NORTHERN LANCASTER COUNTY GROUNDWATER STUDY: A RESOURCE EVALUATION OF THE MANHEIM–LITITZ AND EPHRATA AREA GROUNDWATER BASINS

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SUSQUEHANNA RIVER BASIN COMMISSION

The Susquehanna River Basin Commission was created as an independent agency by a federal-interstate compact* among the states of Maryland, New York, Commonwealth of Pennsylvania, and the federal government. In creating the Commission, the Congress and state legislatures formally recognized the water resources of the Susquehanna River Basin as a regional asset vested with local, state, and national interests for which all the parties share responsibility. As the single federal-interstate water resources agency with basinwide authority, the Commission's goal is to coordinate the planning, conservation, management, utilization, development and control of basin water resources among the public and private sectors.

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ACKNOWLEDGMENTS

The authors acknowledge those who made significant contributions to the completion of this project. Local municipal representatives and citizens of the Water Budget Advisory Committee (WBAC) who live in the study area provided guidance and recognized the need for managing the resource. Matt Kofroth, Lancaster County Conservation District, provided helpful insight and leadership on the WBAC. Kelly Gutshall, LandStudies, Inc., provided insight into the local issues and tied together local initiatives, plans, ordinances, and municipal input into recommendations and management strategies. Additional thanks go to the Pennsylvania Department of Environmental Protection (PADEP), which provided funding for this project, and Jineen Boyle, PADEP's project advisor, who provided helpful comments and assistance.

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EXECUTIVE SUMMARY

Achieving a balance among environmental, human, and economic needs in the management of the basin's water resources is a critical mission of the Susquehanna River Basin Commission (Commission), as described in the 1971 Susquehanna River Basin Compact (Compact). The Commission carries out its water resource management responsibilities in a number of ways through its regulatory program, public education and information, and resource evaluation. In areas of intense water resource utilization, the Commission may conduct special studies, water budget analyses, and identify critical aquifer recharge areas (CARAs).

The Commission, in partnership with the Lancaster County Conservation District (LCCD), performed a groundwater resources evaluation of a carbonate valley located in northern Lancaster County, Pennsylvania. The project was funded by the Pennsylvania Department of Environmental Protection (PADEP) through its Growing Greener Grant Program. The study area includes an isolated carbonate aquifer of 50 square miles and a surrounding siliciclastic contributing area of 20 square miles. Parts of 13 municipalities, including the Boroughs of Manheim, Lititz, Akron, Ephrata, and Denver, are located in the study area.

Groundwater is the primary source of water for municipal, domestic, industrial, and agricultural uses. As groundwater withdrawals increase to meet growing demands, stakeholders need information on the location and quantity of water resources available, and how to best develop, conserve, and protect them. Removal of groundwater resources faster than the sustainable rate could lead to a growing water deficit, the gradual failure of water supplies, diminishing stream and spring flows, and degraded aquatic and riparian habitat.

Project participants involved the local public during the course of a study through a Water Budget Advisory Committee (WBAC) and educational workshops. Important resource areas are identified, and management recommendations for these areas are provided in this report.

The study area has experienced rapid growth. From 1990 to 2000, several municipalities in the study area exceeded Lancaster County's growth rate of 11.3 percent. Warwick Township, located in the Manheim–Lititz groundwater basin, experienced the highest growth rate of 33.2 percent. Anticipated growth and development in the study area are expected to result in increased water demand. Population projections from 2000 through 2025 represent a 26 percent increase.

Historic changes in land use have led to increased impervious areas, increased stormwater runoff, and reduced infiltration. Impervious cover was 9 percent of the 70-square-mile study area. This potentially reduces average annual recharge by 1,575 million gallons in the study area. When one considers the carbonate areas of the Manheim-Lititz and Ephrata area groundwater basins, 12.6 percent and 8 percent of these areas are impervious, respectively.

The focus of the study is a valley approximately 50 square miles in area, underlain by a highly productive carbonate aquifer, and herein informally termed the “carbonate valley.” The carbonate valley is nearly completely surrounded by hills underlain by aquifers of much lower permeability (Figure 2). The carbonate valley includes parts of the Chiques Creek, Cocalico Creek, and Lititz Run watersheds. Streams generally flow from north to south across the study area, with the exception of the largest stream, Cocalico Creek, which flows from northeast to southwest.

The study area includes parts of 8 townships and 5 boroughs, and had a population of approximately 61,000 in the year 2000. Water supply needs are met almost entirely by groundwater. The valley was once largely agricultural, but is rapidly changing to a mosaic of urban, suburban, and agricultural areas. The population in the carbonate valley is rapidly growing, as is the need for water. However, the amount of water available is limited. Most of the groundwater is derived from the carbonate aquifer that underlies the valley.

The presence of sinkholes, abundant closed depressions, large springs, and lack of streams in many areas suggests that dissolution of the carbonate bedrock, a condition known as karst, has substantially enhanced the ability of the aquifer to store and transmit water. Karst aquifers are known for their abundant water resources and extremely high well yields, as well as their hard water, enigmatic flow patterns, sinkholes, and high susceptibility to contamination.

Findings

From June 2003 to June 2005, the Commission evaluated the groundwater resources to address water quantity issues in a 70-square-mile area underlying parts of Chiques Creek, Cocalico Creek, and Lititz Run watersheds. Normal annual precipitation was 43.5 inches, of which 14.4 inches was estimated to be groundwater recharge.

Two groundwater basins were delineated (Figure 10) based on water table mapping, and two sets of water level measurements were made during this study.

The Manheim-Lititz groundwater basin is 21.8 square miles and contains the upper Lititz Run watershed and part of Chiques Creek watershed. The groundwater basin is in the area westward from Manheim to within a few thousand feet of the Cocalico Creek water gap, and includes parts of Rapho, Penn, Warwick, and Elizabeth Townships, and the Boroughs of Manheim and Lititz. Groundwater level measurements taken during the study indicate a water table that gradually declines from 400 to 340 feet in elevation.

East of the Manheim-Lititz groundwater basin, the water table rapidly falls 40 to 60 feet. This area is called the Ephrata area groundwater basin, and has a water table graded to the lower reaches of Cocalico Creek, where it crosses the Cocalico Formation through the Cocalico Creek water gap at an elevation of approximately 300 feet. The 48.4-square-mile Ephrata area groundwater basin contains parts of Elizabeth, Warwick, Clay, Ephrata, West Cocalico, and East Cocalico Townships, and parts of Akron, Ephrata, and Denver Boroughs within the Cocalico Creek drainage area.

The annual recharge for each groundwater basin, for the 2-, 10-, and 25-year recurrence intervals, was based on previous regional studies that employed extensive base flow separations, water table mapping, and groundwater modeling. The annual recharge of the Manheim-Lititz groundwater basin, for the 2-, 10-, and 25-year recurrence intervals, was estimated to be 5,822 million gallons, 3,531 million gallons, and 2,449 million gallons, respectively. The annual recharge of the Ephrata area groundwater basin, for the 2-, 10-, and 25-year recurrence intervals, was estimated to be 11,676 million gallons, 7,077 million gallons, and 4,917 million gallons, respectively.

Annual Recharge in Million Gallons for the Study Area and Groundwater Basins

	1-in-2	**1-in-10**	**1-in-25**	**Area (sqmi)**
Manheim-Lititz	5,822	3,531	2,449	21.8
Ephrata Area	11,676	7,077	4,917	48.4
Study Area	17,498	10,608	7,366	70.2

The Commission uses the 1-in-10-year recharge as the sustainable limit of groundwater development. This limit attempts to balance the amount of groundwater available for development, instream flow needs, and required reservoir or tank storage capacity. This would suggest a maximum sustainable limit for groundwater withdrawals of 3,531 million gallons per year (mgy) for the Manheim-Lititz basin and 7,077 mgy for the Ephrata area basin. However, passby flows can place further restrictions on availability.

The Commission, in coordination with the Commonwealth of Pennsylvania, requires that regulated withdrawals negatively impacting streamflows must cease or streamflows be augmented when the flow in a stream classified as a warm water fishery falls below 20 percent of the average daily flow. Discharge of an equal amount of wastewater immediately upgradient or adjacent to the impacted stream reach would largely mitigate this impact.

Groundwater withdrawals in the Ephrata area groundwater basin have not exceeded 10 percent of the lowest flow for 7 consecutive days in 10 years (Q7-10) for Cocalico Creek as it leaves the carbonate valley (Figure 12). However, most of the existing groundwater withdrawals are located in the southern half of the basin, and are compensated for by the discharge from the Ephrata area wastewater treatment plant. However, future withdrawals could trigger the passby requirement in one of the subbasins. This can be avoided by locating wells in downstream areas where the Q7-10 flow is higher.

Streamflows in the study area will be below 20 percent of their average daily flow approximately 30 days per year. Groundwater withdrawals in the Manheim-Lititz groundwater basin have exceeded the Q7-10 for the surface water flow (combined flow from Chiques Creek and Lititz Run) as it leaves the carbonate valley (Figure 13). However, most of the existing groundwater withdrawals are located in the southern half of the basin, and are compensated for by the discharge from the Manheim and Lititz wastewater treatment plants. Future withdrawals located in the northern half of the basin could trigger the passby requirement. The passby requirement can be avoided by locating wells in downstream areas where the Q7-10 flow is higher.

Existing conditions

Groundwater withdrawals were evaluated to determine the total amount of water currently approved for withdrawal (i.e., allocated withdrawals) and the portion of such allocations currently being withdrawn to meet present demands (i.e., existing withdrawals). The total allocated groundwater withdrawals in each basin includes both existing withdrawal amounts plus approved but unused amounts. Existing (actual, current) water withdrawals, plus currently allocated but unused quantities, were identified and totaled for each groundwater basin. These total allocated groundwater withdrawals were compared to the Commission's criterion for allocated withdrawals in potentially stressed areas, (PSAs), which is 50 percent of the 1-in-10-year recharge.

Actual, current (year 2000) withdrawals for the Manheim-Lititz groundwater basin, the Ephrata area groundwater basin, and the entire study area do not exceed 50 percent of the 1-in-10-year recharge.

Allocated and Existing (Current Year 2000) Groundwater Withdrawals and Comparison to the 1-in-10-Year Recharge

	Allocated Withdrawal	**Existing Withdrawal**	**Percent Allocated to the 1-in-10**	**Percent Existing to the 1-in-10**
Manheim-Lititz	2,478	1,493	70	42
Ephrata Area	2,418	1,497	34	21
Study Area	4,896	2,990	46	28

The total groundwater withdrawal in the Ephrata area groundwater basin of 1,497 mgy is approximately equal to that of the Manheim-Lititz groundwater basin (1,493 mgy). However, the area of the Manheim-Lititz groundwater basin (21.8 square miles) is less than half the area of the Ephrata area groundwater basin (48.4 square miles) that results in a groundwater yield of approximately 188,000 gallons per day (gpd) per square mile versus 85,000 gpd per square mile, respectively. The size of a groundwater basin (recharge catchment area) relative to the volume of total withdrawals is an important consideration in determining groundwater sustainability in a given area.

For the entire study area, allocated groundwater withdrawals were 46 percent of the 1-in-10-year recharge. For the Manheim-Lititz groundwater basin, allocated groundwater withdrawals were 70 percent of the 1-in-10-year recharge, which exceeds the Commission's PSA standard. Allocated groundwater withdrawals from the Ephrata area groundwater basin are 34 percent of the 1-in-10-year recharge.

Projected conditions

Groundwater withdrawal for the study area has been projected for 2010 and 2025. The water demand projection is based on census data showing a population of 61,085 in 2000 and a per-capita water use of 116 gpd. Using data provided by Lancaster County Planning Commission, the projected population in 2010 and 2025 will be 67,400 and 76,905, respectively. Utilization in 2010 (3,753 mgy) is estimated to be 35 percent of the 1-in-10-year recharge and 51 percent of the 1-in-25-year recharge. Utilization in 2025 (4,337 mgy) is estimated to be 41 percent of the 1-in-10-year recharge and 59 percent of the 1-in-25-year recharge.

Existing and Projected Total Use and Percent Utilization of 1-in-10 and 1-in-25-Year Recharge for the Study Area

Study Area	2000	2010	2025
Total Population	61,085	67,400	76,905
Total Use mgy*	3,382*	3,753	4,337
Percent Utilization of 1-in-10	28	35	41
Percent Utilization of 1-in-25	41	51	59

*Includes surface withdrawals at Ephrata and Denver.

For the Ephrata area groundwater basin, water use in 2010 (2,070 mgy) is estimated to be 29 percent of the 1-in-10-year recharge and 42 percent of the 1-in-25-year recharge. Water use in 2025 (2,357 mgy) is estimated to be 33 percent of the 1-in-10-year recharge and 48 percent of the 1-in-25-year recharge. The project population in 2010 and 2025 will be 41,329 and 47,174, respectively.

Existing and Projected Total Use and Percent Utilization of 1-in-10 and 1-in-25-Year Recharge for the Ephrata Area Basin

Ephrata Area	2000	2010	2025
Total Population	37,449	41,329	47,174
Total Use mgy*	1,889	2,070	2,357
Percent Utilization of 1-in-10	27	29	33
Percent Utilization of 1-in-25	38	42	48

*Includes surface withdrawals at Ephrata and Denver.

The project population in the Manheim-Lititz groundwater basin in 2010 and 2025 will be 26,071 and 29,732, respectively. Water use in 2010 (1,677 mgy) is estimated to be 47 percent of the 1-in-10-year recharge and 68 percent of the 1-in-25-year recharge. Water use in 2025 (2,007 mgy) is estimated to be 57 percent of the 1-in-10-year recharge and 82 percent of the 1-in-25-year recharge.

Existing and Projected Total Use and Percent Utilization of 1-in-10 and 1-in-25-Year Recharge for the Manheim-Lititz Groundwater Basin

Manheim-Lititz Area	2000	2010	2025
Total Population	23,636	26,071	29,732
Total Use mgy	1,493	1,677	2,007
Percent Utilization of 1-in-10	42	47	57
Percent Utilization of 1-in-25	61	68	82

The existing allocations for groundwater withdrawal are sufficient to meet these projected demands, assuming that the new demand is located on the systems with existing excess capacity or can be served through interconnections with water systems that have excess capacity.

Recommendations

The Commission developed a series of recommendations to address water resource problems in the study area, after consideration of the following: (1) a review of existing ordinances and regulations that impact water resources; (2) a review of related plans and water resource initiatives; (3) community input on issues and concerns through the WBAC and at a June 2004, workshop; and (4) the findings of this study. The *Water Resource Management Recommendations* section provides a detailed explanation of the issues, problems, and recommendations and description of the existing management tools available to the Commission, PADEP, and municipalities.

The recommendations address four major issues. Recommendations 1 through 5 address overall reduction of infiltration and groundwater recharge. Recommendations 6 and 7 address excess withdrawal of groundwater in PSAs. Recommendations 8 through 11 address overall increase in water use, and recommendation 12 addresses consistency among municipal ordinances.

1. ***Problem:*** *Loss of critical aquifer recharge areas (CARAs) from future growth and development is a concern.*

   Recommendation: Municipalities should maintain or enhance the unique hydraulic characteristics of CARAs to maximize the amount of groundwater available for utilization within a groundwater basin. Mapping of these important water resource areas provides information that municipal governments can use to make informed decisions on planning for future growth (Plate 1).

2. ***Problem:*** *Increased areas of impervious cover will reduce the potential for recharge.*

   Recommendation: Municipalities should encourage developers to reduce the effect of impervious cover by implementing technologies that increase the infiltration capability of that cover. Developers should consider using designs such as porous pavement in areas where natural recharge rates are higher than other land areas. Where the infiltration capability of the land cover cannot be increased, such as rooftops, the stormwater runoff can be directed to other areas and enhance groundwater recharge through distributed infiltration best management practices.

3. ***Problem:*** *Floodplain systems that were once areas of natural recharge are now filled with fine sediment and less permeable, thereby reducing recharge.*

   Recommendation: Municipalities should consider floodplain restoration in a limited number of areas that historically contained meandering stream channels, thereby improving groundwater recharge along those reaches.

4. ***Problem:*** *Lack of stormwater plans in the study areas misses opportunities to address infiltration and recharge of stormwater runoff.* .

   Recommendation*:* County and local governments should complete Act 167 stormwater management plans for the remaining areas. They also should implement the PADEP's new comprehensive stormwater policy, which promotes the use of distributed infiltration best management practices to increase groundwater recharge.

5. ***Problem:*** *Certain carbonate areas, such as those identified as karst modified uplands, may not be suitable for on-site stormwater management best management practices.*

   Recommendation: County and local governments should consider distribution of stormwater runoff to regional stormwater management facilities in restored floodplains and CARAs. They also should explore transfer of stormwater requirements to receiving areas (i.e., CARAs or stormwater management facilities) for the expansion of development rights in sending areas (i.e., areas in a development that would normally be set aside for stormwater best management practices).

6. ***Problem:*** *Water use in the Manheim-Lititz and Ephrata area groundwater basins is 70 percent and 34 percent, respectively, of the sustainable limit.*

   Recommendation: The Commission should continue to require groundwater availability analyses for new water withdrawal projects and detailed water budgets in PSAs.

   Regional and local planning agencies should evaluate the impacts of different post build-out scenarios on recharge and water demand.

7. ***Problem:*** *Intensive groundwater withdrawals in localized areas will diminish groundwater yields, base flows, and perennial streamflow.*

   Recommendation: Project sponsors applying for new or increased withdrawals should utilize groundwater models in localized areas to evaluate the withdrawal impact and address sustainability. For localized areas where the sustainable yields have been exceeded, new wells should not be installed and additional withdrawals should be discouraged.

   Since existing allocations for groundwater withdrawal are sufficient to meet projected demands, the Commission should encourage municipalities and water authorities to consider addressing new demand with systems with existing excess capacity or through interconnections with water systems that have excess capacity.

8. ***Problem:*** *The public is not well educated about the limits of groundwater resources.*

   Recommendation: Water resource management agencies should partner with schools to introduce material on water and the environment into the curricula for grades K through 12.

   Water resource management agencies should continue to conduct basinwide or regional workshops to acquaint citizens with water management issues, problems, and solutions. The Commission should present the findings and recommendations of this study to watershed groups, civic organizations, and legislative leaders.

9. ***Problem:*** *Insufficient or incomplete beneficial reuse of process water or wastewater results in increased water demand.*

   Recommendation: Industrial and commercial users should identify opportunities to reclaim water from one application for use in another application. Within the context of appropriate water quality limitations, agricultural sites near urban areas may provide opportunities to recycle industrial and commercial water for irrigation.

   Reuse water is a sustainable water supply. Municipalities should be evaluating ways to take advantage of their wastewater plant effluent for reuse, thus lessening the demand on their potable water supplies. Municipalities can perform "Reuse Master Plans" that focus on reuse opportunities as a water resource for their community and surrounding area.

10. ***Problem:*** *Inefficient water use or lack of conservation measures wastes water.*

    Recommendation: Water authorities and purveyors, in partnership with municipalities, should offer residential water surveys. Water surveyors check for leaking plumbing, provide water conservation tips, offer advice on retrofitting with water-efficient fixtures, and may distribute water-efficiency kits (containing, for example, faucet aerators and low flow showerheads).

    When businesses apply for new or increased withdrawals in PSAs, water resource management agencies should encourage them to consult with qualified engineering firms that specialize in on-site water use evaluations and assist in replacement of water-inefficient equipment.

    Watershed organizations should organize and conduct public information programs consisting of conservation brochures, displays, and classes dealing with outdoor use practices, such as landscaping alternatives and changing wasteful practices, to conserve water.

11. ***Problem:*** *Water discharged from mining operations is underutilized as a resource.*

    Recommendation: The Commission should encourage cooperative efforts to promote alternative water supplies such as mining operations for public drinking water, commercial operations, and industrial supplies.

12. ***Problem:*** *Municipal ordinances that influence water supply availability are inconsistent across municipal boundaries.*

    Recommendation: Local governments should continue to utilize the opportunities presented in the Pennsylvania Municipalities Planning Code to develop comprehensive land management ordinances that address groundwater resource protection and enhancement.

INTRODUCTION

Purpose and Scope

The Susquehanna River Basin Commission (Commission), in partnership with the Lancaster County Conservation District (LCCD), performed a groundwater resources evaluation of a carbonate valley located in northern Lancaster County, Pennsylvania. The purpose of this study is to evaluate the groundwater resources available for development and to provide guidance on how best to develop and conserve them. The study was prompted by a concern about groundwater sustainability, due to the combination of rapid growth and increasing water needs. The study area has an unusual hydrogeological setting, being a carbonate valley that is encircled by hills underlain by aquifers with relatively low permeability. The study was conducted over a two-year period from June 2003 to June 2005.

Location and Geographic Setting

The study area is located in northern Lancaster County in south-central Pennsylvania, approximately 30 miles southeast of Harrisburg, the state capital, and 10 miles north of the City of Lancaster (Figure 1). This area includes a regional groundwater basin and the surrounding contributing area.

The focus of the study is a valley approximately 50 square miles in area, underlain by a highly productive carbonate aquifer, and herein informally termed the "carbonate valley." The carbonate valley is nearly completely surrounded by hills underlain by aquifers of much lower permeability (Figure 2). The carbonate valley includes parts of the Chiques Creek, Cocalico Creek, and Lititz Run watersheds. Streams generally flow from north to south across the study area, with the exception of the largest stream, Cocalico Creek, which flows from northeast to southwest.

The study area includes parts of 8 townships and 5 boroughs, and had a population of approximately 61,000 in the year 2000. Water supply needs are met almost entirely by groundwater. The valley was once largely agricultural, but is rapidly changing to a mosaic of urban, suburban, and agricultural areas. The population in the carbonate valley is rapidly growing, as is the need for water. However, the amount of water available is limited. Most of the groundwater is derived from the carbonate aquifer that underlies the valley.

The presence of sinkholes, abundant closed depressions, large springs, and lack of streams in many areas suggests that dissolution of the carbonate bedrock, a condition known as karst, has substantially enhanced the ability of the aquifer to store and transmit water. Karst aquifers are known for their abundant water resources and extremely high well yields, as well as their hard water, enigmatic flow patterns, sinkholes, and high susceptibility to contamination.

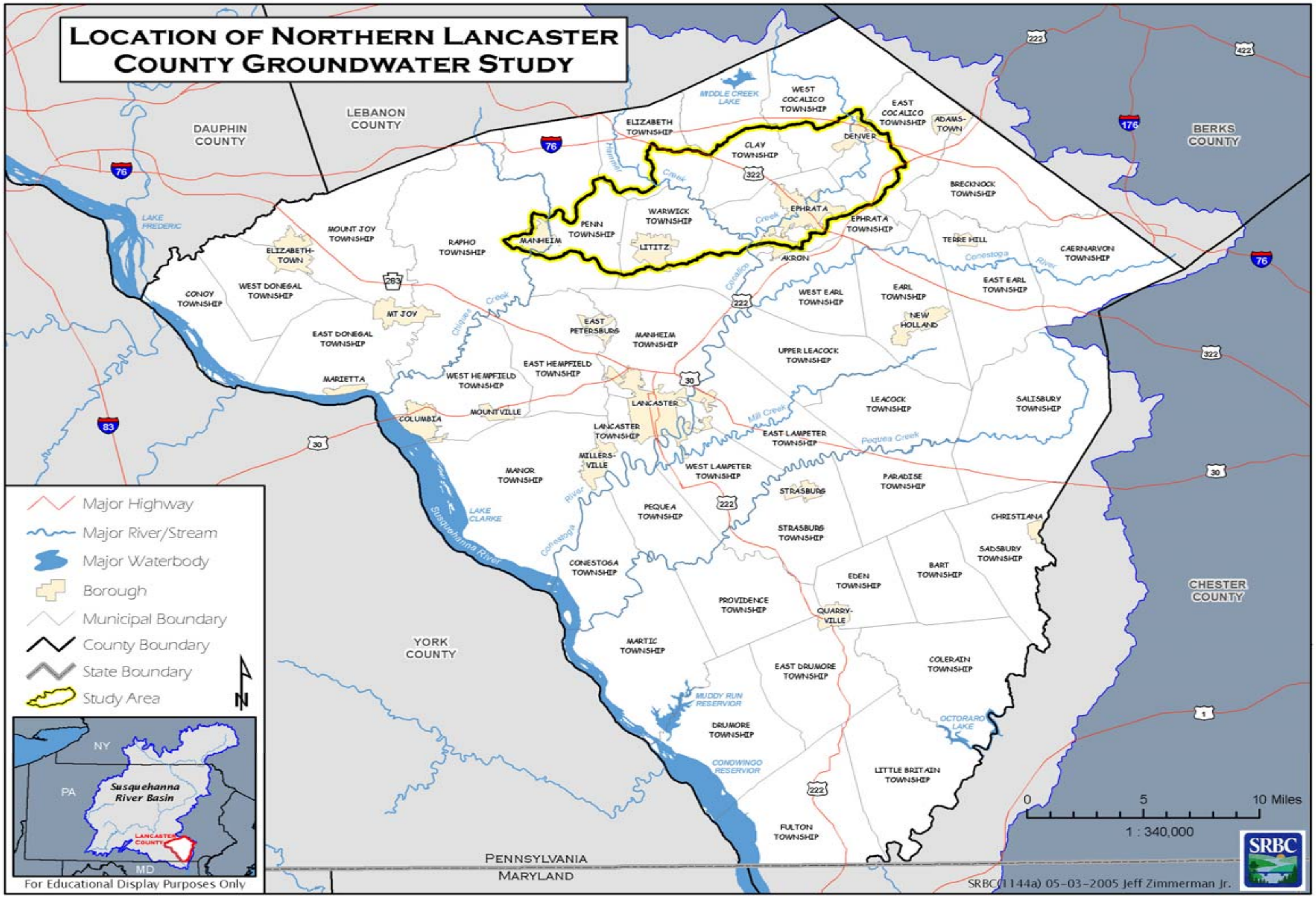

Figure 1. Location of Study Area, Lancaster County

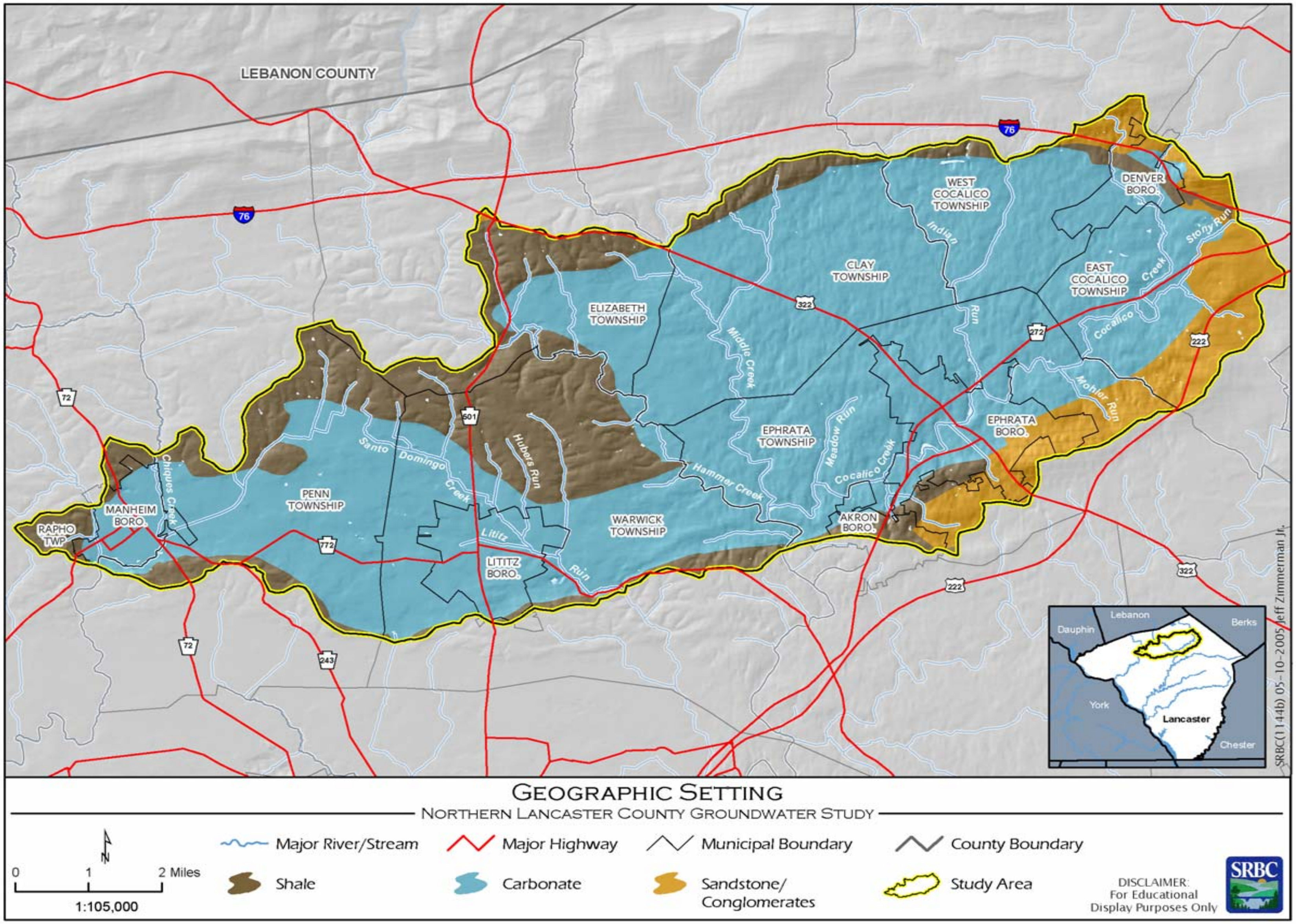

Figure 2. ***Geographic Setting of the Study Area, Lancaster County***

GROUNDWATER BASICS

What is groundwater? Groundwater is any water beneath the earth's surface that supplies wells and springs, and replenishes streamflow. For the purposes of this study, groundwater is the water that has reached the water table and the saturated zone, where all interconnected voids in unconsolidated (loose) sediments, and fractures and openings between layers in consolidated (hard) rock are filled.

Where can groundwater be found? Groundwater occurs virtually everywhere beneath the land surface. Aquifers are the rocks and sediments that contain significant quantities of groundwater and have sufficient permeability to allow groundwater to flow to wells.

What kind of aquifers are in the study area? Groundwater in the study area occurs, with few exceptions, in unconfined, water table aquifers. When a well in an unconfined aquifer is pumped, a region of drawdown and dewatering develops around the well.

The aquifers are primarily composed of consolidated bedrock. The water occurs within interconnected fractures and openings between layers, as well as voids within the bedrock. The density and width of fractures and openings generally decrease with increasing depth. In noncarbonate rocks (sandstones, siltstones, and shales; also termed siliciclastics), most of the fractures are located within 100-300 feet of the ground surface. In carbonate bedrock (limestone or dolostone), some of the fractures have been enlarged where acidic water has dissolved the rock. Fractures may be solutionally enlarged up to depths of several hundred feet, but most occur within 250 feet of the ground surface (Meisler, 1963).

Locally, the saturated zone within weathered bedrock and overlying soils functions as a porous media type aquifer. These porous media aquifers may provide a substantial amount of groundwater storage.

What is karst? Karst refers to a distinctive landscape and underlying soluble bedrock that are characterized by features formed by or resulting from the dissolution of bedrock by acidic water. Some of the karst features typical of the study area include sinkholes, losing streams, dry valleys, large springs, and conduits (natural pipes).

Where does the water found in aquifers come from? Water in aquifers primarily comes from precipitation—mostly rain. Replenishment or "recharge" occurs on most of the land surface, wherever water can soak into the ground. Exceptions include areas covered by impermeable materials like rooftops and paved areas, and areas where groundwater is upwelling, such as most perennial stream valleys.

Precipitation landing on the ground surface must be absorbed by the soil in order to become recharge. If the soil is frozen or precipitation is delivered at a rate that exceeds the ability of the soil to absorb it, then some of the precipitation is "rejected" and becomes surface runoff to streams and wetlands. Surface runoff moves downslope and becomes channelized flow.

Some of the precipitation absorbed by the ground is taken up by plant roots and transpired; the remaining water filters downward through the pores and fractures in the soil in the unsaturated zone. Eventually, this water reaches the water table, the boundary below which all of the spaces and cracks in the soil or rock are filled with water. Water that filters through the ground to the water table recharges the aquifer.

Some water becomes "stranded" in depressions or as drops on leaf (and other) surfaces. Most of this water evaporates and is returned to the atmosphere. The water returned to the atmosphere by plants (transpiration) or by evaporation is grouped under the single term evapotranspiration.

How much groundwater is there in a given area? Although this is difficult to generalize due to differences in recharge rate and geologic controls, the catchment area is an important factor. The groundwater equivalent of a watershed is the recharge area of a groundwater basin. For water table aquifers like those in the study area, the recharge area includes the land surface overlying the aquifer plus that for groundwater flowing into the aquifer from neighboring aquifers.

Where does all the groundwater go? With precipitation and recharge occurring year after year, and a limited amount of interconnected pore space available, aquifers eventually fill up and overflow. When the water table rises to the land surface, the overflow is termed groundwater discharge. Groundwater discharge to streams is termed base flow. For small watersheds, such as those in the study area, the groundwater component of streamflow (base flow) constitutes nearly all of the day-to-day streamflow with the exception of periods of precipitation and a few days afterward, when surface water runoff provides much higher peak flows.

How does groundwater flow? Groundwater flows from areas of higher "head" to areas of lower "head." In the study area, "head" is predominantly the force of gravity and the resulting pressure. Said another way, the water table is a subdued reflection of the topography, being higher beneath hills than it is in valleys. Groundwater flows under the influence of gravity and pressure, from the hills, downward and laterally toward the stream valleys, where it discharges to streams.

What is an underdrained carbonate terrain? A carbonate terrain is said to be "underdrained" when the water table is below most of the stream channels. Underdrained carbonate terrains are underlain by aquifers having extensive karst conduit development. The high permeability results in a water table with a low gradient (slope) and low relief beneath hills. Such areas typically have few flowing tributaries, and extensive areas "drained" by dry valleys, the terrain being effectively drained by the karst conduits. Most of the flowing streams in an underdrained carbonate terrain are through-flowing; that is, they originate outside the carbonate terrain, enter at a lower elevation than smaller streams, flow across it, and leave.

What is the safe yield of a groundwater basin? The safe yield of a groundwater basin is equal to the amount of natural replenishment that the aquifer receives annually. In water budget terms, water withdrawals cannot exceed the average annual water income received by a groundwater basin. The use of the safe yield as a maximum limit for groundwater development will result in a substantial reduction of stream and spring flow during extended periods (several months or longer) with below average precipitation. Stream base flow represents aquifer overflow, which on a long-term basis is equal to the amount of recharge the aquifer receives. During a year with average recharge, the safe yield is equal to the total recharge received. When withdrawals equal the safe yield, the result is the loss of base flow during a year with average (or less) recharge. On a long-term basis, management of groundwater withdrawals using the safe yield as a limit results in a stable average water table elevation, but a substantial reduction in streamflow during years with below average recharge.

What is the sustainable yield of a groundwater basin? The sustainable yield of a groundwater basin is equal to the amount of natural replenishment that the aquifer receives during a year with average recharge (i.e., the safe yield) minus the amount of water required to maintain groundwater discharge sufficient to support the existing aquatic and riparian habitat.

PREVIOUS INVESTIGATIONS

The study area and hydrologically similar neighboring areas have been the subject of several water resource reports. The Pennsylvania Geologic and Topographic Survey has produced a number of reports (Hall, 1934; Meisler, 1963; Johnston, 1966; Meisler, and Becher, 1971; Poth, 1977; Wood, 1980; Royer, 1983; Taylor and Werkheiser, 1984) on this area. These reports focus on county-size areas or the outcrop area of geologic formations of a particular age or rock type, and provide valuable information on the general geology, existing wells, well yields, well performance, well construction, depth to water-bearing fractures, and water quality. More recently, this and additional information have been summarized in a report titled “Geohydrology of Southeastern Pennsylvania” (Low and others, 2002). A statistical summary and searchable database of the hydrogeologic and well construction characteristics of the formations in Pennsylvania were made available on CD (Fleeger and others, 2004).

A quantitative evaluation of the groundwater resources of the lower Susquehanna River Basin was performed by Gerhart and Lazorchick (1984a, 1984b, 1988). They employed extensive water table mapping, base flow separations for 26 watersheds, and groundwater modeling to estimate average annual groundwater availability, and break down the base flow contribution by specific rock types and geologic formations.

Chichester (1991, 1996) studied the hydrogeologic characteristics of the carbonate aquifer in the Cumberland Valley, Pennsylvania. Water level mapping and streamflow measurements were used in conjunction with existing geologic and topographic mapping to develop a hydrogeologic framework. Hydraulic parameters were calculated from specific capacity data. Recharge values were derived from base flow separations of two watersheds in the study area. These were used to develop a groundwater flow model.

The study area is known as a highly productive agricultural region, and one with water quality problems related to agricultural activities. Recently, these problems and the effectiveness of “best management practices” in addressing them has been summarized in several United

States Geological Survey (USGS) publications (Lietman and others, 1996; Hall and others, 1997; Hainly and Loper, 1997; Lietman, 1997; Koerkle and others, 1997; Hainly and others, 2001).

HYDROGEOLOGIC SETTING

Physiography

The study area is located within the Piedmont Lowland Section of the Piedmont Physiographic Province. The Piedmont Lowland Section is underlain by carbonate and siliciclastic rocks of Cambrian, Ordovician, and Triassic Age. These are relatively nonresistant to weathering and erosion, and have developed a landscape that is characterized by relatively low relief and gentle slopes. A noteworthy exception is the resistant Hammer Creek Formation of Triassic Age (Figure 3), which is composed of well-cemented sandstone and conglomerate, and forms a range of rugged hills with up to 550 feet of local relief adjacent to the study area.

The focus of this study is a gently rolling terrain of Cambro-Ordovician carbonates that is almost completely surrounded by hills underlain by Ordovician and Triassic Age siliciclastics (Figure 3). The hills underlain by the Ordovician Age siliciclastic rocks are typically 100 feet higher than the carbonate valley. The hills underlain by the Triassic Age siliciclastic rocks are up to 400 feet higher than the adjacent carbonate valley.

Three streams and their tributaries drain the study area. Surface water drainage is generally from north to south across the width of the carbonate valley. The extreme western portion of the carbonate valley is crossed by Chiques Creek. The topography on the floor of the carbonate valley in the vicinity of Chiques Creek is a gently rolling plain with 10 to 30 feet of local relief. Lititz Run, a tributary of Cocalico Creek, crosses the carbonate valley near Lititz and heads into the Cocalico Formation hills on the north side of the valley. The topography consists of broad, low hills with 40 to 60 feet of local relief. Cocalico Creek and its tributaries drain the eastern two-thirds of the carbonate valley. Cocalico Creek flows along the southeastern edge of the carbonate valley. Major tributaries include, from east to west, Middle Creek, Indian Run, and Hammer Creek. The topography of this portion of the carbonate valley is hilly, with 80 to 120 feet of local relief.

Stratigraphy

Table 1 is a summary of the stratigraphy of formations in the study area arranged in order of increasing geologic age. Formation names and map symbols follow the Geologic Map of Pennsylvania (Berg and others, 1980). The lithologic information presented is from Meisler and Becher (1971).

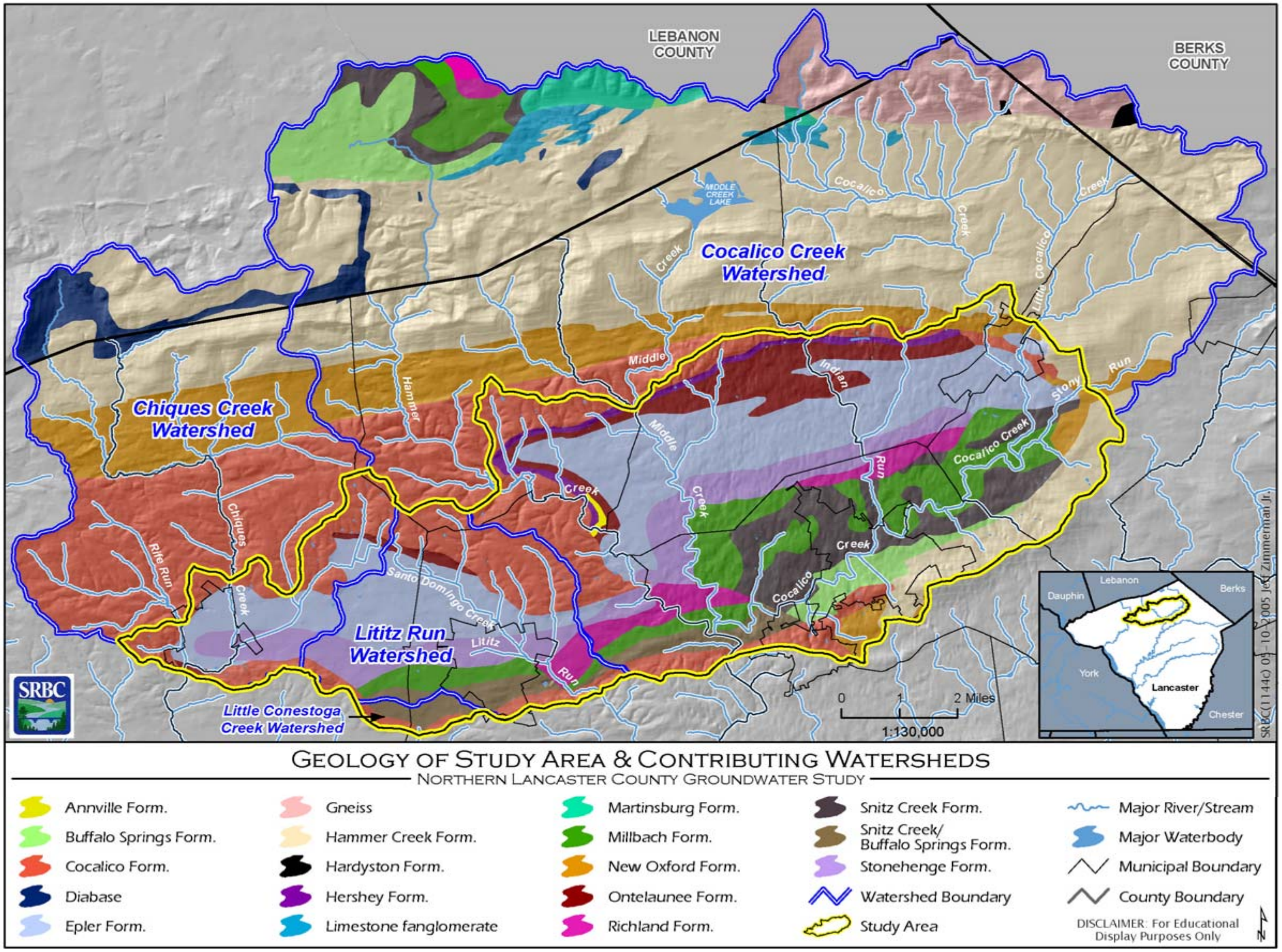

Figure 3. ***Topography and Geology of the Study Area and Upgradient Watersheds***

Table 1. Stratigraphy and Lithologic Characteristics of Formations in the Study Area

Formation	Map Symbol	Description
Hammer Creek; and Conglomerate	Trh; Trhc	Interbedded red shales, red, brown, gray sandstones, and fine to coarse quartz conglomerates.
New Oxford; and Conglomerate	Tnh; Tnhc	Interbedded red shale, siltstone, fine-grained and arkosic sandstones, some with carbonate cement and conglomerate.
Cocalico	Oco	Bluish-black to dark gray fissile shale; purple and green shale with thin quartzite bed near base.
Hershey	Oh	Dark gray, thin bedded, argillaceous limestone; shaly near top of bed.
Myerstown	Omy	Medium gray, thin bed limestone grading to black at base.
Annville	Oa	Light gray, massive bed limestone.
Ontelaunee	Oo	Medium to dark gray, thick-bedded crystalline dolomite with minor limestone.
Epler	Oe	Medium-light gray, thick-bedded limestone and dolomite.
Stonehenge	Os	Medium-gray, crystalline, cherty limestone and gray shaly calcarenite.
Richland	Cr	Gray, thick-bedded, finely crystalline dolomite.
Millbach	Cs	Pinkish-gray and medium gray, laminated limestone with thin sandstones.
Snitz Creek	Csc	Light to medium gray, thick-bedded, oolitic dolomite with medium gray interbeds.
Buffalo Springs	Cbs	Light gray to pinkish-gray crystalline limestone with alternating light gray crystalline dolomite.

