2.0 IMPERVIOUS COVER METHOD

This section provides a description of the impervious cover method and a description of how the IC method has been applied to evaluate stream conditions. A step-by-step description of how the IC method was applied to complete the seven pilot TMDL allocations is also provided.

2.1 Overview of the Impervious Cover Model

The impervious cover model (ICM) relates an aquatic system's health (i.e., state of impairment) to the percentage of impervious cover in its contributing watershed. This method is largely based on the work of the Center for Watershed Protection, which has compiled and evaluated extensive data relating watershed impervious cover to the hydrologic, physical, water quality, and biological conditions of aquatic systems (Schueler, 2003).

The relative portion of a watershed's impervious cover can be used as an effective means of determining aquatic system health. Urbanization, primarily through the construction of impervious cover, causes progressive hydrologic, physical, water quality and biological impacts to aquatic health. Agricultural and other land-modifying activities can also contribute significantly to aquatic health degradation.

Figure 2-1 provides a schematic representation of modification to the water budget that can accompany increased IC in a watershed. Increasing impervious cover reduces the amount of infiltration/recharge and increases the amount of runoff. As a result, the stream experiences lower low flows, due to reduced baseflow, and higher high flows, due to large stormwater runoff volumes.

Table 2-1 provides a tabulation of specific stream impacts associated with increasing impervious cover. Hydrologic impacts are illustrated in Figure 1. Physical impacts are directly related to modification in stream hydrology. For example, flooding causes channel enlargement and incision, while low flows can result in warmer in-stream temperatures. Water quality impacts are due primarily to direct conveyance of additional materials into the steam with stormwater runoff. Lastly, biological impacts are the result of degradation of hydrology, physical, and water quality conditions in the stream ecosystem. Impervious cover serves as an excellent surrogate for many types of stormwater-related impairments because it relates primary causal factors to specific impairments.

Figure 2-2 provides a representation of the relationship between stream quality and watershed impervious cover, based on the ICM. This research indicates that a decline in stream quality occurs when impervious cover (IC) for a watershed exceeds 10% and that severe impairment can be expected when the IC exceeds 25%. For the New England pilot TMDLs using the ICM, a target of 9% IC was selected as a surrogate for a whole suite of stressors related to stormwater. The 9% IC metric is a target to attain water quality standards (WQSs) through implementation of BMPs. Based on extensive data and the best information available, it appears that if the IC target is met, stormwater-impaired waters will be brought back into compliance with WQSs. The IC target, however, is not intended to assess ultimate compliance with State WQSs. Compliance will be determined by monitoring of appropriate state-specific parameters in the affected water body and comparison to water quality criteria. Depending on specific state water quality classifications and site-specific assessment data, targets lower or higher than 9% may be appropriate. For instance, a water body classified as class C might not need an IC target as low as 9%, as would a water body which needed to attain class B. Similarly, a water body impaired by stormwater runoff may already have an IC rating of 9% and require a lower target and TMDL targets to address other stressors in addition to stormwater runoff volume.

The IC Method provides direct guidance toward removing impairments and evaluating management scenarios because this surrogate relates the cause of an impairment directly to the impairment. The IC Method is also relatively efficient to apply. Thus, it is suitable for evaluating the sub-watersheds of large watersheds and is capable of rapidly identifying problem areas (i.e., hot spots).

Table 2-1 Hydrologic, Physical, Water Quality, and Biological Impacts Associated with IC

Hydrologic Impacts
- Increased runoff volume
- Increased peak flow rates
- Increased bankfull flow
- Decreased baseflow

Biological Impacts
- Reduced aquatic insect diversity
- Reduced fish diversity
- Reduced amphibian diversity
- Reduced wetland plant diversity

Physical Impacts
- Modified sediment transport
- Channel enlargement
- Channel incision
- Stream embeddedness
- Loss of large woodsy debris
- Changes in pool/riffle structure
- Loss of riparian cover
- Reduced channel sinuosity
- Warmer in-stream temperatures

