Non-Point Source Pollutant Loading Build-Out Analysis for the Lockatong and Wickecheoke Creek Watersheds

Draft Report -- January 2009

Author: Jen Zhang
Water Quality Statistical Analysis support by Todd Kratzer

This Document was prepared as part of a 319(h) grant for the Lockatong and Wickecheoke Creek Watersheds Restoration and Protection Project under Contract RP05-082.

New Jersey Water Supply Authority

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Introduction of Build-Out Analysis

Lockatong and Wickecheoke, though separate streams, have complementary components of an exceptional watershed area located in a rather remote part of Hunterdon County (**Figure 1**). The Lockatong-Wickecheoke Watersheds encompass approximately 49.9 square miles (31,917 acres). They include portions of Franklin, Delaware, Raritan, and Kingwood Townships, and a small portion of Stockton Borough. Both the Lockatong and Wickecheoke Creek are third order (tributaries are first and second order) streams that flow into the D & R Canal.

Though the watersheds are predominantly rural, recent census data showed a significant population increase during the past thirty years, with Raritan Township increasing the most, 186% since 1970, and Delaware Township growing the slowest at 38%. Because of their underlying geology and steep topography, these watersheds are particularly sensitive to the growing pressure of development and its associated environmental impacts. If growth continues at these rates, the health of these creeks will continue to decline, reflecting the associated impacts.

Therefore, as part of a 319(h) grant for the Lockatong and Wickecheoke Creek Watersheds Restoration and Protection Project, this build-out analysis report was prepared to "illustrate the form and pattern that development can be expected to take under a continuation of current trends and the manner and degree to which this form and pattern are contrary to planning goals" (Build-Out Analysis - Creating Communities of Place, NJ Office of State Planning, 1995).

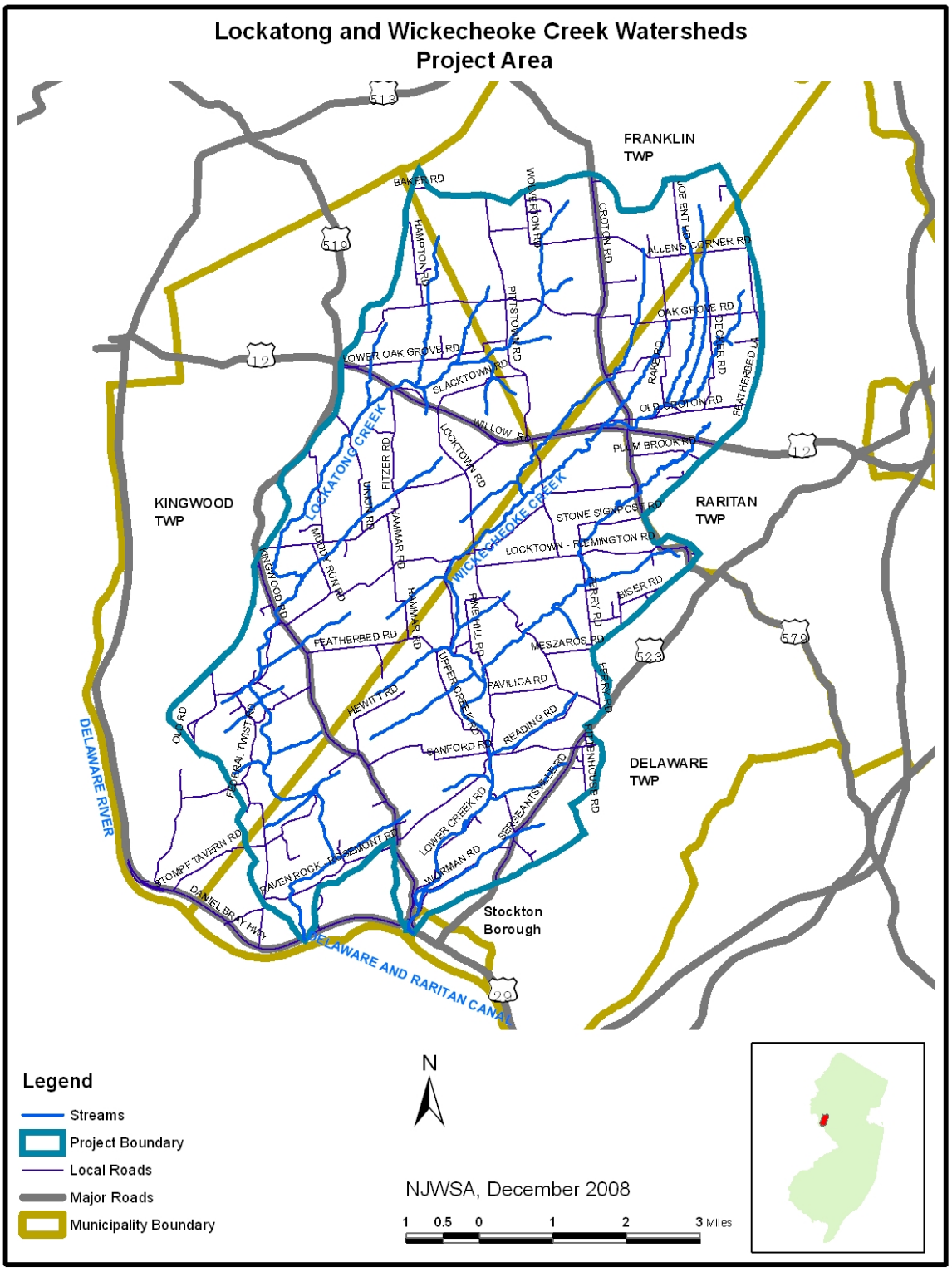
A build-out analysis maps potential future development across the landscape under specific sets of constraints. The scope and location of future development is identified in this type of analysis, although timing of development is not predicted. Information gained through a build-out analysis can be very useful in long-term planning efforts.

The build-out analysis in this report compared two future development patterns, one was based on current zoning and the other one was based on the Nitrate Dilution Model. A non-point source pollutant-loadings build-out was assessed to help to understand the impacts of future development on the water quality issues in the Watersheds. Build-out scenarios were created based on regulations and environmental constraints. To identify the potential impacts of build-out, impervious surface cover was used as a measure of non-point source water pollution from urban run-off with a comparison of non-point source pollution from forest and agricultural lands using NJDEP approved pollutant-loading Unit Aerial Load (UAL) values. A comparison of measured loadings from fieldwork with estimated loadings from UAL was also analyzed as part of the build-out report.

The goal of this report is to provide insight into the magnitude of future impacts on non-point source pollutant loadings on water quality issues, and help local municipalities and other interested entities determine what measures need to be taken to prevent over-development and depletion of natural resources. Such actions may include changes to

Master Plan elements, current zoning practices and development regulations. For the purposes of this analysis, a critical use of the build-out loading analysis is the estimation of future pollutant loads and the associated changes in water quality.

Figure 1: The Lockatong and Wickecheoke Creek Watersheds Project Area



Study Area

The Lockatong and Wickecheoke Creek watersheds are located within the Central Delaware Watershed Management Area (WMA11), which encompasses a drainage area of approximately 271.9 square miles, running through parts of Hunterdon, Mercer and Monmouth Counties and includes 27 municipalities. Most of the area in the Lockatong and Wickecheoke Creek Watersheds are in the Hunterdon (or Croton) Plateau with its hard argillite bedrock.

