	Acid-ity mg/l	Cond umhos
Gravelly Run #7	08/02/88	<0.01	0.02	28*	1	5.2	2		38.7
(Rte. 559)	08/23/88	0.01	0.02	36	1	4.8	1		38.6
	09/21/88	<0.01	<0.02	25	4	5.0	2		89.1
	11/16/88	<0.01	0.02	40	1	4.4		44	52.6
	02/07/89	0.01	<0.02	49	4	4.4		50	62.3
	05/31/89	<0.01	0.03	48	4	4.1E		34	63.6
	07/11/89	<0.01	<0.02	6	67	4.2		56	61.8
Gravelly Run #8	08/02/88	0.01	0.02	33*	2	4.9	2		50.5
(New York Ave.)	08/23/88	0.01	<0.02	37	1	5.0	1		51.2
	09/21/88	0.01	<0.02	36	6	5.0	2		45.5
	11/16/88	<0.01	<0.02	41	2	4.9	1		47.0
	02/07/89	0.01	0.02	45	4	4.8	1		64.8
	06/01/89	0.03E	0.03	50	8	4.4		24	63.3
	07/11/89	0.02	0.04	5	63	4.5	<1		61.1
Jack Pudding Br	02/08/89	0.01	0.02	96	<1	5.5	3		126.0
(Cologne Ave.)	06/01/89	0.01	0.04	90	11	5.2	2		384.0
	07/12/89	0.01	0.03	3	73	5.8	4		79.5
Man Killer Br	02/08/89	0.05	-	79	<1	4.0		46	126.5
(Holly Street)	06/01/89	0.01	0.03	112	6	4.3		32	158.7
	07/12/89	0.01	0.02	36	120	5.0	4		134.0
Miry Run #12	02/07/89	<0.01	0.02	56	6	4.0		66	83.8
(Alt. Rt. 559)	05/31/89	<0.01	<.02	63	2	4.3E		46	60.3
	07/11/89	<0.01	<.02	<2	58	4.2		44	59.1
Miry Run #13	05/31/89	<.01	<.02	29	2	4.6E	1		50.9
(Pine Ave.)	07/11/89	<.01	<.02	3	34	4.7	1		43.1

FOOTNOTES

* low quality control results

E estimated value; may not be accurate

PROJECTED DEVELOPMENT AND HYDROLOGIC IMPACT ANALYSES

Buildout Estimates

Buildout within sewerable and unsewerable zones was estimated for each of the study basins. Sewerable areas are limited to Regional Growth Areas, Pinelands Villages and Pinelands Towns. Projected residential and non-residential (commercial, industrial) development was estimated using a series of overlay maps showing 1) watershed boundaries, 2) municipal zoning 3) land use, and 4) soil types (upland, wetland). From these map overlays, a planimeter was used to measure the developed and undeveloped acreage in each study basin by municipal zone and soil type. The undeveloped acreages were then used as a basis for calculating future development in each study basin.

Buildout was estimated by a two step process. First, maximum zone capacities were found by applying appropriate municipal zoning densities to the undeveloped acreages (wetland and/or upland, as appropriate) in each zone. In addition, a 50% floor-area ratio was applied to undeveloped commercial/industrial zones, a maximum value representative of urban areas.

The maximum zone capacities were then adjusted downward to reflect constraints on development in the local area and to produce a maximum buildout estimate. Historical and planned development densities were analyzed and used as a guide to determine realistic zone densities. Historical development data were obtained from Pinelands Commission development application records. Planned development data was obtained from material supplied by HTMUA, which delineated new development projects slated for inclusion in the Atlantic County Utilities Authority Coastal Interceptor project. In the maximum buildout estimate, residential buildout in Regional Growth Areas, Pinelands Villages and Pinelands Towns was reduced by a realization factor, the magnitude of which was related to the zone density. The commercial/industrial floor-area ratio was reduced from 50% to 30% of the available acreage, based on a review of locally derived information, consultation with local experts and a review of the literature.

In the case of the PIRD zone of Galloway Township, which overlaps the Jack Pudding Branch and Upper Babcock subbasins, an actual development application plan was used to project buildout. This zone is projected for 685 residential units and a golf course. Water loss resulting from ground water derived irrigation of the golf course was estimated at 50% of the projected annual irrigation volume (49.1 MG) to account for evapotranspiration, a factor commensurate with rainfall evapotranspiration.

Table 10 shows the totals of new residential units and non-residential (commercial/industrial) square footage in each study basin for each step in the analysis. The table also differentiates development between private water and septic, and public water and sewer.

The maximum buildout totals show that the study basins in Hamilton Township could experience an increase of 14,967 residential units at buildout. It also shows that 12.1 million square feet of new commercial/industrial development is possible in the Hamilton study basins. Galloway Township's projections for maximum buildout of the study basins are less: commercial development at 3.6 million square feet, and residential at 1125 new units. Egg Harbor buildout figures are negligible owing to the small area of the township in the study basins. It should be noted that portions of the Hamilton Regional Growth Area lie outside of the study basins, e.g,, May's Landing, some of the Industrial zone south of Harding Highway, and the corridor between Route 559 and the Great Egg Harbor River. Given these omissions from the buildout analysis, the final estimates may be considered low or conservative with respect to the ultimate buildout of the RGA zones in the township.

