CDM

Appendix I
Delaware River Basin Commission

Methodology for Statewide Water Demand Forecast with Pilot Study

November 2005

Contents

Section 1
Introduction

This report presents the results of a project directed by the Delaware River Basin Commission to develop a water demand forecasting methodology applicable to the Commonwealth of Pennsylvania. The demand forecasting methodology addresses future water demands in the key water use sectors of:

- Public Water Supply
- Industrial
- Mining
- Thermoelectric Power
- Hydroelectric Power
- Agriculture

Section 2 presents a review of potentially applicable water demand forecasting methodologies, a review of statewide data available in Pennsylvania to support water demand forecasting, and a set of recommended water demand forecasting methodologies for the key water use sectors. The set of recommended methodologies were selected to optimize available data and support the Pennsylvania State Water Plan as well as identification of Critical Water Planning Areas. This section of the report was previously submitted to DRBC in its entirety as the *Task 1 Methodology Report*.

Section 3 of this report presents a pilot application of the set of water demand forecasting methodologies recommended in Section 2. The pilot application of the methodologies was implemented for the Lehigh River Basin. This pilot application allowed testing and refinement of the recommended methodologies outlined in Section 2 and resulted in modifications and improvements to the set of recommended methodologies. The pilot application presented in Section 3 is an application of the set of models at a basin level. Further modifications to the methodologies may be required when the models are applied at a different geographic level.

Section 4 presents a description of the automated water demand forecasting tool developed in conjunction with this effort. The automated forecasting tool was created in Microsoft Excel® and is submitted to DRBC with this report. The automated water demand forecasting tool was used in estimating future water demand for the Lehigh River Basin the pilot study as described in Section 3.

Section 2 - Methodology Pilot Study Report

Water Demand Forecast for
Lehigh River Basin

CDM

Section 2
Water Demand Forecasting Methodologies for Pennsylvania
Executive Summary

Accurate forecasts of future water demand are essential to evaluate the future adequacy of water supplies, and they are critical in managing the future need for water by the many categories of use. The water resource planning literature identifies several generalized ways to analyze and describe water demands for the purposes of forecasting. Water demand forecasting techniques rely on established theories that are based on historic observations of water use behavior.

Water demand is driven by demographic trends in population, housing, and employment, as well as economic activity and the broader demand and supply for goods and services. These factors vary geographically, and the demand for water can be analyzed and expressed sectorally and spatially. Furthermore, the patterns of water use are affected by long-term climate conditions and short-run fluctuations in weather conditions, as well as technological factors related to production processes and water use efficiency.

Broadly defined, there are four methodological options for forecasting water demand:

- Trend extrapolation – extending historic water demand trends, without constraint.
- Per capita method – determining water demand based entirely on change in population.
- Disaggregated factor forecast approach (per unit use is fixed) – determining water demand separately for residential and non-residential water use sectors.
- Functional (modeled) unit approach (per unit use varies by influencing factors) – where economic and climate factors, for example, influence the water use factor. The functional model often takes a multivariate form.

The first two methods do not incorporate information regarding the full range of factors that create water demand. They blindly assume continuation of past trends and water use practices, or assign all demand trends to only one category of use (residential).

The third method, the disaggregated factor forecast method, separates water demand into the principal water use sector (i.e., residential, manufacturing, non-manufacturing, agricultural, etc.) and permits each sector demand to be forecast independently. The fourth method, the functional unit approach, often in a multivariate form, estimates the per unit use of each sector given the influences of known factors that affect sector water demand.

The choice of a particular forecasting methodology for any set of water using sectors is strongly influenced by the data that is available to evaluate and model the relationships among demand determinants for each of many sectors of water use. The availability and quality of data to support the development of models typically serves as a practical constraint on the ability to employ specific water demand forecasting methods. This report surveys existing information on historical water use, housing, income, employment, agricultural irrigated acres, livestock, mining, power generating capacity, weather, and other factors related to water use in Pennsylvania to help identify forecasting methods that can be supported by available data. Currently, data availability for Pennsylvania can be characterized as marginal in its ability to support sophisticated demand forecasting methods. It is expected that significantly expanded data availability created by Pennsylvania's Act 220 legislation, which calls for the development of a State Water Plan and water use registration program, will allow significant increases in the accuracy and effectiveness of demand forecasts in the near future.

While existing data to support demand forecasting may be somewhat limited, new data collection efforts are providing significant increases in scope and detail with respect to water use characteristics. A set of demand forecasting methodologies are recommended that are both implementable now and are expandable to benefit from the availability of new demand information. A generalized model is recommended for forecasting the water demand of each sector for Pennsylvania. This model includes parameters for water use per unit of demand, and the number of existing and future units of demand. A modified version of this model is also recommended which includes an adjustment factor for climatic conditions and an adjustment factor for water use efficiency.

The recommended forecasting methodologies introduce several improvements to past demand forecasting approaches and provide significant improvement in the accuracy of the projected volume of demand, and the geospatial accuracy of demand, throughout the state. Specifically, the recommended methodologies include:

- A disaggregated water demand forecasting methodology for Public Water Systems that projects separately the residential and non-residential water demand. This method captures changes in the characteristics of business-related water demand for the state, and is a significant improvement over the per capita approaches previously employed.

- A new agricultural demand forecasting methodology, based on irrigated acreage by crop type and livestock use, based on the excellent work available from SRBC and Penn State.

- An approach to projecting thermoelectric water demand that incorporates regional projections of power demands.

The disaggregation of demand geospatially to small areas, such water purveyor service areas and minor civil divisions. Thus, these methodologies can support the USGS Screening Tool being developed for identification of Water Supply Critical Areas.

2.1 Introduction and Objectives of Study

Water demand forecasting is essential for evaluating both the future reliability of water supplies and for managing the future need for water among the many categories of use. The water resource planning literature identifies several generalized ways to analyze, describe, and portray water demands for the purposes of forecasting. Water demand forecasting techniques rely on established theories that revolve around historic observations of water demand behavior.

Several variables are known to influence the demand for water. These determinants of demand vary by type of water use or water use sector, such as water used for domestic purposes and in industrial, agricultural and power production. Water demand is driven by demographic trends in population, housing and employment, as well as economic activity and the broader demand for and supply of goods and services. As these factors vary geographically, the demand for water can be analyzed and expressed sectorally and spatially. Furthermore, the intensity of water use is affected by long-term climate conditions and short-run fluctuations in weather conditions, as well as technological factors related to production processes and water using efficiency.

The choice of a particular forecasting methodology for any set of water using sectors is affected by the data that can be used to model relationships among demand determinants and sector water use. The availability and quality of data to support the development of models typically serves as a practical constraint on the options that are applicable for water demand forecasting.

This report summarizes the development of water demand forecasting methodologies for the following key water use sectors in Pennsylvania:

- Public Water Supply
- Industrial
- Mining
- Thermoelectric Power
- Hydroelectric Power
- Agriculture

Based on the review of data and methodologies, the water demand for the public water supply and industrial sectors have been merged and redefined as the *residential* and *nonresidential* sectors.

The report describes the data collection, data analysis, and review of forecasting methodologies conducted in the effort to develop these forecasting methodologies.

2.1.1 Objectives

A chief objective of the study was to develop a set of forecasting methodologies for the six key sectors that would integrate into a holistic methodological framework, and make maximum use of available data. Secondarily, the methodologies need to be capable of supporting the development of a Pennsylvania State Water Plan and identification of Critical Water Planning Areas. Thus, the resulting set of forecasting methodologies are designed to:

- Provide meaningful information to decision-makers
- Utilize available data without requiring additional data collection
- Consistently apply available data across geographies
- Be applicable to different spatial scales, such as basin, county or other geographies
- Easily integrate into existing software environments
- Allow assessment of:
  - Normal versus dry conditions
  - Annual or peak demand
  - Effects of water efficiency (conservation)
  - Alternative growth scenarios

2.1.2 Organization of Methodology Report (Section 2)

Section 2.2 of this report offers a review of water demand forecasting methodologies as presented in water resources planning literature. Section 2.3 reviews the existing Pennsylvania Department of Environmental Protection (PADEP) Water Demand Forecasting Model. Section 2.4 provides a summary of the data collection and assessment efforts for this study. Section 2.5 describes the recommended set of forecasting methodologies and Section 2.6 provides a summary and recommendations for future applications of the demand forecasting methodologies.

2.2 Review of Water Demand Forecasting Methodologies

This section provides a review of water demand forecasting methodologies as found in the water resource planning literature. This review offers a background for: (a) the review of the existing water demand methodology used by the State of Pennsylvania, as discussed in Section 2.3, (b) the discussion of available data related to water use in Pennsylvania, as discussed in Section 2.4, and (c) the recommended set of water demand models discussed in Section 2.5. A thorough discussion of forecasting urban water demands can be found in:

- *Urban Water Demand Management and Planning* by Duane D. Baumann, John J. Boland, and W. Michael Hanemann. McGraw Hill. 1998.

- *Urban Water Supply Management Tools* by Larry W. Mays. McGraw Hill. 2004.

- *Water Resources Planning: Manual of Water Supply Practices M50*. American Water Works Association. 2001.

Broadly defined the methodological options for forecasting water demand are:

- Trend extrapolation – extending historic water demand trends, without constraint.

- Per capita method – determining water demand based entirely on change in population.

- Disaggregated factor forecast approach (per unit use is fixed) – determining water demand separately for residential and non-residential water use sectors.

- Functional (modeled) unit approach (per unit use varies by influencing factors) – where economic and climate factors, for example, influence the water use factor. The functional model often takes a multivariate form.

The first two methods do not incorporate information regarding the full range of factors that influence water demand.

The forecasting methodologies discussed below follow the general format of *number of units* times *a per unit use*. Each methodology examines a different approach to determining the per unit use element.

Each of these methodologies follows the approach:

$$Q_{s,m,y} = q_{s,m,y} \bullet N_y$$

where:

Q = monthly water use
q = per unit use
N = number of units
s = customer sector
m = month
y = year

Thus, the projected number of units times the estimated water use per unit yields the estimate of water use for the given customer sector (e.g., single-family, commercial, agricultural). The number of units (N) may be defined for any geographic level, such as planning area, basin, or political jurisdiction (e.g., county), depending upon defined forecast geography and the availability of data. The per unit value of (q) is estimated by one of the following methods.

2.2.1 Trend Extrapolation

This method assumes that the average per unit use value of (q) will continue to change over time as it has done in the past. Alternatively, trend extrapolation was often used to project total water use (Q) as an extension of past water use before more advanced forecasting methodologies were developed.

Trend extrapolation assumes that water use is a function of time. That is, the rate of change in water use over the recent past is assumed to continue into the future at the same rate of change. Further underlying assumptions are that either: (a) there is no correlation between time and factors that affect water use, or that (b) time and factors that affect water use are perfectly correlated.

The advantage of this methodology is that no projected number of units are required if the total water demand (Q) is estimated as an extrapolation of existing historical water use. That is to say, this method can be applied when there is no information available about future water determinants.

2.2.2 Per Capita Rate of Use

This approach assumes the average per unit use value of (q) for a defined geography and time period is a function of population, and is held constant throughout the forecast period. It follows the general form:

$$q_{s,m,l} = (Q_{s,m}/N_s)$$

where:

q = average use per capita
s = customer sector
m = month
l = location (e.g., county, basin)
Q = water consumption
N = population served

Note that the values for Q and N for a given geography or location (l) may be derived from multiple reporting utilities and that each reporting utility may provide data for multiple years. Thus, an average rate of use can be determined for a given geography.

The utility data must be in matched sets; for each reported water delivery ($Q_{u,s,m,y}$) there must be a corresponding population served ($N_{u,s,y}$), where (u) indicates an individual utility or water provider. The population served data may need to be verified. Such data are often reported as estimates, or derived from Census data of municipalities that may differ from service area boundaries.

The methodology requires the projected population be available by geography (e.g., county or basin) in order to estimate future water demand.

Per capita water use has been widely used to estimate total system water demand and assumes that population is the principal factor that explains the change in water use. One caveat that should be remembered when comparing per capita usage rates is that there are inconsistencies in defining both the numerator and the denominator of the metric. For example, "total utility water system per capita use" defined as raw water withdrawals divided by population served is quite different from "residential customer per capita water use" defined as average residential customer use divided by average persons per household.

2.2.3 Disaggregated Factor Forecast

The disaggregated factor forecast assumes a constant per unit rate of use and follows the general form:

$$\mathbf{q_{s,m,l} = (Q_{s,m}/N_s)}$$

where:

q = *average use per unit*
s = *customer sector*
m = *month*
l = *location (e.g., county, basin)*
Q = *water consumption*
N = *number of units (e.g., accounts, acres, households, employees)*

The units used to define the *per unit* use (i.e., the denominator) may be defined independently for each sector. Historical sector water use and historical sector units are required to determine the per unit use (q) for each sector. In addition, the projected number of units (future N) are required to estimate future water demand for each sector.

Alternatively, the disaggregated factor forecast allows an adjustment to the per unit use factor and follows the general form:

$$Q = N^*q$$

where:

$$q_{s,m,y} = (Q_b/N_b)_{s,m}\ (X1_f/X1_b)^{\beta 1_{s,m,y}}\ (X2_f/X2_b)^{\beta 2_{s,m,y}} \ldots (Xn_f/Xn_b)^{\beta n_{s,m,y}}$$

and:

q = *adjusted per unit use*
s = *customer sector*
m = *month*
y = *year (b = base period; f = future year)*
Qb = *base year use*
Nb = *counting unit (e.g., account, housing unit, population, etc.)*
Xb = *base year factor variable*
Xf = *projected factor variable*
β = *elasticity*

Unlike the functional per unit use described below, factor variables are not determined by regression analysis. The factor forecast can be developed from base year values for water use data (Q and N) and base year and future year values for the factor variables. Factor variables can include median household income, persons per household, maximum temperature, precipitation, cooling degree days, housing density, marginal price, etc.

The elasticities for the factor variables may be selected from a literature review of water demand models. The result of this model is a per unit use (q) adjusted, or normalized, for variations in selected factors that affect water demand.

2.2.4 Functional (or Multivariate) Per Unit

The functional per unit use model estimates values of per unit use from a set of explanatory variables and follows the general form:

$$Q = N^*q$$

where:

$$q_{s,m,y} = \alpha\ (X1^{\beta 1}\ X2^{\beta 2} \ldots Xn^{\beta n})_{s,m,y}$$

and:

q = *per unit use*
s = *customer sector*
m = *month*
y = *year*
α = *intercept*
X = *explanatory variable*
β = *elasticity*

In most cases, the function includes multiple explanatory variables and is thus referred to as a *multivariate* model. Explanatory variables are specified based on a prior knowledge and data availability and elasticities are estimated using regression analysis. These can include median household income, persons per household, maximum temperature, precipitation, cooling degree days, marginal price, employment to housing ratios, industrial group employment to total employment ratios, etc. Historical per unit use data (q) can be obtained from multiple locations and time periods. Corresponding values for explanatory variables may be obtained from weather stations and Census data at the county, municipal (Census Designated Place), census tract or census block level. The regression analysis would provide a statistical model for estimating the average rate of water use (q) from a given set of explanatory variables.

Projected values for each explanatory variable are required to develop the estimated future per unit use values for each location (e.g., county or planning area). Projected values for the number of units (N) are also required.

This approach may be constrained by the absence of, or inability to project, reliable explanatory variable values. Also, the counting unit data must be defined in the same units as the sector units (N). For example, if the per unit use (q) is defined as gallons per account, then N must be defined as number of accounts. Alternatively, the per unit use may defined as water use per demographic unit, such as housing unit or employment, and the sector unit (N) would be defined as the same unit.

This approach requires a commitment of resources for data collection and statistical modeling of the database, in addition to the development of the forecasting procedures.

2.2.5 Tradeoffs between Methodologies

Selection of a water demand forecast methodology is driven in part by the data that is available through primary and secondary data collection efforts. Time and money are required to identify and compile existing (secondary) data that can support the forecasting methodology and additional costs will be incurred to generate new (primary) information, if considered necessary.

Each of the water demand forecasting methodologies described above offer different levels with respect to:

- Complexity of data requirements and effort for collection
- Explanatory power with respect to the full range of factors that affect water demand
- Level of information provided by the forecast
- Specification error and uncertainty of the methodology
- Cost of analysis in time and resources

The tradeoffs among the different forecasting methodologies are illustrated in Figure 2.2.1. Increasing information and explanatory power reduces forecast error. For example, trend analysis and the per capita method offer no information as to the variability of water demand with respect to weather. At the same time, increasing data requirements and collection effort increase the cost of analysis. Selection of the optimal water demand forecasting methodology for any given application requires a balance of:

- The specificity of information needed to meet the objectives of the study
- The data available
- The resources available to conduct the study and collect additional data as needed

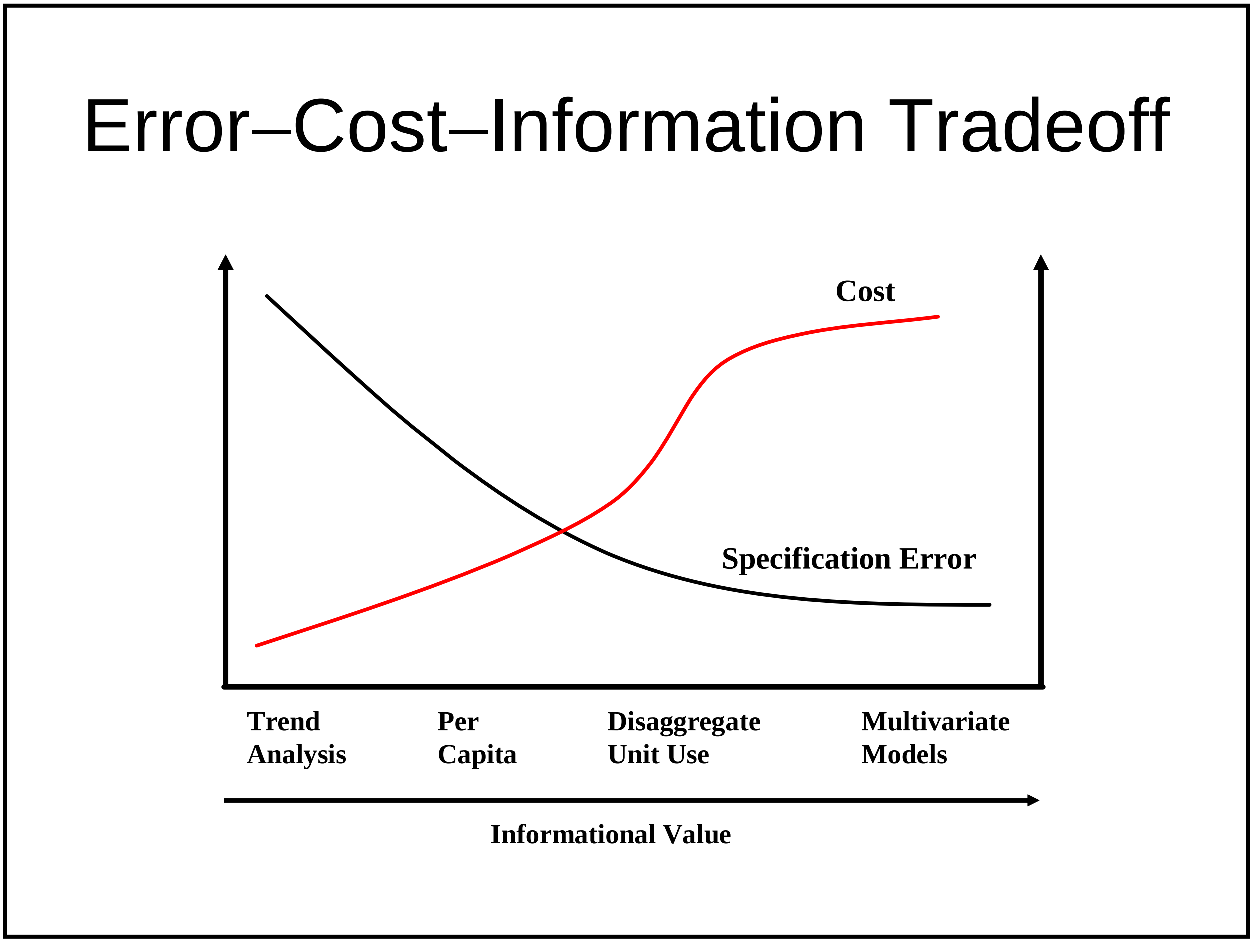


FIGURE 2.2.1
TRADEOFFS BETWEEN METHODOLOGIES

This review of water demand forecasting methodologies provides the background for the review of the existing forecasting model discussed in the following section, as well as the discussion in Section 2.4 of data related to water use in Pennsylvania and the recommended set of water demand models discussed in Section 2.5.

2.3 Review of PADEP Forecasting Model

The Pennsylvania Department of Environmental Protection (PADEP) currently estimates future water demand of public water supply areas using their PADEP Forecasting Model. The following review of this model is based upon information provided in the memo *PADEP Demand Projections* (dated September 9, 2004).

The PADEP model estimates future water demand for public water suppliers only. This model does not estimate water demand for self-supplied residences and other nonresidential water use sectors. The model consists of per capita factor which is derived from the WUDS database times the percent of municipal population served times the municipal population. Mathematically, the PADEP model can be expressed as:

$$\mathbf{Q_{i,y} = q_i * \%Served_i * N_y}$$

where:

Q = water demand for PWS(i) in gallons per day
q = per capita use, or base year water use divided by population served for PWS(i)
%Served = percent of municipal population served by PWS(i)
N = municipal population in year (y)

The PADEP model is automated to allow the user to select a forecast that includes one of the following options:

- Population served is constant
- Unserved population is constant
- Percent served is constant
- Manual adjustment

Thus, the user may adjust the methodology for a given public water supplier if information is known about growth of the service area population. The PADEP model, as with other per capita models discussed in the previous section:

- Does not separately calculate the residential and nonresidential demands of communities served.
- Does not shift per capita use rate with future growth of community, or account for water use efficiency.
- Does not account for weather variations such as normal or dry year demand.
- Does not permit alternative growth scenarios.

- Functions with minimum data requirements.
- Does not factor in environmental constraints to growth

It is the purpose of this study to develop a more comprehensive set of water demand forecast models that address all sectors of water use within Pennsylvania and maximize the use of available data. The following section of this report summarizes the available data related to water use and related factors. Once the recommended set of models has been tested in a pilot application, it is recommended that these models replace the use of the PADEP Forecasting Model for estimating future water demand within the State of Pennsylvania.

2.4 Summary of Data Collection, Sources and Assessment

The choice of a particular forecasting methodology for any set of water using sectors is affected by the data that can be used to model relationships among demand determinants and sector water use. The availability and quality of data to support the development of models typically serves as a practical constraint on the options that are applicable for water demand forecasting. This section provides a review of data collected and evaluated with respect to its utility in developing water demand models for the major water use sectors within Pennsylvania. The data discussed in this section support the set of recommended water demand forecast models described in Section 5.

2.4.1 Introduction to the Data Collection Effort

Research data can be classified as either primary or secondary data. Primary data consists of information gathered directly from surveys and reporting units specifically for the purpose of the research at hand. Secondary data consists of data compiled by other entities for other purposes. The data reviewed and evaluated for this analysis are entirely secondary data. Future efforts to refine the water demand forecasting methodologies may wish to consider the gathering of primary data, such as sampling of water use from billing records, or interviews with water users.

This section of the report discusses available water use information on a state-wide basis, as well as demographic, climatic and other data pertinent to the forecasting of water demand.

A complete listing of data sources is provided in Section 2 Appendix 2.A.

2.4.2 Water Use Information

A number of data sets regarding historical water use and water users were provided as examples of state-wide water use data for review. Two of the databases are extracts from PADEP's Water Users Data System (WUDS), which is a quite large database. One database is from Act 220 registrations data. A fourth file also derived from WUDS lists water purveyors and contains detailed information on each water purveyor. In addition, a database of permitted surface water users maintained by DRBC was provided.

The files provided for this analysis are listed below with a description of the data provided:

1. *WUDS Extract.mdb* This Access database contains 7 tables. Two tables were used to determine water usage:
   - *Delaware_Primaries_03_01_05* – This table is assumed to contain all unique Primary Facility IDs in the Delaware River Basin (DRB)
   - *WUDS_USE_Histories_03_01_05* - This table includes annual water usage by Primary Facility ID with data from 1975 - 2003
2. *PADEP_DRB.mdb* This Access database contains two tables with water withdrawal locations and amounts:

- *tbl_Withdrawal_Locations* - Table of approximately 2267 facilities based on the count of unique Primary Facilities IDs
- *tbl_Withdrawals(MG)* – This table contains water withdrawals by month and year for each SUBS Facility ID with data from 1983, 1987 - 1999

3. *DRB_Act220_CDM.mdb* This Access database contains one table (tbl DRB Registration) which has 406 unique Primary Facility IDs with annual and monthly water use data from 2003 - 2004 by Primary Facility ID.
4. *Wuds_Water_Purveyors_03_08_05.xls* This Excel file contains the percent allocations between different types of water use (residential, commercial, industrial, etc.) for 165 water purveyors with total annual water use with report dates ranging from 1983 to 2004.
5. *Annual_Reports.xls and Quarterly_Reports.xls* These files contain water withdrawals by DRBC permitted surface water permitted facilities. The annual reporting data is for facilities permitted prior to 1961, with data from 1993 to 2004. The quarterly reporting data is for facilities permitted after 1961, with data from 1994 to 2004. These files identify facilities by name, use type, sub-basin, and source, but do not directly link to the WUDS or Act 220 identification systems. It is understood that SRBC has similar data of permitted users.

The majority of tables described above are subsets extracted from PADEP's Water Users Data System. To make full use of the data provided, each table was reviewed for its usefulness. The table with the broadest geography and historical time of record is the WUDS_USE_Histories table of the WUDS extract Access database. This table includes water records with report dates ranging from 1975 to 2003, though many earlier and most recent years have very few observations. It is understood that the WUDS database is no longer updated as statewide reporting is now compiled in the Act 220 database. In addition to water records for the Pennsylvania portion of the Delaware River Basin, the WUDS_USE_Histories table also includes water records from other river basins in Pennsylvania.