Water Quality Impacts
- Increased sediment concentrations
- Increased nutrient concentrations
- Increased trace metal concentrations
- Increased hydrocarbon conc.
- Increased bacteria and pathogens
- Increased organic carbon conc.
- Increased MTBE concentrations
- Increased pesticide concentrations
- Increased deicer concentrations

Figure 2-1 Schematic Water Balance: Natural Conditions vs. Developed Conditions

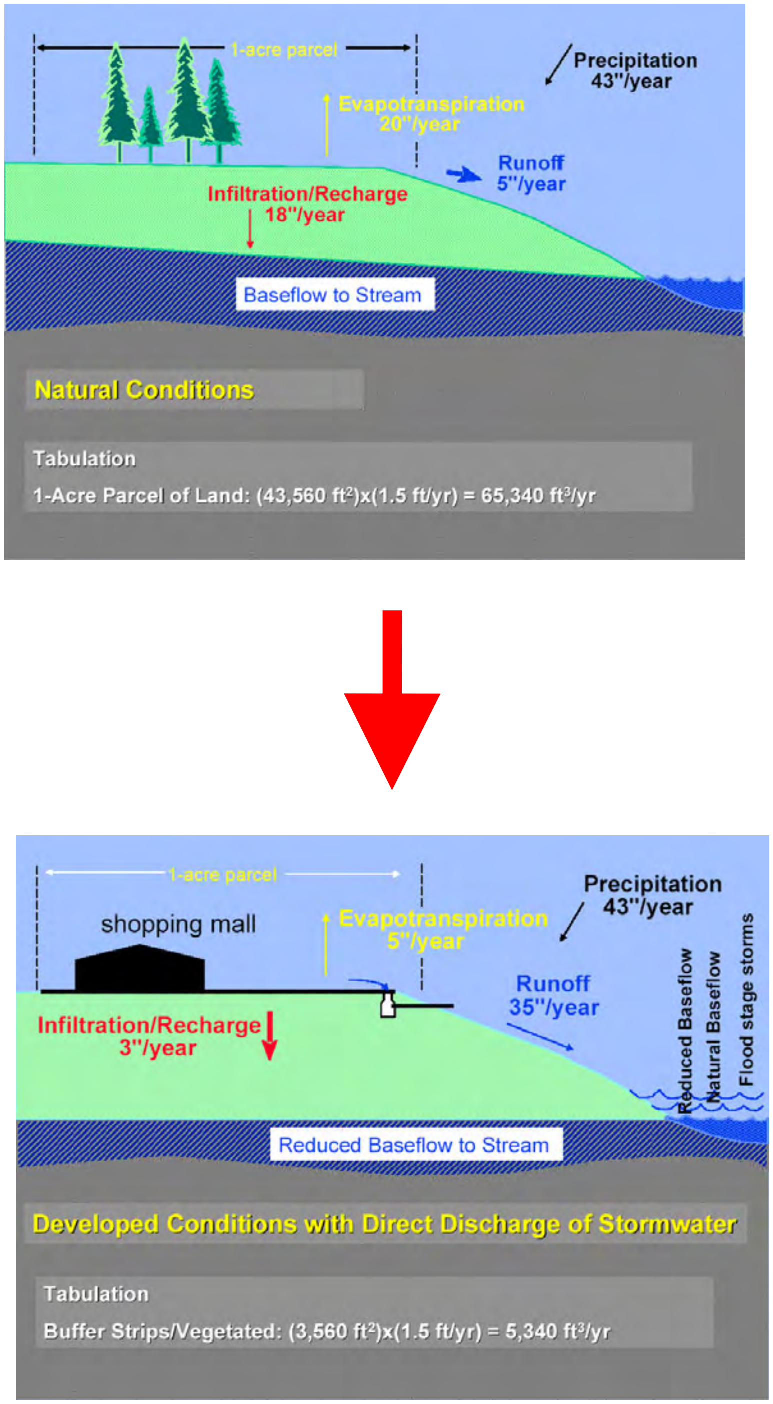
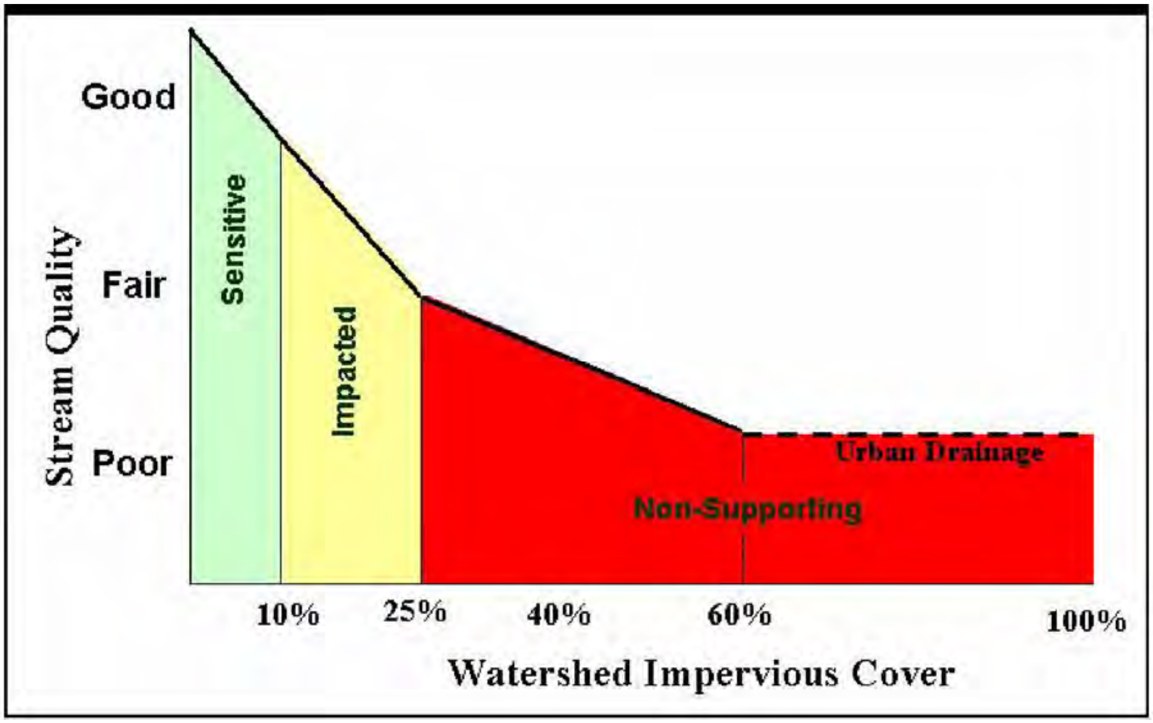


