

**EPA’s Methodology to Calculate Baseline Estimates of
Impervious Area (IA) and
Directly Connected Impervious Area (DCIA)
for Massachusetts Communities**

This document presents EPA’s methodology for calculating baseline estimates of impervious area (IA) and directly connected impervious area (DCIA) to support and provide guidance for relevant provisions of the Massachusetts North Coastal Small MS4 General Permit (“General Permit”). Baseline estimates are available for each Massachusetts municipality in a Microsoft Excel format, titled “IC Stats” on the following EPA website: <http://www.epa.gov/ne/npdes/stormwater/ma.html>.

EPA also provides maps showing the extent of impervious cover within each community, also available on the above-mentioned website. The “IC Maps” display subbasins, impervious area (IA), and the portion of each community subject to the Permit as defined by 2000 Census urbanized areas (“Regulated/Urbanized Area”). The methodology used by EPA to develop the estimates is presented here to provide the user with an understanding of the basis for the estimates, and to facilitate refinements to the estimates by the user where desired.

Step 1: Aggregation of the MassGIS Land Use 2005 Datalayer into 10 Land Use Codes

EPA aggregated the forty (40) land use categories included in the Commonwealth’s Office of Geographic and Environmental Information (MassGIS) Land Use 2005 datalayer (available at url: <http://www.mass.gov/mgis/lus2005.htm>) into ten (10) commonly used land use categories. The EPA Code, Code Definition, and corresponding MassGIS 2005 Land Use Codes for these land uses are shown in below in Table 1.

Table 1: EPA Aggregation of MassGIS 2005 Land Use Codes

<u>EPA Code</u>	<u>Code Definition</u>	<u>MassGIS 2005 Land Use Codes</u>
1	Commercial	15
2	Industrial	16, 18, 19, 29, 39
3	Low Density Residential	13, 38
4	Medium Density Residential	12
5	High Density Residential	10, 11
6	Urban Public/Institutional	7, 8, 31
7	Agriculture	1, 2, 35, 36
8	Forest	3, 40
9	Open Land	5, 6, 9, 17, 24, 26, 34
10	Water	4, 14, 20, 23, 25, 37

For communities required by the General Permit to implement a Phosphorus Control Plan, please note: the *Final TMDL for Nutrients in the Lower Charles River Basin, Massachusetts (CN 301.0)* presents annual phosphorus loadings based on land cover area (shown in Table 6-4 in the TMDL). The TMDL aggregated the twenty-one (21) land use

categories included in the Commonwealth's Office of Geographic and Environmental Information (MassGIS) Land Use 1999 datalayer (available at url: <http://www.mass.gov/mgis/lus.htm>) into eight (8) commonly used land use categories.

Because EPA's aggregation for the IA and DCIA baseline estimates uses the MassGIS Land Use 2005 datalayer, the categories shown in Table 1, above, do not perfectly match the land cover areas identified in Table 6-4 of the TMDL. For further clarification, please refer to the Phosphorus Control Plan (PCP) Information on EPA's website at url: http://www.epa.gov/region1/npdes/stormwater/draft_manc_sms4gp.html

Table 1A, at the end of this document, shows the MassGIS 2005 Land Use Codes, the descriptions, and the EPA aggregations.

Step 2: Identification of Subbasins

EPA selected the "Massachusetts Nested Subbasins" presented in "Local and Cumulative Impervious Cover of Massachusetts Stream Basins," U.S. Geological Survey Data Series 451, developed by Sara L. Brandt and Peter A. Steeves in cooperation with the U.S. Environmental Protection Agency, for use in the IA-DCIA analysis. This document is available at url: <http://pubs.usgs.gov/ds/451/>. The Massachusetts Nested Subbasins datalayer is available at url: http://water.usgs.gov/GIS/metadata/usgswrd/XML/ds451_subbasins.xml

The hydrology of the Cape Cod and Plymouth-Carver Regions of Massachusetts is dominated by groundwater flow. Subbasins in these areas cannot be delineated by surface topography, but are instead defined by groundwater elevation and flow direction. For the following municipalities, the area of one or more subbasins is based on "Groundwater Contributing Area":