The following table shows the realization factors that were applied to the maximum zone capacities to produce a maximum buildout figure for residential RGA zones.

Zone Density (units/acre)	Realization Factor
<0.1	.88
0.1-0.3	.86
0.3-1.0	.83
1.0-2.0	.79
2.0-4.0	.72
>4.0	.64

These factors represent a reduction for streets and other conditions that lead to reduced buildout, e.g., fragmented land ownership, isolated or poorly situated lots, and the variation found in actual development densities.

TABLE 10: MAXIMUM ZONE CAPACITIES AND MAXIMUM BUILDOUT (NEW RESIDENTIAL AND NON-RESIDENTIAL UNITS)

STUDY BASIN (TOWNSHIP)	MAXIMUM ZONE CAPACITY		MAXIMUM BUILDOUT	
	RESIDENTIAL (UNITS)	NON-RES (SQUARE FEET)	RESIDENTIAL (UNITS)	NON-RES (SQUARE FEET)
LOWER BABCOCK (HAMILTON)				
PUBLIC WATER & SEWER	3514	3,094,938	2249	1,856,963
PRIVATE WELL AND SEPTIC	41	0	41	0
BABCOCK SWAMP (HAMILTON)				
PUBLIC WATER & SEWER	1756	1,877,436	1123	1,126,462
PRIVATE WELL AND SEPTIC	196	0	196	0
ADAMS BRANCH (HAMILTON)				
PUBLIC WATER & SEWER	528	106,722	338	64,033
PRIVATE WELL AND SEPTIC	8	0	8	0
NORTH BABCOCK (HAMILTON)				
PUBLIC WATER & SEWER	0	0	0	
PRIVATE WELL AND SEPTIC	189	0	189	
UPPER BABCOCK (HAMILTON)				
PUBLIC WATER & SEWER	0	0	0	
PRIVATE WELL AND SEPTIC	441	0	441	
UPPER BABCOCK (GALLOWAY)				
PUBLIC SEWER	1841	5,932,872	640	3,559,722
PRIVATE WELL AND SEPTIC	143	0	143	0
JACK PUDDING BR (GALLOWAY)				
PUBLIC SEWER	1090	0	342	
PRIVATE WELL AND SEPTIC	0	0	0	
JACK PUDDING BR (HAMILTON)				
PUBLIC WATER & SEWER	293	368,082	187	220,849
PRIVATE WELL AND SEPTIC	374	0	374	0
MAN KILLER BRANCH (HAMILTON)				
PUBLIC WATER & SEWER	0	0	0	0
PRIVATE WELL AND SEPTIC	324	10,000	324	10,000
LOWER GRAVELLY RUN (HAMILTON)				
PUBLIC WATER & SEWER	166	8,400,546	131	5,040,328
PRIVATE WELL AND SEPTIC	0	0	0	0
RD/RGD (WATER & SEWER)	5168	0	3721	0
UPPER GRAVELLY RUN (EGG HARBOR)				
PUBLIC WATER & SEWER	179	0	142	
PRIVATE WELL AND SEPTIC	0	0	0	
UPPER GRAVELLY RUN (HAMILTON)				
PUBLIC WATER & SEWER	8105	6,048,306	5188	3,628,983
PRIVATE WELL AND SEPTIC	0	0	0	0
CEDAR BROOK (HAMILTON)				
PUBLIC WATER & SEWER	552	228,690	437	137,214
PRIVATE WELL AND SEPTIC	20	0	20	0
TOTAL	24,928	26,067,592	16,235	15,644,555

Note: Study basins do not cover the entire Hamilton RGA

Hydrologic Impact Analyses

Six hydrologic impact analyses were carried out in this study. Each analysis provides an estimate of average streamflow reductions resulting from existing or projected development levels and water supply and disposal schemes. In turn, streamflow reduction serves to qualitatively indicate other environmental impacts, i.e., the lowering of ground water levels and wetlands degradation. Streamflow reduction percentage is defined in this study as the sum of ground water withdrawals in a study basin divided by the estimated average streamflow (the average streamflow of the hydrologic budget, plus any sewered well withdrawals in the stream basin). It must be stressed that the analyses consider only the water losses associated with ground water withdrawals in the basins and not the myriad of other impacts that accompany development.

The analyses cover a wide range of conditions, from those existing at the time of the study (1988-1989) to those projected at buildout of the study basins. A discussion of the methods and assumptions used in the analyses may be found in Appendix C.

The hydrologic impact analyses were structured to provide a view of the effects of increasing water losses associated with existing and projected development in the study basin regions of Hamilton and Galloway Townships. The do not represent a list of alternative water supply and disposal schemes from which a best or acceptable choice may be found. Rather, they denote the environmental consequences of incremental growth in the study basins.

