North Jersey Resource Conservation & Development

Estimating Impervious Cover and Its Impact on Water Resources

A Technical Report for the Upper Delaware Watershed Management Project

May 2002

• Impervious areas like these mean more runoff and less infiltration

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The North Jersey Resource Conservation and Development Council is a six-county regional nonprofit supported by the Soil Conservation Districts and county governments from Hunterdon, Somerset, Sussex, Morris, Warren, and Union Counties. Though organized by local communities, RC&D Councils nationwide receive technical and administrative support from the United States Department of Agriculture – Natural Resources Conservation Service through the Resource Conservation and Development Program.

We would like to acknowledge the Upper Delaware Project Team for their assistance in the creation of this report. The Project Team consists of members from the following agencies or groups:

New Jersey Department of Environmental Protection (NJDEP)
United States Department of Agriculture, Natural Resources Conservation Service (NRCS)
United States Department of the Interior, Geological Survey (USGS)
New Jersey Conservation Foundation

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Introduction

The term *Impervious Cover* is generally understood to be those man made areas that seal off the natural, permeable soil surface. This includes roofed structures, sidewalks, driveways, roads, and parking lots. Impervious cover prevents the infiltration of rainfall into the soil.

When naturally pervious soils are compacted and covered with impervious surfaces, a greater percentage of the annual rainfall amount is converted to surface runoff and evaporation. This reduces the amount of water available for aquifer recharge. Pollutant transport to surface waters increases, with a new group of toxic compounds, including hydrocarbons, metals, bacteria, pesticides and salts now carried quickly and efficiently to the stream. Aquatic organisms are impacted, and human water use is compromised.

The increased runoff also means more water flowing into streams in a shorter time period, which often means greater flooding. The normal response by a stream to increased flow is to increase its width or cross sectional area. This manifests as streambed down cutting, and streambank widening.

Because of the accelerated erosion process in the stream channel, downstream sedimentation increases where the flow slows. Stream bottom habitat declines. Water quality declines from the polluted runoff. These all lead to decreased biological diversity, which in turn negatively impacts fish and other aquatic organisms.

Purpose for this Report

Numerous studies (Horner, 1996; Taylor, 1995; Booth, 1991; Crawford, 1989) have clearly shown the relationship between impervious cover and degraded water resources. Consequently, it is important to the watershed planner or planning official to be able to estimate the percentage of both existing and potential impervious coverage in a watershed in order to help to predict the impacts of development on the receiving water body. The impervious cover evaluation is another useful tool for decisions relating to scope of development versus conservation. It is the responsibility of the land use decision-maker to protect the public interest and maintain or improve water resources within the area of planning jurisdiction.

North Jersey Resource Conservation and Development (RC&D) has developed this report in order to provide a transferable impervious cover estimation technology to the land use planners of the Upper Delaware Watershed. This impervious cover report is divided into three distinct parts:
1. Estimating existing impervious cover
2. Estimating future impervious cover based on predicted buildout
3. Estimating trends in annual pollutant loadings based on predicted buildout

A tale of two land covers

Consider what happens when an area changes from natural cover to impervious cover. We'll use an example of a forested tract, which is the optimum land cover in terms of environmental quality. The forest is being developed into a large condominium complex. In its natural state, the woods absorbed all but the most intense rainfall events with virtually no runoff. The healthy soil, containing a thriving symbiotic community featuring large amounts of organic matter and a network of roots, microbes and soil organisms, accepts the rainfall and absorbs it. Some of this water is utilized by the vegetation, the rest percolates deeper into the soil. There, it replenishes the ground water. Slowly, the ground water moves laterally below the surface, following the natural hydraulic gradient, to the bottom of the stream. This cool, clean water enters the stream in a controlled way over a long period of time. This helps to maintain baseflow of the stream during periods when no rainfall has occurred, preserving the ecosystem of the stream bottom, crucial to the overall health of the stream. The stream channel can handle the natural inflow, as it is in equilibrium with the hydrology. The stream is healthy, maintaining clean water and a balanced population of the plants and organisms adapted to the region.

Now, let's fast forward. The tract is sold. The earth moving equipment comes in, clearing all vegetation from the site. The soil is severely disturbed and compacted from the clearing and grading process. The natural drainage pattern of the site is completely altered, with all of the grading and an artificial conveyance system installed to take the stormwater to a detention basin, which theoretically stores the water and releases it slowly, an attempt to approximate the peak storm discharge from the site in its pre-developed state. The condos and associated parking area are constructed, multi story structures surrounded by some turf, concrete sidewalks and asphalt pavement. Let's see what happens now when it rains. It's been a hot summer day, and a thunderstorm moves in. The raindrops hit the hot black roof and asphalt and are prevented from infiltrating. Instead, some of the water quickly evaporates. The rest runs off. Rain hitting the roof goes to the gutters and downspouts; from there it joins the sidewalk and parking lot runoff toward the nearest catchbasin. As the water flows over paved surfaces, it picks up a myriad of pollutants. Things like hydrocarbons relating to vehicular traffic, heavy metals from brake linings, sediments, tire breakdown, antifreeze, and in the winter, road salts and sands. There may be organic pollutants like grass clippings, leaves, or pet waste. Maybe some lawn fertilizers and pesticides join the mix. This stormwater is quickly conveyed to the detention basin, where the first flush moves through the concrete low flow channel and out, discharging to the stream in a concentrated fashion from the end of a pipe. As the storm continues, the water comes in faster than it leaves, and it builds up in the basin for a few hours. The storm ends and the basin drains back down to a dry condition.

The stream now is exposed to a completely different hydrologic situation. The soil underneath the development receives almost no moisture, so there is no gradual infiltration of cool, clean water to naturally recharge the stream. Instead, the stream becomes more 'flashy' - low baseflow and excessive stormflow. During the storm, the stream receives a blast of heated runoff containing any pollutants available from impervious surfaces and the compacted, intensively managed turf areas. The stream, not used to flows of this nature, begins to erode along the banks and bottom. Sediment is deposited in the slower sections of the stream, covering the stony habitat on the bottom. Macroinvertebrate habitat is destroyed. The previously cool stream temperatures are elevated, reducing the habitat for trout. The pollutants from the development are added to the stream, creating both acute and chronic health effects on the organisms. In a relatively short time, the stream is transformed from a clean, sensitive watercourse to one characterized by warmer temperatures, unstable bed and banks, reduced dissolved oxygen, increases in nutrients, metals, hydrocarbons, and other pollutants. Several dry weeks later, the stream is back down to a trickle, and the remaining fish have moved elsewhere.