While the Act 220 database submitted for this review contains data only for 2003 with some 2004 entries, it is understood that this database is the active repository for water use data and will serve as the basis of future water use assessments. Links can be established between the WUDS and Act 220 data for those facilities in both databases, thus providing a historical time series of data for some facilities. However, there is a significant gap in records from about 1998 to 2002 during the transition in reporting from WUDS to Act 220.

The WUDS data is derived from all self-supplied water users drawing more than 100,000 gallons per day (gpd). For Act 220 registrations, the reporting requirement applies to water users withdrawing more than 10,000 gallons per day. Thus, the Act 220 data should contain records for a greater number of facilities.

Both the WUDS and Act 220 data include reported water withdraws as daily, monthly, and/or annual water use figures. The files generally contain data as to the type of water usage, the source of water, and the geographic location of the water user. However, this information is not complete for each water user. For example, many water users report annual usage but not monthly usage.

Tables 2.4.1A to 2.4.1C present summary statistics of WUDS tables to illustrate the variation in available water withdrawal information. Specifics about how water withdrawal data contained within each table is used are explained in Section 2.5 of this report, as well as Section 2 Appendices 2.B and 2.C.

Table 2.4.1A shows summary statistics from the WUDS_USE_Histories data. The table presents a summation of daily water withdrawal records in gallons. However, it is important to note that the reported quantity used is in gallons per day for only those days per year that withdrawals occurred. *This is not an annual average value*. The data shown in Table 2.4.1A represent all facilities included in the WUDS Extract database and is not limited to the Delaware River Basin. There are reasonable counts of facility identifiers from 1983 to 1995, though there is substantial variation in the water use records reported by year. Similarly, there are significant water withdrawals reported from about 1983 through 1996 with substantial variation in reported withdrawals. The dramatic jump in total withdrawals observed in 1989 is caused by one observation that may be an anomaly. There is no apparent correlation between the variation in number of reporting facilities and the reported withdrawals. This suggests that the variation in withdrawals may be dominated by the reporting, or non-reporting, of a small number of larger users.

TABLE 2.4.1A
NUMBER OF REPORTING FACILITIES AND SUMMATION OF QUANTITY USED
(from WUDS Extract database)

Report Year	Number of Reporting Facilities	Sum of Daily Quantity Used (gallons)
1975	1	175,000
1977	4,600	7,765,068,962
1978	450	328,355,314
1979	30	664,090,210
1980	79	104,901,560
1981	2,111	3,080,736,294
1982	419	356,173,396
1983	7,310	7,419,375,891
1984	2,078	14,867,651,081
1985	3,463	18,066,225,887
1986	2,049	163,642,087,191
1987	6,409	3,257,776,448
1988	5,778	166,503,753,048
1989	6,632	50,603,563,439,168
1990	7,617	166,403,505,155
1991	3,241	1,838,232,821
1992	2,888	48,922,047,822
1993	11,810	55,345,498,095
1994	6,656	86,123,391,322
1995	3,782	74,220,059,756
1996	128	89,776,279,074
1997	2,021	152,273,085,370
1998	146	126,629,901,668
1999	93	99,442,470
2000	64	76,488,361
2001	10	2,102,106
2002	5	1,372,722
2003	4	1,460,800
TOTAL	**79,874**	**51,791,332,676,989**

Table 2.4.1B is a subset of Table 2.4.1A. Table 2.4.1B shows the number of records from the WUDS_USE_Histories data that were identified as those from the Delaware River Basin. This identification is based on a match of WUDS FACILITY IDs to the appropriate river basin code. Thus, data in Table 4.1B represents the Pennsylvania portion of the Delaware River Basin. Out of the 79,000 plus records in the WUDS Extract database, only 7,441 records were identified as records associated with facilities within the Delaware

River Basin. As in Table 2.4.1A, the reported quantity used shown in Table 2.4.1B is in gallons per day for only those days per year that withdrawals occurred. *This is not an annual average value*. Records matched to Delaware River Basin withdrawals had a summed daily withdrawal of approximately 21.6 billion gallons.

TABLE 2.4.1B
NUMBER OF REPORTING FACILITIES AND SUMMATION OF QUANTITY USED IN DRB
(from WUDS Extract database)

Basin Code	Report Year	Number of Reporting Facilities	Sum of Daily Quantity Used (gallons)	Total DRB as a percent of Total
1	1977	524	671,323,604	9%
1	1978	36	24,931,924	8%
1	1979	7	14,234,000	2%
1	1980	27	96,524,210	92%
1	1981	112	1,053,544,630	34%
1	1982	48	42,704,120	12%
1	1983	838	1,324,321,524	18%
1	1984	124	1,034,894,623	7%
1	1985	289	1,642,803,097	9%
1	1986	89	1,125,436,110	1%
1	1987	399	792,424,397	24%
1	1988	1,224	2,136,867,846	1%
1	1989	319	272,031,410	0%
1	1990	446	1,806,010,454	1%
1	1991	147	93,073,219	5%
1	1992	50	555,176,395	1%
1	1993	1,718	1,790,517,345	3%
1	1994	35	1,409,142,931	2%
1	1995	598	2,137,610,783	3%
1	1996	11	1,525,992,001	2%
1	1997	389	1,762,037,718	1%
1	1998	4	330,994,708	0%
1	1999			
1	2000	5	1,735,717	2%
1	2001	1	353,000	17%
1	2002	1	352,961	26%
1	2003			
	TOTAL	**7,441**	**21,645,038,727**	**0%**

Table 2.4.1C presents annual water withdrawal statistics from the tbl_Withdrawals(MG), data which is another WUDS-extracted table. This table presents annual withdrawals for the Pennsylvania portion the Delaware River Basin from 1983, 1987 – 1999. The water use shown in Table 2.4.1C is the reported annual total water use and is a better indicator of annual average water use than the water use values shown in Table 2.4.1B. Table 2.4.1C shows that the number of facilities that reported water withdrawals steadily increased from 1987 through 1994, and declines in 1999. Though not as consistent, annual water withdrawals follow a similar trend.

Many water purveyors have multiple withdrawal facilities in different locations. Historical water use for these purveyors is determined by aggregating the water use by Primary Facility ID.

TABLE 2.4.1C
NUMBER OF REPORTING FACILITIES AND SUMMATION OF ANNUAL TOTAL IN DRB
(from PADEP_DEP database)

Year	Number of Reporting Facilities	Sum of Annual Total (MG)
Unknown	1769	--
1983	1	73
1987	207	271,196
1988	306	464,449
1989	345	449,136
1990	375	463,548
1991	375	419,776
1992	380	401,661
1993	408	724,820
1994	428	1,047,207
1995	427	866,227
1996	416	990,200
1997	414	878,361
1998	423	505,392
1999	236	410,986
TOTAL	**6,510**	**7,893,030**

Nonresidential (commercial, industrial and institutional) water demand consists of both publicly supplied water and self-supplied water. Most public water utilities, which are listed in WUDS and Act 220 databases as water purveyors, categorize their water use between residential use and nonresidential uses as indicated in the WUDS Water Purveyors File.

Self-supplied water use reported by commercial, industrial and institutional water users can be added to the nonresidential portion of purveyor water use in order to determine total nonresidential water use for a given area.

To analyze residential and nonresidential water use, data from WUDS and Act 220 registration databases were compiled to form one data file for analysis. Data compilation was achieved by matching and merging available records by common field identifiers. In general, the PRMRY_FAC_ID and WUDS_FACILITY_ID were the main identifiers of individual facilities, though other codes such as the SUB_FAC_ID and the WUDS_SUBS_FACILITY_ID were all used to link records. Using the SAS statistical software application, water use records were then used to calculate total annual water use and annual average daily water use by year and for various spatially disaggregated sectors. Section 2.5 of this report and the discussions in Appendix 2.B and 2.C provide further explanation on how water use data was used for the residential and nonresidential analysis.

The WUDS and Act 220 databases contain water use data for each reporting mine. These water withdrawals are for each withdrawal site. Many mines have several withdrawal sites. In some cases several mines are operated at the same location, or next to each other. Historical water use for these mines is determined by aggregating the water use by Primary Facility ID.

The WUDS and Act 220 databases contain water use data for each reporting power plant. These water withdrawals are for each withdrawal site. Many power plants have several withdrawal sites. The water withdrawal figures were summarized for each power plant.

In summary, the WUDS and Act 220 data provide historical time-series data on water use that can be classified by the key water using sectors. There are acknowledged gaps in the data; however the available information is deemed adequate to provide a representative sampling of water use, by sector, from which average rates of water use may be derived. It is anticipated that the Act 220 data will serve as a more complete source of water use information in future years.

2.4.3 Demographic and Other Information

Several variables are known to influence the demand for water. These determinants of demand vary by type of water use or water use sector, such as water used for domestic purposes and in industrial, agricultural and power production. Water demand is driven by demographic trends in population, housing and employment, as well as economic activity and the broader demand for and supply of goods and services. As these factors vary geographically, the demand for water can be analyzed and expressed sectorally and spatially. Furthermore, the intensity of water use is affected by long-term climate conditions and short-run fluctuations in weather conditions, as well as technological factors related to production processes and water using efficiency.

This section describes the availability of information typically associated with water demands among the key water using sectors.

2.4.3.1 Population

Although the water demand methodologies recommended in Section 2.5 are not per capita methodologies, population projections are the most common projection of demographic information. When projections of other demographic drivers, such as housing and employment, are unavailable estimates of future housing or employment are often derived from the population projections.

Population projections by county to the year 2020 are available from the Pennsylvania State Data Center. In addition, DEP developed population projections at the municipal level to the year 2040 from the Pennsylvania State Data Center county projections. The DEP projections include both an allocation of the county projections to municipal levels and an extension of the projections from 2020 to 2040. The municipal level projections of population can serve as the basis for deriving estimates of municipal level future housing.

2.4.3.2 Housing

The primary factor driving residential water demand is the number of households served. Historical housing data can be used in conjunction with historical residential water use to determine an average rate of water use per household. In addition, estimates of future housing are used to drive the forecast of future residential water demand.

The number of households in each water utility's service area can be estimated using GIS and 2000 Census data by census block. GIS files that delineate the service area of water purveyors (water utilities) were obtained. Figure 2.4.1 illustrates the service area boundaries throughout the state. Census block data from the Census Bureau was matched with service area boundaries to determine the population and number of households within each utility service area for the year 2000.

Projections of housing were not available from a consistent state-wide source. Some local planning agencies have housing projections available, however it was deemed important to maintain a state-wide consistency in the data recommended for use in the development of the water demand forecast methodologies. The future number of households in each service area can be estimated based upon current household size (i.e., the 2000 average persons per household) and available population projections.

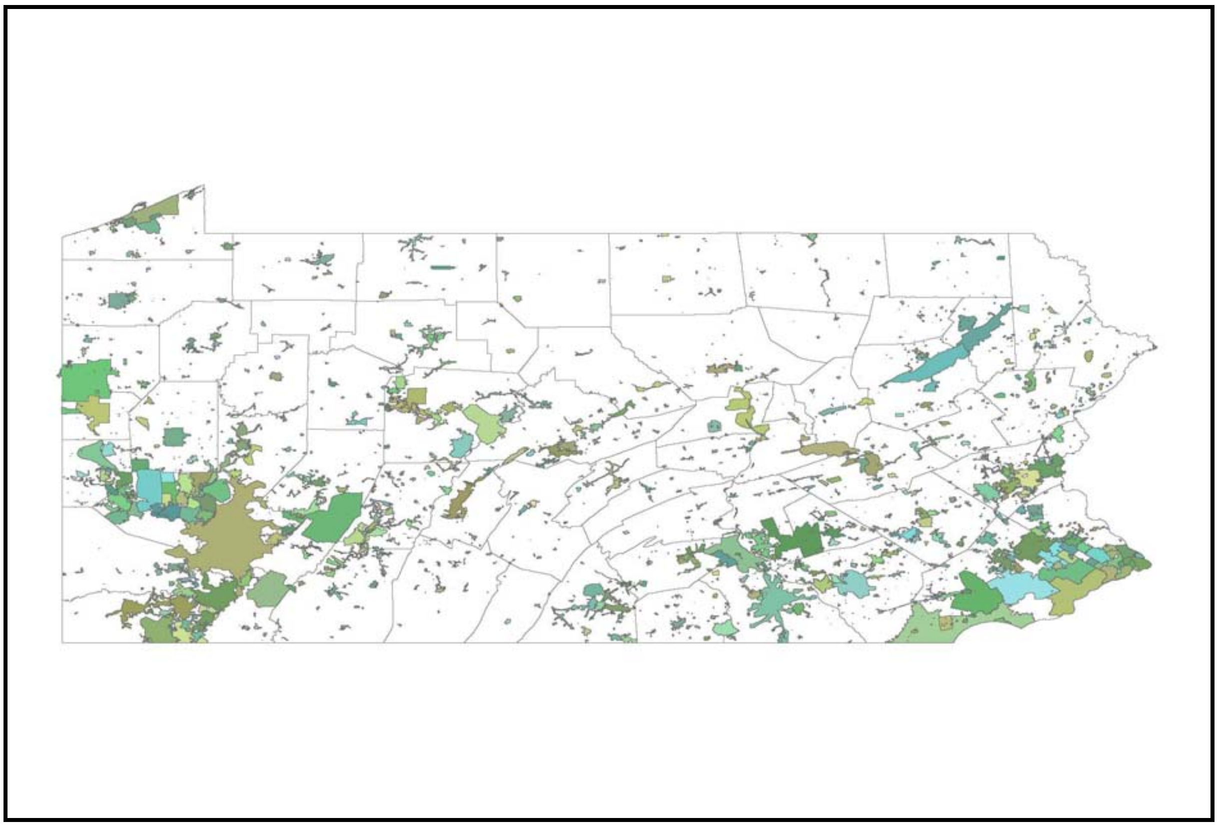


FIGURE 2.4.1
WATER PROVIDER SERVICE AREA BOUNDARIES IN PENNSYLVANIA

2.4.3.3 Median Household Income

Median household income is often correlated with variations in residential water use when evaluating variation in water use over time or across geographies. Higher income levels are associated with higher levels of water use. Median Household Income by county was obtained from the 2000 Census. Income by county can be matched with residential water use data by public water supplier and used in an analysis of variation of residential use. However, the methodology recommended for the residential sector in Section 2.5 is not an analysis of variance (multiple regression) model.

2.4.3.4 Price of Water and Sewer Service

The marginal price of water and sewer service is typically related to variation in residential and nonresidential water use. The marginal price is the amount paid for the last unit of water plus any wastewater volume charge. The marginal price is usually measured in dollars per 1,000 gallons, or dollars per hundred cubic feet. Increases in the marginal price of water and sewer service are correlated with lower water use. For utilities with tiered rate structures, the average volumetric use may be used as the representative marginal price for that utility. In this analysis, no effort was made to collect water and sewer rate information from water providers identified in the WUDS and Act 220 data bases.

2.4.3.5 Employment

Employment is the primary factor driving nonresidential water demand. Nonresidential water use is highly variable and can be expressed as water use per establishment, per account, or as a per unit use measure such as number of square feet, employment, or unit of production. Using employment to normalize water use diminishes the range in variation is establishment level water use rates (*Commercial and Institutional End Uses of Water,* Dziegielewski et al., AWWA Research Foundation, 2000). In addition, employment as a predictor of future water demand is more readily available that projections of future square footage of facility space, production, or even number of accounts. Nonresidential water demand includes commercial, industrial and institutional water use, but excludes the mining, thermoelectric, hydroelectric, and agricultural sectors, which are estimated separately for this project.

Historical employment data can be used in conjunction with historical nonresidential water use to determine an average rate of water use per employee. Average rates of water use in gallons per day per employee (ged) may be calculated for major employment groups, such as the manufacturing and non-manufacturing sectors, or for more detailed employment levels such as 2- or 3-digit North American Industry Classification System (NAICS) codes. For example, the IWR-MAIN Water Demand Analysis Software (Version 6.0, 1994) contained gallon per employee per day water use coefficients for 2- and 3- digit Standard Industry Classification (SIC, which preceded NAICS) codes.

Annual historical employment by county is available from the County Business Patterns maintained by the U.S. Census Bureau. Employment reported by the CBP excludes data on self-employed individuals, employees of private households, railroad employees, agricultural production employees, and most government employees. County Business Patterns data is reported by SIC codes prior to 1998 and by NAICS codes beginning in 1998. Employment figures are not disclosed at an SIC/NAICS level that would reveal information about a single business establishment within a county. Therefore, for some employment categories the data may only be available for the larger employment groups.

In addition, estimates of future employment are typically used to drive forecasts of future nonresidential water demand. Long term industry employment projections for Pennsylvania are available from the Center for Workforce Information and Statistics within the Pennsylvania Department of Labor and Industry. Estimates of 2000 employment and projections for 2010 are available at the 2- and 3-digit SIC level, and are updated every two years to incorporate national economic trends. Geographically, the projections are by Workforce Investment Areas (WIAs), which are organized by counties as shown in Table 2.4.2.

In WIAs comprised of multiple counties, county level employment can be estimated by allocating WIA employment to each county based upon employment reported in the 2000 County Business Patterns. The projected growth in employment from 2000 to 2010 for the WIA can be assumed for each county within the WIA. Also, the rate of growth in employment can be continued at the same rate to project employment in 2020 and 2030 for each county.

Separately, the Center for Workforce Information provided 2004 employment figures by minor civil divisions (MCDs), which are smaller geographic areas than counties. MCDs consist of cities, townships and boroughs. The MCD level data may be used to identify approximate employment within a water provider service area, or to identify approximate employment by watershed or sub-basin.

The MCD employment figures are for "covered employment", which is employment covered by the unemployment insurance program. These figures exclude the self employed and government employees. In addition, approximately 5-10 percent of covered employees were excluded because the Center did not have addresses for all business establishments. Nonetheless, employment by MCD can be used to proportionally allocate county-, or WIA-, level data to smaller geographies.

TABLE 2.4.2
WORKFORCE INVESTMENT AREAS AND COUNTIES

Berks County WIA	**Montgomery County WIA**	**South Central WIA**
Berks	Montgomery	Adams
Bucks County WIA	**North Central WIA**	Dauphin
Bucks	Cameron	Franklin
	Clearfield	Juniata
Bucks	Cameron	Franklin
	Clearfield	Juniata
Central WIA	Elk	Lebanon
Centre	Jefferson	Perry
Clinton	McKean	York
Columbia	Potter	
Lycoming		**Southern Alleghenies WIA**
Mifflin	**Northern Tier WIA**	Bedford
Montour	Bradford	Blair
Northumberland	Sullivan	Cambria
Snyder	Susquehanna	Fulton
Union	Tioga	Huntingdon
	Wyoming	Somerset
Chester County WIA		
Chester	**Northwest WIA**	**Southwest Corner WIA**
	Clarion	Beaver
Delaware County WIA	Crawford	Greene
Delaware	Erie	Washington
	Forest	
Lackawanna County WIA	Venango	**Three Rivers WIA**
Lackawanna	Warren	Allegheny
Lancaster County WIA	**Philadelphia WIA**	**Tri-County WIA**
Lancaster	Philadelphia	Armstrong
		Butler
Lehigh Valley WIA	**Pocono Counties WIA**	Indiana
Lehigh	Carbon	
Northampton	Monroe	**West Central WIA**
	Pike	Lawrence
	Wayne	Mercer
Luzerne-Schuylkill Counties WIA		**Westmoreland and Fayette WIA**
Luzerne Schuylkill		Fayette Westmoreland

2.4.3.6 Mining Employment and Production

There are two sources of mining output data. The Pennsylvania Bureau of Mining and Reclamation reports annually on the employment and production of each mine. This database was used for estimating the water use of non-fuel mines. The Energy Information Administration (EIA) of the U.S. Department of Energy maintains a database of coal mine employment and production. Within the Pennsylvania, mining activities are for coal and aggregate materials. Aggregate materials consist of granite, gravel, sand and other materials. There are no published projections of the demand for aggregate material, as this industry is dependent upon the cyclical construction industry. The EIA projects constant coal production in the eastern U.S. for the next 20 years.

The Pennsylvania Department of Conservation and Natural Resources maintains maps of mines listing the type of mine, which can be used to identify locations by watershed and county.

2.4.3.7 Thermoelectric Power Capacity and Production

The Energy Information Administration maintains a database of power plants with power generation capacity and a database of monthly power production.

The Pennsylvania Public Service Commission projects power demand for the state and for utility service areas. The Commission also lists new power plant projects in its annual report. The U.S. Department of Energy, National Renewable Energy Laboratory developed estimates of water consumption for the different types of power generation facilities.

The Electric Utility Companies of Pennsylvania prepared a water use study in1991 that provided data on water use by different types of power plants. These coefficients can be used statewide. Additional water use data for power plants built during the past several years was obtained from dockets at the Delaware River Basin Commission as shown in Table 2.4.3.

TABLE 2.4.3 THERMOELECTRIC REFERENCES
♦ Electric Power Outlook for Pennsylvania, Pennsylvania Public Utility Commission, 2004
♦ Master Siting Study - Susquehanna River Basin, Susquehanna River Basin Electric Utilities Group, 1977
♦ Master Siting Study - Delaware River Basin, Delaware River Basin Electric Utilities Group, 1989
♦ Pennsylvania Water Use Study, Electric Utility Companies of Pennsylvania, 1991
♦ Electric Utility Generating Facilities in Pennsylvania - Water Use Data Sheets, Various Companies, 1994
♦ Merrill Creek Reservoir Docket, DRBC, Table A - Revision 16, 2003
♦ DRBC Docket No. D-99-54, Lower Mt. Bethel Energy, 2000(a)
♦ DRBC Docket No. D-99-69, Phila Suburban Water Company, Interconnection, 2000(b)

2.4.3.8 Hydroelectric Power Capacity

A list of hydropower facilities and license applications for hydropower facilities was obtained from the Federal Energy Regulatory Commission (FERC). The FERC list contains power generation capacity. A list of all dams was obtained from the National Inventory of Dams, U.S. Army Corps of Engineers.

2.4.3.9 Agriculture

Current and historical irrigated acres by state and county are available from the Census of Agriculture conducted every five years (2002, 1997, 1992, and 1987) by U.S. Department of Agriculture and the supplemental Farm and Ranch Irrigation Survey, which is also conducted every five years (2003, 1998, 1993 and 1988). The trends in irrigated acres are discussed in Section 2.5 as part of the methodology for the agricultural forecast.

The USDA has projections of planted and harvested acres by crop type at the national level to the year 2014. Projections of irrigated acres in Pennsylvania can be based on a study conducted by the

U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station which projects irrigated acreage by region to 2040. This document shows a 16 percent increase in irrigated acreage in the Mid Atlantic Region from 1995 to 2040.

Water use per irrigated acre by crop type for Pennsylvania can be obtained from the 2003 Farm and Ranch Irrigation Survey.

Livestock inventories for U.S., states and counties are also available from the Census of Agriculture. Projections of livestock by category can be derived from published national baseline projections by the U.S. Department of Agriculture which project livestock inventories and production for various farm animals to the year 2014.

Two reports from the College of Agricultural Sciences, Cooperative Extension, Pennsylvania State University, provide estimates of water usage per animal per day. The reports are:

- Estimating Water Use for the Farm and Home
- Agricultural Water Needs and Sources Water Supply

In addition, a Susquehanna River Basin Commission study (Jarrett and Hamilton 2002) on agricultural *consumptive* use provides very detailed information on irrigation crop requirements by crop for two-month increments during the growing season from May through November. The SRBC study also provides estimates of the number of livestock by animal type in the year 2025 for sub basins within the Susquehanna River Basin.

2.4.3.10 Weather

National Weather Service (NWS) monthly weather data is available for stations throughout Pennsylvania. Stations should be screened to assure that data are available for the time period corresponding with the historical period of water use data.

Monthly mean daily maximum temperature and monthly total precipitation have been found to be correlated with residential and nonresidential water use. Irrigation and cooling water use increase as maximum temperature increases, while water use decreases as precipitation increases. Monthly weather data may be matched with monthly water use data in an analysis of variance (multiple regression analysis) of water use. Alternatively, monthly, or annual, weather data can be compared to long-term averages to derive departure from normal values, which can be used in an analysis of variance of water use. Departure from normal data may also be used to normalize observed water use if the period of record of historical water use is unusually hot and dry, or cool and wet.

Weather station data may be matched with given water use data if the location of the water use facility and the weather station are in reasonable proximity. Data from multiple weather stations may be weighted by distances from a given water use facility or service area to provide an estimated average for the given location. For example, five NWS stations were identified in, or near, the Lehigh Valley with robust data for 1994 through 2003. These stations are:

- Allentown International Airport – Lehigh County

- Beltzville Dam – Lehigh County
- Claussville – Carbon County
- Lehighton - Carbon County
- Stroudsborg.- Monroe County

The Claussville and Lehighton stations only provide precipitation data, while the remaining three stations provide both precipitation and maximum temperature data. Thus, data from these five weather stations can be used to calculate the monthly mean daily maximum temperature and mean monthly precipitation for the Lehigh Valley.

Average annual temperature, average summer temperature (3-month average) and total precipitation for the entire state of Pennsylvania were obtained from the National Climatic Data Center (NCDC) of the National Oceanographic and Atmospheric Administration. The NCDC reports the historical statewide averages since 1895 and ranks each year relative to all recorded years. Data since 1980 are shown in Table 2.4.4. Note that 1996, 2004, and 2003 rank as the three wettest years, respectively. The years 2004 and 2003 also rank as the 12th and 35th coolest summers, respectively.