- | | |
|-------------------------------------|--|
| <input type="checkbox"/> Barnstable | <input type="checkbox"/> Marion |
| <input type="checkbox"/> Bourne | <input type="checkbox"/> Marshfield |
| <input type="checkbox"/> Brewster | <input type="checkbox"/> Mashpee |
| <input type="checkbox"/> Carver | <input type="checkbox"/> Middleborough |
| <input type="checkbox"/> Chatham | <input type="checkbox"/> Orleans |
| <input type="checkbox"/> Dennis | <input type="checkbox"/> Pembroke |
| <input type="checkbox"/> Duxbury | <input type="checkbox"/> Plymouth |
| <input type="checkbox"/> Eastham | <input type="checkbox"/> Plympton |
| <input type="checkbox"/> Falmouth | <input type="checkbox"/> Rochester |
| <input type="checkbox"/> Halifax | <input type="checkbox"/> Sandwich |
| <input type="checkbox"/> Harwich | <input type="checkbox"/> Wareham |
| <input type="checkbox"/> Kingston | <input type="checkbox"/> Yarmouth |

The Massachusetts Groundwater Contributing Areas are available at url: http://water.usgs.gov/GIS/metadata/usgswrd/XML/ds451_gwcontrib_areas.xml

Step 3: Calculation of Impervious Area in each Subbasin for each EPA Land Use Code

Using its GIS, EPA estimated the area and relative percentage of IA (both within the entire subbasin and only within the Regulated/Urbanized Area) for each EPA Land Use Code within the Massachusetts Nested Subbasins in each community. The IA estimates were generated using the MassGIS 2005 Impervious Surface 1-meter datalayer (available at url: http://www.mass.gov/mgis/impervious_surface.htm).

The Regulated/Urbanized Area is equivalent to the urbanized area as defined by the 2000 Census. EPA provided urbanized area maps to all regulated communities and web-published the maps at url: <http://www.epa.gov/ne/npdes/stormwater/2003-permit-archives.html>. The Urbanized Area datalayers are available from MassGIS at url: http://www.mass.gov/mgis/eot_layers.htm.

Step 4: Application of Sutherland Equations to Estimate DCIA %

Using the percent IA estimates calculated in Step 3, EPA applied the “Sutherland Equations” taken from Sutherland, R.C., "[Methodology for Estimating the Effective Impervious Area of Urban Watersheds](#)", Watershed Protection Techniques, Vol. 2, No. 1, fall 1995, to calculate DCIA %. Table 2 shows the EPA Land Use Class and Land Use Name, the watershed selection criteria, and the Sutherland Equation applied to each EPA Code. The Sutherland Equations are only valid where IA % is greater than 1; therefore, EPA assumed DCIA % to be zero where the IA % within a given land use is less than one.

Table 2: EPA Land Use Classes and Corresponding Sutherland Equations

<u>EPA Code</u>	<u>Land Use</u>	<u>Watershed Selection Criteria</u>	<u>Sutherland Equation (where IA(%) >1)</u>
1	Commercial	<u>Average</u> : Mostly storm sewered with curb & gutter, no dry wells or infiltration, residential rooftops not directly connected	$DCIA\% = 0.1(IA\%)^{1.5}$
2	Industrial	<u>Average</u> : Mostly storm sewered with curb & gutter, no dry wells or infiltration, residential rooftops not directly connected	$DCIA\% = 0.1(IA\%)^{1.5}$
3	Low Density Residential	<u>Somewhat connected</u> : 50% not storm sewered, but open section roads, grassy swales, residential rooftops not connected, some infiltration	$DCIA\% = 0.04(IA\%)^{1.7}$
4	Medium Density Residential	<u>Average</u> : Mostly storm sewered with curb & gutter, no dry wells or infiltration, residential rooftops not directly connected	$DCIA\% = 0.1(IA\%)^{1.5}$
5	High Density Residential	<u>Highly connected</u> : Same as above, but residential rooftops are connected	$DCIA\% = 0.4(IA\%)^{1.2}$
6	Urban Public/ Institutional	<u>Average</u> : Mostly storm sewered with curb & gutter, no dry wells or infiltration, residential rooftops not directly connected	$DCIA\% = 0.1(IA\%)^{1.5}$
7	Agriculture	<u>Mostly disconnected</u> : Small percentage of urban area is storm sewered, or 70% or more infiltrate/disconnected	$DCIA\% = 0.01(IA\%)^2$

