

Watershed Analysis

York County

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Introduction

In order to ensure that Maine's coastal marine beaches remain safe, clean, and ultimately protective of public health, the Maine Healthy Beaches Program (MHB) was established in 2002 with just a handful of flagship beaches. Today there are approximately 90 beaches comprising 60 beach management areas (BMAs) participating in the program spanning Kittery to Mt. Desert Island. Currently this program is managed jointly by the Maine Department of Environmental Protection (ME DEP) and the University of Maine Cooperative Extension Program and is federally funded by the US Environment Protection Agency (EPA). To assess beach water quality, water samples and environmental data are collected weekly from Memorial Day to Labor Day each summer by more than 200 volunteers. Samples are analyzed for the fecal indicator Enterococci, a parameter used to assess the presence of fecal material in water samples produced from humans and other warm blooded animals (Elmir et al. 2007). The US EPA threshold is 104 MPN/100 ml of sample water and anything above this value is considered to put the public at an increased risk of illness.

The MHB Program is interested in not only monitoring marine waters for bacterial contamination and alerting the public when there is a potential health risk, but also in assisting in the identification and elimination of pollution sources. As part of that goal, MHB is interested in the relationship between antecedent rainfall and bacteria exceedances, particularly as many of our beaches are crescent shaped pocket beaches at the end of large river systems and are therefore susceptible to the effects of runoff during rain events. To answer this question, MHB has tried to correlate bacteria and rainfall data collected by the program over the last 6 years using traditional statistical correlations (i.e. Pearson Product Moment and Spearman Rank correlations). In addition, our program has provided rainfall reports to beach managers for every

beach detailing the percent of samples that exceed the US EPA bacteria threshold at different antecedent rainfall events. However, understanding this relationship between these parameters is not straight forward and requires the consideration of other parameters including but not limited to freshwater inputs (rivers, streams, storm drains, etc.), old or faulty sewer and storm water infrastructure, illicit discharges, impervious surfaces, wildlife, and population density. Therefore, analyses conducted thus far have not been sufficient to draw a meaningful relationship.

Because of the complicated nature of the rainfall/bacteria question, the objective of this initial analysis was instead on a watershed analysis that did not incorporate rainfall at all but rather data to assess human impacts through development including impervious surfaces, road density, and parcel density. The objective was to assess which beaches in southern Maine, particularly York County were the most susceptible to effects from the human impact parameters used in the analysis. Once the effects of these parameters are understood, other parameters can be incorporated and the study can be expanded along the coast of Maine.

Beach water quality is of particular importance in Maine because of how heavily southern Maine coastal towns in particular are dependent on clean beaches for revenue, a fact not isolated to Maine coastal regions but for municipalities around the country (Boehm et al. 2005, McGee et al. 2000). A substantial portion of many town budgets depend on money brought in every summer by tourists who are primarily visiting Maine to vacation at the beach. If high bacteria counts on beaches during these heavily populated months results in beach advisories that deter visitors from going to the beach, towns lose crucial revenue. Even more detrimental is the risk that individuals who swim at beaches with bacterial exceedances might get sick (Yoder et al. 2004) and be deterred from visiting those areas in the future. One example of revenue received

by a southern Maine town as a result of beach activity is the \$1.65 million dollars Ogunquit's parking lots alone brought the town in 2013.

Because the majority of Maine's tourist populated beaches are in southern Maine, this analysis focused on those beaches participating in the MHB program that are contained within the borders of York County (Figure B-1). The coastal towns comprising York County include Kittery, York, Ogunquit, Kennebunk, Kennebunkport, Biddeford, Saco, and Old Orchard Beach (OOB). This included 56 distinct beach sites comprising 35 BMAs (Figure B-2). The client for this analysis was the Maine Healthy Beaches program. The context in which this application can be used depends on the interest of towns. Once this analysis is test and reliable, MHB can use this data to help towns focus watershed restoration efforts where restricted funds often limit the ability of municipalities to carry out large scale analyses.

Methods

Data sources

Data layers used for the ARCGIS portion of the project were gathered from the ME GIS database and the ME DEP GIS servers. Bacteria data used for a supporting piece of the analysis was obtained from the MHB program and included Enterococci counts collected from 2008-2013. Data included parcels, roads, impervious surfaces, Maine coastal boundary, Maine boundary, counties, towns, beach locational data, Enterococci counts, and Hydrologic units (HUCs).

Analysis

To begin the analysis, an area of interest had to be defined. Once it was decided that the analysis would be focused on beaches contained within York County (Figure B-1), it was necessary to determine how to best characterize the regions/watersheds impacting those beaches. To address this, a 1000 m coastal buffer was set, a value four times the shoreland zoning setback

distance of 250m (Figure B-3). Then it was necessary to determine the units within that coastal boundary that would be used to represent areas impacting beaches. Rather than using a zone such as towns, a 12 digit HUC layer was used. The 12 HUC representation delineates hydrologic units into the subwatershed level, the lowest level available and thus was the most appropriate representation to use for this analysis (Figure B-4). These units are typically an average size of 40 square miles. This HUC layer was intersected with the 1000m coastal buffer boundary to allow for the analysis of the portion of those HUCs within the coastal boundary (Figure B-5). This resulted in 19 HUCs to be used in the analysis containing 56 beaches (Figures B-6, B-7). While this method was not ideal, it was a useful starting point for initial analyses and successfully allowed for the creation of summary units for the beaches. Parameters analyzed within each of these summary units included included parcels, roads, and impervious surfaces. Impervious surfaces typically refer to any type of artificial structure that does not allow water to permeate. They can include any type of pavement, rooftops, very compacted soils, etc.

Python

The python portion of this project was incorporated by creating a code that would read a text file with MHB beach locational data, beach name, and site name. This code included creating a shapefile with a specific spatial reference (4269). As part of this process, a feature class was created as a point object with the correct spatial reference in a defined output folder. The field names Beach_Name and Beach_Site were added to the shapefile as text fields. Then the name and XY coordinate records were written to the shapefile. To add data to the shapefile, the file was opened, the lines were counted as they were read in, and the line was segmented based on tabs separating the name. Specific segments were included to segment the line where the latitude and longitude started. Then the latitude and longitude were converted to float

variables and the beach name was extracted. Lastly a row was crated with the two extracted text fields and the point data and the records were written to the shapefile from the MHBdata textfile (Appendix A).

Bacteria Analysis

For all beaches within each of the 35 BMAs, Enterococci counts were extracted from the 2008-2013 seasons. This resulted in counts from the months May-September. Data was collated for each BMA and the minimum, mean, and maximum bacteria count was calculated for all samples per BMA per month (Table 1). Because the sampling season extends from Memorial Day (end of May) to Labor Day (beginning of September), bacteria data used for comparison with watershed analysis results focused on the most heavily sampled months (June, July, August).

Parcel Density

To calculate parcel density, the parcel data file was first clipped to the York County boundary (Figure B-8). This layer was incomplete for parts of inland York County, but for the purposes of this analysis this was not an issue as it was focused on coastal parcels . The file was then clipped to the 1000 m coastal boundary buffer zone (Figure B-9). Then the centroid of each parcel was generated (Figures B-10, B-11). To generate the centroid of each parcel, an X and Y coordinate field was added to the parcel attribute table. Then the calculate geometry tool was used to calculate the X coordinate of the centroid and the same was done for the Y coordinate of the centroid. The table was then exported as a dbf file and added to the project map. To generate a point shapefile from this table, the table was added as XY data and the coordinate system was specified to a Geographic Coordinate System (GCS_WGS_1984). Then to save the point layer created as a shapefile the data was exported as a shapefile. Then using the spatial analyst

extension, the point kernel density tool was used to produce a floating point density raster of the parcel point data (Figure B-12). The parameters used for this tool included a cell size of 15, a search radius of 300m, and square meters as the units.