TABLE 2.4.4
RECENT PENNSYLVANIA PRECIPITATION AND SUMMER TEMPERATURE

Year	Annual Precipitation	Rank Based on the Period of Record (1895-2005)	Average Summer Temperature	Rank Based on the Period of Record (1895-2005)
2005	----	----	----	----
2004	53.79 inches	110	67.3 deg F	12
2003	53.65 inches	109	68.3 deg F	35
2002	43.50 inches	87	70.9 deg F	103
2001	34.20 inches	12	68.9 deg F	55
2000	40.83 inches	71	67.5 deg F	16
1999	41.34 inches	75	70.3 deg F	92
1998	39.96 inches	59	68.7 deg F	47
1997	38.38 inches	45	67.8 deg F	23
1996	56.09 inches	111	68.8 deg F	51
1995	37.10 inches	33	71.2 deg F	106
1994	47.31 inches	102	69.5 deg F	73
1993	45.56 inches	95	69.9 deg F	83
1992	41.56 inches	78	66.1 deg F	2
1991	33.15 inches	8	70.7 deg F	100
1990	49.07 inches	105	68.3 deg F	35
1989	44.02 inches	91	68.6 deg F	44
1988	35.53 inches	19	70.4 deg F	94
1987	40.58 inches	67	69.9 deg F	83
1986	43.31 inches	86	67.9 deg F	25
1985	41.83 inches	79	66.9 deg F	7
1984	45.32 inches	94	68.3 deg F	35
1983	46.22 inches	98	69.6 deg F	77
1982	38.58 inches	47	66.2 deg F	3
1981	40.56 inches	66	68.1 deg F	31
1980	36.82 inches	30	68.8 deg F	51

2.4.4 Data Gaps and Issues

There are a number of issues related to the available data. WUDS and Act 220 water use data bases provide incomplete coverage of water users throughout the state. As an example some aggregate mines and power plants did not report water usage. Thus, some known users are not represented in the data. Similarly, given the reporting regulations, small water users are not represented. In addition, there are issues of classification error in the databases, e.g., at least one major power plant was categorized as an industrial user. Similarly, there may be some cross-over of business enterprises between commercial and agricultural classifications.

Reported water use is from inconsistent time periods. Some facilities report annual use and some report monthly use. Data are reported from a variety of years. Water use data for some facilities is reported for multiple years while data for other facilities is reported for only one year. Some years are better represented than others in the water use data.

Within the WUDS database, the proportion of public water supply deliveries that are residential, commercial, industrial, institutional, bulk, unaccounted, and other are reported as percentages. These percentages are for a given point in time as indicated by the report date for each facility. As noted above, the reported information can represent different years for different facilities. These percentages may be estimates and could be expected to change over time for some public water suppliers. Thus, the reported allocation of water use across user categories can introduce error and uncertainty into the data when the reported allocations are used to derive the residential and nonresidential water use of a given supplier.

Matching of data geographies can introduce some degree of error. For example, matching census blocks with service area boundaries and matching county-level data with watersheds. Figure 2.4.4 shows an overlay of county boundaries (in black) with the Lehigh sub-basin (in purple) and the service area boundaries of public water suppliers with water use reported in the WUDS database (in green). Identifying the employment within the Lehigh basin requires allocation of county-level employment data from 10 counties. Identifying water use among public water suppliers within the Lehigh basin requires compiling data from a wide range of suppliers ranging from major metropolitan utilities to individual mobile home parks. Identifying census demographic data for the public water suppliers requires an overlay of the service area boundary with census blocks. Each level of overlay requires assumptions regarding the allocation of data from one geography to another.

The matching of demographic data with water use data can sometimes be problematical. While Census data represents demographics in the year 2000, most of the reliable water use data typically represents from 1995 to 1998, or 2003. Thus, correlating Census data with reported water use assumes that either (a) the demographic data equally represents the conditions in the year in which the water use is reported, or (b) water use in 2000 is the same as in the year reported.

Estimating future housing from population projections assumes that the persons per household for a given area remain constant. Similarly, estimating future employment from Workforce Investment Area level projections assumes that employment is evenly distributed throughout the WIA, that the distribution of WIA projected employment among the major employment sectors is evenly applicable to the smaller geographies.

Methodologies employed to extend demographic projections to the required planning horizon require assumptions about the consistency of growth patterns into the future. Available demographic projections, such as future employment or crop acreage, do not extend into the future as far as the project planning horizon. Therefore, the projections must be extended to meet the planning horizon. Typically, the rate of growth in the last projected interval (e.g., 2015 to 2020) can be assumed to continue to the planning horizon. Other more advanced statistical techniques may be used to extend existing projections if sufficient supporting data are available.

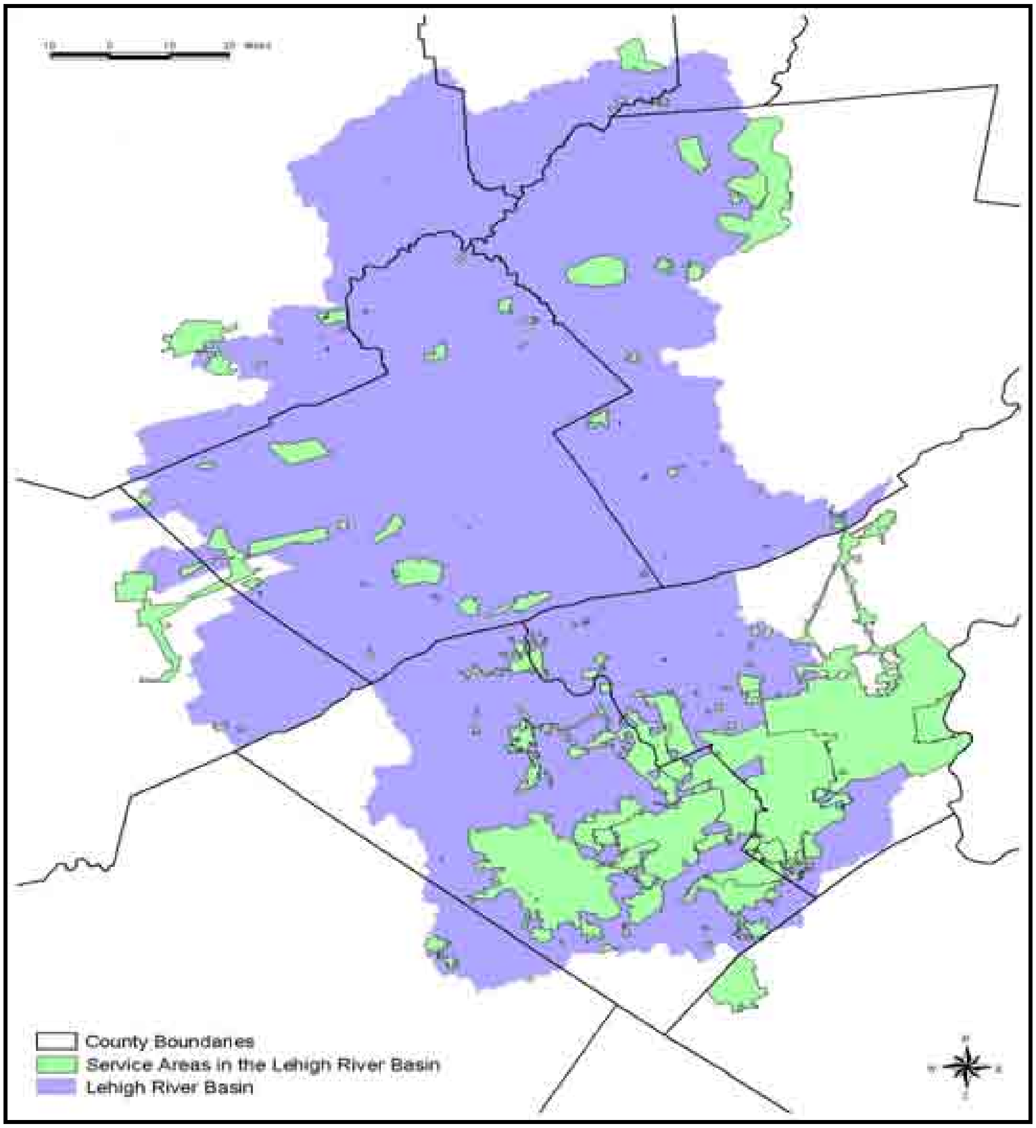


FIGURE 2.4.4
LEHIGH BASIN WITH COUNTY BOUNDARIES AND PWS SERVICE AREAS

These issues should be acknowledged as assumptions upon which the water demand forecasts are based. Future improvements in the available data may reduce the uncertainty and error contained within the water demand forecasts that result from these data issues.

This section provides a review of data related to water use and water use factors that can be utilized in developing water demand models for the major water use sectors. An effort has been made to maximize the use of the available data and acknowledge issues related to the data that may introduce error and uncertainty into the water demand forecasts. The following section provides a set of recommended water demand models built upon the available data discussed in this section.

2.5 Recommended Forecasting Models

A primary objective of this study is the development of water demand forecasting methodologies for the following major water use sectors in Pennsylvania:

- Public Water Supply
- Industrial
- Mining
- Thermoelectric Power
- Hydroelectric Power
- Agriculture

Based on the review of data and methodologies, the water demand for the public water supply and industrial sectors have been merged and separated as the *residential* and *nonresidential* sectors.

Section 2.2 of this report provided an overview of water demand forecast methodologies and Section 2.4 provided a summary of data that may be utilized in developing water demand forecasts for the key water use sectors. This section of the report describes a water demand forecasting model for each of the major water use sectors.

The generalized model recommended for forecasting water demand of each sector for Pennsylvania is shown below. This model includes parameters for water use per unit and the number of units. A modified version of this model which includes an adjustment factor for climatic conditions and an adjustment factor for water use efficiency is discussed later in this section following the discussions of methodologies for the individual sectors. The recommended methodologies for thermoelectric and hydroelectric power sectors do not follow this general model. The generalized model is as follows:

$$Q_{s,m,y} = N_{s,y} * q_{s,m}$$

where:

Q = *sector water demand*
N = *units*
q = *per unit use*
s = *sector*
m = *month*
y = *year*

The specifics of estimating the per unit use factor and the corresponding units for each sector are discussed below.

2.5.1 Residential

Taking into consideration the limitations on available data about the sources of demand (i.e., drivers, such as population, employment, production, acres, etc.), it was determined that the best approach for estimating future residential water demand is to use the available WUDS and Act 220 records of water withdrawals. These water withdrawals records can be used to estimate a per unit residential water use factor that can then be multiplied by projections of a demographic driver such as number of households (or population). A per unit residential water use factor is calculated by dividing the quantity of reported residential withdrawals by the number of households served. An alternative per unit residential water use factor can be calculated by dividing reported residential withdrawals by the population served. The most suitable demographic driver for projecting future residential water demand changes is the number of households because of its known correlation with changes in water demand.

2.5.1.1 Per Unit Residential Water Use Factor

Available water withdrawal records from WUDS and Act 220 can be compiled so that water withdrawals can be summed by each unique primary facility id/WUDS facility id. Water use by facility for available years and months can then be evaluated. Relying on the use type codes and other identifiers in WUDS and Act 220 databases, facilities that are associated with residential water use can be isolated.

2.5.1.2 Identification of Public Water Supply Data Useful for Forecasting Purposes

Public water suppliers (PWS) are generally a good source of residential water use estimates. Public water suppliers are classified a use type code 12 in both WUDS and Act 220 and are respectively referred to as Water Purveyors and Water Suppliers. Further differentiation between PWSs is provided based on their facility designation code. This coding differentiates PWSs into a variety of designations. PWS withdrawals designated as municipal, authority, and investor-owned water providers are deemed most suitable for estimating an overall residential water use factor.

However, prior to estimating residential water use factors from PWS, it is necessary to estimate what portion of PWS water withdrawals are for residential use. Most public water providers withdrawal water for nonresidential use as well as residential water use. One of the files that was provided contains a list of water providers in the state. Some of these PWS also provide a percent allocation to domestic, commercial, industrial, institutional, bulk, other, and unaccounted water use. It is therefore possible to estimate residential and nonresidential water use by assuming that domestic represents residential while the sum of commercial, industrial, institutional, bulk, and other represents nonresidential. The unaccounted portion is assumed to consist of both residential and nonresidential uses and requires a method to allocate unaccounted use.

To estimate residential water use by PWS, reported withdrawals for each PWS are multiplied by percent domestic to get an estimate of accounted domestic water use by PWS. A portion of the unaccounted withdrawals (total reported withdrawals multiplied by percent unaccounted) is added to residential use based on the ratio of accounted residential withdrawals to accounted total withdrawals for each PWS.

2.5.1.3 Matching PWS with Demographic Data

In order to be able to estimate per unit use at the PWS level it is necessary to match the residential water use to the appropriate demographic data. This would allow the division of water withdrawals by the number of households or population to get water use per household or per capita.

Digitized service area boundaries for a list of water purveyors are available from PADEP. Using GIS, these service area boundaries can be overlaid with census block demographic data. A census block is a subdivision of a census tract and is the smallest geographic unit for which the Census Bureau tabulates 100-percent data. Many census blocks correspond to individual city blocks bounded by streets, but in rural areas a census block may include many square miles and may have boundaries that are not streets. Since some census block polygons may be partially contained within a PWS service area, it is necessary to establish a method of assigning population and number of households to a service area when a census block is split by service area boundaries.

The general approach of assigning population and number of households to a PWS service area requires an estimation of the percent of the census block that is contained within the boundaries of the service area. The population or number of households for this portion of the census block is estimated by multiplying the total number of households or population for the entire block by the percent of the census block that is contained within the service area boundary. The total number of households or population for each PWS service area is the sum of block data that is within that service area boundary. This approach assumes a constant household and population density across any census block.

2.5.1.4 Dividing Residential Withdrawals by Demographic Data

Water withdrawals for each PWS is divided by the estimated number of households served to obtain an estimate of water use per household (similarly by population). Residential water use by PWS varies. This variation is an indication that different communities/regions served by PWS have different demographic and economic characteristics that may affect their average water use tendencies. With this knowledge, it is thus possible to use different residential water use factors depending on region. A unique residential water use factor for each basin or sub basin can be generated by calculating weighted water use factor for each basin or sub basin as function of the number of PWS within each basin or sub basin and the number of households (or population) served by each PWS. Section 2 Appendix 2.B provides a further assessment of preliminary calculations of average water use factors within the Delaware River Basin.

2.5.1.5 Residential Base Year and Projection Estimates

Base year estimates of residential water use are calculated by multiplying the established water use factor for each basin or sub basin by the number of households in that basin or sub basin. The number of households in a basin or sub basin is estimated from county level estimates. The number of households for each county is apportioned to a basin or sub basin based on a percent county allocation with an assumption for household density.

Projected water demand by basin or sub basin can be estimated by multiplying the established water use factor for the basin or sub basin by projected households for the basin or sub basin. Projected households for the basin or sub basin are derived from county level projections that are then apportioned to basins or sub basins following the same approach as in the baseline scenario. Presently, county level household projections of households can be derived from population census projection data that is available at a county level in the WUDS Extract file from PADEP. These population projections can be translated into number of household projections by assuming a constant value for persons per household.

The above method of projecting residential water use is found suitable because not only does it capture public water withdrawals, but because it also captures all residential water use including those on self supply. Multiplying water use factors by all total households assumes that households on self supply use water at a similar rate as those getting their water from the public water provider.

2.5.2 Nonresidential

Nonresidential water use for this analysis includes all water use excluding that used in the mining, thermoelectric, hydroelectric, and agriculture sectors. These sectors are evaluated separately. The estimation of future nonresidential water use follows an approach similar to that described for residential water use in that available water withdrawals data in WUDS and Act 220 are used to estimate water use. However, the nonresidential water use factor is estimated by dividing water withdrawals by employment.

2.5.2.1 Nonresidential Per Unit Water Use Factor

Similar to residential PWS demand, PWS nonresidential demand is estimated by multiplying the PWS withdrawals by the identified percent of PWS demand that is associated with nonresidential use. The value obtained represents the accounted-for portion of nonresidential use. Unaccounted water withdrawals associated with nonresidential water use is estimated by splitting PWS unaccounted water use between residential and nonresidential use based on the ratio of accounted residential and accounted nonresidential water use to total PWS use. Total PWS nonresidential water use is therefore the sum of accounted and unaccounted estimated PWS nonresidential use. Total PWS nonresidential water use is then divided by total employment within the PWS service area to estimate the per employee rate of water use for each PWS.

In addition, the WUDS and Act 220 data provide information on self-supplied water use. That is, water users classified as self-supplied commercial, industrial, or institutional users. Water use for self-supplied establishments located within a PWS service area can be included in the water use estimate (i.e., the numerator) for the calculation of the per employee rate of water use for the given PWS.

Employment for each PWS (i.e., the denominator) can be derived from labor statistics by minor civil division (MCD) provided by the Pennsylvania Department of Labor and Industry. GIS is used to overlie MCD boundaries with PWS service areas to determine the PWS employment. Note that the MCD employment statistics represent employment covered by unemployment insurance and must be adjusted up to full employment given the ratio of MCD employment to county total employment.

Results of these calculations yield a set of gallon per employee per day (ged) coefficients for each PWS. Preliminary calculations shown in Section 2 Appendix 2.C illustrate the range of ged coefficients across several PWS. The PWS ged coefficients may be weighted to generate a weighted average ged coefficient for a given geography, such as a basin, sub basin or watershed.

2.5.2.2 Nonresidential Base Year and Projection Estimates

Base year estimates of nonresidential water use by geography (e.g., basin or sub basin) are calculated by multiplying the weighted basin or sub basin nonresidential water use factor by the total employment for the geography. Employment by basin or sub basin can be derived from adjusted employment by minor civil divisions. Again, MCD employment must be adjusted to represent total employment given the ratio of MCD to county employment.

Projections of nonresidential water use by basin or sub basin are calculated by multiplying the basin or sub-basin nonresidential water use factor by the projected basin or sub-basin employment. Future employment by MCD can be derived from the growth rate of employment for the corresponding Workforce Investment Area (WIA). Growth trends for WIAs are assumed for all counties and minor civil divisions within a given WIA. The DLI projections of employment to 2010 by WIA are extrapolated to 2030 by assuming constant growth by WIA.

2.5.3 Agriculture

Water use in the agricultural sector is typically separated between irrigation water use and livestock water use.

2.5.3.1 Irrigation Water Use

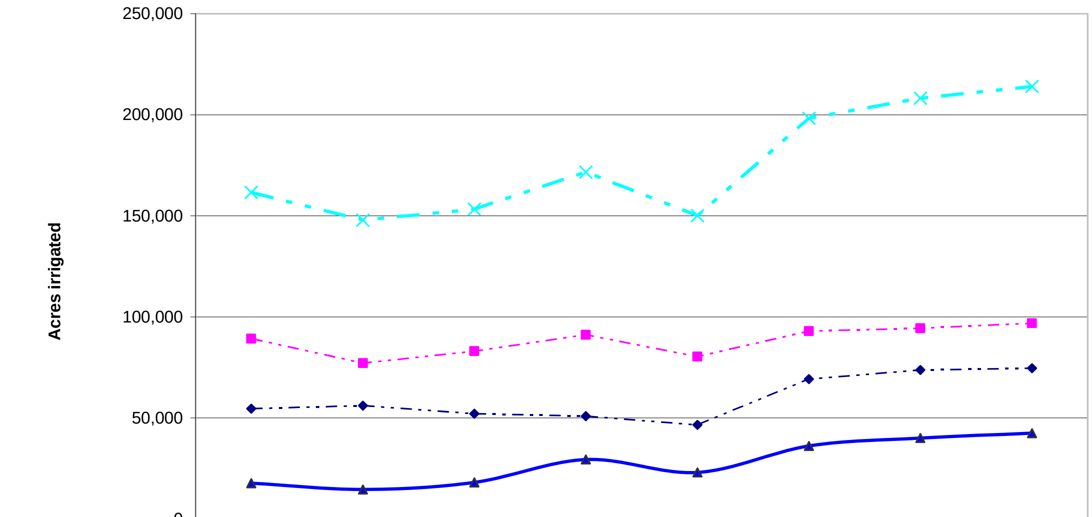
Irrigation water use can be estimated as the number of irrigated acres times the estimated water use per acre which is typically provided by standard crop irrigation requirements, such as those published by Pennsylvania State University. The preferred method of estimating irrigation water use allocates the irrigated acres to specific crop types and multiplies these irrigated acres by an estimate of water use per acre for each crop. The U.S. Census of Agriculture provides data on irrigated crops and associated irrigated acres by county. These data can be aligned with basins using GIS to indicate the number of irrigated acres by crop type for each basin.

Suggested crops for this analysis would be those with relatively significant irrigated acreage. Crops suggested for Pennsylvania include but not limited to vegetables, corn for grain, corn for silage, potatoes, forage crops and orchard crops. The suggested crops are based on reported irrigated acreage for the state in the 2002 Census. Table 2.5.3.1 presents the suggested crops and associated acreage. As can be seen in the table, many crops in Pennsylvania do not show significant irrigation. The highest number of irrigated acres is associated with vegetable production.

TABLE 2.5.3.1 2002 CENSUS ESTIMATES OF TOTAL HARVESTED AND IRRIGATED ACRES FOR MAJOR CROPS IN PENNSYLVANIA				
Crop Name	**Harvested cropland acres (A)**	**Irrigated crop acres (B)**	**B as a percent of A**	**Percent of all crops irrigated**
Vegetables harvested for sale	48,698	12,586	25.80%	39.00%
Land in orchards	50,287	5,561	11.10%	17.23%
Forage	1,956,072	4,007	0.20%	12.42%
Corn for grain	790,111	3,277	0.40%	10.15%
Potatoes	11,094	3,169	28.60%	9.82%
Corn for silage	536,615	2,521	0.50%	7.81%
Soybeans for beans	378,846	480	0.10%	1.49%
Wheat for grain all	172,137	265	0.20%	0.82%
Tobacco	5,470	245	4.50%	0.76%
Oats for grain	117,653	111	0.10%	0.34%
Barley for grain	54,292	43	0.10%	0.13%
Sunflower seed all	937	6	0.60%	0.02%
Sorghum for grain	4,529	0	0	0.00%
Dry edible beans excluding limas	525	disclosure	-	-
Total irrigated acres from reported estimates for each of the selected crops		32,271		100.00%
All Harvested Cropland	**4,079,276**	**40,880**	1.00%	**-**

Projections of future acreage by crop type are available at the national level to the year 2014. However, these projections are for planted and harvested acres by crop – no projections of irrigated acres are provided. A study conducted by the U.S.D.A., Forest Service, projects irrigated acreage by region to 2040. The Forest Service report shows a 16 percent increase in irrigated acreage in the Mid Atlantic region (PA, NJ and NY) from 1995 to 2040. This is equivalent to approximately 0.36 of a percent growth per year over the 45 year period (assuming constant growth). The trend for the Mid Atlantic region from Forest Service report can be applied to county level or basin level irrigated acreage in the base year.

The use of the trend established by the Forest Service report for the Mid Atlantic region assumes that irrigated acres in Pennsylvania will change at the same rate as that estimated for the region. This assumption is reasonable considering the locality of the Mid Atlantic region. Figure 2.5.3.1 shows the historical trends in irrigated acres for three states in the Mid Atlantic region obtained for Agriculture Census years. Trends in irrigated acres for the three states move in the same direction, and thus support of the assumption that the regional growth trend is applicable to Pennsylvania. Note that the year 1997 appears twice. This is because the Census of Agriculture introduced a new methodology to account for all farms including those that were not surveyed. The last two columns show estimates that are adjusted using the new methodology.
Water use per irrigated acre by crop type can be obtained from the most recent Farm and Ranch Irrigation Survey published in 2004. The Farm and Ranch Irrigation Survey provides estimates of average quantities of water used per acre by crop type for Pennsylvania in 2003. Per acre water use estimates for Pennsylvania in 2003 can be assumed to be those for a considerably wet year. According to statewide precipitation totals from the National Oceanic and Atmospheric Administration (NOAA), annual precipitation in Pennsylvania for 2003 is ranked 109th in terms of highest precipitation in the past 111 years (1895 to 2005).



	1974	1978	1982	1987	1992	1997	1997	2002
New York	54,580	56,106	52,125	50,920	46,600	69,197	73,791	74,663
New Jersey	89,321	77,159	83,049	91,208	80,409	92,965	94,380	96,893
Pennsylvania	17,734	14,662	18,139	29,505	23,096	36,150	40,089	42,516
Three state total	161,635	147,927	153,313	171,633	150,105	198,312	208,260	214,072

FIGURE 2.5.3.1
HISTORICAL TREND IN ACRES IRRIGATED IN PENNSYLVANIA, NEW JERSEY AND NEW YORK

A study for the SRBC on agricultural water demands within the Susquehanna River Basin by Jarrett and Hamilton (2002) indicates the irrigation requirements during a once in two year drought occurrence, once in ten year drought, and once in fifty year drought. Water requirements relationships in the SRBC study can be used to adjust water use factors for each crop type to reflect assumed drought conditions. As noted by Jarrett and Hamilton, crop irrigation in Pennsylvania varies according to the levels of precipitation. In addition, the SRBC study (Jarrett and Hamilton 2002) provides very detailed information on irrigation crop requirements by crop for two-month increments during the growing season from May through November. Thus, the seasonality of irrigation water use can be estimated.

2.5.3.2 Livestock Water Use

Livestock water use is estimated as the water requirements per animal unit times the number of animals. The U.S. Census of Agriculture provides data on the number of dairy cattle, beef cattle, sheep, swine, and poultry per county. Water requirements estimates per animal are available from Pennsylvania State University. Table 2.5.3.2 shows the recommended water requirement estimates from two reports by the College of Agriculture Sciences, Cooperative Extension at Pennsylvania State University. These water requirements estimates can be used in conjunction with other available estimates such as those reported in the SRBC study.

Livestock projections for the Mid Atlantic region are also provided in by the Forest Service report. However, unlike irrigated acreage projections, they are not considered the best source of livestock projections because they simply rely on a per capita growth assumption in the region. Such an assumption is not preferred because it assumes all changes in livestock production will be due to local changes in demand. Also, the Forest Service report does not provide different growth rates for different types of livestock. This would assume that all livestock production would change at equal rates.