The Lockatong Creek is 13 miles long and originates from springs and wetlands near Quakertown in Franklin Township. It drains a 23.3 square mile watershed passing by cliff and rock formations, waterfalls, hemlock groves and historic old mills on its way to the Delaware and Raritan Canal and Delaware River. The Wickecheoke Creek is 14 miles long and originates from wetlands in Franklin and Raritan Townships, and springs in Delaware Township, flowing south through Delaware and Kingwood Townships to the D&R Canal and Delaware River at Prallsville Mills in Stockton. It drains a 26.6 square mile watershed.

These watersheds are still predominantly rural, having areas of agricultural and residential development. The major roads running through the watersheds include: State Highway 12, and County Routes 519, 523 and 579. State Highway 29 runs along the southern border of the watersheds. The upper segments of the streams, including the headwater segments, are designated as FW2-Non Trout status. The lower third (approximately) of the streams are categorized as FW2-Trout Maintenance status. Both streams and all the tributaries are classified as Category 1 status.

The total project area is about 31,960 acres; covering part of five municipalities: Franklin Township, Raritan Township, Kingwood Township, Delaware Township and Stockton Borough. The tables below show the percentage of the Lockatong and Wickecheoke Creek watersheds in each of the five municipalities and the percentage of each municipality covered within the watersheds.

Table 1: Percent of the Lockatong and Wickecheoke Creek Watersheds in each Municipality

Municipality	**Total acres of each Municipality within the Lock-Wick Project Area**	**% of the Lock-Wick Project Area within each Municipality**
Franklin Twp	5,501.3	17.2
Raritan Twp	3,172.3	9.9
Kingwood Twp	10,632.4	33.3
Delaware Twp	12,630.7	39.5
Stockton Boro	24.0	0.1
Total Acres of Lock-Wick Project Area	31,960.7	

Table 2: Percent of each Municipality within the Watersheds

Municipality	Total acres of each Municipality	Total acres of each Municipality within the Lock-Wick Project Area	% of each Municipality within the Lock-Wick Project Area
Franklin Twp	14,712.5	5,501.3	37.4
Raritan Twp	24,159.2	3,172.3	13.1
Kingwood Twp	22,900.6	10,632.4	46.4
Delaware Twp	23,675.4	12,630.7	53.3
Stockton Boro	383.7	24.0	6.3

A Literature Review of Build-Out Techniques

There are many variations of build-out methodology that can be used; however most are based on the same principles and standards. The build-out methodology used for the Lockatong and Wickecheoke Creek Watersheds was developed by the Watershed Protecton Program Unit office, New Jersey Water Supply Authority, with techniques borrowed and combined from ANJEC and New Jersey Stormwater Best Management Practice Manual. Here is a brief summary of four approaches for build-out analyses.

ANJEC developed a "Smart Growth Kit for Build-Out and Capacity Analysis" (http://www.anjec.org/pdfs/SG_Planning.pdf). This document outlines the basics of creating and completing a build-out analysis in steps and also includes "A Carrying Capacity of Natural Systems".

EPA's "Green Communities Kit" (http://www.epa.gov/greenkit/build_out.htm) includes a "How To Do A Build-Out Analysis" article. This build-out methodology is slightly different, as it provides for a phased approach. Phase One is a visual description of changes, and Phase Two is a quantification of those changes.

The Grant F. Walton Center for Remote Sensing and Spatial Analysis (CRSSA), Rutgers University, developed a methodology for build-out – "Build-out Data for Each Municipality with the New York/New Jersey Highlands Regional Assessment Study Area" (http://crssa.rutgers.edu/projects/highlands/hi_data/popch_metadata.htm). This methodology focuses only on residential capacities, and deals only with municipalities in the New York and New Jersey Highlands Region. Although there are some limitations present in this type of analysis, this method may be timesaving and cost-effective for some municipalities. Because a build-out analysis was completed for each municipality in the Highlands, selected municipalities will be able to take this document and use it immediately in their analysis.

The final methodology included is from the "New Jersey Stormwater Best Management Practices Manual" (http://www.co.hunterdon.nj.us/pdf/stormwater/NJDEP_SAMPLE_SW_PLAN.pdf). This method is very similar to the others, however specific requirements for meeting storm water BMPs are outlined here. This would be a useful way of controlling storm

water through a build-out analysis and eventual implementation of the recommended courses of action.

Results of hydrogeologic evaluations of the ground water supply should be used as a planning tool for delineating zones of suppressed aquifer recharge and/or water use in excess of the available aquifer supply. Zoning should mandate lot sizes based on areas required to infiltrate precipitation for diluting and maintaining ground water nitrate (from on-site septic systems) at 2 milligrams per liter (mg/l), and to maintain a balance between water use and the available recharge. Critical dry, summertime conditions should be targeted for estimating recharge and water-use rates.

Current Observed and Calculated Pollutant Loadings in Lockatong and Wickecheoke Creek Watersheds

Total phosphorus loadings, total suspended solids, and total nitrogen loadings were compared between those estimated using Unit Aerial Load (UAL) values and those determined from field measurements. USGS 30-minute interval flow data from the Lockatong and Wickecheoke Creek continuous flow-measurement stations were used as the "x" variable for the respective regression equations in Figures 2 thru 7 to determine total phosphorus, total suspended solids, and total nitrogen loadings. Combined data sets, NJWSA and DRBC, were used to construct these relationships at monitoring sites L1 (near mouth of Lockatong Creek) and W1 (near mouth of Wickecheoke Creek).

Figure 2: Relationship (natural ln-ln) of total phosphorus (TP) load to flow for site L1 on Lockatong Creek

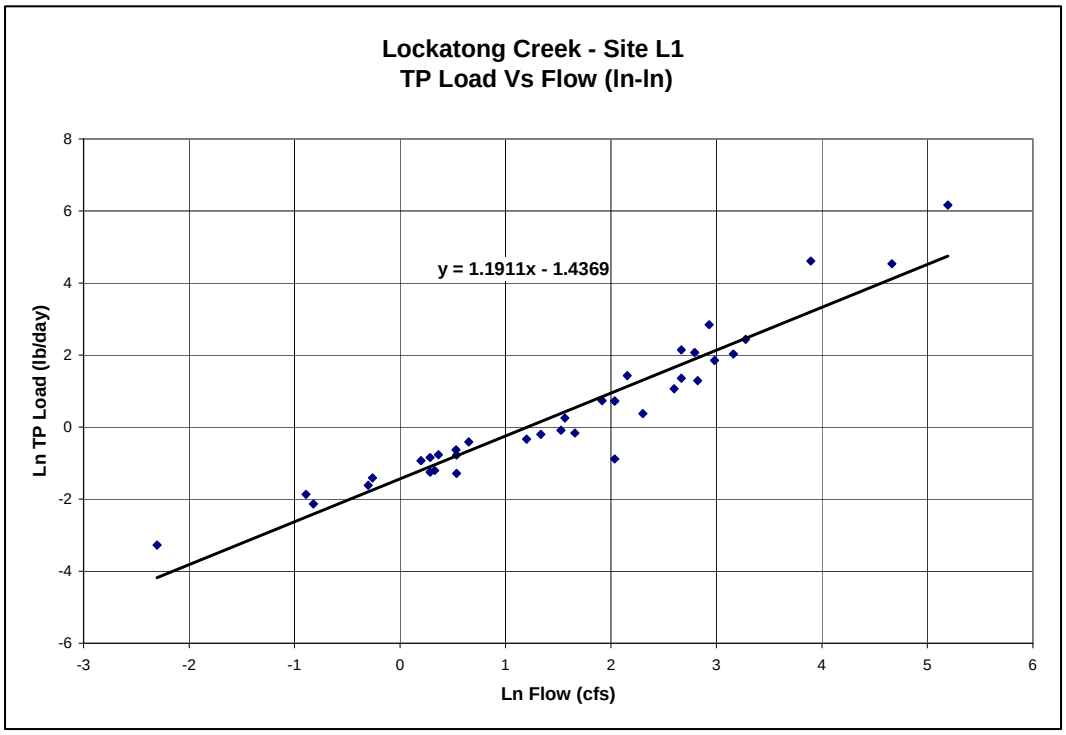


Figure 3: Relationship (natural ln-ln) of total phosphorus load (TP) to flow for site W1 on Wickecheoke Creek