<u>EPA Code</u>	<u>Land Use</u>	<u>Watershed Selection Criteria</u>	<u>Sutherland Equation (where IA(%) >1)</u>
8	Forest	<u>Mostly disconnected</u> : Small percentage of urban area is storm sewered, or 70% or more infiltrate/disconnected	$DCIA\% = 0.01(IA\%)^2$
9	Open Land	<u>Average</u> : Mostly storm sewered with curb & gutter, no dry wells or infiltration, residential rooftops not directly connected	$DCIA\% = 0.1(IA\%)^{1.5}$
10	Water	n/a	n/a

Step 5: Estimation of DCIA Area

EPA used the DCIA % calculated in Step 4 to estimate the acres of DCIA, for each EPA land use class, within each subbasin, within each community.

For Total Area, (including Un-Regulated Areas), calculation is as follows:

$$DCIA \text{ (acres)} = DCIA \% \text{ of Total Area } (\%) * \text{ Total Area (acres)} / 100$$

For the Urbanized/Regulated Area Only, calculation is as follows:

$$DCIA \text{ (acres)} = DCIA \% \text{ of Urbanized/Regulated Area } (\%) * \text{ All Urbanized/Regulated Area (acres)} / 100$$

Step 6: Summation of Total Area, IA, and DCIA for each Subbasin within Massachusetts Communities

EPA summed the IA and DCIA areas of all land use classes over each subbasin, and recalculated IA % and DCIA % based on these summations.

Table 1A: MassGIS Land Use Codes and Descriptions, and EPA Codes

<u>MassGIS Land Use Code</u>	<u>MassGIS Land Use Description</u>	<u>MassGIS Detailed Definition</u>	<u>EPA Code</u>
1	Cropland	Generally tilled land used to grow row crops. Boundaries follow the shape of the fields and include associated buildings (e.g., barns). This category also includes turf farms that grow sod.	7
2	Pasture	Fields and associated facilities (barns and other outbuildings) used for animal grazing and for the growing of grasses for hay.	7
3	Forest	Areas where tree canopy covers at least 50% of the land. Both coniferous and deciduous forests belong to this class.	8
4	Non-Forested Wetland	DEP Wetlands (1:12,000) WETCODEs 4, 7, 8, 12, 23, 18, 20, and 21.	10

<u>MassGIS Land Use Code</u>	<u>MassGIS Land Use Description</u>	<u>MassGIS Detailed Definition</u>	<u>EPA Code</u>
5	Mining	Includes sand and gravel pits, mines and quarries. The boundaries extend to the edges of the site's activities, including on-site machinery, parking lots, roads and buildings.	9
6	Open Land	Vacant land, idle agriculture, rock outcrops, and barren areas. Vacant land is not maintained for any evident purpose and it does not support large plant growth.	9
7	Participation Recreation	Facilities used by the public for active recreation. Includes ball fields, tennis courts, basketball courts, athletic tracks, ski areas, playgrounds, and bike paths plus associated parking lots. Primary and secondary school recreational facilities are in this category, but university stadiums and arenas are considered Spectator Recreation. Recreation facilities not open to the public such as those belonging to private residences are mostly labeled with the associated residential land use class not participation recreation. However, some private facilities may also be mapped.	6
8	Spectator Recreation	University and professional stadiums designed for spectators as well as zoos, amusement parks, drive-in theaters, fairgrounds, race tracks and associated facilities and parking lots.	6
9	Water-Based Recreation	Swimming pools, water parks, developed freshwater and saltwater sandy beach areas and associated parking lots. Also included are scenic areas overlooking lakes or other water bodies, which may or may not include access to the water (such as a boat launch). Water-based recreation facilities related to universities are in this class. Private pools owned by individual residences are usually included in the Residential category. Marinas are separated into code 29.	9
10	Multi-Family Residential	Duplexes (usually with two front doors, two entrance pathways, and sometimes two driveways), apartment buildings, condominium complexes, including buildings and maintained lawns. Note: This category was difficult to assess via photo interpretation, particularly in highly urban areas.	5
11	High Density Residential	Housing on smaller than 1/4 acre lots. See notes below for details on Residential interpretation.	5
12	Medium Density Residential	Housing on 1/4 - 1/2 acre lots. See notes below for details on Residential interpretation.	4