The reader will note that Cedar Brook does not show any streamflow losses in any of the analyses. No wells were allocated to this basin for the simple reason that its low average flow (1.15 MGD) cannot sustain a major production well without severely stressing the system.

While streamflow reduction is a key number by which to assess the environmental impact of any water supply and disposal scheme, some discussion is needed as to what levels constitute a safe or acceptable impact. This question does not have a simple numerical answer, chiefly because the quantitative aspects of this relationship have not been studied by the scientific community. The following paragraphs are an attempt to help the reader evaluate the meaning of the streamflow reduction number.

> To state the obvious, we may assume that smaller streamflow reductions produce less of an impact than larger reductions.

For the Hamilton Township study basins, a 10% streamflow reduction is roughly equal to a 50% reduction in the 7-day 2-year low flow statistic. This means that a 10% reduction in average streamflows will exacerbate drought conditions, but should not dry up the streams during such periods. As the streamflow reduction factor exceeds 10%, we can expect to approach conditions of no flow during severe droughts.

Based on Rhodehamel (1979), a typical 1.0 MGD public supply well coupled with sewer export of the used water will use roughly one square mile of recharge in the Pinelands. In small basins or upstream subbasins (10 to 20 square miles), such as are typical of the study area and the Pinelands in general, such a well will produce a streamflow loss of 5% to 10%. As such, it may be suggested that a 5% to 10% streamflow loss is an inherent lower limit resulting from the combination of high density zoning and sewered export of wastewater in small Pinelands basins.

In comparing the relative effects of streamflow losses among basins, the percentage of wetlands area may also be compared. As a general rule, one would expect that areas with higher percentages of wetlands are more susceptible to degradation than areas with less wetlands area, and hydrologic stresses should be located accordingly.

With regard to streamflow reductions and wetlands degradation, there is not necessarily a direct relationship between the two. That is, a 10% streamflow reduction does not imply a 10% wetlands loss. Well location and well discharge rates are probably more significant factors in wetlands degradation, because they have the direct effect of lowering the ground water levels that define wetland conditions. In addition, because the relationship between streamflow and stream stage (the altitude of the stream surface) is a power function, the percentage ground water level decline in the vicinity of an affected stream cannot be directly equated with the percentage streamflow reduction.

Streamflow reductions in the upper portions of a basin will also reduce streamflows downstream. On the other hand, streamflow reductions in the lower portions of a basin will not affect streamflows in the upstream portions of the basin. Finally, any hydrologic stress applied in the upstream portion of a basin will have a greater percentage impact on the upstream portions than the same stress applied to the downstream portions. These general facts may be combined to state that if you must stress a basin, the least impact will be felt if you concentrate the stress downstream. One caveat to this rule of thumb is that wetlands may account for more area downstream. However, this is not generally the case in the study basins.

In comparing the effects of upstream vs downstream stress placement and associated streamflow reductions, zoning should also be considered. Zones that allow high density development and sewering will have secondary hydrologic impacts on the local environment that zones with lower densities and without sewers will not have, e.g., leakage between sewer lines and the ground water system, large cones of depression associated with public supply wells, altered stormwater runoff patterns. As such, basins dominated by Regional Growth Area zoning are inherently more difficult to protect than basins dominated by rural development and other low density zoning.

Table 11, at end of this section, denotes the streamflow reduction percentages, streamflow losses in MGD, and ground water withdrawals in each subbasin for each hydrologic impact analysis. The following is a description of each hydrologic impact analysis:

1. Existing Conditions - 1988 (1.04 MGD)

This analysis shows the modeled effects of the 1.04 MGD water loss resulting from the operation of public supply wells #5 and #6 and the disposal of the treated wastewater into Babcock Creek downstream of the Babcock Creek study basin boundary. In general streamflow losses in the study basins are negligible under these conditions.

As well #5 (0.55 MGD) is screened in the Kirkwood 800 Foot Sand aquifer, no local surface loss is assumed. However, the analysis does assume that recharge flows to this well from the upstream portions of the Great Egg Harbor River basin that overlay the aquifer subcrop in Hamilton Township. As such, this water loss is allocated to the Great Egg Harbor River totals.

Well 6 screened in the Kirkwood-Cohansey near the surface divide of three stream basins, is assumed to have local impact on streamflows (0.49 MGD). Part of this impact (0.15 MGD) occurs in (and is, therefore, allocated to) the Great Egg Harbor River Basin. In addition, 0.27 MGD is allocated to the Lower Babcock study basin, and 0.07 MGD is allocated to the Lower Gravelly Run study basin.

2. Approved Allocation (2.5 MGD) and Well #8

HTMUA has received approvals for an increase in its water supply allocation to 2.5 MGD, and for a new well (f8 on Map 2) tapping the Kirkwood-Cohansey aquifer. Located near a surface drainage divide, well f8 draws ground water from 1) Jack Pudding Branch of the Upper Babcock basin (0.03 MGD), 2) Adams Branch of the Babcock Swamp basin (0.29 MGD), 3) the Upper Gravelly Run basin (0.42 MGD), and 4) the Absecon Creek basin (0.26 MGD). The increased diversion was allocated to the HTMUA wells on the basis of information supplied by the MUA and is shown below.