Once the floating point raster was created, zonal statistics within the spatial analyst tool were used to calculate the mean parcel density. To do this, several inputs were needed including an input raster or feature zone data file, a zone field, an input value raster, and the statistics type. For parcel data, the input raster or feature zone data used was the layer created by intersecting the 1000m coastal boundary with the 12 digit HUC. The zone field used was the 12 digit HUC name, the input value raster was the parcel floating point density raster created using the kernel density tool, and the statistics type used was the mean.

Road Density

To calculate road density, the road data file was first clipped to the York County boundary (Figure B-13). The file was then clipped to the 1000 m coastal boundary buffer zone (Figure B-14). Then using the spatial analyst extension, the polyline kernel density tool was used to create a floating point density raster of the road data (Figure B-15). The parameters used for this tool were identical to the parameters used for the parcel kernel density analysis and included a cell size of 15, a search radius of 300m, and square meters as the units. Kernel density was used for both parcels (points) and roads (polylines) because it allows the user to obtain a calculation of a magnitude per unit area from the particular feature being used (point or polylines) to fit a smooth surface each feature.

Once the floating point raster was created, zonal statistics within the spatial analyst tool were used to calculate the mean road density. The methodology for the road density zonal statistics was identical to that of the parcel density zonal statistics as far as the input raster or

feature zone data used the zone field, and the statistics type used. The input value raster was the road floating point density raster created using the kernel density tool.

% Impervious Coverage

The data file used for the impervious cover represented a binary layer with values of 0 impervious surfaces and values of 1 representing non-impervious surfaces (Figure B-16). This file was intersected with the coastal boundary/HUC layer (Figure B-17). Then zonal statistics within the spatial analyst tool were used to calculate the area of impervious pixels. To do this, several inputs were needed including an input raster or feature zone data file, a zone field, an input value raster, and the statistics type. For impervious coverage data, the input raster or feature zone data used was the layer created by intersecting the 1000m coastal boundary with the 12 digit HUC. The zone field used was the 12 digit HUC name, the input value raster was the % Impervious Coverage raster clipped to the 1000m coastal boundary, and the statistics type used was the area. The area obtained was the area of impervious pixels and this value was then used in the following calculation:

$$\text{Area of Impervious Pixels/Area of Coastal HUC} = \text{\% Impervious Cover}$$

To obtain the area value of the coastal HUC, the attribute table of the layer created via the intersect between the 1000m coastal buffer and the 12 digit coastal HUC was used.

Results

Bacteria Analysis

Bacteria results used to supplement the watershed analysis included the top three beaches with the highest mean Enterococci value for the months most frequently sampled (June, July, August). For June, the top three beaches with regards to elevated Enterococci counts included Cape Neddick Beach (York), Colony Beach (Kennebunkport), and Goose Rocks Beach

(Kennebunkport) respectively. For July the beaches included Cape Neddick Beach (York), Ocean Park (OOB), and Short Sands Beach (York) respectively. Lastly, for the month of August the highest mean Enterococci values were for Kinney Shores (Saco), Ocean Park (OOB), and Gooches (Kennebunk) (Table 1).

Parcel Density

Results from the zonal statistics calculated mean parcel density indicate that the top five coastal 12 digit HUCs with the highest mean parcel density included Saco Bay Frontal Drainages, Frontal Drainages off Kennebunk River, Frontal Drainages off Mousam River, and Stevens Brook-Cape Neddick River respectively (Figure 1). The beaches contained within these specific HUCs that also represented one of the top three beaches for June, July, and August with regards to bacterial exceedances include Ocean Park (OOB), Kinney Shores (Saco), Gooches Beach (Kennebunk), Cape Neddick Beach (York), and Short Sands Beach (York) (Figure B-18).

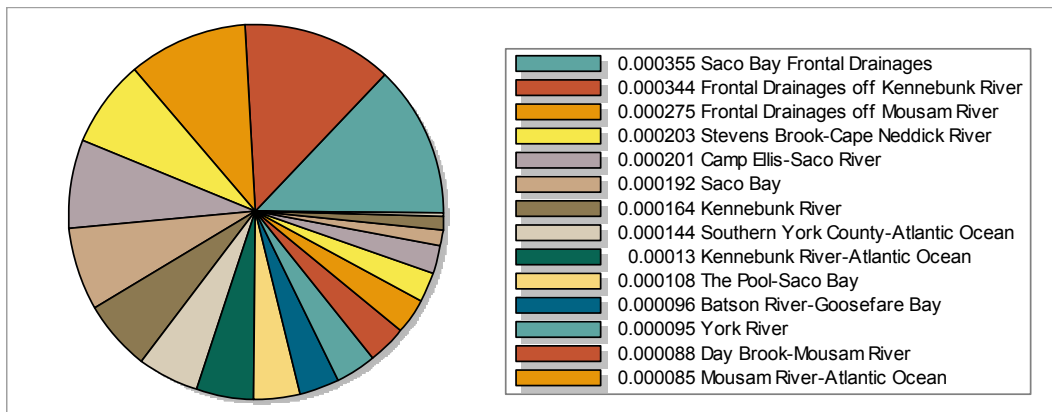


Figure 1. Results of mean parcel density analysis ranked by HUCs with the highest mean parcel density to those with the lowest.

Road Density

Results from the zonal statistics calculated mean road density indicate that the top five coastal 12 digit HUCs with the highest mean road density included Frontal Drainages off Kennebunk River, Frontal Drainages off Mousam River, Saco Bay Frontal Drainages and

Kennebunk River respectively (Figure 2). The beaches contained within these highlighted HUCs that also represented one of the top three beaches for June, July, and August with regards to bacterial exceedances include Ocean Park (OOB), Kinney Shores (Saco), Goochs Beach (Kennebunk), Colony Beach (Kennebunkport) Cape Neddick Beach (York), and Short Sands Beach (York) (Figure B-19).

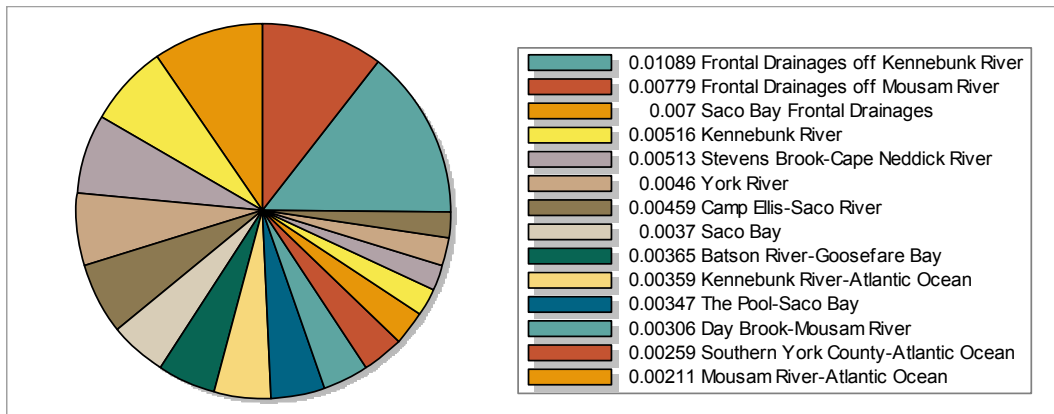


Figure 2. Results of mean road density analysis ranked by HUCs with the highest mean road density to those with the lowest.

% Impervious Coverage

Results from the calculated % impervious coverage equation indicate density indicate that the top five coastal 12 digit HUCs with the highest % impervious cover included Frontal Drainages off Mousam River , Frontal Drainages off Kennebunk River, Brave Boat Harbor, The Pool-Saco Bay, and Batson River-Goosefare Bay respectively (Figure 3). The beaches contained within these HUCs that also represented one of the top three beaches for June, July, and August with regards to bacterial exceedances include Goochs Beach (Kennebunk) and Colony Beach (Kennebunkport) (Figure B-20).