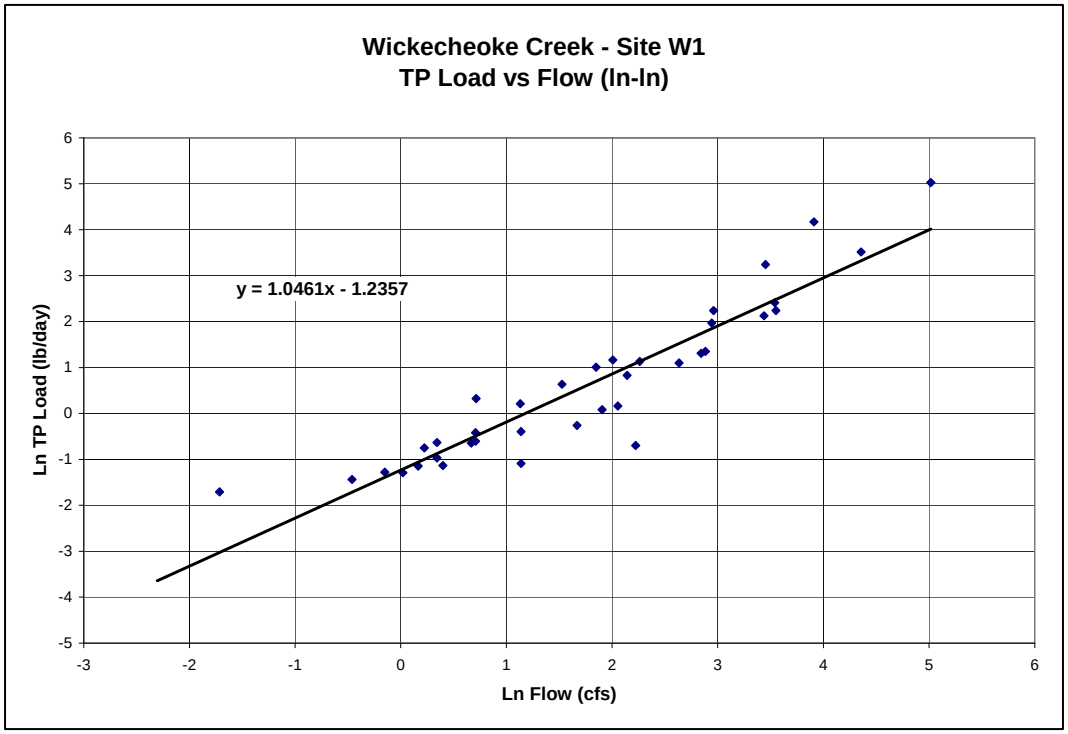


Figure 4: relationship (natural ln-ln) of total suspended solids (TSS) load to flow for site L1 on Lockatong Creek

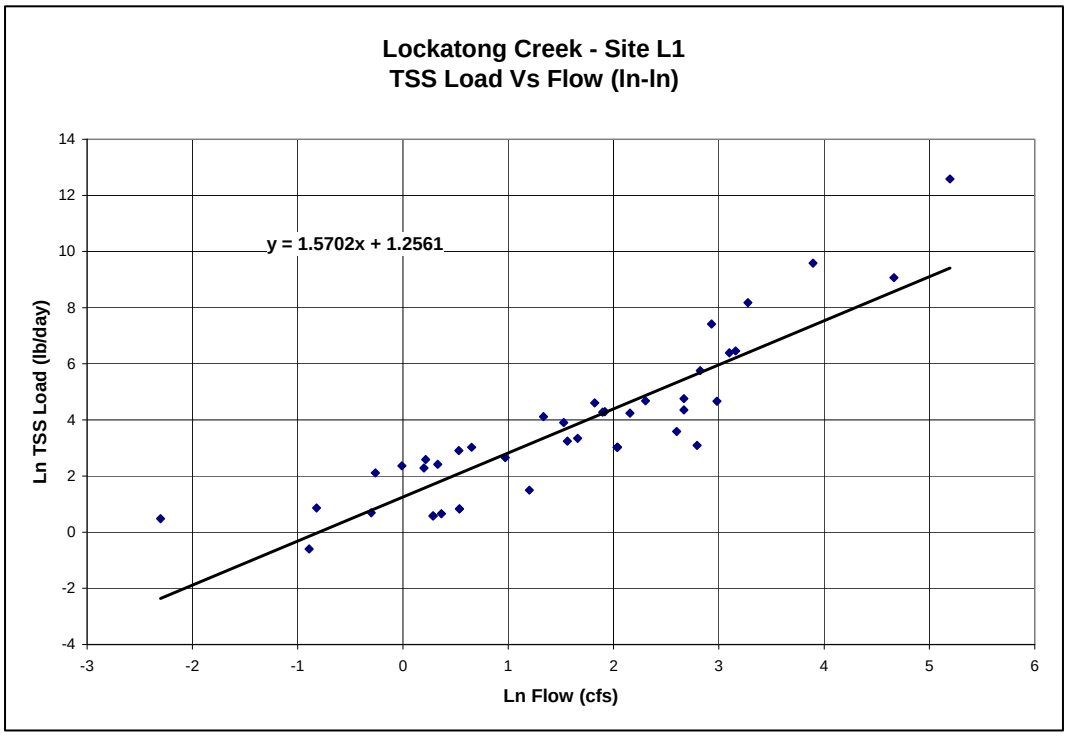


Figure 5: Relationship (natural ln-ln) of total suspended solids (TSS) load to flow for site W1 on Wickecheoke Creek