TABLE 2.5.3.2
WATER USE FACTORS FOR SELECT LIVESTOCK
(Based on Pennsylvania State University Recommendations)

Livestock Description	Estimated Water Use in Gallons per Day	
	Source 1	*Source 2*
1. Dairy cow	35	35
2. Dry cow, beef cattle or steers** 2. Steer*	12**	20*
3. Hogs	1.5	1.5
4. Chickens (per 100 head)	9	9

A preferred approach for estimating future livestock inventories in Pennsylvania is to assume livestock patterns in Pennsylvania will follow national trends estimated by the U.S. Department of Agriculture. The Department of Agriculture projects national livestock inventories and production to the year 2014. These projections are based on specific assumptions regarding macroeconomic conditions, policy, weather, and international developments among other specific assumptions. Projections of livestock inventories and production to 2014 by the U.S. Department of Agriculture can be extrapolated to 2030 by assuming constant growth past 2014. The benefit of using these national projections is that trends are provided for each major animal type. Alternatively, the SRBC study (Jarrett and Hamilton 2002) provides estimates of the number of livestock by animal type in the year 2025 for sub basins within the Susquehanna River Basin.

Multiplying the future number of animal units by animal type within a basin or sub basin times the water requirements by animal type results in the estimated water demand for livestock by basin or sub basin. Water requirements per animal unit and growth rates can be adjusted to account various scenarios.

2.5.4 Mining

The forecasting model for mining water demand can be based upon mining employment and the average annual water use per mine. Mining production, man-hours worked, and total employment are compiled annually for each mine by the Pennsylvania Department of Mining and Reclamation. Since mining employment is seasonal, especially with aggregate mining, full time equivalent employment is the best estimator of water use.

The average annual water use per mine can be derived from WUDS and Act 220 data for each mine that reports water withdrawals. Reported water withdrawals can be matched with employment by mine. Thus, average annual water use per employee can be calculated for those mines that report water withdrawals. Water use data are not available for all mines, therefore the calculated water use per employee factors represent a sample from mines throughout the state.

The water use and employment data for the individual mines can be aggregated to provide a weighted sample per employee water use factor for a selected geography, such as a county or basin. Table 2.5.4 shows the water use per employee from available water use and employment data aggregated by counties within the Pennsylvania portion of the Delaware River Basin. Employment figures were obtained for the mines which reported water use. These mines constitute approximately 25-40 percent of the overall mining employment in each county as reported by the Pennsylvania Department of Labor and Industry for the mining sector. The number of mines registered and reporting water use in the WUDS or Act 220 database is approximately half the number of the mines reporting employment and production to the Pennsylvania Department of Mining and Reclamation.

As illustrated in Table 2.5.4, some counties may have known mining employment but are not represented in reported mining water use information. Mining water use for such geographies may be estimated by using the average of available water use and employment data for the next larger geography. For example, the basin-level average water use per employee can be applied to the county-level employment to estimate the county mining water demand.

Additional data on the specific location of mines from maps and geographic coordinates can be used to assign mining water use to specific watersheds and basins.

Projected employment by Workforce Investment Area (WIA) to the year 2010 is provided by the Pennsylvania Department of Labor and Industry as discussed in Section 2.4.3.5. These projections include employment for the mining sector in each WIA. As discussed in Section 2.4.3.5, these projections can be allocated to smaller geographies within each WIA and can be extended to the year 2030. Thus, projections of mining employment for a given geography, such as county, watershed, or basin, can be derived from the WIA employment projections. Employment data are available at the minor civil division, which can be used to allocate WIA employment projections to this MCD geography. However, the assumption that trends in WIA mining employment are applicable to mining employment within a given MCD may in fact be making assumptions about an individual mining establishment.

TABLE 2.5.4
DELAWARE RIVER BASIN MINING WATER USE

County	2000 Mining Employment From PA-DLI	Water Use per Employee (MG per Year)
Berks	250	18.41
Bucks	490	10.67
Carbon	280	15.03
Chester	140	Not available
Lehigh	972	5.15
Luzerne	751	Not available
Monroe	155	3.54
Montgomery	180	36.72
Northampton	99	11.37
Pike	21	Not available
Schuylkill	251	21.49
Wayne	50	3.90

The projected water use for mining for a selected geography (e.g., county, watershed or basin) can be estimated by multiplying the per employee water use factor for that geography by projected mining employment for that geography.

2.5.5 Thermoelectric power

Thermoelectric power plants generally use large amounts of water, primarily for cooling. There are several technologies used for cooling power plants, which impact water usage. Plants having typical "once-through" or open-cycle cooling systems withdraw large amounts of water from a river, lake or stream and return the water to the source essentially undiminished in quantity, but at a significantly higher temperature; the heated discharge induces some evaporation in the receiving water body. Plants with typical evaporative or closed-cycle cooling systems recycle cooling water through one or more cooling towers. Most power plant cooling towers are evaporative, where evaporation of a portion of the flow cools the remaining, recycled flow. Compared to once-through plants, closed-cycle plants withdraw a relatively small amount of water from the river, lake or stream as necessary to replenish the evaporated water.

To develop a methodology for forecasting future water withdrawals, water withdrawals can be estimated for each power plant. For example, the amount of water withdrawn for thermoelectric power was estimated for each watershed in the Pennsylvania portion of the Delaware River Basin. Although there are many power plants spread throughout this portion of the Delaware River Basin, the larger power plants and the greater water use are generally found in the greater Philadelphia region, along the lower Schuylkill and lower Delaware Rivers.

Several sources of electric utility data were researched to ensure that all large power plants in the basin were included. Water use data from WUDS and Act 220 was used where available. Several large power plants have never reported water usage, and several power plants have been completed within the past several years For the few power plants where water use data was not available, estimates of water withdrawals were made based upon generation capacity, fuel type and cooling technology. The baseline water use estimates by state water plan watershed are shown in Table 2.5.5.1 below. These are the amounts of water that are on average being withdrawn annually by existing power plants.

TABLE 2.5.5.1
THERMOELECTRIC WATER USAGE IN THE PA-DRB

Watershed	Watershed	Sub-basin	MG per Year	% of Total
1F	Jacoby	Upper Delaware	108,100	18
2B	Middle Lehigh	Middle Delaware	300	0
2C	Lower Lehigh	Middle Delaware	700	0
2E	Pidcock	Middle Delaware	11,600	2
3A	Upper Schuylkill	Lower Delaware	300	0
3C	Tulpehocken	Lower Delaware	4,800	1
3D	Manatawny	Lower Delaware	67,200	11
3F	Lower Schuylkill	Lower Delaware	21,200	4
3G	Darby	Lower Delaware	350,800	60
3J	Poquessing	Lower Delaware	24,500	4
		Total	**589,500**	**100**

CDM

A listing of Pennsylvania-Delaware River Basin power plants, the associated generation capacity, the estimated power production in gigawatt hours (GWH) per year, and the estimated water use in millions of gallons per year is shown in Table 2.5.5.2. All information was obtained from publicly available documents or was estimated. A water withdrawal rate for each power plant was estimated based on the ratio of water use to power generation (MGD per MW or MG per MWH). Where this ratio was not known for an individual plant, the ratio was assumed equal to a ratio typical of plants of the same type.

TABLE 2.5.5.2
PA-DELAWARE RIVER BASIN THERMOELECTRIC PLANTS

Plant/Unit Name	MW	Watershed	2000-2004 MG/year	Estimated 2000-2004 GWH/yr
AES Ironwood	705	3C	160	345
Bethlehem	1,100	2C	223	483
Cromby	345	3D	53,433	1,241
Delaware 7&8	250	3J	24,515	553
Eddystone 1-4	1,340	3G	350,135	7,671
Fairless Hills	60	2E	11,634	680
Frackville (Wheelabator)	42	3A	209	245
Greys Ferry (co-gen)	174	3F	13,444	785
Liberty	578	3G	320	741
Limerick 1&2	2,286	3D	13,458	12,306
Lower Mt. Bethel	575	1F	267	737
Marcus Hook	800	3G	330	637
Martins Creek	1,920	1F	27,836	5,293
Northampton	107	2C	440	516
Northeastern (Tractebel)	58	3A	48	56
Ontelaunee	561	3D	300	719
Panther Creek	80	2B	253	296
Portland 1&2	401	1F	79,973	2,475
Schuylkill	166	3F	7,737	200
Titus 1-3	274	3C	4,642	1,131

A power plant's capacity factor is the percentage of full load generating capacity at which the power plant is operating. A comparison of the estimated average power generation of power plants in the Pennsylvania portion of the Delaware River Basin from 2000 to 2004 with their peak generation capacity indicates that the increasing demand for power within the basin can be met primarily with existing power plants. The Table 2.5.5.3 shows the weighted average capacity factors for different types of power plants in the PA - Delaware River Basin.

TABLE 2.5.5.3 ESTIMATED POWER GENERATION AND CAPACITY FACTOR (C.F.) FOR POWER PLANTS IN THE PA - DELAWARE RIVER BASIN						
Fuel	**Once-through Cooling**		**Evaporative Cooling**		**Hybrid Cooling (Helper Tower)**	
	GWH/yr	C.F. (%)	GWH/yr	C.F. (%)	GWH/yr	C.F. (%)
Nuclear			12,306	61		
Coal-fired	7,112	60	1,113	44	1,131	47
il-fired	6,003	50	4,317	30		
Combined Cycle [1]	1,467	59	3,660	10		

Projections of power demand are available through 2015 by PJM, the regional transmission organization for nearly all of Pennsylvania. Power demand is projected to grow by 1.7 percent annually through 2015 for the PJM Mid-Atlantic Region, which includes most of the Delaware River Basin. The historical growth rate and projected growth rate for power demand in the PJM Mid-Atlantic Region are shown in Table 2.5.5.4.

TABLE 2.5.5.4 PJM MID-ATLANTIC REGION POWER DEMAND HISTORICAL GROWTH AND PROJECTION			
Year		**Energy (GWH)**	**Average Growth %/ Year**
1988	actual	218,400	
1993	actual	237,700	1.7
2004	actual	282,300	1.6
2015	projected		1.7

To estimate future water withdrawals, power production by the power plants in Pennsylvania can be assumed to grow at the same rate as power demand in the corresponding PJM region. So long as no plants are planned to be added or retired, and additional power generating capacity is neither imported nor exported, power production and hence water demand at each plant can be assumed to grow at the same rate. In years when a new power plant is planned to begin service, the new plant can be assumed to have a capacity factor equal to the weighted average capacity factor of its plant fuel/type and to have a ratio of water use to power production typical of its plant type. The assumed production of other plants in a given basin can be reduced so that the combined production in the basin remains as forecasted.

Nationally, water withdrawals per unit of power generated are declining while the water consumed (evaporated) per unit of power generated is increasing. This slow change is because of changing power generation technology, which is usually implemented as new power plants are constructed and old ones are retired. The same trend can be expected throughout Pennsylvania and will be captured to the extent that information on planned power plants is available.

2.5.6 Hydroelectric Power

In Pennsylvania, hydroelectric facilities have little variation in water withdrawals and generate power based upon water availability. Hydroelectric facilities do not significantly alter the amount, or timing, of water flowing through impeded rivers.

It is recommended that the current level of water use be inventoried from the available data by location, or facility, for each basin. Future water use for each basin can be held constant at the present level, unless there is specific information indicating that additional facilities will be brought online in the future.

The generating capacity and water usage of existing and planned hydroelectric facilities can be compiled for a given basin. For example, available information on hydroelectric facilities within the Pennsylvania portion of the Delaware River Basin is shown in Table 2.5.6. The amount of power generated by hydroelectric facilities in this region is minor. The largest of the facilities, Wallenpaupack Hydroelectric Plant, has a 44 megawatt capacity, while the largest thermoelectric facility in the Basin has greater than a 2,113 megawatt capacity.

The proposed methodology is to assume water withdrawals continue at the rate. Where known, additional water use for future facilities may be added to the inventory of facilities.

TABLE 2.5.6
DELAWARE RIVER BASIN HYDROELECTRIC FACILITIES

Project Name	Capacity (MW)	County	WUDS Annual (MG)	Act 220 Annual (MG)
Wallenpaupack	44.00	Pike	91,002	153,421
Pocono Lake	.29	Monroe		
Lavon Dam (apply)	2.15	Carbon		

2.5.7 Techniques for Scenario Adjustments

The generalized model for forecasting water demand presented above is further modified to permit adjustments for the analysis of alternative conditions and scenarios. This modification includes parameters for an adjustment factor for climatic conditions, an adjustment factor for water use efficiency and an adjustment factor for peak day water demand. Mathematically, the model is as follows:

$$Q_{s,m,y,t,a,c,e} = \left[N_{s,y,a} * q_{s,m}\right] * \left[C_{s,m} * E_{s,y} * P_t\right]$$

where:

Q = sector water demand
N = units
q = per unit use
C = climatic conditions (e.g., normal, dry, wet)
E = efficiency factor (i. e., water conservation effect)

CDM

P = peak day to annual day ratio
s = sector
m = month
y = year
a = growth scenario (e.g., expected, low, high) of N
t = time element (i.e., annual or peak)

Each of the adjustment factors, particularly the climate conditions factor and the water use efficiency factor, can be specified as numeric value based on information obtained from related studies. Alternatively, the factor can be specified as a function in which the adjustment factor itself is derived from a set of explanatory factors. The development of functions for any given adjustment factor for a given sector requires data related to that sector.

2.5.7.1 Growth Scenarios

Adjustment of the water demand forecast for alternative growth scenarios is accomplished by using an alternative set of projected values for the units (N) for the given sector forecast. This adjustment is applicable in any of the (q) times (N) models.

Demographic projections, such as the DEP municipal population projections for Pennsylvania may be treated as the *expected* projected values. Alternative growth projections can be determined for *lower than expected* growth and *higher than expected* growth. The lower and higher alternative demographic projections can be estimated as a percent change from the expected growth values, or calculated given a standard error of the expected growth values if such a statistic is available from the demographic forecast.

Alteration of the projected number of units can be established independently for each sector.

2.5.7.2 Climatic Conditions

Adjustment of the water demand forecast for changes in climatic conditions is accomplished by multiplying the (q) times (N) forecast by an adjustment factor that represents a departure from normal weather conditions, assuming that the per unit (q) rate of water use reflects water use during normal weather conditions. The climatic adjustment factor can be derived as a ratio of baseline to alternative weather conditions as follows:

$$c_{s,m} = (X_f/X_b)^{\beta}{}_{s,m}$$

where:

c = climatic adjustment factor
s = customer sector
m = month
b = base period
f = future year
Xb = base year factor variable (e.g., temperature or precipitation)
Xf = projected factor variable (e.g., temperature or precipitation)
β = elasticity

Alternatively, the climate adjustment factor can be provided as a scaled factor where a value of 1.0 represents normal, or baseline, conditions and departures are indicated as values less than, or greater than 1.0.

Climatic adjustment factors may vary by month and thus represent varying degrees of sensitivity to climatic change. For example, irrigation requirements may show a higher sensitivity to drought conditions in July and August, than in April and May. Climatic factors for the agricultural irrigation use may be derived from precipitation deficit functions by crop type from the SRBC *Estimation of Agricultural Animal and Irrigated-Crop Consumptive Water Use in the Susquehanna River Basin* (2002).

2.5.7.3 Efficiency Factor

Adjustment of the water demand forecast for changes in water use efficiency is accomplished by multiplying the (q) times (N) forecast by an efficiency adjustment factor. An adjustment factor value of 1.0 indicates that the water use efficiency remains at the same level of efficiency as in the baseline conditions. The efficiency adjustment factor is reduced to indicate an improvement in water use efficiency from the baseline. For example, an adjustment factor of 0.85 indicates a 15 percent improvement in water use efficiency from the baseline. The efficiency adjustment factor can vary over time, and is independent for each sector.

2.5.7.4 Peak Day Forecast

Adjustment of the water demand forecast to a peak day demand forecast is accomplished by multiplying the (q) times (N) forecast by an adjustment factor that represent the ratio of peak day demand to average annual day demand. This assumes that the per unit use (q) is representative of average annual day demand. The peak day ratio can be set independently for each sector.

2.5.8 Application of Models

The recommended set of water demand forecasting models can be applied at any geographic level, such as county, sub-watershed, or basin, as long as the demographic units of each sector align with the selected geography. Given that the demographic units of each sector are aligned geographically, the sector water demand forecasts can be summed for the geography.

The resulting water demand forecast is built upon the forecast assumptions of each sector. Such assumptions may include:

- Future demographic projections for each sector reflect future conditions.
- Historic water use patterns upon which the per unit use is based will remain the same.
- Historic weather conditions from period of historic per unit use reflect long-term normal weather conditions that will remain the same.
- Demographic and economic factors that affect per unit water use will remain the same as in the historic baseline conditions.

A primary objective of this study is the development of water demand forecasting methodologies for the major water use sectors in Pennsylvania. Selection of an appropriate methodology is constrained by the availability and quality of data that support a given methodology. This section has described a set of recommended methodologies based on the data discussed in the previous section. The recommended forecast models are flexible enough to support improvements as more refined data become available, can be incorporated into existing software environments, and allow assessment of alternative scenarios.

2.6 Summary and Recommendations for Future Applications

This report (Section 2) presents findings from a review of available data and a review of standard water demand forecasting methodologies. A set of recommended water demand forecasting methodologies is offered that are applicable within the state of Pennsylvania. The forecasting methodologies are based upon the available information, and the objectives and needs of water demand forecasts.

A generalized model is recommended for forecasting water demand of each sector for Pennsylvania. This model includes parameters for water use *per unit* and the number of units. A modified version of this model is also recommended which includes an adjustment factor for climatic conditions and an adjustment factor for water use efficiency.

The recommended set of forecasting methodologies introduce several improvements to past demand forecasting approaches and provide significant improvement in the accuracy of the projected volume of demand, and the geospatial accuracy of demand, throughout the state. Specifically, the recommended methodologies include:

- A disaggregated water demand forecasting methodology for PWS that projects separately the residential and non-residential water demand. This method captures changes in the characteristics of business-related water demand for the state, and is a significant improvement over the per capita approaches previously employed.

- A new agricultural demand forecasting methodology, based on irrigated acreage by crop type and livestock use, based on the excellent work available by SRBC and Penn State.

- An approach to projecting thermoelectric water demand that incorporates regional projections of power demands.

- The disaggregation of demand geospatially to small areas, such as provider service areas and minor civil divisions. Thus, these methodologies can support the USGS Screening Tool being developed for identification of Water Supply Critical Areas.

Refinements of the water demand forecasts can be made with improved information on water use and associated factors. More specifically:

- Include projections of housing at the county, or municipal, level with population projections from the Pennsylvania State Data Center.

- Extension of employment projections by Workforce Investment Area beyond 2010 by the Center for Workforce Information

- Resolve issues of confidentiality that inhibit release of sector level (e.g., manufacturing, mining, etc.) at the minor civil division level.

- Establish reporting channels between PJM and the DEP with respect to power facility applications regarding location, capacity, fuel and cooling type of facility, and expected on-line date.

- Establish an annual survey of water purveyors to provide information to support water forecasting and resource planning throughout the state. Survey information would include:

    - Monthly production
    - Monthly wholesale purchases
    - Metered consumption by customer sector (residential, commercial, industrial, irrigation, other)
    - Monthly wholesale deliveries
    - Monthly total consumption and deliveries
    - Monthly unaccounted-for water use

Appendix 2.A
Data Sources for Pennsylvania Demand Forecast

PUBLIC WATER SUPPLY (MUNICIPAL DEMAND)
Historical Data

U.S. Census of Population and Housing 2000, 1990
- Data by: county, census designated place, census tract, census block group, census block
- Contains: population, housing units, persons per household, median household income, housing units per structure, age of housing

Pennsylvania Dept of Labor and Industry (www.dli.state.pa.us)
- Center for Workforce Information and Analysis
- County Profiles
    - Population – 2003 estimate
    - Land area – % urban/rural
    - Labor force – Dec 2004
    - Income – BEA 2002, Census 2000
    - Major employers with corresponding industry sector
    - Employment by NAICS
    - Wages

County Business Patterns 1988-2002
U.S. Census Bureau
Contains employment figures by sector for counties
Available at http://www.census.gov/epcd/cbp/download/cbpdownload.html

Projected Data

*Population Projections, Pennsylvania Counties: 2000 To 2020 By 5 Year Incre*ments
The Pennsylvania State Data Center and the Population Research Institute at the Pennsylvania State University

Projected municipal population to 2040. Developed by DEP from Pennsylvania State Data Center county projections and extended to2040, contained within WUDS database.

Pennsylvania Dept of Labor and Industry
- Workforce Information & Statistics
    - Industry Employment Projections by Workforce Investment Area 2010

Water Use Data

WUDS: WATER PURVEYOR & COMMERCIAL monthly withdrawals

Nonresidential Water Use Coefficients, *Planning and Management Consultants, Ltd. (1994) IWR-MAIN 6.0: User's Manual and System Description, Appendix D.*

INDUSTRIAL WATER USE

Historical Data

County Business Patterns 1988-2002
U.S. Census Bureau
Contains employment figures by sector for counties
Available at http://www.census.gov/epcd/cbp/download/cbpdownload.html

Projected Data

Long Term Industry Employment Projections by Workforce Investment Area
Employment projections for ten sectors to 2010
Pennsylvania Department of Labor and Industry, Center for Workforce Information
Available at http://www.dli.state.pa.us/landi/cwp/view.asp?a=140&q=196374

Water Use Data

WUDS: INDUSTRIAL monthly withdrawals

Nonresidential Water Use Coefficients, *Planning and Management Consultants, Ltd. (1994) IWR-MAIN 6.0: User's Manual and System Description, Appendix D.*

MINING WATER USE

Historical Data

Directory of Non-fuel Mineral Producers in Pennsylvania
Pennsylvania Department of Conservation and Natural Resources
Contains location of mines.
Available at http://www.dcnr.state.pa.us/topogeo/mineral/index.aspx

2002 Annual Report on Mining Activities
Pennsylvania Bureau of Mining and Reclamation
Contains: mine location; Industrial Surface and Underground Mines Reporting Production 1993-2002 by mine; Bituminous and Anthracite Surface and Underground Coal Production 1993-2002; employment by mine.
Available at http://www.dep.state.pa.us/dep/deputate/minres/bmr/reports/

Coal Production Data Files 1991-2003
U.S. Department of Energy, Energy Information Administration
Contains coal production by mine, employment by mine.
Available at http://www.eia.doe.gov/cneaf/coal/page/database.html

Projected Data

No projections of mining production.
See projections of employment.

Water Use Data

WUDS: MINERAL USE monthly withdrawals

THERMOELECTRIC POWER WATER USE

Historical Data

Inventory of Electric Utility Power Plants in the United States 2000
DOE/EIA-0095(2000)
U.S. Department of Energy, Energy Information Administration
Contains location, capacity of plants.

2003 EIA-906/920 Monthly Time Series File
U.S. Department of Energy, Energy Information Administration
Contains monthly power production and fuel use for every power plant
Available at http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html

Projected Data

None

Water Use Data

WUDS: ELECTRIC USE monthly withdrawals

Consumptive Water Use for U.S. Power Production, December 2003
P. Torcellini, N. Long, and R. Judkoff. National Renewable Energy Laboratory, Golden, CO. Department of Energy.
Contains: formulas for estimating water consumption based upon power production for different types of power plants.

HYDROELECTRIC POWER

Historic Data

Hydroelectric Projects under Commission License
Hydroelectric Projects Exempted from Commission License
Preliminary Licenses Issued for Hydroelectric Projects
Federal Energy Regulatory Commission
Contains: location, capacity by plant
Available at: http://www.ferc.gov/industries/hydropower/gen-info.asp

National Inventory of Dams
U.S. Army Corps of Engineers
Contains: location and reservoir size
Available at: http://crunch.tec.army.mil/nid/webpages/nid.cfm

Projected Data

None

Water Use Data

WUDS: ELECTRIC USE monthly withdrawals

AGRICULTURE

Historic Data

Census of Agriculture

Irrigated acres by crop type; livestock inventories
Level: State and County.
Years: 2002, 1997, 1992 and 1987.
Source: U.S. Department of Agriculture.

Livestock inventories (cattle, hogs, poultry and sheep).
Level: County and State
Dates: 1975 – 1997/98
Source: National Agricultural Statistics Service - Livestock County Data (93105)

Crop Production (planted and harvested acres; possibly irrigated acres)
Level: County and State
Dates: 1970/80 – 2003
Source: National Agricultural Statistics Service - Crops County Data Files

Projected Data

Planted and harvested acreage for major field crops

Data Items	Level	From	To	Source:
Planted and harvested acreage for major field crops (includes: corn, sorghum, barley, oats, wheat, rice, upland cotton and soybeans).	National	2003	2014	USDA Baseline Projections, February 2005
Production projections (in millions of pounds) for potatoes, tobacco, vegetables and fruits.	National	2003	2014	USDA Baseline Projections, February 2005
Livestock Inventories (Cattle, Beef cows, milk cows, Hogs).	National	2003	2014	USDA Baseline Projections, February 2005
Poultry stocks (millions pounds - young chickens and turkey)	National	2003	2014	USDA Baseline Projections, February 2005

Water Use Data

Estimation of Agricultural Animal and Irrigated-Crop Consumptive Water Use in the Susquehanna River Basin for the Years 1970, 2000 and 2025 by Jarrett A.R. and Hamilton M. for the Susquehanna River Basin Commission. 2002.

Average acre-feet applied per acre for an exhaustive list of irrigated crops (major irrigated crops in Pennsylvania determined from 2002 Agriculture Census - irrigated acres estimates).

Level: state averages by crop type
Source: 2002 Census of Agriculture Farm and Ranch Irrigation Survey (2003): Released November 15, 2004, by the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, U.S. Department of Agriculture.