The Cambrian and Ordovician carbonates in the study area are similar to those exposed in the Lebanon Valley Subsection of the Great Valley Section of the Valley and Ridge Physiographic Province. They differ in being more strongly deformed and recrystallized, in having more sand and interbedded sandstone, and in their carbonate mineralogy (limestone vs. dolomite). Recrystallization has all but erased the primary rock fabric and fossils. These changes, along with additional sand content and changes in carbonate mineralogy, have made subdivision and detailed correlation with the Cambro-Ordovician Formations of the Great Valley somewhat uncertain. Therefore, a new stratigraphic subdivision for these rocks has gradually developed. Those interested in the detailed stratigraphy of the study area are encouraged to review works by Jonas and Stose (1930); Gray, Geyer and McLaughlin (1958); Hobson (1963); MacLachlan (1967); and Meiser and Becher (1971).

The Ordovician Cocalico Formation is a lightly metamorphosed shale (phyllite) with some interbedded sandstone and siltstone. Lithologic subdivisions within the Cocalico Formation were mapped and described by Jonas and Stose (1930). The Cocalico Formation underlies the low hills that partially encircle the carbonate valley.

The Triassic Age rocks in and near the study area are a part of the northeastern portion of the Gettysburg Basin and are classified as such. They are well described in Glaeser (1966). The basal rock unit, the New Oxford Formation, consists of a discontinuous basal conglomerate zone overlain by light-colored arkosic sandstones, siltstones, and shales. The New Oxford Formation is relatively nonresistant and forms a belt of lowlands.

The New Oxford Formation is overlain by the Gettysburg Formation, which consists of red shale, siltstone, and sandstone. In the study area, the typical Gettysburg is largely replaced by the Hammer Creek member, which is characterized by a dominance of hard sandstone and conglomerate. The Hammer Creek member is relatively resistant to erosion and forms high, rugged hills to the north and east of the study area.

Recent high resolution, infrared air photography of the study area indicates that the structure and stratigraphy locally diverge, sometimes significantly, from the published mapping. However, a comparison of the more recent published mapping (Meiser and Becher, 1971; Berg and Dodge, 1981) suggests that the published mapping is generally correct and is useful for large area hydrogeologic studies such as this one.

Geologic Structure

The geologic structure essentially divides the study area into two geologic terrains. The terrain underlain by Cambro-Ordovician rocks is characterized by complex, recumbent folding and imbricate thrust faulting (Meiser and Becher, 1971). The strike of the beds is generally east-west. Bedding generally dips to the south at 10 to 70 degrees, and is locally overturned. Older beds cover successively younger beds from north to south across the width of the carbonate valley.

The terrain underlain by Triassic Age rocks is characterized by monoclinal structure and normal faulting (Root and MacLachlan, 1999). The strike of the beds is generally east-west. Beds generally dip to the northwest at 20 to 40 degrees. Locally, the structure is often more complex, with open folds and block faulting.

Both the Triassic siliciclastic rocks and the Cambro-Ordovician rocks have well-developed joints. Three sets are usually discernable: strike parallel, strike perpendicular, and strike oblique. The Cambro-Ordovician carbonates and siliciclastics also display well-developed cleavage that is generally strike parallel (axial plane cleavage), although a variety of orientations may be locally present.

Groundwater Flow Types

In the saturated zone, groundwater flows through interconnected openings of three types in the study area: intergranular pores, fractures, and karst openings. While all three types may be present in a given area, one of them is usually dominant.

Porous media

Groundwater flow through the space between individual rock and mineral particles (i.e., intergranular pores) is called porous media flow (Figure 4). Within the study area, porous media flow occurs in the saturated weathered bedrock residuum, saturated soil and colluvium, alluvium in stream valleys, and silt and clay that fills some karst conduits.

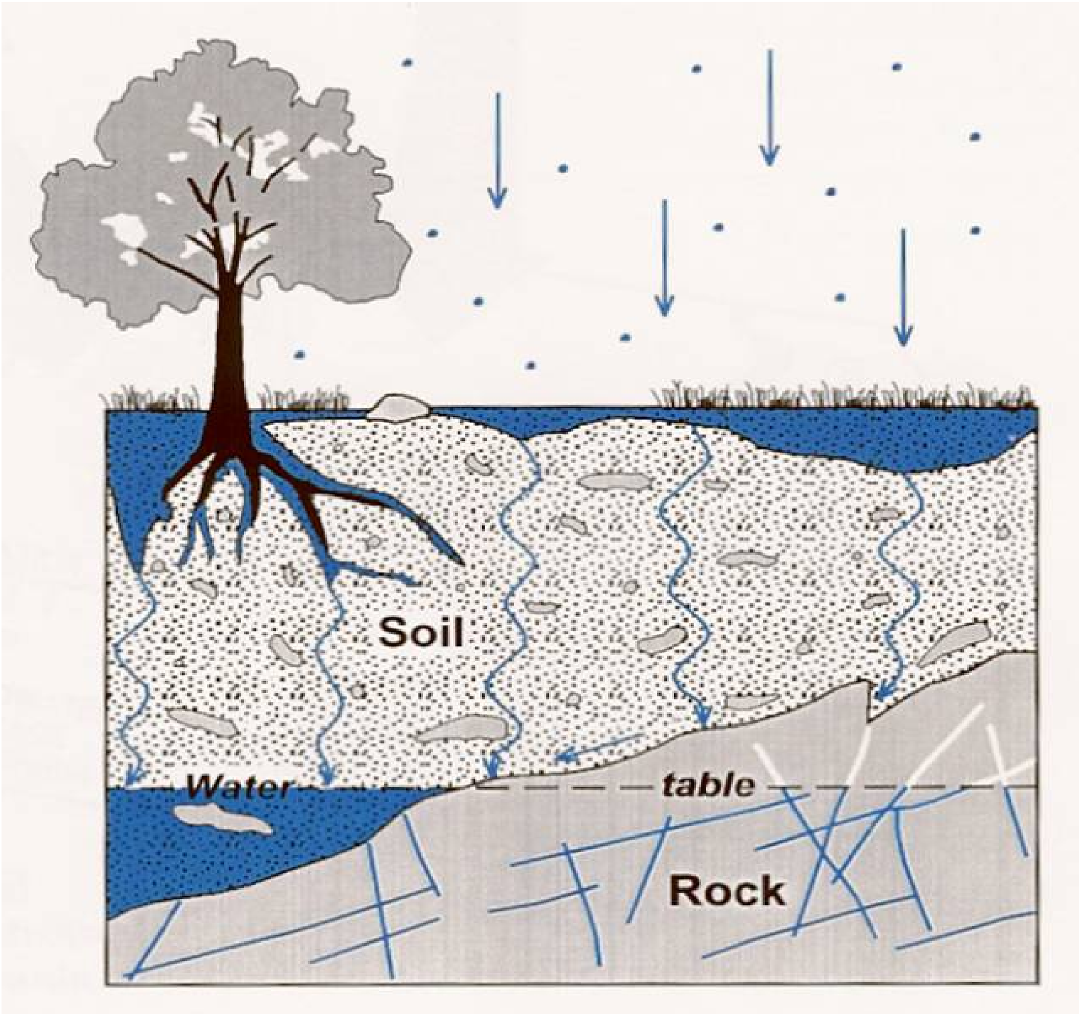

Figure 4. Diagram of Flow through Porous Media (Fleeger, 1999)

Fractures

In fracture flow, water is stored and moves through various fractures in the bedrock (Figure 5). Types of fractures that are important to groundwater flow include bedding partings, cleavage, joints, and fracture traces.

Bedding partings are naturally occurring fractures developed along the boundaries between beds or laminae of sedimentary rock. They are generally more open at shallow depths due to unloading of lithostatic pressure. Some are relatively open at considerable depths due to breakage along rock beds of contrasting strength. Bedding partings are commonly more laterally continuous than other fracture types. They often impart a strong preferential flow direction to the groundwater flow system.

Joints are fractures resulting primarily from the relief of stress within the rock mass, such as the unloading of lithostatic pressure due to erosional removal of the overlying rocks. They typically are widest near the top of rock and gradually close up with depth.

Cleavage planes are fracture surfaces along which the platy and elongate minerals are parallel. They are formed during the folding of the rocks and are oriented perpendicular to the compressive force. They are present to great depths, but may be more open near the surface due to weathering and erosional unloading.

Fracture traces are linear zones of closely spaced sub-parallel, vertical to sub-vertical fracturing extending to great depth (hundreds to several thousand feet) that are a few tens of feet wide and several hundred to a few thousand feet in length.

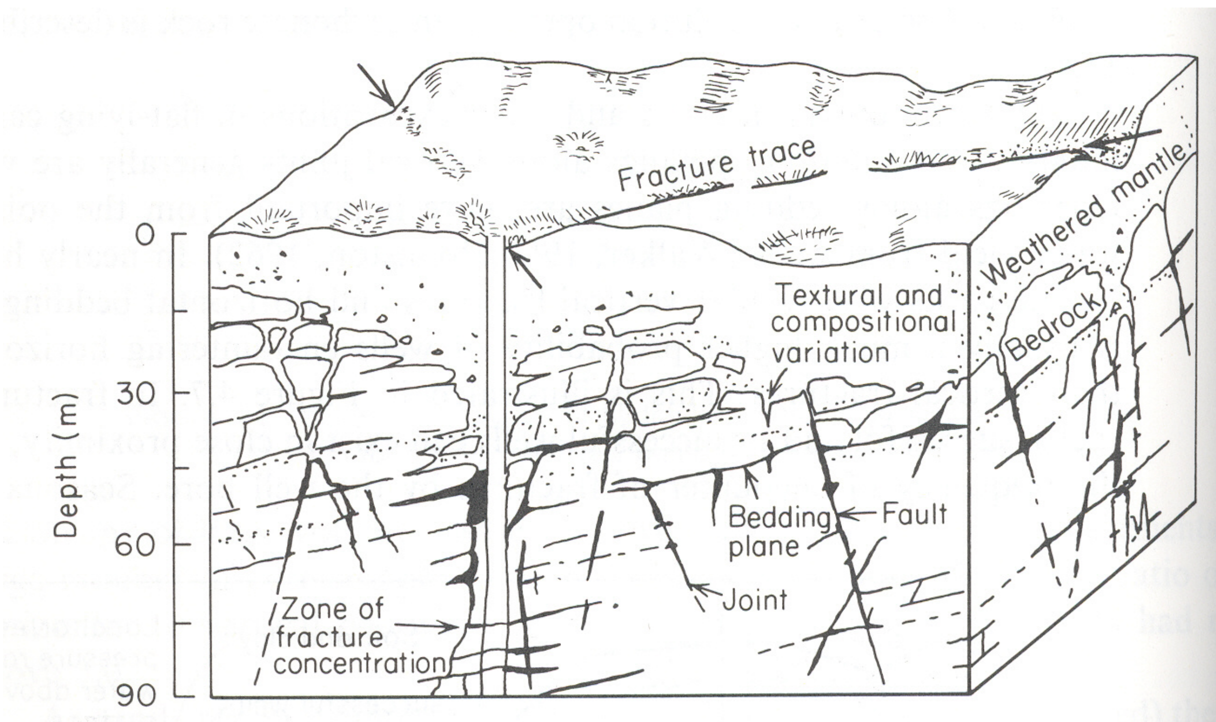

Figure 5. Diagram of Flow through Fractured Media (Lattman and Parizek, 1964)

Karst/conduit

Carbonates are readily soluble in acidic water. Groundwater flow along fractures in carbonate bedrock concentrates solutional activity along the fracture surfaces, gradually causing their enlargement and, locally, the formation of open cavities or conduits (Figure 6). Over time, an extensive, integrated network of karst conduits may develop. This network imparts a much higher permeability to the aquifer than the original fractures. Flow velocities are much higher than those for fracture flow and porous media flow, and may approach those of surface streams. The resulting water table is substantially more subdued than that for fractured bedrock or porous media aquifers. In advanced stages of karstification, groundwater flow may be oblique to surface topography and leave stream valleys perched well above the water table. Such valleys are said to be underdrained. Streams may continue to flow on relatively impermeable, clay-rich carbonate weathering residuum with only minor leakage, or they may exhibit losing reaches where leakage is substantial.

Signs of advanced karstification include the presence of extensive, dry (abandoned) trunk stream valleys, karst springs, perched stream reaches, losing streams, abundant sinkholes, and a lack of a normal (flowing) stream drainage network.

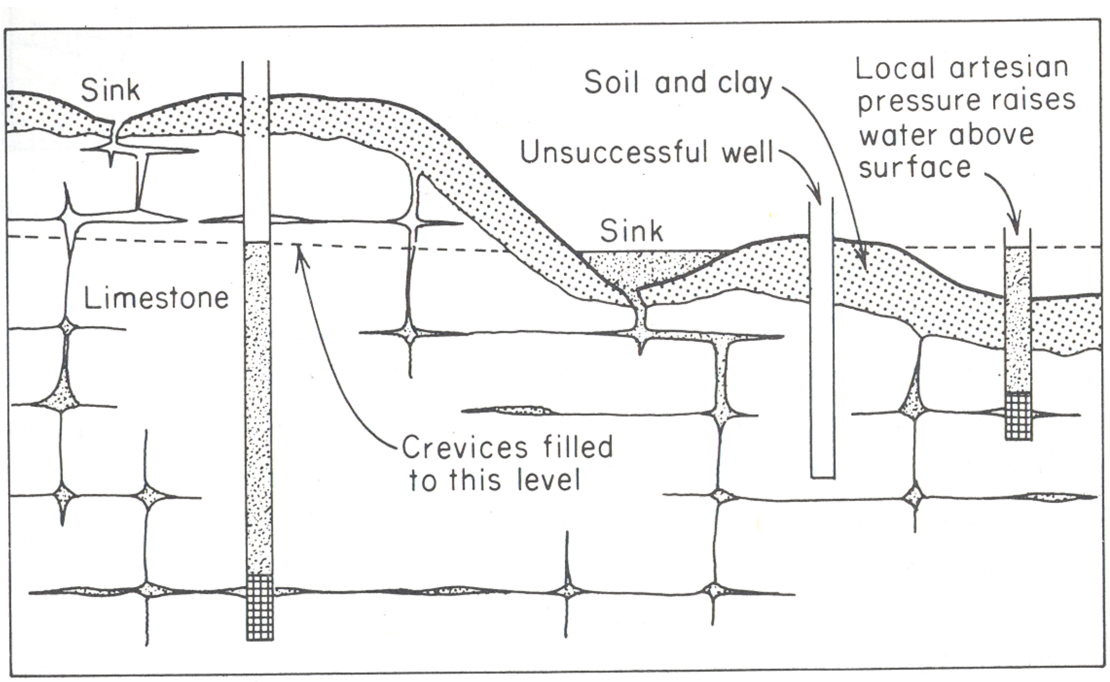

Figure 6. Diagram of Flow through Karst Features (Walker, 1956)

GROUNDWATER FLOW

Water Table Mapping

Water levels from more than 80 wells were measured in the spring (May 24-27, 2004) and fall (October 25-27, 2004) to allow a comparison between the spring and fall water tables in the study area. Water levels in southeastern Pennsylvania are generally highest in the late spring and lowest in early fall.

The water level data were collected from residential and municipal wells using electronic water tapes. Water levels were measured from the top of the well casing, and the height of the casing above ground surface was subtracted to obtain a depth to water below ground surface. Given the unevenness of the ground surface adjacent to the casing, the depth-to-water measurements are accurate to within approximately 1/10 foot. The elevation of the ground surface was estimated in the field from on-site observations and reference to a USGS 7.5-minute topographic map with a 20-foot contour interval. The ground surface elevation estimates depend on both the accuracy of the map contouring and the field interpretation. The ground elevations and, therefore, the water level elevations are accurate to within only a few feet. The depth to water was converted to a water table elevation by subtracting the depth to water below ground surface from the elevation of the ground surface.

The year 2004 was unusually wet throughout the spring, summer, and fall, and there was very little difference between the two data sets. Therefore, a water table contour map that depicts the configuration or "topography" of the water table was prepared only from the May 2004 data set (Figure 7).

Surface Water, Base Flow, and Groundwater

Water flowing in streams is a combination of surface runoff and groundwater discharge (base flow). The discharge of groundwater from springs and seeps in the channel and the valley alluvium supplies most of the water in streams during periods between precipitation and meltwater events. Streamflow increases markedly in response to the inflow of surface runoff; however, the high peak flows from precipitation and meltwater events are of relatively short duration. The flow in the small to medium-sized watersheds within and crossing the study area is dominantly base flow within hours to a few days after precipitation events.

Base flow is a measure of the groundwater recharge above the point of measurement. The base flow in a stream gradually increases, from headwaters to mouth, as the contributing aquifer area increases. Base flow somewhat underestimates the amount of groundwater recharge due to uptake by plants where the water table is within the root zone. There is also some loss due to evaporation from the surface of the stream. Nevertheless, base flow is a good measure of the groundwater available for development, after the water needs for riparian plants are met.

Streamflow Measurements

Stream discharge was measured at 67 stations from June 8-18, 2004, and October 29, 2004 to November 2, 2004 (Appendix A; Figure 8). Streamflow measurements were made with a Price Pygmy flow meter using a protocol used by the USGS and described in Buchanan and Somers (1969). Measurement accuracy was estimated in the field to have a margin of error of five to eight percent. Flow measurement locations were selected for accessibility, appropriate channel geometry, flow uniformity, measurement of surface water flows into and out of the carbonate valley, and proximity to mapped geologic contacts.

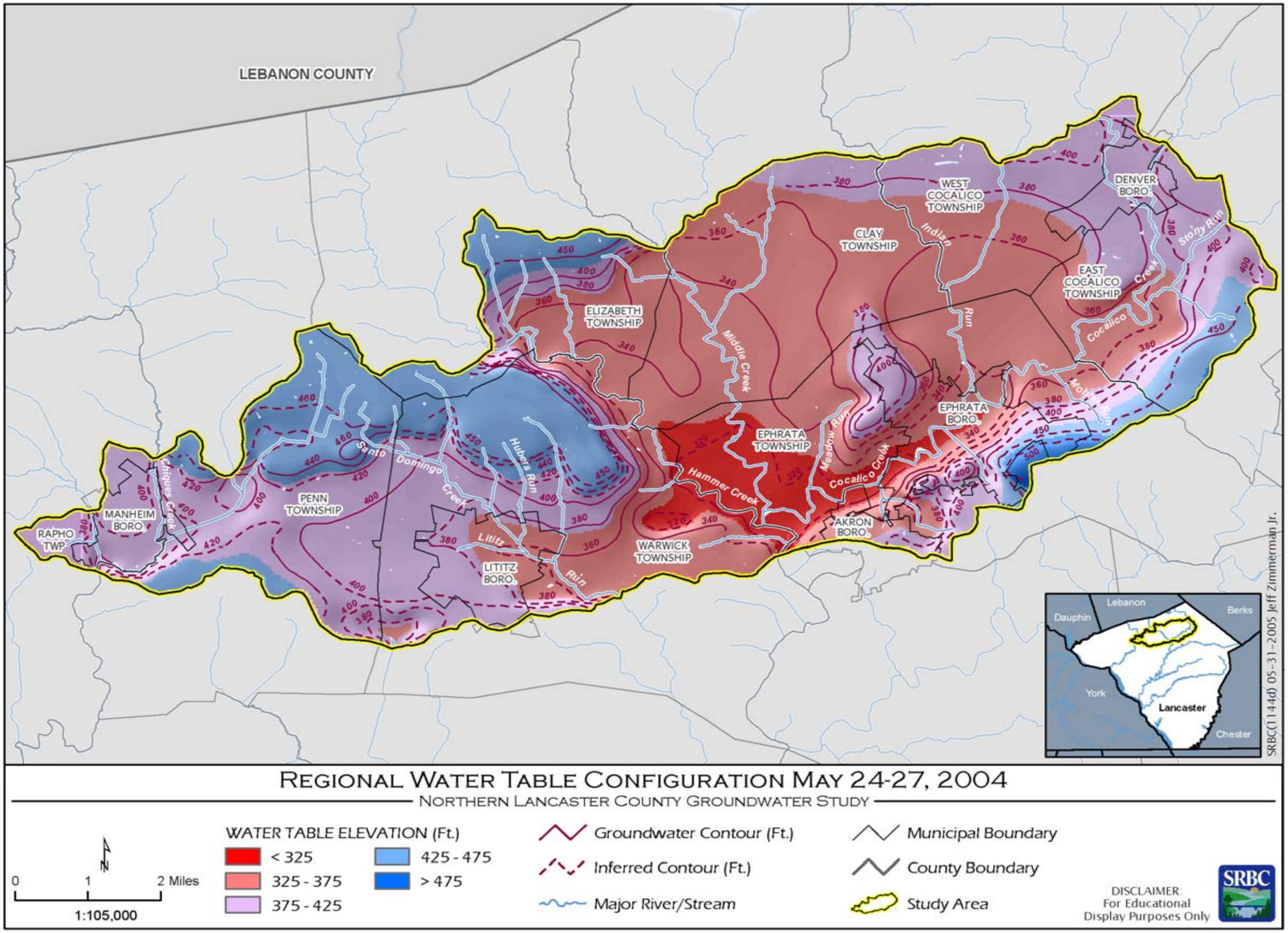

Figure 7. Regional Water Table Configuration of the Study Area, May 24-27, 2004

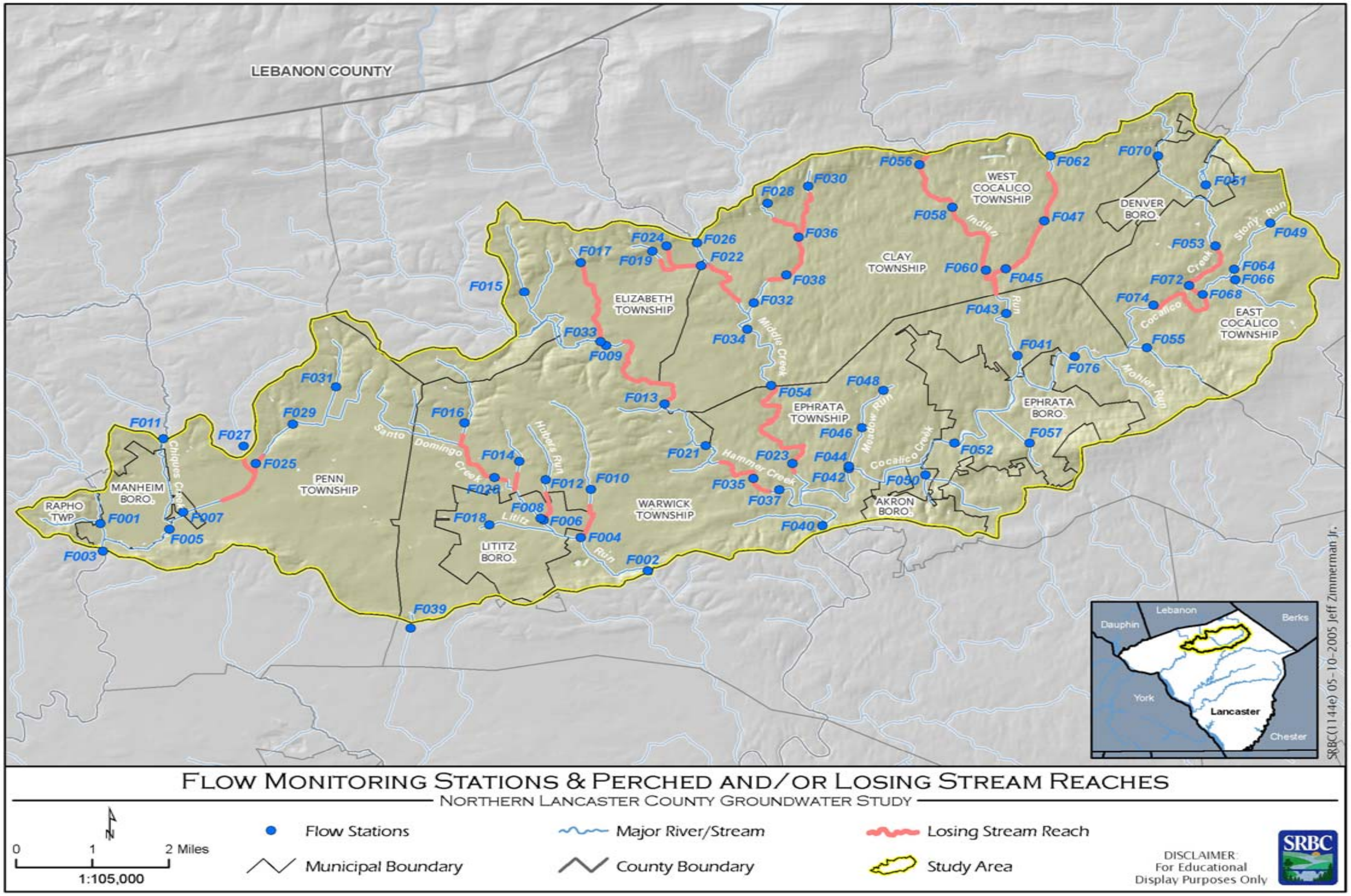

Figure 8. Location of Stream Discharge Measurement Stations and Perched or Losing Stream Reaches

Streamflow measurements provided evidence of both losing and gaining stream reaches. As tributary streams leave the upland shale ridge area of the Cocalico Formation and enter the more permeable carbonates, they lose water by infiltration through streambeds. Some reaches observed during the field survey contained too little water to measure stream discharge, or were dry. More accurate seepage rates are required to determine the amount of recharge to the underlying formations. As streams flow across the carbonate valley, discharge measurements indicated a change from losing to gaining reaches mid-valley. Many of the measured streams behave similarly. The distribution and characteristics of streams throughout the study area suggest that the northern half of the carbonate valley is an important recharge area.

Groundwater and Surface Water Interactions

Streamflow measurements along the course of a stream during periods of base flow allow the determinations of flow gained or lost between stations. Streams within the study area exhibited reaches that either gained or lost measurable base flow, or had base flow that remained stable.

Losing stream reaches generally lose flow because their channels are above the water table, and there is a permeable flow path from the streambed to the water table. Since water flows from areas of higher head (elevation in unconfined, water table aquifers) to areas of lower head, stream water seeps through the bed of the channel downward to the water table, where it contributes water (i.e., recharge) to the aquifer. Losing streams can be found in many hydrogeologic settings. Nearly all of them have in common a localized area along the stream channel that is underlain by material with a much higher permeability than that up and downstream.

In areas underlain by carbonate bedrock, some beds or zones in the bedrock are more soluble than others and may, as a result, have greater karst-enhanced permeability. Where such a high permeability bedrock zone passes beneath a stream channel and has a connection to an area of lower head, the head in the bedrock may be lower than the water level in the stream. If the stream has a permeable connection with the underlying high permeability zone, substantial flow may be lost to the aquifer.

A stream reach is said to be perched if it flows over a bedrock zone with a water level lower than that in the stream, but no measurable flow is lost. This typically occurs where the stream is flowing over a low permeability material such as clay-rich carbonate weathering residuum.

Streams flowing across the carbonate valley that have gaining, perched, and losing reaches along their course (Figure 8) may vary in response to changing head conditions in the aquifer and the stream. Some reaches may be gaining during wet periods when the water table is high, and losing or perched (during dry periods) when the water table falls below the stream.

The longitudinal profile of Indian Run (Figure 9) illustrates the topography, groundwater table, and stream discharge measurements as it enters the carbonate valley from the siliclastic hills, and is representative of many of the larger, through-flowing streams in the study area. Groundwater from the siliciclastics north of the carbonate valley provides base flow to Indian Run. When Indian Run enters the carbonate area near the Hershey and Ontelaunee Formations, groundwater elevations begin to fall below the elevation of the streambed. On June 16, 2004, streamflow at stations F056, F058, and F060 over a 2-mile reach was 3.46 cubic feet per second (cfs), 3.20 cfs, and 3.33 cfs, respectively. The elevation of the water table and the steady flow rates through this reach suggest a generally perched stream with local losing reaches. Measurements made on October 29, 2004, for the same stations showed streamflows of 3.17 cfs, 3.20 cfs, and 2.95 cfs, respectively. The larger streams entering the carbonate valley have gaining, perched, and losing reaches as they flow out onto the carbonate valley, but are predominantly perched.

An eastern tributary to Indian Run is representative of many of the smaller streams that head in the siliclastic hills and flow out onto the carbonate valley. On June 16, 2004, the measured streamflow at the shale-carbonate contact was 0.79 cfs and reduced to 0.07 cfs at station F045 near the confluence with Indian Run. On October 29, 2004, no flow was observed at station F045.

A losing stream, such as Indian Run, that recharges the underlying aquifer is a valuable source of groundwater recharge. Riparian areas and floodplains associated with losing streams may allow infiltration of floodwaters or stormwater runoff. Similarly, small swales or the larger dry valleys may represent stream channels that historically flowed out onto the carbonate valley and be important for recharge and in the conveyance of stormwater. However, to obtain maximum recharge benefit, pollutant loads must be managed to avoid groundwater contamination.

Overall Hydrogeologic Setting

The overall hydrogeologic setting consists of a carbonate-aquifer floored valley, surrounded by much less permeable, topographically higher, siliciclastic aquifers. Surface water drainage is generally from north to south across the valley. The through-flowing streams decline in elevation at a rate of 10-15 feet per mile as they cross the valley. The total elevation change from entry to exit is approximately 25 feet for Chiques Creek, 60 feet for Hammer Creek, 75 feet for Middle Creek, 100 feet for Indian Run, and 100 feet for Cocalico Creek.

While Chiques Creek is a gaining stream throughout its course across the carbonate valley, the other major streams exhibit gaining, perched, and losing reaches. Smaller streams with headwaters in the siliciclastic hills surrounding the carbonate valley generally have losing reaches as they enter the carbonate valley. The loss of flow as small streams cross from siliciclastic formations to carbonates in other locations in Pennsylvania has been described from the Spring Creek watershed (Parizek, 1971) and the Cumberland Valley (Chichester, 1996).

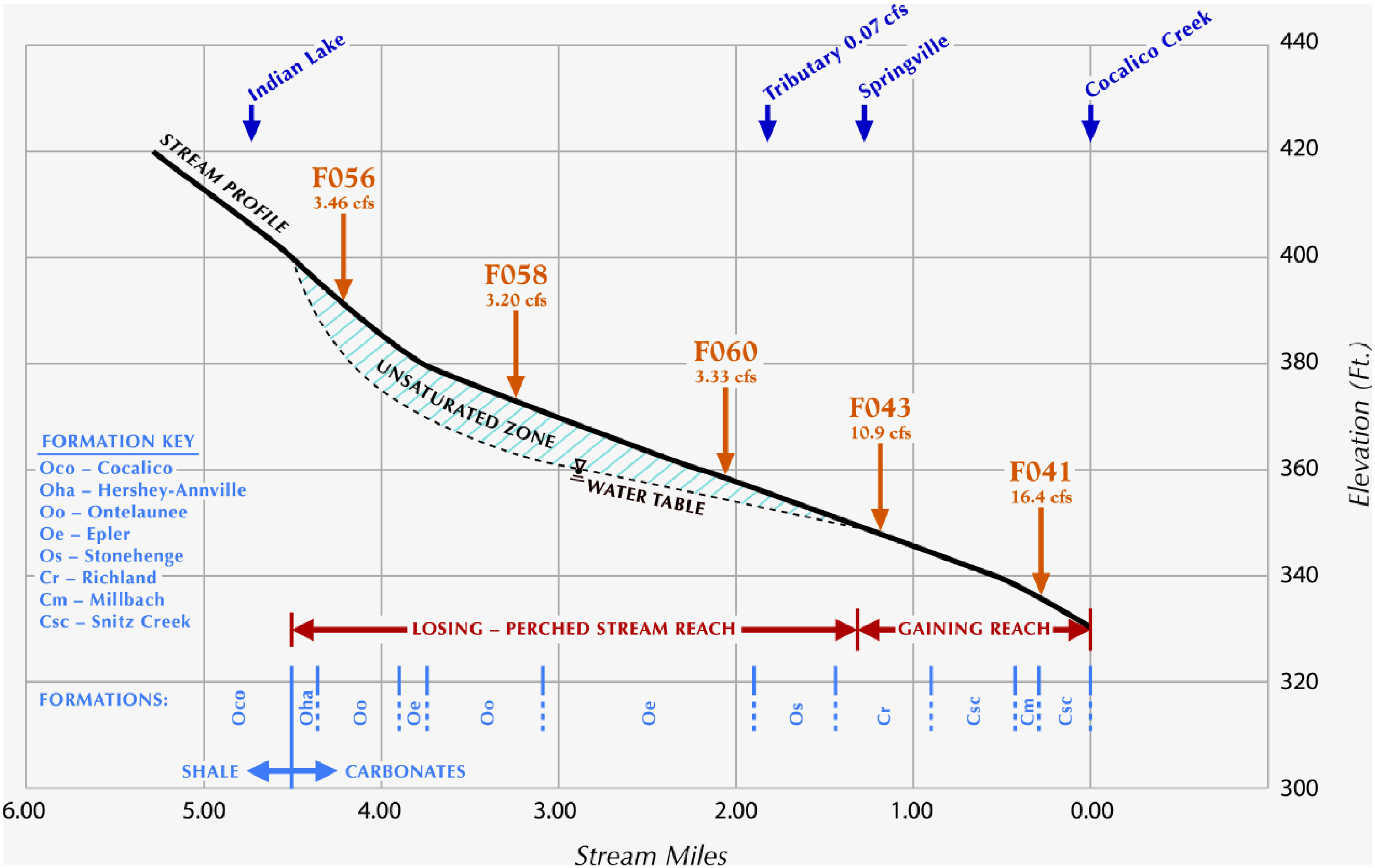

Figure 9. Profile of Indian Run from Shale Upland Area to Cocalico Creek

The siliciclastic hills along the southern margin of the carbonate valley form a groundwater dam. Three water gaps through these hills act as spillways for both surface water and groundwater, and set both the lowest head in the groundwater flow system and the base level for streams in the carbonate valley. Along the southern margin of the carbonate valley, through-flowing streams gain flow as they leave the carbonates. Similar groundwater damming by low permeability formations has been described from the Spring Creek watershed (Parizek, 1971) and the Cumberland Valley (Chichester, 1996).

The water table in the carbonate valley is generally near the elevation of the major, through-flowing streams. However, smaller streams, such as Middle Creek and Indian Run, have extensive perched and losing reaches. Smaller tributaries are scarce, and there are large parts of the study area without perennial streams. The areas between the major through-flowing streams generally lack surface water flow and have underdrained, dry valleys similar to those described by Parizek and others (1971) in the Spring Creek watershed and Chichester (1996) in the Cumberland Valley.

Hydrogeologic Terrains

The water table mapping and seepage runs, in combination with the existing geologic and topographic mapping, allow the division of the carbonate valley into several distinct hydrogeologic terrains (Figure 10), including two major groundwater basins, each having several sub-regions.

Manheim-Lititz Groundwater Basin: The western end of the carbonate valley, herein called the Manheim-Lititz groundwater basin, is one to two miles wide (north-south) and nine miles long (east-west), and contains the Boroughs of Manheim and Lititz, and parts of Rapho, Penn, Warwick, and Elizabeth Townships. The western end is crossed by Chiques Creek and contains the most subdued terrain in the carbonate valley. On the valley floor, the hydraulic gradients are relatively low and graded to Chiques Creek. Chiques Creek is a gaining stream across the valley floor. A subtle, low relief groundwater divide separates the Chiques Creek section from the remaining portion of the Manheim-Lititz groundwater basin. In the area east of the Chiques Creek subbasin, the water table gradually declines from 400 to 340 feet above mean sea level, and is graded to the elevation of Lititz Run and the Lititz spring. Most of this area is “drained” by the Limerock dry valley. The Limerock dry valley is underlain by a groundwater trough, and appears to discharge to the Lititz spring. Conduits in the “headwaters” of the Limerock dry valley are probably very slowly extending westward, gradually underdraining and capturing the groundwater in that area.

A small headwater area for a tributary to Bachman Run, located along the southern margin of the carbonate valley between Manheim and Lititz, allows some “leakage” through the southern margin siliciclastic hills. The divide between this small basin and the Manheim-Lititz basin is subtle with very low relief, and probably changes position in response to seasonal variations in precipitation.

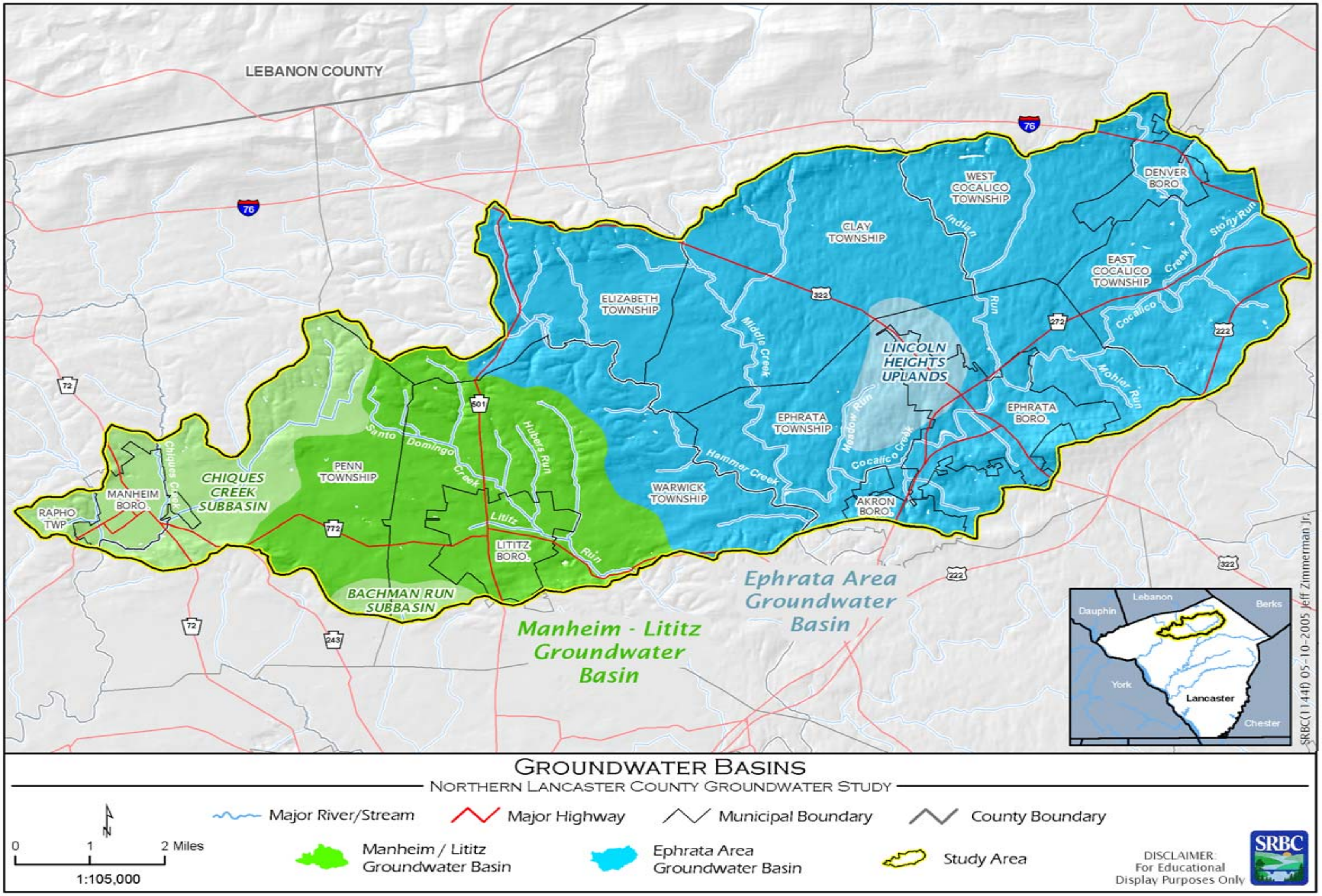

Figure 10. Groundwater Basins of the Study Area

Ephrata Area Groundwater Basin: East of the Lititz Run water gap, the water table rapidly falls 40 to 60 feet into the Hammer Creek valley and the Ephrata area groundwater basin. The Ephrata area groundwater basin contains parts of Elizabeth, Warwick, Clay, Ephrata, West Cocalico, and East Cocalico Townships, and parts of Akron, Ephrata, and Denver Boroughs within the Cocalico Creek drainage area. The groundwater divide between the Manheim-Lititz groundwater basin and the Ephrata area groundwater basin is markedly asymmetrical, with a gentle gradient to Lititz Run and a very steep gradient to Hammer Creek. The water table within the Ephrata area groundwater basin is graded to the major tributaries of Cocalico Creek and its exit from the carbonate valley at approximately 300 feet above mean sea level. The Ephrata area groundwater basin contains subbasins corresponding to the valleys of Hammer Creek, Middle Creek, Indian Run, and Cocalico Creek.