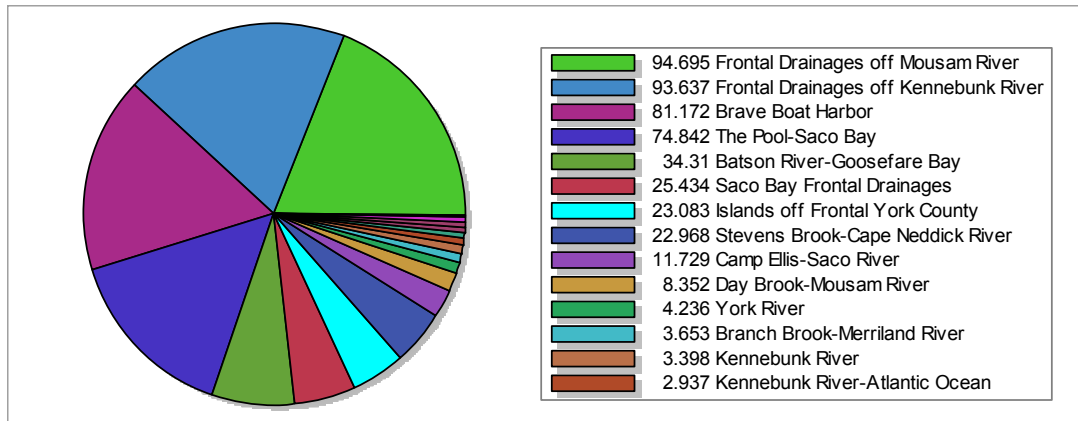


Figure 3. Results of % impervious coverage analysis ranked by HUCs with the highest % impervious coverage to those with the lowest.

Discussion

The most interesting results from this watershed analysis was the apparent relationship between the HUCs and associated beaches targeted via kernel density analysis and calculations of % impervious coverage with the bacterial data collected through the MHB program. For all three parameters (parcels, roads, impervious coverage), HUCs targeted and their corresponding beaches lined up with many of those beaches that were isolated as the top beaches for bacterial exceedances from 2008-2013. Also, while it was somewhat intuitive, many of the same HUCs were highlighted between all three analyses. This makes sense if we consider that for areas of increased parcel density there is likely increased road density and increased impervious surfaces, indicating higher human influence. While further analyses are certainly needed, this was a successful first approach at analyzing watershed characteristics and MHB beaches in York County.

This analysis is particularly advantageous for the MHB program because of our direct involvement with municipalities within southern Maine. We are often part of the design and analysis stages of projects funded through various sources including MHB and DEP. Using GIS to conduct large scale analyses to pinpoint regions for remediation/watershed restoration is

imperative for situations where limited funds restricts what work can be done to target problem areas. Ideally, once the methodology from this analysis is refined, the analysis would be expanded along the coast of Maine to other communities with beaches monitored through the MHB program.

Future Analyses/ Issues and Recommendations

As this analysis was a first step at characterizing particular watersheds and the impacts to beaches parameters such as parcels, roads, and impervious coverage can have on beach water quality, improvements on this methodology can certainly be applied. For instance, the primary interest is assessing any negative impacts to particular beach sites. To take an initial approach at answering this question, statistics were computed based on 12 digit HUCs within the 1000m coastal boundary. While this method is useful and would certainly be more accurate than using a summary unit such as towns, there are other approaches that would allow a more refined analysis of each particular beach area. This approach would include creating a buffer zone around each beach and use those buffer zones as the zone units when using zonal statistics to summarize the mean parcel density, mean road density, and the area of the impervious pixels. This method is still not quite ideal as it treats each beach the same as far as the zone around each beach that would represent potential sources of negative impacts. The components that comprise a beach and the resulting system that potentially impact a beach are unique and using the same parameters for each does not represent each system ideally. Another option would be to further explore how to more robustly delineate watershed boundaries based on topographical features such as slope.

Another aspect of this analysis that could be modified includes the kernel density analysis parameters. For the parcels and roads kernel density representations, analysis the parameters

used included a cell size of 15 and a search radius of 300m. If a larger search radius is used, a more generalized density layer is produced, and using the smaller radius as was used for this analysis produces a raster with more detail. These parameters can be adjusted to produce various scenarios for a particular beach.

Future analyses could also incorporate more data including environmental data collected by the MHB program (salinity, water temperature, air temperature, weather variables) to better understand the relationship of these parameters representing human impacts and resulting bacteria levels. Also including robust rainfall data collected from local weather stations would be advantageous.

References

- Elmir SM, Wright ME, Abdelzaher A, Solo-Gabriele HM, Fleming LE, Miller G, Rybolowik M, Shih MTP, Pillai SP, Cooper JA, Quaye EA. 2007. Quantitative evaluation of bacteria released by bathers in a marine water. *Water Research*. 41.1: 3-10.
- Boehm AB, Keymer DP, Shellenbarger GG. 2005. An analytical model of enterococci inactivation, grazing, and transport in the surf zone of a marine beach. *Water Research*. 39.15: 3565-3578.
- McGee CD, Hunder DE, Mowbray S, Ghirelli RP. 2000. Bacteria Contamination at Huntington City and State Beaches. *Proceedings of the Water Environment Federation*. 8: 393-403.
- Yoder JS, Blackburn BG, Craun GF, Hill V, Levy DA, Chen N, Lee SH, Calderon RL, Beach MJ. 2004. Surveillance for Waterborne-Disease Outbreaks Associated with Recreational Water-United States. 2001–2002. *CDC, MMWR, Surveillance Summaries*. 53(SS08): 1–22.

Appendices

Appendix A-Python Code

#Meagan Sims, 5.9.2014, Final Project Script

```
>>> import arcpy
... from arcpy import env
... arcpy.env.overwriteOutput=True
... env.workspace = "C:/sie510project" #defines the environment workspace
...
... outFolder = "C:/output" #defines the output location of the shapefile to be created
... outname= "beachdata" #defines the output name of the shapefile to be created
... sr=arcpy.SpatialReference(4269) #defines spatial reference to be assigned to shapefile
...
...
... arcpy.CreateFeatureclass_management(outFolder, outname, "POINT", spatial_reference=sr)
#creates the feature class in the output folder with the assigned name as a point object with the
specific spatial reference
...
... outshapefile= "C:/output/beachdata.shp" #defines the name and location of the output
shapefile
... fieldName1= "Beach_Name" #defines the first field name to be added to the shapefile
... fieldlength=20 #defines the length of the first field to be added to the shapefile

... arcpy.AddField_management(outshapefile, fieldName1, "TEXT", "", "", fieldlength) # adds
fieldname1 to shapefile
...
... cursor = arcpy.da.InsertCursor(outshapefile,("Beach_Name", "SHAPE@XY")) #writes
records to the shapefile for Beach_Name and coordinates
...
...
>>> beachdata= open("C:/sie510project/mhbdata.txt", "r") #open a file for reading
...
... linecount=0 #initialize a variable to count the number of lines read
... skipped=0
... with open ("C:/sie510project/mhbdata.txt") as file:
...     for line in beachdata:
...         linecount+=1 #count the lines as they are read in
...         piece=line.split("\t") # segment the line
...         lattext=piece[1] # segment line where latitude starts
...         longtext=piece[2] # segment line where longitude starts
```

```
...     lat1=float(lattext) # convert latitude data to type float
...     long1=float(longtext) # convert longitude to type float
...     Beach_Name= piece[0] #extract beach name
...
...     row=(Beach_Name, (long1, lat1)) #create a row with extracted Beach_Name and point
data
...     cursor.insertRow(row) #writes records to the shapefile from the mhldata textfile
...
...
... print str(linecount) +" lines were read."
```