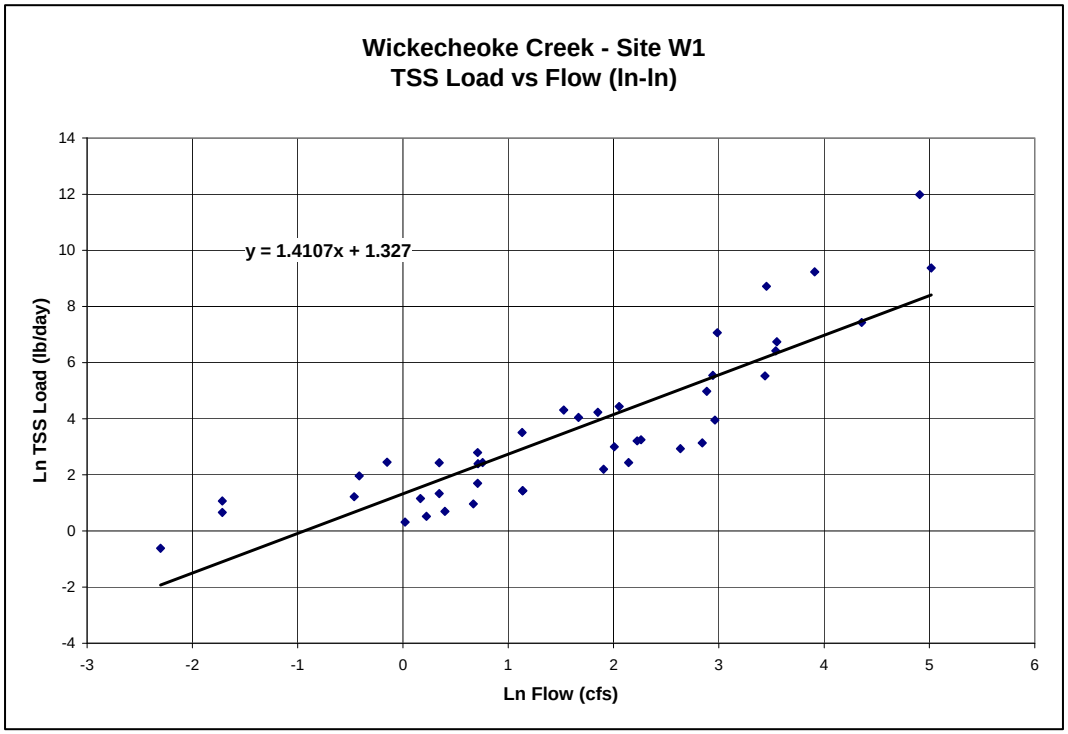


Figure 6: Relationship (natural ln-ln) of total nitrogen (TN) load to flow for site L1 on Lockatong Creek

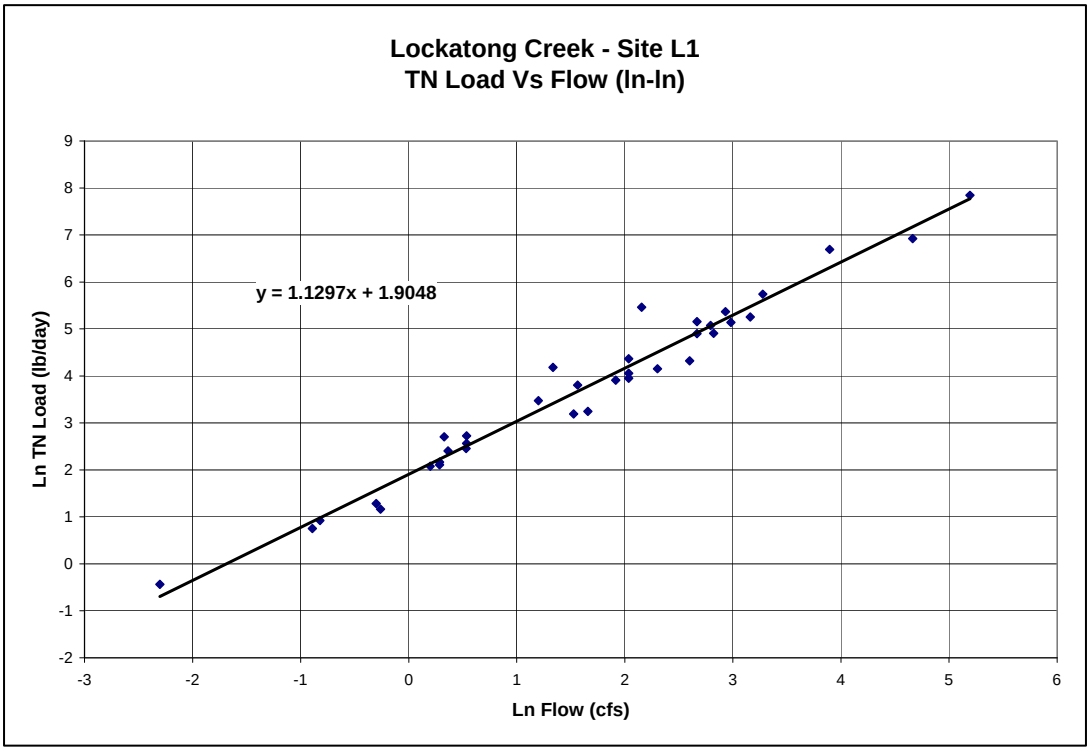
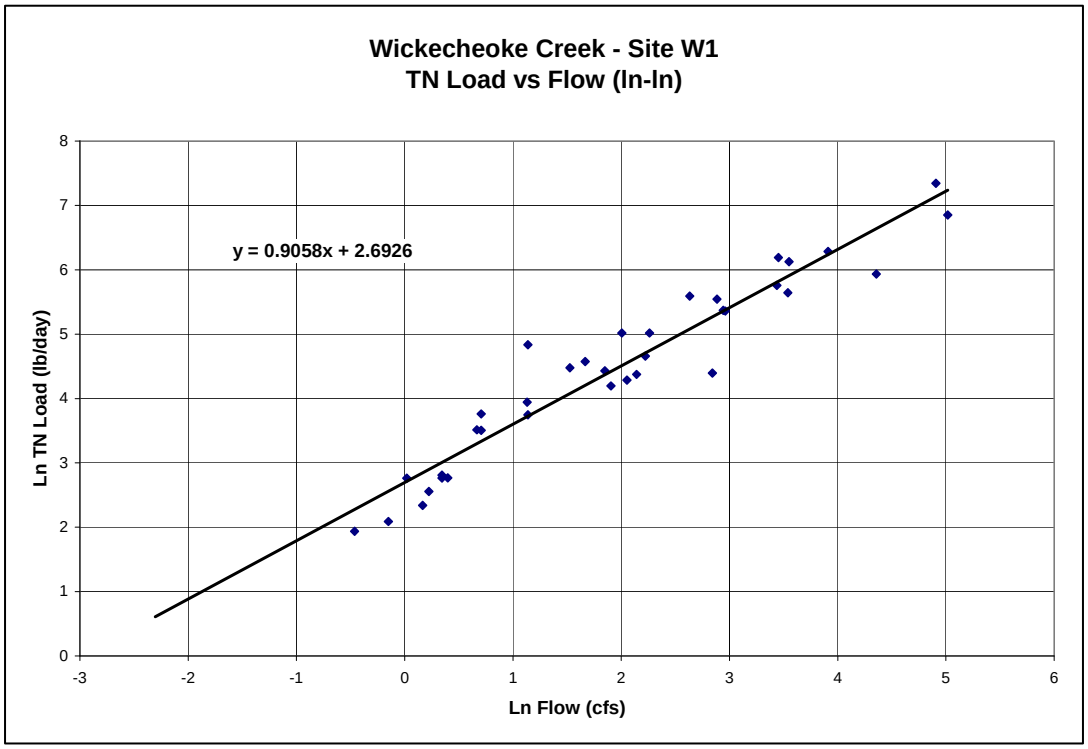


Figure 7: Relationship (natural ln-ln) of total nitrogen (TN) load to flow for site W1 on Wickecheoke Creek



The estimated non-point source pollutant loads for total phosphorus were calculated based on the NJDEP 2002 land use land cover data and the pollutant loads UAL from the NJDEP TMDL Report (Amendment to the Sussex County and Upper Delaware Water Quality Management Plans: Total Maximum Daily Loads for Phosphorous to Address Seven (7) Stream Segments in the Northwest Water Region, WMA 2 and WMA 11 (Black Creek, Wawayanda Creek, Lockatong Creek and Wickecheoke Watersheds, Proposed by NJDEP in July 2005 and EPA approved on September 2005). Table 3 shows a comparison between estimated and measured loadings for total phosphorus.