MassGIS Land Use Code	MassGIS Land Use Description	MassGIS Detailed Definition	EPA Code
13	Low Density Residential	Housing on 1/2 - 1 acre lots. See notes below for details on Residential interpretation.	3
14	Saltwater Wetland	DEP Wetlands (1:12,000) WETCODEs 11 and 27.	10
15	Commercial	Malls, shopping centers and larger strip commercial areas, plus neighborhood stores and medical offices (not hospitals). Lawn and garden centers that do not produce or grow the product are also considered commercial.	1
16	Industrial	Light and heavy industry, including buildings, equipment and parking areas.	2
17	Transitional	Open areas in the process of being developed from one land use to another (if the future land use is at all uncertain). Formerly identified as "Urban Open".	9
18	Transportation	Airports (including landing strips, hangars, parking areas and related facilities), railroads and rail stations, and divided highways (related facilities would include rest areas, highway maintenance areas, storage areas, and on/off ramps). Also includes docks, warehouses, and related land-based storage facilities, and terminal freight and storage facilities. Roads and bridges less than 200 feet in width that are the center of two differing land use classes will have the land use classes meet at the center line of the road (i.e., these roads/bridges themselves will not be separated into this class).	2
19	Waste Disposal	Landfills, dumps, and water and sewage treatment facilities such as pump houses, and associated parking lots. Capped landfills that have been converted to other uses are coded with their present land use.	2
20	Water	DEP Wetlands (1:12,000) WETCODEs 9 and 22.	10
23	Cranberry bog	Both active and recently inactive cranberry bogs and the sandy areas adjacent to the bogs that are used in the growing process. Impervious features associated with cranberry bogs such as parking lots and machinery are included. Modified from DEP Wetlands (1:12,000) WETCODE 5.	10
24	Powerline/Utility	Powerline and other maintained public utility corridors and associated facilities, including power plants and their parking areas.	9
25	Saltwater Sandy Beach	DEP Wetlands (1:12,000) WETCODEs 1, 2, 3, 6, 10, 13, 17 and 19	10

<u>MassGIS Land Use Code</u>	<u>MassGIS Land Use Description</u>	<u>MassGIS Detailed Definition</u>	<u>EPA Code</u>
26	Golf Course	Includes the greenways, sand traps, water bodies within the course, associated buildings and parking lots. Large forest patches within the course greater than 1 acre are classified as Forest (class 3). Does not include driving ranges or miniature golf courses.	9
29	Marina	Include parking lots and associated facilities but not docks (in class 18)	2
31	Urban Public/Institutional	Lands comprising schools, churches, colleges, hospitals, museums, prisons, town halls or court houses, police and fire stations, including parking lots, dormitories, and university housing. Also may include public open green spaces like town commons.	6
34	Cemetery	Includes the gravestones, monuments, parking lots, road networks and associated buildings.	9
35	Orchard	Fruit farms and associated facilities.	7
36	Nursery	Greenhouses and associated buildings as well as any surrounding maintained lawn. Christmas tree (small conifer) farms are also classified as Nurseries.	7
37	Forested Wetland	DEP Wetlands (1:12,000) WETCODEs 14, 15, 16, 24, 25 and 26.	10
38	Very Low Density Residential	Housing on > 1 acre lots and very remote, rural housing. See notes below for details on Residential interpretation.	3
39	Junkyard	Includes the storage of car, metal, machinery and other debris as well as associated buildings as a business.	2
40	Brushland/Successional	Predominantly (> 25%) shrub cover, and some immature trees not large or dense enough to be classified as forest. It also includes areas that are more permanently shrubby, such as heath areas, wild blueberries or mountain laurel.	8