Appendix B-Supporting figures

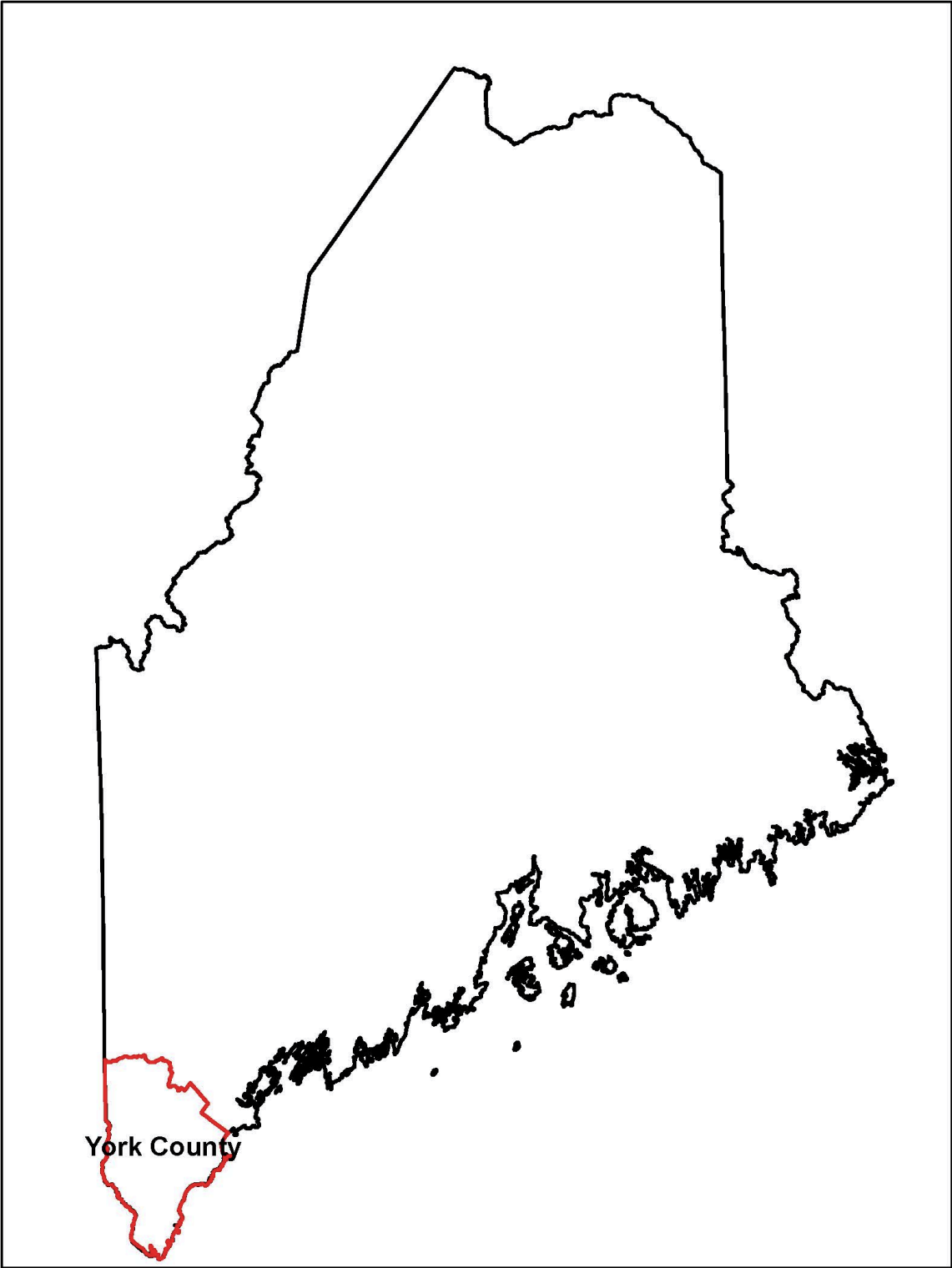


Figure B-1. Outline of Maine with York County delineated.

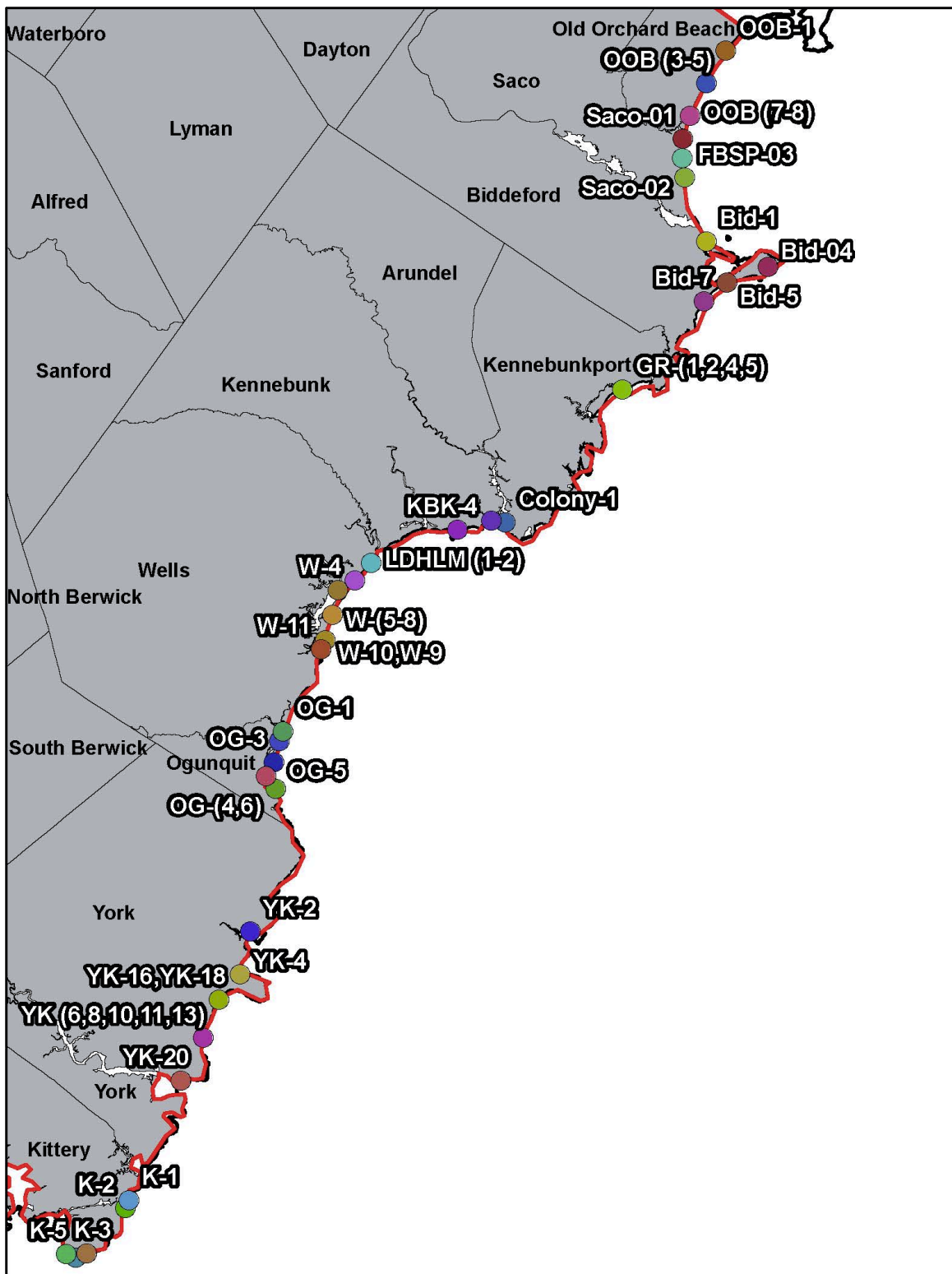


Figure B-2. Beaches participating in MHB program within York County, ME and associated towns.