Figure 2-2 Stream Quality vs. Watershed Impervious Cover



(Source: Schueler, 2003)

2.2 IC Method Application Process

The IC Method may be described in several steps as outlined below.

1. Watershed Delineation including delineation of each sub-watershed in an area of interest and development of a GIS data-layer.

2. Impervious Cover Mapping including development of watershed coverages for land cover and impervious cover within a GIS data-layer.

3. Impervious Cover Determination for overall watershed and sub-watershed impervious cover magnitude and percentage of watershed area

4. Estimation of Annual Runoff Volume – Expanded Application of the Basic, Recommended Procedure This parameter may be calculated and is strongly correlated with stormwater impairments in streams.

5. Pollutant Selection and Estimation of Pollutant Loads – Expanded Application of the Basic, Recommended Procedure This step uses precipitation, event mean pollutant concentration, and other data to estimate average annual pollutant loads.

Each of these steps is described below.

2.2.1 Watershed Delineation

This step requires development or acquisition of a GIS datalayer of the watershed for the subject water body or water bodies. Topographic data sources for watershed delineation, such as USGS quad maps (preferably scanned images), serve as the default data sources for these analyses, but more detailed information are used, if available. Digital elevation models may be employed to automate delineation of watersheds using GIS. Storm sewer network maps can also be useful for delineating watersheds in urbanized areas.