Suggested Crops (based on total irrigated acres in the state)
1. Vegetables
2. Corn for grain
3. Corn for silage
4. Potatoes
5. Forage crops
6. Orchards

Farm animal water use (gal per animal per day).
Level: general averages.
Source: Two reports from the College of Agricultural Sciences, Cooperative Extension, Penn State.
1) *Estimating Water Use for the Farm and Home,*
2) *Agricultural Water Needs and Sources Water Supply.*

Suggested Livestock (based on 2002 inventories in the state)		
	Estimated Water Use in Gallons per Day	
	Source 1	*Source 2*
1. Dairy cow	35	35
2. Dry cow, beef cattle or steers** 2. Steer*	12**	20*
3. Hogs	1.5	1.5
4. Chickens (per 100 head)	9	9

CDM

WUDS: AGRICULTURAL USE monthly withdrawals

Maps and Cartographic Resources

Production, acreage and yield data maps.
Level: National and State and County level boundaries.
Source: Census of Agriculture

Appendix 2.B
An Assessment of Residential Water Use per Household

As described in the methodology for residential water use, data from WUDS and Act220 databases were compiled to form one data file for analysis. Data compilation was achieved by matching and merging available records by common field identifiers. In general, the PRMRY_FAC_ID and WUDS_FACILITY_ID were the main identifiers of individual facilities, though other codes such as the SUB_FAC_ID and the WUDS_SUBS_FACILITY_ID were all used to link records. Tables that were compiled for this process included:

- WUDS_Withdrawals – contains multi-year, sub facility level water withdrawals by month and year
- DRB_Registration – contains 2003 sub facility level water withdrawals by month and year
- WUDS_USE_Histories – contains historical water use

Each of the tables offered some useful insights about the water withdrawing facilities and their water withdrawal tendencies. For purposes of clarity, the terms water use and water withdrawals are used synonymously.

Facilities that could potentially be associated with residential water withdrawals were identified by several fields. These include the Use Type Code, Primary Facility Kind ID, Facility Type and Facility Designation. Public water supply or water purveyor withdrawal records generally share the same codes for most of these fields except for their facility designation code. This field and associated descriptor differentiates the different types of water purveyors. Table 2.B.1 below presents some typical facility designations associated with water purveyors. Looking at the facility designation descriptions in the far right column, it is clear that some of these water purveyors have little relevance in regards to estimating residential water use.

TABLE 2.B.1
COMMON FACILITY DESIGNATIONS ASSOCIATED WATER PURVEYORS

Use Type Code	Primary Facility Kind ID	Facility Type Description	Facility Designation	Facility Designation Description
12	31	Water Purveyor	0	Unidentified Facility Type
12	31	Water Purveyor	53	Authority
12	31	Water Purveyor	54	Auth Leases Back To Mun
12	31	Water Purveyor	55	Municipal
12	31	Water Purveyor	56	Private Investor Owned
12	31	Water Purveyor	57	Association - Co-Op
12	31	Water Purveyor	58	Mobile Home Park
12	31	Water Purveyor	61	Municipal - (Purchases)
12	31	Water Purveyor	62	Institutional Military
12	31	Water Purveyor	63	Institutional Health
12	31	Water Purveyor	64	Institutional Education
12	31	Water Purveyor	65	Institutional Correctional
12	31	Water Purveyor	66	Institutional Recreational
12	31	Water Purveyor	80	Priv Investr Owned-(Pu)
12	31	Water Purveyor	84	Apartments

To obtain a better understanding of the

relevance and significance of water withdrawals by each of these designations, total annual water withdrawals were evaluated. Table 2.B.2 shows 2003 water purveyor estimated annual water withdrawals, grouped and summed by facility designation for all data reviewed. Table 2.B.2 shows that in 2003 the majority of purveyor water withdrawals (58.4 percent) were by facilities designated as municipal facilities. Approximately 25 percent of reported purveyor withdrawals were made by private investor owned type facilities, while 11 percent of reported purveyor withdrawals were by authority designated facilities. The majority of other facility designations accounted for less than 1 percent of total water purveyor withdrawals in 2003. The findings in Table 2.B.2 are consistent across all years analyzed (1990 to 2003), with minor exceptions in years with markedly low total purveyor volumes. Table B.2 also indicates that focusing residential water use analysis on water withdrawals by municipals, authorities and private investor owned type facilities is reasonable. Based on these observed distributions, a decision was made to use municipals, authorities and private investor owned type facilities in estimating the residential water use factor.

TABLE 2.B.2
20003 ANNUAL WITHDRAWALS BY FACILITY DESIGNATION

Year	3asir Cod	Use Type Code	Primary Facility Kind ID	Facility Type Description	Facility)esignatio	Facility Designation Description	Sum of Annual Quantity (in gallons)	Percent of Annual Total
2003	1	12	31	Water Purveyor	0	Unidentified Facility Type	3,821,840	0.0%
2003	1	12	31	Water Purveyor	53	Authority	22,308,677,904	11.0%
2003	1	12	31	Water Purveyor	54	Auth Leases Back To Mun	10,534,277,320	5.2%
2003	1	12	31	Water Purveyor	55	Municipal	118,153,303,908	58.4%
2003	1	12	31	Water Purveyor	56	Private Investor Owned	50,169,149,226	24.8%
2003	1	12	31	Water Purveyor	57	Association - Co-Op	506,437,702	0.3%
2003	1	12	31	Water Purveyor	58	Mobile Home Park	305,923,130	0.2%
2003	1	12	31	Water Purveyor	61	Municipal - (Purchases)	20,719,000	0.0%
2003	1	12	31	Water Purveyor	62	Institutional Military	172,331,348	0.1%
2003	1	12	31	Water Purveyor	63	Institutional Health	44,393,657	0.0%
2003	1	12	31	Water Purveyor	64	Institutional Education	27,500,890	0.0%
2003	1	12	31	Water Purveyor	66	Institutional Recreational	9,725,967	0.0%
2003	1	12	31	Water Purveyor	80	Priv Investr Owned-(Pu)	7,022,000	0.0%
2003	1	12	31	Water Purveyor	84	Apartments	20,512,858	0.0%
TOTAL							202,283,796,750	100.0%

Estimation of Annual Average Daily Residential Water Use

Water withdrawals in WUDS and Act220 are recorded in various magnitudes. Many of the records have reported month, years and daily estimates. However, few records have water withdrawal information that this is not in a consistent format for analysis. This variation in reported water withdrawal magnitudes and formats would result in a loss of some observations when performing some analytical functions. To maximize the number of available records for analysis, all water withdrawal estimates were converted to annual average daily estimates in gallons. A simple protocol was established that allowed for the calculation of this value where one was not provided. Annual average daily water use is defined as:

(daily water use x number of use days in a year)/365

In some instances, water use may have been provided in years. In this case annual average daily water use is simply the annual total divided by 365. Annual average daily water use estimates by water purveyor were used in calculating the residential water use factor.

Per Household Water Use Estimates

In order to estimate residential water use per household, water purveyor withdrawals were matched to demographic data. This process required the overlaying of census demographic data over each water purveyor's (PWS) water service area boundaries. A zipped shape containing purveyors with digitized water service areas boundaries was obtained from PADEP. Using GIS, each defined water service area was matched to applicable census block demographic data. The number of households falling within each service area boundary was assumed to be served by the purveyor. This procedure provides a means of associating water withdrawals or water use with the population served.

Having already estimated the annual average daily water use for each water purveyor, residential water was estimated using the provided percent allocation contained in one of the WUDS tables. Each individual facility had its own percent allocation. A portion of unaccounted water estimates was distributed to residential use based on the ratio of accounted-residential water use to total accounted-water use for each purveyor. Facilities that did not have a percent allocation were not used.

Per household water use estimates were generated by simply dividing the derived annual average residential daily water use estimate for each purveyor by the matching number of households assumed to be served by that purveyor. Table 2.B.3 provides average percent allocations of water withdrawals by facility designation for all data reviewed.

TABLE 2.B.3
AVERAGE PERCENT ALLOCATIONS BY FACILITY DESIGNATION

Facility Designation	Facility Designation Description	Domestic	Commer cial	Institu-tional	Industrial	Bulk	Un-accounted	Other
0.00	Unidentified Facility Type	100.00	0.00	0.00	0.00	0.00	0.00	0.00
53.00	Authority	54.61	9.08	0.02	7.72	5.88	18.86	4.49
54.00	Auth Leases Back To Mun	51.42	9.25	0.00	9.24	2.16	22.33	5.59
55.00	Municipal	56.79	7.87	0.00	8.17	3.27	16.66	7.23
56.00	Private Investor Owned	66.06	11.19	0.00	4.09	0.78	13.26	3.02
57.00	Association - Co-Op	72.68	13.33	0.00	0.01	0.00	13.88	0.10
58.00	Mobile Home Park	91.22	0.18	0.00	0.00	0.00	8.60	0.00
61.00	Municipal - (Purchases)	73.00	10.00	0.00	0.00	0.00	13.00	4.00
62.00	Institutional Military	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63.00	Institutional Health	0.00	0.00	0.00	0.00	0.00	0.00	31.11
64.00	Institutional Education	4.36	0.00	4.35	0.00	0.00	0.00	9.08
65.00	Institutional Correctional	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66.00	Institutional Recreational	3.76	41.67	0.00	0.00	0.00	2.19	52.38
80.00	Priv Investr Owned-(Pu)	92.00	0.00	0.00	0.00	0.00	8.00	0.00
84.00	Apartments	99.36	0.00	0.00	0.00	0.00	0.64	0.00

RESULTS:

- Table 2.B.4 presents results of a broad based comparison of per household water use by facility designation.

TABLE 2.B.4
ANNUAL AVERAGE DAILY RESIDENTIAL WATER USE PER HOUSEHOLD
BY FACILITY DESIGNATION
(Combined Years between 1990 and 2003)

Facility Designation	Facility Designation Description	N	Mean	Minimum	Maximum	StDev
0	Unidentified Facility Type	1	5,235	5,235	5,235	-
53	Authority	378	179	0	2,840	164
54	Auth Leases Back To Mun	133	258	12	1,205	188
55	Municipal	333	199	13	507	84
56	Private Investor Owned	320	346	0	3,739	548
57	Association - Co-Op	98	736	144	5,350	857
58	Mobile Home Park	91	698	23	8,377	1,063
61	Municipal - (Purchases)	1	36	36	36	-
62	Institutional Military	-	-	-	-	-
63	Institutional Health	21	0	0	0	0
64	Institutional Education	3	0	0	1	0
65	Institutional Correctional	-	-	-	-	-
66	Institutional Recreational	21	163	0	529	184
80	Priv Investr Owned-(Pu)	1	310	310	310	-
84	Apartments	20	464	0	1,324	424

- Table 2.B.5 shows the variation in annual average daily residential water use per household between 1990 and 2003.

TABLE 2.B.5
ANNUAL AVERAGE DAILY RESIDENTIAL WATER USE PER HOUSEHOLD
BY YEAR
Authority, Municipal & Private Investor Owned (Combined)

Facility Type Description	Year	N	Mean	Minimum	Maximum	StDev
Water Purveyor	1990	88	264	21	3,251	383
Water Purveyor	1991	91	223	0	3,015	353
Water Purveyor	1992	97	214	0	2,736	314
Water Purveyor	1993	96	243	4	2,984	325
Water Purveyor	1994	101	215	5	1,996	234
Water Purveyor	1995	103	246	0	3,685	373
Water Purveyor	1996	102	222	0	3,739	376
Water Purveyor	1997	108	256	0	3,728	447
Water Purveyor	1998	107	226	0	2,139	236
Water Purveyor	1999	53	240	15	1,651	252
Water Purveyor	2003	85	267	0	1,731	253

- Table 2.B.6 shows how preliminary annual average daily residential per household water use factors vary from one watershed code to the next. Values are unweighted averages.

TABLE 2.B.6
1998 ANNUAL AVERAGE DAILY RESIDENTIAL WATER USE PER HOUSEHOLD BY WATERSHED CODE
Authority, Municipal & Private Investor Owned (Combined)

Basin Code	Sub Basin Code	Watershed Code	Watershed Name	N	Mean	Minimum	Maximum	StDev
1	1	B	Shehawken	3	167	89	269	92
1	1	D	Shohola	5	435	132	978	349
1	1	E	Brodhead	5	784	301	2,139	767
1	1	F	Jacoby	2	132	113	151	27
1	2	A	Upper Lehigh River	3	174	75	282	104
1	2	B	Middle Lehigh River	4	205	58	423	163
1	2	C	Lower Lehigh River	12	164	15	241	64
1	2	D	Cooks	8	203	19	350	101
1	2	E	Pidcock	4	252	180	398	99
1	2	F	Neshaminy	10	212	0	501	196
1	3	A	Upper Schuylkill River	6	202	161	268	38
1	3	B	Maiden Creek	5	168	120	202	30
1	3	C	Tulpehocken Creek	9	166	112	215	38
1	3	D	Manatawny	5	136	85	272	78
1	3	E	Perkiomen Creek	15	176	18	448	105
1	3	F	Lower Schuylkill	4	262	10	579	236
1	3	H	Brandyywine Creek	2	217	191	243	37
1	3	I	White Clay Creek	3	213	63	384	161
1	3	J	Poquessing	2	118	43	194	107

CDM

Appendix 2.C
An Assessment of Nonresidential Water Use per Employee

Following the methodology discussed in Section 2.5 for nonresidential water use, this appendix presents some preliminary exploratory estimates of the number employees associated with a sample of PWS service areas, the per employee water use for different types of PWS designations, and the per employee water use for a sample of watersheds.

Table 2.C.1 presents the range of estimates of the number of employees associated with each water purveyor service area for the Pennsylvania portion of the Delaware River Basin. Estimates were derived using GIS by overlaying employment by minor civil division (MCD) and service area boundaries of each PWS. The employment data represents 2004 employment and was adjusted such that the sum of employment by MCDs in a given county equals the total county employment from WIA estimates.

Employment associated with each PWS service area is estimated from those MCDs that fall within the PWS service area boundary. Some MCDs only partially intersect with PWS service areas. For these MCDs, only the portion of the MCD that falls within the service area boundaries is attributable to the PWS. Table 2.C.1 shows that service area for water purveyors that are designated as authorities, municipals or private investor owned, account for relatively more significant numbers of employment compared to other types. Very low employment is associated with water PWS service areas designated as mobile home parks, institutional recreational, or apartment purveyors.

TABLE 2.C.1
ASSOCIATED EMPLOYMENT BY PWS BY FACILITY DESIGNATION
(based on 2004 estimates of employment by minor civil division and available digitized boundaries of each PWS)

Facility Type Description	Facility Designation	Facility Designation Description	N	Employees Mean	Employees Minimum	Employees Maximum	Employees StDev
Water Purveyor	53	Authority	41	6,738	3	48,604	11,069
Water Purveyor	54	Auth Leases Back To Mun	16	4,697	0	56,852	14,079
Water Purveyor	55	Municipal	33	24,964	1	681,199	118,263
Water Purveyor	56	Private Investor Owned	41	7,848	0	234,397	36,471
Water Purveyor	57	Association - Co-Op	9	13	0	85	27
Water Purveyor	58	Mobile Home Park	4	22	3	66	30
Water Purveyor	61	Municipal - (Purchases)	1	1,096	1,096	1,096	
Water Purveyor	63	Institutional Health	8	260	0	1,675	583
Water Purveyor	64	Institutional Education	3	126	2	307	160
Water Purveyor	66	Institutional Recreational	2	10	1	18	12
Water Purveyor	84	Apartments	2	1	1	2	1

Table 2.C.2 show the statistics of estimated per employee annual average daily water use calculated for different types of PWS service areas in the Pennsylvania portion of the Delaware River Basin. These estimates also account for self supply water demand falling with the boundaries of each PWS. Available water use in each year between 1987 and 2003 for each PWS is divided by the 2004 employment estimate for the PWS. Calculated estimates of gallons per employee per day show

significant variation across PWS designations and within each PWS designation. A closer scrutiny in the framework of a pilot study is recommended prior to providing guidance on what values would be appropriate. What is important to note from Table 2.C.2 is the variation in water use and how specific characteristics within a service area generate these variations.

TABLE 2.C.2
PWS NONRESIDENTIAL WATER USE IN GALLONS PER EMPLOYEE PER DAY (GED) BY FACILITY DESIGNATION
(Combined Years between 1987 and 2003)

Facility Designation	Facility Designation Description	N	GED Mean	GED Minimum	GED Maximum	GED StDev
53	Authority	435	561	0	52,466	2,812
54	Auth Leases Back To Mun	164	12,036	2	604,241	74,368
55	Municipal	380	1,899	2	60,679	8,789
56	Private Investor Owned	355	6,351	0	146,306	23,549
57	Association - Co-Op	42	257,143	286	1,513,287	412,381
58	Mobile Home Park	3	864	586	1,028	241
61	Municipal - (Purchases)	1	8	8	8	
63	Institutional Health	28	29,165	54	80,494	33,523
64	Institutional Education	3	450	256	786	292
66	Institutional Recreational	26	32,266	1,179	98,245	35,548

Following the reasoning in the Section 2 Appendix 2.B, and referring to Table 2.C.1 above, service areas associated with water purveyors designated as authorities, municipals, or private investor-owned facilities (designation 53, 55, and 56 only) appear to be more relevant for purposes of estimating per employee water use factors. Table 2.C.3 shows statistical results from calculations of gallons per employee per day based on a selected sample of water purveyors designated as either authorities, municipals, or private investor owned. As with Table 2.C.2, the GED values shown in Table 2.C.3 are the result of dividing available water use for a PWS in a given year by the estimated 2004 employment for that PWS service area. Table 2.C.3 shows that within service areas that are serviced by authorities, municipals, or private investor-owned purveyors, average (mean) per employee water use has been relatively steady between 1987 and 2003.

TABLE 2.C.3
PWS NONRESIDENTIAL WATER USE IN GALLONS PER EMPLOYEE PER DAY (GED) BY YEAR
Authority, Municipal & Private Investor Owned (Combined)

Facility Type Description	Year	N	GED Mean	GED Minimum	GED Maximum	GED StDev
Water Purveyor	1987	74	2,594	1	105,149	13,740
Water Purveyor	1988	81	2,608	2	117,843	14,090
Water Purveyor	1989	82	3,058	1	132,049	16,227
Water Purveyor	1990	84	3,013	2	127,201	15,797
Water Purveyor	1991	86	2,646	1	117,961	13,969
Water Purveyor	1992	90	2,469	0	107,051	12,827
Water Purveyor	1993	88	2,408	0	107,994	12,755
Water Purveyor	1994	91	2,451	1	78,103	11,614
Water Purveyor	1995	94	2,741	1	144,175	16,072
Water Purveyor	1996	92	3,145	1	146,306	17,156
Water Purveyor	1997	96	3,522	1	145,860	17,332
Water Purveyor	1998	95	2,360	0	83,707	11,427
Water Purveyor	1999	48	2,902	6	64,611	12,361
Water Purveyor	2003	69	2,606	0	67,746	10,727

Finally, Table 2.C.4 shows the variation in the annual average daily water use per employee by watershed codes within the Pennsylvania portion of the Delaware River Basin. The GED values shown in Table 2.C.4 are calculated by PWS with available 2003 water use data and estimated 2004 employment by PWS. Recognizing the variation in per employee water use by watershed can be very useful when trying to estimate future water demands by basin or sub basin. Though the estimates in Table 2.C.4 are preliminary in nature, they show the likely variation that can be expected in different service areas. Such variation can be the result of the types and mix of industries within a service area and water use patterns among those industries.

TABLE 2.C.4
PWS NONRESIDENTIAL WATER USE IN GALLONS PER EMPLOYEE PER DAY (GED) BY WATERSHED
Authority, Municipal & Private Investor Owned (Combined)

Basin Code	Sub Basin Code	Watershed Code	Watershed Name	N	GED Mean	GED Minimum	GED Maximum	GED StDev
1	1	B	Shehawken	2	42	28	56	20
1	1	D	Shohola	3	1,335	40	3,820	2,152
1	1	E	Brodhead	2	33,880	14	67,746	47,894
1	1	F	Jacoby	1	777	777	777	
1	2	A	Upper Lehigh River	1	141	141	141	
1	2	B	Middle Lehigh River	4	10,773	226	30,705	13,606
1	2	C	Lower Lehigh River	10	496	5	2,252	712
1	2	D	Cooks	3	12	0	21	11
1	2	E	Pidcock	2	299	92	506	292
1	2	F	Neshaminy	7	100	3	429	149
1	3	A	Upper Schuylkill River	3	461	64	1,174	619
1	3	B	Maiden Creek	3	266	197	335	69
1	3	C	Tulpehocken Creek	6	292	35	1,153	440
1	3	D	Manatawny	4	122	2	237	130
1	3	E	Perkiomen Creek	9	5,797	9	51,557	17,160
1	3	F	Lower Schuylkill	4	143	54	228	94
1	3	H	Brandyywine Creek	1	50	50	50	
1	3	I	White Clay Creek	3	142	99	221	69
1	3	J	Poquessing	1	11	11	11	

Section 3 - Pilot Study Report

Water Demand Forecast for Lehigh River Basin

Section 3
Water Demand Forecast for Lehigh River Basin

3.1 Introduction

Following the approval of the water demand forecasting methodologies proposed in Section 2, *Water Demand Forecasting Methodologies for Pennsylvania,* a pilot scale implementation of the recommended water demand forecasting approach was approved. The pilot study was implemented through the execution of Task 3 of the scope of work. Task 3 entailed applying recommended forecasting methods from Section 2 to a designated study area within the Delaware River Basin and incorporating forecasting models into an automated forecasting tool for use by Delaware River Basin Commission (DRBC).

DRBC selected the Lehigh River Basin as the representative study area. The objective of the pilot study was to separately forecast future water demand for:

- Residential
- Nonresidential
- Agriculture
- Mining
- Thermoelectric Power
- Hydroelectric Power

Data recently made available from the Pennsylvania Department of Labor and Industry (PDLI) offered an opportunity to separately evaluate water demand for the manufacturing and non-manufacturing portions of nonresidential water demand. This report presents findings from the pilot study.

Following this introductory section, Section 3.2 through 3.7 provide separate but parallel descriptions of data collection efforts for the study area and estimation of water demand for the six respective water demand sectors listed above. Section 3.8 provides a summary of findings and recommendations for future application of the forecasting methodology.

3.2 Residential Water Use

Residential water demand in the Lehigh River Basin was estimated from the Act 220 registrations Access table of water withdrawals and was taken to generally represent water withdrawals in 2003. This Access table contained approximately 406 unique primary facility IDs which were assumed to represent establishments that withdrew water in 2003. A total of 261 of the facility IDS had a Use Type code classification of 12 (described as Public Water Supply or PWS). Separately, 144 unique facility IDs were identified to have service area boundaries that intersect or are within the Lehigh River Basin. Linking the 261 PWS IDs with the available 144 service area boundaries resulted in a match of 56 records. These matched records represented PWS from the Act 220 registrations Access table with service area boundaries that intersect or are within the Lehigh River Basin. A closer review of available PWS records indicated that though public water supply facilities are identifiable by their Use Type code of 12, the facilities have different facility designations. Facility designations describe the different types of public water purveyors and include the following designations: authority, municipal, private investor owned, mobile home park, institutional military, and institutional correctional. See Section 2 Appendix 2.B for a discussion of facility designation codes.

For purposes of estimating a representative residential household water use factor, only PWS's with a designation of authority, municipal, and private investor owned were selected. The general reasoning was that authority, municipal, and private investor owned type purveyors typically provide a representative estimate of residential per household water use. The PWS establishments selected to estimate residential water demand were a combination of water authorities, municipals, and private investor owned operations within the Lehigh Basin. To be useful in determining a residential water use factor, these establishments needed to:

- show a percent allocation of water to domestic purposes,
- have digitized service area boundaries,
- have the associated number of households served.

Table 3.2.1 presents summary residential water use and the number of household statistics for public water providers that met these criteria. These providers show a 2003 annual average daily combined withdrawal of approximately 2.00 million gallons per day of which an average of 0.92 million gallons a day are attributable to domestic or residential use. Residential water use consists of accounted domestic water use and an allocation of unaccounted water. Unaccounted residential water was estimated as a portion of total unaccounted water based on the ratio of accounted residential (domestic) water use to the sum of accounted domestic, commercial, institutional, and industrial water use. The average number of households served by the public water providers was 4,421; resulting in an average per household water use estimate of 283 gallons a day. Using the number of households served by each PWS as weights, the weighted average water use factor from public water providers in the Lehigh River Basin is 208 gallons per day per household. The weighted average water use factor is taken to reflect a value that is representative of per household use for all households throughout the basin.

TABLE 3.2.1
RESIDENTIAL WATER USE AND THE NUMBER OF HOUSEHOLDS SERVED BY PUBLIC WATER SUPPLY AREAS

	N	Average	Median	Minimum	Maximum	St.dev.	Sum	Weighted Average
PWS Annual Average Daily (gallons per day) [1]	22	1,999,046	244,024	6,556	15,462,999	3,694,013	43,979,006	--
Percent of PWS water attributable to Residential [2]	22	62%	53%	18%	100%	30%	--	--
Accounted Domestic Water Use (gallons per day)	22	717,675	151,408	6,556	5,412,050	1,284,447	15,788,852	--
Unaccounted Residential Water Use (gallons per day) [3]	22	201,934	48,146	0	1,211,653	317,919	4,442,556	--
Total PWS Residential Water Use (gallons per day) [4]	22	919,609	186,743	6,556	6,623,702	1,584,565	20,231,408	--
Weights (number of households in PWS) [5]	22	4,421	1,050	26	41,131	9,051	97,257	--
Per Household Water Use (gallons per household per day)	**22**	**283**	**250**	**86**	**479**	**139**	**--**	**208**

[1] Water use estimates based on 2003 reported Act 220 Water Withdrawals.
[2] Percent allocations are based on percentages provided in a WUDS extracted table provided (Wuds_Water_Purveyors_03_08_05.xls). Percent of PWS attributable to accounted residential use is assumed to be equal to percent domestic.
[3] For any PWS, unaccounted residential water was estimated as a portion of total unaccounted water based on the ratio of accounted residential (domestic) water use to the sum of accounted domestic, commercial, institutional, and industrial water use.
[4] Data on any self supplied residential water potentially located within the PWS service area boundary was not available and is not included in the total.
[5] Number of households per PWS based on GIS overlay of 2000 Census block demographic data.