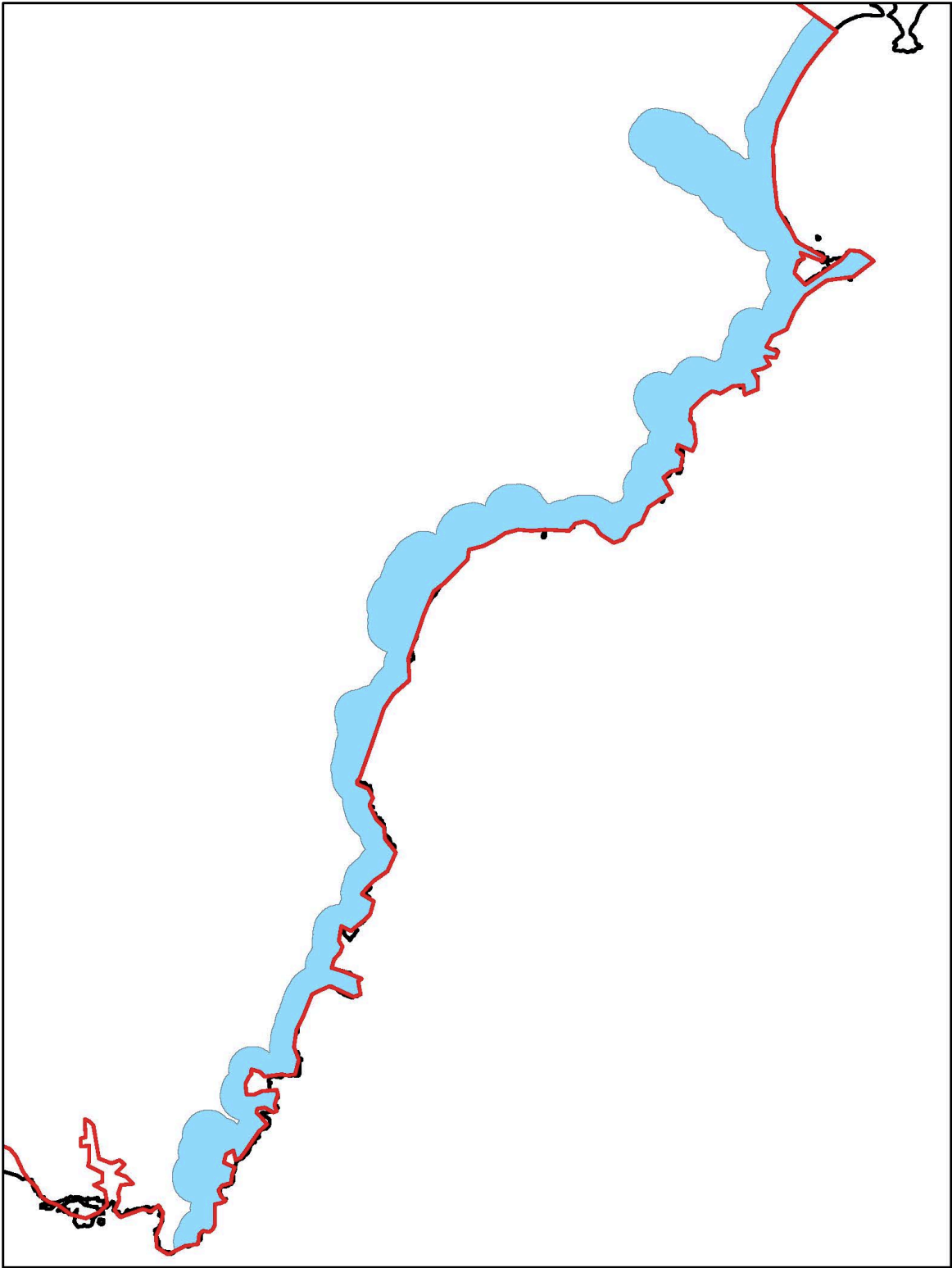


Figure B-3. Delineation of 1000m coastal boundary within York County, ME.

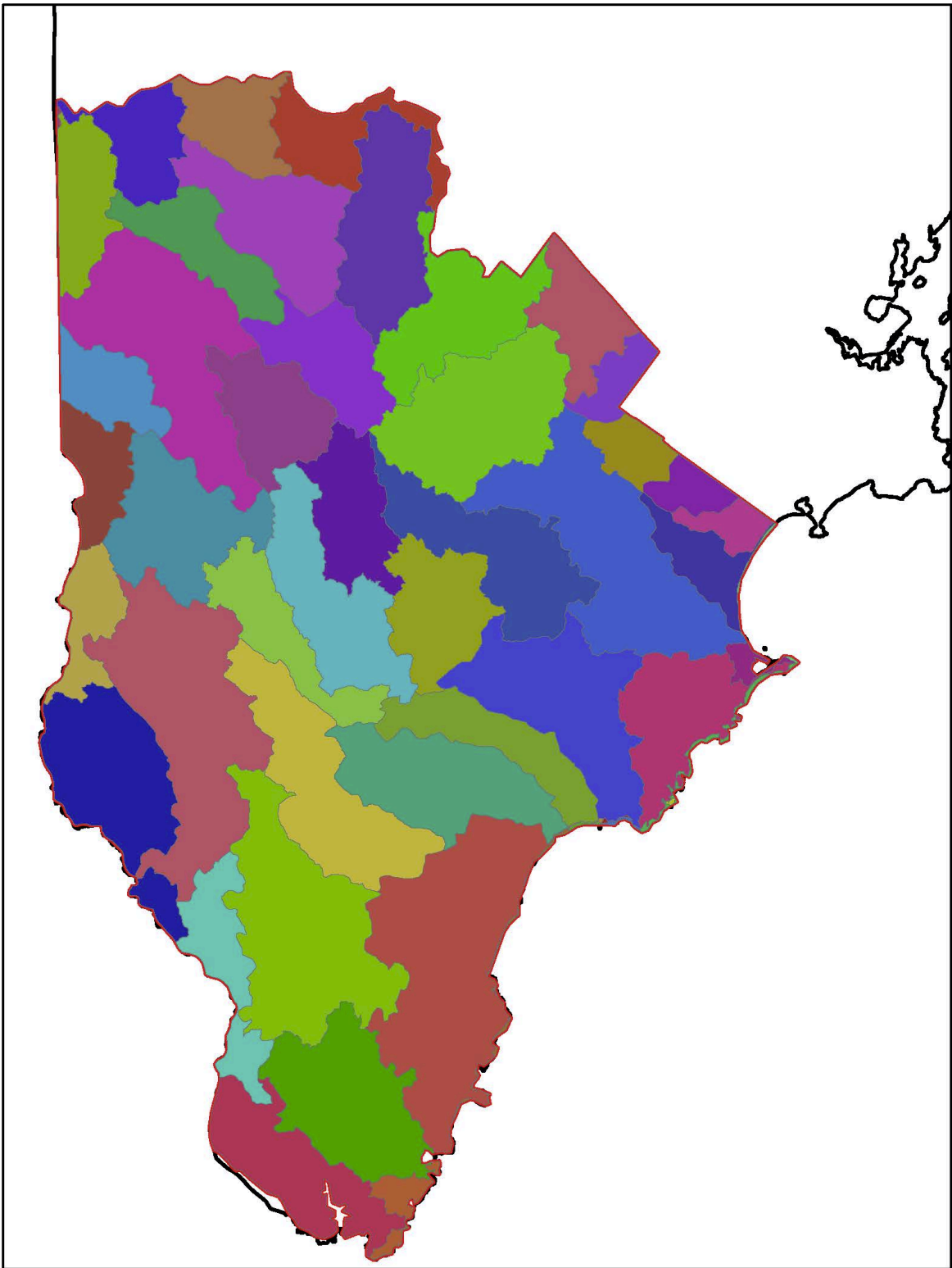


Figure B-4. HUCs within York County, ME.