WELL	Daily Withdrawal
5	1.0 MGD
6	0.5 MGD
8	1.0 MGD

The higher allocation leads to a total streamflow loss of 1.08 MGD in the study basins (see Table 11 analysis #2 for a breakdown by basin) and a 1.42 MGD streamflow loss in other basins: 1.16 MGD in the Great Egg Harbor River basin (from well #5 and #6) and 0.26 MGD in the Absecon Creek basin (from well #8).

The increased allocation and the new well show little impact on the Babcock Creek basins. The most pronounced effect appears in Upper Gravelly Run, which jumps to an 11% streamflow reduction, due to well #8. This stream flow reduction in Upper Gravelly Run also impacts Lower Gravelly Run, which increases from a 0.9% streamflow reduction under existing conditions to a 6.5% reduction.

3. Maximum Buildout, No Galloway stress (6.827 MGD)

This is the first of two maximum buildout hydrologic impact analyses which provide a comparison of the streamflow losses resulting from Hamilton township's projected water needs (this analysis) and from the combined needs of Hamilton and Galloway Township (the next analysis). The elimination of Galloway Township's buildout water needs from this first analysis is not entirely hypothetical. It is entirely possible that buildout in the Upper Babcock portions of Galloway Township could be served by water supply drawn from outside of the study basins.

This analysis approximates conditions associated with the approval for HTMUA to export 5.825 MGD of wastewater to the Atlantic County Utilities Authority sewage treatment system via the Coastal Interceptor. An additional 1.175 MGD of sewage export has been approved and apportioned among Egg Harbor Township, Galloway Township, the Parkway Authority, and FAATEC. This buildout analysis closely approximates the water supply need associated with the HTMUA sewer export limit (roughly 7.0 MGD). In general, the water supply buildout projections of this study are in close accord with similar projections used to determine Hamilton's sewer export allocation.

Within Hamilton township this analysis assumes that the RGD zone in Lower Gravelly Run will eventually have public water and sewer. The projected water supply demand of this analysis is 6.827 MGD, an increment of 4.327 MGD over the prior analysis.

For this analysis, a single well withdrawing 0.72 MGD was located near the drainage divide of Lower Gravelly Run and Miry Run. The well location and discharge volume were determined such that the total streamflow reduction in each basin would not exceed 10%. It may be envisioned that this well would help to supply the water needs of the RGD zone that overlaps these two basins.

In addition, multiple wells withdrawing 2.607 MGD were located in the Lower Babcock basin. This additional hydrologic stress (plus that of another 1.0 MGD well in Babcock Swamp -- discussed in the next paragraph) increases the streamflow reduction in Lower Babcock from 3.1% under analysis #2 to 22.2%. This large stress was restricted to the Lower Babcock subbasin for the following reasons. The allocation helps to preserve the streamflows of the two upstream subbasins in Babcock Creek (Babcock Swamp and Upper Babcock). It also places the greatest stress on the subbasin with the largest percentage area of Regional Growth zoning (91% in Lower Babcock vs. 34% in Babcock Swamp and 12.4% in Upper Babcock). The proportion of wetlands area is roughly equal in these three subbasins, and therefore, does not provide a preferential basis for well placement. Lower density zoning and existing wells eliminate large portions of the two upper subbasins (Babcock Swamp and Upper Babcock) from well placement and water line consideration. In addition, a significant portion of Upper Babcock's area is in Galloway township, which, as will be seen in subsequent analyses, will need its own water supply wells. Finally, allocating any of the 2.607 MGD to the upstream Babcock Creek subbasins will not reduce the total streamflow reduction (22.2%) of Lower Babcock and will further reduce the upstream flows.

Finally, a new 1.0 MGD well was located in the Babcock Swamp subbasin. This action raises the streamflow losses in the subbasin from 2.6% to 10.7%. While this percentage is high, the only available alternative, that of allocating the 1.0 MGD to the Gravelly Run and Miry Run basins, would raise their combined streamflow reductions to above 18%. The water supply assumptions of this analysis essentially sacrifice the Lower Babcock subbasin in order to maintain all the other subbasins near the 10% limit.

In general, maximum buildout of the study basins in Hamilton township cannot be supplied with locally derived Kirkwood-Cohansey ground water without stressing the entire hydrologic system. All subbasins, with the exception of Upper Babcock and Cedar Brook, have reached or exceed the 10% streamflow reduction limit. Babcock Creek, the largest of the drainages, is severely stressed in its downstream reaches.

4. Maximum Buildout, Galloway included (7.801 MGD)

This is second maximum buildout analysis, which denotes the impact of Galloway Township's projected additional water supply demand of 0.974 MGD. Added to the water supply demand of the prior buildout analysis (6.827 MGD), the Galloway increment yields the total buildout water demand of 7.801 MGD.