Pollutants related to Impervious Cover

As mentioned in the previous section, there are a number of pollutants that are associated with impervious surfaces. These pollutants can have a costly impact on surface waters used for public water supply. Aquatic organisms and habitat can also be acutely affected. The point to remember is that the impervious surface *itself* is not the potential pollutant, in the way a freshly plowed farm field may be. Rather, it is the impenetrable, smooth nature of the impervious surface that acts as a trap and conveyance mechanism for any pollutants that are deposited on or near the surface.

Sediment

Sediment related to impervious surfaces comes from the disturbance and construction process, insufficient vegetative stabilization after construction, from stream channel erosion, off of tires, and from road sanding for wintertime traction. Sediment reaching surface waters means turbidity, lost aquatic habitat, and reduced recreational opportunities.

Nutrients

Nitrogen and phosphorous runoff is increased by impervious surfaces primarily because of what is *associated* with the change in land use. These nutrients can come from lawn fertilizers and waste from pets, small mammals and resident Canada Geese in developed residential and corporate areas. In addition, there is significant atmospheric deposition of nitrogen compounds derived from fossil fuel emissions. Excessive phosphorous reaching surface waters leads to weed and algae growth and eutrophication, which impacts aquatic life and recreational opportunities. Elevated nitrogen levels can be toxic to humans, livestock, wildlife, and fish species.

Organic Matter

Organic matter in the form of waste, leaves, and grass clippings also are generated and available for transport to surface waters. These elements, especially phosphorous, create accelerated weed and algae growth in surface waters. These contribute to reduced dissolved oxygen because when the vegetation dies, or the extra organic matter is added to the stream, the process of breaking the material down uses oxygen. This can create depressed dissolved oxygen levels, which negatively impact aquatic habitat for many organisms.

Metals

Metals such as zinc, lead, nickel, and cadmium build up on impervious road and parking surfaces, the products of vehicular operation and atmospheric deposition. Metals are toxic to most aquatic organisms and are linked to cancer and other chronic human conditions such as liver disease.

Pathogens

Pathogens also increase with development. The sources of these bacteria and viruses usually are associated with wastes emanating from pets, resident Canada Geese, and sometimes, small mammals that move into the storm sewer system. Many diseases can be transmitted to surface waters by these wastes being washed into storm sewers and flowing to the stream.

Chlorides

Road salt contributes large amounts of chlorides to streams. Chlorides have a toxic effect on many aquatic organisms, especially salmonids (trout).

Thermal pollution

Galli (1990) studied five headwater streams in the Maryland Piedmont that differed in percentage of impervious cover. Each of the urban streams had mean temperatures that were consistently warmer than a forested reference stream. The magnitude of the temperature increase was found to be directly tied to the degree of watershed imperviousness. Elevated stream temperatures negatively impact important aquatic organisms, most notably salmonids.

These pollutants are not necessarily all. Depending upon the specific location, pesticides from lawns, floatable debris (litter), and other toxic byproducts of automobile operation such as hydrocarbons, fuel oxygenation additive MTBE and anti freeze all can accumulate on impervious surfaces and dramatically impact water resources.

The relationship between impervious cover and water quality

Research of numerous studies summarized by Schueler (1994) show a clear correlation between the percent of impervious surface in a watershed and the degree of stream impairment observed. In other words, the more predominant impervious cover is within a watershed, the more dramatic water quality decline can be expected, due to the aforementioned factors. It is a direct relationship. Because of this connection, estimation of impervious cover compares favorably with other land use evaluation techniques to predict water quality impacts from development. Table 1, below, illustrates how impervious cover estimation compares with other land use indicators as tools for local watershed planning.

Table 1: Comparison of Different Land Use Indicators and their Applicability to Local Watershed Planning

Land use indicator	Water quality impact threshold	Method advantage	Method disadvantage	Appropriate watershed scale	Applicability for local watershed planning
Percent Impervious Cover	10%	Most accurate	Highest level of effort and cost	Catchment and Subwatershed- 50 acres 1-10 square miles	High
Housing Density	1 unit/acre	Moderate accuracy at larger scales	Less accurate at smaller scales and in areas with substantial commercial/industrial land use	Watershed-10-100 square miles	Moderate
Population Density	2.5 people/acre	Moderate accuracy at larger scales	Less accurate at smaller scales and areas of substantial commercial/industrial land use	Watershed-10-100 square miles	Moderate

Adapted from: Technical Note 116, Watershed Protection Techniques 3(3): 735-739

Caraco et al. (1998) proposes an impervious cover model that classifies urbanizing streams into three categories: sensitive; impacted; and non-supporting streams, determined on the aforementioned subwatershed basis. The model uses the following thresholds of percent impervious cover:

Sensitive streams typically have a watershed impervious cover percent 10% or less. The streams have characteristically good to excellent water quality, excellent habitat for macroinvertebrates and indigenous organisms, diverse fish communities, and stable channels and banks. Where <10% of a watershed is covered with impervious surface, streams are considered protected, although highly sensitive stream ecosystems may be stressed.

Impacted streams posses watershed impervious cover percent ranging from 11 to 25%. There are signs of degradation, including streambank erosion, channel instability, physical habitat declines, water quality shifts from excellent/good to good/fair; biodiversity declines, and sensitive fish and macroinvertebrates leave the stream. Where 11- 25% of a watershed is covered with impervious surface, streams are assumed impacted. Some mitigation may be possible with well planned stormwater best management practices.

Non-supporting streams are greatly degraded. Where over 25% of a watershed is covered by impervious surface, a stream is most likely degraded. Water quality is generally poor; habitat is monotonous, diversity is low, stream channel stability is poor. A secondary threshold of 30% impervious cover has been put forth by Arnold and Gibbons (1996), which states that degradation has become unavoidable, even if efforts are made to remediate the quantity and quality of stormwater reaching the stream. Pre development stream form and function cannot be fully maintained even with the use of best management practices or retrofits. Actual stream restoration projects addressing inflow, bed, and banks may have some measurable positive impact.