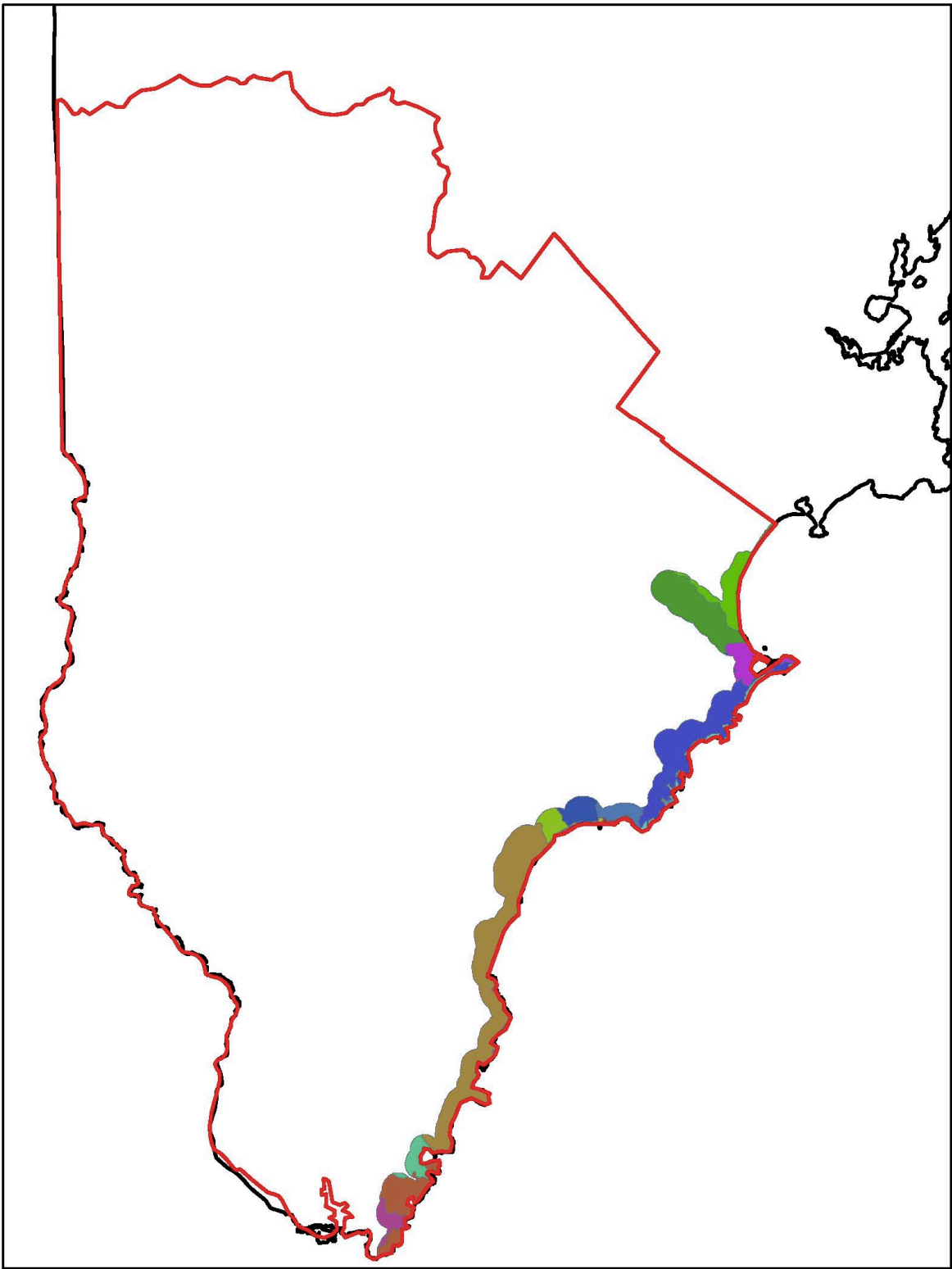


Figure B-5. HUCs within 1000m coastal boundary for York County, ME.

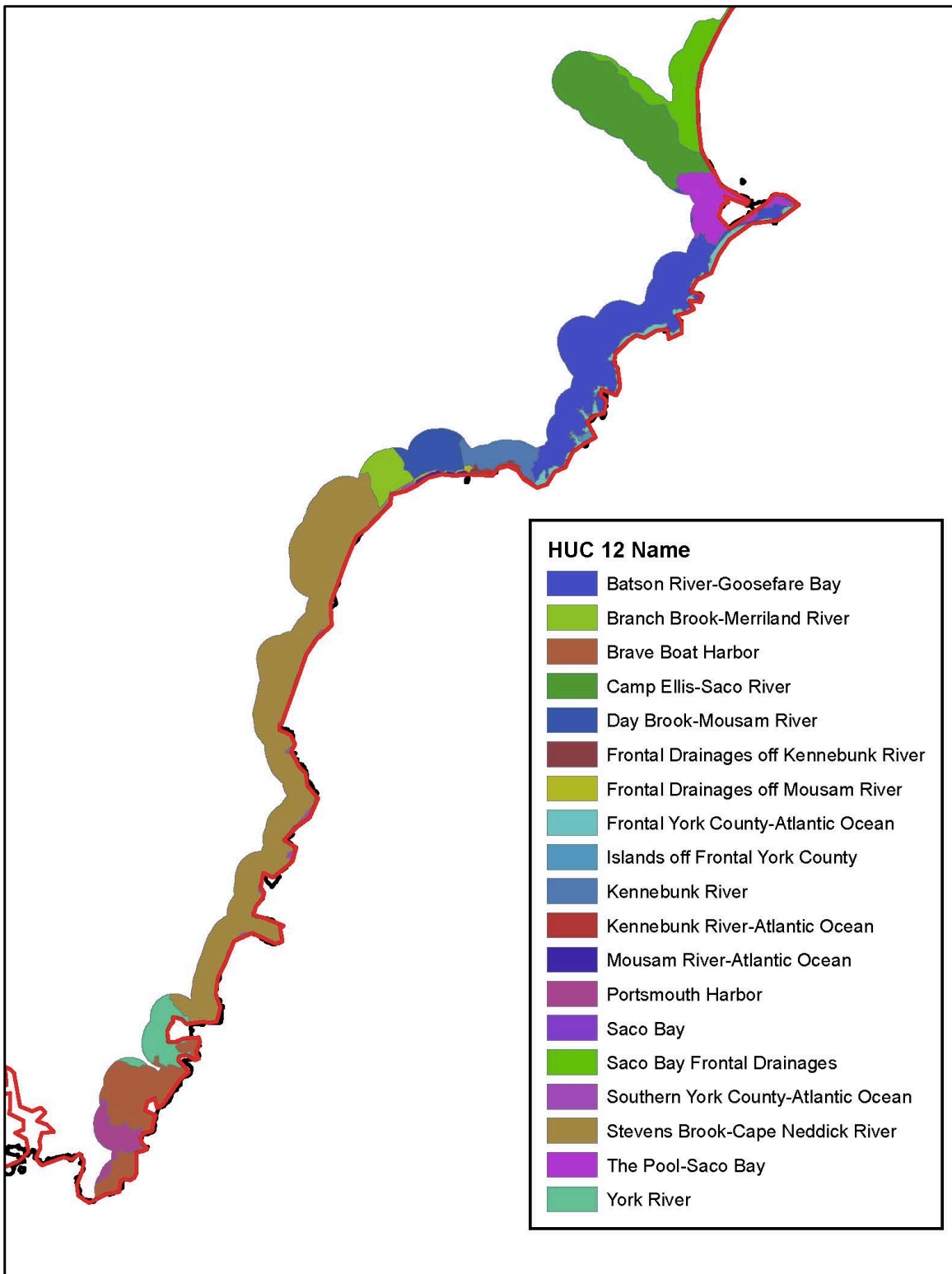


Figure B-6. HUCs within 1000m coastal boundary for York County, ME with names of each HUC.