The only study basin available to accommodate the Galloway water demand is Upper Babcock. Streamflow reductions increase to 10.8%, 18.7% and 27.4% in Upper Babcock, Babcock Swamp and Lower Babcock, respectively. Streamflow reductions in all other basins remain at the levels of the prior analysis.

Obviously, the addition of Galloway's water demand can only exacerbate the detrimental findings of the prior analysis. Even the two upstream subbasins of Babcock Creek are severely stressed under these buildout conditions.

5. No RGD Rezoning (6.832 MGD)

This is the first of two hydrologic impact analyses that examine the effect of reducing future development potential in Hamilton Township. In this analysis, the only change to the buildout conditions of the prior analysis is that the RGD zone in Hamilton Township will not be rezoned to Regional Growth -- it will remain a rural development zone. This action reduces the total water demand by 0.969 MGD from the prior analysis to yield a total demand of 6.832 MGD, a value virtually equal to that of the first buildout analysis (#4).

As the RGD zone will remain rural development, the proposed 0.72 MGD well near the drainage divide of Gravelly Run and Miry Run (analysis #3) may be eliminated from the water supply system. This action eliminates streamflow reductions in Miry Run and reduces it in Lower Gravelly Run to the level resulting from the approved water allocation (analysis #2). In general, the stress in Miry Run and Lower Gravelly Run is reduced substantially.

The remaining water demand reduction of 0.249 MGD, when applied to either of the two downstream Babcock Creek subbasins, is too small to provide any substantial benefit to this system. Babcock Creek remains severely stressed.

In general, the action to prohibit high density, RGA growth in the RGD zone of Hamilton Township will moderately improve conditions in Lower Gravelly Run, return Miry Run to essentially undisturbed flow levels, but will not substantially reduce the impacts of buildout in Babcock Creek or the other study basins.

6. No RGD Rezoning, Reduction in RGA Zone Capacities (6.219 MGD)

This second analysis, which considers less total development, includes the condition of no zoning change in the RGD zone plus a cutback in RGA residential densities of 25%. This results in a water demand reduction of 0.613 MGD with respect to the prior downzone analysis (a total of 1.582 MGD water demand reduction from the Maximum Buildout analysis #4). The total water supply demand in this analysis is 6.219 MGD.

Given that the streamflow reductions of all of the basins, except for Babcock Creek, have been reduced to moderate levels in the prior analysis, all of the water demand reduction in this analysis was allocated to the Babcock Creek study basin. Streamflow reductions become 10.6%, 10.4%, and 22.8% in Upper Babcock, Babcock Swamp and Lower Babcock, respectively. Only the Babcock Swamp subbasin experiences a substantial change, and the entire basin remains in a high state of stress. Very little change occurs in the Upper Babcock subbasin (10.8% in the prior analysis to 10.6%) because of the preponderance of non-residential water demand in the Galloway Township zones, and the fact that the PIRD zone figures are based on an actual development plan.

In general, environmental benefits resulting from the downzoning conditions of this analysis are minimal for Babcock Creek and at the same levels for all of the other study basins.

TABLE 11: STREAMFLOW REDUCTIONS (%)

STREAM SUBBASIN	ANALYSIS:	1	2	3	4	5	6
UPPER BABCOCK	% LOSS	0.0	0.3	0.3	10.8	10.8	10.6
	FLOW LOSS(MGD)	0.0	0.03	0.03	1.004	1.004	0.984
	WELL LOSS(MGD)	0.0	0.03	0.03	1.004	1.004	0.984
BABCOCK SWAMP	% LOSS	0.0	2.6	10.7	18.7	18.7	10.4
	FLOW LOSS(MGD)	0.0	0.32	1.32	2.294	2.294	1.274
	WELL LOSS(MGD)	0.0	0.29	1.29	1.29	1.29	0.29
LOWER BABCOCK	% LOSS	1.4	3.1	22.2	27.4	26.1	22.8
	FLOW LOSS(MGD)	0.27	0.59	4.197	5.171	4.922	4.309
	WELL LOSS(MGD)	0.27	0.27	2.877	2.877	2.628	3.035
UPPER GRAVELLY	% LOSS	0.0	11.0	11.0	11.0	11.0	11.0
RUN	FLOW LOSS(MGD)	0.0	0.42	0.42	0.42	0.42	0.42
	WELL LOSS(MGD)	0.0	0.42	0.42	0.42	0.42	0.42
LOWER GRAVELLY	% LOSS	0.9	6.5	10.0	10.0	6.5	6.5
RUN	FLOW LOSS(MGD)	0.07	0.49	0.75	0.75	0.49	0.49
	WELL LOSS(MGD)	0.07	0.07	0.33	0.33	0.07	0.07
CEDAR BROOK	%LOSS	0.0	0.0	0.0	0.0	0.0	0.0
	FLOW LOSS(MGD)	0.0	0.0	0.0	0.0	0.0	0.0
	WELL LOSS(MGD)	0.0	0.0	0.0	0.0	0.0	0.0
MIRY RUN	% LOSS	0.0	0.0	10.0	10.0	0.0	0.0
	FLOW LOSS(MGD)	0.0	0.0	0.46	0.46	0.0	0.0
	WELL LOSS(MGD)	0.0	0.0	0.46	0.46	0.0	0.0
GREAT EGG HARBOR RIVER							
	FLOW LOSS(MGD)	0.70	1.16	1.16	1.16	1.16	1.16
ABSECON CREEK							
	FLOW LOSS(MGD)	0.0	0.26	0.26	0.26	0.26	0.26