Thus, it becomes apparent that just a small amount of impervious surface has far reaching impacts on the quality of surface water.

An important caveat: this correlation is most valuable at the subwatershed level, 1 to 10 square miles, or the smaller catchment level, 50 to 500 acres. In watersheds larger than 10 square miles, the relationship between impervious cover percentage and water quality begins to break down. Above 100 square miles, the relationship is no longer useful as a tool to predict water quality impacts. The proximity of the impervious cover to the stream also is a big factor. The threshold percentages of impervious cover will vary according to the width of the stream buffer, condition and prevalence of stormwater management best management practices, land use/land cover, and topography.

Making an impervious cover estimation

Seeing the direct relationship between impervious cover and declining water quality, the next logical step is to get a handle on estimating current and future impervious cover. Several decisions must be made up front relating to the estimation. Will all impervious cover be counted equally? There are different types of impervious areas that can be evaluated, depending upon the size and scope of the project:

Total Impervious Area (TIA) vs. Effective Impervious Area (EIA) should be considered. TIA is just what it sounds like - all impervious areas: roofs, sidewalks, driveways, streets, and parking lots. On the other hand, EIA's are impervious surfaces that are *directly connected* to the surface waters by the stormwater collection and drainage system. Examples would be parking lots and streets containing catchbasins and storm sewers to surface waters. Another EIA would be a rooftop with downspouts connected directly to the storm sewer. It is thought that effective impervious areas have a more immediate and negative impact on surface water quality than those impervious areas that are not directly connected to the surface waters. EIA evaluation requires a thorough mapping of the storm sewer system of the subwatershed. However, to count *only* EIAs is to ignore significant impervious areas that greatly impact the natural environment. In order to provide a complete and simple methodology for impervious cover evaluation, this report will focus on Total Impervious Area (TIA).

Rock outcrop and compacted turf areas are another consideration. Should these areas be counted as impervious cover? Certainly, rock outcrops are impervious, basically being solid, exposed bedrock. However, bedrock is a natural condition and to consider it as impervious cover is inconsistent with the goal of evaluating the impact of development on water resources.

Some lawn areas, parks, and athletic fields are severely compacted and produce runoff. However, they are not true impervious areas. The fact that the surface several inches consist of a network of grass, roots, thatch, decayed organic matter, and microorganisms means that there is initial abstraction, storage, and plant intake of the first portion of the rainfall event. If steady rain continues, most of it will run off, albeit more slowly than from pavement of similar gradient. In extremely compacted conditions, once the surface has become saturated the runoff volume from turf can approach that of pavement. However, these conditions vary widely from site to site. Because of this variability and the lack of consistent regionwide data to determine impervious levels of turf, these areas will also not be included as impervious cover for the purposes of this study.

Choosing a criteria for an impervious estimation methodology

In order for an impervious estimation methodology to useful, it should have three basic attributes:

1. It must be relatively accurate
2. It must be relatively easy to do
3. The information required to do the estimate must be easily derived and readily available

When deciding on a methodology, some basic questions need to asked:

1. How much time, labor, and funding is available to carry out the analysis?
2. How much accuracy is needed?
3. Can the technique be used to predict future impervious cover?

Generally, there are four acknowledged methods to estimate impervious cover. The four techniques become progressively less expensive to use, but also less accurate:

Direct measurement: This is actually a physical measurement of impervious cover. The areas of all rooftops, streets, sidewalks, parking lots, and other impervious areas are measured in a subwatershed. The data is derived from actual on site survey, 'drive-by' estimation, aerial photography, or satellite imagery. Direct measurement is the most accurate but also the most time consuming method of determining impervious cover. However, it has very limited use for determining <u>future</u> impervious cover.

One effective methodology for direct measurement has been developed by the Delaware River Basin Commission (DRBC) (V'Combe & Albert, 1998). This method can work well if staff and time parameters are compatible for stand alone impervious cover estimation and as a way to ground-truth a remotely generated estimate. This assessment can be found in the paper cited in References.

The DRBC methodology, known as a ground survey, involves driving over every road in the watershed and working with a map, marking the estimated percent impervious cover on either side of the road. This method can be quite accurate, if personnel are available to do the field work- it is a two person operation. This method can be valuable for cross checking remote derived data and updating or adding to an existing impervious cover dataset. Global positioning systems, or GPS, can be valuable when doing ground surveys. The GPS will provide an exact location, transferable to a geographic information system map or aerial photograph.

Land Use: This method estimates impervious cover based on specific land use categories, such as agricultural, forest, low density residential, commercial, etc. The information is derived from interpretation of satellite imagery or aerial photography, where land use categories are separated. Each land use category (i.e. commercial, industrial, 1/8 acre residential, 2 acre residential, etc) can be assigned an average percent impervious cover, based on data from direct measurement studies done elsewhere or on a small portion of the study area. There are a number of ways to come up with the land use-impervious cover percentages. Recently, The Center for Watershed Protection in Ellicott City, Maryland published an analysis of several impervious cover studies done in the Chesapeake Bay watershed (Cappiella & Brown, 2000). The study, which focused on four Chesapeake communities, found that land use-impervious cover relationships are broadly transferable to other Chesapeake regions with similar development patterns. Table 2 summarizes for the study area the major land use categories and associated impervious cover cited in the executive summary.

The Land Use method can also be used to forecast future impervious cover at build-out by evaluating the various zoning types within the watershed and equating to a corresponding existing land use impervious cover. The latest municipal zoning map is the basis for the categories, and previous data or a current measurement of the portion of the zoning impervious coverages within the watershed is used. <u>The opinion of many is that the best compromise of accuracy and cost is the land use method.</u>

An important facet of the analysis of future impervious cover is the amount of land, regardless of its zoning type, that is known to be unbuildable. Unbuildable lands could include preserved open space, wetlands, some floodplains, ordinance-regulated lands, and already developed land. Depending upon the community, there may be readily available data available to help make this determination. Unbuildable lands could include existing developed lands from the current 1995/97 Land Use/Land Cover coverage, wetland maps from the New Jersey Department of Environmental Protection (NJDEP), floodplain maps from the Federal Emergency Management Agency (FEMA), preserved lands data from county and state, and local ordinances that prohibit building on lands with limitations such as steep slopes or riparian buffers. These lands are taken out of the equation, and the rest of the buildable land is analyzed according to zoning type.