Table 3: Comparison of Unit Aerial Loading (UAL) versus measured loading for Total Phosphorus (TP), at sites L1 (Lockatong Creek) and W1 (Wickecheoke Creek)

Site	Land Use Type	Acres	TP UAL (lb/acre/yr)	TP UAL (lb/yr)	Measured TP (lb/yr)	TP % Difference
Lockatong Creek						
L1	Urban	1,792.60	1.25 - Average	2,240.80		
	Agriculture	5,959.30	1.34	7,985.50		
	Forest, Wetland, Water	6,872.70	0.09	618.5		
	Barren Land	41.8	0.45	18.8		
Totals		14,666.40		10,863.60	11,700.80	7.16
Wickecheoke Creek						
W1	Urban	1,937.00	1.25 - Average	2,421.20		
	Agriculture	6,410.40	1.34	8,589.90		
	Forest, Wetland, Water	8,433.10	0.09	759		
	Barren Land	29.4	0.45	13.2		
Totals		16,809.90		11,783.30	11,243.20	-4.80

The estimated non-point source pollutant loads for total suspended solids and total nitrogen were calculated based on the NJDEP 2002 land use land cover data and the pollutant loads UAL from the New Jersey Stormwater BMP Manual (Chapter 3: Regional and Municipal Stormwater Management Plans, February 2004). Tables 4 and 5 show comparisons between estimated total suspended solids and total nitrogen pollutant loadings and measured loadings.

Table 4: Comparison of Unit Aerial Loading (UAL) versus measured loading for Total Suspended Solids (TSS), at sites L1 (Lockatong Creek) and W1 (Wickecheoke Creek)

Site	Land Use Type	Acres	TSS UAL (lb/acre/yr)	TSS UAL (lb/yr)	Measured TSS (lb/yr)	TSS % Difference
Lockatong Creek						
L1	Urban	1,792.60	152 - Average	272,475.20		
	Agriculture	5,959.30	300	1,787,790.00		
	Forest, Wetland, Water	6,872.70	40	274,908.00		
	Barren Land	41.8	60	2,508.00		
Totals		14,666.40		2,337,681.20	2,181,300.80	-7.17
Wickecheoke Creek						
W1	Urban	1,937.00	152 - Average	294,424.00		
	Agriculture	6,410.40	300	1,923,120.00		
	Forest, Wetland, Water	8,433.10	40	337,324.00		
	Barren Land	29.4	60	1,764.00		
Totals		16,809.90		2,556,632.00	2,787,261.70	8.27

Table 5: Comparison of Unit Aerial Loading (UAL) versus measured loading for Total Nitrogen (TN), at sites L1 (Lockatong Creek) and W1 (Wickecheoke Creek)

Site	Land Use Type	Acres	TN UAL (lb/acre/yr)	TN UAL (lb/yr)	Measured TN (lb/yr)	TN % Difference
Lockatong Creek						
L1	Urban	1,792.60	13.6 - Average	24,379.36		
	Agriculture	5,959.30	10	59,593.00		
	Forest, Wetlands, Water	6,872.70	3	20,618.10		
	Barren Land	41.8	5	209.00		
Totals		14,666.40		104,799.46	226,774.50	53.79
Wickecheoke Creek						
W1	Urban	1,937.00	13.6 - Average	26,343.20		
	Agriculture	6,410.40	10	64,104.00		
	Forest, Wetlands, Water	8,433.10	3	25,299.30		
	Barren Land	29.4	5	147.00		
Totals		16,809.90		115,893.50	213,001.80	45.59

Locktong and Wickecheoke Creek Watersheds Build-Out Analysis

While build-out studies are useful, they generally cannot predict when full development will occur. This depends on many pressures, such as the economy, which are generally outside the municipality's control.

NJWSA performed two build-out analysis scenarios for the Lockatong and Wickecheoke Creek watersheds; one was based on the Nitrate Dilution Model described in the Water Quality Management Planning Rule, N.J.A.C. 7:15 - A Recharge-Based HUC 11-Scale Nitrate-Carrying-Capacity Planning Tool for New Jersey, v1.0 (MS Excel Workbook) (http://www.nj.gov/dep/watershedmgt/rules.htm), and the second scenario was based on the municipality zoning ordinance.

Both of these analyses were based on the computerized mapping program, GIS. Having high quality data was imperative to the result. The build-out will be only as good as the information and data collected. Good data are critical to build confidence in the results of the study. Please be advised that all the results and numbers are the best approximate even though we used the most recent data available.

Nitrate Dilution Model Build-Out

Nitrate (NO3) is a constituent found in the effluent from individual on-site wastewater disposal systems (septic systems). Ensuring that nitrate concentrations in ground water do not exceed targets should be one goal when planning or reviewing proposed developments that will use septic systems. The model used in the build-out scenario was developed by Hoffman and Canace (NJGS, 2002) to estimate region-average lot sizes needed to provide enough recharge to dilute nitrate to a specified target on a HUC11-scale planning effort. The model assumes a uniform average-annual recharge with no seasonal adjustment for a regional average.

This model workbook was designed with a municipality-oriented process. After inputting the county and municipality, HUC11s that drain the municipality, the percentage of the municipality in each HUC11, population density (expressed as people per home), HUC11-average ground-water recharge and a nitrate target, the workbook would provide an estimate of the average land area needed (in acres per septic system) to generate enough recharge to dilute the effluent nitrate-nitrogen coming out of the septic system to the specified standard. Currently, the nitrate level is not to exceed 2.0 mg/l (milligrams per liter). This approach assumes that all runoff from impervious cover on the lot is redirected to recharge facilities. This is compatible with the NJDEP's stormwater regulations that require no net decrease in ground-water recharge on developed lots. Please be aware that this nitrate dilution model recharge-area estimate is based on NJDEP Water Quality Management Planning Rules, and should be verified for site conditions by field inspection, based on critical recharge conditions.

Based on Hoffman's model, the average number of acres per equivalent dwelling units for each of the four municipalities associated with the HUC11 that drain them were estimated. The numbers of acres per septic unit are pretty similar within the same municipality, but slightly different if portions of the municipalities are located in different HUC11s.

A spatially explicit build-out model using a Geographic Information System was built to identify the undevelopable lands. These lands include those areas considered as undevelopable for environmental reasons, such as the Federal, State or local regulated wetlands, floodplains, steep slopes and stream corridors. Urban area was also considered as undevelopable since they were already developed. This build-out scenario was based on land use conditions within the watersheds and not a parcel-based scenario. The New Jersey Department of Environmental Protection's (NJDEP) digital mapped land use/ land cover (LULC) data from 2002, the most recent data available were used. By using this data set, 2002 represents the baseline year of the study.