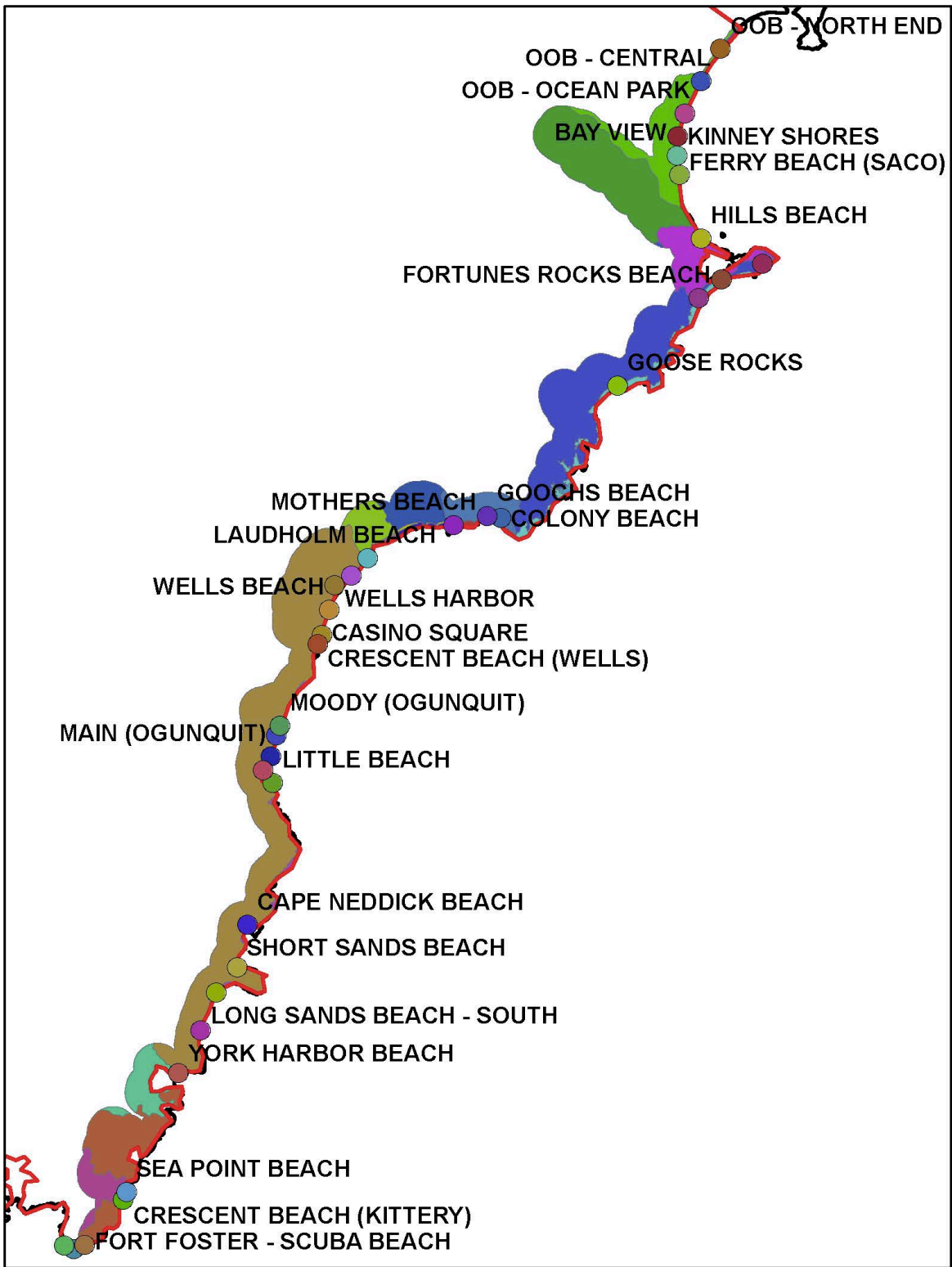


Figure B-7. HUCs within 1000m coastal boundary for York County, ME with MHB beaches contained within each.

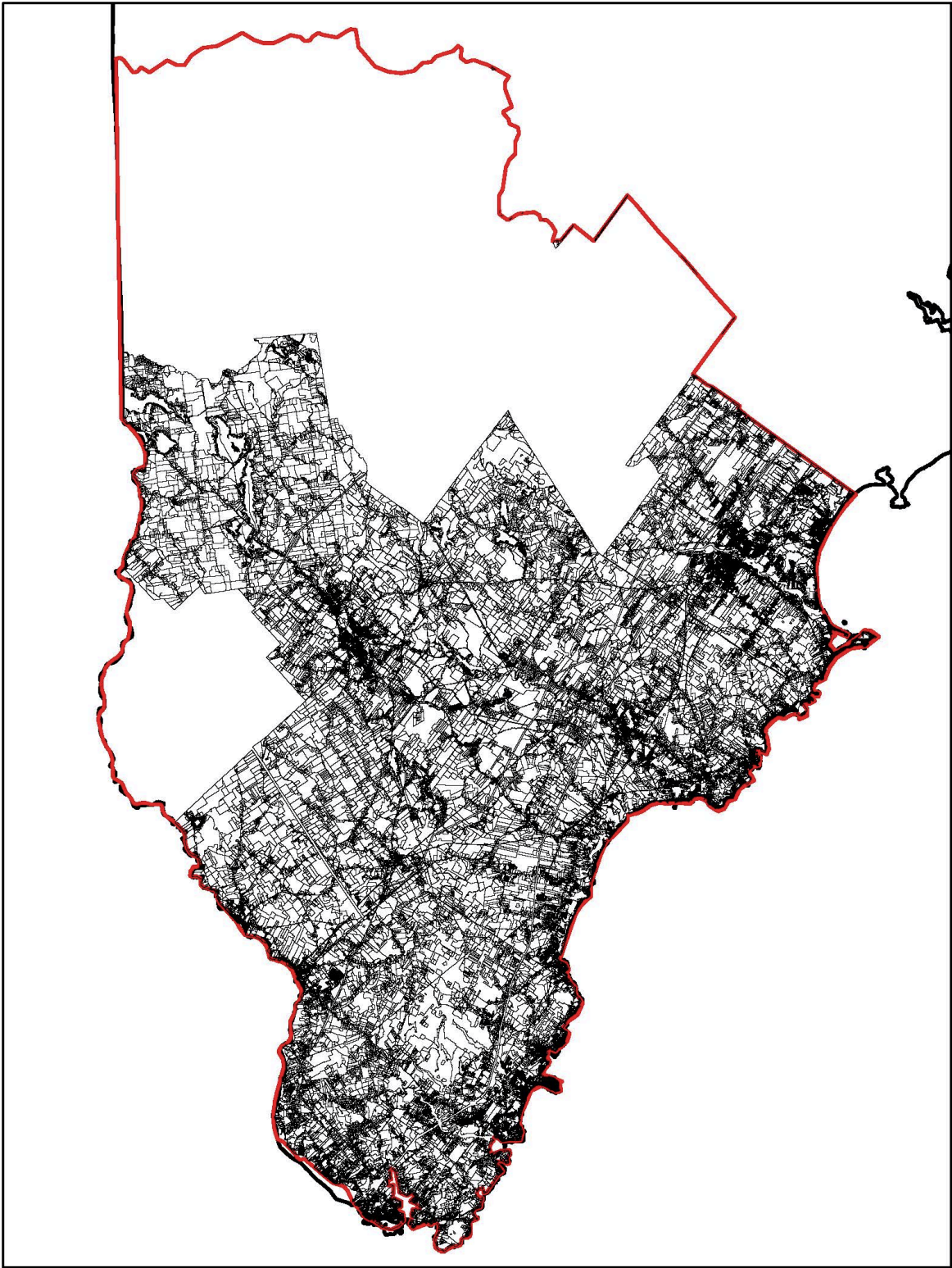


Figure B-8. MEGIS parcel layer displayed within York County, ME.