Road density: This indirect measure method makes an interpolation of total impervious cover based on a correlation between development and road length. It must be calibrated and combined with another method. The road density method is easy to use, and requires only a street map. However, there is very little data available relating road density to impervious coverage. One study in the Puget Sound, Washington area, found a linear relationship between road density and impervious cover. However, it likely will not apply in other regions. In addition, this method cannot be used to predict future cover.

Population density: This method correlates impervious cover percentage with population density. This method has some applicability in New Jersey, where population data from 527 of 566 municipalities has been developed. This method must be combined with the land use or direct measure methods; it is not applicable at the subwatershed level.

Upper Delaware Watershed Impervious Estimation Procedure

The most practical methodology to estimate impervious surfaces in the Upper Delaware is a land use method, specifically the so-called 'NEMO' Method. NEMO is the University of Connecticut Cooperative Extension Program, **N**onpoint **E**ducation for **M**unicipal **O**fficials. This program was created in 1991 and is designed for transfer of information and technology to land use planners in order to minimize the impact of development on environmental quality. The impervious methodology put forward here is for people and organizations that have geographic information systems (GIS) capability and assumes a working knowledge of GIS in order to perform the calculations. The methodology requires four distinct data groups:

1. 1995/1997 NJDEP land use - land cover imagery
2. Subwatershed boundaries at the HUC-14 (Hydrologic Unit Code) or smaller scale
3. Digitized zoning maps
4. Unbuildable areas

The NEMO methodology provides the best combination of accuracy, flexibility, and labor requirement to estimate the percent impervious cover in this watershed. The technical process employed can be found in Appendix A.

Here are the basic steps necessary to make the estimate:

Calculate existing impervious cover

There are a great many studies that have assigned an impervious cover percentage to a given land use. The aforementioned Chesapeake Bay Study (December 2000) evaluated several of these and summarized them (Table 2). USDA-Natural Resources Conservation Service has impervious numbers for various land uses in Technical Release 55 and Chapter 2 of the Engineering Field Handbook. The Rutgers Center for Remote Sensing and Spatial Analysis has also developed these numbers. This data is generally consistent across land uses and can be used in an impervious cover estimation.

Table 2: Average Impervious Cover by Land Use - Chesapeake Bay Study

Land Use Category	Mean Impervious Cover %
2 Acre Lot Residential	12
1/2 Acre Lot Residential	21
1/4 Acre Lot Residential	28
1/8 Acre Lot Residential	33
Townhome Residential	41
Multifamily Residential	44
Institutional**	34
Light Industrial	53
Commercial	72

*Open urban land includes developed parkland, recreation areas, golf courses, and cemeteries.
**Institutional is defined as places of worship, schools, hospitals, government offices, and police and fire stations
Source: Cappiella and Brown, 2001

However, this report uses a summary of impervious cover percentages assigned to 66 different land use categories designated by NJDEP from the 1995/97 land use-land cover data for the Upper Delaware Watershed (Table 3). This data is the result of individual polygon estimation of impervious percentage. A preliminary validation of this data by NJDEP has found it to be extremely accurate. Because the goal here is to provide a readily transferable methodology, we are using this single, available set of data consistent across the state. One caveat, however: if the local official working on the impervious cover estimate has better information relating to the land use/impervious relationship in a specific watershed, it should be utilized.

The Arc Info GIS program will calculate the existing impervious cover based on the impervious cover values assigned by NJDEP to each of the unique land use/land cover categories. The individual polygons are summed, divided by the subwatershed area, and a total percent impervious cover is generated for the subwatershed.

Table 3. Average Impervious Cover by Land Use- Upper Delaware Watershed

NJDEP 95 Land Use/Land Cover Category	Average Impervious Percentage
AGRICULTURAL WETLANDS (MODIFIED)	0.0
ALTERED LANDS	7.0
ARTIFICIAL LAKES	0.0
ATHLETIC FIELDS (SCHOOLS)	9.1
ATLANTIC WHITE CEDAR SWAMP	0.0
BARE EXPOSED ROCK, ROCK SLIDES, ETC.	21.6
COMMERCIAL/SERVICES	59.9
CONFINED FEEDING OPERATIONS	20.4
CONIFEROUS BRUSH/SHRUBLAND	0.6
CONIFEROUS FOREST (10-50% CROWN CLOSURE)	1.1
CONIFEROUS FOREST (>50% CROWN CLOSURE)	0.5
CONIFEROUS SCRUB/SHRUB WETLANDS	0.0