In this process, protected open space and farmland were not excluded as undevelopable lands since the Nitrate Dilution Model is an estimate of region-average lot sizes needed to provide enough recharge to dilute nitrate to a specified target on a HUC11 planning scale and will require the cooperation between municipalities to decide where the new development should locate to average the nitrate target.

Properties not excluded in this step were deemed available for development. The final step needed to create the build-out scenarios was to identify the type of development that could occur on the available land. Commercial and industrial areas that were available for development were calculated for new additional equivalent dwelling units based on the average number of acres per dwelling unit extracted from the Nitrate Dilution Model.

The build-out results from the Nitrate Dilution Model allowed a total of 4,181 additional equivalent dwelling units for the five municipalities within the watershed area in addition to the 1,346 dwelling units already existing in the study area.

Table 6: New dwelling units at built-out based on Nitrate Dilution Model

Municipality	Total Acres of Each Municipality within the Lock-Wick Project Area	Acres of Constrained Lands	Acres of Developed Lands	Average Acre Per Unit based on Nitrate Dilution Model*	Potential New Dwelling Units (Excluding both Constrained and developed lands)	Existing Dwelling Units	Potential % Increase in Dwelling Units
Franklin Twp	5,501.30	780.2	570.4	5.3	783	164	477
Raritan Twp	3,172.30	1,051.80	329.1	5.6	320	159	201
Kingwood Twp	10,632.40	2,659.10	1,347.10	5.3	1,250	465	269
Delaware Twp	12,630.70	1,428.30	1,513.00	5.3	1,828	554	330
Stockton Boro	24	1.2	6.4	5	1	4	25
Total					4,181	1,346	311

Zoning Build-Out

A zoning based build-out analysis can help residents understand what their municipality, or a section of it such as a highway corridor, will look like if built to the capacity allowed in current zoning. The analysis can also include environmental, social and economic impacts of full development and evaluate whether the current zoning will achieve the goals of the master plan. A build-out can help identify changes needed in local master plans, zoning ordinances and development regulations. A zoning-based build-out will not address the capacity of the natural or infrastructure systems, because it is based on zoning that may not recognize the capacity of these systems. Table 7 shows the summary of zoning in the five municipalities.

Table 7: Zoning for the five Municipalities within the Lockatong and Wickecheoke Creek Watersheds

Municipality	Zoning Name	Zoning Type	Minimum Lot Size (acre)	FAR (Floor Area Ratio)	Cluster Allowed	Cluster Minimum Lot Size (acre)	Cluster Required Open Space (%)
Delaware Township	Highway Commercial	Commercial/Office/Indus	3.00	0			
	Village Residential/Commercial	Mixed Use	0.46	0			
	Village Residential/Commercial	Mixed Use	3.00	0			
	Agricultural/Residential	Residential	6.00	0	yes	3.0	50
	Agricultural/Residential	Residential	3.00	0	yes	1.5	50
	Village Zone	Residential	0.28	0			
Franklin Township	Neighborhood Business	Commercial/Office/Indus	7.00	8			
	Commercial South	Commercial/Office/Indus	7.00	5			
	Residential	Residential	3.00	0			
	Agricultural Residential	Residential	7.00	0			
Kingwood Township	Village Commercial-1	Commercial/Office/Indus	1.00	0			
	Village Commercial-2	Commercial/Office/Indus	2.00	0			
	Professional Office/Residential	Mixed Use	2.00	15			
	Highway Commercial	Commercial/Office/Indus	4.00	10			
	Business Park	Commercial/Office/Indus	5.00	10			
	Village Residential-2	Residential	2.00	0			
	Agricultural/Residential	Residential	4.00	0	(7ac?)		
Raritan Township	Rural Residential	Residential	6.00	0			
	Rural Residential	Residential	1.84	0	yes		
Stockton Borough	Low Density Residential	Residential	0.92	0			
	Public Land	Park/Conservation	0.00	0			

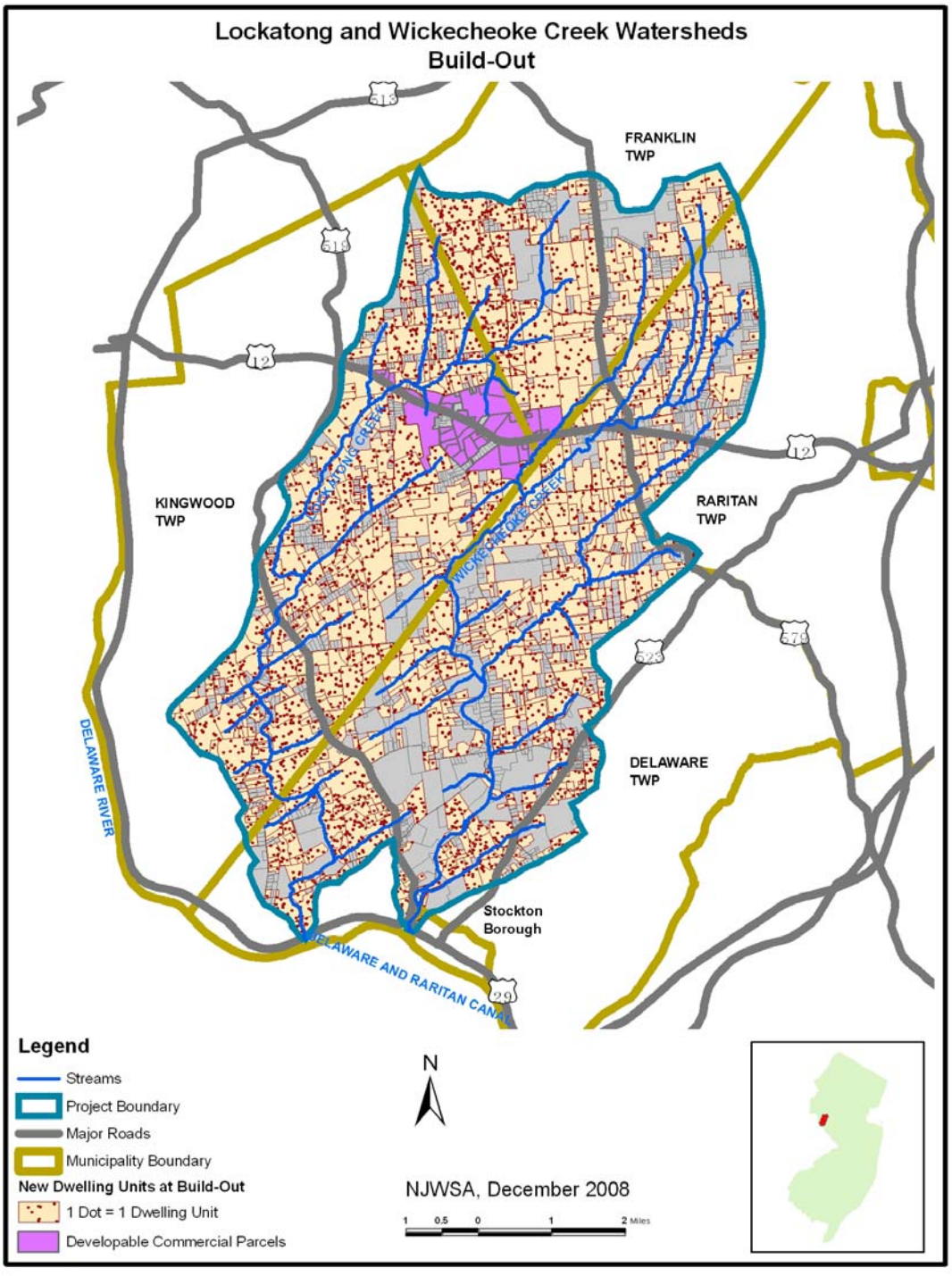
We created the spatially explicit build-out model using a Geographic Information System for the zoning-based build-out scenario. This is a computer-based tool used to manage, manipulate, and analyze digital data. The approach allowed us to examine potential changes to specific areas within the watershed.