For a TMDL analysis, the watershed should be divided into sub-watersheds or by other features (such as tributaries) for separate IC calculation, unless it is very small or homogenous. Sub-watersheds should then be evaluated individually to support identification of problem areas (with high IC values) where investigators should focus water quality remediation efforts. This will prevent localized problem areas from getting overshadowed by areas with low IC values. Investigators may concentrate water quality protection efforts in areas with low %IC. Generally, the analysis should begin at the bottom of the impaired water body segment, and work upstream delineating sub-basins and/or sub-watersheds.

2.2.2 Impervious Cover Mapping

Land cover and impervious cover GIS data are required to support determination of watershed impervious cover. If general land cover and land use datalayer information is used, then imperviousness may be determined based on a typical percentage of each land use. Impervious cover also may be determined using computer image analysis of multi-spectral orthophotographs.

In some cases, the best-available land cover datalayer may require additional editing for use with the impervious cover method. For example, some datalayers use lumped or broad land use categories that include a wide range of land cover types or intensity of development, such as commercial/industrial/residential. If available, orthophotos may be used to assist with manual splitting and attributing of the ambiguous data, but this approach is more labor intensive.

2.2.3 Determination of Watershed Impervious Cover

Watershed impervious cover is determined by digitally intersecting watershed, land cover, and impervious cover GIS data layers and then calculating an area-weighed average impervious cover percentage for each sub-watershed and for the overall watershed. This information may be presented in both tabular and graphical formats.

2.2.4 Annual Runoff Volume Estimate – Expanded Application

The IC method is particularly useful for aquatic life criteria violations where specific pollutants are not known. However, we include discussion of runoff volume estimation for illustrative purposes as these expanded applications may become more feasible as the IC method is refined over time.

Annual runoff volume is the total volume of stormwater that runs off watershed land and into the stream each year. Runoff increases in areas with increasing % IC because water cannot infiltrate IC and more water runs over land and into the receiving water body, as described in Section 2.1. The ICM can estimate annual stormwater runoff volume using two empirically derived equations presented in Steps 1 and 2 of Figure 2-1 below. In Step 1, a runoff volume coefficient is calculated that increases directly with % IC (expressed as "Ia" in the Step 1 equation).

In Step 2, total annual runoff volume is calculated as a component of total annual precipitation. Total runoff volume is directly proportional to the runoff volume coefficient calculated in Step 1. As a result, total annual runoff volume (R) increases with increasing % IC. The equation in Step 2 also accounts for the portion of precipitation events that do not produce runoff. Lastly, annual runoff as a component of total precipitation is multiplied by watershed area (acres) to obtain total annual runoff volume in acre*ft.

Stormwater runoff volume is calculated and provided as an optional TMDL target parameter because it has been strongly correlated with stormwater impairments in streams. Existing and target stormwater runoff volumes may be calculated using the IC method in impaired streams. These values may then be compared and used to support development of TMDL targets and specification of TMDL implementation BMPs.

2.2.5 Pollutant Selection and Estimation of Pollutant Loads – Expanded Application

The IC method is particularly useful for aquatic life criteria violations where specific pollutants aren't known. However, we include discussion of pollutant load estimation for illustrative purposes as these expanded applications may become more feasible as the IC method is refined over time.

The IC Method may be applied to estimate loads for various pollutants. The method may be applied to estimate existing loads contributing to watershed impairments. It may also be applied to estimate target loads required to remove impairments (based on the target watershed impervious cover values). Pollutant selection and estimation of pollutant loads are described below.

Pollutant Selection Process

For stormwater-impaired streams, EPA Region 1 is considering the feasibility of using %IC as a surrogate for both the pollutant and non-pollutant stressors involved. Stormwater volume, which is proportional to %IC, is being investigated as a surrogate of pollutant, as well. Using the ICM, target loads for specific pollutants may also be calculated and may serve as *surrogates* for the suite of pollutants in stormwater runoff. Pollutants of choice could potentially be those listed in the 303(d) list or related to impairments in the 303(d) listings. These calculated pollutant loadings are also proportional to %IC and stormwater volume.