NJDEP 95 Land Use/Land Cover Category	Average Impervious Percentage
CONIFEROUS WOODED WETLANDS	0.0
CROPLAND AND PASTURELAND	0.5
DECIDUOUS BRUSH/SHRUBLAND	1.2
DECIDUOUS FOREST (10-50% CROWN CLOSURE)	0.9
DECIDUOUS FOREST (>50% CROWN CLOSURE)	0.6
DECIDUOUS SCRUB/SHRUB WETLANDS	0.0
DECIDUOUS WOODED WETLANDS	0.0
DISTURBED WETLANDS (MODIFIED)	0.5
EXTRACTIVE MINING	1.9
FORMER AGRICULTURAL WETLAND-BECOMING SHRUBBY, NOT BUILT-UP)	0.1
HERBACEOUS WETLANDS	0.0
INDUSTRIAL	61.3
INDUSTRIAL/COMMERCIAL COMPLEXES	85.0
MANAGED WETLAND IN BUILT-UP MAINTAINED REC AREA	3.2
MANAGED WETLAND IN MAINTAINED LAWN GREENSPACE	0.3
MILITARY RESERVATIONS	83.3
MIXED BRUSH AND BOG WETLANDS, CONIFEROUS DOMINATE	0.0
MIXED DECIDUOUS/CONIFEROUS BRUSH/SHRUBLAND	0.8
MIXED FOREST (>50% CONIFEROUS WITH 10%-50% CROWN CLOSURE)	0.9
MIXED FOREST (>50% CONIFEROUS WITH >50% CROWN CLOSURE)	0.4
MIXED FOREST (>50% DECIDUOUS WITH 10-50% CROWN CLOSURE)	0.8
MIXED FOREST (>50% DECIDUOUS WITH >50% CROWN CLOSURE)	0.3
MIXED FORESTED WETLANDS (CONIFEROUS DOM.)	0.0
MIXED FORESTED WETLANDS (DECIDUOUS DOM.)	0.0
MIXED RESIDENTIAL	30.0
MIXED SCRUB/SHRUB WETLANDS (DECIDUOUS DOM.)	0.0
MIXED URBAN OR BUILT-UP LAND	46.1
NATURAL LAKES	0.0
OLD FIELD (< 25% BRUSH COVERED)	1.3
ORCHARDS/VINEYARDS/NURSERIES/HORTICULTURAL AREAS	4.5
OTHER AGRICULTURE	15.5
OTHER URBAN OR BUILT-UP LAND	4.2
PLANTATION	0.8
RECREATIONAL LAND	22.1
RESIDENTIAL, HIGH DENSITY, MULTIPLE DWELLING	55.2
RESIDENTIAL, RURAL, SINGLE UNIT	12.9
RESIDENTIAL, SINGLE UNIT, LOW DENSITY	20.8
RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	30.5
STREAMS AND CANALS	0.0
TRANSITIONAL AREAS	3.5
TRANSPORTATION/COMMUNICATIONS/UTILITIES	30.6
UNDIFFERENTIATED BARREN LANDS	0.3
WETLAND RIGHTS-OF-WAY (MODIFIED)	0.1

Calculate buildout impervious cover

Step 1 - Identify areas that can't be developed. In this model, we used available digital information that will indicate unbuildable lands. This may include: developed lands, roads, wetlands, floodplains, surface waters, deed-restricted land, preserved open space, and preserved farmland. In addition, research must be done at the municipal levels to ascertain if ordinances exist that prevent building in riparian areas (as distinct from floodplains), steep slopes, or other areas. Once these areas are delineated and summed, the remaining lands are what is left for development. In this analysis, no deduction for floodplains or steep slopes was made, since under New Jersey law, some development may be possible.

Step 2 -Assign impervious values to the buildable lands. The objective is to equate the municipal zoning category to an impervious cover. If the zoning category assigns a maximum impervious lot coverage percent, use that. Otherwise, the zoning is compared to the average impervious cover assigned by NJDEP to similar existing categories of land use. The calculation is then carried out in much the same way as the existing impervious analysis. The total amount of existing and future impervious acres is divided by the total area of the subwatershed to give a percent impervious cover.

The selected subwatersheds

To illustrate this methodology, two subwatersheds in Warren County were selected for the existing vs. buildout estimation. Both are subwatersheds of HUC - 14 watersheds. This terminology means **h**ydrologic **u**nit **c**ode, 14 digit designation. The United States is divided and sub-divided into successively smaller hydrologic units which are classified into four levels: regions, sub-regions, accounting units, and cataloging units. The hydrologic units are arranged within each other, from the smallest (cataloging units) to the largest (regions). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of up to fourteen digits based on the four levels of classification in the hydrologic unit system. The system of hydrologic unit coding was developed by the United States Geological Survey (USGS) to provide a means of delineating and compiling watersheds and subwatersheds of different size areas. These HUC-14 subwatersheds are available on a readily available data set from NJDEP, 'GIS Resource Data Series 1, Volume 3', released March 1996.

The criteria used in the Upper Delaware to select these subwatersheds was:

1. Have both the Valley and Ridge and the Highlands physiographic provinces represented
2. Have different existing land uses and zoning designations represented
3. The buildout information (primarily in the form of zoning) had to already be available in a geo-referenced digital format

The two subwatersheds chosen (Figure 7) for the analysis are:
Watershed 1, located in Blairstown Township, Paulins Kill watershed.
Watershed 2, located in Franklin Township, Musconetcong watershed.

Results of the Impervious Cover Estimate

Existing Impervious Cover

Existing impervious cover was estimated for the entire Upper Delaware watershed (Figure 1), the five major subwatershed groups (Figures 2-6), and the two test subwatersheds (Figures 8 & 9). This was easily accomplished, using the 1995/97 NJDEP land use/land cover designations and associated percent impervious cover. From the results in Table 4, it is easy to understand why the Upper Delaware has a large proportion of non-impaired surface waters. All of the watershed groups have impervious cover well below the 11% impacted threshold.

Table 4. Existing Impervious Cover Estimates

Watershed Area	1995/97 Impervious Cover (%)
Entire Upper Delaware Watershed Management Area	3.2
Flat Brook Watershed Group	1
Paulins Kill Watershed Group	3
Pequest Watershed Group	3
Pohatcong-Lopatcong Watershed Group	5
Musconetcong Watershed	5
Test Subwatershed 1 in Paulins Kill, Blairstown Twp.	2
Test Subwatershed 2 in Musconetcong, Franklin Twp.	0

When broken down by HUC-14 subwatershed using the impervious cover percentage thresholds, it is apparent that the watersheds associated with established towns are where potential water quality impacts could likely occur (Figure 1). Specifically, this includes the environs of Phillipsburg, Washington, Belvidere, Hackettstown, Netcong, Stanhope, Mt. Arlington, Hopatcong, Newton, and Branchville. A summary of the HUC-14 breakdown is shown in Table 5.

Table 5. Existing Impervious Cover Estimates by HUC-14 Watershed

Percent Impervious Threshold	Number of HUC-14 Basins	Percent of WMA1 (%)
Less than 10% Impervious	275	88
10%-14.99% Impervious	17	5
15%-19.99% Impervious	9	3
20%-24.99% Impervious	4	1
25% or greater Impervious	6	2

Existing Impervious Cover and Water Quality

The low percentage trend of impervious cover is consistent with the overall water quality reflected in stream monitoring results. Although chemical monitoring results vary by pollutant, in general terms the surface water quality is excellent in the Flat Brook watershed group, very good in the Paulins Kill and Pequest groups, and fair to good in the Pohatcong-Lopatcong Group and Musconetcong watershed.