The northern half of the Ephrata area groundwater basin between Cocalico Creek and Middle Creek is largely underdrained. Several dry valleys are present, including the Weidmanville dry valley and the Stevens dry valley (Plate 1).

The Lincoln Heights is a hilly upland northwest of Ephrata, with approximately 120 feet of local relief. The relatively steep hydraulic gradients in this area suggest a minimum of karst conduit permeability and a dominance of fracture permeability.

GROUNDWATER RESOURCE EVALUATION

The Hydrologic Cycle

The natural cycle of water movement from the atmosphere to groundwater and surface water and back to the atmosphere is called the hydrologic cycle (Figure 11). Water falls to the ground as precipitation and follows many pathways on its way back to the atmosphere. Understanding the hydrologic cycle and human impact to these pathways is fundamental to the proper management of water resources.

The amount of water in the atmosphere, on the earth's surface (as water and ice), and in the ground is largely controlled by climate. An accounting of the amounts of precipitation, streamflow, evapotranspiration, and groundwater is called a water budget.

A water budget treats water in the hydrologic cycle in much the same way as a financial budget treats income, savings, and expenditures. In a water budget, the major components of the hydrologic cycle are quantified and itemized so that water income (precipitation) is balanced against water expenditures (evapotranspiration, groundwater flow, streamflow expenditures) and water savings (groundwater storage). This balance is often expressed in the simple equation:

Water Income (Precipitation) = Water Expenditures (Surface Runoff + Groundwater Discharge + Evapotranspiration) +/– Water Savings (Change in Groundwater Storage)

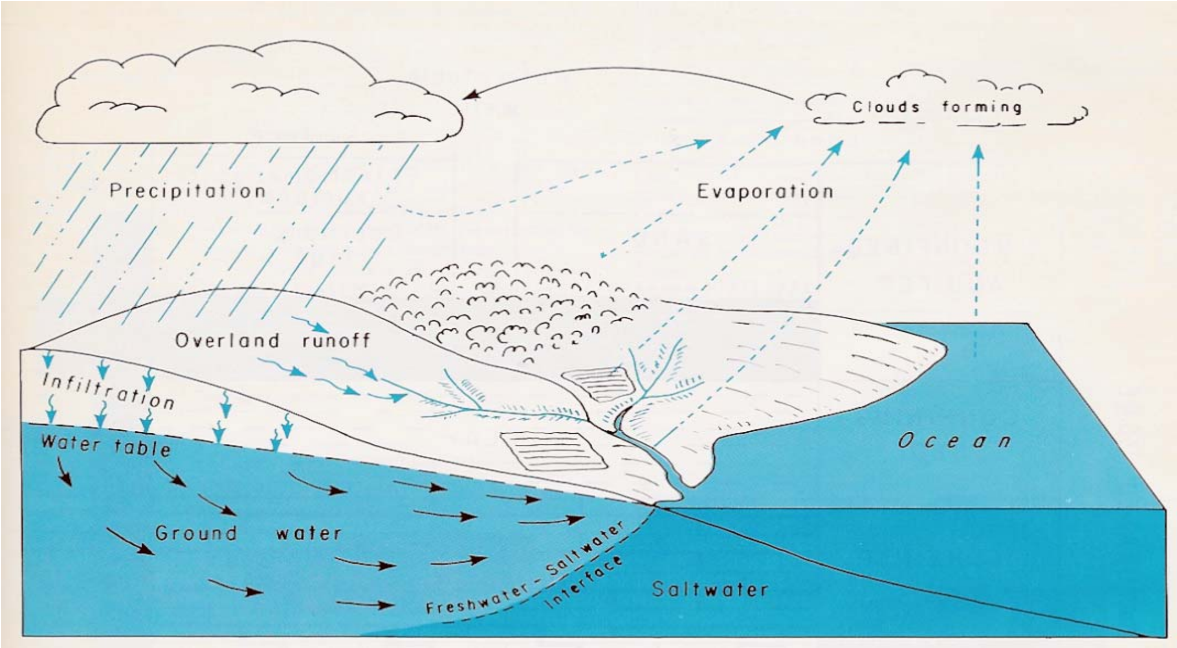

Figure 11. Diagram of The Hydrologic Cycle (After Heath, 1987)

Over the long term with no water resource development, the change in water storage (savings) is zero and the equation simplifies to:

Precipitation (Income) = Surface Runoff + Groundwater Discharge + Evapotranspiration (Expenditures)

Daily stream discharge measurements, at established USGS stream gages, and daily precipitation records provide the data sets needed to calculate water budgets for watersheds.

For several small watersheds where a stream gage record was available, water resource scientists have evaluated the relationship of groundwater discharge or base flow to total streamflow in the lower Susquehanna River Basin (Table 2). These water budgets illustrate how the water income (precipitation) is divided between the water expenses (evapotranspiration, surface runoff, and groundwater) on an annual basis for the period of record. The water budgets are averages for entire watersheds and do not reflect local topography, land cover, and hydrogeologic heterogeneity within the watersheds.

Table 2. Summary of Groundwater Contributions to Streamflow for Select Watersheds of the Lower Susquehanna River Basin

Watershed/ Reference	Drainage Area (sqmi)	Period of Record	Annual Precip (inches)	Average Streamflow (inches)	Average Groundwater Flow (inches)	Percent Groundwater of Total Streamflow
Little Conestoga Creek/ Meisler and Becher (1971)	38.2	01/1964-12/1964		15.3	11.6	76
Muddy Creek/ Lloyd and Growitz (1977)	133	01/1969-12/1970	43.00[1]	14.4	10.0	69
Yellow Breeches Creek/ Becher and Root (1981)	216	1968-1974	43.22	21.0	16.8	80
Conodoguinet Creek/ Becher and Root (1981)	470	1968-1974	42.23	19.9	13.3	67
Swatara Creek/ Stuart and others (1967)	337	42-year composite record	46.38	23.2	11.3	49
Quittapahilla Creek/ Meisler (1963)	42	10/1960-9/1961		17.3	15.1	87
West Conewago Creek/ Taylor and Werkheiser (1984)	510	1961-1980	39.87	16.9	8.4	50
East Mahantango Creek/ Taylor and Werkheiser (1984)	162	1961-1980	42.28	19.5	12.6	65
Chiques Creek/Gerhart and Lazorchick (1984b)	29	10/1978-9/1979	53.27	22.59	14.21	63
Conestoga River/Gerhart and Lazorchick (1984b)	324	10/1966-9/1967	41.78	12.57	9.05	72
Bowery Run/ Gerhart and Lazorchick (1984b)	5.98	10/1966-9/1967	38.9	15.14	10.75	71
Little Conestoga/Gerhart and Lazorchick (1984b)	38.2	11/1963-10/1964	34.97	16.45	13.82	84
Little Conestoga Gerhart and Lazorchick (1984b)	14	10/1963-9/1964	33.29	13.8	11.59	84
Pequea Creek Gerhart and Lazorchick (1984b)	148	10/1977-9/1978	51.9	27.15	19.28	71
		10/1979-9/1980	37.32	17.48	15.16	87
Average from all studies			42.16	18.18	12.86	72

[1] Muddy Creek period of record from 1931-1939; modified after Taylor and Werkheiser, 1984 and Gerhart and Lazorchick, 1984b.

Groundwater Recharge Estimated from Base Flow

Base flow

Base flow is the groundwater contribution to streamflow originating from recharge areas upstream and upgradient of the streamflow measurement station. Under natural conditions and during a year with average recharge, the amount of recharge received by the aquifer is balanced by the groundwater discharged to streams (i.e., base flow) and used by riparian plants in the discharge zone. The water used by riparian plants in the discharge portion of the groundwater flow system is commonly combined with water use by riparian plants in the recharge portion as evapotranspiration. Recharge in this study refers to the amount of precipitation contributed to the groundwater flow system minus evapotranspiration by plants in the discharge zone. Base flow data can be used to estimate the amount of recharge per unit area of land surface. Drier periods yield lower base flows, and calculated "drought" base flows can be quantified as annual base flow for various recurrence intervals. The annual base flows for the various aquifers/formations were estimated for the 2-, 10-, and 25-year recurrence intervals.

Recharge estimation methodology

The recharge values used in this study were modified from those developed in studies by Gerhart and Lazorchick (1984a, 1984b, and 1988). Gerhart and Lazorchick derived average annual (i.e., 1-in-2-year) recharge rates from base flow separations for 26 watersheds in the lower Susquehanna River Basin. They developed average annual recharge values for specific rock types and geologic formations, and refined those values using regional finite-difference groundwater models.

The studies by Gerhart and Lazorchick (1984a, 1984b, and 1988) assumed that a year with average precipitation would have average base flow and, therefore, average recharge. The validity of this assumption depends upon a number of factors, including the following:

1. There was no deficit or excess of groundwater storage.
2. The distribution of precipitation over the year was average:
    a. The amount occurring while the ground was frozen was average; and
    b. The amount received prior to and during the plant growing season was average.
3. Soil moisture conditions inherited from the previous year were average.
4. The distribution of the precipitation events was not skewed by an unusual amount of precipitation received during high intensity events such as thunderstorms or hurricanes.

White and Slotto (1990) calculated the base flow frequency characteristics for Pennsylvania streams by performing base flow separations of streamflow data for the entire period of record. As a result, their calculated base flows include the factors not considered by Gerhart and Lazorchick (1984a, 1984b, and 1988). Their average annual (i.e., 1-in-2-year) recharge rate for the Conestoga River at Lancaster (station # 01576500) was 1.158 times greater than that calculated by Gerhart and Lazorchick. This factor was applied to the lithology and formation-specific 1-in-2-year recharge rates to derive the corrected 1-in-2-year recharge rates used in this study (Table 3). White and Slotto (1990) also provided annual minimum base flows for the 1-in-10-year and 1-in-25-year recurrence intervals. The 1-in-10-year base flow was 60.7 percent of the 1-in-2-year base flow. The 1-in-25-year base flow was 41.7 percent of the 1-in-2-year base flow. These factors were applied to the corrected 1-in-2-year recharge rates of this study to estimate formation-specific recharge values for the 1-in-10-year and 1-in-25-year recurrence intervals.

Table 3. Average Annual Recharge for Selected Recurrence Intervals for Geologic Formations within the Study Area

Map Symbol	Formation Name	1-in-2-Year Recharge[1] mgd/sqmi.	Unit Number [2]	Corrected 1-in-2-Year	1-in-10-Year	1-in-25-Year	Lithology
Oan	Annville	0.66	4	0.76	0.46	0.32	High-Calcium Limestone
Cbs	Buffalo Springs	0.53	6	0.61	0.37	0.26	Limestone
Oco	Cocalico	0.55	13	0.64	0.39	0.27	Shale
Oe	Epler	0.66	4	0.76	0.46	0.32	Limestone
Trhc	Hammer Creek	0.39	19	0.45	0.27	0.19	Quartz conglomerate

Map Symbol	Formation Name	1-in-2-Year Recharge[1] mgd/sqmi.	Unit Number [2]	Corrected 1-in-2-Year	1-in-10-Year	1-in-25-Year	Lithology
	Conglomerate						
Trh	Hammer Creek	0.39	18	0.45	0.27	0.19	Sandstone
Ohm	Hershey and Myerstown, undivided	0.66	4	0.76	0.46	0.32	Argillaceous Limestone
Oha	Hershey through Annville, undivided	0.66	4	0.76	0.46	0.32	Argillaceous Limestone
Cm	Millbach	0.51	7	0.59	0.36	0.25	Limestone
Trnc	New Oxford Conglomerate	0.40	21	0.46	0.28	0.19	Quartz Conglomerate
Oo	Ontelaunee	0.54	10	0.63	0.38	0.26	Dolomite
Cr	Richland	0.53	9	0.61	0.37	0.26	Dolomite
Csb	Snitz Creek and Buffalo Springs, undivided	0.53	6	0.61	0.37	0.26	Limestone
Csc	Snitz Creek	0.53	6	0.61	0.37	0.26	Dolomite
Os	Stonehenge	0.87	1	1.01	0.61	0.42	Limestone

[1]after Gerhart and Lazorchick (1984b) Table 11
[2]after Gerhart and Lazorchick (1984b) Table 2

Accuracy of recharge estimates

The recharge values developed in this report are estimates and, as such, are subject to a number of variables and based on a number of assumptions.

Areal Extent of Geologic Formations: Perhaps the most significant, practical limitation on the accuracy of the recharge estimates is the geologic mapping. Recent high resolution aerial photography reveals outcrop and structural trends that locally diverge from the mapped geology. The recharge estimates for the two groundwater basins would change only if, for example, some of the areas of formations with higher recharge rates were actually lower recharge units. All else being equal, the total recharge for the groundwater basin would increase. However, if the changes in formation areas are random, the increased area with higher recharge rates might be balanced by an increase in area of formations with lower recharge, and the total recharge to the basin would be essentially unchanged. While an exact balance between the changes in area for high and low recharge rate formations is unlikely, a strong imbalance is also unlikely. However, the change in total recharge to the two groundwater basins due to more accurate geologic mapping will only be known after the area is remapped.

Stream Gage Record: The record for the USGS Lancaster stream gage on the Conestoga River is somewhat compromised and does not provide an entirely accurate record or reflection of surface water and base flow responses to year-to-year variation in precipitation for the period of record due to hydrologic changes within the watershed. A stream intake for Lancaster has impacted the most recent half of the gage record. Records of withdrawal amounts are generally unavailable. Estimates based on related factors such as system water use and known withdrawals from other sources suggest a long-term maximum of 1.2 mgd, but with considerable variability. This represents about 1.2 percent of the 1-in-10-year base flow and 1.8 percent of the 1-in-25-year base flow.

The record has also been somewhat compromised by alteration of the landscape brought about by urbanization. The gradual change from a dominantly agricultural landscape to a mixed agricultural-urban landscape has brought about substantial changes in vegetative cover, impervious cover, and the micro-topography that affects drainage and drainage patterns. Studies of the impact of urbanization on the local water budget have generally produced less than clear results. While there is no doubt that impervious cover causes a virtually complete loss of recharge from the covered area, other changes appear to offset much of this loss. These complimentary changes include increased roadside infiltration for roads without curbs, and leakage from water mains and sewage lines.

Climatic Variability: Climatic variability would appear to be taken into account by the relatively long period of record (52 years) for the Lancaster stream gage. This would be true if the year-to-year variation in precipitation was varying about a central (i.e., average) value. If the climate was actually changing, the numerical average would simply be that and would not represent the increasingly wet or dry actual conditions. Climate change can significantly affect the hydrologic cycle (Sophocleous, 2004). Changes in precipitation quantities, when it is received, event intensity, evapotranspiration, and other factors could strongly alter the quantity of water resources available for development. Recent changes in global climate are suggested by the marked shrinkage of alpine glaciers and a rate of sea level rise that is ten times higher than that for the previous three thousand years (Sophocleous, 2004). While accurate records of climate exist for the last hundred years in many parts of the world, there is a lack of detailed knowledge about climatic variation for the Holocene or even the previous two thousand years. A number of paleoclimatological studies (for example, Solc and others, 2005; Linderholm and Chen, 2005; Van Beynen and others, 2004; Brown and others, 2000) suggest significant variability from the centennial and decadal scales to hundreds of years.

Groundwater resource availability

The formation-specific annual recharge rates for the 1-in-2-year, 1-in-10-year, and 1-in-25-year recurrence intervals were applied to the aerial extent of the study area and to the Manheim-Lititz and Ephrata area groundwater basins (Table 4).

Table 4. Water Availability in Million Gallons per Year for the Study Area and Select Sub-Areas

Area of Interest	1-in-2 Year	1-in-10 Year	1-in-25 Year	Sqmi
Manheim-Lititz Basin	5,822	3,531	2,449	21.79
Ephrata Area Basin	11,676	7,077	4,917	48.36
Total Study Area	17,498	10,608	7,366	70.15

Passby requirement

When the total withdrawal from a groundwater basin or local subbasin exceeds 10 percent of the lowest flow for 7 consecutive days in 10 years (Q7-10), the Commission, in coordination with the Commonwealth of Pennsylvania, may impose a passby requirement in order to protect aquatic habitat during periods of low flow. A passby flow is a prescribed quantity of flow that must be allowed to pass a prescribed point downstream from an intake at any time during which a withdrawal is occurring. When the natural flow is equal to, or less than, the prescribed passby flow, no water may be withdrawn from the water source, and the entire natural flow shall be allowed to pass the point of withdrawal. Passby flows may be associated with the Commission's surface water and groundwater withdrawal approvals.

The passby requirement triggers for a stream classified as a *warm water fishery*, when the flow falls below 20 percent of the average daily flow. At that time, withdrawals must cease and waters be allowed to "pass by" the point or area of taking, or the flow could be augmented with a release of water equal to the rate of withdrawal. Discharge of wastewater upgradient of or adjacent to groundwater withdrawals would largely mitigate this impact.

Groundwater withdrawals in the Ephrata area groundwater basin have not exceeded 10 percent of the Q7-10 for Cocalico Creek as it leaves the carbonate valley (Figure 12). However, most of the existing groundwater withdrawals are located in the southern half of the basin, and are potentially mitigated by the discharge from the Ephrata area wastewater treatment plant. However, future withdrawals could trigger the passby requirement in one of the subbasins. This can be avoided by locating wells in downstream areas where the Q7-10 flow is higher.

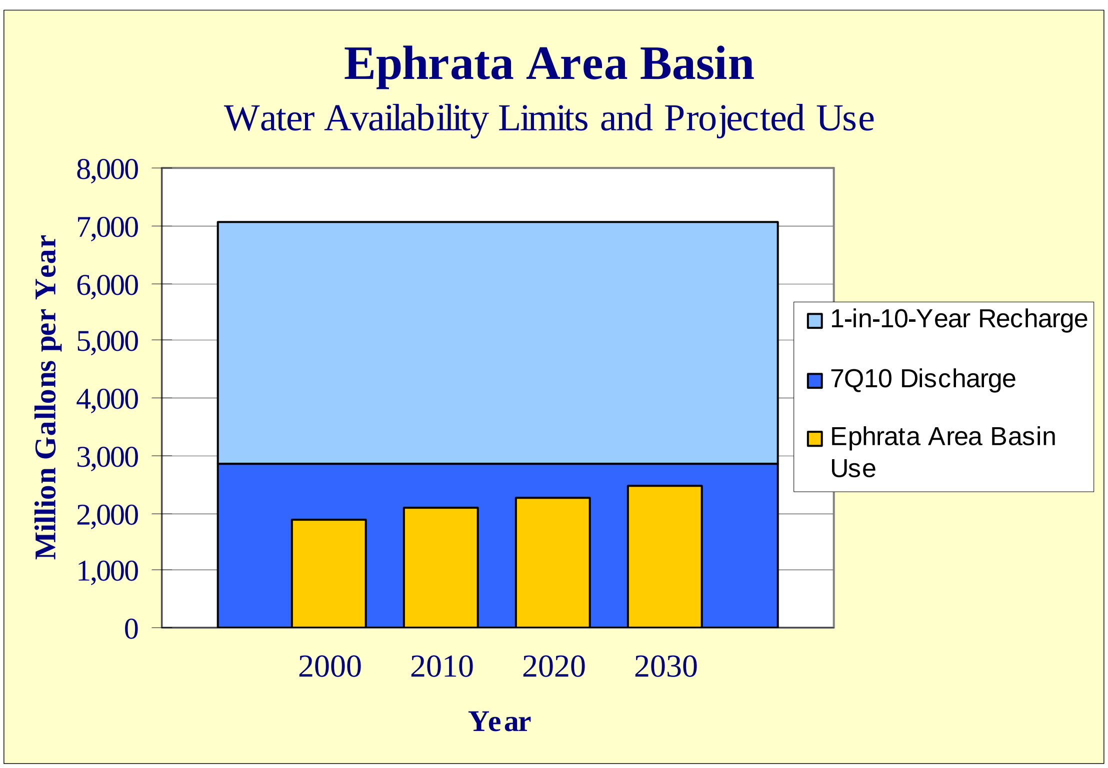

Figure 12. ***Current and Projected Water Use, Q7-10 for Cocalico Creek as it Leaves the Carbonate Valley, and the 1-in-10-Year Commission Withdrawal Limit***

Groundwater withdrawals in the Manheim-Lititz groundwater basin have exceeded the Q7-10 for the surface water flow (combined flow from Chiques Creek and Lititz Run) as it leaves the carbonate valley (Figure 13). However, most of the existing groundwater withdrawals are located in the southern half of the basin, and are compensated for by the discharge from the Manheim and Lititz wastewater treatment plants. Future withdrawals located in the northern half of the basin could trigger the passby requirement. The passby requirement can be avoided by locating wells in downstream areas where the Q7-10 flow is higher.

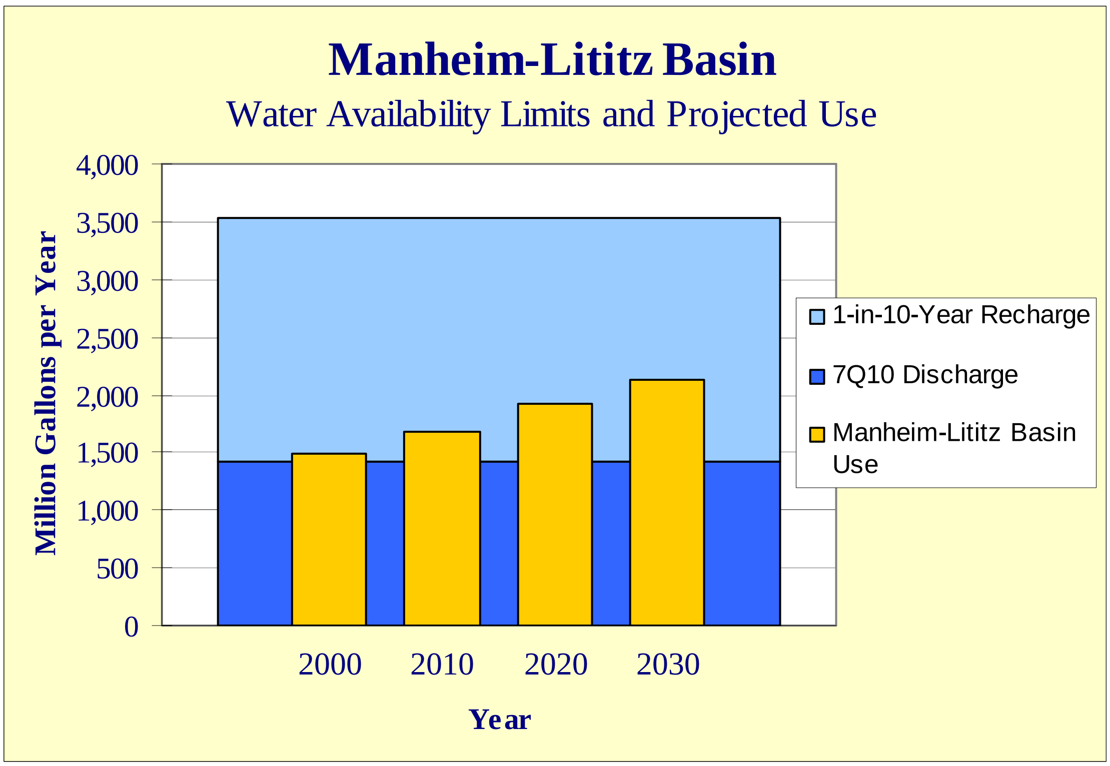

Figure 13. ***Current and Projected Water Use, Q7-10 for the Combined Flow of Chiques Creek and Lititz Run as it Leaves the Carbonate Valley, and the 1-in-10-Year Commission Withdrawal Limit***

WATER USE

Information Sources and Methodology

The availability, reliability, and detail of water use information vary widely. Water use data in this report are based on several information sources, which were cross-referenced to obtain the most recent information on water use and specific withdrawal locations. The Commission developed a water use database for this study. Each record includes a reference to the data source.

The Water Use Data System (WUDS) initially developed for the Pennsylvania State Water Plan in the mid-1970s (PADER, 1975) and Ground Water Information System (DCNR,

2004) provided the base upon which the water use database was populated for this study. The annual water supply reports from 1998 through 2002 were reviewed and considered the most reliable source of public supply water use information.

The Commission’s Project Review Database contains information on nonagricultural water users (public, industrial, and commercial) capable of withdrawing more than 100,000 gallons per day (gpd) on a 30-day average. This database provides an approved allocation and use summaries submitted on a quarterly basis, and is considered to be a reliable source of information.

Nonpublic water uses under 100,000 gpd on a 30-day average are based on WUDS unless more recent information was available.

During the course of the study, Pennsylvania enacted the Water Resources Planning Act (Act 220). Act 220 requires users of 10,000 gallons a day or more to register and then periodically report their water use to the Pennsylvania Department of Environmental Protection (PADEP). The Commission entered into an agreement (Memorandum of Understanding [MOU]) with PADEP to exchange the data collected. Any user’s registration with PADEP satisfies the Commission’s registration regulation. The Commission reviewed information from PADEP and updated the project database where appropriate.

The data on agricultural water uses are less reliable. The total estimated use for this sector is thought to be significantly underestimated. In 1998, the Commission initiated an agricultural water use registration program to obtain better water use information for the agricultural sector. While some results were obtained for individual operations, reviews of these records indicate estimates are less accurate than the information available for other sectors. Also, locations of groundwater withdrawals are approximated by address location.

The data presented in this report have several qualifications:

1. Withdrawals are reported on the basis of the location of the withdrawal point, not where the water is used.
2. Domestic use from non-serviced areas is based on census block data adjusted to the non-service area of the census block, and a per capita rate of 65 gpd.
3. Water withdrawn from groundwater is not equivalent to water consumed. Some water reenters the surface water system via treated discharge facilities.
4. The import of water from wells outside the study area is minimal.

Groundwater withdrawals were grouped into six categories or use sectors: Agriculture (AGR), Industrial & Commercial (IND), Mining (MIN), Public Supply (PWS), Product Incorporation (PRO) such as bottling, and Domestic (DOM) use (private wells). The withdrawal data were compiled from a series of information sources representing use over a period of years. The distribution of major groundwater withdrawals is shown on Figure 14.

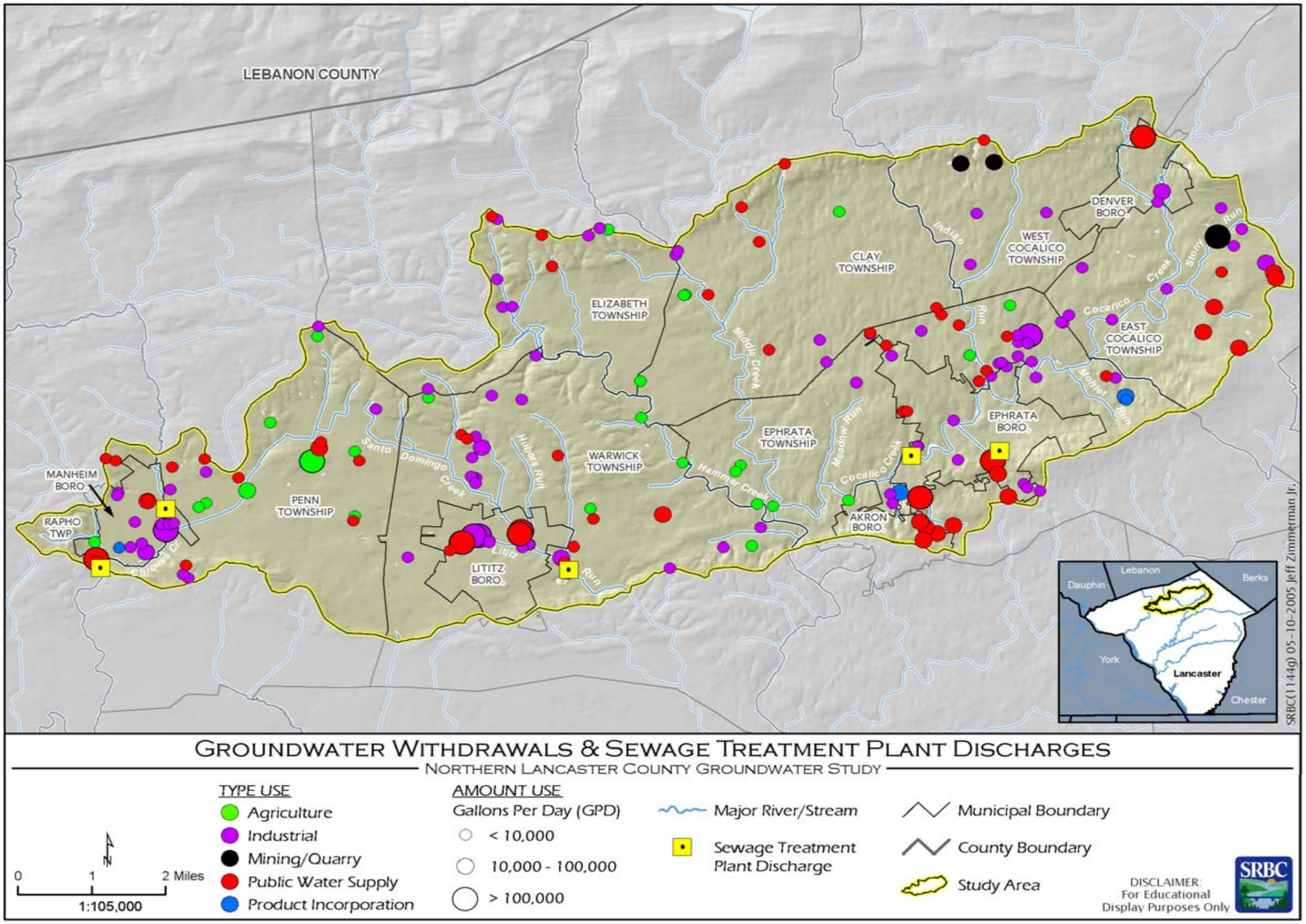

Figure 14. Major Groundwater Withdrawals

Table 5 presents the most recent data reported and results should be considered as an annual average for year 2000. The total use statistic is an estimate of current average annual use. The total allocated groundwater withdrawals in each basin includes both existing withdrawal amounts plus approved but unused amounts.

Year 2000 Water Use and Allocated Water vs. Resource Availability

The total estimated quantity of groundwater used in the year 2000 by all sectors in the study area is 2,990 million gallons per year (mgy) or an average of 8.2 mgd. When allocated amounts are considered, potential annual groundwater use is 4,896 million gallons or an average 13.4 mgd. Table 5 presents the annual use for defined sub-areas within the study area.

The public water supply sector is the largest user at 1,549 mgy or 4.2 mgd. This represents 52 percent of the total groundwater withdrawal in the study area. Based on the 2002 census and location of water service areas, approximately 75 percent of the population (45,765 persons) is served by public supply systems.

The year 2000 resident population not served by public systems, supplied by private wells was estimated at 15,320. Based on literature values, per capita water use ranges from 55 gpd in Pennsylvania to 70 gpd in Maryland (Van der Leeden and others, 1990). Pennsylvania's Act 57 states that water authorities can use a value of 65 gpd in designing facilities. Using that value, an estimate of the annual domestic water use is 363 million gallons (approximately 1 mgd) or 12 percent of the total groundwater use in the study area.

The second largest use sector is industry and commercial, with an average annual use of 523 millions gallons (1.4 mgd) or 17.5 percent of the total use in the study area.

Table 5. Groundwater Withdrawals in Million Gallons per Year for Select Areas

Area of Interest	AGR	IND	MIN	PWS	PRO	DOM	Total Use	Total Allocated Use
Manheim-Lititz Basin	106	356	0	890	0	141	1,493	2,478
Ephrata Area Basin	25	167	388	659	36	222	1,497	2,418
Total Study Area	131	523	388	1,549	36	363	2,990	4,896

AGR – Agriculture
IND – Industrial & Commercial
MIN – Mining
PWS – Public Water Supply
PRO – Product Incorporation (e.g., Bottling)
DOM – Domestic Use on Private Wells

The annual average recharge estimate was 17,498 mgy (Table 6) or 47.9 mgd. The current 2000 use and total allocated use represent 17 percent and 28 percent of the groundwater available during a normal year. However, recharge variability, groundwater withdrawal locations, and the size of the contributing areas are factors in determining groundwater availability.

Table 6. Current and Allocated Groundwater Demand, Resource Availability, and Utilization Level

Area of Interest	Total Use (mgy)	Allocated Use (mgy)	1-in-2 Year	1-in-10 Year	1-in-25 Year	Utilization Level (percent)
Manheim-Lititz Basin	1,493	2,478	5,822	3,531	2,449	70
Ephrata Area Basin	1,497	2,418	11,676	7,077	4,917	34
Total Study Area	2,990	4,896	17,498	10,608	7,366	46

Groundwater storage declines during times of drought and recovers during years of normal or above normal precipitation. The Commission has defined the sustainable limit of a watershed as the amount of recharge that occurs during a 1-in-10-year annual drought. For practical purposes, this value is considered the 1-in-10-year annual base flow. The selection of the 1-in-10-year annual drought recharge attempts to balance the amount of groundwater available for development, instream flow needs, and required reservoir or tank storage capacity.

As part of the regulatory review process of large groundwater withdrawals, the Commission identifies potentially stressed areas (PSAs) by evaluating several criteria. Criteria may include expanded dry stream reaches, diminishing stream or spring flows, and declining water levels. Another criterion is where known withdrawals for rapidly developing areas exceed 50 percent of the 1-in-10-year annual drought recharge. This provides a "milepost" where decision-makers should begin to consider taking additional steps to manage the resource.

Existing water withdrawals plus currently allocated unused quantities were identified and totaled for each groundwater basin, as well as the total study area. These total allocated withdrawals were compared with the 1-in-10-year recharge to assess if the utilization level exceeded 50 percent of the 1-in-10-year recharge (Table 6).

The allocated groundwater use of 4,896 million gallons (13.4 mgd) for the entire 70-square-mile study area is 46 percent of the 1-in-10-year annual drought recharge of 6,226 million gallons (17.1 mgd). The initial assessment indicates that the region has an adequate water supply.

The allocated groundwater use of 2,418 million gallons (6.6 mgd) for the 48.4-square-mile Ephrata area groundwater basin is 34 percent of the 1-in-10-year annual drought recharge of 7,077 million gallons (19.4 mgd). The initial assessment indicates that the region has an adequate water supply.

The allocated groundwater use of 2,478 million gallons (6.8 mgd) for the 21.8-square-mile Manheim-Lititz groundwater basin is 70 percent of the 1-in-10-year annual drought recharge of 3,531 million gallons (9.7 mgd). The initial assessment indicates that the region has an adequate water supply, but is approaching the Commission's allocation limit. The largest use sector in the Manheim-Lititz groundwater basin was public water supply using 890 mgy. A significant increase in public water use was due in part to a population growth of 33 percent in

Warwick Township from 1990 to 2000. New developments in the area are expected to increase public supply needs and continue the population trends.

Projected Water Demand vs. Availability

Projection Method: Population estimates in Table 7 were determined using year 2000 census block data and applying geographic information systems (GIS) techniques. The total population estimate was based on a sum of population values for each year 2000 census block located within the study area boundary. Similarly, the total population on public water supply was determined by overlaying the public service area boundaries in the study area with the 2000 census block data. The 2000 base population in the study area was 61,085, with nearly 75 percent (45,765) of the population being served by public water systems.

Table 7. ***Projected Annual Water Use in Million Gallons per Year and Population of the Study Area and the Ephrata Area and Manheim-Lititz Groundwater Basins, 2000-2030***

Use Sector	2000	2010	2020	2030
AGR	131	153	175	197
IND	523	569	616	660
MIN	388	388	388	388
PWS	1,941	2,283	2,657	3,047
PRO	36	40	44	49
DOM	363	320	263	190
Total	**3,382**	**3,753**	**4,143**	**4,531**
Population on PWS	45,765	53,920	62,762	71,975
Population on private wells	15,320	13,480	11,076	7,997
Total Population	**61,085**	**67,400**	**73,838**	**79,972**
Ephrata Area Basin				
AGR	25	29	33	38
IND	167	182	197	211
MIN	388	388	388	388
PWS	1,051	1,236	1,439	1,650
PRO	36	40	44	49
DOM	222	196	161	116
Total	**1,889**	**2,070**	**2,261**	**2,452**
Population on PWS	28,087	33,092	38,518	44,173
Population on private wells	9,362	8,238	6,769	4,887
Total Population	**37,449**	**41,329**	**45,287**	**49,060**
Manheim-Lititz Basin				
AGR	106	124	142	159
IND	356	387	419	449
MIN	0	0	0	0
PWS	890	1,047	1,218	1,397
PRO	0	0	0	0
DOM	141	124	102	74
Total	**1,493**	**1,677**	**1,881**	**2,132**
Population on PWS	17,678	20,828	24,244	27,802
Population on private wells	5,958	5,242	4,307	3,110
Total Population	**23,636**	**26,071**	**28,551**	**30,912**

Population projections for years 2010, 2020, and 2030 were based on Lancaster County Planning Commission's preliminary population projections for Lancaster County and municipalities (Table 8) (Lancaster County Planning Commission, 2002). Population estimates by municipality within the study area were totaled, and the percent increase in population each decade was applied to the 2000 base population of 61,085.

Table 8. Population Projections for Municipalities in or Partially in the Study Area (modified after Lancaster County Planning Commission, 2002)

Municipality	2000 Census	2010 Projection	2020 Projection	2030 Projection
Akron Borough	4,046	4,244	4,432	4,588
Clay Township	5,173	5,762	6,357	6,918
Denver Borough	3,332	3,666	3,990	4,283
East Cocalico Township	9,954	11,291	12,653	13,961
Elizabeth Township	3,833	4,386	4,961	5,523
Ephrata Borough	13,213	14,010	14,771	15,422
Ephrata Township	8,026	9,284	10,606	11,931
Lititz Borough	9,029	9,483	9,913	10,270
Manheim Borough	4,784	4,648	4,521	4,391
Penn Township	7,312	8,151	9,017	9,849
Rapho Township	8,578	9,355	10,132	10,844
Warwick Township	15,475	18,084	20,828	23,586
West Cocalico Township	6,967	7,668	8,359	8,989
Total	**99,722**	**110,032**	**120,540**	**130,555**
Percent Increase	—	10.3	9.5	8.3
Study Area Total	**61,085**	**67,400**	**73,837**	**79,972**

For the public water supply sector, the average daily water use per resident of 116 gpd was determined from the total annual use estimate of 1,941 mgy (total groundwater withdrawal for public water supply of 1,549 mgy [Table 5] plus surface water withdrawals of 392 mgy from the Ephrata [1.0 mgd] and Denver [0.075 mgd] systems) and a population of 45,765 serviced by public water systems. The public water supply includes residential, institutional, commercial, and industrial use from these public systems. With the expected growth in public system service areas, the percent of the population served also should increase. For the succeeding years of 2010, 2020, and 2030, the percent of population served by public systems in the study area was assumed to be 80, 85, and 90 percent, respectively. Based on the expected growth of service areas, the assumption was made that some private domestic users will convert to public supplies.

Based on the findings of a 1994 Lancaster Water Systems Study noted in the Lancaster County Water Resources Plan (LCWRP) (Lancaster County Water Resources Task Force, 1996), the projected new industrial water use was determined by a per capita multiplier of 19.84 gpd for existing industrial water use not on public systems. The projected increase represents the water demand for self-supplied industries.

While the area of agricultural land may be expected to decrease with increasing land development, every indication points to continued growth of intensive animal operations. The LCWRP stated that growth in intensive animal operations during the last few decades has been accompanied by a doubling of total water use for livestock. Jarrett and Hamilton (2002) estimated agricultural consumptive water use for farm animals and irrigated crops in the lower Susquehanna River Basin, and reported a 41.7 percent increase in agricultural animal consumptive water use from 1970 to 2000 and a 19.7 percent increase from 2000 to 2025. Jarrett and Hamilton (2002) based their estimates on the Census of Agriculture county data. The latter rate of increase from 2000 to 2025 translates to a 25 percent increase over a 30-year period from 2000 to 2030. While these estimates were an average for several counties, it is reasonable to expect higher water use estimates for Lancaster County due to a higher number of farm animals as compared to other counties in the area.

Based on information presented in the LCWRP and Jarrett and Hamilton (2002) report, a 50 percent increase was applied to the 2000 agricultural water use value to obtain the 2030 agricultural water use. Water use estimates for the intervening periods were incrementally increased.

Mining operations are expected to continue at a constant rate and no new mining operations are expected in the study area. Therefore, water use from the mining sector is expected to remain constant.

Water bottling operations are expected to increase in the Susquehanna River Basin as a whole, and also in the study area, in response to market demands. In 1986, Pennsylvania ranked in the top 10 states for the consumption of bottled water in the United States (Van der Leeden and others, 1990). The Beverage Marketing Corporation indicated that bottled water was the fastest growing major beverage segment in the United States, increasing 7.5 percent in 2003 (Bottle Water Store, 2004). From 1991 to 1996, the Beverage Marketing Corporation provided growth statistics for non-sparkling water consumption by distribution sector (Van der Leeden and others, 1990). They reported growth rates of 4.0 percent, 4.8 percent, 5.0 percent, and 10.1 percent in the commercial, home, vending, and retail distribution sectors. These values translate to an annual growth rate of one to two percent.

Based on general information from industry sources, an increase of one percent per year was applied to the current use for water bottling withdrawals in the study area.

Projection Results: The projected water demand estimates in Table 7 were compared to groundwater availability presented in Table 6. Table 7 presents the projected water use demand by use sector and population for the study area. For comparison purposes, results from the LCWRP and linear interpolation of those results for future years are presented in Table 9. Discussion of projected demand is based on Table 7 results.