Estimation of Pollutant Loads

Figure 2-3, Step 3, provides the calculations required to apply the IC method to estimate pollutant loads. The IC Method uses Event Mean Concentrations (EMCs) to predict storm water pollutant loads for urban watersheds, using IC as the key predictive variable. EMCs represent the average concentration of the pollutant during an entire stormwater runoff event. EMCs are empirically derived from large stormwater data sets compiled by the Nationwide Urban Runoff Program, the US. Geological Survey, and the EPA' NDPES Phase I stormwater program (Schueler, 2003). EMC estimates were selected because they are based on field data collected from thousands of storm events. These estimates are based on nationwide data, however, so they do not account for regional variation in soil types, climate, and other factors. Thus, EMCs applied to support the New England pilot TMDLs should be considered to be screening-level estimates.

This method accounts for pollutant loadings generated by storm events and could be used for estimating loadings of sediment, nutrient and metals. While estimates can be made for other constituents, such as bacteria, hydrocarbons, and pesticides, these constituents are not as dependent on stormwater and the resulting correlations are less robust. Thus, use of other parameters in ICM applications is not recommended. EMC values are provided in the Impacts of Impervious Cover document (Schueler, 2003) for a variety of constituents including:

- TSS
- Total P
- Soluble P
- Total N
- KN
- Chromium
- Nitrite & Nitrate
- Copper
- Lead
- Zinc
- Cadmium

The EMC variable may then be used, along with the annual rainfall and impervious area, to estimate an annual pollutant loading rate for the watershed. If available, watershed or region-specific EMC data are preferred to published values, such as those contained in the impervious cover document. Regional rainfall records also will be required to identify average annual rainfall depth for the determination of annual runoff volumes.

Using EMC data will provide reasonable accuracy over long time periods (i.e., annual loads), but since concentrations vary significantly from storm to storm, this method should <u>not</u> be used for calculating loads for individual storm events.

Figure 2-3 IC Method for Calculating Runoff Volume and Constituent Loads

Step 1 – Calculate Runoff Volume Coefficient

Rv = Runoff Volume Coefficient = 0.05 + 0.9Ia, where
Ia = Impervious Fraction (from GIS analysis)

Step 2 – Calculate Annual Runoff Volume

R = Annual runoff (acre*ft) =P * Pj * Rv*A, where
P = Annual rainfall (ft)
Pj = Fraction of rainfall events producing runoff = 0.9
A = Watershed area (acres)

Step 3 – Calculate Annual Pollutant Load

L = Annual pollutant load (lbs) = R * C * U, where
C = Pollutant concentration in stormwater, EMC (mg/l) from literature
U = Unit conversion factor = 0.226

2.3 Modifications to the Basic IC Method

The impervious cover method may be applied in various levels of detail and sophistication depending on several factors, including the specific watershed and available data. The most efficient and cost-effective studies rely on maximizing the use of existing data. The pilot TMDL applications described herein were conducted efficiently using available data. Available land cover data and event mean concentration estimates were obtained and applied to estimate impervious cover and associated pollutant loads. This approach is generally suitable for conducting initial or screening level evaluations. In cases where more precise predictions are required, the following modifications to the IC method are recommended. These modifications serve to increase the resolution of the impervious cover method:

- Project-specific impervious cover datalayer,
- Project-specific estimates of directly-connected impervious cover,
- Incorporation of storm sewer networks to refine watershed delineation and directly connected impervious cover, and
- Accounting for existing BMPs in IC and load determinations.

These modifications to the IC method were not applied to the pilot TMDL project applications in Chapter 4, but some may be required to support identification and implementation of management plans.

2.4 Assumptions and Limitations of the IC Method

The impervious cover method can be employed to efficiently characterize watershed impairments and establish pollutant reduction goals for watersheds impaired by stormwater. However, this method is not intended for detailed analysis of instream water quality and includes the following limitations and limiting assumptions:

- This method does not account for wastewater pollutant loadings, but wastewater point source loading may be added to the TMDL allocation process in a straightforward manner.
- This method does not account for in-stream water quality processes.
- The impervious cover model applies to 1st through 3rd order streams.
- Additional site specific information is required for identification and specification of BMPs to achieve TMDL goals.

The ICM can provide an evaluation of stream condition throughout the watershed. Detailed and on-the-ground evaluation will be required to support identification and implementation of management actions (e.g., installation of BMPs).