% LOSS = PERCENTAGE STREAMFLOW REDUCTION IN THE DESIGNATED BASIN
FLOW LOSS = STREAMFLOW REDUCTION IN MGD IN DESIGNATED BASIN: SUM OF WELL LOSS IN THE BASIN AND FLOW LOSS OF NEXT UPSTREAM BASIN.
WELL LOSS = WELL WITHDRAWLS IN THE BASIN (MGD)

Conclusions of the Analyses

The analyses show that the uppermost aquifers of the study basins cannot provide the water supply for projected sewered development without placing excessive stresses on the hydrologic system. There is no optimum Kirkwood-Cohansey water supply scheme for the study basins at levels of development above that associated with the approved HTMUA water supply allocation of 2.5 MGD (analysis #2). The following is a list of specific conclusions.

The water table aquifers in the study basins cannot supply water for development at the levels required to meet the demands associated with the ACUA Coastal Interceptor or maximum buildout without severely stressing the hydrologic system.

Restricting the RGD zone to rural development could have beneficial effects on the Gravelly Run and Miry Run drainages -- assuming no other stresses are placed on these systems.

Even a 25% cut in residential RGA densities will not substantially reduce the hydrologic stresses on any of the study basins at buildout.

Water supply decisions made between the period of HTMUA's full utilization of their existing water supply allocation (2.5 MGD) and the future allocation implied by buildout and by the full implementation of their ACUA Coastal Interceptor sewer export limit (5.825 MGD) are critical to the future status of the study basins.

Ground water withdrawals in the Upper Babcock subbasins of Galloway Township, coupled with sewered export of the wastewater, at buildout severely exacerbates hydrologic stresses in the entire Babcock Creek drainage basin.

Babcock Swamp and Upper Babcock have significant wetlands area and minimal RGA zone area compared to the other study basins.

The fundamental problem in the study basin region is that the Kirkwood-Cohansey water table aquifer and streamflows would be severely stressed at buildout -- given the extent of sewered export of wastewater. With the exception of the mainstem of the Great Egg Harbor River, the drainage basins are relatively small in comparison with the high proportion of their area allocated to high density development zones.

Alternative Sources of Water Supply

Given its location, Hamilton Township has several significant sources of water supply outside of the study basins that may have the potential to provide all of their projected water needs with less of an impact on streamflows than is implied in the hydrologic impact analyses. These other sources include:

1. the Great Egg Harbor River,
2. Lake Lenape, and

3. the Atlantic City 800 Foot Sand aquifer.

The average flow of the Great Egg Harbor River over the Lake Lenape dam is conservatively estimated at 201 to 277 MGD. Water supply could be withdrawn from wells in hydraulic connection with the lake or with the mainstem of the river. In addition, surface withdrawals of winter and spring high flows from the lake and/or the river could be considered, the former being an alternative under review in the Atlantic County Water Supply Study. The use of either alternative to supply all of the future HTMUA water supply needs and that of Galloway Township in Upper Babcock would have a small effect on average streamflow in the mainstem of the Great Egg Harbor River (3.9% to 2.8%, respectively). However, the effects of this reduction on the estuary should be studied as part of any alternative supply plan. One additional fact is critical in the consideration of the use of the Great Egg Harbor River: because the study basin streams are tributaries of the Great Egg Harbor River, the estimated 3.9% to 2.8% streamflow loss in this major drainage will occur regardless of where the water supply system is located.

A third alternative is to make use of the Atlantic City 800 Foot Sand Aquifer in the eastern portions of Hamilton Township. Use of this aquifer for public water supply would essentially negate local streamflow losses in the study basins, given the present interpretation of the ground water flow system. Groundwater and streamflow losses would be diffused over a larger area. However, the Atlantic City 800 Foot Sand Aquifer has formed a large cone of depression due to pumping near the coast over the last several decades, and the effect of using this resource in Hamilton Township would have to be studied. In addition, this aquifer has been under NJDEP moratorium in the recent past, and water supply problems in Cape May County may cause the moratorium to be renewed in the future. In general, this aquifer is part of a larger regional water supply problem, and Hamilton's use of this resource must be considered in the larger context.

It must be recognized that the suggested alternative sources of water supply would require detailed hydrologic, environmental and engineering study before any final decision could be made. The NJDEP estuary study results would also be significant in considerations of the river use alternatives. In addition, the NJDEP-USGS studies of the Atlantic City 800 Foot Sand Aquifer in Atlantic County and Cape May County would also be significant. The following is a list of recommended actions:

1. Investigate the hydrologic, environmental and engineering feasibility of using the Atlantic City 800 Foot Sand aquifer as a major source of water supply in Hamilton Township.