To create the build-out scenarios, existing land use and property data in the watershed needed to be identified. We used the New Jersey Department of Environmental Protection's (NJDEP) digital mapped land use/ land cover (LULC) data from 2002 and Hunterdon County parcel data as of 2007, the most recent data available. By using this data set, 2002 represents the baseline year of the study.

Next, we identified properties that are available for development. Protected open space and already developed areas were identified as unavailable for development. Permanently protected open space includes state, county, and municipal land. Developed area include privately managed open space (i.e. designated conservation area), and developed properties with existing structures and cannot be subdivided.

Properties not excluded in this step were deemed available for development. Then the areas on each property deemed undevelopable for environmental reasons (including Federal, State or local regulated wetlands, floodplains, steep slopes and stream corridors) were identified, as well as the existing urban area on each property. The final developable area on each property equals the total acres of that property excluding the developed urban area and the undevelopable environmental area. The final step needed to create the build-out scenarios was to identify the type of development that could occur on the available land. Areas that were available for development were calculated for build-out dwelling units base on municipal zoning minimum lot size (**Figure 8**).

Figure 8: The Lockatong and Wickecheoke Creek Watersheds Build-Out



The results indicate current zoning for the five municipalities within Lockatong and Wichechoeke Creek watersheds allows for a total of 3,225 new residential units on a total of 974 developable residential parcels (Table 8).

Table 8: New build-out dwelling units based on Zoning breakdown by Municipality and Watershed

		Total Acres	Total Acres of Developable Residential Parcels	Total Acres of Developed Area within the Developable Parcels	Total Acres of Constrained Areas within the Developable Parcels	Build-Out New Dwelling Units	Existing Dwelling Units	Potential % Increase in Dwelling Units
Municipality within the Watersheds								
	Franklin Twp	5,501.30	3,891.20	176.91	630.76	616	164	376
	Raritan Twp	3,172.30	1,885.90	70.56	596.35	194	159	122
	Kingwood Twp	10,632.40	7,425.70	376.70	1,968.29	1,174	465	252
	Delaware Twp	12,630.70	7,324.70	482.40	908.44	1,228	554	222
	Stockton Boro	24.00	12.10	0.16	0.04	13	4	325
Total		31,960.70	20,539.60	1,106.73	4,103.87	3,225	1,346	240
Watersheds								
	Lockatong	14,904.50	11,459.72	589.43	2,360.87	1,965	610	322
	Wichecheoke	17,056.20	9,079.88	517.31	1,743.00	1,260	736	171
Total		31,960.70	20,539.60	1,106.73	4,103.87	3,225	1,346	240

For commercial area build-out analysis, we assume a 60% impervious surface cover with full development, this number 60% comes from an average summary from NJDEP 2002 land use/land cover data for commercial and service areas. The new impervious urban area at build-out will equal 60% at full development excluding the existing urban area in all the developable commercial parcels.

New IS = Total Acres of Parcel * 60% - Existing Urban Area on Property
IS = Impervious Surface

There are 75 developable commercial parcels within the Lockatong and Wichechoke Creek watersheds. Of which, 37 exist in the Lockatong watershed and 38 in the Wichechoke watershed. Most of the developable commercial parcels are located along the Route 12 corridor. A total of 605.4 acres of new impervious surface will be created if this area reaches its full development based on current zoning. Below is a breakdown of the commercial build-out for the Lockatong and Wichechoke watersheds.

Table 9: Commercial area build-out based on existing zoning

		Total Acres of Developable Parcels	Existing Impervious Urban Acres	Total Impervious Urban Acres at Full Build-Out	New Impervious Urban Acres	Potential % Increase in Urban Impervious Surface
Watersheds						
	Lockatong	767.1	26.2	460.2	434.0	1654
	Wichecheoke	345.2	35.7	207.1	171.4	480
Total		1112.3	62.0	667.4	605.4	977

Non-Point Source Pollutant Loadings Build-Out Based On Current Zoning

Based on the above described build-out results, new impervious surface and land use change can be predicted at build-out, therefore non-point source pollutant loads can now be determined by applying the UALs for total phosphorus, total suspended solids and total nitrogen to predict total pollutant loadings. The zoning based build-out result instead of the Nitrate Dilution Model was used for the non-point source pollutant loadings build-out as the zoning build-out is more accurate than Nitrate Dilution Model which assumes a region wide average groundwater recharge level and lot size.

As used above, the UAL for phosphorus comes from the NJDEP TMDL report, the UAL for total suspended solids and nitrogen come from the New Jersey Stormwater BMP Manual (Chapter 3: Regional and Municipal Stormwater Management Plans, February 2004).

To determine non-point source pollutant loadings at the build-out scenario, first, the new impervious surface at build-out was calculated. For any residential area with the minimum lot size more than 3 acres, we use the average 1.2 acres as the new impervious surface. The 1.2-acre standard comes from a study by Camp Dresser & McKee Inc. (CDM) who performed research associated with the "Watershed Model for Watersheds of the Spruce Run Reservoir" for New Jersey Water Supply Authority in 2003. For all other residential area with zonings less than 3 acres, we used the percentage of impervious surface summarized from NJDEP 2002 land use land cover data and the local zoning information.

In CDM's study, to evaluate the potential build-out land use scenario, modified impervious surface estimates were developed. The method used in this study to determine impervious surface is based on the assumption that large lot zoning (lots >= 3 acres) will be left in a mostly natural state (low impact development) and that only a small percentage of the lot will contain the house, driveway, patio, pool, etc, herein referred to as the homestead. The study showed that the average area of a homestead is approximately 1.2 acres.

After the total acres of new impervious surface is decided at build-out, the agriculture and forested lands which will be lost and contribute to the new impervious surface should then be calculated to compare the land use type change at the build-out (Table 10). These

comparisons show how much agricultural and forest lands will be lost and become impervious surface, in turn affecting local streams and lakes, specifically for stormwater management measures, causing pollutant loading and water quality issues.

Table 10: Comparison of land use type and acres change at build-out

	Land Use Type	Total Acres -Residential Build-Out	Total Acres - Commercial Build-Out	Total Acres of Build-Out
Lockatong Creek				
	Ag which will be changed to urban at build-out	1,288.7	296.1	1,584.8
	Forest which will be changed to urban at build-out	943.2	137.9	1,081.0
	New Urban Area at Build-Out	**2,231.9**	**434.0**	**2,665.9**
Wickecheoke Creek				
	Ag which will be changed to urban at build-out	885.4	117.0	1,002.3
	Forest which will be changed to urban at build-out	722.9	54.4	777.3
	New Urban Area at Build-Out	**1,608.3**	**171.4**	**1,779.7**

When the total new impervious surface and the associated loss of agricultural and forest lands are determined at build-out, then UALs for total phosphorus, total suspended solids and total nitrogen can apply to the change of land use type to estimate the total new pollutant loading at build-out, and then compare to the estimated current pollutant loadings.