To estimate the number of households in the Lehigh River Basin to be multiplied by the estimated water use factor, GIS was used to overlie the digitized boundary that defines the entire basin with Year 2000 Census block demographic data. The sum of population and number of households from census blocks that matched to the basin produced the population and household estimates for the basin. Census blocks were considered to match to the basin when they fell within the basin boundaries or when they intersected the basin boundaries. When census blocks intersected basin boundaries, a constant density assumption was used to assign portions of the block's population and households to the basin based on the percent of the block that matched to the basin. Dividing the population by the number of household establishes a baseline estimate of persons per household for each county that is used to derive household projections from county level population projections. Table 3.2.2 presents population and number of household estimates from the 2000 Census data by county for the Lehigh River Basin. For each county, a GIS-based estimate of in-basin population and number of household estimate for each county is provided as well as a percent ratio of in-basin number of households to total county households. This ratio is used to allocate portions of county number of household projections to the basin.

TABLE 3.2.2
ESTIMATED CENSUS 2000 POPULATION AND NUMBER OF HOUSEHOLDS FOR COUNTIES AND PORTIONS OF COUNTIES IN-BASIN

	Population	Households	Persons per household	In-basin population	In-basin households	Percent of in-basin number of households
Berks	376,206	142,543	2.64	6,406	2,427	1.70%
Bucks	597,635	218,725	2.73	251	92	0.04%
Carbon	58,802	23,701	2.48	52,017	20,966	88.46%
Lackawanna	213,295	86,218	2.47	2,061	833	0.97%
Lehigh	312,090	121,906	2.56	303,197	118,432	97.15%
Luzerne	319,250	130,687	2.44	20,744	8,492	6.50%
Monroe	138,687	49,454	2.80	43,728	15,593	31.53%
Northampton	267,066	101,541	2.63	170,216	64,718	63.74%
Schuylkill	150,336	60,530	2.48	4,407	1,774	2.93%
Wayne	47,722	18,350	2.60	1,310	504	2.75%
Lehigh River Basin Total	**--**	**--**	**2.58**	**609,581**	**235,831**	

Estimates based on the 2000 Bureau of Census data.

The water demand projection driver for residential water use is the number of households. Projections of the number of households for a river basin are derived from county level projections that are then apportioned to the basin based on the ratio of households "in-basin" compared to households "outside-basin" for each county in the baseline year. County level household projections were derived from population projection data at the county level in the WUDS Extract file from Pennsylvania Department of Environmental Protection (PADEP). Projections contained in this file are in 10-year intervals from 2010 to 2040. County level populations for 2005, 2015, and 2025 were estimated by assuming constant change respectively between the interval 2000-2010 and 2010-2020, and 2020-2030. Projections of population are converted to number of household projections by assuming a constant value for persons per household over time. A constant persons per household value by county was assumed for the analysis because no better information was available about future persons per household estimates in the counties.

Residential water use for the forecast years is estimated by multiplying the established weighted average water use factor from Table 3.2.1 by projected number of households in each year. Table 3.2.3 presents the projected number of households in the Lehigh River Basin and the corresponding water demand estimate. Water demand projections presented in Table 3.2.3 can be considered as baseline forecasts given the baseline projections of the number of households and constant residential water use factor. The multiplication of a residential water use factor by the total number of households in the service area in essence implies that all households in the basin are accounted for and thus indirectly accounts for self supplied residential use in the basin. Annual water demand totals are also presented in Figure 3.2.1. The projections show a gradual increase in residential water demand in the Lehigh River Basin between 2005 and 2030.

TABLE 3.2.3
LEHIGH RIVER BASIN NUMBER OF HOUSEHOLDS AND RESIDENTIAL WATER DEMAND PROJECTIONS

	2005	2010	2015	2020	2025	2030
Lehigh River Basin Households Projections	238,364	240,897	243,604	246,311	247,269	248,228
Per Household Average Daily Water Use (gallons per household per day)	208	208	208	208	208	208
Per Household Average Annual Water Use (gallons per household per year)	75,927	75,927	75,927	75,927	75,927	75,927
Residential Annual Water Use (MG per year)	**18,098**	**18,291**	**18,496**	**18,702**	**18,775**	**18,847**

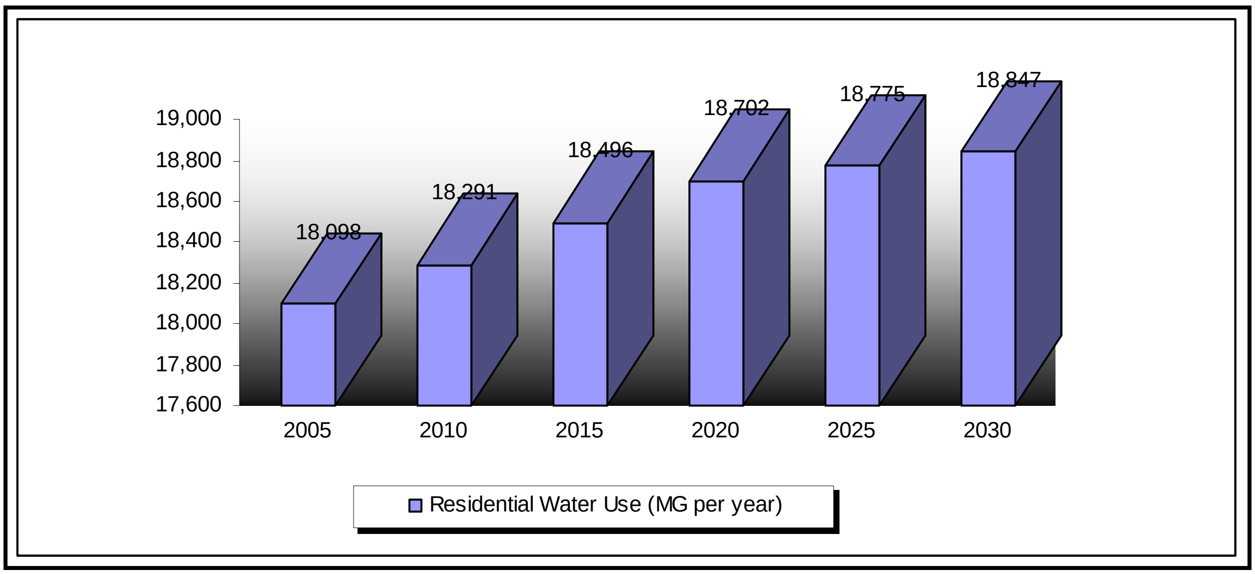


FIGURE 3.2.1
PROJECTED RESIDENTIAL WATER DEMAND IN THE LEHIGH RIVER BASIN

3.3 Nonresidential Water Use

In a slight deviation from what was recommended in Section 2, recently acquired employment data from PDLI offered an opportunity to further disaggregate nonresidential water use. Recently acquired employment data that was provided by PDLI are available at the 2-digit North American Industrial Classification System (NAICS) level. The data are also spatially referenced by county, census block, and employment site (specified by latitude and longitude coordinates). This level of employment disaggregation permits the estimation of manufacturing and non-manufacturing water use factors since these two categories of employment can now also be estimated. Generating separate water demand estimates for manufacturing and non-manufacturing is particularly desirable because it makes the forecasted water demand more in line with the USGS screening tool being developed for identification of water supply critical areas.

To estimate the water use factor for manufacturing, the quantity of reported manufacturing (industrial) withdrawals of each PWS is divided by estimated manufacturing employment in the PWS service area. PWS providers reporting water withdrawals and a percent allocation for industrial water use purposes were identified. The working assumption was that each PWS' percent allocation for industrial purposes represents manufacturing. A portion of each PWS' reported unaccounted water withdrawal was distributed to manufacturing water use based on the ratio of industrial use to the sum of domestic, commercial, institutional, and industrial water use.

Similarly, the quantity of reported non-manufacturing withdrawals of each PWS is divided by the associated non-manufacturing employment in the PWS service area. Water withdrawals attributable to non-manufacturing use for a PWS was assumed to be that water use allocated to commercial and institutional water use plus a portion of unaccounted water based on the ratio of commercial and institutional water use to the sum of domestic, commercial, institutional, and industrial water use. The PWS providers selected to estimate manufacturing and non-manufacturing water use factors were also those that could be matched to manufacturing and non-manufacturing employment respectively. To ensure that all manufacturing and non-manufacturing water use within a PWS service area was captured, any manufacturing and non-manufacturing self-supply water withdrawals within a PWS service area that could be identified were added to the PWS nonresidential water estimate. Self-supply water using facilities within PWS service areas were identified by their latitude and longitude coordinates using GIS.

PDLI provided industry disaggregated employment estimates that were spatially referenced by county, census block, and employment site (XY coordinates). Table 3.3.1 presents the general breakout of PDLI covered employment data. The employment data provided by PDLI provides a means of estimating employment within each PWS. However, the data provided only represents employment covered by unemployment insurance and approximately a third of the employment sites have not been linked to census block or latitude and longitude coordinate information. As a result, reported covered employment at employment sites with XY coordinates was used to estimate the proportional distribution of employment in each PWS service area by first using GIS to overlie employment sites with PWS service areas, and then applying the established county based distribution of employment to total employment obtained from WIA 2000 to 2010 employment projections. Employment was categorized as manufacturing, mining, or non-manufacturing based on the associated industry code. Mining employment was excluded from nonresidential analysis since this sector is analyzed separately.

TABLE 3.3.1
2004 Covered Employment Estimates for Counties Around Lehigh River Basin

County Name	Covered Employment		
	At All Employment Sites[1]	Sites with XY Coordinates	XY Employment as a Percent of Total
Berks	161,521	110,426	68.4%
Bucks	254,516	168,652	66.3%
Carbon	16,488	12,697	77.0%
Lackawanna	98,246	68,825	70.1%
Lehigh	172,667	99,515	57.6%
Luzerne	138,487	95,298	68.8%
Monroe	50,679	32,798	64.7%
Northampton	90,865	57,478	63.3%
Schuylkill	48,438	34,259	70.7%
Wayne	14,475	10,110	69.8%
TOTAL	**1,046,382**	**690,058**	

[1]*Employment of 16,469 Statewide, was reported to have no physical location and is not accounted for in the county totals above*
[1]*Employment of 60,655 statewide, was reported as unassigned and is not accounted for in the county totals above*
source: Access file of PDLI covered employment data provided, DEP Data.mdb

Table 3.3.2 presents water use and manufacturing employment statistics for PWS service areas associated with manufacturing water use in the Lehigh River Basin. The service areas presented are those that:

- reported water withdrawals,
- provided a percent water allocation to industrial use, and
- could be matched to manufacturing employment.

The annual average daily manufacturing water use estimate for this collection of service areas is approximately 1.0 million gallons per day. Estimated manufacturing employment per PWS service area is 2,293 and the average per employee water use factor is 637 gallons a day. The weighted average for this collection of service areas is 438 gallons per employee per day.

Table 3.3.3 shows non-manufacturing water use statistics for 23 PWS service areas in the Lehigh River Basin. These service areas are those that reported water withdrawals, provided a percent water allocation to commercial or institutional water use, and could also be matched to non-manufacturing employment. Daily non-manufacturing water use averages approximately 0.34 million gallons. Non-manufacturing employment by service area is 7,983 on average. The average non-manufacturing per employee daily water use factor is 64 gallons per employee per day and the weighted average is 42 gallons per employee per day.

TABLE 3.3.2
MANUFACTURING WATER USE AND EMPLOYMENT ASSOCIATED WITH PUBLIC WATER SUPPLY AREAS FROM THE LEHIGH RIVER BASIN

Variable Description	N	Average	Median	Minimum	Maximum	St. Dev.	Sum	Weighted Average
PWS Annual Average Daily (gallons per day)[1]	18	3,674,259	1,393,792	8,290	15,689,945	4,862,680	66,136,658	--
Percent of PWS water attributable to manufacturing [2]	18	18%	9%	1%	72%	22%	--	--
Accounted Manuf. Water Use (gallons per day)	18	777,738	113,848	2,062	4,550,084	1,338,585	13,999,287	--
Unaccounted Manuf. Water Use (gallons per day) [3]	18	192,796	41,480	0	1,614,546	400,007	3,470,323	--
Manuf. Self Supply within PWS (gallons per day) [4]	18	34,013	0	0	579,290	136,300	612,231	--
Tot PWS Manuf. Water Use (gallons per day)	18	1,004,547	159,114	4,398	6,743,920	1,812,547	18,081,841	--
Weights (number of Manuf. Emp. in PWS) [5]	18	2,293	708	5	10,924	3,397	41,274	--
Manuf. per employee Wtr. Use (gallons per employee per day)	18	637	619	21	1,808	568	--	**438**

[1] Water use estimates based on 2003 reported Act 220 Water Withdrawals
[2] Percent allocations are based on percentages provided in a WUDS extracted table provided (Wuds_Water_Purveyors_03_08_05.xls). Percent of PWS attributable to accounted manufacturing use is assumed to be equal to percent industrial.
[3] For any PWS, unaccounted manufacturing water was estimated as a portion of total unaccounted water based on the ratio of accounted manufacturing (industrial) water use to the sum of accounted domestic, commercial, institutional, and industrial water use.
[4] To ensure that all manufacturing water use within a PWS service area was captured, any self supply identified to be industrial within the PWS service area boundary was added.
[5] Based on 2000 to 2010 WIA employment growth projections distributed to PWS service areas based on the distribution of 2004 Covered Employment with XY coordinates

TABLE 3.3.3
NON-MANUFACTURING WATER USE AND EMPLOYMENT ASSOCIATED WITH PUBLIC WATER SUPPLY AREAS FROM THE LEHIGH RIVER BASIN

	N	Average	Median	Minimum	Maximum	St.dev.	Sum	Weighted Average
PWS Annual Average Daily (gallons per day) [1]	23	2,979,866	1,291,260	23,288	15,689,945	4,491,581	68,536,916	
Percent of PWS Water Attributable to Non-manuf. (gallons per day) [2]	23	12%	9%	2%	100%	20%	--	--
Accounted Non-manuf. Water Use (gallons per day)	23	260,536	55,449	1,118	1,546,300	385,647	5,992,330	--
Unaccounted Non-manuf. Water Use (gallons per day) [3]	23	71,467	22,915	0	346,187	99,457	1,643,734	--
Non-manuf. Self Supply within PWS (gallons per day) [4]	23	5,175	0	0	73,258	17,639	119,020	--
Tot PWS Non-manuf. Water Use (gallons per day)	23	337,178	80,023	1,315	1,892,486	486,307	7,755,085	--
Weights (number of 2003 Non-manuf Emp. in PWS) [5]	23	7,983	1,923	87	54,708	13,601	183,606	--
Non-manuf. per employee Wtr. Use (gallons per employee per day)	23	64	51	3	228	55	--	42

[1] *Water use estimates based on 2003 reported Act 220 Water Withdrawals.*
[2] *Percent allocations are based on percentages provided in a WUDS extracted table provided (Wuds_Water_Purveyors_03_08_05.xls). Percent of PWS attributable to accounted non-manufacturing use is assumed to be equal percent commercial plus percent institutional.*
[3] *For any PWS, unaccounted non-manufacturing water was estimated as a portion of total unaccounted water based on the ratio of accounted non-manufacturing (commercial plus institutional) water use to the sum of accounted domestic, commercial, institutional, and industrial water use.*
[4] *To ensure that all non-manufacturing water use within a PWS service area was captured, any self supply identified to be commercial or institutional within the PWS service area boundary was added.*
[5] *Based on 2000 to 2010 WIA employment growth projections distributed to PWS service areas based on the distribution of 2004 Covered Employment with XY coordinates*

The GIS overlay of basin boundaries with employment data at sites with XY coordinates also enabled the estimation of total manufacturing and non-manufacturing employment in the Lehigh River Basin. The proportion of manufacturing and non-manufacturing employment at sites with XY coordinates in-basin were applied to total manufacturing and non-manufacturing employment estimates obtained from WIA 2000 to 2010 employment projections.

Future employment in the basin was calculated from employment trends in the counties. County trends are assumed to be same as those observed in the WIA encompassing each county. It was possible to separately project manufacturing and non-manufacturing employment since each WIA provides individual projections for each major employment industry. Manufacturing and non-manufacturing employment projections were derived by simple aggregation. Projections of employment beyond 2010 are simple constant growth extrapolations from 2010. Manufacturing and non-manufacturing employment projections can therefore be derived.

The following are the WIA sectors:

Industry Title
Mining
Construction
Manufacturing - Non Durables
Manufacturing - Durables
Transportation
Public Utilities and Communications
Wholesale Trade
Retail Trade
Finance, Insurance, and Real Estate
Services
Government

Baseline demand forecasts for manufacturing and non-manufacturing water use in the river basin were calculated by respectively multiplying the basin manufacturing water use factor by total basin manufacturing employment; and the basin non-manufacturing water use factor by the total basin non-manufacturing employment. Table 3.3.4 and Table 3.3.5 respectively show manufacturing and non-manufacturing employment projections to 2030 and associated water demand forecasts. Figure 3.3.1 and Figure 3.3.2 graphically illustrates projected annual manufacturing and non-manufacturing water demand.

TABLE 3.3.4
LEHIGH RIVER BASIN EMPLOYMENT AND WATER DEMAND PROJECTIONS FOR THE MANUFACTURING SECTOR

YEAR	2005	2010	2005	2020	2025	2030
In-Basin Manufacturing Employment	43,916	42,513	41,169	39,883	38,653	37,477
Per Employee Average Daily Water Use (gallons per employee per day)	438	438	438	438	438	438
Per Employee Average Annual Water Use (gallons per employee per year)	159,902	159,902	159,902	159,902	159,902	159,902
Manufacturing Water Use (MG per year)	**7,022**	**6,798**	**6,583**	**6,377**	**6,181**	**5,993**

TABLE 3.3.5
LEHIGH RIVER BASIN EMPLOYMENT AND WATER DEMAND PROJECTIONS FOR THE NON-MANUFACTURING SECTOR

YEAR	2005	2010	2005	2020	2025	2030
In-Basin Non- manufacturing Employment	243,912	259,141	275,483	293,039	311,918	332,244
Per Employee Average Daily Water Use (gallons per employee per day)	42	42	42	42	42	42
Per Employee Average Annual Water Use (gallons per employee per year)	15,417	15,417	15,417	15,417	15,417	15,417
Non-Manufacturing Water Use (MG per year)	**3,760**	**3,995**	**4,247**	**4,518**	**4,809**	**5,122**

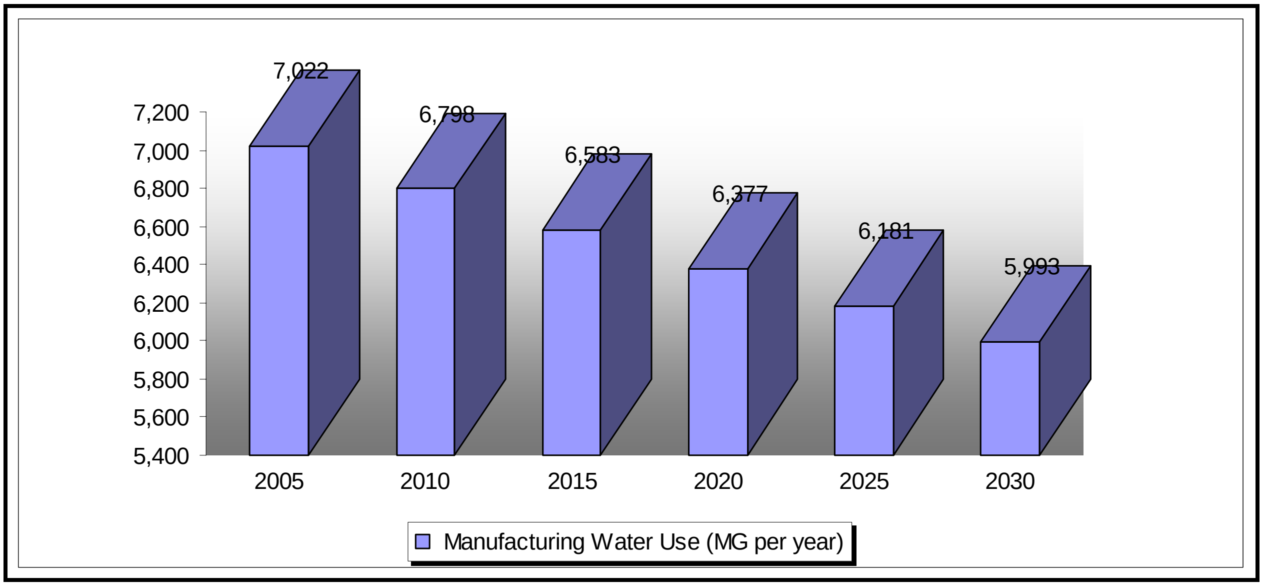


FIGURE 3.3.1
PROJECTED MANUFACTURING WATER DEMAND IN THE LEHIGH RIVER BASIN

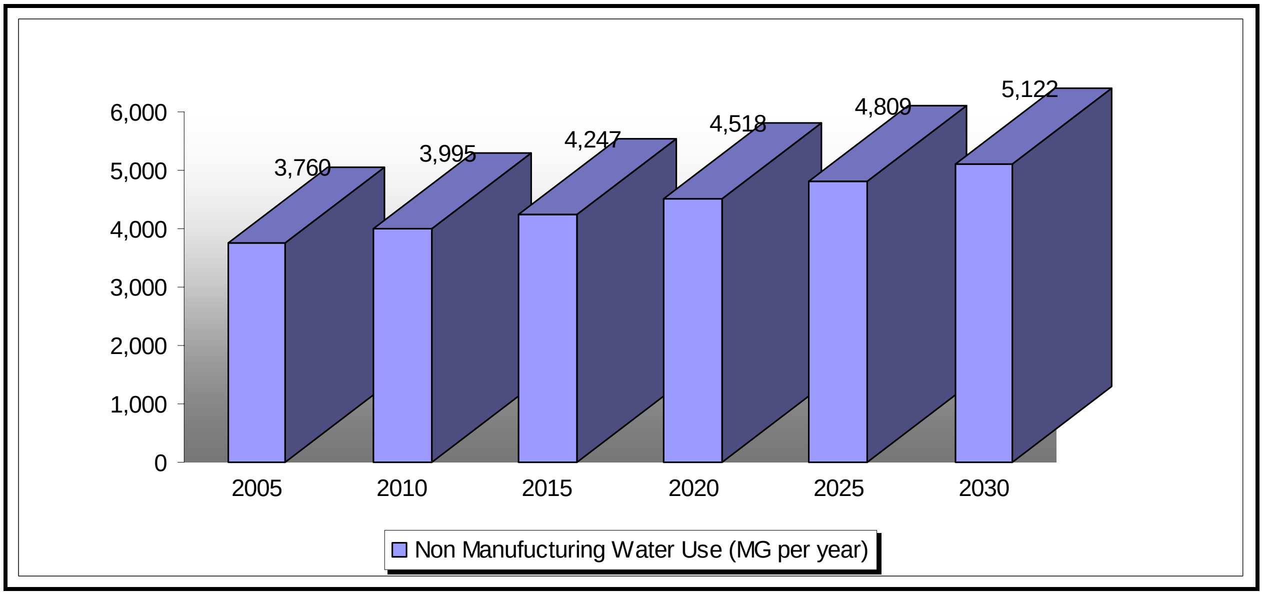


FIGURE 3.3.2
PROJECTED NON-MANUFACTURING WATER DEMAND IN THE LEHIGH RIVER BASIN

3.4 Agriculture Water Use

3.4.1 Irrigation Water Use

Irrigation water use for the Lehigh River Basin was estimated by multiplying the number of irrigated acres by estimates of water use per acre. The number of irrigated acres in the study area was derived from 2002 Census of Agriculture data. Table 3.4.1 shows the number of irrigated acres for counties around the Lehigh River Basin. Schuylkill and Berks counties reported the largest number of irrigated acres of the ten counties listed. Data on irrigated acres was not available for three counties due to potential disclosure of individual information as indicated by (D) in Table 3.4.1. Irrigated acres for these counties were assumed to be negligible.

To determine the number of irrigated acres that fall within the study area, National Land Cover Data (NLCD) maintained by the USGS was used. Land cover areas classified as Herbaceous Planted/Cultivated in the NLCD system generally capture land that has been planted or is intensively managed for the production of food, feed, or fiber (http://landcover.usgs.gov/classes.asp). For each county the ratio of Herbaceous Planted/Cultivated land located in-basin was applied to county irrigated acres to approximate the number of irrigated acres located in the study area. The working assumption was that the percent of Herbaceous Planted/Cultivated land located in-basin by county was a reasonable estimator of the percent of irrigated acres in-basin by county. GIS was used to estimate the percent of Herbaceous Planted/Cultivated land located in-basin and outside-basin by county. The percent located in-basin is shown in column 4 of Table 3.4.1. Column 5 of Table 3.4.1 provides the resultant estimates of irrigated acres by county and total irrigated acres in the Lehigh River Basin.

TABLE 3.4.1
ESTIMATION OF AGRICULTURAL IRRIGATED ACRES IN THE LEHIGH RIVER BASIN

County Name	Harvested Cropland Acres [1]	Irrigated Crop Acres [1]	Estimate of Herbaceous Planted/Cultivated land located in the Basin [2]	Estimated County Irrigated Acres in the Basin
Berks	154,108	1,822	0.1%	1.82
Bucks	50,013	D	1.3%	-
Carbon	10,497	80	99.9%	79.92
Lackawanna	16,161	174	1.0%	1.74
Lehigh	66,322	D	79.9%	-
Luzerne	29,194	D	3.2%	-
Monroe	14,111	87	51.2%	44.54
Northampton	60,798	366	37.1%	135.79
Schuylkill	63,729	1,876	11.8%	221.37
Wayne	43,085	133	0.1%	0.13
TOTAL	**508,018**	**4,538**		**485.31**

[1] *Harvested and irrigated acres obtained from 2002 Census of Agriculture data.*
[2] *The estimate of planted and cultivated land in-basin relies on a GIS overlay of National Land Cover Data (NLCD) maintained by USGS with county and basin boundaries data.*

On a county by county basis irrigated acres estimated to be located in the Lehigh River Basin were distributed to prominent irrigated crop types in Pennsylvania based on the state level distribution of irrigated acres by major crop types. Table 3.4.2 presents the final distribution of study area irrigated acres by major crop types. Table 3.4.2 shows that vegetable, orchards, and forage crops had relatively more irrigated acreage in the study area. To establish water use factors, water use per irrigated acre by crop type provided by the Farm and Ranch Irrigation Survey publication were used. The Farm and Ranch Irrigation Survey provides estimates of average quantities of water used per acre by crop type for Pennsylvania, as summarized in Table 3.4.3.