2. **Investigate the hydrologic, environmental and engineering feasibility of using public supply wells in hydraulic connection with the Great Egg Harbor RIver mainstem or Lake Lenape.**

3. **Investigate the hydrologic, environmental and engineering feasibility of using surface flows from the Great Egg Harbor River at Lake Lenape for water supply.**

Appendix A: Methods for Streamflow Estimation

Estimates of streamflow characteristics in study basins are used to develop hydrologic budgets, to estimate ground water recharge to a basin, to evaluate the amount of water supply available for public needs and the ecology, and to evaluate chemical loading and dilution from sewage treatment plants and other sources of pollution. Streamflow characteristics refer to flow values, as defined by statistical methods (e.g., average, median, etc.), or by extreme climatic conditions (e.g., maximum flow, 7-day 2-year low flow, 7-day 10-year low flow).

Streamflow values may be estimated on the basis of area and average regional values per unit area, or on the basis of streamflow data collected in the basin in question and in other basins in the region. The choice of methodology depends upon the availability of streamflow data for a particular basin.

At gaged locations streamflow values may be estimated by using a set of regional regression equations that were developed for the Pinelands Commission Camden County water supply study in 1988. In this study, a regression equation for average flow, 7-day 2-year and 7-day 10-year low flow was developed from the data of 112 streams in the New Jersey Coastal Plain. The method requires an estimate of basin area in order to use the equations:

$$Q\ average = 0.941(Area^{1.15})$$

$$7Q2 = 0.120(Area^{1.36})$$

$$7Q10 = 0.102(Area^{1.25})$$

Each equation requires a basin area in units of square miles and produces a flow value in units of cubic feet per second.

At partial record stations, where instantaneous flows were measured by wading rod techniques, the resulting values can be subject to regression and correlation analysis, as discussed by Riggs (1968 and 1972). The partial record is regressed with values from continuously gaged streams in the nearby region. The regression equation may then be used to estimate the study basin flow value using the continuously gaged stream value in the equation. The regression equation is of the form:

$$Q\ study\ basin = A\ (Q\ gaged\ stream)^{B}$$

where

A = Y-intercept of the regression line,
B = slope of the regression line, and
Q = streamflow value in cubic feet per second.

It should be noted that the actual regression is carried out with log transformations of the measured flow values. Thus, the regression is denoted as log-log.

In this study, both methods were used to estimate flow characteristics of study basins and non-study basin streams. Regression was carried out on data from the continuous gaging stations on the Mullica River near Batsto (U.S.G.S. station 01409400), Batsto River near Batsto (01409500), Great Egg Harbor River at Folsom (01411000), Oswego River at Harrisville (01410000), and McDonalds Branch in Lebanon State Forest (01466500). McDonalds Branch data was used in the case of the smallest study basins, but the results proved unacceptable.

Appendix B: Hydrologic Budget Methods and Assumptions

A hydrologic budget is, more precisely, a quantitative mass balance model of water fluxes with respect to some defined region, typically a stream basin. Mass balance models are used in many scientific disciplines to evaluate system behavior under equilibrium or quasi-equilibrium (long-term average) conditions. The assumption of equilibrium in stream basin fluxes and boundaries allows us to use long term average values derived from historical records and measurements to predict future system behavior as specified fluxes change.

The advantage of using such models is that they are relatively simple to manipulate, require a minimum amount of data, and provide a reasonably valid first approximation of real system values. The nitrate loading models used by the Pinelands Commission and by the New Jersey Department of Environmental Protection to determine the development acreages necessary to achieve prescribed nitrate concentration in the ground water system beneath septic fields are demonstrative of the utility of mass balance models in a regulatory environment.

A mass balance model (or a hydrologic budget) is stated as a mathematical equation:

Inflows = Outflows +/- Change in mass stored

In order to validly apply this model to a system, the three terms of the equation must be defined. The definitions applied in the case of a hydrologic model are the components of the hydrologic cycle.

The hydrologic cycle is a qualitative description of the myriad processes of water flux and storage on the earth. A simple hydrologic cycle appropriate to New Jersey would include the components of precipitation (in), imported water (in), ground water underflow from other states (in), evapotranspiration (out), streamflow to the oceans (out), ground water underflow to the oceans (out), exported water (out), and changes in storage of both surface water impoundments and the ground water system.

The use such a model relies on a comprehensive interpretation of the hydrologic system being evaluated. In general, one has to identify and define, qualitatively, all significant flux and storage processes with respect to a given system and then determine, quantitatively, the magnitudes of the processes. The difficulties inherent to this analysis are several:

1. Many hydrologic system components are not subject to direct observation or measurement. Ground water underflow and storage and evapotranspiration are the best examples. Un-

derflow and the change in storage are generally assumed negligible, unless other information points to their significance. Evapotranspiration is often determined by an empirical model that uses climatic and other data for the region.