Table 9. Projected Water Use in Million Gallons per Year and Population Based on Lancaster Water Resources Plan

Use Sector	1990[1]	2000[2]	2010[1]	2020[2]	2030[2]
RICO[3]	1,836	2,319	2,801	3,284	3,766
Industrial	214	306	399	491	584
Total	**2,050**	**2,625**	**3,200**	**3,775**	**4,350**
Population	51,527		77,639		

[1]1990 and 2010 based on Table III-1 Lancaster County Water Resources Plan (Lancaster County Water Resources Task Force, 1996)
[2]2000, 2020, and 2030 projection based on linear trend of 1990 and 2010 data
[3]RICO defined as residential, institutional, commercial, and other.

For the 70-square-mile study area, the projected increase in water use based on Table 7 estimates from 2000 to 2030 is 1,149 mgy (3.1 mgd). This represents a 34 percent increase and a total annual use of 4,531 mgy (12.4 mgd) by the year 2030. The projected 2030 annual use estimate is less than 50 percent of the 1-in-10-year annual recharge of 5,304 mgy (14.5 mgd). In addition, the total allocated use of 4,896 mgy (13.4 mgd) exceeds the 2030 projected annual use estimate. This suggests that the available supply will meet the 2030 projected demand over the entire 70-square-mile area. However, increases in withdrawals may cause adverse local impacts.

Unused surface water system capacity could meet part of the projected demand. This capacity is the difference between the surface water allocation and average use. In the study area, the Pennsylvania Source Water Assessment Program identified two public water systems operating surface water facilities: Ephrata Area Joint Authority and Denver Borough Water Authority. Ephrata Area Joint Authority is allocated 1.0 mgd from the Cocalico Creek; however, withdrawals averaged nearly 1.0 mgd from January to June in 2002 (Susquehanna River Basin Commission, 2003a). Denver Borough Water Authority is allocated 300,000 gpd, but on average withdraws between 50,000 and 75,000 gpd (Susquehanna River Basin Commission, 2003b). The estimated potential surface water available from the Denver Borough Water Authority is 82 mgy (0.23 mgd). Considering the current system capacity of these two surface sources, the net projected groundwater demand for public water supply in the Ephrata area groundwater basin by 2030 is 517 mgy.

CRITICAL AQUIFER RECHARGE AREAS

Recharge occurs wherever the land surface is pervious and the water table is below the surface. However, some areas are characterized by features or attributes that provide an exceptional amount of replenishment (recharge) to the aquifer per unit area, and are herein termed critical aquifer recharge areas (CARAs). Four CARAs were identified in the course of this study.

Dry Valleys

Dry valleys occur throughout the carbonate valley. They consist of an integrated network (drainage net) of broad valleys that lack streamflow or even discrete stream channels, and resemble a surface drainage net. These valleys were abandoned (perennial streamflow ceased) when karst permeability in the underlying carbonate bedrock underdrained the valley, lowering the water table to the level of the solutional openings and leaving the surface streams deprived of base flow.

The valleys have been further modified by differential solution of the underlying carbonate bedrock, resulting in wider, subtly depressed areas over more soluble bedrock formations. During major precipitation and meltwater events, water floods the broad valley floor depressions and spills from pool to pool. As the amount of water delivered to the valley declines, continuous surface water flow breaks up into a series of shallow pools. The pooled water may be present for a period of days to weeks. The pools gradually diminish in area as the water evaporates and percolates to the water table. Use by plants (evapotranspiration) may be significant if the pooling occurs during the growing season, and the existing plants are adapted to saturated soil conditions.

The dry valleys are thought to contribute an exceptional amount of recharge because the underlying bedrock has greater karst permeability (more voids and conduits), the water table is below the land surface so that head conditions are favorable to recharge, and the surface runoff covers a large surface of absorption while pooled water is present. Although the rate of percolation for these soils is not exceptionally high (i.e., the soils are not well drained), percolation occurs over an extended period of time and over a large surface area due to the pooling of surface water. The pooling allows some of the rejected recharge (i.e., surface runoff) from surrounding uplands to percolate to the water table.

The larger dry valleys have been identified (Plate 1) and three major dry valley systems have been informally named: the Limerock Dry Valley System is located between Manheim and Lititz and has a surface water collection area of over 3 square miles; the Weidmanville Dry Valley System is located northwest of Ephrata and has a surface water collection area of over 2.5 square miles; and the Stevens Dry Valley System has a surface water collection area of over 2 square miles.

Losing Stream Reaches

Streams flowing over an underdrained carbonate terrain are typically perched on low permeability carbonate residuum (orange-brown silty clay) over much of their length and have minimal flow loss to the aquifer. However, where the channel crosses a stratigraphic horizon with well-developed karst conduits and a hydraulically efficient connection between the stream and the aquifer is present, streamflow is lost to the aquifer. A number of losing stream reaches were bracketed by the streamflow measurement stations. The actual losses were only a small fraction of the total streamflow for larger streams, but were a substantial fraction of the total flow for smaller streams. Losses ranged from a few tenths of a cubic foot per second for small streams to several cubic feet per second for the larger streams. Streamflow measurement locations and losing reaches are shown on Figure 8 and Plate 1. Measured flows are shown in Appendix A.

Siliciclastic to Carbonate Stream Crossings

Stream water draining siliciclastic terrains is generally acidic due to the lack to soluble buffering compounds in the rock. When streams with acidic water emerge onto a carbonate terrain that is underdrained, the acidic water may percolate through the streambed and valley floor alluvium, past the root zone and into the underlying carbonate bedrock aquifer. The seasonal to continuous supply of acidic water produces enhanced karst permeability beneath the percolation area, which may extend for some distance downgradient from the siliciclastic to carbonate crossing. This represents an increase in the amount of water in the carbonate basin above that derived from the recharge of local precipitation. This same process occurs to some degree all along the non-carbonate-carbonate contact, where local groundwater flow from the higher, non-carbonate terrain flows into the carbonate valley. However, it is more important at perennial stream crossings where recharging streamflow substantially augments the local groundwater flow from the non-carbonates.

Karst Modified Uplands

The broad uplands between the major stream valleys (see Plate 1) are inferred to have solution-enhanced permeability based on the occurrence of numerous small, shallow depressions. These depressions have dimensions similar to active sinkholes in the study area and have been interpreted as dormant sinkholes (Kochanov, 1990). While some of these may be of non-karst origin (i.e., pseudo-karst), the abundant carbonate bedrock pinnacles in these areas strongly suggest the presence of solution-enhanced permeability. The upland setting provides aquifer porosity for the storage of recharging water that is higher in elevation than local groundwater discharge areas, an essential characteristic for a recharge area.

WATER QUALITY

The amount and rate of precipitation, soil and rock composition, and the influence of human activities, such as the use of fertilizer and disposal of wastes and sewage, are all factors that influence the chemical quality of surface water and groundwater. The amount and type of dissolved mineral matter found in stream water is determined largely by the composition of the soil and rock through which water flows in its path to the stream.

In order to evaluate water quality within the study area, water samples were obtained from 65 wells and springs, and 70 stream sites during the spring and fall of 2004 (Appendix B).

Specific Conductance

Specific conductance of water depends on the amount and nature of its dissolved solids. Differences in the mineral composition of each geologic formation influence the amount of dissolved solids in that aquifer. Higher than normal values in isolated areas may be indicative of groundwater contamination.

Specific conductance of 65 groundwater samples ranged from 231 to 1,623 micromhos with 4 samples exceeding 1,000 micromhos. The median value was 684 micromhos. Figure 15 is a map showing the spatial distribution of specific conductance. Groundwater having high specific conductance (greater than 600 micromhos) is typical of groundwater in the carbonate valley. In the non-carbonate areas such as the Cocalico Formation and the Triassic sandstones and conglomerates, specific conductances below 600 micromhos predominate. Specific conductances of over 1,000 micromhos occur in the eastern portion of the Ephrata area groundwater basin.

Specific conductance of 61 stream samples ranged from 174 to 735 micromhos, with a median value of 407 micromhos. Surface water samples from Cocalico Creek upstream of Ephrata and streams flowing from upgradient, noncarbonate watersheds had low specific conductance (less than 300 micromhos). Specific conductances higher than 300 micromhos were scattered among the stream sites in the carbonate valley. With few exceptions, specific conductances higher than 500 micromhos predominate in the more populated areas.

Nitrate

Nitrogen is naturally a very abundant element found in air and water. However, high concentrations in the form of nitrate in water are indicative of contamination. Nitrate in well water may result from point sources such as sewage disposal systems and livestock facilities, and from non-point sources such as fertilized cropland, parks, golf courses, lawns, and gardens.

Nitrate concentrations of 64 groundwater samples ranged from 0.3 to 33.95 milligrams per liter (mg/l), with a median value of 9.08 mg/l. Figure 16 is a map showing the spatial distribution of nitrate-nitrogen sampling points and the measured values above and below safe drinking water standards. Groundwater having nitrate concentrations exceeding 10 mg/l is scattered throughout the study area, indicating that potential nitrate contamination of new water supplies is a significant concern.

For the 64 groundwater samples, nearly 47 percent of the nitrate concentrations exceeded the Environmental Protection Agency (EPA) drinking water limit of 10 mg/l. According to EPA, water containing more than 10 mg/l nitrate as nitrogen is potentially dangerous to infants, causing a blood disorder called methemoglobinemia. This blood disorder is caused by the interaction of nitrate with the hemoglobin in red blood cells, reducing the amount of oxygen carried to the body's cells. While rare among adults, the "blue-baby" syndrome has been reported among infants, where nitrate-contaminated well water was used to prepare formula and other baby foods.

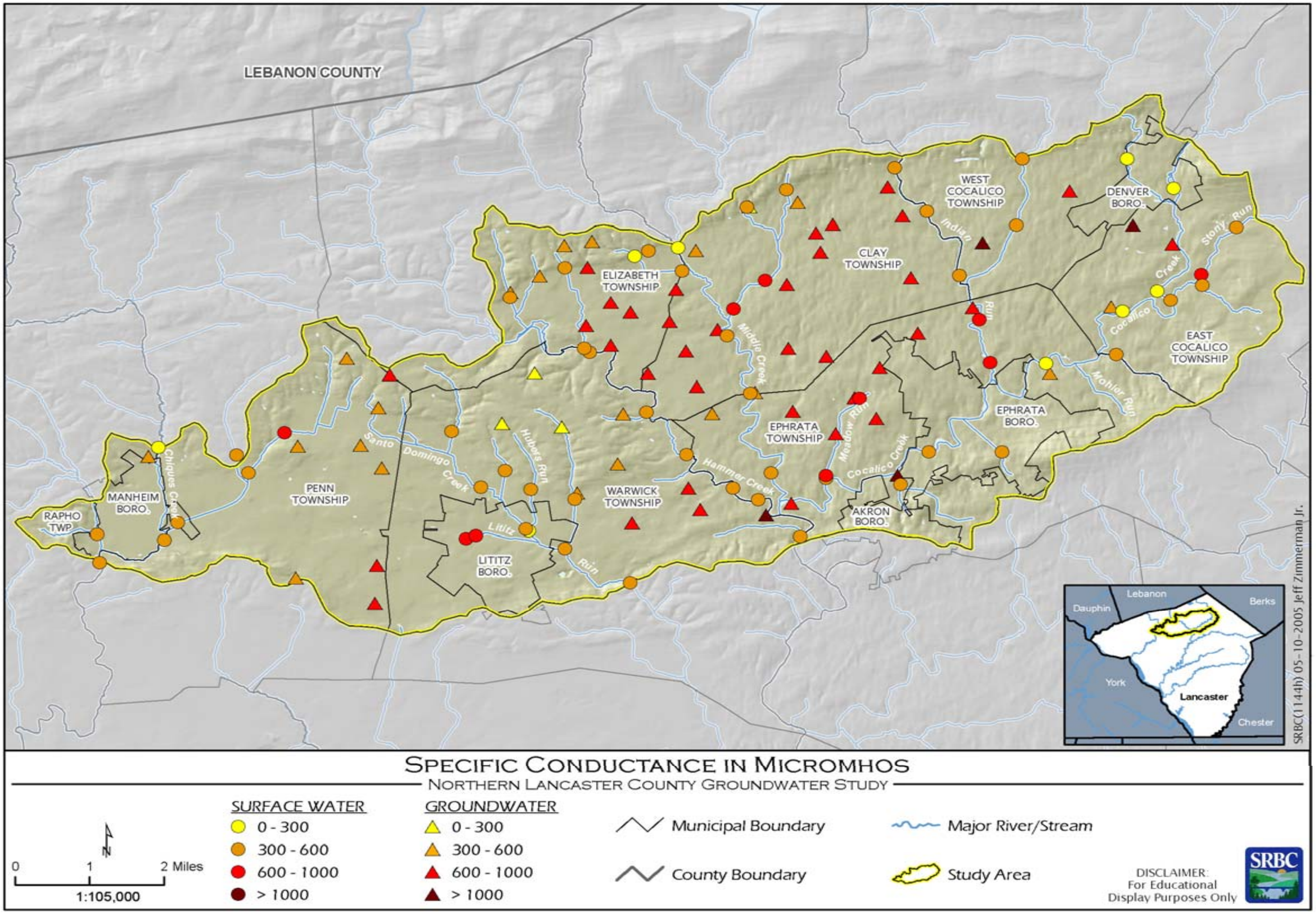

Figure 15. Spatial Distribution of Specific Conductance in Micromhos in the Study Area

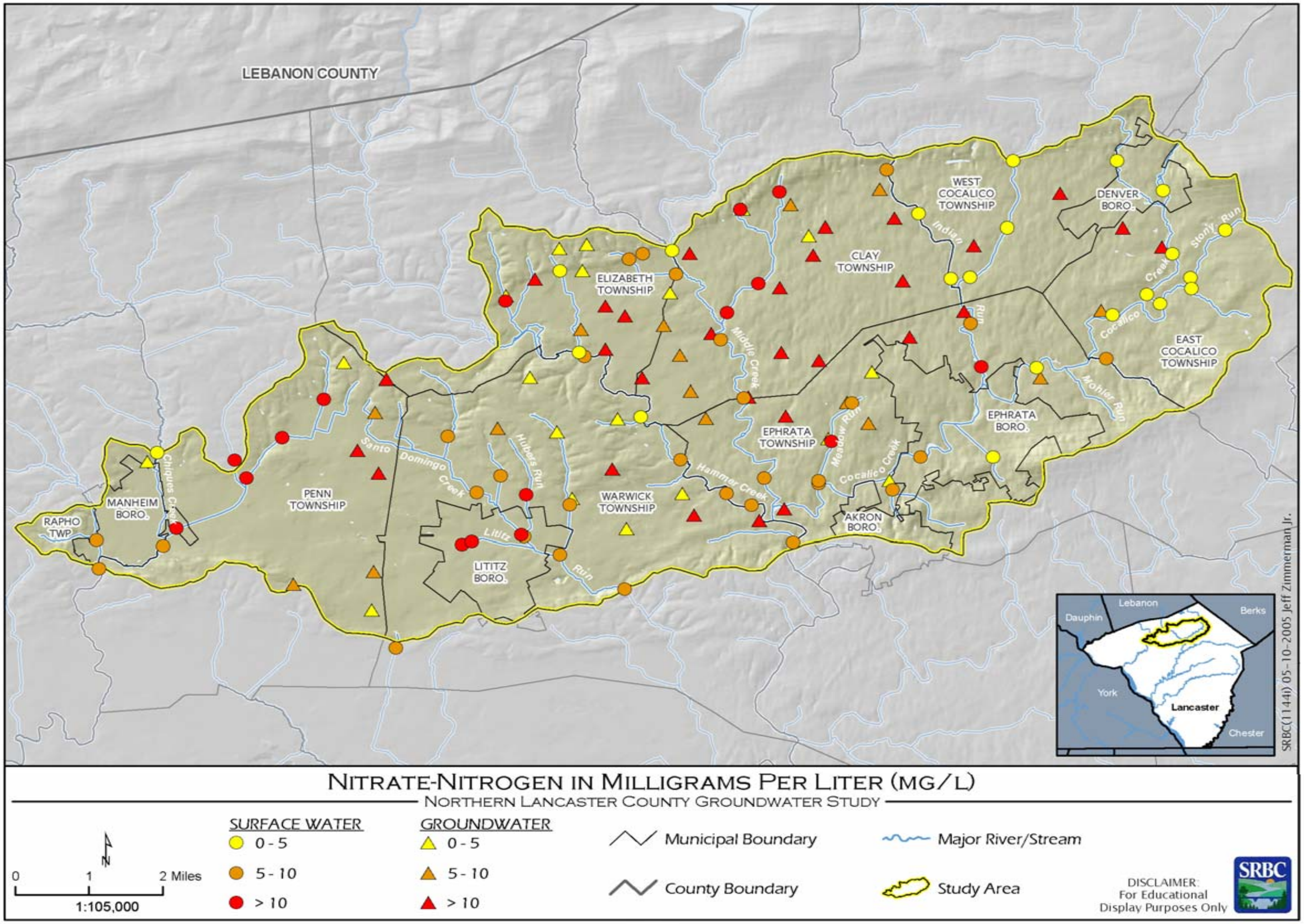

Figure 16. Spatial Distribution of Nitrate-Nitrogen in Milligrams per Liter in the Study Area

Nitrate concentrations in 70 stream samples ranged from 0.7 to 18.25 mg/l, with 23 percent exceeding the EPA drinking water limit of 10 mg/l. The median nitrate concentration in stream water was 6.58 mg/l. Spatially, the lowest nitrate concentrations (less than 5.0 mg/l) were located along Cocalico Creek and its tributaries upstream of Ephrata. West of Ephrata, stream nitrate concentrations greater than 5.0 mg/l predominate. Stream reaches where nitrate concentrations exceeded 10 mg/l include: (1) Doe Run, a tributary of Chiques Creek in Penn Township; (2) the upper reach of Lititz Run and the lower reach of Santo Domingo Creek in Lititz Borough; (3) tributary of Middle Creek, flowing south from Durlach; and (4) the lower reach of Indian Run, downstream of Springville.

WATER RESOURCE MANAGEMENT RECOMMENDATIONS

Management

The Commission, the Commonwealth of Pennsylvania, and other agencies and levels of government have a range of regulations, programs, policies, and options that influence and control water resources management in the study area. In particular, the Commission and PADEP have regulations that govern water withdrawals and use. At the local level, counties and municipalities can guide land use and growth. Local ordinances and land use regulations can help protect water quality and enhance water availability.

The Commission

The mission of the Commission is to achieve a balance among environmental, human, and economic needs. In its regulatory program, the Commission strives to:

1. Manage water as a sustainable/renewable resource;
2. Avoid conflicts among water users;
3. Protect public health, safety, and welfare;
4. Foster economic development; and
5. Protect fisheries, aquatic habitat, and the environment.

Some of the elements of its regulatory program and water management policies are described below.

Registration: The Commission adopted water withdrawal registration regulations to document water use throughout the basin and provide the necessary data to make informed water management decisions. Registration is important to the Commission's regulatory activities because it provides basic water use data, thereby allowing the Commission to protect existing uses. Information on water use is important for other Commission water management activities, including preparation of water budgets.

Regulation of Groundwater Withdrawals: The Commission adopted withdrawal regulations to manage large water withdrawals (in excess of 100,000 gpd, or 20,000 gpd if used consumptively) in order to avoid conflicts between users and to ensure beneficial management of the water resources. By regulation, withdrawals are limited to the amount (quantity and rate) that is needed to meet the reasonably foreseeable needs of a project and that can be withdrawn without causing adverse impacts. The Commission's application process has a number of standard criteria that are applied to all projects. These include a constant-rate pumping test, metering, monitoring and reporting, mitigation of adverse impacts, water conservation, and a docket reopener provision.

Commission staff formulates specific recommendations so that the project can operate without causing any undesirable environmental effects. Water quantities and rates of withdrawal can be reduced from those requested or otherwise limited, as necessary, to protect other uses or mitigate impacts. Many projects are conditioned with instream passby flow requirements or a minimum groundwater level that must be maintained in the production well.

Compliance Monitoring and Enforcement: The Commission's objective is to have all water users in the basin in compliance with water management regulations in order to properly manage the basin's water resources. The Commission requires certain monitoring data to be submitted for approved projects.

Passby Flows: The Commission utilizes passby flows, conservation releases, and consumptive use compensation to help protect aquatic resources, competing users, and instream flow uses downstream from the point of withdrawal. Additionally, these requirements are intended to prevent water quality degradation and adverse lowering of streamflow levels downstream from the point of withdrawal.

Protected Areas: The Commission's Compact allows for the creation of protected areas in regions of water shortage within the basin. According to the Compact, protected areas are intended to correct, mitigate, and manage local area water supply shortfalls or threatened shortfalls on a quantitative basis. Protected areas may be managed to limit groundwater withdrawals, surface water withdrawals, both groundwater and surface water withdrawals, and cumulative consumptive water uses. To date, the Commission has not exercised its protected areas authority, but could do so if needed.

Water Conservation: A requirement to institute appropriate water conservation measures is included, by regulation, for any project that is subject to Commission approval. A number of specific requirements apply to public water suppliers (source and customer metering, unaccounted-for water to be less than 20 percent, an appropriate rate structure, etc.). The regulations do not include specific conservation measures for other water users. Incentives for promoting conservation measures and implementing technical solutions may also be considered by the Commission.

Water Reuse: Groundwater used by municipalities and industries is typically treated and discharged to a stream. The quality of treated water is generally quite good and is potentially usable for many non-potable uses. The reuse of treated wastewater may allow the water budget to be "stretched" in areas of rapid growth and limited water resources.

Conjunctive Use: The availability of groundwater and surface water resources frequently varies in a complimentary manner during the year, such that one of them is relatively abundant while the other is relatively scarce. Water users can develop both groundwater and surface water sources, and rely on each as it is "in season." This approach is called conjunctive use and it should be generally encouraged, especially in areas where groundwater resources are nearing exhaustion.

<u>The Commonwealth of Pennsylvania</u>

PADEP conducts many water resource management activities, most of which relate to water quality and pollution, as described in the following pages.

The Bureau of Water Supply and Wastewater Management regulates sewage disposal by both on-lot and community systems, spray irrigation, underground injection of wastes, surface impoundments (nonhazardous waste), and underground storage tanks. This bureau responds to miscellaneous groundwater pollution incidents, including hydrocarbon spills, and those resulting from the aerial application of agricultural fertilizers and pesticides. Public water supplies are regulated and monitored by field staff, with a primary concern being water potability. The Commonwealth of Pennsylvania regulates the quality and rate of groundwater withdrawals for public water supplies.

The Bureau of Waste Management regulates solid waste. All facilities for the storage, treatment, and disposal of municipal, residual, or hazardous waste are permitted including, but not limited to, landfills, incinerators, and land application sites. Storage and treatment facilities also pose a potential threat to the groundwater, and are also regulated by this bureau.

The Bureau of Mining and Reclamation and the district mining offices permit surface mines, deep mines, coal preparation plants, coal refuse disposal sites, and insure regulatory compliance of all permitted activities. District mining offices are charged with monitoring of groundwater quality around all regulated activities, and protecting the yield of groundwater sources (wells and springs) from being severely diminished as a result of surface mining activities. Impoundments associated with surface and deep mining activities are also regulated by district mining offices. The Bureau of Mining and Reclamation licenses mine operators.

The Bureau of Watershed Management manages Pennsylvania's Wellhead Protection Program, which serves as the cornerstone of the Source Water Assessment and Protection Program. While these programs address pollutants and water quality concerns, the bureau also is responsible for water quantity issues through managing surface water allocation permits to public water suppliers, comprehensive water resource planning for the Commonwealth (State Water Plan), and stormwater management through Act 167.

Surface Water Allocations: The Bureau of Watershed Management issues surface water allocation permits to public water suppliers both for direct withdrawal of surface waters (i.e., springs, streams, quarries, and deep mine discharges) and for purchase of surface water from another public water supply agency. The review process addresses source quantity requirements and effects of a surface water withdrawal on other resources protected by laws administered by PADEP. Therefore, the Bureau of Watershed Management review process coordinates internally with other department bureaus to assess potential adverse impacts related to their respective program areas from the requested allocation. These assessments are primarily reviewed for impacts on water quality. An example review activity is determining if the quantity of the requested withdrawal will result in any adverse water quality impacts downstream of the proposed taking point. PADEP also coordinates with other agencies and receives comments on the proposed surface water withdrawal. The Commission reviews these allocation applications for potential water quantity issues to both surface and groundwater.

PADEP reviews population projections and historical water use to determine projected need. This includes an evaluation of any consistent increase in total water use over the previous 10 years and a review of the total system per capita and residential per capita daily usage. A determination of the projected future need over a 20- to 30-year period is made. The proposed water use is reviewed for water conservation possibilities and to determine compliance with the Commission's water conservation policy and standards. The capacity of water supply sources is reviewed to determine the supply of water available during drought periods and what passby flow requirement at the intake is needed. Depending on the stream's designation standard, additional instream flows may be required. For example, streams designated as a Cold Water Fishery (CWF) with naturally reproducing trout may require a determination of instream flow needs to protect the fishery.

PADEP surface water approvals are given where it is determined that the: (1) proposed new source of supply will not conflict with the water rights held by any other public water supply agency; (2) water and water rights proposed are reasonably necessary for the present purposes and future needs of the public water supplier making application; and (3) taking of said water or exercise of water rights will not interfere with navigation and public safety, and will not cause substantial injury to the Commonwealth. Where conflict of interests may occur, PADEP considers the extent of conservation development and use of existing water resources to the best advantage. The life of water allocation permits is generally for a period of 25 years.

Comprehensive Water Resource Planning: Pennsylvania is currently implementing the Water Resources Planning Act (Act 220) under the guidance of a Statewide Water Resources Committee to develop the state water plan. The water resources planning program is to address basic questions regarding how much water the Commonwealth has, uses, and needs. Major components of Act 220 are:

1. Update the state water plan within five years;
2. Register and report certain water withdrawals;
3. Identify Critical Water Planning Areas (CWPAs);
4. Create critical area resource plans; and
5. Establish a voluntary water conservation program.

The critical area resource plans are to include a water availability evaluation, assess water quality and water quantity issues, and identify existing and potential adverse impacts on water resources uses. CWPAs are "any significant hydrologic unit where existing or future demands exceed or threaten to exceed the safe yield of available water resources." The methods by which a CWPA may be identified are through the state water planning process as a component of a regional plan, or in advance of the regional plan based upon information developed in (or during) the planning process.

The Lower Susquehanna Regional Water Resource Committee (LSRWRC) is implementing several priorities for the management of the region's water resources. These priorities include:

1. Water Supply: Inventory all sources of groundwater and surface water.
2. Water Quantity: Calculate total water budget for each watershed.
3. Water Quality: Ensure quality to protect designated uses.
4. Water Demand: Identify current and future water needs.
5. Managing Supply vs. Demand: Identify and assess alternatives to balance supply and demand.

Storm Water Management Act 167: The Pennsylvania Storm Water Management Act of 1978 (Act 167) has provided the legislative basis for much of the stormwater management planning carried out by the Commonwealth. Act 167 planning must be performed by the respective counties in a given watershed and then adopted and implemented by the municipalities. While Act 167 planning has been occurring for nearly 30 years, the program is being expanded to merge with the National Pollution Discharge Elimination System (NPDES) Phase II Municipal Separate Storm Sewer (MS4) Program. Also, NPDES Construction Permits required for land disturbances of more than one acre must be consistent with any existing Act 167 plans.

Another initiative is PADEP's Comprehensive Stormwater Policy, which is designed to:

1. Address critical water quality issues;
2. Sustain stream base flow, and groundwater in general, through stormwater management systems that infiltrate and provide for groundwater recharge;
3. Minimize site-specific and watershed-wide flooding problems; and
4. Prevent serious streambank erosion and overall stream impact with related aquatic biota damage.

One of the goals of PADEP's new policy is to replicate, to the maximum extent possible, preconstruction infiltration, water quality treatment, and volume and rate controls by preserving natural areas and utilizing constructed infiltration best management practices.

Local government

Within the study area, there are several forms of local government, including one county, eight townships, and five boroughs. These municipalities control land use, land development, stormwater management, and several aspects of water resource management. A summary of municipal ordinances in the study area is shown in Table 10.

The Pennsylvania Municipalities Planning Code enables comprehensive planning, zoning, and subdivision and land development regulation at the municipal and county level. Recent changes in the Municipalities Planning Code allow for and encourage more area-wide planning on a multi-municipal basis. This provides local governments an opportunity to comprehensively address stormwater management and groundwater protection issues on a watershed or regional basis.

The availability of an adequate water supply is important to a region's economic development and vitality. Therefore, local governments need to be well informed about the implications of their land use decisions on groundwater availability. A variety of tools are available for municipalities to plan and accommodate different types of land uses to promote or enhance water resources. With regard to ordinances that impact water resources, Table 10 provides a baseline of what is already being done by local governments in the study area and also identifies areas of inconsistency. The ordinances are categorized by impervious cover reduction, open space protection, stormwater management, land use and development, water supply and disposal, and agricultural land use.

Table 10. Summary of Municipal Ordinances for Municipalities in the Study Area

Ordinances	BOROUGHS					TOWNSHIPS								
	Akron Boro	Denver Boro	Ephrata Boro	Lititz Boro	Man-heim Boro	Clay Twp.	East Cocalico Twp.	Elizabeth Twp.	Ephrata Twp.	Penn Twp.	Rapho Twp.	War-wick Twp.	West Cocalico Twp.	Lancaster County SLDO
Impervious Cover Reduction														
STREETS														
Street width allowed < 24'		X		X	X			X					X	X
Alternative pedestrian networks may be substituted for sidewalks along roadways												X		
Joint use driveways encouraged and standard agreement provided							X					X		
Parking Ratios														
Minimum parking for profess-ional office (per 1,000 s.f.)	5		3.3	5	3.3	5	3.3		4	3.3	3.3	3.3		3.5 - 4.5
Minimum parking for shopping centers (per 1,000 s.f.)	5		4	5.5	5.5	5	5		4	5	5	5.5		4-5
Minimum parking for single family (per unit)	2		2-3	2	2	2	2		2	2	2	2		2
Shared parking is encouraged	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ratios reduced with shared/joint parking			X				X							
PARKING LOTS														
Minimum parking stall of < 10' x 20'		X	X	X	X				X	X	X	X		
Pervious paving materials permitted				X			X			X				
Landscape islands and landscaping required within parking lot			X	X			X		X	X	X	X	X	
Parking garages encouraged					X									

Table 10. Summary of Municipal Ordinances for Municipalities in the Study Area (continued)

Ordinances	BOROUGHS					TOWNSHIPS								
	Akron Boro	Denver Boro	Ephrata Boro	Lititz Boro	Man-heim Boro	Clay Twp.	East Cocalico Twp.	Elizabeth Twp.	Ephrata Twp.	Penn Twp.	Rapho Twp.	War-wick Twp.	West Cocalico Twp.	Lancaster County SLDO
Open Space Protection														
RESOURCE CONSERVATION														
Floodplain protection or district	X	X	X	X		X	X	X	X	X	X	X	X	
Steep slope protection	X	X				X	X	X	X	X			X	
Wetland protection			X	X			X				X	X		
Existing tree protection measures		X	X	X			X							
Forested land protection		X	X	X		X	X	X		X	X	X	X	X
Conservation development standards		X						X				X		
Ecologically sensitive or resource conservation district			X					X				X	X	
Riparian buffers	X	X	X		X	X	X			X	X	X		
Environmental performance standards				X										
Alternative energy - wind energy conversion systems				X										
Growth Limits/Agri-cultural Preservation														
Active farm preservation program							X	X	X	X	X	X		
TDR program												X		
UGB/VGB boundary in place						X			X	X	X	X		
Clean and green enrollment						X	X	X	X	X	X	X	X	
Agricultural security district						X	X	X	X	X	X	X	X	
Prime agricultural soils protection	X					X		X	X		X	X		
Agricultural Preservation District												X		
Adaptive re-use / infill development encouraged					X						X			
Sliding scale zoning	X										X			
Condensed housing or cluster use permitted with open space requirements			X	X	X		X	X	X	X	X	X	X	
By right			X								X			
Conditional or special use				X	X		X	X	X	X		X	X	

Table 10. Summary of Municipal Ordinances for Municipalities in the Study Area (continued)

Ordinances	BOROUGHS					TOWNSHIPS								
	Akron Boro	Denver Boro	Ephrata Boro	Lititz Boro	Man-heim Boro	Clay Twp.	East Cocalico Twp.	Elizabeth Twp.	Ephrata Twp.	Penn Twp.	Rapho Twp.	War-wick Twp.	West Cocalico Twp.	Lancaster County SLDO
Public Water Supply Protection														
Wellhead or aquifer recharge area protection				X			X					X		
OPEN SPACE MANAGEMENT														
Guidelines for establishing native plant communities								X				X		
Enforceable requirements to establish associations to effectively manage open space												X		
Open space may be managed by a third party using land trusts or conservation easements												X		
Storm Water Management														
ACT 167 ordinance in place			X			X	X					X	X	
Encourages reduction of impervious surfaces	X	X		X			X	X				X	X	X
SWM/ BMPs required	X	X	X	X		X	X		X	X	X	X	X	
Groundwater recharge encouraged			X	X		X	X		X	X		X		
Recommends replicating existing drainage patterns	X	X	X	X			X	X	X			X	X	
Standards or methods are in place to monitor and maintain SWM BMPs and infiltration facilities						X	X					X		
Transition from E&S facilities to retention facilities is monitored to ensure system is working following build-out. Delay construction of BMP until all land disturbance activities are completed to minimize clogging and remediation							X							

Table 10. Summary of Municipal Ordinances for Municipalities in the Study Area (continued)

Ordinances	BOROUGHS					TOWNSHIPS								
	Akron Boro	Denver Boro	Ephrata Boro	Lititz Boro	Man-heim Boro	Clay Twp.	East Cocalico Twp.	Elizabeth Twp.	Ephrata Twp.	Penn Twp.	Rapho Twp.	War-wick Twp.	West Cocalico Twp.	Lancaster County SLDO
Land Use/ Development														
KARST GEOLOGY ISSUES														
Hydrogeologic study req.			X				X			X	X	X		
Sinkhole and depression ID req.										X	X			X
Sinkhole protection measures		X					X			X	X		X	X
Limitations (blasting, land use, SWM basins, underground storage, tanks, manure storage, etc.)			X	X			X		X	X	X	X		
SPECIFIC WATER-RELATED USES														
Car wash facilities req to use public sewer and water system			X					X		X	X	X	X	
Car wash facility req to recycle water			X				X	X			X			
Swimming pool disposal and filling standards		X			X		X					X		
Ornamental ponds, wading pools, lakes, dams, or impoundments standards		X			X		X	X		X	X	X		
Quarry or extractive related use standards							X	X		X	X	X	X	
Mushroom operations/comp							X				X	X		
Septage and /or solid waste disposal and processing facilities			X				X	X		X	X	X		
Cemeteries not permitted in floodplain, flood fringe or areas of high water			X								X	X	X	
Subsurface storage or tanks	X					X								
Manure storage									X				X	
Hospital and medical facilities waste disposal											X	X		
Stockyard, slaughtering and feedlots											X	X		
Intensive farming operations													X	

Table 10. Summary of Municipal Ordinances for Municipalities in the Study Area (continued)

Ordinances	BOROUGHS					TOWNSHIPS								
	Akron Boro	Denver Boro	Ephrata Boro	Lititz Boro	Man-heim Boro	Clay Twp.	East Cocalico Twp.	Elizabeth Twp.	Ephrata Twp.	Penn Twp.	Rapho Twp.	War-wick Twp.	West Cocalico Twp.	Lancaster County SLDO
LAND DEVELOPMENT REVIEW														
Sketch Plan optional	X	X	X			X	X	X	X	X	X	X	X	X
Sketch Plan required				X										
Natural, cultural resources inventory		X					X	X		X	X	X	X	X
Environmental impact statements							X			X				
Site meeting with LCCD rep		X						X		X		X	X	X
Water Supply and Disposal														
PRIVATE WELLS														
Yield and quantity aquifer testing (quantity of water available for proposed use)		X				X	X	X		X	X	X	X	X
Hydrogeologic impact study or water supply study (impact on adjacent properties)		X	X			X	X	X		X	X	X	X	
Well capping requirements or standards										X				
Public system required				X										
SEWAGE DISPOSAL														
Sewage Enforcement Officer		X				X	X	X	X	X	X	X	X	
Lot size increased to ensure acceptable level of nitrate-nitrogen in adjacent groundwaters								X		X	X			
Alternative on-lot systems permitted							X			X	X			
Public system required				X										
Ag Land Use														
AGRICULTURAL MANAGEMENT														
PA Nutrient Management Plan recommended						X	X	X	X	X	X	X		
Ag Best Management Practices	X								X			X		
Manure Storage regs.						X	X					X		
Conservation Plan Requirements												X		

Recommendations

Using the information about groundwater use, groundwater availability, CARAs, and the current conditions and regulations within the study area, the Commission developed recommended actions to address issues identified. The issues, problems, and recommendations are presented below. The recommendations were developed through: (1) a review of existing ordinances and regulations that impact water resources; (2) a review of related plans and water resource initiatives; (3) community input on issues and concerns through the Water Budget Advisory Committee (WBAC) and at a June 2004, workshop; and (4) the findings of the Northern Lancaster County Groundwater Study. Some of the recommendations can be implemented on an individual basis by each municipality, while others will require a more comprehensive approach.

The recommendations address four major issues: (1) overall reduction of infiltration and groundwater recharge; (2) excess withdrawal of groundwater in PSAs; (3) overall increase in water use; and (4) consistency among municipal ordinances.

Issue: Overall reduction of infiltration and groundwater recharge

Historic changes in land use have led to increased urbanization and, with it, a sharp increase in impervious surfaces—roads, parking lots, driveways, and roofs—replacing meadows and forests. The result is a 70-square-mile area that is 9 percent impervious and contributes less infiltration and recharge, and has increased stormwater runoff. In the carbonate areas of the Manheim-Lititz and Ephrata area groundwater basins, 12.6 percent and 8 percent, respectively, of these areas are impervious.

Land use and land cover significantly affect the quantity of recharge of groundwater available for public supply, stream base flows, and wetlands. Awareness of this important connection is vital to local municipal governments charged with making land use decisions. Comprehensive municipal planning, protective ordinances, and stormwater management can address the issues of impervious cover and promote infiltration.

Land development commonly increases stormwater runoff. Conventional stormwater management practices have focused on the volume of runoff and on minimizing flooding problems using such practices as detention basins. However, in areas underlain by carbonate geology that are inherently susceptible to surface and subsurface failures, areas where standing water will occur can be lined with impervious material to prevent sinkholes. As a consequence, the natural infiltration and recharge of groundwater also can be reduced.

PADEP’s new comprehensive stormwater policy will expand Act 167 to include control standards that achieve objectives for infiltration and recharge, aquifer and stream base flow protection, and water quality management. Carbonate aquifers are now considered “Special Areas,” acknowledging the need for special control guidelines.

Problem: *Loss of critical aquifer recharge areas (CARAs) from future growth and development is a concern.*

The overall reduction in infiltration throughout the region is an important issue, but the loss of infiltration in CARAs is particularly vital to the overall sustainability of the water supply.

Recommendation: Municipalities should maintain or enhance the unique hydraulic characteristics of CARAs to maximize the amount of groundwater available for utilization within a groundwater basin. Management actions for CARAs commonly include limiting the amount of impervious land cover, preventing soil compaction, and concentrating or diverting stormwater. The management actions may locally restrict land use options, but can result in greater economic growth and community development by: (1) maximizing the amount of groundwater available for development as water supply; (2) minimizing economic loss due to flooding; and (3) providing natural filtering of some agri-chemicals. CARAs typically provide a substantial fraction of the recharge to the aquifer, while constituting only a small fraction of the basin's surface area. As a result, a large fraction of aquifer recharge can be protected and maintained while restricting development activities in a relatively small total area of the basin. Mapping of these important water resource areas provides information that municipal governments can use to make informed decisions on planning for future growth (Plate 1). A detailed data collection effort through site-specific field investigations would further refine the delineation of CARAs.

Problem: *Increased areas of impervious cover will reduce the potential for recharge.*

As development continues to expand in the study area, land that was once open to infiltration is covered with impervious material. The carbonate valley area important to groundwater recharge also is a highly desirable area for development.

Recommendation: Developers should reduce the effect of impervious cover by implementing technologies that increase the infiltration capability of that cover. They also should consider using designs such as porous pavement in areas where natural recharge rates are higher than other land areas. Where the infiltration capability of the land cover cannot be increased, such as rooftops, the stormwater runoff can be directed to other areas and enhance groundwater recharge through distributed infiltration best management practices.

Problem: *Floodplain systems that were once areas of natural recharge are now filled with fine sediment and less permeable, thereby reducing recharge.*

Groundwater monitoring results indicate that water table elevations in the northern part of the study area are several feet below the base of stream channels. Streams flowing from the shale to carbonate areas begin to lose water to the underlying aquifer. However, some stream reaches crossing this area that were naturally losing streams are now perched due to historic land use impacts. During settlement and rapid urbanization, much of the vegetation disappeared, soils were eroded, and floodplains were filled with fine sediment. Now stream channels are underlain by fine-grained, eroded materials and are disconnected from groundwater flow systems.

Recommendation: Many of the problems associated with perched streams can be effectively mitigated through floodplain restoration. Municipalities should consider floodplain restoration in a limited number areas that historically contained meandering stream channels, thereby improving groundwater recharge. Riparian root systems and vegetation can protect the valley floors from scour and provide a means to increase surface water infiltration. Other benefits of restored floodplain systems include attenuation of storm flows, increasing groundwater recharge along losing reaches, reducing erosion and sedimentation, filtering harmful nutrients from groundwater and surface water, and enhancing aquatic and riparian wildlife habitat.

Problem: *Lack of stormwater plans in the study areas misses opportunities to address infiltration and recharge of stormwater runoff.*

Many of the municipalities in the study area have not adopted an Act 167 plan. Only four municipalities (Ephrata Borough, East Cocalico Township, Warwick Township, and West Cocalico Township) have Act 167 plans in place.

Recommendation: County and local governments should complete Act 167 stormwater management plans for the remaining areas. They also should implement PADEP's new comprehensive stormwater policy, which promotes the use of distributed infiltration best management practices to increase groundwater recharge, for new and existing Act 167 plans.