More detailed water quality information is available in the Settings of the Upper Delaware Watershed Report and the Preliminary Evaluation of Water Quality Status of Tributaries to the Upper Delaware Watershed in NJ, Water Years 1985-2001 Report, available at www.upperdelaware.org.

Future impervious cover

Future impervious cover in the two test watersheds was estimated by first eliminating all lands deemed unbuildable. The second step was then to correlate the existing zoning categories with NJDEP land use/land cover categories and using the percentages assigned. The results are as follows:

Subwatershed 1

Located in Blairstown Township, this subwatershed is 558 acres in size. The existing land use makeup is primarily woodland, with some meadow. Unbuildable lands included wetlands and protected open space. No ordinances preventing development on specific terrain were found during discussion with township officials.

The zoning for the watershed consists of a single category: rural residential, 5 acre. According to the lot coverage limits established by the Land Development Ordinance of the Township of Blairstown this zoning designation carries a maximum lot coverage of 10% for detached dwellings, and 25% for fire, first aid, and church buildings. In most cases, the land will be developed for residential use. This designation equates most closely with the NJDEP Land Use/Land Cover Low Density Residential, which has an average impervious cover value statewide of 13%. This is the figure used for the estimate.

Subwatershed 2

Located in Franklin Township, this subwatershed is 380 acres in size. The existing land use makeup is a mix of open space: agriculture and woodland. Unbuildable lands included wetlands. No ordinances were apparent preventing development on specific terrain. The zoning designations for this watershed are: Industrial Park; Industrial Park Option; and Rural Conservation (residential).

According to the current Land Use and Development Regulations, Township of Franklin, the zoning designations carry maximum impervious lot coverages which are less than comparable land uses in the Upper Delaware Watershed.

This is related to the fact that much of the municipality is located in limestone geologic areas, which by their potentially cavernous nature are sensitive to development due to risk of sinkholes and groundwater pollution. The Franklin maximum impervious coverages used in this analysis are:

Industrial Park; Industrial Park Option 50%
Rural Conservation (residential) 5%

By comparison, average values found by NJDEP in the Upper Delaware are:

Industrial Park 61%
Rural Conservation 13%

Table 6. Future Buildout Impervious Cover Estimates

Watershed	Existing Impervious Cover (%)	Buildout Impervious Cover (%)
Subwatershed 1 In Blairstown Township	2	10
Subwatershed 2 In Franklin Township	0	28

Buildout Estimate Water Quality Impacts

The results of the buildout estimate for impervious cover clearly show the potential for water quality impacts, when linked back to the 10%, 11-25%, and over 25% thresholds. In Subwatershed 1, as displayed in Table 6; and Figure 8, Blairstown NEMO Buildout, the estimated impervious cover changed from 2% to 10%. This implies that the waters receiving this drainage, Yards Creek, will be right on the fringe of moderate degradation with planned buildout.

In Subwatershed 2, the results are far more dramatic and can be seen in Table 6; and Figure 9, Franklin NEMO Buildout. This land, primarily in agriculture and woodland, saw the estimated impervious cover percent increase from 0% to 28%. This implies the strong possibility of degradation to the receiving surface water body, the Musconetcong River, if total buildout occurs consistent with present zoning.

Estimating Changes in Pollutant Loadings

After establishing the impervious cover percent in a watershed, an additional evaluation of water quality trends can be derived from a pollutant loading model. This additional step can help to better quantify the potential impacts of existing and zoned development. For the purposes of this report, we are using the Simple Method model, (Schueler et al, 1994), which is a basic predictive tool using readily available information. Three data groups are needed to run this model. First, the existing land use and impervious cover in the drainage area; Second, the future land use and impervious cover; Third, pollutant loading event mean concentrations (EMCs) for both the existing and future land use.

Background

In 1983, the Environmental Protection Agency (EPA) published the National Urban Runoff Program Report (NURP). This paper was the result of a study of urban runoff from over 2,300 storms at 81 sites around the United States, coming up with Event Mean Concentrations (EMC's). The usefulness of this paper was that it enabled land use decision makers to compare the projected changes in land use from undeveloped to developed and estimate the kinds of pollutant loads that could result from the changes.

The NURP study focused on nutrients, metals, and organic matter as primary constituents, and broke land use into five general categories:

1. undeveloped woodland
2. commercial
3. residential, half acre lots
4. industrial
5. urban

Pollutant loads can be estimated when the change in land use and impervious acreage in a HUC 14 or smaller watershed is compared to the undeveloped condition.

Updating of NURP

In 1999 Camp, Dresser, and McKee (CD&M) published a paper (Smullen, et.al, 1999) that updated the NURP pollutant EMC's with data that had been gathered by USGS and EPA as part of the NPDES program. This new data was analyzed and updated, developing new EMC's. These EMC's are included in Table 7. However, these numbers are not used for this pollutant loading estimate, because the sampling methods, especially the cleaner techniques used in the 1990s, may not be consistent with the sampling done for the open space and forest land use EMCs developed by NURP. To use the new numbers with the old may be comparing 'apples with oranges', so to speak.

CD&M verified, both in the 1983 U.S. EPA Nationwide Urban Pollutant Runoff Quality (NURP) and the more recent monitoring work, that there are no statistically significant differences of central tendency of the 10 EMCs investigated for urban land use. Thus, the only scientifically defensible approach is to use one single set of EMCs for the pollutants across all types of developed land.