2. While the magnitude of the processes varies over time and space, measurement is usually restricted to individual points in space and time. Stream flow gaging by wading rod technique may be done monthly at one or two points along a stream. Even continuous streamflow gaging stations are limited to measuring the flow at a single point in the stream. Precipitation is another case where a point source of information must be assumed to apply across an entire region.

3. The boundaries of the natural system are not directly observable and may not be static. Basins are defined by surface water divides which are interpretations based on topographic information. Their equivalence to basin ground water divides is an assumption.

4. The best data available is usually that related to human use of the resources. Large well withdrawals are recorded and reported, as are sewage treatment plant discharges. The magnitude of human water use is reasonably well documented by historical records and studies.

Given all these difficulties it may seem that the hydrologic budget approach is rife with uncertainty. That would be true, except for the fact that mass balance models test the validity of the assumptions and values from which they are constructed. The degree to which the inflows and outflows of the hydrologic budget balance is an indicator of the accuracy of the system interpretation and of the values describing the magnitudes of the processes.

When inflows and outflows do not converge, it indicates that the basin may have been improperly defined, that significant sources or sinks were missed, or that values are inaccurate. Such a situation typically indicates areas where the system is more complex than originally thought. The hidden value in a hydrologic budget that does not balance is that it identifies the regions where further study needs to be carried out in order to generate a comprehensive understanding of how the real system works.

The hydrologic budget for this study was constructed on the basis of published data and data collected by Pinelands Commission staff. The methods used to analyze the data were in keeping with those of a similar Pinelands Commission study carried out in Camden County (An Assessment of Sewer and Water Supply Alternatives for Pinelands Growth Areas in the Mullica River Basin, Camden County, May, 1988). The following is a brief description of the assumptions and methods that went into generating the values of the hydrologic budget for this study.

Precipitation (inflow) refers to the 30-year Normal at the Atlantic City Airport weather station as reported in the Climatological Data Annual Summary, New Jersey, 1988, and published by the National Oceanic and Atmospheric Administration. The 30-year Normal is the average precipitation at a station over the period 1951 to 1980. This value (41.93 inches) was also used in the computation of evapotranspiration.

Septic recharge (inflow) reflects wastewater re-entering the ground water system after passing through a septic system. Residential septic recharge was computed by multiplying the number of units on private septic, 3.1 persons per unit, 75 gallons per day per person, and 95% occupancy rate. Non-residential septic recharge was computed by multiplying the square footage of the units and .15 gallons per day per square foot. If square footage of the unit(s) was not available, the residential formula was applied.

Treatment plant discharge (inflow) reflects the 1988 discharge to Upper Gravelly Run from the Federal Aeronautical Administration Technical Center. It should be noted that this discharge is planned for inclusion in the Atlantic County Utilities Authority sewer interceptor project.

Upstream inflow (inflow) and Average Streamflow (outflow) reflect long term average values computed on the basis of data, assumptions and methods discussed in other sections of this report.

Evapotranspiration (outflow) was calculated using the methods of Thornthwaite and Mather (1957) as programmed for personal computer by Hughes and others (1985). Temperature data used was the 30-year Normal for the Atlantic City Airport weather station.

Public withdrawals (outflow) were those of the Hamilton Township Municipal Utilities Authority wells (#5 and #6) for 1988.

Private withdrawals (outflows) refers to well withdrawals from residential and non-residential development units in a study basin. Residential withdrawals were calculated by multiplying the total number of units, 3.1 persons per unit, 90 gallons per day per person, and a 95% occupancy rate. Non-residential withdrawals were computed by multiplying the square footage of the units by .18 gallons per day per square foot. If square footage of the unit(s) was not available, the residential formula was applied.

Appendix C: Assumptions of the Hydrologic Impact Analyses

For study basins that are subject to water losses under existing conditions, the existing water loss was added to the average streamflow figure of Table 8 to produce a revised average streamflow. This revised average streamflow was then used in all of the analyses in the calculation of average streamflow reduction shown in Table 11.

Public well withdrawals that affect multiple basins were allocated on the basis of a calculated radius of well influence. The radius of well influence was calculated by dividing the well discharge (gallons per day) by a regional recharge factor of 1487.7 gallons per day per acre (Rhodehamel, 1979). The ratio of in-basin well influence area to total well influence area was then multiplied by the total well discharge to estimate the portion of well discharge withdrawn from the basin. In addition, the withdrawals of well #5, screened in the Atlantic City 800 Foot Sand aquifer, were assumed to be recharged from the updip or overlying Kirkwood-Cohansey and were, therefore, allocated to the Great Egg Harbor River basin. These methodologies resulted in a 0.70 MGD streamflow loss in non-study basins for the first analysis and a 1.42 MGD streamflow loss for all subsequent analyses.

A complicating factor to the buildout scenarios in Hamilton Township is the eventual zoning of the Lower Gravelly Run RD/RGD zone -- presently a Rural Development zone that does not allow public water or sewer. This particular area is slated for rezoning in 1991 to allow public water and sewer services. The buildout hydrologic impact analyses (#4 and #5) assume the rezoning.

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