TABLE 3.4.2
DISTRIBUTION OF IRRIGATED ACRES BY MAJOR CROP TYPE IN THE LEHIGH RIVER BASIN

County Name	Vegetables harvested for sale	Land in orchards	Forage	Corn for grain	Potatoes	Corn for silage	Total
Berks	0.74	0.33	0.23	0.19	0.19	0.15	1.82
Bucks	-	-	-	-	-	-	-
Carbon	32.32	14.28	10.29	8.42	8.14	6.47	79.92
Lackawanna	0.70	0.31	0.22	0.18	0.18	0.14	1.74
Lehigh	-	-	-	-	-	-	-
Luzerne	-	-	-	-	-	-	-
Monroe	18.01	7.96	5.74	4.69	4.54	3.61	44.54
Northampton	54.91	24.26	17.48	14.30	13.83	11.00	135.79
Schuylkill	89.53	39.56	28.50	23.31	22.54	17.93	221.37
Wayne	0.05	0.02	0.02	0.01	0.01	0.01	0.13
Total distribution of irr. acreage in the Lehigh Basin	**196.27**	**86.72**	**62.49**	**51.10**	**49.42**	**39.31**	**485.31**

TABLE 3.4.3
AVERAGE WATER QUANTITIES APPLIED PER ACRE FOR DIFFERENT CROPS IN PENNSYLVANIA

Crop type	Geographic area	Average water applied per acre (acre-feet per year)	Average water applied per acre (gallons per year)	Annual average daily (gallons per day)
Land in vegetables	Pennsylvania	0.4	130,340	357
Land in bearing and non-bearing orchards, vineyards, and nut trees	Pennsylvania	0.7	228,096	625
Potatoes	Pennsylvania	0.2	65,170	179
Corn for grain or seed	Pennsylvania	0.2	65,170	179
Alfalfa and alfalfa mixtures	Pennsylvania	0.2	65,170	179
Corn for silage or green chop	Pennsylvania	0.1	32,585	89

2002 Census of Agriculture Farm and Ranch Irrigation Survey (2003): Released November 15, 2004, by the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, U.S. Department of Agriculture.

Projections of future irrigated acreage for the basin were derived by applying the trend for the Mid Atlantic region from the USDA, Forest Service report to basin level irrigated acreage in the base year. The Forest Service report shows a 16 percent net increase in irrigated acreage in the Mid Atlantic region (PA, NJ and NY) from 1995 to 2040. This is equivalent to approximately 0.33 of a percent growth per year over the 45 year period (assuming constant growth). Total irrigated acres in the Lehigh River Basin by major crop type were projected in 5-year intervals by assuming a 0.33 percent annual percent growth in all irrigated acres from the base year (2002). Projected irrigated acres for the Lehigh River Basin by each identified crop type were then multiplied by the corresponding crop type annual average daily quantity of water applied per acre. Table 3.4.4 shows the total projected irrigated acres for the Lehigh River Basin and corresponding projected water demand for agricultural irrigation.

TABLE 3.4.4
BASELINE PROJECTIONS OF IRRIGATED ACRES AND CORRESPONDING IRRIGATION WATER USE FOR THE LEHIGH RIVER BASIN

Projection Year	2005	2010	2015	2020	2025	2030
Total Acres Irrigated	490.14	498.29	506.57	515.00	523.56	532.27
Annual Average Daily Water Use (million of gallons per day)	0.16	0.16	0.16	0.17	0.17	0.17
Annual Water Use (millions of gallons per year)	**57.86**	**58.82**	**59.80**	**60.79**	**61.80**	**62.83**

3.4.2 Livestock Water Use

Livestock water use was estimated by multiplying the number of farm animals in the Lehigh River Basin by the corresponding per animal unit water requirement estimate. County level inventories of livestock from the 2002 Census of Agriculture were used to estimate livestock inventories.

To determine what percent of each county's reported estimates were in the study area, it was assumed that concentrations of livestock operations are directly correlated to land cover areas classified as Herbaceous Planted/Cultivated in the NLCD system (a proxy for agricultural areas). It was further assumed that the distribution of Herbaceous Planted/Cultivated land cover areas (agricultural areas) in the basin was a reasonable indicator of where livestock inventories where concentrated. The percent of Herbaceous Planted/Cultivated land located in-basin by county was used to determine what percent of each county's livestock inventories was located in-basin. Table 3.4.5 presents total Lehigh River Basin livestock inventory estimates for different livestock categories as reported in the 2002 Census of Agriculture.

TABLE 3.4.5
ESTIMATED BASELINE LIVESTOCK AND POULTRY INVENTORIES IN THE LEHIGH RIVER BASIN
(based on livestock categories reported in the Census of Agriculture)

Census Category	Number In-Basin
Cattle and calves inventory - Beef cows	1,364
Cattle and calves inventory - Milk cows	2,631
Cattle and calves inventory – (minus beef & milk cows)	4,801
Hogs and pigs	6,513
Broilers and other meat-type chickens	59,661
Layers 20 weeks old and older	100,283
Pullets for laying flock replacement	1,832
Sheep and lambs inventory	1,531

Water requirements estimates per animal are available from the College of Agriculture

Sciences, Cooperative Extension at Pennsylvania State University. These requirements are shown in Table 3.4.6.

Future livestock inventories for the study area assume that livestock patterns in Pennsylvania will follow national trends estimated by the USDA. The USDA has projected national livestock inventories and production to the year 2014. These projections are based on specific assumptions regarding macroeconomic conditions, policy, weather, and international developments among other specific assumptions (USDA, National Agricultural Statistics Service). Projections of livestock inventories and production to 2014 were extrapolated to 2030 by assuming constant growth past 2014. Projected numbers of livestock by type for the basin are multiplied by the water use factor for each livestock type. Table 3.4.7 presents the resultant water demand estimates for livestock use in the Lehigh River Basin. Figure 3.4.1 presents the agricultural water use trend projected for the Lehigh River Basin.

TABLE 3.4.6
TYPICAL LIVESTOCK AND POULTRY WATER USE
(gallons per animal unit per day)

Livestock category	Estimated water use
Dairy cow	35
Dry cow, beef cattle or steers	12
Hogs	1.5
Sheep or goats	2
Chickens (per 100 head)	9

TABLE 3.4.7
BASELINE PROJECTIONS OF LIVESTOCK WATER USE FOR THE LEHIGH RIVER BASIN

Projection Year	2005	2010	2015	2020	2025	2030
Total livestock Annual daily water use (millions gallons per day)	0.19	0.19	0.19	0.19	0.19	0.20
Total livestock annual water use (millions gallons per year)	**69.85**	**70.59**	**70.64**	**70.79**	**71.04**	**71.41**

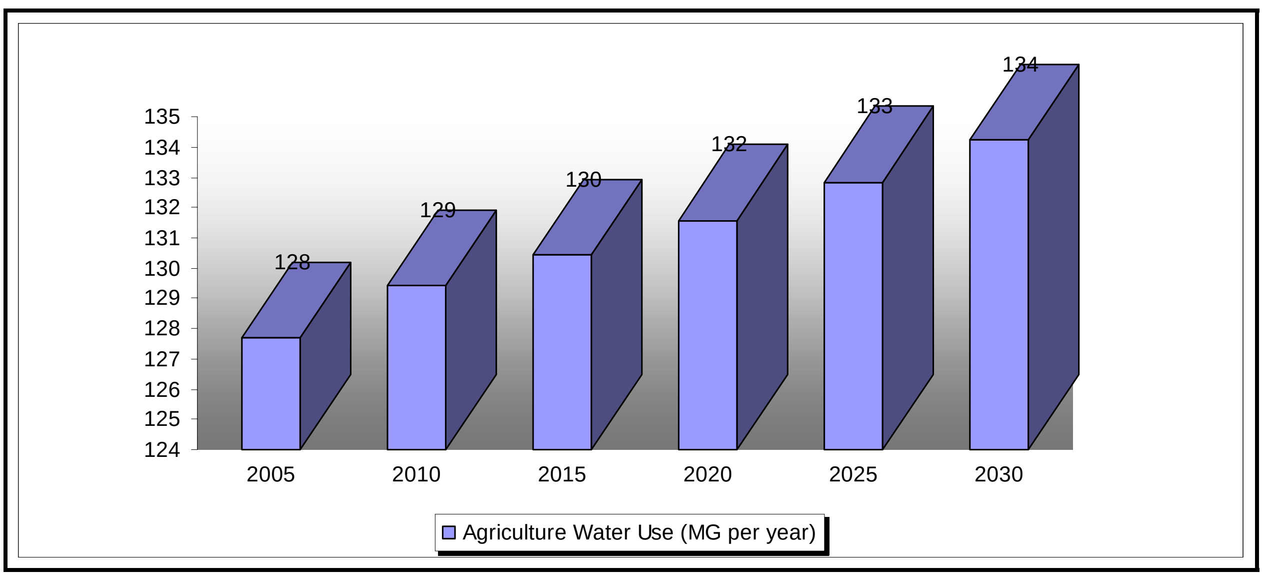


FIGURE 3.4.1
PROJECTED TOTAL AGRICULTURAL WATER DEMAND IN THE LEHIGH RIVER BASIN

3.5 Mining Water Use

Mining in the Lehigh River Basin consists of aggregate mining for the construction industry. Aggregate mining includes mining for topsoil, sand and other ingredients of cement, and stone and gravel for use in construction. The Lehigh River Basin is historically a major center for the mining of aggregates, especially stones. Water is used in aggregate mining for dust control and the sorting of aggregate.

Table 3.5.1 shows the mining employment in Lehigh River Basin counties and the water use per employee for mines reporting in those counties. The data in this table is based upon Table 2.5.4 in Section 2. Note that the mining employment for Carbon County and Lehigh County in 2000 are corrected from that shown in Section 2. The average water use per employee for mining in the Lehigh River Basin is 14.54 MG per year.

TABLE 3.5.1
LEHIGH RIVER BASIN COUNTIES
MINING EMPLOYMENT

County	2000 Mining Employment From PA-DLI
Carbon	55
Lehigh	201
Luzerne	751
Monroe	155
Northampton	99
Schuylkill	251
TOTAL	**1,512**

To project water withdrawals in the Lehigh Basin, the mining employment within the basin had to be determined. Carbon County is entirely within the Lehigh Basin. Although small portions of Lehigh County and Northampton County are outside of the Basin, all of the mining operations in these counties are within the basin. The mining operations in Monroe County are in the southern portion, which is in the Lehigh Basin. Only small portions of Luzerne County and Schuylkill County are in the Lehigh Basin, and allocating mining employment in these counties to the Lehigh River Basin was more difficult. The geographic coordinates of mining operations with "covered" employment were provided by the Department of Labor and Industry. These mines were classified as either within the basin or outside the basin using GIS. Based upon the employment levels of "covered" mines determined to be in the basin, approximately 13 percent of Luzerne County mining employment is assumed to be within the basin and approximately 5 percent of Schuylkill County mines are in the basin.

The amount of water used per employee for mining in different counties varies by type of mining operation. Aggregate mining operations vary significantly based upon the location and the product mined. These differences in operations explain the variation in the amount of water used per mining employee.

Most of the mines in the Lehigh River Basin that are listed by the Pennsylvania Bureau of Mines and Reclamation did not report water withdrawals. These mines are small operations employing several employees that are open seasonally. These mines may not meet the threshold for reporting water use. Also many aggregate mines are part of cement manufacturing operations, and this water use may not be classified as mining in the WUDS and Act 220 databases.

Both the WUDS and the Act 220 databases were used to determine water use per employee for each mine. The annual water use per mining operation was matched with the employment levels of the mining operations as reported to the Bureau of Mines and Reclamation. The water use and employment of these mines were then aggregated by county for those mines for which both employment and water use were available. These county aggregations are shown in Table 3.5.2.

TABLE 3.5.2
AGGREGATION OF LEHIGH RIVER BASIN MINING EMPLOYMENT AND WATER USE BY COUNTY
(For those mines where both data are available)

County	Matched Employment	Matched Water Use (MG per year)	Weighted Average (MG per employee)
Carbon	7	26.1	3.7
Lehigh	66	294.4	4.5
Luzerne	N/A	N/A	N/A
Monroe	15	4.3	0.3
Northampton	149	1,908.3	12.8
Schuylkill	194	3,669.6	18.9
TOTAL/ AVERAGE	**431**	**5,902.7**	**13.7**

The employment in 2000 and projected employment in 2010 by Workforce Investment Area (WIA) as reported by the Pennsylvania Department of Labor and Industry was determined to be to best source for projecting mining employment data. Mining employment in each county is projected to 2030 in Table 3.5.3 by extending the Department of Labor and Industry's 2010 employment projection.

To assist with this pilot study, the Pennsylvania Department of Labor and Industry provided employment figures by location, with XY geographic coordinates, for "covered" employment (covered by the unemployment insurance program). The total mining employment in each county obtained from this database was not consistent with the mining employment figures compiled by Workforce Investment Area (WIA) or with employment figures reported to the Bureau of Mines and Reclamation. This difference in mining employment figures results from some mines not being covered by unemployment insurance. The covered employment data was used to allocate employment to the Lehigh River Basin for two counties where only a portion of the county is within the basin. Mining employment in Luzerne and Schuylkill Counties was allocated to the Lehigh River Basin based upon the portion of covered employment in these counties within the basin. Table 3.5.3 includes the results of this allocation.

Projections of water use for mining in the Lehigh River Basin are shown in Table 3.5.4. These projections are based upon projected mining employment and a constant level of water use per mining employee in each county.

The forecast of water use for mining indicates that although water use in some individual counties will undergo significant change, overall water use for mining will remain relatively constant. These trends occur because many aggregate mines are dependent upon proximity to constructions sites but are less likely to continue when their surrounding areas urbanize. Figure 3.5.1 presents the graphical illustration of mining annual projections.

TABLE 3.5.3
PROJECTED MINING EMPLOYMENT
IN THE LEHIGH RIVER BASIN

County	2000 Mining Employment	2010 Mining Employment Projected	Ten Year Projected Change	2020 Mining Employment Projected	2030 Mining Employment Projected
Carbon	55	67	22%	82	99
Lehigh	201	201	-	201	201
Luzerne	99	72	-27%	52	38
Monroe	155	188	21%	228	277
Northampton	99	99	-	99	99
Schuylkill	13	9	-28%	7	5
TOTAL	**622**	**636**		**668**	**719**

TABLE 3.5.4
MINING WATER USE IN THE LEHIGH RIVER BASIN

County	2000 Annual Water Use (MG)	2010 Annual Water Use (MG)	2020 Annual Water Use (MG)	2030 Annual Water Use (MG)
Carbon	205	250	304	370
Lehigh	897	897	897	897
Luzerne	1,351	981	712	517
Monroe	2,123	2,575	3,123	3,788
Northampton	1,268	1,268	1,268	1,268
Schuylkill	247	179	129	94
TOTAL	**6,090**	**6,149**	**6,433**	**6,934**

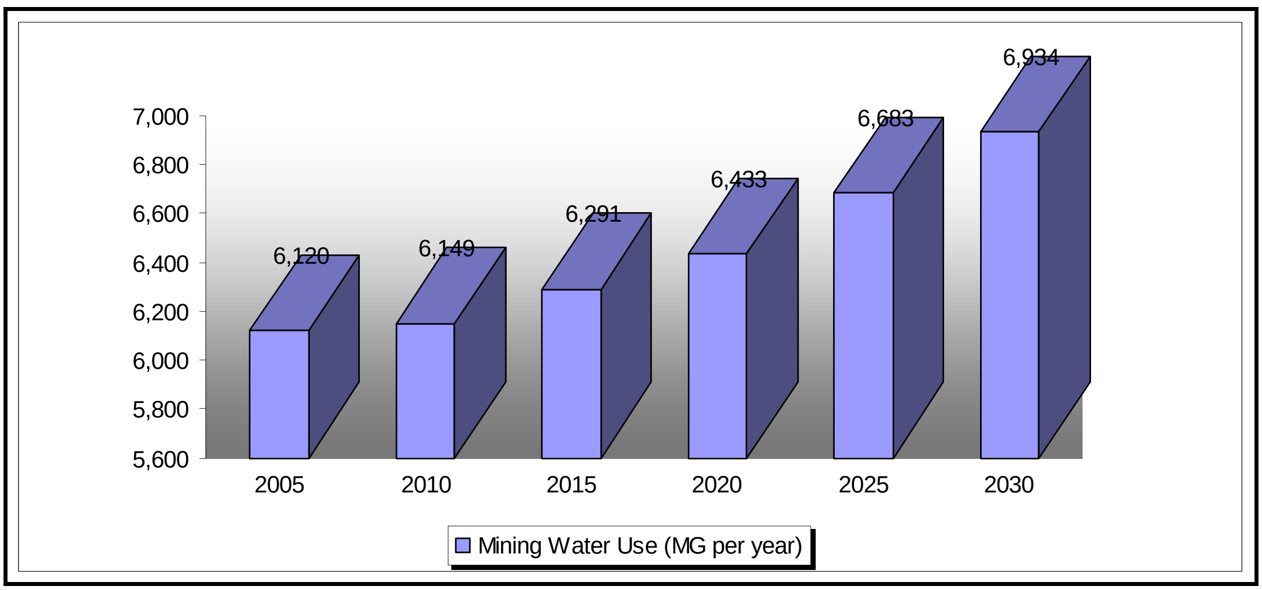


FIGURE 3.5.1
PROJECTED MINING WATER DEMAND
IN THE LEHIGH RIVER BASIN

3.6 Thermoelectric Water Use

The Lehigh River Basin has three thermoelectric power plants. The characteristics of these power plants are shown in Table 3.6.1 below. The Northampton Power Plant and Panther Creek Power Plant are relatively small. The Bethlehem Power Plant is a mid-size power plant designed to generate power to meet peak demand. Therefore, the capacity of this power plant is not indicative of its power generation or water use. As a combined cycle power plant powered primarily by natural gas, it is not suitable for use as a primary generation facility. Together, these three power plants provide a small portion of the power needs of the Delaware River Basin, and use a small portion of the water withdrawn for power plants in the Delaware River Basin.

Table 3.6.1
Lehigh River Basin Thermoelectric
Power Plants Characteristics

Plant Name	Construction Year	MW Capacity	Watershed	Fuel	Cooling
Bethlehem	2003	1,100	Lower Lehigh	combined cycle	evaporative
Northampton	1995	107	Lower Lehigh	waste coal	evaporative
Panther Creek	1994	80	Middle Lehigh	waste coal	evaporative

These three power plants are relatively new and use evaporative cooling, which is typical for power plants built during these years. Since the power plants are new, they are expected to remain operable throughout the forecast period. Evaporative cooling requires less water withdrawals but consumes more water than “once through” cooling used by older power plants.

The water demand forecasting methodology for thermoelectric power described in Section 2 is dependent upon the characteristics of the power plants and their power generation relative to capacity (capacity factor). The Bethlehem Power Plant has been operational since March 2003. The Panther Creek Power Plant has not reported power generation to the EIA since 2003, but is assumed to be operating because it is reporting water withdrawals under Act 220. The capacity factors for all three power plants are shown in Table 3.6.2 below. The capacity factor is the ratio of power generated to the maximum generating capacity of the power plant and is calculated by comparing the annual power generation as reported to the Energy Information Administration to the potential production capacity of the plant. Note that the Panther Creek power plant is operating at about 85 percent of capacity, which is assumed to be the maximum sustainable operating capacity.

Table 3.6.2
Estimated Power Generation and Capacity Factor (C.F.)
for Power Plants in the Lehigh River Basin

Plant			2003		2004	
	Capacity MW	Potential GWH/yr	Produced GWH/yr	Capacity Factor (%)	Produced GWH/yr	Capacity Factor (%)
Bethlehem	1,100	9,636	634	8.0*	920	9.5
Northampton	114.07	999	742	74.3	650	65.1
Panther Creek	94.0	823	704	85.5	Not avail	Not avail

** Capacity factor based upon ten months operation*

Table 3.6.3 shows water withdrawals, measured in millions of gallons, for each power plant. These values were obtained from both the WUDS and the Act 220 databases. The table shows relatively constant water use for the Northampton Power Plant and the Panther Creek Power Plant for the years that water data was reported.

Table 3.6.3
Water Withdrawals by Power Plants
in the Lehigh River Basin

Plant	WUDS Average 95-99 MG	Act 220 2003 MG	Act 220 2004 MG
Bethlehem	Not avail	179.3	266.8
Northampton	557.28	464.2	399.2
Panther Creek	364.95	329.2	368.3
TOTAL		**972.7**	**1,034.3**

Table 3.6.4 below shows the water use per megawatt hour generated for each power plant. These values range from 300 gallons per megawatt hour for the Bethlehem Power Plant to 600 gallons per megawatt hour for the Panther Creek Power Plant. Power plant generation data was obtained from the Energy Information Administration. These figures show consistent water withdrawals for each power plant over an extended period. For this reason the Lehigh River Basin water withdrawal forecast is based upon specific power plants. The methodology recommended in Section 2 of using water withdrawal estimates based upon power plant technology has been improved upon for the Lehigh River Basin because water withdrawal and power generation data for each power plant is available and consistent.

Table 3.6.4
Estimated Water Withdrawals per MWh Generated for Power Plants in the Lehigh River Basin

Plant	2003			2004		
	MG	MWh	MG/MWh	MG	MWh	MG/MWh
Bethlehem	179.3	634,518	0.0003	266.8	919,587	0.0003
Northampton	464.2	742,337	0.0006	399.2	649,616	0.0006
Panther Creek	329.2	703,734	0.0005	368.3	Not avail	Not avail

PJM is the regional power authority that projects future power demand. PJM projects that peak demand for power will increase at 1.8 percent annually while the total demand for power will grow at 1.7 percent annually through 2015. This projection was extended to 2030 for this forecast. Power generation at the Bethlehem Plant is assumed to grow at 1.8 percent annually, since the plant is specifically designed to produce power for peak demand periods. The Northampton Plant production is assumed to increase by 1.7 percent annually until 2020 when it reaches 85 percent of capacity. The Panther Creek Plant is assumed to be operating at maximum sustainable capacity. These power plants are not expected to meet all power demand for the Lehigh River Basin, but are expected to increase power generation at the same rate as power demand growth for the PJM service area.

Annual growth rates are applied to 2004 production data to estimate future production to the year 2030. Table 3.6.5 shows the resulting projected capacity factors for the three power plants in the Lehigh River Basin based upon the projected increase in power demand and the current capacity of the existing power plants. A review of public sources determined that there are no plans to expand these power plants, nor are there published plans to construct new power plants in the Lehigh River Basin. However, the construction of new power plants, and the closure of existing plants, can not accurately be forecasted for this extended period. Furthermore, the construction of new power plants in the Lehigh River Basin is not likely because of the proximity of the Delaware River outside the basin. Power plants are more likely to locate adjacent to a larger river that provides easier transportation access, more water availability for cooling, and better access to transmission lines. The configuration of the three plants in the basin indicates that the Lehigh River Basin is not a prime power generation location (i.e. two of three existing plants are small and intended to exploit nearby waste coal, and the other is a peak power plant).

Table 3.6.5
Projected Capacity Factor
Thermoelectric Power Plants in the Lehigh River Basin

Plant	2005 CF %	2010 CF %	2015 CF %	2020 CF %	2025 CF %	2030 CF %
Bethlehem	9.7	10.6	11.6	12.7	13.9	15.2
Northampton	66.2	72.0	78.3	85.2	85.2	85.2
Panther Creek	85.5	85.5	85.5	85.5	85.5	85.5

The estimated water withdrawals for each power plant are shown in Table 3.6.6. These figures are based upon water withdrawals increasing at each plant given PJM power growth rates, or until the plant's capacity factor is approximately 85 percent. The water withdrawals increase at the rate shown in Table 3.6.6 for each power plant as additional megawatt hours are generated to meet increasing demand. The total estimated water withdrawals for the basin increase from 1,029 MG in 2005 to 1,301 MG in 2030. Annual water projections are also presented graphically in Figure 3.6.1.