Problem: *Certain carbonate areas, such as those identified as karst modified uplands, may not be suitable for on-site stormwater management best management practices.*

The use of on-site stormwater best management practices may increase the potential for sinkhole development and groundwater contamination in high-density karst areas. Development in urban areas may not allow for distributed infiltration best management practices.

Recommendation: Areas that are not conducive to on-site stormwater management best management practices should be located and mapped. County and local governments should consider distribution of stormwater runoff to regional stormwater management facilities in restored floodplains and CARAs. The benefits include maximizing the recharge potential of CARAs. Innovative approaches should be explored, such as the transfer of stormwater requirements to receiving areas (i.e., CARAs or stormwater management facilities) for the expansion of development rights in sending areas (i.e., areas in a development that would normally be set aside for stormwater best management practices).

Issue: Excess withdrawal of groundwater in potentially stressed areas (PSAs)

Intense growth and development from all use sectors have resulted in a greater demand for groundwater resources. As growth continues, these areas will experience impacts to the quantity and quality of water resources and their ability to serve as reliable water supplies. PSAs are those areas where the utilization of water resources is approaching the sustainable yield. The Manheim–Lititz groundwater basin is considered a PSA and is approaching the sustainable yield. While total water withdrawals in the Ephrata area groundwater basin did not meet the criteria for a PSA, localized areas of intense groundwater withdrawals could stress the aquifer.

The sustainable yield generally is considered to be equal to the average annual recharge for a groundwater basin, minus the amount of water needed to maintain groundwater-dependent ecosystems. The amount of flow required to meet ecosystem needs is dependent on the nature, sensitivity, and quality of the habitat. If groundwater withdrawals substantially reduce stream and spring flow and dry up wetlands, the sustainable yield is exceeded.

Problem: *Water use in the Manheim-Lititz and Ephrata area groundwater basins is 70 percent and 34 percent, respectively, of the sustainable limit.*

The Manheim-Lititz-Ephrata valley is a rapidly growing area. From 1990 to 2000, several municipalities in the study area exceeded the 11.3 percent growth rate of Lancaster County, with Warwick Township having the highest growth rate of 33.2 percent. Development of water supplies to serve the local needs has increased proportionally, placing greater demands upon groundwater resources. Findings from the study indicate that water use is approaching the sustainable yield for select areas.

Recommendation: Through its regulatory program, the Commission should continue to require groundwater availability analyses for new water withdrawal projects and detailed water budgets in PSAs. The Commission should educate the public and local land use planners about sustainability of water resources in PSAs and the need to properly manage them. The Commonwealth should work with municipal governments and water authorities to develop future water demand projections based on full build-out conditions under current zoning and land use plans. Regional and local planning agencies should evaluate the impacts of different post build-out scenarios on recharge and water demand. This process should provide insight on revising comprehensive and land use plans.

Problem: *Intensive groundwater withdrawals in localized areas will diminish groundwater yields, base flows, and perennial streamflow.*

The determination of a PSA is partly a function of the scale or size of a groundwater basin or recharge catchment area relative to the quantity of total withdrawals. While the 48.4-square-mile Ephrata area groundwater basin is not considered a PSA, localized areas may experience groundwater availability problems. The amount of groundwater available at a given location is proportional to the recharge area upgradient of the point of withdrawal. In growing areas, many wells may be located within close proximity to one another in a relatively small recharge area. The effective recharge area may also be reduced due to increased impervious cover. Wells may experience a loss of yield as groundwater drawdown areas for each well begin to overlap and the total withdrawal exceeds the recharge rate of the catchment area. Other impacts may occur such as the loss of perennial streamflow and adverse effects on aquatic habitat.

Recommendation: The primary management objective in these localized areas is groundwater sustainability. Groundwater models should be utilized to evaluate the impact and assist in determining the most effective solution to address sustainability. For localized areas where the sustainable yields have been exceeded, new wells should not be installed and additional withdrawals should be discouraged. Water resource management agencies should review existing permits and coordinate with existing users to adjust withdrawal rates to achieve groundwater sustainability.

Since existing allocations for groundwater withdrawal are sufficient to meet projected demands, the Commission should encourage municipalities and water authorities to consider addressing new demand with systems with existing excess capacity or through interconnections with water systems that have excess capacity.

Issue: Overall increase in water use

Whether an area is considered a PSA or not, an important consideration in water resources management is the overall increase in water use throughout the study area. The carbonate aquifer is often described as a "bathtub." This analogy should help municipalities understand that while the use of water may be localized and potentially intensive, water withdrawn from any place in the bathtub affects the water level of the entire tub. Thus, it is important to consider the overall sustainability of the aquifer within the entire region, not just the stressed areas or the areas closest to the where the water is being used.

Problem: *The public is not well educated about the limits of groundwater resources.*

Groundwater forms the "hidden part" of the hydrological cycle, which can lead to misconceptions by the public. When users turn on the tap, their expectation is that water will flow, which leads to a natural complacency about water supply. This results from a lack of understanding about the sustainability of groundwater.

Recommendation: Informing the public begins with the education of children. Material on water and the environment should be introduced into the curricula for grades K through 12. Water resource management agencies should partner with schools to conduct classroom presentations and workshops.

Water resource management agencies should conduct basinwide or regional workshops to acquaint citizens with water management issues, problems, and solutions. The Commission should present the findings and recommendations of this study to watershed groups, civic organizations, and legislative leaders.

Problem: *Insufficient or incomplete beneficial reuse of process water or wastewater results in increased water demand.*

Water use is generally demand-orientated rather than conservation-based. Therefore, water reuse may not be a major issue at established facilities, and conservation strategies may not have been explored or implemented. Peak water use is typically two to three times higher in the summer season when demand for lawn watering is high. Using treated wastewater or reuse water for non-potable applications to reduce peak demand is a very effective strategy. An emerging method of maximizing wastewater reuse is to locate small wastewater treatment plants, called scalping plants, in the collection system near large irrigation water users such as golf courses, cemeteries, or parks (Carter & Burgess's Quarterly, 2003). The use of treated wastewater from municipal wastewater treatment facilities also has been effectively recycled in cooling water for industrial processes.

Recommendation: Industrial and commercial users should identify opportunities to reclaim water from one application for use in another application. Within the context of appropriate water quality limitations, agricultural sites near urban areas may provide opportunities to recycle industrial and commercial water for irrigation.

Reuse water is a sustainable water supply. Municipalities should be evaluating ways to take advantage of their wastewater plant effluent for reuse, thus lessening the demand on their potable water supplies. Municipalities can perform “Reuse Master Plans” that focus on reuse opportunities as a water resource for their community and surrounding area.

Problem: *Inefficient water use or lack of conservation measures wastes water.*
The easiest and most cost-effective means of extending the current water supply is to use less water. Conservation can be achieved many ways, including the installation of water-saving devices and modifications to personal behaviors. As growth places increased demands on the water supply, purveyors and water authorities should implement strategies for reducing water demand. Businesses should consult with qualified engineering firms that specialize in on-site water use evaluations and assist in replacement of water-inefficient equipment. Watershed organizations can play an important role in public education by offering information on outdoor use practices such as landscaping alternatives and conservation practices.

Recommendation: The Commonwealth or Lancaster County Planning Commission should consider organizing a residential retrofit program where water purveyors could give away water-efficiency kits. Each kit could contain a low flow showerhead, faucet aerators, package of toilet leak detection tablets, and written information on residential water conservation and use efficiency.

Water authorities and purveyors, in partnership with municipalities, should offer residential water surveys. Water surveyors check for leaking plumbing, provide water conservation tips, offer advice on retrofitting with water-efficient fixtures, and may distribute water-efficiency kits (containing, for example, faucet aerators and low flow showerheads). Water surveys provide a way which encourages homeowners to install water-efficient appliances and implement water conservation practices.

When businesses apply for new or increased withdrawals in PSAs, water resource management agencies should encourage them to consult with qualified engineering firms that specialize in on-site water use evaluations and assist in replacement of water-inefficient equipment.

Watershed organizations should organize and conduct public information programs consisting of conservation brochures, displays, and classes dealing with water-saving irrigation methods and drought-tolerant planting methods.

Problem: *Water discharged from mining operations is underutilized as a resource.*
Mining of rock and mineral deposits below the water table requires that enough water be pumped to keep mine workings dry. This pumped water is released to surface streams where it becomes available to downstream communities. Within the appropriate water quality constraints, water available from both active and abandoned quarries may provide a resource for community water systems and other similar uses. Beneficial use also requires careful evaluation of potential surface withdrawals downstream of mine discharge outfalls.

Recommendation: The Commission should encourage cooperative efforts to promote alternative water supplies such as mining operations for public drinking water, commercial operations, and industrial supplies.

Issue: Consistency among municipal ordinances

Given the decentralized nature of municipal government and land management activities at the local level, there are inconsistencies in local ordinances among municipalities in the study area. This has hindered the consideration of groundwater protection and sustainability across municipal boundaries. Important resource areas and aquifers do not coincide with a single municipal boundary. The benefits gained from the good stewardship of one municipality may be exploited by a neighboring municipality, thereby causing conflicts. Thus, water resource gains may be short-lived.

Problem: *Municipal ordinances that influence water supply availability are inconsistent across municipal boundaries.*

Recommendation: Local governments should continue to utilize the opportunities presented in the Municipalities Planning Code to develop comprehensive land management ordinances that address groundwater resource protection and enhancement. The key to planning most effectively for future water needs within the 70-square-mile study area is the collaboration of municipalities, water authorities, agriculture, industry, and wellhead protection task forces. The current WBAC should consider moving forward as a planning team in accordance with the steps outlined in the Lancaster County Water Resources Plan. Local governments should be encouraged to participate in water resource planning efforts at the regional level.

SUMMARY

The Commission has performed a water resource study for a rapidly growing area located in northern Lancaster County, Pennsylvania. The study area includes an isolated carbonate aquifer of 50 square miles and a surrounding contributing area of 20 square miles. The study area includes parts of 13 municipalities, including the Boroughs of Manheim, Lititz, Akron, Ephrata, and Denver.

Two groundwater basins were delineated, based on water table mapping, and two sets of water levels made during this study. The annual recharge for each groundwater basin, for the 2-, 10-, and 25-year recurrence intervals, was based on previous regional studies that employed extensive base flow separations, water table mapping, and groundwater modeling.

The annual recharge for the Manheim-Lititz groundwater basin, for the 2-, 10-, and 25-year recurrence intervals was estimated to be 5,822 million gallons, 3,531 million gallons, and 2,449 million gallons, respectively.

The annual recharge for the Ephrata area groundwater basin, for the 2-, 10-, and 25-year recurrence intervals was estimated to be 11,676 million gallons, 7,077 million gallons, and 4,917 million gallons, respectively.

Existing water withdrawals were identified and totaled for each groundwater basin. Withdrawal totals were compared to the Commission's utilization level for identification as a PSA, which is 50 percent of the 1-in-10-year recharge.

Actual groundwater use for the total study area was projected for 10 (year 2010) and 25 years (year 2025), and compared with availability. Utilization at 10 years (year 2010) is estimated to be 35 percent of the 1-in-10-year recharge and 51 percent of the 1-in-25-year recharge. Utilization at 25 years (year 2025) is estimated to be 41 percent of the 1-in-10-year recharge and 59 percent of the 1-in-25-year recharge.

The Commission uses the 1-in-10-year annual recharge as the sustainable limit of groundwater development. This limit is a compromise between maximum developable water, instream flow needs, and required reservoir or tank storage capacity. This limits groundwater withdrawals to 3,531 mgy for the Manheim-Lititz basin and 7,077 mgy for the Ephrata area basin.

Actual, current (year 2000) withdrawals for the Manheim-Lititz basin, the Ephrata area basin and the entire study area do not exceed 50 percent of the 1-in-10-year recharge.

Allocated groundwater withdrawals (year 2000) in the Manheim-Lititz groundwater basin were 70 percent of the 1-in-10-year recharge, which exceeds the Commission's PSA standard (50 percent of the 1-in-10-year recharge). Allocated withdrawals (year 2000) from the Ephrata area groundwater basin were 34 percent of the 1-in-10-year recharge. Allocated groundwater withdrawals (year 2000) in the entire study area were 46 percent of the 1-in-10-year recharge.

In order to protect riparian and aquatic habitat, the Commission, in coordination with the Commonwealth of Pennsylvania, requires that withdrawals cease or be augmented with a release of makeup water when the flow in a stream falls below a set percentage of the average daily flow. All of the streams within the carbonate valley are classified (Pennsylvania Chapter 93) as warm water fisheries.

Withdrawals in the study area must cease or be augmented with a release of makeup water when the flow in local streams falls below 20 percent of the average daily flow. Streamflows in the study area will be below 20 percent of their average daily flow an average of 30 days per year. Discharge of wastewater adjacent to or upgradient of groundwater withdrawals would largely mitigate this impact. For municipal water supply withdrawals located in the Manheim-Lititz basin or in the southern portion of the Ephrata area basin, the withdrawals are made-up by the releases from the municipal wastewater treatment plants.

The results of two detailed seepage runs on the trunk streams and principal tributaries performed during this study were used to identify aquifer discharge areas and losing stream reaches.

Areas contributing unusually high amounts of recharge, termed CARAs, were identified in the study area. These included several "siliciclastic to carbonate streamflow crossings," three dry valleys, and several losing stream reaches. Preservation of the hydrologic (recharge) function of these areas will help to maintain the natural abundance of water resources available in the study area. The emplacement of impervious cover and other growth-related changes to the land surface that result in reduced recharge should be carefully considered.

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APPENDIX A

Seepage Run Measurements

Stream Discharge from 2004 Field Survey

Station ID	Latitude Dec Degree	Longitude Dec Degree	Date	Flow cfs	Date	Flow cfs	Stream Name
							Chiques Creek Watershed
F011	40.177111	-76.389639	06/09/04	18.86	10/28/04	20.97	Chiques Creek-1
F005	40.157167	-76.388278	06/09/04	25.82	10/28/04	24.58	Chiques Creek-2
F003	40.152500	-76.404667	06/08/04	33.06	10/28/04	32.03	Chiques Creek-3
F007	40.160900	-76.384800	06/09/04	1.48	10/28/04	3.90	Doe Run, at mouth
F007	40.160900	-76.384800	06/13/04	1.65			Doe Run, at mouth
F031	40.188194	-76.346889	06/13/04	0.58			Doe Run, headwaters
F029	40.180056	-76.357556	06/13/04	0.967	10/28/04	1.67	Doe Run, upstrm F025
F025	40.171528	-76.366778	06/13/04	1.55	10/28/04	2.20	Doe Run, upstrm trib 1
F001	40.158556	-76.405222	06/08/04	5.59	10/28/04	5.92	Rife Run
F027	40.175333	-76.369750	06/13/04	1.22	10/28/04	2.02	Trib 1 to Doe Run
							Cocalico Creek Watershed
F070	40.237444	-76.143417	06/17/04	16.08	11/01/04	18.00	Cocalico Creek-1
F053	40.217639	-76.129444	06/17/04	29.67			Cocalico Creek-2
F072	40.209083	-76.136111	06/17/04	26.73	11/02/04	23.63	Cocalico Creek-3
F074	40.204667	-76.144917	06/17/04	31.96	11/02/04	18.20	Cocalico Creek-4
F076	40.193583	-76.164500	06/17/04	37.8	11/02/04	42.27	Cocalico Creek-5
F052	40.174889	-76.194389	06/14/04	49.24	11/02/04	50.26	Cocalico Creek-6
F042	40.169389	-76.220556	06/14/04	58.43	11/02/04	61.38	Cocalico Creek-7
F040	40.157000	-76.227167	06/14/04	126.7	11/02/04	134.70	Cocalico Creek-8
F055	40.195361	-76.146667	06/17/04	0.581	11/02/04	0.38	Coover Run
F051	40.231056	-76.131639	06/17/04	10.69	11/01/04	9.87	Little Cocalico Creek
F044	40.170000	-76.220500	06/14/04	1.14	11/02/04	0.90	Meadow Run at mouth
F048	40.186528	-76.211833	06/14/04	0.037	11/01/04	0.00	Meadow Run, headwaters
F046	40.178444	-76.217167	06/14/04	0.903			Meadow Run, mid-reach
F068	40.207056	-76.132806	06/16/04	3.74	11/02/04	2.24	Stony Run at mouth
F064	40.212528	-76.124944	06/16/04	2.47	11/01/04	2.51	Stony Run mid-reach
F049	40.222528	-76.115889	06/16/04	1.66	11/01/04	1.13	Stony Run upstrm quarry
F050	40.167889	-76.201611	06/14/04	0.632	11/02/04	0.51	Trib from Akron
F057	40.174722	-76.175944	06/17/04	0.601	11/02/04	0.28	Trib near Fulton School
F066	40.210167	-76.124667	06/16/04	0.324	11/01/04	0.39	Trib to Stony Run
							Hammer Creek Watershed
F009	40.196833	-76.280083	06/09/04	32.04	10/28/04	65.53	Hammer Cr-1
F013	40.183889	-76.265917	06/10/04	30.71	10/28/04	48.27	Hammer Cr-2
F013	40.183889	-76.265917	06/14/04	37.46			Hammer Cr-2
F021	40.174750	-76.255778	06/10/04	31.71	10/28/04	59.06	Hammer Cr-3
F035	40.167444	-76.244167	06/14/04	42.78	10/28/04	44.46	Hammer Cr-4
F037	40.164944	-76.237722	06/14/04	43.59	10/28/04	48.27	Hammer Cr-5
F017	40.215083	-76.286167	06/10/04	0.176	10/28/04	0.32	Trib from Brickerville, headwater
F017	40.215083	-76.286167	06/14/04	0.243			Trib from Brickerville, headwater
F033	40.197639	-76.281472	06/14/04	0.109	10/28/04	0.36	Trib from Brickerville, mouth
F015	40.208778	-76.300222	06/10/04	0.437	10/28/04	0.73	Trib near Speedwell, headwater
							Indian Run Watershed
F056	40.235972	-76.202389	06/16/04	3.46	10/29/04	3.17	Indian Run-1
F058	40.226583	-76.194333	06/16/04	3.2	10/29/04	3.20	Indian Run-2
F060	40.212778	-76.186250	06/16/04	3.33			Indian Run-3
F060	40.214440	-76.186860			10/29/04	2.95	Indian Run-3 (new location)
F043	40.203139	-76.181306	06/16/04	10.9	10/29/04	10.31	Indian Run-4
F041	40.193944	-76.178611	06/16/04	16.43	10/29/04	13.29	Indian Run-5
F062	40.237639	-76.169917	06/16/04	0.785	10/29/04	0.73	Trib from Schoeneck, headwater
F047	40.223444	-76.171611	06/16/04	0.206	10/29/04	0.16	Trib from Schoeneck, mid-reach
F045	40.213056	-76.181278	06/16/04	0.065	10/29/04	0.00	Trib from Schoeneck, mouth
							Lititz Run Watershed
F012	40.167528	-76.295333	06/09/04	0.302	11/01/04	0.65	Hubers Run, headwater
F006	40.158639	-76.295917	06/09/04	0.201	11/01/04	0.44	Hubers Run, mouth
F018	40.157694	-76.309306	06/10/04	4.86	11/01/04	7.41	Lititz Spring

Station ID	Latitude Dec Degree	Longitude Dec Degree	Date	Flow cfs	Date	Flow cfs	Stream Name
F002	40.147389	-76.270417	06/09/04	21.23	11/01/04	40.76	Lititz Run
F010	40.165361	-76.284250	06/09/04	0.59	11/01/04	0.93	Moores Run, headwater
F004	40.154806	-76.286806	06/09/04	0.426	11/01/04	0.84	Moores Run, mouth
F008	40.159028	-76.296750	06/09/04	0.901	11/01/04	2.97	Santo Domingo Run
F020	40.168028	-76.307972	06/10/04	0	11/01/04	0.00	Santo Domingo Run
F014	40.171556	-76.301778	06/10/04	0	11/01/04	0.20	Trib 2 from Bethel Cemetery
F016	40.180083	-76.315250	06/10/04	0.655	11/01/04	0.87	Trib 3, headwater
							Middle Creek Watershed
F026	40.219194	-76.257444	06/10/04	14.74	10/28/04	19.82	Middle Cr-1
F034	40.200167	-76.245278	06/10/04	23.68	10/28/04	28.64	Middle Cr-2
F054	40.187750	-76.239472	06/14/04	27.82	10/28/04	34.87	Middle Cr-3
F023	40.170667	-76.234444	06/10/04	29	10/28/04	33.43	Middle Cr-4
F036	40.220306	-76.232333	06/10/04	0	10/28/04	0.00	Trib 1 near Snyder Park
F038	40.212111	-76.235472	06/10/04	0	10/28/04	0.33	Trib 1 rte 322
F030	40.231417	-76.229917	06/10/04	0.101	10/28/04	0.17	Trib 1, headwater Durlach
F032	40.205917	-76.243528	06/10/04	2.39	10/28/04	3.95	Trib 1, mouth
F019	40.217444	-76.268444	06/10/04	0.227	10/28/04	0.24	Trib 2, headwater
F022	40.214278	-76.256444	06/10/04	0.158	10/28/04	0.12	Trib 2, mouth
F028	40.227806	-76.239917	06/10/04	0.068	10/28/04	0.12	Trib to Trib 1 near Snyder Park
F024	40.218583	-76.264917	06/10/04	0.075	10/28/04	0.06	Trib to Trib 2
							Bachman Run Watershed
F039	40.135139	-76.328972	06/14/04	1.06			Trib to Bachman Run, out of basin

APPENDIX B

Water Quality Analytical Results

Average Nitrate Concentration, Conductivity, pH, and Temperature of Wells, Springs, and Streams from May and October 2004

Station Type	Station ID	Temp degree C	pH	Nitrate mg/l	Conductance micromhos
Well	A-04	15.1	6.9	4.6	402
Well	A-05	16.5	6.78	10.95	645
Well	A-06	17.3	6.31	9.3	389
Well	A-07	15.9	7.1	22.1	529
Well	A-09				539
Well	A-16	16	7.1	1.7	478
Well	A-17			6.8	390
Well	A-18	19.1	7.22	1.95	682
Well	A-19	14.2	7.02	8.85	826
Well	A-20	17	6.9	26.1	553
Spring	A-LSP	15	7.07	19.75	655
Well	B-01			0.3	409
Well	B-03			17.6	752
Well	B-04	14.5	7.06	15.25	811
Well	B-05	15.1	7.09	12.8	722
Well	B-07	15.9	7.08	18.3	749
Well	B-08	17.4	7.07	2.25	509
Well	B-09	14.4	7.07	11.2	485
Well	B-10	16.3	7.06	4	834
Well	B-11	15.6	7.07	3.1	467
Well	B-12	15.1	7.04	4.2	364
Well	B-13			13.2	526
Well	B-14	17.4	7.06	1.35	231
Well	B-16	16.8	7.08	0.65	285
Well	B-18	16.6	7.06	8.15	248
Well	B-19	15.2	7.07	1.2	777
Well	B-20	13.9	7.08	9.95	691
Well	B-21	19	7.07	13.7	674
Well	B-22	18.7	7.07	8.25	838
Well	B-23	15.6	7.08	8.6	654
Well	B-24	15	7.04	14.8	586
Well	B-25	20.4	7.06	2.8	1275
Well	B-26			2.8	696
Well	B-27	14.1	7.06	8	840
Well	B-28	12.4	7.05	5.5	684
Well	B-29	15.5	7.02	2.8	897
Well	B-30	13.2	7.06	12.5	909
Well	B-31	17.9	7.07	1.4	603
Well	B-32	14.4	7.08	1.4	570
Well	B-34	19.5	7.08	3.6	688
Well	B-35	16.7	7.08	14.75	734
Well	B-36	12.3	7.06	13	1466
Well	B-37	14.4	7.04	13.95	755
Well	B-40	14.9	7.04	6.3	880
Well	B-41	15	7.07	10.6	712
Well	B-42	15.1	7.06	10.8	854
Well	B-43	15.6	7.06	5.7	592
Well	C-01	18		12.55	498
Well	C-02	18.5		4.4	253
Well	C-03	18		5.85	595
Well	C-04	15		7.1	730
Well	C-06	19		20.8	762
Well	C-07	17.5		10.9	705
Well	C-14	14.5		8.2	532

Station Type	Station ID	Temp degree C	pH	Nitrate mg/l	Conductance micromhos
Well	C-15	16.5		7	566
Well	C-18	15		33.95	1623
Well	C-19	12.5		23.7	765
Well	C-21	12.5		11.9	687
Well	C-22	12.5		10.75	748
Well	C-23	13		22.05	778
Well	C-29A	17		12.75	704
Well	C-30	15.5		21.35	768
Well	C-31	14.5		16.7	681
Well	C-W01	14.5		2.2	646
Well	C-36	16.5		16.5	1168
Stream	F001	11		8.1	365
Stream	F002	18.9	7.03	9.1	511
Stream	F003	11		6.35	358
Stream	F004	18.9	7.03	8.2	367
Stream	F005	10.5		6.65	350
Stream	F006	18.7	7.04	10	246
Stream	F007	13		15	525
Stream	F008	18.5	7.03	13.4	594
Stream	F009	13.6	6.9	5.45	402
Stream	F010	18.9	7.03	6.1	330
Stream	F011	10.5		4.4	275
Stream	F012	20.2	7.02	11.25	381
Stream	F013	15.7	6.89	5.95	396
Stream	F014	17.6	7.02	6.5	423
Stream	F015	11.8	6.94	10.15	368
Stream	F016	18.4	6.91	8.1	385
Stream	F017	12.9	6.92	4.3	344
Stream	F018	17.1	7.03	14	718
Stream	F019	13.3	6.94	6.65	288
Stream	F020	18.7	6.8	6.8	440
Stream	F021	16.8	6.88	5.2	389
Stream	F022	11.7	6.95	7.5	395
Stream	F023	13.9	6.9	7.35	394
Stream	F024	12	6.96	9.15	487
Stream	F025	15		18.25	553
Stream	F026	12.2	6.93	2.6	174
Stream	F027	14		13.3	485
Stream	F028	12.4	6.92	10.15	365
Stream	F029	13		13.55	602
Stream	F030	12.5	6.9	11.4	436
Stream	F032	16.5	6.85	14.35	718
Stream	F033	12.8	6.91	4.1	452
Stream	F034	14.8	6.9	5.1	344
Stream	F035	17.2	6.87	5.75	378
Stream	F037	17.4	6.87	6.1	414
Stream	F038	13.2	6.93	12.8	692
Stream	F040	14.5		6	478
Stream	F041	13.8	6.87	10.65	643
Stream	F042	14		6.85	590
Stream	F043	13.9	6.87	8.05	606
Stream	F044	15		7.55	735
Stream	F045			0.7	
Stream	F047	12.6	6.88	3.6	391
Stream	F048	12		9.35	703
Stream	F049	14		2.5	337
Stream	F050	14		6.9	518
Stream	F051	13		2.5	258

Station Type	Station ID	Temp degree C	pH	Nitrate mg/l	Conductance micromhos
Stream	F052	13		5.2	476
Stream	F054	14.3	6.92	6.8	407
Stream	F055	18.4	7.02	5.1	363
Stream	F056	11.1	6.91	6.1	450
Stream	F057	19.7	7.03	1.9	472
Stream	F058	11.3	6.9	5	479
Stream	F062	12	6.89	4.9	366
Stream	F064	14.5		1.05	605
Stream	F066	14.5		2.75	415
Stream	F068	17.7	7.03	1.3	550
Stream	F070	14		3.35	230
Stream	F072	15.9	7.05	3.4	186
Stream	F074	19.6	7.02	2.6	298
Stream	F076	19.6	7	3.9	261
Stream	F060a	11.3	6.91	7.3	465
Stream	F007a			12.5	
Stream	F013a			4.3	
Stream	F017a			3.5	
Stream	F031			13.3	
Stream	F039			9.7	
Stream	F046			12.7	
Stream	F053			2.3	
Stream	F060			3.3	
All Streams	**Min**	10.50	6.80	0.70	174
	Max	20.20	7.05	18.25	735
	Med	14.00	6.92	6.58	407
	Count	61	42	70	61
All Wells	**Min**	12.30	6.31	0.30	231
	Max	20.40	7.22	33.95	1623
	Med	15.50	7.06	9.08	684
	Count	59	41	64	65

Resource Management Recommendations

Northern Lancaster County Groundwater Study:

A Resource Evaluation of the Manheim - Lititz and Ephrata Area Groundwater Basins

September 6, 2005

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Lititz, PA 17543

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TABLE OF CONTENTS

I Recommendations: Background and Findings

Summary of Resource Management Recommendations

When water makes the news it is usually because we have too much – flooding – or too little – drought. When water is in balance and we have just the right amount to meet our everyday needs, we tend to take it for granted. In recent years, it seems we have been out of balance more than in the past, so we are paying more attention to how we manage this important resource.

This document presents the strategies to better plan for the future balance of groundwater supply and demand, based on results of the SRBC report, "Northern Lancaster County Groundwater Study: A Resource Evaluation of the Manheim - Lititz and Ephrata Area Groundwater Basins". The plan includes a set of viable recommendations and actions that can be applied at multiple levels: county, regional, municipal, and landowner. The hope is that each of these levels can apply these recommendations simultaneously and at various intensities to achieve comprehensive results for both the short and long term.

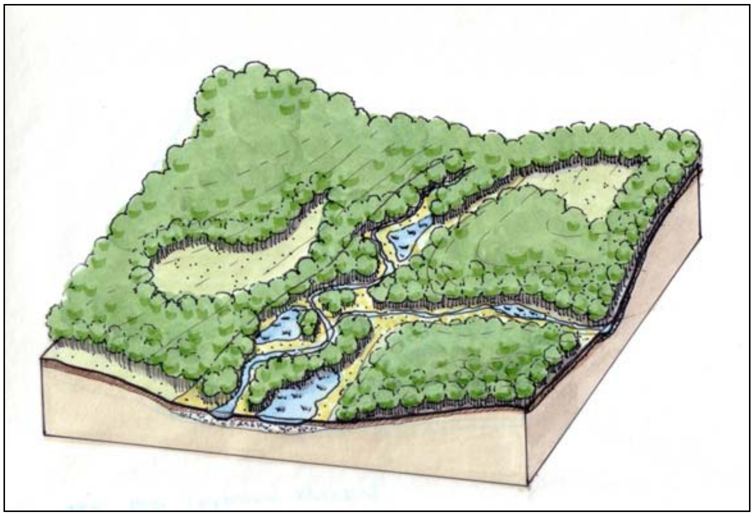
In the on-going debate over how best to manage our water resources, the role of historically degraded hydrologic systems provides both a cause and potential solutions. The background section of the report, **I Historical Context –** "How the past shaped what we have today," explains how past activities influenced current conditions. With an understanding of the data collected, mapping, and historical context we then begin to explore strategies to improve water resource management. Through input from related initiatives, an audit of current regulations related to water supply, and feedback from community groups and stakeholders, the primary issues facing the goal of a sustainable water supply are identified. In **II Reversing the Trend** - "What can be done to move toward a sustainable approach to water resource management?" we look at past and current planning efforts and discuss their relationship to water resource management. Finally, **III Recommendations / Strategies –** "Various approaches for local government and water resource planners to consider" we have identified specific issues along with the inherent problems and then provide a broad selection of strategies and recommendations for improving water resource management on different levels and to various degrees. The recommendations Toolbox, see Appendix, is designed to provide simple recommendations for ease of implementation as well as cutting edge ideas that will spark discussions. This report is not meant to be static and relinquished to a shelf. It is meant to be a springboard to move regulations and current thinking in new directions to address the challenges of today and begin a sustainable trend for the future.

II Historical Context

How the past shaped what we have today

A Natural Equilibrated Stream Channels

Prior to the 18th century, the majority of the land surface was stabilized by forests and naturally vegetated valleys. Natural ground cover on undisturbed soils provided the highest infiltration capacities, absorbing the maximum quantity of precipitation through transpiration and ground water recharge. Floodplains were broad and flat, accessed by flood flows more frequently than they are today. In these valleys, groundwater flowed near the floodplain surface, interacting with the base flow of the streams. The typical floodplain was slightly above the stream channel base flow water surface elevation or inundated because of beaver dams.



Pre-18th Century Stream Valley

In many areas, the floodplain provided an opportunity for a great deal of groundwater recharge. Under-drained or dry stream valleys, very characteristic in carbonate terrains, were highly effective recharge areas capturing runoff from surrounding areas. As land use, natural drainage patterns, soil type, and permeability changed over time, the ability for water to infiltrate was reduced. Today hydrologic regimes that at one time were simple (think of the water cycle diagram) have been dramatically altered by land-use changes. Major alterations in how land and water were managed over the last two centuries are responsible for this change.

Valley view during industrialized period

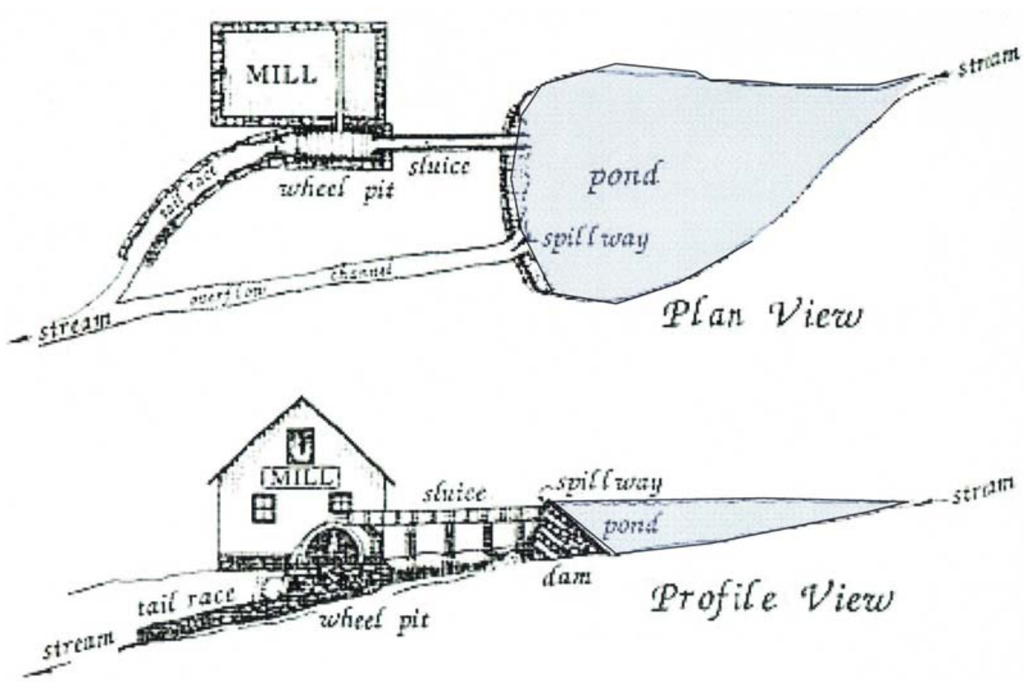
B Deforestation

The first change occurred when large-scale forest clearing and poor farming practices removed slope-stabilizing natural vegetation, allowing the rapid, widespread erosion of soils from hillsides and their deposition in local streams, valleys, and floodplains.

Logging and Resulting Erosion in PA

C Mill Dams

Mill dams were built on stream channels throughout the Piedmont by the thousands (over 500 mill dams are documented in Lancaster County alone) and in many cases, to make it easier for farming and other human activities, meandering stream channels were straightened and moved from the lowest elevations in the valley centers to the higher elevations at valley edges.

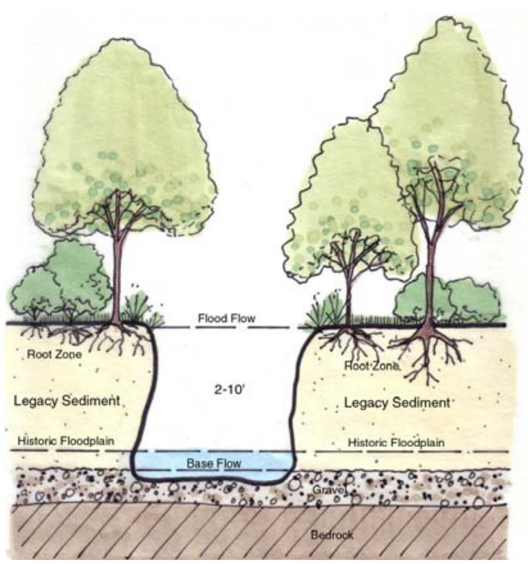


Typical Water-powered Mill System

Behind the dams, water ponded and its flow velocity slowed down. All the eroded sediments and pollutants (phosphorus attaches to soil particles) that had moved into the valleys accumulated behind the dams and on the floodplains between the dams. Stream channel beds and floodplains grew artificially high, perched on the fine-grained eroded materials thickened and compacted over time into an impermeable layer. Elevated channel beds and floodplains were no longer closely connected to groundwater supplies; therefore, flows were composed predominantly of surface water runoff, with temperatures far exceeding that of groundwater.

D Removal and Loss of Mill Dams

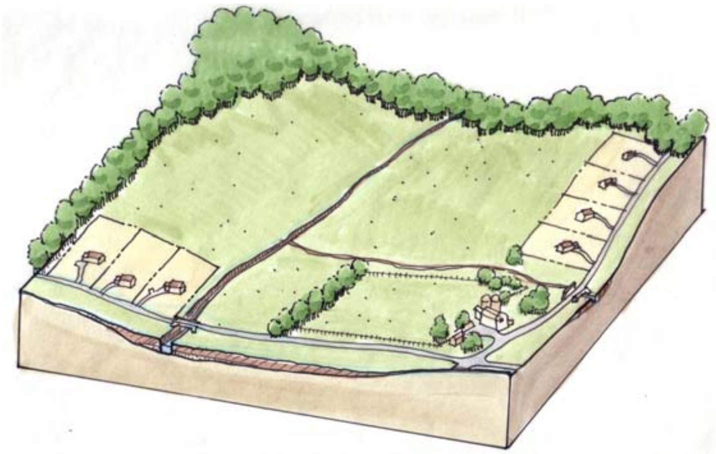
As dams were removed or fell into disrepair – a condition that continues today – stream channels that had been aggrading (building up) for centuries began degrading (cutting down) through thick stacks of legacy sediments, approaching or exposing peats, sands, and gravels of the submerged pre-settlement valley floors. Many miles of stream remain where the stream bed is still perched on the fine-grained, less permeable sediment deposits.



Disconnected Floodplain Section View

E Disconnected Floodplains

Stream channels began to work their way down through the accumulated sediments toward their historical elevations, leaving the artificially elevated floodplain behind and becoming more and more "detached." In reality, the floodplain became more accurately a terrace, composed of dense, fine-grained sediments rather than porous, peaty, organic soils and with quite a different plant community. Some stream channels are eroding or have eroded back down through sediments that collected behind mill dams, leaving their alluvial, legacy sediments, floodplains high above the current base flow water elevation, and disconnecting riparian root systems from groundwater flows. The processes of frequent floodplain inundation, relieving in-channel stresses; groundwater infiltration through porous floodplain material; and nitrogen removal from groundwater through root systems are lost under these conditions that are prevalent today throughout the Piedmont Province of the United States.



Typical Stream Valley Today

F Urbanization and Stormwater Run-off

Increasing urbanization and its accompanying impervious surfaces and stormwater run-off continue to degrade stream and floodplain systems. When meadows and forests are replaced with asphalt, buildings, and lawns, the land surface providing infiltration is reduced, resulting in an increase in runoff and a decrease in recharge.

G Loss of Stream Base Flow Due to Overpumping

In addition to the decrease in recharge potential and increase in run-off leaving the aquifer, water use has increased dramatically because we have more people, more intensive agricultural practices, and larger and more intensive industrial uses then ever imagined just 50 years ago. The withdrawal of water from the hydrologic system to meet various human needs has increased dramatically with urbanization and the market-driven need for greater agricultural productivity.

III Reversing the Trend

What can be done to move toward a sustainable approach to water resource management?

The conditions we are accustomed to today were formed through years of change in how the land is used. As problems arose, great effort was invested in many techniques implemented to address the problems. The result is a landscape shaped by a hydrologic system that has been forced and dramatically altered over time. We are also facing the challenges associated with increased land use, heavy with impervious cover in the form of asphalt paving and buildings, relocated and straightened streams, storm water management methods designed for individual sites, and a geology vulnerable to failures because of its karst nature. All of this contributes to the current hydrologic system, once a sponge with high potential for infiltration, but now a routing system that transports its increased flows into the rivers and ultimately the Chesapeake Bay.

A Goal and Objectives for the Resource Management Recommendations

A goal of the Northern Lancaster County Groundwater Study (NLCGS) is to develop a series of water resource management recommendations that considers local interests in future planning activities. The intent of the recommendations is to provide local governments with a selection of strategies to address water resource issues within existing township plans, county plans, and state/local initiatives, and to help guide future activities.

Objectives for the Recommendations

1. Education - to educate policy makers, stakeholders (including land developers and sewage treatment plant operators), and landowners about the important information derived from the NLCGS and how to ensure a sustainable water supply.

2. Partnerships - to strengthen existing relationships and develop the partnerships necessary to address water planning issues.

3. Practical Applications - flexible enough to work with the many demands of local planning and easily implemented on all levels.

B The Strategy

The following steps were considered as part of this project to develop viable tools for managing the water supply:

1. Conduct a review of current zoning codes with respect to water use and groundwater recharge.

2. Conduct a Work Group meeting to review what is being done, the viability of the current codes, and their effectiveness in protecting water resources. (Meeting was conducted June 15, 2004)

3. Develop list of current local codes and regulations that could be applied to address the specific issues

4. Determine what is missing and how the gaps may be addressed.

5. Explore alternative codes.

6. Develop management guidelines/recommendations for Work Group review.

7. Finalize the recommendations.

The challenge of the recommendations is to provide a framework for better water resource management within which the many diverse local interests can work. To meet this challenge, current initiatives and planning efforts were considered on state, county, and local levels (see **Related Initiatives** below). Integral to this framework is a comprehensive review of local ordinances to better understand how these regulations are being implemented, their effectiveness on a regional basis, and what barriers exist in water resource management (see **Municipal Regulations – An Overview** below). A Workshop was held with municipal and local planning officials and steering committee members to review these documents and discuss the effectiveness of the current measures to manage water resources. The results of this workshop are outlined below in **Community Input – Workshop**.

C Related Initiatives

Many of the issues being addressed in this report are being looked at in varying degrees on local and state levels. The following is a listing of some of the current initiatives, their goals, and how they relate to the NLCGS.