Table 7. Selected pollutant constituent concentrations for use in factor 'C' of the Simple Method for developed lands

Pollutant Constituent (mg/l)	Open Space-Non urban, (NURP, 1983)	Hardwood Forest, Wetland (NURP, 1983)	All Developed Land: mean (NURP, 1983)	All Developed Land: mean (C,D & M,1999)
Total Phosphorous (P)	0.23	0.15	0.34	0.32
Total Kjeldahl Nitrogen (TKN)	1.36	0.61	1.67	1.73
Chemical Oxygen Demand (COD)	51	40	66.1	52.8
Zinc (Zn)	0.23	0	0.18	0.16
Lead (Pb)	0.05	0	0.18	0.07

Sources: USEPA 1983; Schueler(1994); C,D&M, Smullen, et.al, 1999. Pooled data from NURP, USGS, and NPDES data

The Simple Method was first published in *Controlling Urban Runoff*, published by the Metropolitan Washington Council of Governments in 1987, and written primarily by Tom Schueler.

The Simple Method estimates stormwater runoff pollutant loads for urban areas. The technique requires a modest amount of information, including the subwatershed drainage area and impervious cover, stormwater runoff pollutant concentrations, and annual precipitation. With the Simple Method, the investigator can break up land use into developed versus undeveloped and calculate annual pollutant loading trends for each type of land. The model is described in Appendix B.

There are other pollutant loading models that are both more accurate and more data intensive. Consequently, they require far more time (and money) to run. Models such as EPA's HSPF and SWMM; and the Army Corps of Engineer's STORM are examples of highly complex computer models which can have value in land use planning.

Table 8 provides the results of the Simple Method for the two test subwatersheds.

Table 8: Pollutant loading estimation results

Subwatershed 1 (Blairstown Township, 558 acres):
Existing EMCs: Hardwood Forest

Constituent	Existing Annual Load, pounds	Future Annual Load, pounds
Total Kjeldahl Nitrogen (TKN)	210	1170
Chemical Oxygen Demand (COD)	13,620	46,350
Total Phosphorous (P)	50	240
Lead (Pb)	0	130
Zinc (Zn)	0	130

Subwatershed 2 (Franklin Township, 380 acres)
Existing EMCs: Open Space/Non-urban

Constituent	Existing Annual Load, pounds	Future Annual Load, pounds
Total Kjeldahl Nitrogen (TKN)	230	1720
Chemical Oxygen Demand (COD)	8700	68,090
Total Phosphorous (P)	40	350
Lead (Pb)	10	190
Zinc (Zn)	40	190

It is important to focus on the trends of drastically increasing pollutant loads, not the numerical values, which are products of estimation. However, the results of the Simple Method clearly show the relationship between the change in land use increasing impervious cover and the associated pollutant loads exported to surface waters. The most dramatic differences occur when woodland is converted to urban land uses. The load increases from developed agricultural land are not so acute, owing to the fact that agriculture produces some pollutants of its own, especially when good conservation is not practiced.

These results underscore the impacts of impervious cover on receiving waters. Consequently, the local planner can be confident that an impervious cover assessment can yield a valuable tool for evaluating trends in water quality resulting from development. This understanding should be a catalyst for properly balancing development with land protection.

Concepts such as conservation easements, maximum site disturbance criteria, clustering, and other open space protection tools can be effective in achieving this balance.

Summary

The relationship between predominance of impervious cover and degraded water resources has been repeatedly demonstrated. Numerous papers have shown that relatively low percentages (25%) of impervious cover in a watershed can result in a clear deterioration of surface water quality. As little as 11% impervious cover can begin to cause water quality impairments. Increases in storm runoff, pollutant runoff, and stream bank erosion combine with reduced infiltration and recharge to impact the natural hydrologic system.

Since percent impervious cover is a useful indicator of potential water impacts, the ability to estimate it is a valuable planning tool. Through a simple procedure of land use specific impervious cover estimation for both current and future conditions, potential trends in water quality can be evaluated. Existing impervious cover can be estimated to get a sense of what may be happening to current water quality. Future impervious cover, estimated through evaluating unbuildable lands and current zoning ordinances, presents the picture of potential development impacts.

Using the impervious cover estimates and the expected pollutant constituent concentration emanating from the land use, current and future pollutant load estimates can be derived.

The process of estimating impervious cover and pollutant loadings, when used within model limitations, can provide municipal and watershed planners with another valuable tool to evaluate the impacts of development on the environment. This concept uses sound science to support the most informed and responsible watershed planning decisions.

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Appendix A

Process Methodology:
Technical Steps for Performing the
Nonpoint Education for Municipal Officials (NEMO) Analysis

Process Methodology:
Technical Steps for Performing the Nonpoint Education for Municipal Officials (NEMO) Analysis

Preparation Before Starting this Process:

1. Average the Impervious Surface for each Land Use/Land Cover "Label", or most detailed Land Use/Land Cover field in the attribute table. In the case of the NJDEP Land Use/Land Cover, the attribute table was summed using the "Label95" field. As part of the summation, average the impervious surface for that detailed Land Use/Land Cover category.
2.In the Zoning dataset, decide what zoning category matches up with the Land Use/Land Cover Category and assign the average Impervious surface value to that Zoning category.
3. Decide what land use/land cover options are "buildable" versus "unbuildable. Create a field labeled "Build" in the attribute table and code the polygons as "True" if they are buildable or "False" if they are not buildable.

NEMO Process:

1. Dissolve based on the the field that defines whether something is buildable or not. Save this new file as; buildableareas_1.shp
2. Union the lands that are preserved with buildableareas_1.shp. Save this new file as; buildableareas_2.shp.
3. Make sure buildableareas_2.shp is active and perform a "Select by Theme...". Select all polygons that have their center in the preserved lands dataset.
4. Open the buildableareas_2.shp attribute table. Make sure the buildable field in the attribute is coded to show that these areas are unbuildable.
5. Dissolve buildableareas_2.shp by the buildable field in the attribute table. Save the new file as; buildableareas_3.shp.
(Please Note: If your drainage basin has more than one zoning category, please skip steps 6 & 7 and go to step 8)
6. Open the attribute table for buildableareas_3.shp and start editing it. Add a new field titled "Acres". Make that field active and click on the Shape Calculator button. In the bottom equation feild type; [Shape].returnarea/43560. This will compute the acres for each polygon (there should only be two, buildable and unbuildable lands).
7. Create another new field titled "New_Imp", this is where the new impervious surface value will be computed. Make this new field active. Open the Shape Calculator and multiply the "Acres" field by the estimated impervious surface for that zoning category. This will compute the increased impervious surface based on worst-case scenario build out.
(Please Note: If your drainage basin only had one Zoning Category, you are done!)
8. Union buildableareas_3.shp with your Zoning dataset. Save this file as buildableareas_4.shp.
9. Open the attribute table for buildableareas_4.shp and make editable. Create a new field titled "Acres". Make that field active and click on the Shape Calculator button. In the bottom equation feild type; [Shape].returnarea/43560. This will compute the acres for each polygon.
10. Create another new field labeled "New_Imp", this is where the new impervious surface value will be computed. Make this new field active. Open the Shape Calculator and multiply the "Acres" field by the estimated impervious surface for that zoning category. This will compute the increased impervious surface based on worst-case scenario build out. Save the edits. Make sure the estimated Impervious surface number you are multiplying by is a percent.
11. Select the buildable field in the attribute table and perform a summarize on it. To compute impervious surface after build out, select the field "New_Imp" and summarize by "Sum". Save the table as "buildout.dbf". The value in the "Sum_New_Imp" field is the new impervious surface generated by the worst case scenario build out.