TABLE 3.6.6
ESTIMATED ANNUAL WATER WITHDRAWALS FOR POWER PLANTS IN THE LEHIGH VALLEY

Plant	2005 MG	2010 MG	2015 MG	2020 MG	2030 MG
Bethlehem	281	307	336	367	439
Northampton	396	431	469	510	510
Panther Creek	352	352	352	352	352
TOTAL	**1,029**	**1,090**	**1,157**	**1,229**	**1,301**

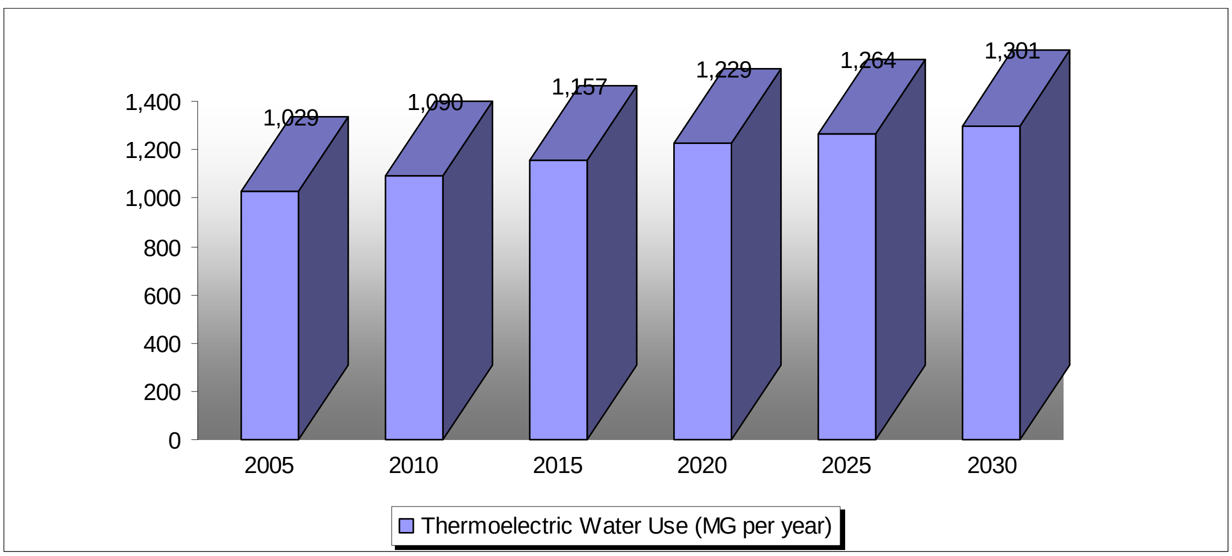


FIGURE 3.6.1
PROJECTED THERMOELECTRIC WATER DEMAND IN THE LEHIGH RIVER BASIN

3.7 Hydroelectric Power

The hydroelectric facilities in the Delaware River Basin were inventoried in Section 2. The only significant facility in the Delaware River Basin, the Wallenpaupack Facility, is not in the Lehigh Basin. The Panther Creek Facility is the only facility in Lehigh River Basin reporting water withdrawals. The Lehigh River Basin Facilities are listed in Table 3.7.1.

TABLE 3.7.1
HYDROELECTRIC FACILITIES IN THE LEHIGH VALLEY

Plant Name	Capacity (MW)	County
Pocono Lake	.29	Monroe
Panther Creek-hydro	10.10	Carbon
Lavon Dam (Apply)	2.15	Carbon
TOTAL	**12.54**	

Hydroelectric facilities are assumed to operate at capacity, meaning the withdrawals they report equal the amount of water available. The demand for power has no impact on water withdrawals. Based upon the withdrawal amounts reported by hydroelectric facilities, water withdrawals vary significantly from year to year. This variation is assumed to be based upon water availability.

Water withdrawals are projected below in Table 3.7.2 and also illustrated in Figure 3.7.1 for the Lehigh Basin. The Panther Creek Facility water withdrawals were reported for one year, 1993, under Act 220. The 400 MG annual withdrawal is assumed to continue indefinitely. Based upon withdrawals reported in the WUDS database for the Wallenpaupack Facility, these withdrawals could vary from 200MG to 800 MG in a given year. Withdrawal forecasts for the Pocono Lake Facility and the Levon Dam Facility are proportional to the Panther Creek Facility based upon their megawatt capacity and the average 39.6 MG per MW use rate of the Panther Creek locality. This assumption is based upon the facilities having similar climate and topography as the Panther Creek Facility.

The monthly water withdrawal rate for the Panther Creek Facility is fairly constant, but for two months, July and August, the water source is listed as a deep mine. Groundwater is not a normal water source for a hydroelectric facility, but additional information on this plant is not available. Better withdrawal forecasts will be possible when multiyear data are available for the Panther Creek Facility.

TABLE 3.7.2
ESTIMATED WATER WITHDRAWALS FOR HYDROELECTRIC PLANTS IN THE LEHIGH BASIN

Plant	2005 MG	2010 MG	2015 MG	2020 MG	2030 MG
Pocono Lake	12	12	12	12	12
Panther Creek	400	400	400	400	400
Lavon Dam (Apply)	0	85	85	85	85
TOTAL	**412**	**497**	**497**	**497**	**497**

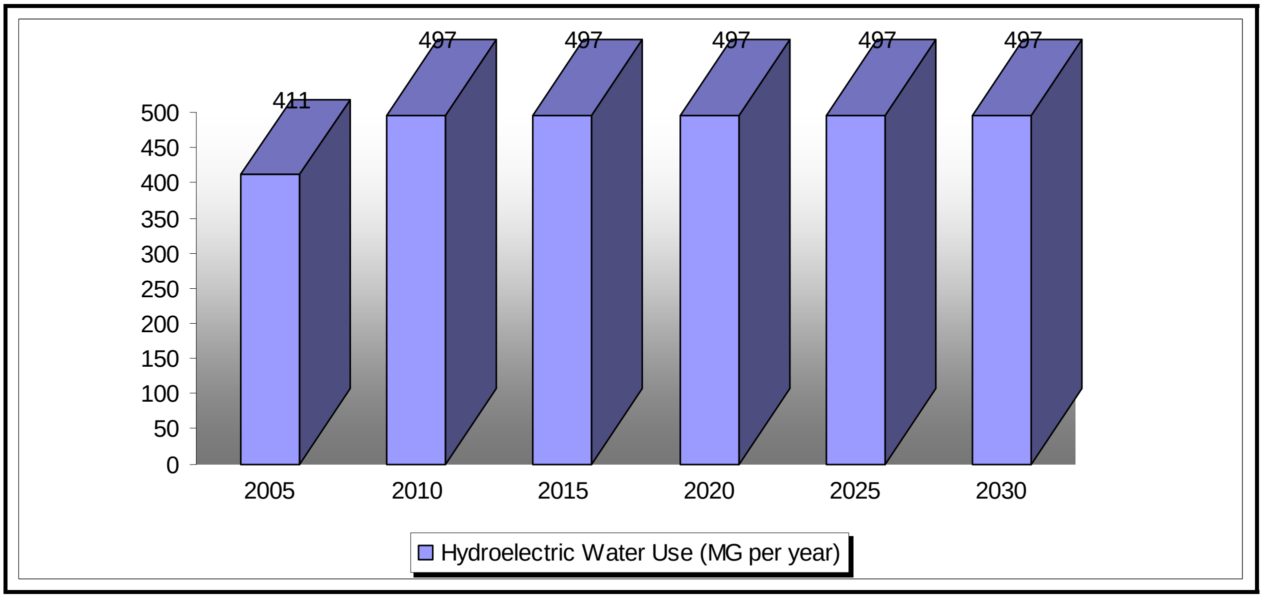


FIGURE 3.7.1
PROJECTED HYDROELECTRIC WATER DEMAND
IN THE LEHIGH RIVER BASIN

3.8 Summary of Findings

Section 3 of this report presents results of a pilot implementation of methodologies proposed in Section 2 of this project, *Water Demand Forecasting Methodologies for Pennsylvania,* to the Lehigh River Basin study area. The pilot study analysis estimated long-term water demand in 5-year intervals to the year 2030 for six major categories of water use. Summarized projection estimates for each major water using category and for the river basin as a whole are presented in Table 3.8.1. These estimates should be considered baseline or initial estimates that can be refined as more information about the demographic driver variables and water use tendencies become available.

Table 3.8.1 shows that total water demand in the Lehigh River Basin will steadily increase over time from approximately 36,569 million gallons a year in 2005 to roughly 38,828 million gallons a year in 2030. Water demand in all categories is estimated to increase over time with the exception of demand for manufacturing and hydroelectric use. Manufacturing water demand is expected to see a gradual decrease over time while hydroelectric is assumed constant beyond 2010. Figure 3.8.1 offers a graphical illustration of the trends in water demand by sector.

The distribution of 2005 estimates of water use across sectors in the Lehigh River Basin is illustrated in Figure 3.8.2. Figure 3.8.2 shows that about 60 percent of the estimated water demand in the Lehigh River Basin is attributable to residential use. This general distribution appears to be relatively stable as is evidenced by distributions shown in Figure 3.8.3 for 2030 estimates. Figure 3.8.2 shows that the residential water demand is expected to continue dominating water use in the Lehigh River Basin.

TABLE 3.8.1
LEHIGH RIVER BASIN BASELINE SCENARIO
WATER DEMAND PROJECTIONS

Projection Year	2005	2010	2015	2020	2025	2030
Residential Water Use (MG per year)	18,098	18,291	18,496	18,702	18,775	18,847
Manufacturing Water Use (MG per year)	7,022	6,798	6,583	6,377	6,181	5,993
Non Manufacturing Water Use (MG per year)	3,760	3,995	4,247	4,518	4,809	5,122
Agriculture Water Use (MG per year)	128	129	130	132	133	134
Mining Water Use (MG per year)	6,120	6,149	6,291	6,433	6,683	6,934
Thermoelectric Water Use (MG per year)	1,029	1,090	1,157	1,229	1,264	1,301
Hydroelectric Water Use (MG per year)	411	497	497	497	497	497
Estimated Total Water use (MG per year)	**36,569**	**36,949**	**37,401**	**37,888**	**38,340**	**38,828**

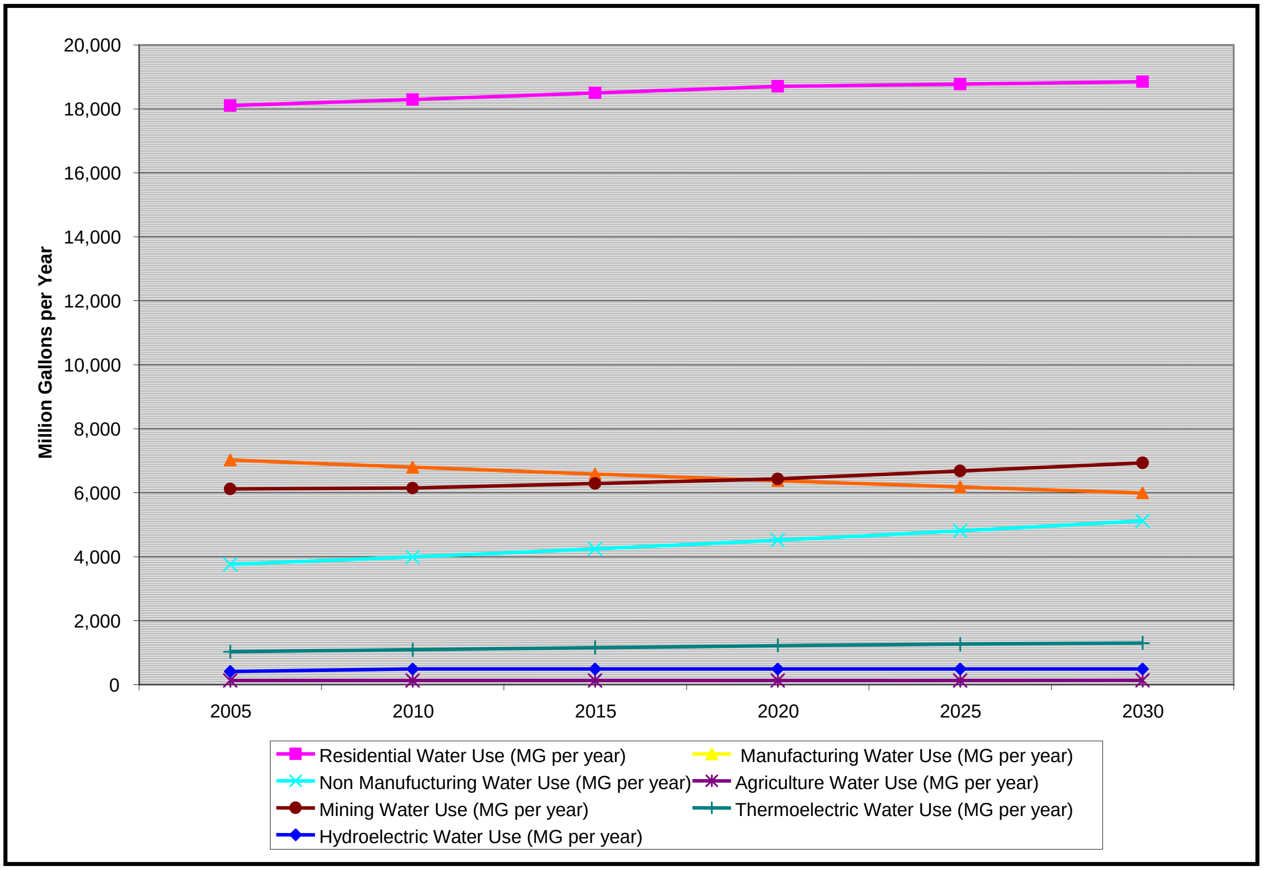


FIGURE 3.8.1
PROJECTED TRENDS IN WATER DEMAND IN THE LEHIGH RIVER BASIN

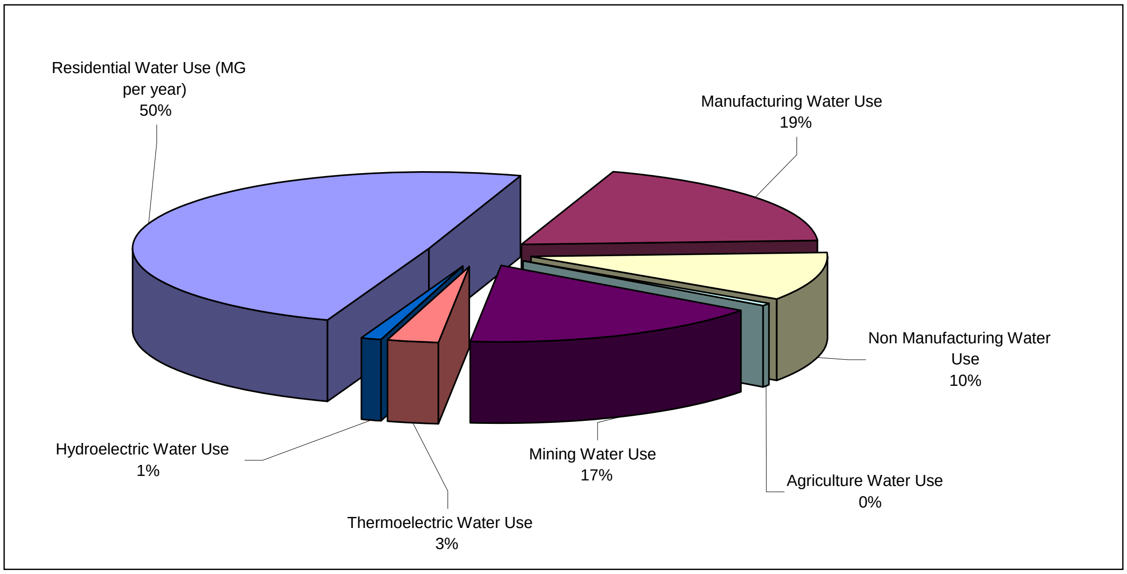


FIGURE 3.8.2
DISTRIBUTION OF 2005 ESTIMATES OF WATER USE ACROSS SECTORS IN THE LEHIGH RIVER BASIN

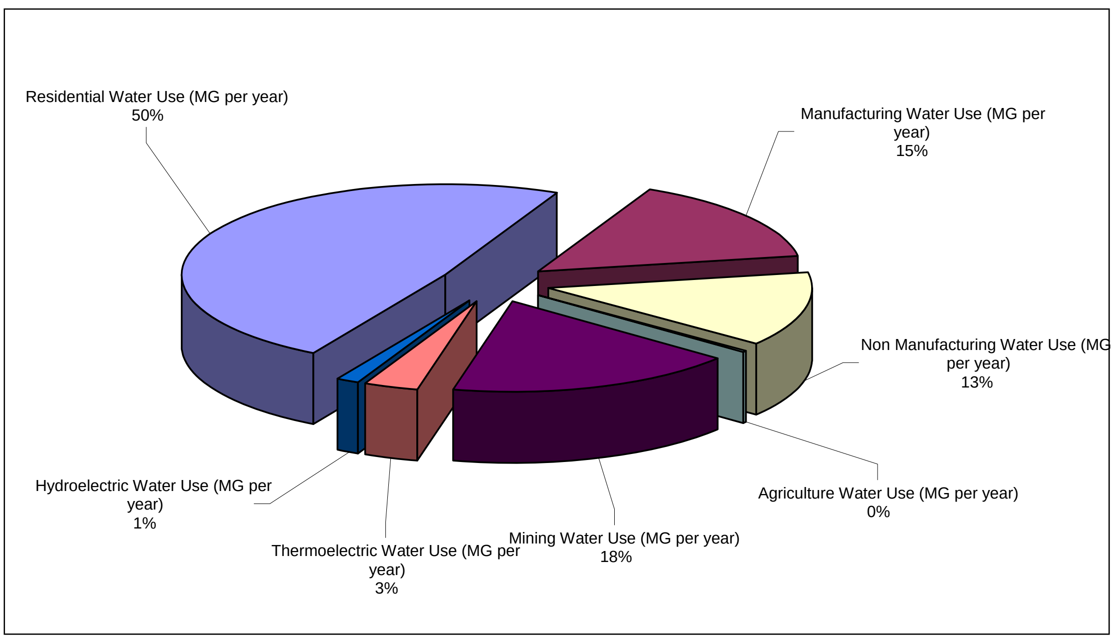


FIGURE 3.8.3
DISTRIBUTION OF 2030 ESTIMATES OF WATER USE ACROSS SECTORS IN THE LEHIGH RIVER BASIN

3.8.1 Scenario Adjustments

This report is supplemented by an automated Excel spreadsheet tool designed to support water demand forecasting efforts in the Lehigh River Basin. The automated spreadsheet tool provides an interface and means through which alternative water demand projection scenarios can be applied. Section 4 provides a more detailed description of the automated spreadsheet tool.

Table 3.8.2 and 3.8.3 that follow present Lehigh River Basin alternative water demand projections under the assumption of peak day demand water use and the assumption of a 10 percent drought response. To account for water demand under a peak day assumption, water use factors for residential, manufacturing, and non-manufacturing were adjusted by factors of 3.5, 1.8, and 2.2 respectively. These ratios were calculated by dividing peak day water withdrawals by the annual average daily water use from PWS providers in the Lehigh River Basin. For purposes of this illustration, water demand for agriculture, mining, thermoelectric and hydroelectric are maintained at baseline forecast levels. Table 3.8.2 shows that under the peak day assumption, water demand in the projection years would be higher than the baseline forecast that was presented in Table 3.8.1.

TABLE 3.8.2
LEHIGH RIVER BASIN PEAK DAY SCENARIO
WATER DEMAND PROJECTIONS

Projection Year	2005	2010	2015	2020	2025	2030
Residential Water Use (MG per year)	63,344	64,017	64,737	65,456	65,711	65,966
Manufacturing Water Use (MG per year)	12,640	12,236	11,849	11,479	11,125	10,787
Non Manufacturing Water Use (MG per year)	8,273	8,789	9,344	9,939	10,579	11,269
Agriculture Water Use (MG per year)	128	129	130	132	133	134
Mining Water Use (MG per year)	6,120	6,149	6,291	6,433	6,683	6,934
Thermoelectric Water Use (MG per year)	1,029	1,090	1,157	1,229	1,264	1,301
Hydroelectric Water Use (MG per year)	411	497	497	497	497	497
Estimated Total Water use (MG per year)	**91,945**	**92,908**	**94,004**	**95,165**	**95,992**	**96,887**

As an example of how climatic considerations may be incorporated, an extended drought scenario is assumed for all projections years. Residential, manufacturing, non-manufacturing and agriculture irrigation are assumed to respond with a 10 percent increase in their water use factors. Mining, thermoelectric and hydroelectric are assumed at baseline forecast levels. To reflect this response in the automated spreadsheet tool, scenario adjustment factors for climate are adjusted from 1 to 1.10. Results of such a response are presented in Table 3.8.3.

TABLE 3.8.3
LEHIGH RIVER BASIN 10 PERCENT REPONSE TO DROUGHT
SCENARIO WATER DEMAND PROJECTIONS

Projection Year	2005	2010	2015	2020	2025	2030
Residential Water Use (MG per year)	19,908	20,120	20,346	20,572	20,652	20,732
Manufacturing Water Use (MG per year)	7,725	7,478	7,241	7,015	6,799	6,592
Non Manufacturing Water Use (MG per year)	4,136	4,395	4,672	4,969	5,290	5,634
Agriculture Water Use (MG per year)	133	135	136	138	139	141
Mining Water Use (MG per year)	6,120	6,149	6,291	6,433	6,683	6,934
Thermoelectric Water Use (MG per year)	1,029	1,090	1,157	1,229	1,264	1,301
Hydroelectric Water Use (MG per year)	411	497	497	497	497	497
Estimated Total Water use (MG per year)	**39,463**	**39,863**	**40,340**	**40,853**	**41,323**	**41,830**

3.8.2 Conclusion

This pilot study demonstrates that the recommended methodology for forecasting water demand can be applied using the available data. The methodology together with the supplemental automated spreadsheet tool offers adequate flexibility to enable revisions to both demographic and water use data as more refined information becomes available. The automated spreadsheet also allows for the modification of water demand forecasts to reflect different forecasting scenarios by use of scenario adjustment factors.

Section 4
Automated Spreadsheet Tool for the Lehigh River Basin Water Demand Forecast

4.1 Introduction

The automated water demand forecasting tool was developed in Microsoft Excel@ in conjunction with the set of recommended water demand forecasting methodologies outlined in this report. A working version of the automated spreadsheet was established for the Lehigh River Basin and used in the estimation of future water demand for the Lehigh River Basin as presented in Section 3.

The automated spreadsheet is designed to project future water use/demand in six major water use sectors: residential, nonresidential, agriculture, mining, thermoelectric, and hydroelectric. It is designed with the flexibility to enable users to modify data inputs as needed or when better information is available for further refinements. The current version of this automated tool is designed specifically for the pilot study basin-wide analysis and forecast of future water demand in the Lehigh River Basin. The general framework of the spreadsheet is also designed to be easily adoptable for a multi-basin or statewide analysis.

A pair of worksheets is assigned for each of the six major water using sectors – one worksheet labeled "worksheet" in the worksheet tabs is used to derive sector water use factors and driver variables, and the other worksheet labeled "projections" in the worksheet tabs shows the calculation of projected water demand in 5-year intervals.

The resultant water demand projections of each sector are summarized on the initial worksheet labeled "summary" in the worksheet tabs. This worksheet also provides the overall basin projections. Supplemental charts are also provided to graphically illustrate water demand forecasts.

This automated water demand projection spreadsheet is designed to be fully automated in the calculation of future water demand. It is populated with default calculations (for the pilot study) but has the flexibility to accommodate user-determined modifications of the default data inputs.

4.2 Key Worksheet Types

Projection Worksheet – For each sector, this is where the *water-use-times-driver* calculation actually occurs. The water use factors used in the calculation of annual and average daily sector demand are presented. These factors are linked from the sector "worksheet". Driver variable values are presented in 5-year intervals and are also linked from the sector "worksheet".

The Sector Worksheet – The sector worksheet principally consists of the Data Input Area at the top. This is the section highlighted in gray and it is where the user can enter data to replace the default water use factors or driver variable values with those obtained from an outside source. Below the data input area are several sections highlighted in green. Data in these cell ranges show the underlying assumptions and calculations that form the basis of the estimates of future driver variables. The default values calculated should be considered baseline values that can be refined as more specific information become available. The values derived in this section of the worksheet are referenced in the data input area at the top and are ultimately linked to the projections worksheet. Similarly, the basis from which water use factors are determined is provided and referenced in the data input area.

Projections Summary Worksheet – The projections summary worksheet is a single worksheet which draws information from all sector specific projection worksheets. This worksheet contains a summary of projected water use in each of the sectors and also provides the summation across all sectors to obtain the total water demand projection in the study area.

4.3 Sub Categories of Water Use Sectors

The general methodology outlined to project future water demand allows for disaggregate analysis of water use. The main categories for which future water demand is projected are:

- Residential Water Use
- Nonresidential Water Use
  - Manufacturing
  - Non-Manufacturing
- Agriculture Water Use
  - Irrigation
  - Livestock
- Mining Water Use
- Thermoelectric Water Use
- Hydroelectric Water Use
- Estimated Total Water use

4.4 Modification of Default Data

The spreadsheet has three established ways by which the user can modify the data:

Scenario Adjustments Factors – These factors permit the comparison of alternative water demand scenarios under otherwise similar conditions. The spreadsheet has been designed to accommodate a combination of up to three factor adjustments in the "projections" worksheet for each sector. Alternative water demand projections can be calculated to consider the impact of peak day water demand level of use, conservation resulting from the use of more efficient technologies or conservation programs, and the impact of climate on water demand projections. Scenario adjustment factors are defaulted to the value on 1 in the baseline projections. The unitary values can be adjusted down or up depending on the scenario being considered.

Use of the Data Input Areas - Data input areas are found at the top of each tab labeled "worksheet". The input areas shaded in gray can be used to directly change the default driver variables and water use factors by simply entering alternative values. This method is ideal when alternative water use factors or driver values in a given year are available from other sources. Entering new values here simply overrides the defaults and the new values are used. It is recommended that a backup of the spreadsheet be maintained since any changes made in the input screen will automatically delete the cell references to the default values found below.

Modification of the various underlying data used to derive default values that are observed in the Input areas - The third method is ideal when the user desires to use the same methodological approach of deriving water use factors and driver variables but may want to modify some assumptions. As an example, one may want to use an alternative persons per household value or alternative employment growth rate. To modify persons per households, the user would "click" on the "Residential Worksheet" tab and enter different values in the cell range containing persons per household values. The spreadsheet would automatically adjust all calculations and graphs to reflect this change. Similarly, to modify the manufacturing growth rate, one would "click" on the "Nonresidential Worksheet" tab and modify growth rates in the cell range containing manufacturing growth rates.

4.5 Final Note

This automated water demand forecasting tool was developed in conjunction with the pilot study for the Lehigh River Basin. The assumptions within the spreadsheet are documented in Section 3 of this report. The spreadsheet tool is set up to estimate water demand at the basin level. Some modification of the spreadsheet may be required to apply the forecasting tool to a different geographic level.