1. State Level Planning Efforts

a. Municipalities Planning Code (MPC)

There are numerous tools available to municipalities to protect their water resources under the MPC, including multi-municipal plans and ordinances.

Relationship to the NLCGS

The following are a few examples from the MPC that relate to water resource planning. The water recharge areas referenced in the MPC directly relate to the Critical Aquifer Recharge Areas (CARA's) delineated as part of the NLCGS.

- Revising the municipalities' Comprehensive Plan to reflect water budget findings as they relate to future development. This may involve re-examining how the existing Comprehensive Plan encourages development patterns and making appropriate modifications to shift development patterns away from important recharge areas, high density karst areas, and areas with water deficits if public water is not available. The comprehensive plan should also address protection of water recharge, particularly within delineated source water protection (SWP) areas, and establishment of open space corridors (riparian corridors, floodplains, streams, wetlands, forested lands, etc.) for the purpose of greenways and water recharge and SWM opportunities.

- Revising subdivision and land development ordinances and zoning ordinances to reflect development patterns encouraged by the revised Comprehensive Plan. The zoning tools included as part of this report may be considered.

- Developing new or revising existing ordinances and incentives to address the recommendations made in this report.

- Providing public outreach and education.

- Undertaking land acquisition, conservation easements, and preservation of agricultural uses.

b. Act 220 Water Resources Planning Act

This legislation establishes a water resources planning program in the Department of Environmental Protection (DEP) utilizing a collaborative process – by actively involving stakeholders at both the regional and statewide level – to prepare and update a comprehensive State Water Plan. The State Water Plan is designed to provide up-to-date information on water availability, an assessment and projection of water use and future demands on a watershed basis, identification of critical water planning areas where water demands are projected to exceed available water supplies, and the development of critical area resource plans for these areas. The bill recognizes that, with proper planning, Pennsylvania's water resources are capable of serving multiple uses in a balanced manner. To gather the data necessary to assess current water demands, the bill provides for registration of major water withdrawals (exceeding 10,000 gallons per day), and periodic reporting of water usage by such major users. The bill establishes a formal program to promote voluntary water conservation and water-use efficiency practices for all water users.

Relationship to the NLCGS

The Northern Lancaster County Groundwater Study is located within the Lower Susquehanna Region of the State Water Plan. A committee has been appointed to determine the priorities for this particular region. The following are the draft Water Resource Committee Priorities as of the date of this report in which the NLCGS could be used as a prototype for the data collection and inventory for water quantity being considered.

- Water Supply: Inventory all sources of groundwater and surface water. Water Quantity: Calculate total water budget for each watershed; Evaluate land use impacts on water quantity; and, Identify source water characteristics that affect quantity.

- Water Demand: Identify current and future water needs, including: Quantify in-stream flow needs for recreation and ecosystem; Identify consumptive and non-consumptive uses; Identify withdrawal uses and non-withdrawal uses; Identify uncertainties and assumptions of projected needs and uses; Assess storage capacity needs; Determine safe yields and demand fluctuations;

and, Identify Critical Water Planning Areas (CWPA) and shortfalls.

- Managing Supply vs. Demand: Identify and assess alternatives to balance supply and demand; Identify and assess alternative potable sources of supply; Promote water conservation strategies to reduce water loss and improve efficiency of water use; Identify alternative uses for, or re-use of, non-potable water; Promote source water protection through education and promote the implementation of SWP Plans; Assess and measure the effectiveness of the SWP plans; Coordinate land-use planning with water resource planning; Explore regional and watershed-based water resource planning; and, Identify and coordinate institutional and regulatory water agencies and authorities.

c. Pennsylvania Stormwater Best Management Practices Manual (2nd Draft January 2005)

The purpose of this manual is to improve stormwater management throughout Pennsylvania. It is now recognized that existing stormwater management is not providing the water quantity and water quality performance that is essential for the protection of the state's water resources. The BMP Manual is part of a broader effort by PADEP to develop a new Stormwater Management Policy and Program that will improve the way stormwater is managed. The manual provides technical guidance on methods and materials that can prevent, reduce, and mitigate the impacts of stormwater. Particular focus is placed on technical management solutions that can be applied in conjunction with new land development and in conjunction with in-fill development and re-development. A comprehensive approach that integrates stormwater management into the total site design and site planning process from the earliest stages is proposed.

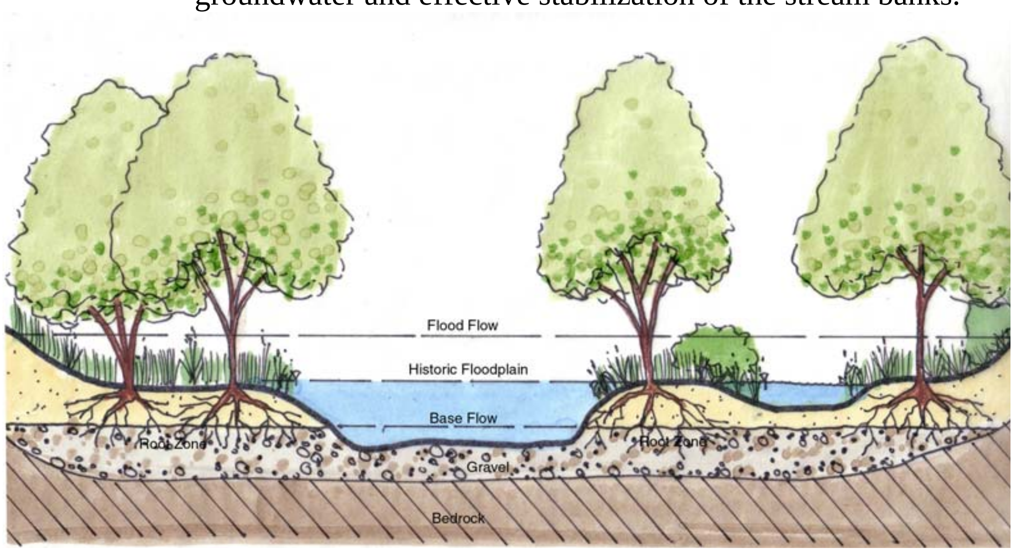
Relationship to the NLCGS

The recommendations of the NLCGS relate to improving the sustainability of groundwater resources. The Stormwater Management Best Management Practices Manual is particularly focused on site-specific solutions associated with land development infill / redevelopment and the site design / planning process. Because of this limitation, it is difficult for the proposed BMPs to address the broader goals of the NLCGS and regional sustainability of groundwater resources and source water protection.

Floodplain restoration is one technique that addresses the goals of the Pennsylvania Stormwater Manual as well as the intent of the SRBC Study of Groundwater Recharge, as well as other benefits inherent in the fully functional system of a restored stream and floodplain. Floodplain restoration reconnects a number of components within a stream and floodplain system so that their interaction protects the stability of the bed and channel while the system receives, holds, infiltrates, and filters overland flow. A restored floodplain is characterized by a lowered elevation and a restoration of historical earthen and plant materials that perform several functions at the same time, including control of overland and in-channel flows (stormwater management), increased infiltration to groundwater (recharge, and increased filtration of soluble pollutants through root system uptake (improved water quality).

Here’s how it works:

- A restored floodplain is low enough to receive more routine flows, thereby reducing excessive and erosive flow forces in the channel at the site and downstream.
- A restored floodplain is wide and flat enough and composed of the proper earthen materials to absorb and hold overland or flood flow while allowing the flow to percolate through to groundwater.
- A restored floodplain is low enough to allow root systems to interact with groundwater, providing denitrification of the groundwater and effective stabilization of the stream banks.



Restored Floodplain Section View

2. County Level Planning Efforts

Lancaster County has been actively planning for its future through numerous initiatives. Selected initiatives with a relationship to water resource planning and the NLCGS are described below.

a. Lancaster County Water Resources Plan

The Lancaster County Water Resources Plan provides a future direction for the County's water resources to 2010 and beyond. This future direction is reflected in a comprehensive set of objectives and implementation tasks making up a plan of action to safeguard the County's water supply.   This plan is slated for an update within the next five years.

Relationship to the NLCGS
The Lancaster County Water Resources Study indicates that “there are requirements for comprehensive planning and wastewater facility plans, but no comparable requirement for water supply planning.” The County Water Resources Plan also states, “ that the Plan specifically focuses on water supply planning at the water facilities and wellhead protection. It does not encompass all aspects of water resources planning and management: those require future attention.”

The NLCGS will provide the 13 municipalities within the study area with detailed water supply information to begin to address this important missing link – water quantity – by providing data on water use, water availability, locations of important resource areas, and some recommendations to protect future supplies. The Lancaster County Water Resource Task Force may want to consider the findings from this project when planning for the update of the Lancaster County Water Resources Plan.

The main goals of the Lancaster County Water Resource Plan are also important to the NLCGS project.

- Protect the quality and quantity of public water supply sources.
- Coordinate water supply planning with county, regional, and local growth management efforts.

The following objectives from the Lancaster County Water Resource Plan support the NLCGS:

- Promote the conservation of surface and groundwater resources.
- Promote public education as a means of increasing public awareness in protecting and conserving water resources.
- Pursue funding opportunities to assist municipalities in professionally delineating wellhead protection areas and developing wellhead protection programs.
- Require the use of Best Management Practices (BMPs) in storm water management design
- Limit growth and development to that which is compatible with the carrying capacity of the county's aquifers.
- Discourage development in rural areas with low-yield aquifers.
- Encourage the formation of local municipal water planning teams to develop water supply and wellhead protection plans.
- Limit new community water systems and extensions to existing systems to land areas within urban and village growth boundaries.
- Coordinate existing federal, state, county, and municipal water resources management activities.

- Promote coordination and cooperation between water providers and municipalities in water planning and growth management efforts.
- Encourage regional solutions to water supply quality and quantity problems.
- Develop strategies for watershed planning and management activities in Lancaster County.
- Coordinate the acquisition of public parks and open spaces with the protection of municipal wellhead protection areas.

b. Lancaster County Comprehensive Plan Growth Management Element Update

The Lancaster County Planning Commission (LCPC) process to update the Growth Management Element of the Lancaster County Comprehensive Plan is under way. The current Growth Management Program was initiated by the Lancaster County Board of Commissioners in 1993 and reinforced through an Update in 1997. The Update will guide growth in Lancaster County through the year 2030.

Relationship to the NLCGS

The growth management plan supports increased growth in Growth Areas, increased Farmland Preservation, and protection of natural resource areas, which is in line with the goals and objectives of the NLCGS. The Update may want to consider the findings of this study, and to specifically include:

- Critical Aquifer Recharge Areas (CARAs) where delineated as priority natural resource protection areas. Include measures to protect and potentially improve the infiltration potential of these important recharge areas.

- A build-out scenario with respect to water resource availability, with special attention paid to "potentially stressed" areas where the water supply may not meet future demand.

c. Coalition for Smart Growth

The Coalition for Smart Growth is a unique and diverse group of community organizations and individuals drawn together by a shared interest in the future direction of Lancaster County…interested enough to craft a roadmap for Smart Growth. The Coalition’s intent is twofold: 1) to provide a framework within which discussions about Lancaster County’s future can take place, and 2) to incorporate public policy recommendations into practical applications.

Relationship to the NLCGS
The August 2003 Policy Paper outlines the following Natural and Cultural Resource policies related to water resources. The following policies relate directly to the NLCGS:

- Adequate rechargeable water supplies are essential for smart growth.
- Adequate water resources and their infrastructure must be provided within all growth areas.
- Storm water management practices must be utilized to prevent pollution and erosion of streams and flooding.
- Ground water infiltration and water conservation practices must be encouraged.
- Vegetative buffers along streams should be encouraged to protect stream ecosystems and water quality.
- Municipalities must partner with each other and community organizations to develop and implement watershed plans on an ongoing basis.
- Access to clean water for active and passive recreation is a vital part of smart growth.
- Public water supplies must be protected. Municipalities should adopt and implement the Lancaster County Water Resource Plan's well-head protection recommendations.

The Coalition may want to consider the findings of the NLCGS and how the water supply relates to future growth management. Specifically the coalition may want to consider the following to address "adequate rechargeable water supplies" and "adequate water resources and their infrastructure":

- Identify Critical Aquifer Recharge Areas (CARAs), prioritize protection measures, and encourage groundwater infiltration at these important recharge areas.

- A build-out scenario with respect to water resource availability, with special attention paid to "potentially stressed" areas where the water supply may not meet future demand.

d. Recommended Model Development Principles for East Hempfield, West Hempfield, and Manor Townships, and Lancaster County, Pa.

This document is a product of the Lancaster Area Site Planning Roundtable, a year-long consensus process initiated by the Builders for the Bay Program to review existing development codes and identify regulatory barriers to environmentally sensitive residential and commercial development at the site level. A diverse cross-section of local government, non-profit, environmental, homebuilding, business development, and other community professionals made up the membership of the Lancaster Area Site Planning Roundtable. Through a consensus process, members of the Roundtable adapted the National Model Development Principles to specific local conditions. Roundtable recommendations include specific code and ordinance revisions that would increase flexibility in site design standards and promote the use of open space and flexible design development in the Lancaster Area.

Relationship to the NLCGS
This model, completed in March 2005, offers a variety of objectives pertinent to water resource protection, including reduced overall site impervious cover, preservation and enhancement of existing natural areas, and integration of water resource management tools. Many of the tools recommended as part of the Model Development Principles have been included in the Toolbox (see Appendix).

3. Local Planning Efforts

a. <u>Watershed Plans</u>
Watershed plans have been completed for each of the watersheds within the water budget project study area. Numerous projects have been implemented and planning efforts initiated as a result of these plans and the work of the active watershed associations. The Watershed Plan Chart (see Appendix) outlines the status of current planning efforts and selected restoration projects for each of the watersheds.

Relationship to the NLCGS
The following specific projects have been completed within the NLCGS area. These projects provide unique, in-ground examples of some of the recommendations proposed to improve groundwater sustainability.

- Lititz Run – Banta Site
  Research and a detailed geomorphic assessment revealed numerous causes of stream instability, including: a historical millpond and race at the site; historical channel straightening within the watershed for agricultural purposes; construction of a weir downstream; bridge crossings; and historical post-settlement deposits of alluvial material in the channel and floodplain.

  Approximately 2,000 linear feet of stream and floodplain was involved in the restoration. The existing channel, which had occupied the location of the former millrace, was relocated to the center of the floodplain, near its historical channel location, and reconfigured to a more natural sinuosity. The floodplain was excavated to an elevation closer to the historical elevation, creating wetlands in the process and removing the fine sediments of the post-settlement alluvial deposition, which provided appropriate areas for receiving, holding, filtering, and infiltrating flood flows and overland flows.

Before *- Banta Site*

After *- Banta Site*

- Santo Domingo Creek – New Street Ecological Park
  Pilot project to help establish nutrient pollution trading parameters in the Conestoga Watershed. The project restored 900 linear feet of straightened stream channel to a more sinuous, natural alignment; excavated the floodplain closer to its pre-settlement elevation; and created wetland pockets within the floodplain. The results are a stabilized stream channel, reduced streambed and bank erosion, increased infiltration and filtering of flood flows, and nutrient-laden sediments collected in the floodplain instead of being carried downstream. The final stage of the project was the installation of herbaceous and woody, native vegetation selected for its adaptation to periodic inundation from minor and desirable flooding. The vegetation, itself, will provide uptake for some of the undesirable soluble nutrients otherwise carried downstream.

Before *- New Street Site*

After *- New Street Site*

- Cocalico Creek Restoration – Wetland Creation

  Causes of stream instability identified through research and geomorphological assessment included: a historical milldam located approximately 1,400 feet upstream of the project site; bridge crossing at downstream end of project site; channel manipulation (straightening); and post-settlement deposits and floodplain fills.

  Restoration involved re-aligning 1,900 linear feet of channel, with significant removal of floodplain fill and post-settlement deposits. Wetland creation and enhancement, plus riparian and wetland plantings and seeding provided appropriate areas for receiving, holding, filtering, and infiltrating flood flows and overland flows.

Before *- Cocalico Creek Site*

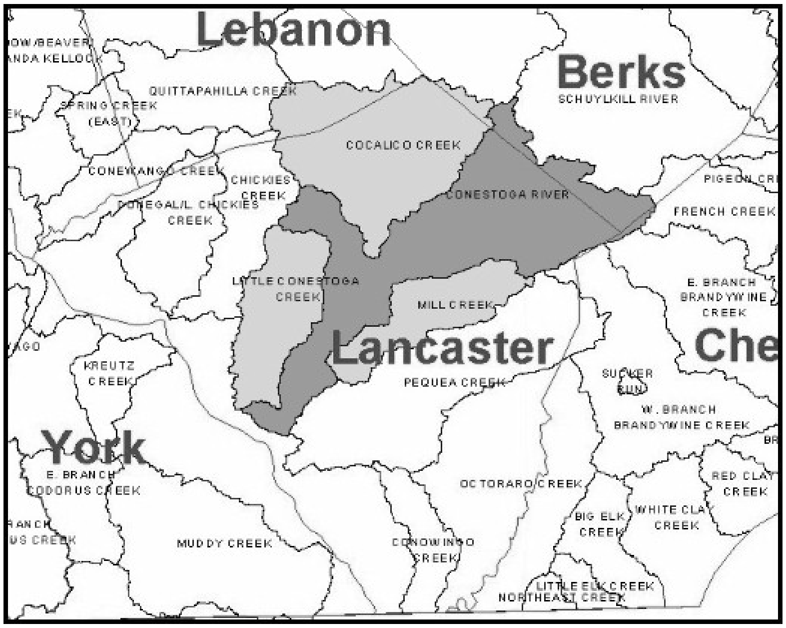
After *- Cocalico Creek Site*

b. ACT 167 Stormwater Management Plans

Lancaster County Engineering staff prepare state-mandated Act 167 Stormwater Management Plans for watersheds within Lancaster County using the County's GIS in combination with stormwater modeling software. The concept behind the plans is to address stormwater, flooding, and water quality issues on a regional basis. Staff also provides reviews, comments, and opinions on subdivision and land development plans for the Lancaster County Planning Commission.

Relationship to the NLCGS

The NLCGS area represents two watersheds that have initiated ACT 167 planning – Cocalico Creek and Conestoga River Watersheds. The Lancaster County Engineering Department has completed work on the Cocalico Creek Watershed, and many of the municipalities have adopted the related model stormwater management ordinance. Work is still being done on the Conestoga River Watershed, with work scheduled to be completed in 2006.



Map Showing Act 167 Watersheds in Lancaster

According to the Cocalico Creek Watershed ACT 167 Storm Water Management Plan, Volume I – Executive Summary, "Storm water management entails bringing surface runoff caused by precipitation events under control. In past years, storm water control was viewed only on a site-specific basis. Recently, local perspectives and policies have changed, with the realization that proper storm water management can only be accomplished by evaluating the comprehensive picture (i.e. by analyzing what adverse impacts a development located in a watershed's headwaters may have on flooding downstream). Proper storm water management reduces flooding, soil and stream bank erosion and sedimentation and improves the overall quality of the receiving streams."

Floodplain restoration is a comprehensive approach to stormwater management. Floodplains, in their restored, functional state, are capable of receiving, holding, infiltrating to groundwater, and filtering overland flow on a watershed, rather than site-specific, level. Regional solutions to stormwater management and to groundwater recharge are logically found in the receiving, or natural recharge, areas within a watershed; i.e., riparian and floodplain area related CARAs. In their restored condition, these areas provide a natural, watershed-level facility to handle water from overland flow as well as flood flow while maintaining their stability with minimal or no maintenance.

c. Regional Comprehensive Plans

The following reviews the regional comprehensive plans implemented within the NLCGS region.

- Cocalico Region Strategic Comprehensive Plan
  The Cocalico region lies within the northeast portion of Lancaster County, adjacent to Berks and Lebanon counties, and encompasses about 50 square miles. The three participating municipalities within the study area include Denver Borough, East Cocalico Township, and West Cocalico Township. The municipalities individually adopted the Cocalico Region Strategic Comprehensive Plan between September and November 2003. The plan is a land-use and growth-management policy plan authorized under Article III of the Pennsylvania Municipalities Planning Code. The plan supercedes any previous comprehensive plans adopted by the participating municipalities.

  Relationship to the NLCGS
  The Cocalico Region Strategic Comprehensive Plan (CRSCP) supports the NLCGS findings through encouraging the protection and conservation of prime ag soils, farming and natural resources and restoration of degraded ecosystems. The plan also includes objectives for the allocation of future growth areas based upon the demand generated by projected growth and compact growth areas that can be efficiently served by a wide range of public facilities, services, and utilities.

. Future updates to the CRSCP may specifically consider the findings of this study, as follows:

  - Include Critical Aquifer Recharge Areas (CARAs) where delineated as priority natural resource protection areas. Includemeasures to protect and potentially improve the infiltration potential of these important recharge areas.

  - A build-out scenario with respect to water resource availability, with special attention paid to "potentially stressed" areas where the water supply may not meet future demand.

  - The Public Utilities Objectives of this plan need to be updated in consideration of the results of the NLCGS. The committees recommended to address regionalization of the water system, wellhead protection, and watershed issues should be represented on the Oversight Committee and Water Planning Teams recommended as part of the NLCGS (see Toolbox in Appendix).

  - The Cocalico Region Green Map may be amended to include the CARAs as defined and located in accordance with the NLCGS.

- Manheim Central Regional Comprehensive Plan
  The Manheim Central Region Comprehensive Plan was written and adopted in 1993, after extensive community discussion and participation. The three participating municipalities within the study area include Penn Township, Manheim Borough, and Rapho Township. It was the first regional comprehensive plan in Lancaster County to incorporate urban growth boundaries, and it encompassed the entire Manheim Central School District. The school district was an active participant in the Plan. In 2000, a Strategic Update to the Comprehensive Plan was adopted by the three municipalities and the school district. This document addresses certain areas of the existing plan that had shown significant changes over the past several years. The background information was not redone, primarily because the most recent census data (2000) was not available at that time.

  Relationship to the NLCGS
  The Manheim Central Regional Comprehensive Plan supports the NLCGS findings through encouraging the protection and conservation of prime ag soils, farming, and natural resources. Future updates to this plan should consider the findings of the NLCGS. These findings directly relate to the following implementation strategies outlined in the Manheim Central Regional Comprehensive Plan: Revise Zoning Ordinance to implement future land use; Commission a public water supply study; Prepare a Comprehensive Recreation and Open Space Plan; and, Reexamine the urban growth boundary together with the County and, if needed, amend it.

  The following may be considered in an update:

  - Include Critical Aquifer Recharge Areas (CARAs) where delineated as priority natural resource protection areas. Include measures to protect and potentially improve the infiltration potential of these important recharge areas.

  - A build-out scenario with respect to water resource availability, with special attention paid to "potentially stressed" areas where the water supply may not meet future demand.

  - The Chiques Creek Watershed Corridor Improvements and Raymark Site re-development should also be considered in any future plan update.

- Lititz / Warwick Strategic Comprehensive Plan
  With over 80 percent of the recommendations from the 1999 plan implemented, this strategic comprehensive plan is currently being updated.

  Relationship to the NLCGS
  Related strategies include: agricultural preservation; urban growth boundary reductions; primary and secondary conservation corridor delineation; design guidelines, riparian corridor / forested buffer preservation program; conservation subdivision and land development process; stormwater management regulations; and natural resource compensation receiving areas.

  Future updates to the Lititz / Warwick Strategic Comprehensive Plan may specifically consider the findings of this study, as follows:

  - Include Critical Aquifer Recharge Areas (CARAs) where delineated as priority natural resource protection areas. Includemeasures to protect and potentially improve the infiltration potential of these important recharge areas.

  - A build-out scenario with respect to water resource availability, with special attention paid to "potentially stressed" areas where the water supply may not meet future demand.

- Warwick Region Comprehensive Recreation, Park and Open Space Plan
  At a joint meeting held on Thursday, May 2, 2002, representatives of Elizabeth Township, Lititz Borough, Warwick Township, and the Warwick School District adopted the Warwick Region Comprehensive Recreation, Park and Open Space Plan. The region’s vision has been to create a viable and realistic plan to address the recreational and open space needs of the community. The plan also addresses the preservation of natural resource areas for a comprehensive open space program.

  Relationship to the NLCGS
  This plan includes numerous related action strategies that address water resource management for the Warwick region including: identify and protect primary conservation areas, identify and encourage protection of secondary conservation areas, promote conservation development and stormwater best management practices, encourage native plant landscaping, protect existing vegetation and eradicate invasive species, implement natural resource compensation receiving areas.

Future updates to the Warwick Region Comprehensive Recreation, Park and Open Space Plan may specifically consider the findings of this study, as follows:

- The Primary and Secondary Conservation Area maps may be amended to include the CARAs as defined and located in accordance with the NLCGS.

D Municipal Regulations – An Overview

The ordinances, including zoning, subdivision and land development and stormwater management, for all 13 municipalities in the study area were reviewed. A listing of which ordinances and a status of their updates and other related information is included on the **Policy Inventory** (see Appendix). Individual ordinances were reviewed with respect to general water resource management criteria, such as whether an ordinance allows reduced paving standards or has resource conservation standards using a standard Ordinance Audit Form.

Municipalities in the Study Area

Townships
Clay
East Cocalico
Elizabeth
Ephrata
Penn
Rapho
Warwick
West Cocalico

Boroughs
Akron
Denver
Ephrata
Lititz
Manheim

After completing a water resource audit for each of the municipalities in the study area, the information was compiled into an **Ordinances Overview** (see Appendix) as a quick reference that illustrates the status of each municipality with respect to the **Local Water Resource Management Categories**(see below)**.** These management standards were derived directly from local ordinances that meet or exceed the water resource protection criteria listed on the Ordinance Audit Form. All of these ordinances or regulations benefit groundwater sources either directly or indirectly. For example, one of the water resource criteria for reducing impervious cover is allowing street paving widths of less then 24 feet. If the municipality's ordinance allows a street paving width minimum of 20 feet' for a public road, then this municipality is noted on the Ordinance Overview (see Appendix) as meeting that Local Water Resource Management Standard.

***An overview of the ordinances in the aquifer study area is important for two reasons*:**

- It provides a baseline to compare what is being done to manage water resources on a local level throughout the northern Lancaster county region.

- It provides a resource for municipalities to identify areas of weakness in various categories or standards. The overview can be used as a resource to determine which other local municipality has successfully implemented a standard that can be used to update or amend current ordinances. For example, a municipality that currently does not have an ordinance in place for a hydrogeologic study may consider reviewing and adopting a similar ordinance from one of the municipalities that has successfully implemented this requirement as part of the land development process.

It is important to note that all regulations listed are based solely on this particular study area and the 13 municipalities that comprise it. To be included in the Ordinances Overview, the regulation must be implemented within at least one of the 13 municipalities in the study area. This then provides a local baseline toward which all the municipalities in the study area can direct their efforts. Considering ordinances that have been successfully implemented locally is a simple first step toward meeting the goals of the NLCGS.

1. General Conclusions
   The following is an overview of the local water resource management categories describing generally the findings from the ordinance review and some considerations for recommendations.

Impervious Cover Reduction

Findings:

- fewer then 50% of municipalities allow street paving widths of less then 24’
- shared drives and limited sidewalks were only encouraged in 2 municipalities.
- none allow cul-de-sacs < 80' dia or landscaped islands
- parking ratios are all based on min. and vary widely
- shared parking is encouraged, but only 2 municipalities provide incentives by reducing the parking requirements.
- most allow reduce parking stalls
- only half require landscape islands
- only one urban center encourages parking garages

Considerations:

- Can further reductions occur in impervious cover associated with roadways and streets, cul-de-sacs?
- Are current parking ratios meeting demands?

Open Space Protection

Findings:

- Resource conservation and agricultural preservation is well represented.
- Growth limits are implemented in most rapidly developing areas.
- All the municipalities have at least one district that protects open space through condensed or cluster housing districts; only two allow it by-right.
- Only three municipalities have wellhead protection requirements.
- Only two municipalities have management requirements for open space.

Considerations:

- Viable conservation development ordinances are needed.
- Wellhead protection areas need to be delineated and protection ordinances implemented.
- Greater emphasis applied to preserving, enhancing, or restoring CARA's as part of open space protection.

Stormwater Management

Findings:

- Most municipalities encourage reduced impervious surfaces, but only three allow alternative pervious surfaces for paving roads and parking areas.
- Only one municipality has standards to monitor and maintain stormwater management BMP's and infiltration facilities or transition from E&S facilities to stormwater management BMP's.

Considerations:

- How to provide infiltration without increasing sinkhole potential.
- How to increase infiltration while increasing removal of soluble pollutants.
- Protocol for identifying locations for regional infiltration / recharge opportunities.
- How to incorporate SWM facilities and CARA's for greater groundwater recharge while maintaining source water protection from soluble pollutants.

Land Use / Development

Findings:

- Approximately 50% of the municipalities require hydrogeologic studies.
- Approximately 50% of the municipalities require sinkhole protection measures.
- Approximately 50% of the municipalities have limitations related to development in Karst geologic areas.

Considerations:

- Develop a protocol for identifying karst-related hazards for land development.
- Determine standards for sinkhole prevention and associated protection measures.
- Address the relationship of karst geology to groundwater recharge.
- Determine specific water related uses that affect water supply.

Water Supply and Disposal
Findings: • Some interesting ordinances have been implemented related to yield and quantity aquifer testing and withdrawal impacts. • Only one municipality has a well-capping requirement. • Only one borough requires public water and sewer systems for future development.
Considerations*:* • Viable and comprehensive yield and quantity testing requirements are needed. • Well-capping requirements should be considered. • Address lot size increase to ensure acceptable level of nitrate-nitrogen levels. • Determine viable alternative systems.

2. Community Input - Workshop

A workshop meeting was conducted to review the overview of municipal regulations, gain input on the viability of the codes, and determine how effective they are in protecting water resources. The work group consisted of stakeholders, watershed groups, municipal officials, the conservation district, and Lancaster County Planning Commission representatives. Held on June 15, 2004, in Warwick Township, the municipal Ordinance Overview was presented along with its relationship to the NLCGS. The completed Ordinance Audit Forms for each municipality were sent in advance to the municipal managers to ensure the documents were complete and accurate. The Policy Inventory, Ordinance Overview, and Local Water Resource Standards were explained and discussed, followed by breakout sessions related to the effectiveness of current measures in place related to water resource management. The breakout groups were divided into Urban Issues, Suburban Issues, and Regional Issues to best gain perspectives from these key areas.

The goal of this work session was to review the ordinances and tools currently in use and determine what is working, what is not working, and how they could be best applied for water resource management. The work session was divided into three groups to address urban issues, suburban/rural issues, and regional issues as discussed in the following sections. Details of the work group session outcomes are included in SRBC Work Group Meeting Outcomes (see Appendix).

a. Urban Issues Work Group

The urban areas in the study area (typically the boroughs) are dealing mostly with existing development and urbanized areas with limited opportunities to protect groundwater recharge areas and CARAs. Historically the boroughs are home to the region’s water supply wells, which support the public water supply. The following constraints are associated with urban areas:

- Most development is existing, and new development is limited.
- Infill development is primarily what is being addressed through the land development process.
- Reducing impervious cover is difficult in areas already developed.
- Shortage of parking is often an issue, especially at urban centers.
- Most development is on public sewer and water.
- Wellhead protection areas are often outside borough limits.
- Aquifer recharge is limited because of impervious cover.
- Flood and stormwater management retrofitting is necessary to upgrade current systems.
- Open space is limited and often in private ownership.

The Urban Issues group identified **impervious cover and stormwater management** as the most important water supply issues in the urban settings. They also highlighted the need for the **practical application of ordinances**, particularly in areas that are close to being, if not completely, built out; there are times when allowances need to be made to allow for economic development or for other reasons.

b. Suburban/ Rural Issues Work Group

The suburban/rural issues are being played out in the townships in the study area. These municipalities are dealing with urbanizing areas and balancing the preservation of open space and agricultural land with land development. The following are some of the issues this Work Group considered when reviewing the ordinance components:

- New development is controlled through the land development process.
- Reduction of impervious cover needs to be addressed through land development controls.
- Parking ratios are typically addressed as a minimum with no maximum.
- Agricultural land and open space protection
- Concentrating development to preserve open space
- Private on-lot sewage and water systems
- Stormwater management for proposed development
- Karst geology and related development limitations
- Open space management

The Suburban / Rural Issues group identified **land use and development** as the most critical issues affecting the management of water resources in suburban / rural areas. Other important issues with this group include:

- With regard to future land development, ordinances related to karst geology were identified as having the greatest benefit to the water supply.
- Addressing and encouraging groundwater recharge as it relates to stormwater management and its relationship to karst geology are important in developing communities.
- Porous paving, as a way to increase infiltration was a topic of great interest; however, there was also an expressed need for more data regarding its effectiveness, the ability to view pilot projects before committing to its use, etc.

c. Regional Issues Work Group

This work group dealt with the “big picture” issues in the study region that are addressed either through the Lancaster County Planning Commission, regional planning initiatives, watershed groups, water planning teams, or water authorities. Important planning issues with a regional perspective include:

- Regional Comprehensive Plans
- Water Planning Teams
- Wellhead protection
- Farmland preservation
- Watershed planning

From a regional perspective, **greater cooperation among municipalities** was discussed with ideas exchanged about pooling resources for equipment needs, more consistency and standardization of ordinances within an area regardless of municipal boundaries, and the formation of teams focused on wellhead protection and other water supply issues. Other important issues with this group include:

- The group overwhelmingly agreed that water planning must be looked at for the next 50-plus years, with an inter-municipal outlook that looks much farther into the future than is typically done today.

IV Recommendations / Strategies

Various approaches for local government and water resource planners to consider.

The following is an overview of the major issues affecting the sustainability of the water supply in the Northern Lancaster County aquifer region. Each issue is described along with the related problems affecting current conditions in the region.

A Toolbox Categories

The Toolbox (see Appendix) provides both expanded tools that improve on existing local standards (see Local Water Resource Management Categories above) and new tools successfully implemented in other areas of Pennsylvania and in a few cases, elsewhere in the country. For ease of reference and use, these tools have been categorized by how they can be used for planning.

Regional Cooperation and Oversight includes aquifer-wide tools that are the responsibility of county- (Lancaster County Water Resources Task Force) or state-level initiatives (such as Pennsylvania State Water Resource Planning - Act 220)

Comprehensive Planning includes tools that would be used by a region or municipality to update or amend comprehensive plans.

Watershed Planning tools are initiatives that directly relate to water supply management.

Urban Growth Areas tools address existing land uses in urban growth areas and what can be done in these areas to improve efficiency and water re-use.

Stormwater Management tools specifically relate to stormwater management and may be used to update or revise current stormwater management regulations on local and regional levels.

Land Development tools are either expanded standards currently being used within the study area (see Local Water Resource Management Categories, above) or new tools using successful models from outside the study area. The sub-categories relate directly to the categories for the Local Water Resource Management Standards.

- Impervious Cover Reduction
- Open Space Protection
- Stormwater Management
- Land Use
- Water Supply and Disposal

Landowner Opportunities tools are specific to managing land by private or public landowners. They provide educational tools for watershed groups, municipalities, or other groups interested in managing water resources.

B. Issues Overview

The water resource management strategies section presents seven major issues (A through G) affecting water supply sustainability within northern Lancaster County. Each issue is described along with current problems related to that issue. The management recommendations are described along with the tools that can be implemented to address the issue. Tools listed here are cross-referenced with their listings in the Toolbox (see Appendix), which includes further details. The issues include:

Issue A: Overall Reduction of Infiltration and Groundwater Recharge
Issue B: Karst Geology
Issue C: Disconnected Stream and Floodplain Systems
Issue D: Over-withdrawal of Groundwater in Stressed Recharge Areas (SRAs)
Issue E: Overall Increase in Water Use
Issue F: Fragmented Governing Bodies
Issue G: Outside Influences on Groundwater Supply

C. Issue A: Overall reduction of infiltration and groundwater recharge

Historical changes in land use have led to increased urbanization and, with it, a sharp increase in impervious surfaces – roads, parking lots, driveways, and roofs – replacing meadows and forests. The result is less surface area to provide infiltration and recharge and, subsequently, an increase in stormwater runoff bypassing the aquifer and flowing directly to streams. The overall reduction in infiltration throughout the region is important, but the loss of infiltration in Critical Aquifer Recharge Areas is particularly critical in the overall sustainability of the water supply.

*Problem: **Loss of Critical Aquifer Recharge Areas***
The continued increase in impervious cover and development in CARAs will reduce the sustainability of the water supply for the aquifer.

*Problem: **No increase in Critical Aquifer Recharge Areas***
Once a CARA is altered and its recharge potential is reduced, it is expensive and difficult to return the land to its original, porous condition.

*Problem: **Increased impervious cover***
Land use associated with residential, commercial, and industrial development is the number one source of increased impervious cover. Growth in these types of land uses is expected to continue.

*Problem: **Straightened and relocated drainage systems within CARAs***
Waterways that are straightened from a naturally meandering pattern provide significantly less infiltration potential, because less stream area and increased velocities mean less infiltration potential. In many cases, waterways have been relocated to higher elevations within the floodplain, closer to the edges of the floodplain. The results are a stream system that is further disconnected from the groundwater elevation, and an increased potential for impervious layers.

Problem: ***Post-settlement deposits within CARAs***
Post-settlement deposits, or Legacy Sediments, within CARAs significantly reduce permeability and decrease the frequency of flows accessing the wide floodplain areas. The result is minimal infiltration in areas where the infiltration potential is high.

Problem: ***Conventional stormwater management methods***
Most of the stormwater management methods being used for new development within the aquifer consider runoff and flood reductions as priorities over infiltration. In municipalities where infiltration is encouraged, the limitation of the karst geology is being used as a justification for not providing infiltration and for using impermeable liners in basins.

Problem: ***Reduced forest cover and riparian buffer zones***
Increased pressure from agricultural practices and development has reduced forest cover and widths of riparian buffer zones along stream systems and within CARAs. With the increased elevation of floodplains as a result of post-settlement deposition, vegetation root systems within these stream systems are farther from groundwater elevations, reducing the ability of vegetation to convey water via root systems into groundwater stores.

Problem: ***Evapotranspiration***
Perched wetland, stream, and floodplain systems reduce infiltration and result in longer periods of standing water, which, consequently, is removed from the aquifer system through evapotranspiration. Most groundwater recharge occurs when evapotranspiration is minimized. Thermal pollution from agricultural area ponding also contributes to increased evapotranspiration.

1. <u>Recommendations:</u>
   Because the reduction of infiltration is directly related to land use and development, municipal planning, ordinances and stormwater management must be addressed in a comprehensive, coordinated effort to reduce impervious cover and promote infiltration. *It is important to note that even though infiltration is a priority for groundwater recharge, the removal of water-soluble pollutants should be considered wherever stormwater management infiltration is proposed. Pre-treatment of run-off prior to infiltration should be used to maximize pollution removal.*

2. <u>Tools:</u>
   The following are important tools that address this issue:

   Comprehensive Planning Category**:** The tools included in this category may be used to direct land development away from CARAs, protect existing open space, and encourage more efficient land use. Because CARAs provide the most important recharge locations for aquifer sustainability, these areas are important considerations for protection, enhancement, or restoration during planning and land development processes.

Tool B1. Multi-municipal - Regional Comprehensive Planning
Tool B6. Open Space Land Acquisition
Tool B7. Open Space Planning

CARA Protection: Since CARAs provide the most important recharge locations for aquifer sustainability, these areas are important considerations for protection during planning and land development processes.

Tool B19. CARA Protection

Stormwater Management Category: Encouraging infiltration of stormwater runoff is important to a sustainable water supply, especially within CARAs. It is also important to consider viable and consistent protocols for determining the potential for stormwater management methods that promote infiltration in carbonate geology areas and high-density karst areas. Close to 100 percent of soluble pollutant removal should be considered before infiltration. The following specific tools include:

Tool F1. Assessment for Regional SWM Locations
Tool F2. Regional Stormwater Management Alternatives
Tool F3. SWM BMP Management Authority
Tool F4. Transfer of Stormwater Rights
Tool F5. Minimum Disturbance - Minimum Maintenance Stormwater
Tool F6. Stormwater Infiltration for Karst Areas - Alternatives to Conventional Methods

Land Development Categories: These tools provide municipalities with ideas for protecting CARAs and open space and managing growth that limits or reduces impervious cover. Reducing impervious cover starts by providing standards that minimize runoff for paved areas. This includes possibly reducing standards for paving needed for parking areas and streets, and improving the efficiency of roadway layouts. Many of the municipalities in the study area already have implemented successful ordinances that reduce paving requirements. These municipalities and the related standards are shown on the Ordinances Overview (see Appendix). The Overview is a good base line to use to update other ordinances and improve the management of impervious cover in the study area. The following specific tools relate to land development:

Impervious Cover Tools
Tool G1. Streets

Tool G2. Cul-de-sacs
Tool G3. Parking Ratios
Tool G4. Driveways
Tool G5. Parking Lots
Tool G6. Model Legal Agreement for Shared Parking
Tool G7. Porous Asphalt Paving

Open Space Protection Tools
Tool G8. Building Envelope Limitations
Tool G9. Forest Conservation
Tool G10. Open Space Development / Conservation Zoning
Tool G11. Dedicated Easements
Tool G12. Green Building Technology
Tool G13. Riparian Buffer Regulations
Tool G15. Buffer Ordinance
Tool G16. Floodplain Restoration Amendment
Tool G17. Steep Slope Conservation District
Tool G18. Low Impact Development (LID) Standards
Tool G19. Management of Existing Vegetation

Growth Limits / Rural Resource Protection Tools
Tool G20. Purchase of Development Rights
Tool G21. Expedited Approval Process

D. Issue B: Karst Geology

The inherent susceptibility of carbonate geology to surface and subsurface failures makes land development in carbonate areas, particularly in high-density karst areas, unpredictable and difficult to manage with conventional municipal land development regulations.

Problem: ***Sinkhole prevention measures related to SWM***
Many conventional SWM facilities address sinkhole prevention by lining with impervious material areas where standing water will occur. This may temporarily appease township officials for approval purposes, but it does not provide infiltration and is not a guarantee that sinkholes or failures will not form.

Problem: ***Repairs or mitigation measures for sinkhole occurrences***
Repair and mitigation of sinkholes after they have formed are often left to construction managers on site or landowners without any experience or expertise in geology and karst failure mitigation.

Problem: ***High contamination potential***
Fractures and open cavities or conduits that form in karst geology convey pollutants directly to groundwater stores without any treatment.