Appendix B

The Simple Method for Estimating Pollutant Loading

The Simple Method for Estimating Pollutant Loading
Adapted from: the Journal of Watershed Protection, Ellicott City, MD, 1999

Introduction

The Simple Method was first published in Controlling Urban Runoff, published by the Metropolitan Washington Council of Governments in 1987, and written primarily by Tom Schueler.

The Simple Method estimates stormwater runoff pollutant loads for urban areas. The technique requires a modest amount of information, including the subwatershed drainage area and impervious cover, stormwater runoff pollutant concentrations, and annual precipitation. With the Simple Method, the investigator can either break up land use into developed versus undeveloped and calculate annual pollutant loads for each type of land.

Stormwater pollutant concentrations can be estimated from local or regional data, or from national data sources. In general, the selected data sources are nationwide in scope (EPA-NURP Study, 1983), or are summaries of several regional studies. Some studies included in these data did not characterize stormwater concentrations for specific land uses, and instead reported a concentration for "urban runoff."

Fecal coliform is more difficult to characterize than other pollutants. Data are extremely variable, even during repeated sampling at a single location. Because of this variability, it is difficult to establish different concentrations for each land use. Although some source monitoring data exists (Steuer et al., 1997; Bannerman et al., 1993), the simple method assumes a median urban runoff default value, derived from NURP data (Pitt, 1998), of 20,000 MPN/100ml. For more information on sources and pathways of bacteria in urban runoff, consult Schueler (1999).

The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as:

$$L = 0.226 * R * C * A$$

Where: L = Annual load (lbs)
R = Annual runoff (inches)
C = Pollutant concentration (mg/l)
A = Area (acres)
0.226 = Unit conversion factor

For bacteria, the equation is slightly different, to account for the differences in units. The modified equation for bacteria is:

$$L = 1.03 * 10\text{-}3 * R * C * A$$

Where: L = Annual load (Billion Colonies)
R = Annual runoff (inches)
C = Bacteria concentration (#/100 ml)
A = Area (acres)
1.03 * 10-3 = Unit conversion factor

Annual Runoff

The Simple Method calculates annual runoff as a product of annual runoff volume, and a runoff coefficient (Rv). Runoff volume is calculated as:

$$R = P * Pj * Rv$$

Where: R = Annual runoff (inches)
P = Annual rainfall (inches)
Pj = Fraction of annual rainfall events that produce runoff (usually 0.9)
Rv = Runoff coefficient

In the Simple Method, the runoff coefficient is calculated based on **impervious cover** in the subwatershed. Although there is some scatter in the data, watershed imperviousness is a reasonable predictor of Rv.

The following equation represents the best fit line for the dataset (N=47, $R2=0.71$).

$$Rv=0.05+0.9Ia$$

Where: Ia = Impervious fraction

Impervious Cover Data

The model uses different impervious cover values for separate land uses within a subwatershed. A study is currently being conducted by the Center for Watershed Protection under a grant from the U.S. Environmental Protection Agency to update impervious cover estimates for these and other land uses. The results of this study will be available in 2002. In addition, some jurisdictions may have detailed impervious cover information if they maintain a detailed land use/land cover GIS database.

Limitations of the Simple Method

The Simple Method should provide reasonable estimates of changes in pollutant export resulting from urban development activities. However, several caveats should be kept in mind when applying this method.

The Simple Method is most appropriate for assessing and comparing the relative stormflow pollutant load changes of different land use and stormwater management scenarios. The Simple Method provides estimates of storm pollutant export that are probably close to the "true" but unknown value for a development site, catchment, or subwatershed. However, it is very important not to over emphasize the precision of the results obtained. For example, it would be inappropriate to use the Simple Method to evaluate relatively similar development scenarios (e.g., 34.3% versus 36.9% impervious cover). The simple method provides a general planning estimate of likely storm pollutant export from areas at the scale of a development site, catchment or subwatershed. More sophisticated modeling may be needed to analyze larger and more complex watersheds.

In addition, the Simple Method only estimates pollutant loads generated during storm events. It does not consider pollutants associated with baseflow volume. Typically, baseflow is negligible or non-existent at the scale of a single development site, and can be safely neglected. However, catchments and subwatersheds do generate baseflow volume. Pollutant loads in baseflow are generally low and can seldom be distinguished from natural background levels (NVPDC, 1979). Consequently, baseflow pollutant loads normally constitute only a small fraction of the total pollutant load delivered from an urban area. Nevertheless, it is important to remember that the load estimates refer only to storm event derived loads and should not be confused with the total pollutant load from an area. This is particularly important when the development density of an area is low. For example, in a large low density residential subwatershed (impervious cover < 5%), as much as 75% of the annual runoff volume may occur as baseflow. In such a case, the annual baseflow nutrient load may be equivalent to the annual stormflow nutrient load.

The Simple Method should not be used for predicting loads of total suspended solids, as the relationship between impervious cover and TSS is not consistent enough to use this method. TSS loads appear to more closely relate to watershed size, and are attributed more to the stream channel erosion and sediment resuspension, rather than wash-off.