The tables below show the comparisons between estimated current pollutant loadings versus the build-out for total phosphorus, total suspended solids, and total nitrogen. A total of 1,923 lbs of total phosphorus could be added to the watershed at build-out with 1,111 lbs per year added to Lockatong Creek Watershed and 812 lbs per year added to Wickecheoke Creek Watershed. The total suspended solids at build-out could be reduced by about 174,730 lbs per year with 113,463 lbs reduced in Lockatong Creek Watershed and 61,267 lbs reduced in Wickecheoke Creek Watershed. The reason for the reduction on the total suspended solids loads is because UAL for agricultural lands is usually higher than urban areas, especially for low-density residential areas. So when agricultural lands are developed into low-density residential areas, as the case in the Lockatong and Wickecheoke Creek Watersheds, a reduction of total suspended solids at build-out will happen. For the pollutant loads of total nitrogen, the watershed will see an increase of 29,014 lbs per year for the whole watershed with 17,165 lbs increase in Lockatong Creek Watershed and 11,849 lbs added to Wickecheoke Creek Watershed.

Table 11: Comparison of current non-point source pollutant loadings versus build-out for total phosphorus (TP) based on Unit Aerial Loading (UAL) for Lockatong Creek and Wickecheoke Creek Watersheds

	Land Use Type	Total Acres	TP UAL (lb/acre/yr)	TP UAL (lb/yr)	Total Existing TP Loadings (lb/year)	Post Build-Out TP Loadings (lb/year)	TP Loadings% Difference
Lockatong Creek							
	Ag which will be changed to urban at build-out	1,584.8	1.3	2,123.6			
	Forest which will be changed to urban at build-out	1,081.0	0.1	97.3			
	New urban area at build-out	2,665.9	1.25 - Average	3,332.4			
Totals					10,863.6	11,975.1	10.2
Wickecheoke Creek							
	Ag which will be changed to urban at build-out	1,002.3	1.3	1,343.1			
	Forest which will be changed to urban at build-out	777.3	0.1	70.0			
	New urban area at build-out	1,779.7	1.25 - Average	2,224.6			
Totals					11,783.3	12,594.9	6.9

Table 12: Comparison of current non-point source pollutant loadings versus build-out for total suspended solids (TSS) based on Unit Aerial Loading (UAL) for Lockatong Creek and Wickecheoke Creek Watersheds

	Land Use Type	Total Acres	TSS UAL (lb/acre/yr)	TSS UAL (lb/yr)	Total Existing TSS Loadings (lb/year)	Post Build-Out TSS Loadings (lb/year)	TSS Loadings% Difference
Lockatong Creek							
	Ag which will be changed to urban at build-out	1,584.8	300.0	475,440.0			
	Forest which will be changed to urban at build-out	1,081.0	40.0	43,240.0			
	New urban area at build-out	2,665.9	152 - Average	405,216.8			
Totals					2,337,681.2	2,224,218.0	-4.9
Wickecheoke Creek							
	Ag which will be changed to urban at build-out	1,002.3	300.0	300,690.0			

	Forest which will be changed to urban at build-out	777.3	40.0	31,092.0			
	New urban area at build-out	1,779.7	152 - Average	270,514.4			
Totals					2,556,632.0	2,495,364.4	-2.4

Table 13: Comparison of current non-point source pollutant loadings versus build-out for total nitrogen (TN) based on Unit Aerial Loading (UAL) for Lockatong Creek and Wickecheoke Creek Watersheds

	Land Use Type	Total Acres	TN UAL (lb/acre/yr)	TN UAL (lb/yr)	Total Existing TN Loadings (lb/year)	Post Build-Out TN Loadings (lb/year)	TN Loadings% Difference
Lockatong Creek							
	Ag which will be changed to urban at build-out	1,584.8	10.0	15,848.0			
	Forest which will be changed to urban at build-out	1,081.0	3.0	3,243.0			
	New urban area at build-out	2,665.9	13.6 - Average	36,256.2			
Totals					104,799.5	121,964.7	16.4
Wickecheoke Creek							
	Ag which will be changed to urban at build-out	1,002.3	10.0	10,023.0			
	Forest which will be changed to urban at build-out	777.3	3.0	2,331.9			
	New urban area at build-out	1,779.7	13.6 - Average	24,203.9			
Totals					115,893.5	127,742.5	10.2

Summary and Recommendations

Due to changes in zoning, open space planning, transfer of development rights, environmental regulations, and socioeconomic factors, and the local ground-water recharge and supply, the actual build-out landscape may deviate from the scenarios predicted in this analysis. However, based on the current situation, the analysis clearly identifies the potential for a large amount of development to occur.

The build-out analysis can go further than accomplished within the scope of this report. In addition to pollutant loadings and impervious surface, the analysis can be used to assess open space plans, and to project school population and demand on municipal services. The build-out analysis can greatly benefit a municipality by envisioning its

future so steps can be taken to prevent unwanted impacts, and to facilitate plans for future needs.

It is important to note that, although the UAL for total suspended solids of agricultural lands are higher than most of the urban areas, especially for low density residential areas, the total loads of suspended solids due to stormwater runoff may decrease due to the conversion of agricultural lands to low density residential. But the percentage of impervious surface increases dramatically, and if those impervious surfaces are not managed properly to capture stormwater runoff flows, these high flows will increase stream bank erosion, thereby increasing sediment loads to the receiving waters. Properly managing impervious surface with updated zoning, and applying BMPs on agricultural lands (i.e., such as those proposed in ***Lockatong and Wickecheoke Creek Watersheds Restoration and Protection Plan – Recommended Watershed-Based Implementation Projects***) are recommended for the prevention of pollutant loads reaching the streams. Each municipality is also encouraged to do their own build-out analysis for pollutant loads for each parameter for the whole municipality since this report only accomplished the portion of each municipality within the Lockatong and Wickecheoke Creek Watersheds.

The build-out results indicated a total of 4,400 acres of new impervious surface converted from either agricultural or forest lands. Proper policies are needed to accommodate this change and mitigate the impacts of impervious surface, such as restoration and protection of vegetation corridors along riparian zones with municipal ordinances. Examples are presented in ***An Assessment of Municipal Plans, Policies and Regulations Effecting Water Quality in the Lockatong and Wickecheoke Watersheds***. Educational programs are recommended for municipal officials and the public about the problems associated with impervious surface, as well as ways to reduce non-point source pollution. If development in the watershed is further limited, through aggressive land preservation efforts, the ultimate impervious surface cover would be reduced. It may be feasible to accomplish this through widespread participation in New Jersey's farmland preservation and open space protection programs. Stormwater runoff can further be reduced through innovative roadway runoff and drainage mitigation techniques; installation of rain gardens and other runoff controls on individual lots; recognition of site-specific characteristics and construction activities that are prone to, or cause additional soil compaction and the associated loss of infiltration and increased runoff (i.e., installation and maintenance of lawns, athletic fields, and some types of structural stormwater controls); and through continuous public education.

Future work could focus on developing a water budget for the Lockatong and Wichecheoke Creek waterhsheds. Additionally, the impacts on non-point source pollutant loadings from agriculture versus urban development could be further examined and calibrated, as there is great potential within the Watersheds for agricultural and forest lands to be converted to residential development in the future.

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