Problem: ***Infrastructure failure potential (roads, pipelines, etc.)***

The vulnerability of karst areas to failures is particularly visible and costly when it affects community infrastructures such as roads, pipelines, etc.

1. Recommendations:
   There are four key components to the recommendations for land development, construction, and utility planning in karst areas. An attempt has been made in this report to make recommendations that address the vulnerabilities of karst and provide municipalities with sound methods and alternatives.

   - A viable and worthwhile protocol is necessary for determining on-site limitations of future development on a specific site. A consistent protocol is necessary to provide municipalities with the information necessary to determine where and how land development, source water protection (SWP) and SWM should occur on a site with karst vulnerabilities.
   - Provide for methods that consider the sensitivity of karst areas as alternatives to conventional SWM and construction.
   - Provide protocols for the remediation of sinkholes when they develop during construction.
   - Provide guidelines for managing existing karst features.

2. Tools:
   The following are important tools that address this issue:

   High-Density Karst Areas Category: This category addresses all four components, see above, of SWM and land development issues related to carbonate areas and high-density karst areas. The following specific tools relate to development in karst:

   Tool E1. Hydrogeologic Investigations
   Tool E2. Stormwater Management in High-Density Karst Locations
   Tool E3. Construction in High-Density Karst Locations
   Tool E4. Response and Remediation of Sinkhole Occurrence During Construction
   Tool E5. Regional Stormwater Management
   Tool E6. Geologic Hazards Areas
   Tool E7. Managing Existing Sinkholes

   Stormwater Management Category: Conventional SWM methods of ponding or impounding water are particularly vulnerable to collapse and failure in karst areas. The following tool provides an alternative to lining the ponded areas with impervious material, through the use of vegetation and root massing to stabilize the mantle. Trees and vegetation allow infiltration via root conduits, even after sediment build-up, and the shade cover reduces evapotranspiration.

Tool F6. Stormwater Infiltration for Karst Areas – Alternative to Conventional Methods

E. Issue C: Disconnected Stream and Floodplain Systems

Before European settlers arrived in the Middle Atlantic Region of the United States, the landscape was dominated by forests of mixed hardwoods, conifers, and a variety of woody and herbaceous flora, from mountain peaks down to valleys, streams, and rivers. In the stream and river valleys, the floodplains were wide and fairly flat. Soils were thin, peaty, and loamy, rich with organic material and highly porous, allowing abundant infiltration of surface water, which then percolated down to groundwater supplies. In these valleys, too, groundwater flowed near the floodplain surface, providing base flow to the streams. The floodplain surface typically rose slightly above the stream channel base flow water surface elevation. The typical pre-settlement scenario, then, looked something like this: relatively narrow stream channels meandered through the lower elevations of the valleys. Channel flows intersected with groundwater during times of high base flows, and they recharged groundwater during drought or normal base flow conditions. Low, frequently inundated floodplains consisted of porous, well-vegetated soils. Root systems throughout the floodplain reached down to groundwater and stream bed elevations, the root zone providing a large surface area for pollutant removal from groundwater and surface water. Floodplains also served as a major recharge area for surface flow. This scenario is nature's design for a fully functioning stream system that holds its stability while helping control storm flow and purifying water supplies. The constant interaction among the various components – surface water, groundwater, soil, and vegetation – is what is required to allow a floodplain and its attendant wetland pockets to be fully functional.

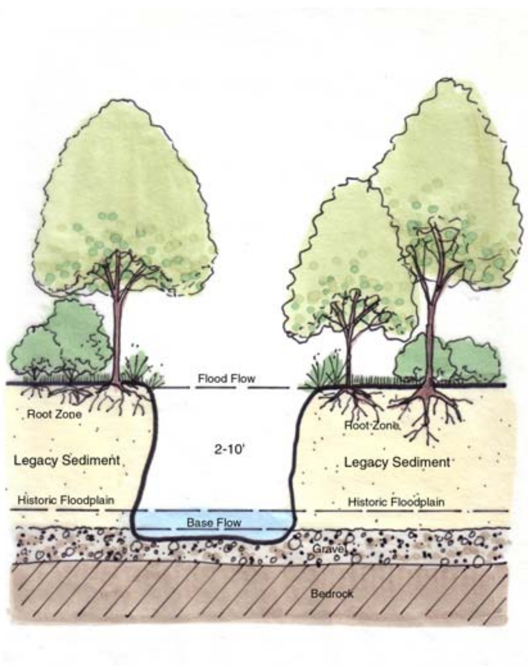
During settlement and on through rapid urbanization, from the 18th century up through the first half of the 20th century, much of the vegetation disappeared through land clearing for timber, agriculture, commerce, and settlements. Massive erosion into stream and river valleys ensued. Meandering stream channels were straightened and moved from the centers to the edges of their valleys. Mill dams were built on stream channels by the thousands. Behind those dams, water was ponded. All the eroded sediments and pollutants that had moved into the valleys accumulated behind the dams and on the floodplains between the dams. Stream channel beds and floodplains grew artificially high, perched on the fine-grained eroded materials. Elevated channel beds and floodplains were no longer closely connected to groundwater supplies; flows became predominantly surface water runoff, with temperatures far exceeding that of the groundwater. Vegetation changed because of the disconnect. Wetland systems were created not because of their proximity to groundwater but because they sat on dense, fine, nearly impervious sediments perched high above the historical stream bed and groundwater. No longer

could those wetland plants extend their root systems into the groundwater to remove the nitrogen compounds.

Later, and still today, as dams were removed or fell into disrepair, stream channels began to work their way down through the accumulated sediments toward their historical elevations, leaving the artificially elevated floodplain behind and becoming more and more "detached" from the floodplain. In reality, the floodplain became more accurately a terrace, with dense, fine-grained sediments rather than porous, peaty, organic soils, and with a quite different plant community.

Channel beds have cut too deeply through the sediments to allow any but the very highest flows to escape from the channel. Flow forces in the channel, therefore, are excessive and erosive, carrying stream bank sediments and attached pollutants downstream, undercutting banks and causing them to collapse, creating ongoing tree falls and resulting debris jams in waterways. Where the channels have reached pre-settlement stream bed levels, flows now recharging the groundwater have higher concentrations of nitrates or other soluble pollutants.

The various components of a stream system can no longer interact properly. Streams banks and beds are eroding as they seek their proper elevation and location within the valleys. Phosphorus attached to the sediments along banks is carried downstream with the eroded sediments. Nitrogen uptake by plants in the historical floodplain no longer occurs. Overland flows from stormwater enter the stream instead of the floodplain, where they were once filtered and percolated through the soil. Normal stream flows now have higher temperatures, because groundwater now intersects the stream bed only infrequently.



Disconnected Floodplain Section View

Problem: ***Reduced base flows***

Groundwater, which was the principal source of a stream's base flow, currently flows well below the stream bed. Seeps and springs that originate from the hillsides previously entered the porous floodplain, recharging the groundwater and base flow; now they directly enter stream systems or ponds perched on dense, fine-grained floodplain sediments.

Problem: ***Losing streams with perched systems***
Stream beds located at their historical, natural cobble or gravel bed elevations allow interaction between surface water and groundwater. As upstream flow or flow from the adjacent floodplain enters these areas, a certain amount percolates through the gravels to groundwater. These "losing" streams are an important source of groundwater recharge. On the other hand, streams perched on less porous legacy sediments or historically relocated to a site higher along the valley on bedrock are not capable of recharging the groundwater, because entire flows are quickly transported downstream rather than partially infiltrated through porous bed material.

Problem: ***Filled floodplains and perched wetlands***
Filled floodplains now separate trees, vegetation, and wetlands from groundwater systems because of much thicker, less permeable layers of dense sediment. Root systems are not deep enough to provide conveyance channels to groundwater levels. Historical or restored floodplains, which are attached to the channel and are flooded many times per year, provide a more constant and wide variety of food sources and habitat to the aquatic and riparian resources along the streams. Functional floodplains also provided large surface areas of porous organic soils that can store significant volumes of water and provide significant groundwater recharge. Today's sediment-filled "terraces" have minimal storage and are either (1) ponded on thick dense soils and then removed by evaporation and transpiration or (2) quickly conveyed via the channel or through the floodplain into downstream receiving waters, causing increased flood flows and elevations.

Problem: ***Perched streams***
Stream reaches with beds located at a natural cobble or gravel bed elevation are located where groundwater is always a source of base flow to the stream, except, possibly, under the most severe drought conditions. When flow from upstream is not available (during dry or moderate drought conditions, for example), groundwater seeps into the channel pools and riffles, providing a constant source of cold, clean water to aquatic life. During precipitation events, floodplains through these reaches then provide significant water storage in the soils, which is then available for recharge to the groundwater.

Streams wholly perched on beds of fine sediments and clays, however, can not provide a source of constant base flow, resulting in ephemeral streams (streams that flow only in response to local precipitation events) that do not support a healthy aquatic community. The floodplain no longer acts as a principal groundwater recharge area. Instead, the channel bed and floodplain consist of dense sediments that quickly convey flows to the downstream receiving waters with minimal groundwater recharge.

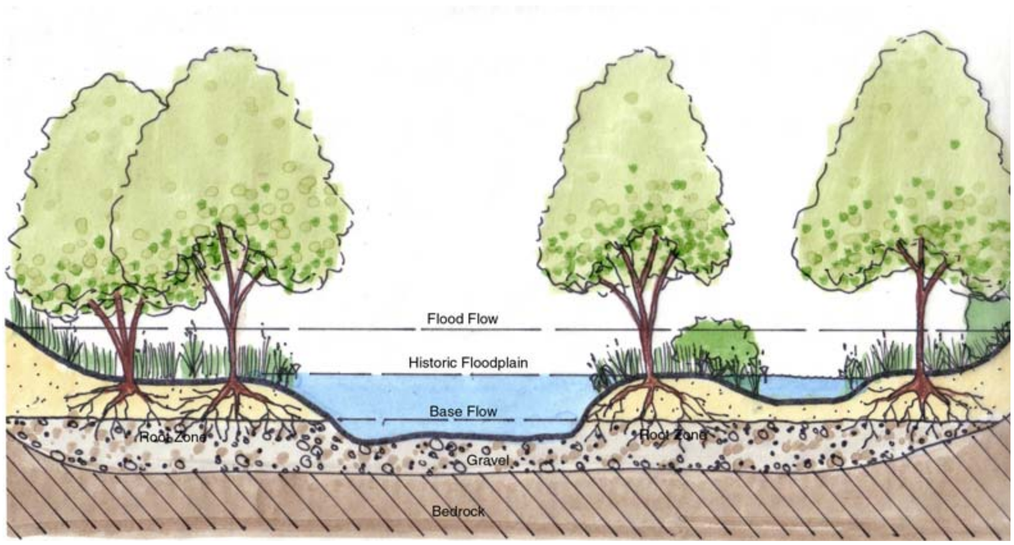
Problem: ***Filling and destruction of functioning wetland systems***
Post-settlement erosion and current land-use impacts also have reduced or removed the functions of wetland systems not directly attached to the floodplain or adjacent to streams. In a healthy, functional system, surface waters flow into

these wetland areas, providing storage, pollutant removal, and, in many locations, significant groundwater recharge. These wetland areas often include the headwaters, which, rather than having distinct stream channels, were historically characterized by large riparian wetlands that removed pollutants from the surface waters and recharged the groundwater and aquifers that provided the base flow to streams farther down the valley. The results of the most recent impacts include ditching and impermeable layers that significantly increase the conveyance of surface waters while dramatically reducing the infiltration and treatment potential of these systems.

Problem: ***Stream impacts***
Pre-settlement streams meandered across the valley at low velocities and with additional stream length that intersected the groundwater at different locations. The historical and recent alteration of stream systems through straightening and relocation has reduced stream length, increased flow velocities, reduced travel time, and reduced or removed the interaction with the groundwater. Channel bank and bed erosion, pollutant loadings, and flood flows and elevations have increased. As the stream and floodplain continue to evolve to pre-settlement conditions, the result will be long-term sediment and pollutant increases to the streams; removal of the existing riparian vegetation; removal of the historic gravels that once protected bedrock and served as a valuable resource to aquatic life, removal of the pre-settlement floodplain, including the seed bed and organic, peat-like floodplain material; increased debris jams; and increased flood elevations. The resultant stream systems may include significant stream reaches with beds of fine-grained sediments or bedrock and floodplains with a high sand content and invasive vegetation.

1. Recommendations:
   Many of the problems associated with disconnected stream and floodplain systems can be mitigated effectively through floodplain restoration. Streams are meant to be connected to groundwater systems either through collecting base flow from the groundwater or recharging the groundwater. Floodplains are meant to be flooded to provide flood water storage, recharge the groundwater, and reduce the flow and stresses within the channel. When stream flows become high, stream channels remain stable only if there is some way to convey higher flows through the valley. The restored or attached floodplain provides conveyance of large flows at much lower depths and velocities. The root systems and vegetation protect the valley floor from scouring and provide a means to increase surface water infiltration to groundwater. The highly porous and organic floodplain material stores significant volumes of water. The channel, with reduced depths and flatter slopes, no longer has velocities and stresses capable of eroding stream beds and banks. Stable, gravel riffle-and-pool systems interacting with the groundwater can better support more diverse aquatic resources. The benefits of a restored stream system include increasing groundwater recharge, reducing erosion and sedimentation, filtering harmful

nutrients from ground and surface waters, increasing flood storage, and enhancing aquatic and riparian wildlife habitat.



Restored Floodplain Section View

2. Tools:
The following are important tools that address this issue:

Comprehensive Planning Category*:* Use stream assessments to identify and prioritize floodplain/stream restoration areas, especially within CARAs.

Tool B19. Critical Aquifer Recharge Area Protection

Watershed Planning Category: A stream assessment is the first step to determine the extent of degradation and potential restoration potential. Prioritize stream assessments in watersheds with existing urban growth areas (UGB / VGBs). The stream assessment will identify opportunities for stream/floodplain restoration, prioritizing CARAs. The next step is to explore private and public funding sources for design and implementation.

Tool C1. Comprehensive Watershed Planning
Tool C2. Stream Assessment
Tool C3. Floodplain Restoration

Land Development Category: It is important to have in place floodplain ordinances that protect the floodplain from obstructions and filling while allowing the opportunity for potential restoration activities that may reduce flooding, improve infiltration and groundwater recharge, increase habitat diversity, and create recreational opportunities.

Tool G16. Floodplain Restoration Amendment

Stormwater Management Category: These tools relate to creating regional stormwater management facilities in restored floodplains. The benefits include maximizing the recharge potential of reconnected streams and floodplains, providing source water protection, managing stormwater runoff in a stable manner, and providing a potential private funding source for the work. The Transfer of Stormwater Rights tool explores the potential of using CARAs as sending areas and designated growth areas as receiving areas for stormwater management rights.

Tool F1. Assessment for Regional SWM Locations
Tool F2. Regional Stormwater Management Alternatives
Tool F4. Transfer of Stormwater Rights

F. Issue D: Over-withdrawal of Groundwater in Stressed Recharge Areas (SRAs)

Stressed recharge areas are those in which supply could potentially exceed demand. An over-withdrawal of groundwater from these areas could expedite this condition.

Problem: ***Increase in residential development water needs***
An increase in private wells and public water use (if public wells are located in stressed recharge areas) will further stress existing supplies.

Problem: ***Unregulated and unknown water use***
Private wells and unregulated water use in the SRAs will further stress supplies and cannot be monitored.

Problem: ***Intensive commercial, industrial, and agricultural uses***
Commercial, industrial, and agricultural enterprises that use significant amounts of water will further stress existing supplies in the SRAs, with the potential of extracted water leaving the aquifer either by being sold (bottled water, canned goods, etc.), consumed (animals, etc.), or discharged into the sewage treatment system. Sewage treatment discharge points in the study area are into streams at the lower end of watershed; therefore, there is no chance for groundwater recharge within the aquifer.

Problem: ***Disturbance of subsurface water***
Blasting, de-watering, and flow direction/magnitude from utilities, etc. could dramatically alter subsurface flow patterns and have the potential to further stress SRAs.

1. Recommendations:
Protection of the water supply in SRAs should be prioritized. Municipalities and water authorities should consider evaluating existing and future land uses in these areas and require or strongly encourage

supply feasibility and impact testing for any future development. Important tools to address this issue include:

Comprehensive Planning Category: GIS technology can be used to locate SRAs and help local and state planners evaluate natural features, geology, water resources, and land-use policies to protect SRAs from over-withdrawal. This mapping can be used to coordinate the water supply by allowing municipalities to identify where existing zoning encourages development influencing SRAs. The municipalities can then make the appropriate adjustments to zoning ordinances to shift development patterns away from important recharge areas and SRAs. These tools will also help determine where public and private wells may be limited in SRAs. They also provide a means to address how regional land uses affect the water supply specifically where it relates to diversion of water into and out of aquifer areas and watersheds, unknown and unregulated uses, mining impacts, sewage treatment discharge locations, etc.

Tool B2. Water Supply Area Mapping
Tool B3. Water Supply Coordination
Tool B4. Inter-municipal Water Supply Coordination

Land Development Category: Prior to the installation of any new water system or subdivision of land into lots that would be served by individual wells in the areas or in proximity to areas of known inadequate yields of potable supplies, aquifer and water quality tests shall be performed.

Tool G23. Aquifer Test Requirements
Tool G24. Water Needs Analysis / Water Feasibility Analysis
Tool G25. Water Supply

G. Issue E: Overall Increase in Water Use

An important consideration is the overall increase in water use throughout the aquifer region. The aquifer supply is often described as a "bathtub." This analogy is fitting and helps multiple municipalities understand that what is withdrawn from anywhere within the aquifer can affect any of the 13 other municipalities or water authority areas within the aquifer region. With this in mind, it is important to consider the overall increase in water use within the entire aquifer region, not just the stressed areas or the areas closest to the where the water is being used.

Problem: ***Growth in housing***
Increases in housing directly relate to an increase in population and water use and can affect the overall sustainability of the aquifer supply.

Problem: ***Increase in intensive commercial, industrial, and agricultural water uses***

Intensive commercial, industrial, and agricultural water uses will continue to increase in the region. These uses are difficult to monitor, and the use of water is localized and potentially intensive. The water use is also often transported out of the region or consumed; therefore, no recycling occurs to recharge and sustain the aquifer supply.

Problem: ***Unregulated and unknown water use***
If there is a lack of information about water use, it is difficult to plan for a sustainable supply.

Problem: ***Lack of water conservation measures***
Alternative water conservation measures such as gray water re-use, sewage spray / drip fields, drip irrigation, water recycling, etc. are not widespread and are especially important during drought conditions when groundwater supplies become more critical for agriculture and residential land use.

1. Recommendations:
   Planning efforts need to consider overall sustainability of the water supply and demand. Municipalities and water authorities should consider evaluating existing and future land uses and require or strongly encourage supply feasibility and impact testing for future development above anticipated growth projections. Important tools to address this issue include:

   Comprehensive Planning Category: All of the comprehensive planning tools may be used to manage growth with respect to water use. Ultimate sustainability of a region is difficult to assess, but should be considered. Data from this study may provide the information necessary to begin a dialogue and begin planning for a sustainable future water supply.

   GIS technology can be used to locate SRAs and help local and state planners evaluate natural features, geology, water resources, and land-use policies to protect SRAs from over-withdrawal. This mapping can be used to coordinate the water supply by allowing municipalities to identify where existing zoning encourages development impacting SRAs. The municipalities can then make the appropriate adjustments to zoning ordinances to shift development patterns away from important recharge areas and SRAs. These tools will also help determine where public and private wells may be limited in SRAs. They also provide a means to address how regional land uses affect the water supply, specifically where it relates to diversion of water into and out of aquifer areas and watersheds, unknown and unregulated uses, mining impacts, sewage treatment discharge locations, etc.

   Tool B2. Water Supply Area Mapping
   Tool B3. Water Supply Coordination
   Tool B4. Inter-municipal Water Supply Coordination

Land Development Category: Prior to the installation of any new water system or subdivision of land into lots that would be served by individual wells in the areas or in proximity to areas of known inadequate yields of potable supplies, aquifer and water quality tests shall be performed. It is also important to promote water recycling and re-use wherever possible for new residential, commercial, and industrial development through measures encouraged by Leadership in Energy Efficient Design (LEED) and Low Impact Development (LID).

Public Water Supply Protection
Tool G23. Aquifer Test Requirements
Tool G24. Water Needs Analysis / Water Feasibility Analysis
Tool G25. Water Supply

Open Space Protection
Tool G12. Green Building Technology
Tool G18. Low Impact Development (LID) Standards

Urban Growth Areas Category: Education about and use of water conservation techniques for recycling and re-use of water resources should be encouraged on residential, commercial, and industrial levels.

Tool D5. Water Recycling

H. Issue F: Fragmented Governing Bodies

Multiple governing bodies, each with their own set of regulations, oversee the land use and development of the aquifer region. Lack of consistency in approach and oversight creates an uncoordinated effort that results in adversarial relationships. The water supply is not limited by political boundaries.

Problem: ***Multiple municipal ordinances***
There are 13 municipalities and at least 20 ordinances addressing land use associated with a common water source. The disparity among each of these ordinances is illustrated in the Ordinances Overview (see Appendix).

Problem: ***Multiple water providers and municipalities***
There is an overall lack of coordination and cooperation among the multiple water providers and municipalities.

Problem: ***Lack of regional oversight of water source***
The Lancaster County Water Resources Task Force serves the entire county, whereas the individual source water protection area task forces serve smaller areas within the region.

Problem: ***Lack of understanding of relationship between surface and groundwater resources going beyond political boundaries***

A few regional comprehensive plans have been completed along with various watershed planning projects. Even with these very successful efforts, until now there was no comprehensive understanding of groundwater resources and their relationship to surface water resources.

Problem: ***Lack of understanding/knowledge of total interaction of groundwater as it relates to the individual aquifer/watershed, etc.***
Even with the data compiled as part of this study, it is still difficult to understand and quantify the interrelationship of groundwater and its relationship to aquifers outside of the region.

Problem: ***Lack of public awareness in protecting and conserving water resources***
A great deal of public education has occurred over the last 10 years about watersheds and the importance of water quality. Water quantity is an issue that directly affects everyone, and yet there is little public understanding of what can be done to protect the water supply.

1. Recommendations:
   The results of this study will equip the municipalities with some consistent tools to begin to address water resource issues on an individual basis. The next step is to establish a regional oversight committee and water planning teams with representation and expertise necessary to plan for a sustainable water supply. Important tools to address this issue include:

   Regional Cooperation and Oversight Category*:* The proposed Oversight Committee would include members from each of the Water Planning Teams within the aquifer region. This committee will make recommendations related to overlap among the water supply regions within the aquifer. Members of the Lower Susquehanna Regional Water Resource Committee would facilitate this committee, which would include technical advisory from the SRBC, Lancaster County Planning Commission, Lancaster County Water Resources Task Force, Lancaster County Conservation District, and other pertinent regional water resource planners. The key to planning most effectively for future water needs is to bring water authorities together with municipalities, watershed groups, wellhead protection task forces, and other parties to share vital information and chart a consistent course of action. The Water Planning Teams proposed here may already be established as part of the Lancaster County Water Resources Task Force. Collaboration and consolidation may be necessary to address the water supply areas located within the aquifer region.

   Tool A1. Establish an Oversight Committee for the Aquifer Region
   Tool A2. Establish Water Planning Teams

Comprehensive Planning Category: All of the comprehensive planning tools listed below may be used to manage growth with respect to water use. Ultimate sustainability of a region is difficult to assess, but should be considered. Data from this study may provide the information necessary to begin a dialogue and planning for a sustainable water supply. These tools also address sustainability by engaging the community in the decision-making process through presentations of alternative future scenarios that can be used to model the growth of a region over a specified time frame and in relationship to water supply.

Tool B1. Multi-municipal / Regional Comprehensive Planning
Tool B6. Open Space Land Acquisition
Tool B7. Open Space Planning
Tool B8. Defined Growth Areas
Tool B9. Rural Resource Areas
Tool B10. Transfer of Development Rights
Tool B12. Build-out Zoning Strategy
Tool B13. Official Map
Tool B17. Community Visioning – Future Regional Drinking Water Supply Forum
Tool B19. Critical Aquifer Recharge Area Protection

Stormwater Management Category: These tools relate to creating regional stormwater management using one approach to SWM that is recommended by the ACT 167 watershed-wide Stormwater Management Plans Sub-regional (combined site) Storage.

Tool F1. Assessment for Regional SWM Locations
Tool F2. Regional Stormwater Management

I. Issue G: Outside Influences on Groundwater Supply

Some land uses have the potential to dramatically alter the landscape in ways that affect groundwater, surface water, and environmental resources. Streams, springs, and wetlands are often substantially altered or even removed from the landscape.

Problem: ***Groundwater is removed or transferred between watersheds***
When groundwater is removed from an aquifer and not replaced, a deficit in the natural system occurs. Dramatic increases in these types of transfers could create deficits and affect the sustainability of the water supply. An example of this type of transfer is when public water source wells are located in the headwaters of a watershed. The water is then processed through consumption or use and eventually discharged into the sewage treatment system. The sewage treatment facilities within the aquifer study area are typically located at the lower end of the watersheds, eliminating the possibility of recharge within the aquifer of origin.

Problem: ***Unknown and unregulated groundwater use***

The withdrawals for land uses with wells providing fewer than 10,000 gallons per day are not regulated; therefore, there is no way of knowing the impact these uses have on the sustainability of the water supply.

Problem: ***Mining impacts***
Mining of consolidated rock and mineral deposits below the water table requires that enough water be pumped to keep the mine workings dry. The magnitude of the pumping is often high, equivalent to that of a small- to medium-size city. However, while cities usually withdraw from multiple sources that are aerially distributed, mine pumping is concentrated at the mine and strives to maintain constant drawdown of the water table. This often results in aquifer dewatering on a scale unique to mining and causes severe impacts to springs, streams, and wetlands. Reduced groundwater flow and groundwater discharge to streams (base flow) frequently result from these activities.

1. Recommendations:
   The area of influence and capture area for the outside influences should be delineated, quantified if possible, and the impacts identified. This is best accomplished through planning tools and studies, which may incorporate more detailed water budget analysis, field mapping of aquifer permeability features and water levels, and groundwater modeling. Once identified, the impacts may be mitigated through a variety of methods, including redirection/redistribution. Important tools to address this issue include:

   Comprehensive Planning Category: GIS technology can be used to locate outside influences on the water supply. This information will help local and state experts and planners evaluate natural features, geology, water resources, and land use policies to address the sustainability of the water supply and reduce unknown transfers and loss of water from the aquifer. These tools help municipalities identify where existing zoning encourages development and help determine where outside influences could affect the water supply and how. They also help identify where outside influences affect the water supply in relationship to land use.

   Tool B2. Water Supply Area Mapping
   Tool B3. Water Supply Coordination
   Tool B4. Inter-municipal Water Supply Coordination

   Land Development Category: Prior to the installation of any new water system or subdivision of land into lots that would be served by individual wells in the areas or in proximity to areas of known inadequate yields of potable supplies, aquifer and water quality tests shall be performed. Education about and use of water conservation techniques for recycling and re-use of water resources should be encouraged, especially for uses that typically transfer water out of the aquifer. It also is important to promote water recycling and re-use wherever possible for new residential, commercial, and industrial development through measures encouraged by LEED and LID.

Public Water Supply Protection
Tool G23. Aquifer Test Requirements
Tool G24. Water Needs Analysis / Water Feasibility Analysis
Tool G25. Water Supply

Open Space Protection
Tool G12. Green Building Technology
Tool G18. Low Impact Development (LID) Standards

Urban Growth Areas Category: Education about and use of water conservation techniques for recycling and re-use of water resources should be encouraged on residential, commercial, and industrial levels.

Tool D5. Water Recycling

J. Potential Projects

The following are specific action items unique to the study area and the goals of the NLCGS.

1. **Chiques Creek and Doe Run Corridor Improvements**
Manheim Borough, Penn Township, Rapho Township
This multi-municipal, multi-watershed study and improvement plan is focused on corridor improvements related to water resource management. A Master Plan highlighting numerous potential projects is in planning stages. The following outlines some specific work in design stages.

Doe Run:
The entire Doe Run Watershed, which will provide a wider array of stream/floodplain restoration, stormwater management, and nutrient trading options for this and future projects.

Chiques Creek:
Stream/floodplain restoration opportunities along Chiques Creek from Power Road upstream to Elizabethtown Road.

Masterplan:
The Master Plan will provide a graphic and written summary of water resource issues on Doe Run and Chiques Creek associated with the redevelopment of the former Raymark site, including but not limited to channel relocations, bridge conveyance, flooding, sewer-line alignments and depths, stormwater management, conservation easements, wetlands, riparian buffers, integration of CARAs and source water protection, areas providing best management practices or stormwater management facilities, reducing localized flooding, sedimentation/water quality and

stream stability issues, aquatic and riparian habitat, and aesthetics. The Master Plan will identify recommended future improvements within the Doe Run Watershed and adjacent reaches of Chiques Creek. Proposed improvements identified on the Master Plan will require more detailed studies in the future, along with associated implementation costs.

Detailed Engineering:
Detailed Engineering (plan and engineer's report) on a 3,000-foot section of Doe Run, beginning approximately 400 feet downstream of the Oak Street crossing, upstream to approximately 400 feet above the proposed railroad crossing in Penn Township. The restoration design will relocate Doe Run to its historical location in the valley, including a channel relocation and restoration of an attached floodplain at appropriate elevation and of appropriate size and earthen materials. The abandoned channel and newly created wetlands, as well as the restored stream and floodplain, will improve flood flow conveyance and will function as a bioengineered water-quality improvement facility through filtering and groundwater recharge. Taken into consideration will be the identification of a section of Doe Run as a losing/perched stream that flows tangentially at one point to an identified high-density karst area (CARA).

2. Floodplain Restoration Feasibility Study
Regional Water Quality and Quantity Management
Warwick Township and Lititz Borough

The purpose of the project is to determine feasibility for implementing floodplain restoration along the Lititz Run corridor from Oak Street to Clay Road in Lititz Borough and Warwick Township. The site will receive discharge from the Lititz Borough Sewage Treatment Plant into a created wetland / restored floodplain. This will be an attempt to infiltrate and recharge water that is currently discharged into Lititz Run and leaves the aquifer. The goals of the project include:

- Increase infiltration and groundwater recharge potential.
- Reduce flooding to Lititz Borough.
- Quantify reduction of flooding.
- Reduce Phosphorus\Nitrogen\Sediment.
- Quantify reductions of Phosphorus\Nitrogen\Sediment.
- Restore stream and floodplain.
- Create wetlands and riparian buffer.

Appendix

Watershed Plan Chart

Policy Inventory

SRBC Work Group Meeting Outcomes

Ordinances Overview

Toolbox

Definitions

References

Northern Lancaster County Groundwater Study

Toolbox

A Regional Cooperation and Oversight

	Tool	Description	Activities	Issues	Related Tool	Source	Existing	Expanded	New	Responsibility	Priority
1	Establish an Oversight Committee for the Aquifer (study area)	The Oversight Committee would include members from each of the Water Planning Teams within the aquifer (study area). This committee will make recommendations unique to the Northern Lancaster County region. Members of the ACT 220 - Lower Susquehanna Regional Water Resource Committee would facilitate this committee and include technical advisory from the SRBC, Lancaster County Planning Commission, Lancaster County Water Resources Task Force, Lancaster County Conservation District, and other pertinent regional water resource engineers and planners.	1. Establish committee and organizational structure. 2. Appoint committee members. 3. Develop an action agenda based on the recommendations of this report and other regional water resource studies, concentrating on CARA management and regional water supply issues. Emphasis should be on coordination between municipalities and water authorities throughout the aquifer.	F	A2, B1, B2, B3, B4, B11, B19, C1, C2 F1, F2				x	Lancaster County Water Resources Task Force ACT 220 - Lower Susquehanna Regional Water Resource Committee	High
2	Establish Water Planning Teams	The key to planning most effectively for future water needs is to bring water authorities together with municipalities, watershed groups, wellhead protection task forces, industry, agricultural community and any other group or individual with interests in water supply and management, to share vital information and chart a consistent course of action. The Water Planning Teams proposed here may already be established for wellhead protection as part of the Lancaster County Water Resources Task Force. Collaboration and consolidation may be necessary to address the water supply areas located within the Northern Lancaster County Water Budget Project aquifer area.	1. Form a Water Planning Team in accordance with the steps outlined in the Lancaster County Water Resources Plan. 2. Appoint representation to the Oversight Committee. 3. Coordinate activities recommended by the Oversight Committee and this report. 4. Prioritize activities based on the unique needs of the region represented.	F	A1, B1, B2, B3, B4, B11, B17, B19, C2, D1, D2, D3, D4, D5, F1, F2	Lancaster County Water Resources Plan		x		Lancaster County Water Resources Task Force	High

B Comprehensive Planning

	Tool	Description	Activities	Issues	Related Tool	Source	Existing	Expanded	New	Responsibility	Priority
1	Multi-municipal / Regional Comprehensive Planning	Integrate results of this water budget project into existing and future multi-municipal and regional planning efforts.	Update comprehensive plans or include strategies in new regional comprehensive planning efforts that address water resource and source water protection. Consider some of the tools proposed as part of this project.	A,D,E,F,G	B2, B3, B4, B5, B6, B7, B8, B9, B10, B11, B12, B13,B14, B17, B19, C2, C3, E5, F1, F3, F4, G9, G10	PA Municipalities Planning Code *Local Models:* Lititz Warwick Strategic Comprehensive Plan Cocalico Region Strategic Plan	x			Municipalities	High
2	Water Supply Area Mapping	Use GIS technology to map water supply areas in relationship to municipal boundaries. These maps will help local planners and the Water Planning Team evaluate natural features and land use policies in surrounding communities with respect to the available resources.	1. ID water authority supply areas as a base. 2. Map land use, natural features, soils, and geology as reference maps. 3. Locate source water protection areas if available.	D,E,F,G	A2, B1, B3, B4, B5,	Lancaster County Water Resources Plan Lancaster County GIS		x		Water Planning Team Municipalities	High
3	Water Supply Coordination	Identify where existing zoning encourages development and make appropriate modifications to shift development patterns away from important recharge areas or provide protection measures for CARA's, high density karst areas and stressed areas.	Update comprehensive plans or include strategies in new regional comprehensive planning efforts that address water resource and source water protection. Consider some of the tools proposed as part of this project.	D,E,F,G	A2, B1, B2, B4, B5,	Lancaster County Planning Commission		x		Oversight Committee	High
4	Inter-municipal Water Supply Coordination	Develop inter-municipal or inter-authority strategy as part of the Comprehensive Plan to address where coordination between water supply areas and municipal boundaries may be necessary. For example, a CARA can cross multiple municipal boundaries, while providing recharge for one water supply.	1. Identify existing inter-municipal / inter-authority overlap between supply and demand. 2. Determine where coordination is necessary to meet future land use plans and water supply/demand projections. 3. Develop cooperative agreements and coordinate with future land use plans.	D,E,F,G	A2, B1, B2, B3, B5,			x		Oversight Committee Municipalities	High
5	Land Use Impacts on Water Supply	Provide a strategy for how to address regional land uses that affect the water supply.	Identify regional land uses that affect the water supply [diversion of water in and out of watersheds, unknown and unregulated water uses, stormwater management (SWM), mining, etc.].	D,E,F,G	A2, B1, B2, B3, B4,				x	Oversight Committee Municipalities	Medium
6	Open Space Land Acquisition	Purchase property using public funds or private land trusts for the purpose of preserving public open space and/or providing opportunities for restoration, SWM regional facilities or management of CARA's.	Use this strategy to prioritize land acquisition in Critical Aquifer Recharge Areas (CARAs), potential future water sources, regional SWM potential locations and other locations with importance to the sustainability of the water supply.	A,B,C,D	B2, B7, B10, B16, B19, C1, E5, F1, F2, F4,	Lancaster County Comprehensive Plan Growth Management Element Update		x		Lancaster County Municipalities	Low

7	Open Space Planning	Provide a framework for future growth by prioritizing where open space may be protected and where development could occur. Identify Primary Conservation Areas (land that is currently regulated on a local, state or national level) and Secondary Conservation Areas (land that provides benefits and expands on the Primary Conservation Areas).	ID and map Primary Conservation Areas for each Municipality or the region. For example, these may include wetlands, steep slopes >25%, 100 year floodplain, geologic features (sinkholes, caves, etc), source water protection areas, etc.. CARAs and high-density karst areas should be included as Primary Conservation Areas. ID and map Secondary Conservation Areas for each Municipality or the region. For example, these may include wetland buffers, riparian buffers, hedgerows, trees stands >5 acres, etc. Include strategies for establishing open space corridors, natural area buffers, protection of water recharge areas, and related natural areas.	A,B,C,D	B1, B2, B6, B8, B9, B10, B11, B19, C1, C2, C3, E5, E6, F1, F2, G9, G10, G11, G13, G14, G,15, G16	Lancaster County Comprehensive Plan Growth Management Element Update South County Greenspace Protection Strategy Rhode Island Dodson Associates, Ltd 413-628-4496 *Local Model:* Warwick Region Comprehensive Recreation and Open Space Plan		x		Municipality	HIgh
8	Defined Growth Areas	As applied in Lancaster County, land within defined growth areas is targeted for densities of at least 5.5 units per acre and planned infrastructure (roads, water, sewer) improvements. Current County designations are Urban Growth Areas (UGAs) and Village Growth Areas (VGAs). Outside of these areas, land is planned to remain in predominantly rural and agricultural use.	Growth areas should consider existing and future public water supply. Adjustments to existing growth areas may be necessary in light of the findings of this report. Municipalities without defined growth areas should prioritize establishing them.	D,E,F,G	B1, B2, B3, B5, B7, B9, B10, B12, B13, B18, B19, E5, F1, F2, F4, G19,	Lancaster County Comprehensive Plan *Local Model:* Warwick Township Comprehensive Plan		x		Lancaster County Municipalites	HIgh
9	Rural Resource Areas	Counterpart of Urban Growth Areas - designated areas that are targeted for agricultural and natural resource land preservation, rural economic development policies, and zoning techniques that discourage sprawl development patterns.	CARAs and high-density karst areas should be located in Rural Resource Areas.	D,E,F,G	B1, B2, B3, B5, B7, B8, B10, B12, B13, B18, B19, E5, F1, F2, F4, G19	Lancaster County Comprehensive Plan Growth Management Element Update		x		Lancaster County Municipalites	HIgh
10	Transfer of Development Rights	Zoning tool that directs growth to preferred locations (see Defined Growth Areas) through the sale and purchase of development rights. Development rights are established for a given piece of land and can be separated from the title of that property. These rights can then be transferred to another location within a defined growth area such as a UGA or VGA.	Consider including CARAs in rural resource areas and prioritized as sending areas for Transfers of Development Rights (TDRs).	A,B,C,D, E	B1, B2, B3, B5, B7, B8, B9, B12, B13, B18, B19, E5, F1, F2, F4, G19	Lancaster Farmland Trust *Local Model:* Warwick Township Zoning Ordinance Section 322 - Transfer of Development Rights		x		Municipalities	Medium
11	Source Water (or Wellhead) Protection Overlay Districts	These ordinances are intended to minimize threats to the quality of groundwater and surface water, particularly groundwater supplies, and assist in determining compliance with federal and state environmental regulations that could affect water quality. They protect designated groundwater recharge areas by applying special design standards, such as setbacks, use limitations, signage, and buffers.	Ordinances may be implemented on a municipal level, but because of multi-municipal overlap in zones of influence (a public water source well in one municipality may have a zone of influence in another municipality), a model ordinance for the entire water authority supply area or aquifer should be encouraged.	A, B, C, D, E	A2, B2, B3, B4, B6, B7, B19, C1, D5, E1, E2, E3, E4, E5, E6, E7, G25, G26, G27, H1, H2,	East Cocalico Township Section 231 Wellhead Protection Overlay Zone (WP)	x			Oversight Committee Water Planning Team Municipalities	Medium
12	Build-out Zoning Strategy	Use current zoning districts and GIS data to develop a build-out scenario for future development in relationship to available water supply and wastewater. Use this map as a guide for updating comprehensive plans and rezoning.	Include CARAs, geologic hazard areas, sewage facilities, and wellhead protection areas on this plan. Consider public water supply and water resources for these plans or specific aquifer studies to determine on-lot availability and impact on surrounding sources.	A,B,C,D, E	B1,B8, B11, B19, E6, G22, G23, G24	South Coventry Township Chester County, PA	x			Municipalities	High
13	Official Map	Official document adopted by a municipality that maps existing and proposed streets, pedestrian easements, open space, and other public lands or easements. The adopted map officially reserves the land for future public purpose.	Include CARAs, geologic hazard areas, and wellhead protection areas on this plan. Consider public water supply and water resources for these plans or specific aquifer studies to determine on-lot availability and impact on surrounding sources.	A,B,C,D, E	B1,B8, B11, B19, E6, G22, G23, G24	Lancaster County Comprehensive Plan Growth Management Element Update	x			Municipalities	Medium
14	Agricultural Management Program for CARAs	This ordinance is intended to minimize threats to the quality of groundwater and surface water, particularly groundwater supplies, and assists in determining compliance with federal and state environmental regulations that could affect water quality.	Consider a funding source for nutrient management programs and monitoring for farms in CARAs, high-density karst areas, and wellhead protection zone 2, if applicable.	G	B11, B19, E6	Local Model: Warwick Township Nutrient Management Pilot Project			x	Municipalities	Medium
15	Act 537 Planning	Requires municipalities to maintain current wastewater facilities plans - indicating when and where public wastewater facilities and private on-lot systems will be provided.	Consider on-lot systems or discharge systems to recharge within the aquifer. CARA's should be prioritzed for infiltration, if soluble pollutants can be removed.	A	B1, B19,	PA DEP ACT 537			x	Municipalities	HIgh
16	Community Land Trusts	A non-profit trust that owns the land and permits the resident owner to retain title to the house, representing a more affordable approach to home ownership. Regulations place limits on the amount profit that can be earned by a single homeowner over a period of time. In places where housing prices are rising quickly, this program helps keep housing affordable for future buyers.	Easements owned by land trusts should be prioritized in CARAs. An Open Space Preservation bill currently under review at the state level would allow municipalities to appropriate money to a land trust for the acquisition of open space, transfer open space property interests to a land trust, and accept nominal payment for the transfer.	A,D,E	B2, B7, B19, C2, E5, F1, F2, F4	Brandywine Conservancy Natural Lands Trust Heritage Conservancy		x		Municipalities	Medium
17	Community Visioning - Future Regional Drinking Water Supply Forum	Engage the community in the decision-making process through presentations of alternative future scenarios that can be used to model the growth of a region over a specified time frame.	Future Regional Drinking Water Supply Forum to gain community input on potential projects for future water supplies, flood protection, natural resource protection, and means of providing more sustainable yields. Result is a Master Water Plan and Conservation Strategies for the region.	F	A1, A2, B1, B2, B3, B4, B5	Tampa Bay Water Company and the Tampa Bay Regional Planning Council Don Manlapaz 727-570-5151			x	Water Authorities Municipalities	Low

18	Farmland Preservation	Focus agricultural preservation through zoning techniques in CARAs. When farms are preserved in these areas, the floodplains may be set aside for potential restoration to promote infiltration.	Use CARAs as priority lands for the County's agriculture conservation easements, the State's agricultural security area programs, and local growth management tools (TDRs, UGB/VGBs, etc.).	A,C,E,G	B1, B5, B7, B8, B9, B10, B19, E5, F1, F2, F4, G19	Lancaster County Agricultural Preservation Board Municipalities	x			Lancaster County Agricultural Preservation Board Municipalities	High
19	Critical Aquifer Recharge Area (CARA) Protection	The comprehensive plan may address protection of water recharge areas, particularly those within delineated source water protection areas, as part of a comprehensive open space plan.	1. Identify and map CARAs within each municipality 2. Identify and incorporate protection strategies for recharge areas that go beyond municipal and authority boundaries. 3. Consider Stream Assessment for reaches in this area and prioritize Watershed Assessment for regional SWM priorities.	A,B,C,E	A1, A2, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10, B11, B14, B17, C1, C2, C3, D5, E5, E6, F1, F2, G10, G11, G15, G17	Susquehanna River Basin Commission SRBC			x	Oversight Committee Municipalities	High
C	**Watershed Planning**										
	Tool	**Description**	**Activities**	**Issues**	**Related Tool**	**Source**	**Existing**	**Expanded**	**New**	**Responsibility**	**Priority**
1	Comprehensive Watershed Planning	Plans for all water resource issues (quality and quantity for surface water and groundwater including drinking water supplies, wastewater and sewage, and stormwater issues) holistically on a watershed basis. Measures include wellhead protection ordinances, riparian buffers, BMP measures for stormwater, recreation and trail development, etc.	Expand on existing watershed plans to incorporate the findings from this study. Goal is to determine the interrelationship between surface and groundwater resources and recommendations for prioritizing watershed restoration projects that could improve the sustainability of the groundwater supply.	A,B,C,G	B1, B7, B8, B9, B10, B11, B19, C1, C2, C3, E5, F1, F2, F5, F6, G8, G9, G10, G13, G15, 16, G17, G18, H1, H2, H3, H4	Rapid Watershed Planning Handbook "A Comprehensive Guide for Managing Urbanizing Watersheds" 'Center for Watershed Protection, Oct 1998 Local Models: Cocalico Creek Watershed Assoc. Hammer Creek Watershed Assoc. Lititz Run Watershed Alliance Chiques Creek Watershed Association			x	Watershed Associations	High
2	Stream Assessment	Identify through historical documentation lost streams or stream reaches located in the CARA's that have been affected by current or historical activities such as mill dams, ponds, stream channel relocations, etc., and where a site investigation provides any of the characteristics described under "Activities." Since all the streams in the NLCWBP area have been altered from historic activities, it may be the most efficient to consider stream assessments on all the streams within each designated watershed and prioritize work on the CARA's and losing / perched stream systems.	A site investigation by a professional water resource engineer experienced in stream / floodplain restoration should assess and locate reaches that include the following characteristics: Channel bed and banks consisting of cohesive sediments that have accumulated between the top of the floodplain and the pre-settlement gravel/bedrock interface. Channels that convey increased flows or precipitation events without accessing the floodplain. Straightened channels that occupy a small portion of the valley or have significant reaches located along the valley wall. Groundwater seeps from hill or valley slopes that discharge directly into the channel. Groundwater seeps that discharge into the channel at higher elevations than the channel bed or normal flow elevations. Stream reaches that do not have the pre-settlement gravels or floodplain visible along the toe of the channel banks in the riffle locations. Sewer discharge or storm drain outfalls discharging directly to the channel. Reaches where large areas of the floodplain are available for frequent recharge of the groundwater.	A,C	A1, A2, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10, B11, B14, B17, C1, C2, C3. D5, E5, E6, F1, F2, G10, G11, G15, G17	LandStudies, Inc. 315 North Street Lititz, PA 17543 717-627-4440			x	Water Planning Team Watershed Association Municipality	High
3	Floodplain Restoration	Floodplains provide an opportunity to reconnect surface water with groundwater stores.	1. Adopt a floodplain ordinance that protects the floodplain from obstructions, while allowing the opportunity for restoration activities that may reduce flooding and improve infiltration and groundwater recharge while creating recreational opportunities and habitat diversity. 2. Floodplain ordinance amendment considerations are included in the appendix.	A,C	A1, A2, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10, B11, B14, B17, C1, C2, C3, D5, E5, E6, F1, F2, G10, G11, G15, G17	LandStudies, Inc. 315 North Street Lititz, PA 17543 717-627-4440		x		Municipality	Medium

D Urban Growth Areas

	Tool	Description	Activities	Issues	Related Tool	Source	Existing	Expanded	New	Responsibility	Priority
1	Stormwater Retrofit Strategies	In many urban or fully developed suburban areas, either there is no infrastructure in place to address stormwater runoff or previously installed structures have not been maintained and no longer serve the purpose for which they were intended.	1. Provide guidelines for voluntary maintenance and for retrofitting existing structures to provide infiltration or water quality benefits. The benefit to land owners is improved aesthetic, lower maintenance, and reduced property damage. 2. Inventory locations where stormwater management facilities have failed and are contributing to urban stream degradation or are no longer functioning. This includes erosion at pipe outflows and runoff damage to private and public property. 3. If the condition is affecting public property or water resources, consider outside funding sources to restore and stabilize the facility or infrastructure. 4. Explore Funding options for a retrofitting program	A	C1, B7, F5, F6	Center for Watershed Protection, Community Stormwater Retrofitting.			x	Local Watershed Group or Association Municipalities	Low
2	Land Recycling (Brownfields Redevelopment)	The Land Recycling Program, administered by DEP, promotes urban revitalization by limiting the environmental liability associated with redeveloping vacant industrial and commercial sites. The program provides incentives for former industrial properties to be returned to productive use. Re-use of existing development keeps new development out of open areas, reducing the increase in impervious surfaces.	ID sites with potential for redevelopment and encourage re-use of these sites by streamlining the review process, especially for sites within designated growth areas.	A	B1	PA-DEP Brownfield Action Team Application www.dep.state.pa.us, Keyword: "Brownfields,"	x			Municipality	Low
3	Community Parking Facilities / Garages	Development of publicly owned and operated parking facilities to remove or significantly reduce parking requirements for infill and/or new mixed-use developments.	Encourage shared structural, multilevel parking to reduce impervious cover in central business districts.	A	B1	Lancaster County Comprehensive Plan Growth Management Element Update			x	Municipality	Low
4	Combined Sewer Overflow (CSO)	The goal is to reduce the burden on the public sewer system by removing stormwater flows into the sewer system.	Inventory and develop retrofit strategy for older neighborhoods.	A, D	B1, B3, B11	"Reducing Combined Sewer Outflows" University of Maryland	x			Municipality	Medium
5	Water Recycling	Encourage water recycling in all areas of existing and proposed development (residential, commercial, and industrial). Water re-use and conservation through recycling could significantly improve sustainability of water resources.	Provide guidelines for homeowners to detach their downspouts and store the water for re-use in rain barrels, tanks or cisterns. Provide ordinances that promote water recycling in commercial and industrial operations such as car washes.	A,E	A1, A2, B1, B19, C1, G17, G24,	SRBC *Local Model:* Ephrata Borough Car Wash Sec 319.76 W	x			Municipality	High

E High-Density Karst Areas

	Tool	Description	Activities	Issues	Related Tool	Source	Existing	Expanded	New	Responsibility	Priority
1	Hydrogeologic Investigations	Any land development proposed for sites where high-density karst is located should consider special site investigations to identify vulnerabilities related to karst on and surrounding the site, how the development will influence the karst features, and what will be done to mitigate potential failures in the form of sinkholes. This information will allow the municipality to make informed decisions about the proposed land development and proposed SWM.	<u>Preliminary Investigation</u> - Review historical aerial photography and published maps of karst features If visible depressions are observed additional investigation, standard penetration testing (SPT) may be necessary to determine if the observed depressions were past sinkholes that had been filled in, or if they were simply topographic depressions. <u>Detailed Investigation</u> - Electromagnetic (EM) and seismic refraction surface geophysical surveys may be necessary to identify subsurface soil and bedrock anomalies; Cone Penetrometer Technology (CPT) logging of subsurface soil hydrogeologic and geotechnical properties; and GeoProbe® direct push soil sampling to characterize the subsurface with regard to carbonate geology issues. These techniques may be employed on site at the same time to gather information on the subsurface for use in addressing the infiltration of stormwater as part of the NPDES Phase II permitting process.	B	A2, B1, E2, E3, E4, E5, F6	Lancaster County Conservation District Alternative Environmental Solutions 930 Pointview Avenue, Suite B Ephrata, PA 717-738-7272		x		Municipality	High

2	Stormwater Management in High Density Karst Locations	A hydrogeologic investigation is the first step toward stormwater management and erosion and sediment control design in areas designated as high-density karst. The most important considerations during design are to replicate existing drainage patterns as closely as possible and to dissipate overland flows over the largest possible areas. Waterway designs should be shallow, broad and provide maximum bottom width and wetted perimeter to disperse flow over the greatest area.	Consider amendments to stormwater and E&S ordinances to reflect the following points: 1. Minimize modifications to site topography and soil profiles. 2. Where practical, drainage facilities should consist of embankments at or above grade. Temporary and final grading of the site should provide for drainage away from known karst areas. 3. All SWM facilities should be designed to disperse the flows across the broadest channel area possible. 4. Shallow, trapezoidal channel cross-sections are preferred over V or parabolic- shaped channels. 5. Sediment basins and traps should be used as a last resort for sediment control. 6. Basin profiles should be broad and flat to allow maximum dispersion of detained flow. Basin bottoms should be smooth to avoid ponding. 7. Avoid concentrated flows. Inlet / outlet structures should be designed to provide diffuse discharge of water. 8. Use underdrains to encourage gradual discharge of water and to avoid prolonged ponding of water.	A,B	A2, B1, E2, E3, E4, E5, F1, F2, F6	Lancaster County Conservation District Virginia Department of Conservation and Recreation - Hydrologic Modeling and Design in Karst Stormwater Management Plan for the Spring Creek Watershed Sweetland Engineering and Assoc. State College, PA 814-237-6518		x		Municipality	High
3	Construction in High Density Karst Locations	Site design and construction procedures are important components of sinkhole development. Sinkholes most often form in areas where storm-water runoff is concentrated, where bearing loads are concentrated, and where ground water is pumped in large volumes.	Minimize site disturbance, including cut/fill and drainage alteration. Minimize impervious surface, waterproof pipe-fittings and pipe-to-basin fittings to reduce the potential for leaks. Place foundations on sound bedrock.	B	A2, B1, E2, E3, E4, E5, F6	Virginia Department of Conservation and Recreation - Hydrologic Modeling and Design in Karst		x		Municipality	Medium
4	Response and Remediation of Sinkhole Occurrence During Construction	Sinkholes that occur during construction should be repaired immediately to prevent enlargement and associated adverse impacts.	Report the occurrence to the approving authority within 24 hours. Halt construction activities in the immediate area of the sinkhole. Stabilize and secure the area. Direct surface water away from the sinkhole area to a suitable storm drain system. The hydrogeologist who performed the hydrogeologic investigation for the site should be contacted to assist with determining the best method of remediation.	B	A2, B1, E2, E3, F6	Virginia Department of Conservation and Recreation - Hydrologic Modeling and Design in Karst		x		Municipality	Medium
5	Regional Stormwater Management	In high-density karst areas, one consideration is to address SWM, particularly NPDES II infiltration requirements, off-site in a regional approach. Municipalities may consider these facilities as part of ACT 167 planning and prioritize off-site regional SWM facilities for future land development sites in high-density karst areas. The location of the facilities may could be prioritized in the CARA's if available within the drainage watershed for the site.	Locations for regional SWM facilities are or will be identified as part of the Watershed Assessment for regional SWM priorities.	A, B	A2, B1, E2, E3, F6	Lancaster County Engineering Office LandStudies, Inc. 315 North Street Lititz, PA 17543 717-627-4440			x	Municipality Watershed Associations	High
6	Geologic Hazards Areas	Geologic Hazard Areas differ from other environmentally sensitive or high-density karst areas in that the latter descriptions are too broad to include the site-specific descriptions associated with Geologic Hazard Areas. Additional maps and information regarding site-specific descriptions are necessary to define an area with geologic hazards. These hazards may include caves within the rock strata that are close to the land surface, existing sinkholes, or failures.	Define Geologic Hazards for the study region. Identify locations of existing GHAs using existing mapping, known sites, aerial infrared data, and depth to bedrock information. These maps may then be used as a guide for future development and for a more site-specific understanding of the high-density karst areas. This work would reduce some of the work associated with the hydrogeologic investigations required for new development.	B	A1, A2, B1, B6, B7, B8, B11, B14, B17, C1, C2, C3, E5, F1, F6, G10, G11	Ordinance for the Control of Urban Development in Sinkhole Areas in the Blue Grass Karst Region, Lexington, KY James Dinger and James Rebmann			x	Municipality	Low
7	Managing Existing Sinkholes	Existing sinkholes are a direct connection to groundwater sources. For this reason, landowners need to be educated about the importance of protecting existing sinkholes and what to do in the case one should appear on a property.	If the sinkhole is in the vicinity of or could damage existing structures, it is recommended that a Hydrogeologist, or other professional with experience in sinkhole remediation is hired to assess the situation and make expert recommendations on the remediation technique. If the sinkhole is in an area where it will not damage surrounding property, the best approach is to stabilize the area and protect the sinkhole from intrusion with fencing or planting. If water is draining into the area, re-route the flow away from the sinkhole and protect the sinkhole from any fill or hazardous materials.	B	A2, B1, E2, E3, E4, E5, F6	Alternative Environmental Solutions 930 Pointview Avenue, Suite B Ephrata, PA 717-738-7272			x	Municipality Land Owners	Medium

F	**Stormwater Management**										
	Tool	**Description**	**Activities**	**Issues**	**Related Tool**	**Source**	**Existing**	**Expanded**	**New**	**Responsibility**	**Priority**
1	Assessment for Regional SWM Locations	A watershed assessment that integrates information compiled as part of ACT 167 and the results of this study to address stream conditions and determine the best location for priority activities that provide multiple functions such as SWM, flood control, nutrient management, habitat restoration, recreation opportunities, etc.	A site investigation by a professional water resource engineer experienced in stormwater management on a watershed basis should assess and locate areas for SWM based on the following priority areas: Priority 1: Regional stormwater management initiatives for quantity control requirements associated with new development should be performed in identified critical/high-recharge areas of stream corridor floodplains within identified surface water watershed boundaries. Using a floodplain/stream restoration approach to meet quantity control requirements provides the most effective approach for maximizing groundwater recharge and reducing regional peak discharges in stream reaches that have been affected by current or historical activities such as mill dams, ponds, and stream channel relocations/straightening. (See Stream Assessment Tool above.) Priority 2: In developing areas of low recharge potential, traditional stormwater management initiatives should be implemented on site or in upland areas after the receiving waters and floodplains have been restored as identified in Priority 1.	A	A2, B1, B5, B6, B7, B8, B19, C1, C2, C3, E5, F2, F4, F6	LandStudies, Inc. 315 North Street Lititz, PA 17543 717-627-4440			x	Lancaster County Municipality	High
			Priority 3: In developing areas of high recharge and underlying karst geology, on-site stormwater management initiatives should focus on improving water quality through the use of bioretention, vegetated filter strips, bioswales, lined wet ponds, etc. In these developing areas, retaining detained and/or infiltrating stormwater for volume control should not be permitted.								
2	Regional Stormwater Management	One approach to SWM that is recommended by the ACT 167 watershed-wide Stormwater Management Plans Sub-regional (combined site) Storage. The difficulty with implementing regional (combined site) SWM is finding the appropriate site and willing land owners. A watershed assessment will provide the best locations and give the municipality locations to recommend to interested developers.	1. ACT 167 needs to be completed in the watershed where this tool is proposed. 2. A Watershed Assessment needs to be performed with the objective of determining locations for combined storage facilities. 3. Once these sites are located, prioritize according to availability (public lands, willing landowner, etc.) and relationship to future development areas and multi-site runoff. 4. Once the locations are prioritized, incentives for the off-site developers and the land owners of the proposed regional SWM facilities must be considered. Some examples may be a tool for SWM modeled after the TDR concept, see tool F4, Transfer of Stormwater Rights or tool B6, Open Space Land Acquisition.	A,F	A2, B1, B5, B6, B7, B8, B19, C1, C2, C3, E5, F1, F4, F6	Lancaster County Engineers Office LandStudies, Inc. 315 North Street Lititz, PA 17543 717-627-4440			x	Lancaster County Municipality	High
3	Stormwater Management BMP Management Authority	Long-term maintenance and management body that oversees the maintenance of the SWM BMPs in a municipality or for a water resource area.	Responsibility may be municipal or by a watershed group or other conservation group with active and willing membership. These groups are particularly well suited to understand the special maintenance needs of BMPs and associated natural areas. With creative funding sources, these groups could provide technical assistance and implementation. Funding sources include fees from homeowner associations, impact fees from developers, and fees from SWM utilities.	A	F2	Lancaster County Comprehensive Plan Growth Management Element Update			x	Municipality	Medium
4	Transfer of Stormwater Rights	Similar concept to Transfer of Development Rights, but in this case provides preferred locations (regional stormwater receiving areas) through the sale or lease of the development rights for the land. Stormwater rights are established for a given piece of land and can be separated from the title of that property. These rights can then be transferred to another location within the watershed to provide SWM or NPDES requirements for a proposed development in a designated growth area.	Locations for regional stormwater management receiving areas need to be determined as part of a Watershed Assessment. Once areas have been identified within the watersheds of designated growth areas, developers are provided the option to purchase the development rights or rental fee for using the land for SWM for the off-site development.	A,C	B1, B2, B3, B5, B7, B8, B9, B12, B13, B18, B19, E5, F1, F2, F4, G19				x	Municipality	Low

5	Minimum Disturbance/ Minimum Maintenance	Minimum Disturbance/Minimum Maintenance (MD/MM) - also called site fingerprinting or site footprinting - is an approach to site design in which the clearing of vegetation and the disturbance of soil are carefully limited to a prescribed distance from proposed structures and other improvements. MD/MM is especially appropriate for those sites with existing tree cover, although the vegetation to be conserved may include any type of natural vegetative cover.	Consider providing stormwater credits when MD/MM is used in open space for a proposed development.	A	F2, F3, G8	Cahill Associates, 104 South High Street West Chester, PA 610-696-4150			x	Municipality	Low
6	Stormwater Infiltration for Karst Areas - Alternative to Conventional Methods	Because traditional methods of ponding or impounding water are particularly vulnerable to collapse and failure in karst areas, the following alternative to not providing infiltration in karst areas is a viable model that address both short- and long-term objectives of SWM: a shallow, flat-bottom basin created in a suitable area, a minimum of four feet above existing bedrock or seasonal high water table as determined by soil borings. The bottom of the basin should be subtlety graded completely flat, thereby reducing ponding of water in certain areas. Vegetate the bottom of the basin with native species of trees, shrubs, and grasses. Use vegetation to promote groundwater recharge via conduits created by root system, reduce evapotranspiration, eliminate thermal heating of impounded water, and dramatically reduce ponding times. A well-established root system (mat) of the vegetation will promote surface stability, reducing the threat of sinkholes.	Determine from mapping and/or site investigation suitable areas for the proposed facilities. Conduct soil borings/subsurface data collection located within the limits of the proposed facility by an appropriate qualified professional to determine underlying rock and soil characteristics. Slopes greater than 15% should be avoided to minimize the disturbance to the site. The site should take advantage of the existing topography to the greatest extent possible, minimizing the disturbance to the existing soil profile. Embankments created at existing grade to develop the facility will be far more effective than excavation in karst areas.	A,B	F2, F3	Maryland Department of the Environment. 2000 Maryland Stormwater Design Manual Volumes I & II. New Jersey Department of Agriculture. New Jersey Soil Erosion and Sediment Control Design Manual. LandStudies, Inc. 315 North Street Lititz, PA 17543 717-627-4440			x	Municipality Developer	High
		The use of vegetation in the facility will virtually eliminate reduced rates of infiltration found in traditional facilities caused by the accumulation of sediments from run-off and can effectively treat excessive nutrients such as nitrogen and phosphorus and total suspended solids (TSS), including harmful heavy metals, before reaching nearby streams and wells. This facility will also eliminate overheated water found in traditional stormwater detention facilities from reaching nearby receiving waters, reducing the threat to downstream aquatic life. Increased groundwater recharge via use of vegetation in the facility will help maintain the hydrology of nearby streams and headwaters, the health of aquatic systems, and the drinking water supply, particularly during times of drought. Construction cost may be reduced by the use of existing topography. Technique eliminates the need for excessive excavation to install a clay/poly liner under the drain system. Maintenance costs will likely be reduced, because of the elimination of regular maintenance such as mowing and clean-out of accu	Subtle grading of the site to create a level bottom to the facility may be necessary to reduce ponding and promote even dispersion of runoff to the total surface area. Quickly establishing vegetation in disturbed areas will reduce overexposure and excessive drying of the soil. Trees and shrubs provide shade; they keep the ground cool and maintain a soil moisture balance.								
G	**Land Development**										
	Tool	**Description**	**Activities**	Issues	Related Tool	**Source**	**Existing**	**Expanded**	**New**	**Responsibility**	**Priority**
	Impervious Cover Reduction										
1	Streets	Residential streets are often unnecessarily wide, and these excessive widths contribute to the largest single component of impervious cover in a subdivision (CWP, 1998). By requiring narrower street widths based on a maximum width, the developer must prove why the additional width is necessary.	Revise street requirements to reduce impervious cover and promote infiltration of runoff. Street width ordinances may use standard, consistent street classification definitions and maximum street widths that are the minimum to accommodate safe travel lanes, maintenance, and emergency management. Allow utilities within ROW and under paving. Allow grass swales instead of curbs and gutters. Require sidewalks on only one side of the street. Reduce total street length by encouraging efficient use and layout.	A	G17	Recommended Model Development Principles for East Hempfield, West Hempfield and Manor Townships and Lancaster County, PA, Alliance for the Chesapeake Bay and the Center for Watershed Protection, March 2005		x		Municipality	Medium
2	Cul-de-sacs	Cul-de-sac turn-arounds provide an opportunity for infiltration of runoff in the middle of the turn-around while reducing the amount of impervious cover and allowing emergency access.	Cul-de-sac turnarounds should incorporate landscaped islands and bioretention in lieu of fully paved turnaround areas.	A	G17	Recommended Model Development Principles for East Hempfield, West Hempfield and Manor Townships and Lancaster County, PA, Alliance for the Chesapeake Bay and the Center for Watershed Protection		x		Municipality	Medium

3	Parking Ratios	Parking ratios determine the amount of parking allowed for various land uses or activities. Many times municipal parking ratios are based on national or outdated standards requiring too much parking for a particular use. The result is large expanses of unused or rarely used impervious cover.	The municipality should review and revise parking ratios to reflect actual parking demands. Consider setting parking ratios as a maximum instead of a minimum. Any additional parking could be defined as "overflow parking" for which alternative pervious paving surfaces should be considered, depending on the intensity of use.	A	G17	Recommended Model Development Principles for East Hempfield, West Hempfield and Manor Townships and Lancaster County, PA, Alliance for the Chesapeake Bay and the Center for Watershed Protection, March 2005		x		Municipality	Medium
4	Driveways	Studies show that 20% of the impervious cover in residential subdivisions can consist of driveways (Schueler, 1995). Consider allowing alternatives and limiting the amount of impervious cover on a lot.	Require a maximum amount of a single family home driveway to be impervious and any additional paving to be porous surface. A 3,000 square-foot maximum may be sufficient for most single family homes on a one-acre lot. Encourage shared driveways, especially on flag lots, and reduce minimum driveway widths to 9' for one way and 20' for double lane.	A	G17	Recommended Model Development Principles for East Hempfield, West Hempfield and Manor Townships and Lancaster County, PA, Alliance for the Chesapeake Bay and the Center for Watershed Protection, March 2005		x		Municipality	Medium
5	Parking Lots	Parking lots are the largest component of impervious cover in most commercial and industrial zones, but conventional design practices do little to reduce the paved area in parking lots (CSP, 1998).	Reduce the amount of imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, and using pervious materials in overflow or spillover parking areas. Wherever possible provide treatment for parking lot runoff using bioretention areas or filter strips integrated into landscaped islands.	A	G17	Recommended Model Development Principles for East Hempfield, West Hempfield and Manor Townships and Lancaster County, PA, Alliance for the Chesapeake Bay and the Center for Watershed Protection, March 2005		x		Municipality	Medium
6	Model Legal Agreement for Shared Parking	Shared parking should be considered wherever possible, especially in urban centers and suburban commercial/industrial zones.	A template agreement for a shared parking easement.	A	G17	Olympia Municipal Code, Olympia, WA		x		Municipality	Medium
7	Porous Asphalt Paving	Porous asphalt paving is being used throughout southeastern Pa. with successful results. These systems provide flexibility in design to accommodate various soil, geologic, and hydrologic conditions while providing infiltration over a broader area. Porous paving surfaces combined with bioretention for overflow provide a reasonable alternative to conventional impervious paving.	Allow alternative porous paving wherever the use permits, especially in low-intensity, infrequent uses or overflow parking areas. Consider porous paving swales in less intensive areas of parking lots that overflow into bioretention facilities.	A	G17	Cahill Associates, 104 South High Street West Chester, PA 610-696-4150 Harbor Engineering 41 South Main Street Manheim, PA 717-665-9000		x		Municipality	High
	Open Space Protection										
8	Building Envelope Limitations	On lots larger than one acre, extensive open space outside of the building envelope is converted to lawn or other ornamental landscaping, which reduces the infiltration potential of each lot.	Consider ordinance language that encourages native meadow or reforestation outside of the building envelope, especially the rear yard if it abuts existing farmland or other natural environment (forest, wetland, pond, stream, etc.) This reduces maintenance, provides buffers, and encourages infiltration.	A	F5	The Homes at Wyncote Design Guidelines Lower Oxford Township, Chester County, PA Haines Township Subdivision and Land Development Ordinance, Centre County, PA		x		Municipality	Medium
9	Forest Conservation	A process for urban greenspace protection during the development process. Individual sites proposed for development are assessed and thresholds for clearing, afforestation, and reforestation are established based on the net tract area, land use category, existing forest cover, and proposed clearing area. Long-term protective instruments are required to ensure that the retained area will remain forested.	Forest Stand Delineation and preparation of Forest Conservation Plans as a means of identifying existing forest stands on a site and mitigating the impact of removal and development either on the site or within the watershed.	A	F5, B7, G17, G18	Maryland State Forest Conservation Act		x		Municipality	Medium
10	Open Space Development / Conservation Zoning	Allows subdivision of smaller lot sizes than typically allowed in rural areas with a minimum open space requirement (usually 50%).	Each township should adopt an Open Space or Conservation Development Ordinance as a by-right form of development within designated zoning districts. A detailed list of design standards pertaining to the quality, quantity, and configuration of open space is important. Consider eliminating a minimum lot size and establish a net density with a minimum amount of open space.	A	B1, B2, B16, B19, G11, G17, G18, G20	"Growing Greener Conservation by Design" Natural Lands Trust Hildacy Farm 1031 Palmers Mill Road Media, PA 19063 610-353-5587		x		Municipality	High
11	Dedicated Easements	Voluntary dedication of open space or agricultural easements to a public entity or qualified private land conservation organization. The landowner still owns the property; however, the land must remain in farming or open space in perpetuity.	To cover their cost in maintaining the land they own or in monitoring the land on which they hold easements, land trusts typically require some endowment funding. When conservation zoning offers a density bonus, developers can donate the proceeds from the additional "endowment lots" to such trusts for maintenance or monitoring. In some situations, a local government might desire to own part of the conservation lands within a new subdivision, such as when that land has been identified in a municipal open space plan as a good location for a park or open space link. Developers can be encouraged to sell or donate certain acreage to municipalities through additional density incentives, although the final decision would remain the developer's.	A	B1, B2, B16, B19, G10, G17, G18, G20	Brandywine Conservancy PO Box 141 Chadds Ford, PA Natural Lands Trust Hildacy Farm 1031 Palmers Mill Road Media, PA 19063 610-353-5587		x		Municipality	Medium

12	Green Building Technology	Environmentally sustainable building design that includes use of energy-efficient materials, recycled materials, solar energy, and structural and mechanical components that save utility costs over the life of the structure and have minimal impact on the environment.	Encourage the U.S. Green Building Council's Leadership in Energy Efficient Design (LEED) program certification based on a rating system for buildings and land development on a municipal level. Review the requirements of LEED and target elements that protect groundwater recharge and promote water recycling and other methods for protecting water resources.	E	D5, G17	United States Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) www.usgbc.org		x		Municipality	Medium
13	Riparian Buffer Regulations	Some municipalities incorporate riparian buffers as an Overlay Zoning District, while others provide only guidelines for voluntary establishment. The important consideration is to provide a required setback from a water course, stream, or drainage swale and to discourage locating structures or other man-made features in these areas. These areas should also be set aside for potential future restoration work that may be necessary to stabilize the stream system. Revegetation is only temporary if the stream reach is actively moving and is characterized by deep cutting.	Using the Stream Assessment as a basis, determine the sections of streams where legacy sediments and clay layers limit infiltration, and prioritize these stream reaches for riparian buffer easements for potential future restoration work. Also determine the most stable stream reaches where short-term revegetation would be the least vulnerable.	A	B1, B2, B16, B19, G11, G17, G18, G20	Rapho Township Zoning Ordinance Section 326 East Cocalico Township Zoning Ordinance Section 233 Pennsylvania Organization for Watersheds & Rivers 610 North Third St. Harrisburg PA 17101 (717) 234-7910		x		Municipality	Medium
15	Buffer Ordinance	Create a general buffer ordinance, applicable to various uses, that incorporates native plant material and accommodates multiple objectives, including visual breaks, stormwater management, infiltration, greenways, and trails. Buffers may have various uses (residential and agricultural, for example) adjacent to streams, steep slopes, wetlands, etc. and may also serve as links to other buffers or natural areas.	Determine types of uses and buffers along with minimum widths for each type of buffer. For example, the minimum width for a riparian buffer may vary depending on the size or order of the stream. A list of native plants to be used in each buffer type, along with the required spacing, should be included. Spacing of the material should directly relate to the size of the plants installed. A base groundcover should be established for each buffer type. Maintenance guidelines describing types of invasive plants and their removal are a vital component of this ordinance.	A	B1, B2, B16, B19, G11, G17, G18, G20	Recommended Model Development Principles for East Hempfield, West Hempfield and Manor Townships and Lancaster County, PA, Alliance for the Chesapeake Bay and the Center for Watershed Protection, March 2005		x		Municipality	Low
16	Floodplain Restoration Amendment to Floodplain Protection Ordinances	Floodplains and streams are many times the only available open space left in developed urban areas. Typically these systems are stressed by the dramatically altered hydrologic systems. These areas must be protected, but at the same time provide excellent opportunities to restore the floodplain and reclaim storage volumes and stream stability. Many municipalities are currently revising their floodplain ordinances to meet new FEMA requirements. When making revisions, consider allowing uses within the floodplain that relate to restoration work while protecting the floodplain from encroachments.	Adopt a floodplain ordinance that protects the floodplain from obstructions, while allowing the opportunity for restoration activities that may reduce flooding and improve infiltration and groundwater recharge while creating recreational opportunities and habitat diversity.	A,C	B1, B2, B16, B19, C1, C2, C3	LandStudies, Inc. 315 North Street Lititz, PA 17543 717-627-4440		x		Municipality	High
17	Steep Slope Conservation District	An overlay of any zoning district with slopes of 20 - 30% and greater. Steep slopes are often adjacent to streams and in wooded areas. Restrictions such as a minimum building envelope or lot size to prevent erosion and removal of vegetation may be warranted if the entire lot is in the Steep Slope District. Provide a list of acceptable slope stabilization plantings that are native and not invasive while providing quick cover.	Designate protection for slopes > 30%. Provide plant list and specifications for planting methods in a guideline format for stabilizing slopes >30% for new construction and any time disturbance eliminates cover. Consider building-envelope or lot-size restrictions if lots are located entirely or partially within the Steep Slope Overlay District.	A	B1, B7, G17,G18	Natural Resource Protection Standards Section 115-43 Steep Slope Conservation District East Bradford Township, PA		x		Municipality	Low
18	Low Impact Development (LID) Standards	LID is an ecologically friendly approach to site development and stormwater management that aims to mitigate development impacts to land, water, and air. The approach emphasizes the integration of site design and planning techniques that conserve the natural systems and hydrologic functions of a site.	Incorporate elements of LID into local zoning ordinances.	A,E	A2, D5, F5, F6,G1, G2, G3, G4, G5, G6, G7, G8, G9, G10, G12, G13, G14, G18	Governor's Green Government Council www.gggc.state.pa.us www.lowimpactdevelopment.org		x		Municipality	High
19	Management of Existing Vegetation	Native plant communities provide a vital role in infiltration capabilities of surface runoff. For this reason, it is important to consider standards for preserving existing woodland and established native plant communities and encouraging the establishment of natural meadows and woodlands in residential areas.	Conserve woodlands, hedgerows, and other naturally occurring established plant systems. Protect vegetation from mechanical injury, excavation, and fill. Establish maintenance standards in residential areas. Selectively control noxious vegetation and manage natural areas that include woodlands, meadows, and sensitive areas such as wetlands and floodplains. Also establish standards for maintenance of vegetation in residential areas that allow for natural meadows while considering proper maintenance to control invasive material.	A	B7, B14, B19, C2, C3, D1, E7, F2, F3, F6, G8, G10, G13, G14, G16, H1, H2, H3, H4	Natural Resource Protection Standards Section 115-45 Management of Existing Vegetation East Bradford Township, PA		x		Municipality	Medium
20	Purchase of Development Rights	Allows landowners to sell development rights to either the County's Agricultural Preserve Board (Conservation Easement Program) or a qualified private land conservation organization. The landowner still owns the property; however, the land must be maintained in farming or open space in perpetuity.	This tool has been successfully implemented in most of the townships within the study area, but only Warwick Township has incorporated the purchase of development rights into a TDR program.	A,C	B1, B2, B3, B5, B7, B8, B9, B12, B13, B18, B19, E5, F1, F2, F4, G19	Warwick Township Zoning Ordinance Section 322 Transfer of Development Rights Lancaster Farmland Trust 128 East Marion Street Lancaster, PA 17602 717-293-0707		x		Municipality	Medium
21	Expedited Approval Process	Faster review of and permit issuance for proposed projects that are compliant with smart codes and smart growth goals and objectives.	Consider making Conservation Development or Open Space Development a by-right use to encourage and expedite approvals.	D,E	C3, E1, E2, F2, G10, G17,	Recommended Model Development Principles for East Hempfield, West Hempfield and Manor Townships and Lancaster County, PA,		x		Municipality	Low
	Water Supply and Disposal										

22	Interconnection of Nonpublic Water and Sewage Systems	Regulations for central water system and/or sewage system to serve five or more dwelling units. This system is NOT part of a municipally-owned water and/or sewage system at the time of initial occupancy.	Management party must be identified along with inspection schedule and responsibility.	G	B11, B12, B13, G23, G24, G25	Mount Joy Borough Code		x		Municipality	Low
23	Aquifer Test Requirements	Prior to the installation of any new water system or subdivision of land into lots that would be served by individual wells in the area or in proximity to areas of known groundwater contamination or inadequate yields of potable supplies, aquifer and water quality tests shall be performed. This test should be required in stressed areas (where the demand exceeds the supply).	Include Aquifer Test Requirements for new water systems or the subdivision of land into lots served by individual wells. Prioritize this requirement in stressed areas identified as part of the NLCWBP.	D	B11, B12, B13, G22, G24, G25	Lancaster County Subdivision and Land Development Ordinance Section 609.03		x		Municipality	High
24	Water Needs Analysis / Water Feasibility Analysis	The applicant shall submit an analysis of raw water needs (groundwater or surface water) from either private or public sources along with a water feasibility analysis to enable the municipality to evaluate the impact of the proposed development on the groundwater supply and on existing wells	Prioritize this analysis for sites with CARAs and in stressed areas as identified as part of the NLCWBP.	D,G	B11, B12, B13, G22, G23, G25	West Cocalico Township Zoning Ordinance Sec 55.q page 153 Mount Joy Borough Code Section 119-16		x		Municipality	High
25	Water Supply	Whenever an existing or approved water system is accessible to a proposed project, a distribution system shall be provided to furnish an adequate supply of water to each unit.	Require a Water Needs Analysis or Feasibility Study as part of this Ordinance.	D,E	B11, B12, B13, G22, G23, G24,	B11, B12, B13, G23, G24, G25	x			Municipality	Medium
26	Well Construction Standards	Pa. is one of only four states that does not have construction standards for private wells. Unlike community water systems, which are permitted and strictly regulated by the state, private water systems are constructed, tested, and treated by the homeowner.	Provide regulations that require new wells to be constructed with a sanitary cap, as well as shock chlorination following construction of the well, and grout seal on new well construction to reduce *E. coli* contamination.	D,E	B11, B19	Center for Rural Pennsylvania 717-787-9555 info@ruralpa.org		x		Municipality	Medium
27	Well Capping / Abandonment	Unsealed or improperly sealed wells may threaten public health and safety and the quality of the groundwater resources. The proper abandonment (decommissioning) of a well is a critical first step in its service life.	1. Eliminate the physical hazard of the well. 2. Eliminate a pathway for migration of contamination. 3. Prevent hydrologic changes in the aquifer system, such as the changes in hydraulic head and the mixing of water between aquifers. The method of decommissioning a well will depend on both the reason for abandonment and the conditions and construction details of the boring or well. Enlist the services of a professional well driller, licensed in Pa., to perform these services.	D,E	B11, B19	ACT 610, the Water Well Drillers License Act "Water-well Abandonment Guidelines" Ground Water Monitoring Guidance Manual, PA DEP. Mount Joy Township's Capped Sewer Ordinance	x			Municipality	Medium
28	Site Plan Review Checklist for Groundwater Protection	The standards include a basic list of groundwater protection site plan review standards. The model is based on those prepared by the consulting team for the Michigan Society of Planning Officials groundwater protection project. These standards need to be revised with respect to individual municipal ordinances and Pa. state laws and are not intended to exceed state laws in stringency.	Determine if the proposed land development includes any of the following: loading/unloading/handling/storage/parking areas for hazardous substances, floor drain use and routing, secondary containment, underground storage tanks, solid waste disposal, emergency response contingency plan, or any other hazard that could impact the groundwater supply.	F,G	B11, G22, G23, G24	Michigan Society of Planning Officials "Site Plan Review Checklist for Groundwater Protection"			x	Municipality	Low
H	**Landowner Opportunities**										
	Tool	**Description**	**Activities**	**Issues**		**Source**	**Existing**	**Expanded**	**New**	**Responsibility**	**Priority**
1	Managing Small Vernal Ponds	Maintaining a healthy pond is challenging because it contains a complex aquatic ecosystem that can be unbalanced by livestock, waterfowl, or runoff from surrounding lands. Many of the ponds in the study area are maintained for water storage and are perched systems with limited aquifer recharge potential. Although in some cases these ponds, if vernal in nature, may provide recharge, it is important to consider the management and health of these eco-systems.	Preliminary Assessment and Monitoring to understand the land uses and drainage area that contribute to the pond. Maintain dams and standpipes to maintain water levels and prevent erosion. Establish a riparian buffer to protect the shoreline, prevent erosion and discourage Canada geese. Create a Pond Management Plan - ID services and resources provided by the pond and its uses and determine a management approach with technical assistance.	G	B19, C1, G18	"Ecologically Based Small Pond Management" report by West Chester University (Fairchild and Velinsky, 2004)			x	Land Owners	Low
2	Natural Landscaping	Bayscapes are environmentally-sound landscapes benefiting people, wildlife, and the Chesapeake Bay. Bayscaping advocates a holistic approach to landscaping through principles inspired by relationships in the natural environment.	Plant conventional landscapes with low-input landscaping (reduced mowing, fertilizing, and pesticide use) that uses native plant material.	A	B19, C1, G18	Alliance for the Chesapeake Bay "Bayscapes - PA" Rebecca Wertime (717) 737-8622		x		Land Owners	Low

3	Managing Land Adjacent to Streams and Waterways	Educational information from the USDA Forest Service about the importance and methods for taking care of property adjacent to streams. Of the 83,161 miles of rivers and streams in Pa., approximately 85% are small, headwater streams. Protecting small streams is crucial because they often influence drinking water sources.	Protect the stream and floodplain from fill, obstructions, and structures. Establish a streamside buffer (riparian buffer) consisting of native trees, shrubs, or other plants as a transition area between the stream and upland areas. Don't try to fix the stream without the assistance of a professional water resource engineer with experience in stream system maintenance and geomorphology.	A	B19, C1, G18	PA DEP USDA Forest Service 814-723-5150		x		Land Owners	Low
4	Conservation Reserve Enhancement Program (CREP)	CREP is a federal/state partnership with a goal of enrolling 100,000 acres of cropland and pasture in conservation plantings to improve water quality and provide wildlife and fisheries habitat. This program provides plant material and installation and rents the non-productive land at a yearly per-acre rate. Planting trees in CRAs may reduce evapotranspiration and provide root zone conduits for infiltration through impenetrable layers.	Educated landowners adjacent to streams, watercourses and within the CRAs about the benefits of this program.	A	B14, B18, B19, C1, G18	NRCS Lancaster Office 717-299-1563	x			Land Owners	Low