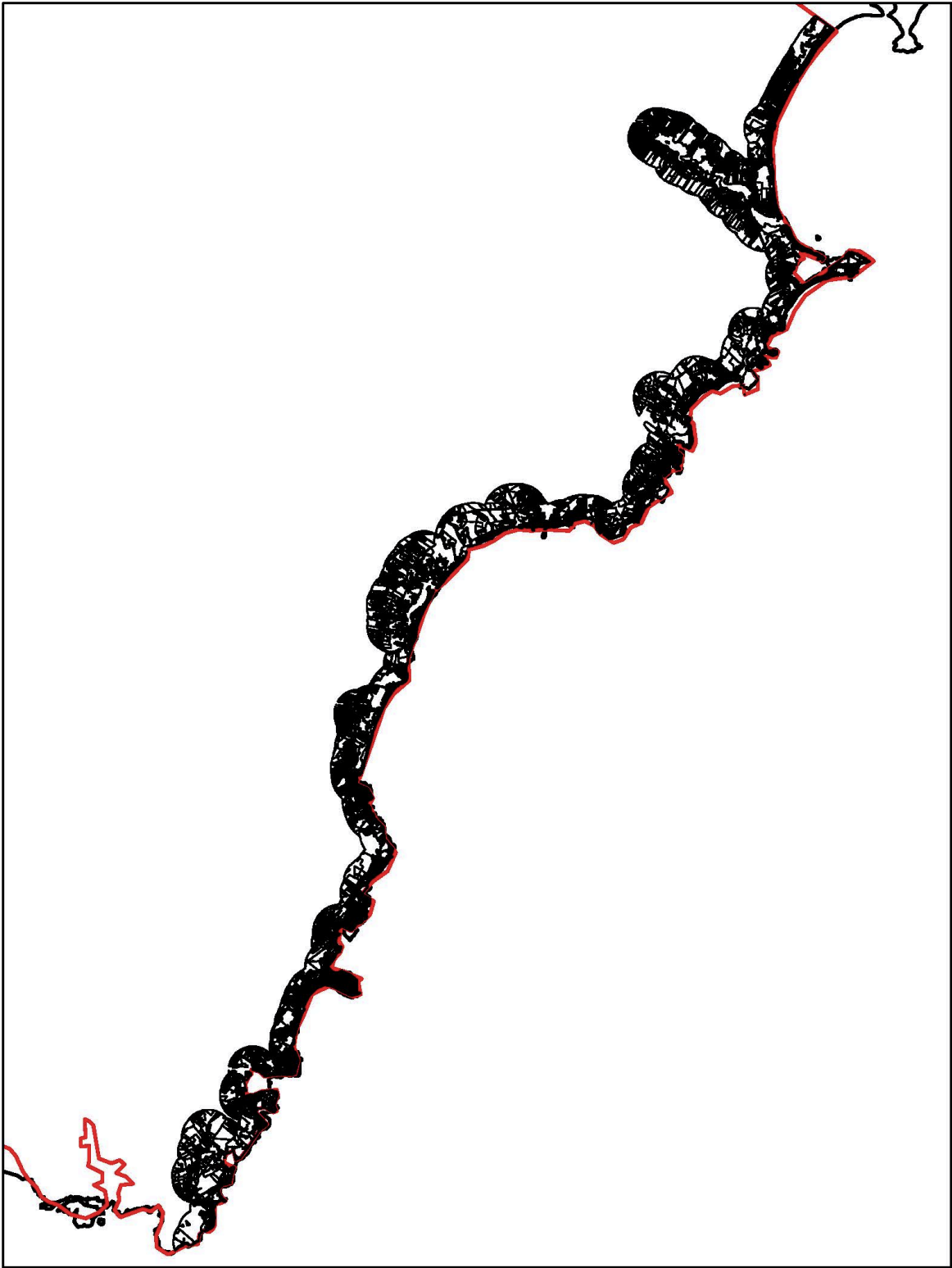


Figure B-9. MEGIS parcel layer displayed within 1000m York County coastal boundary.

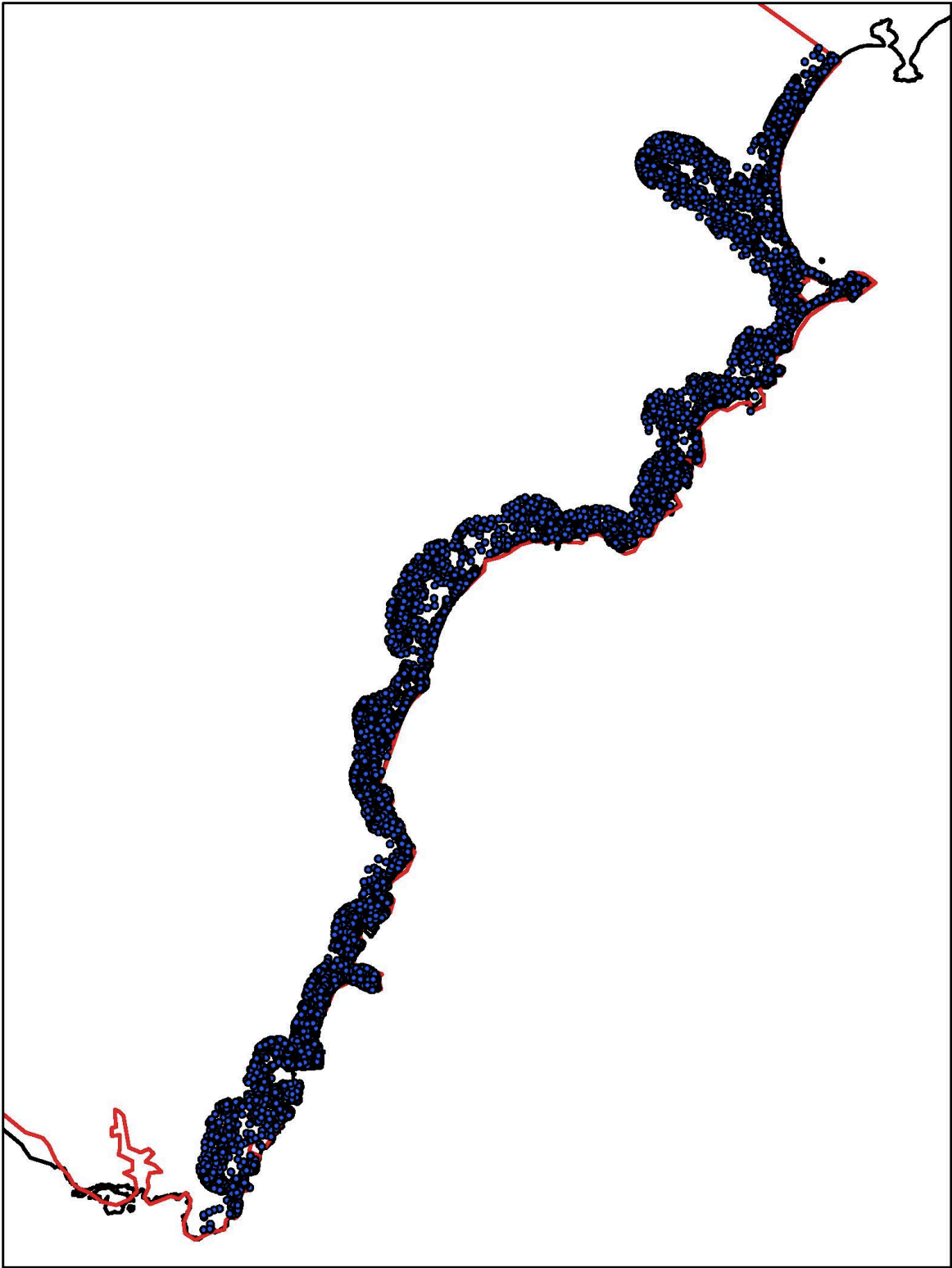


Figure B-10. Centroids within each parcel located in 1000m York County coastal boundary.

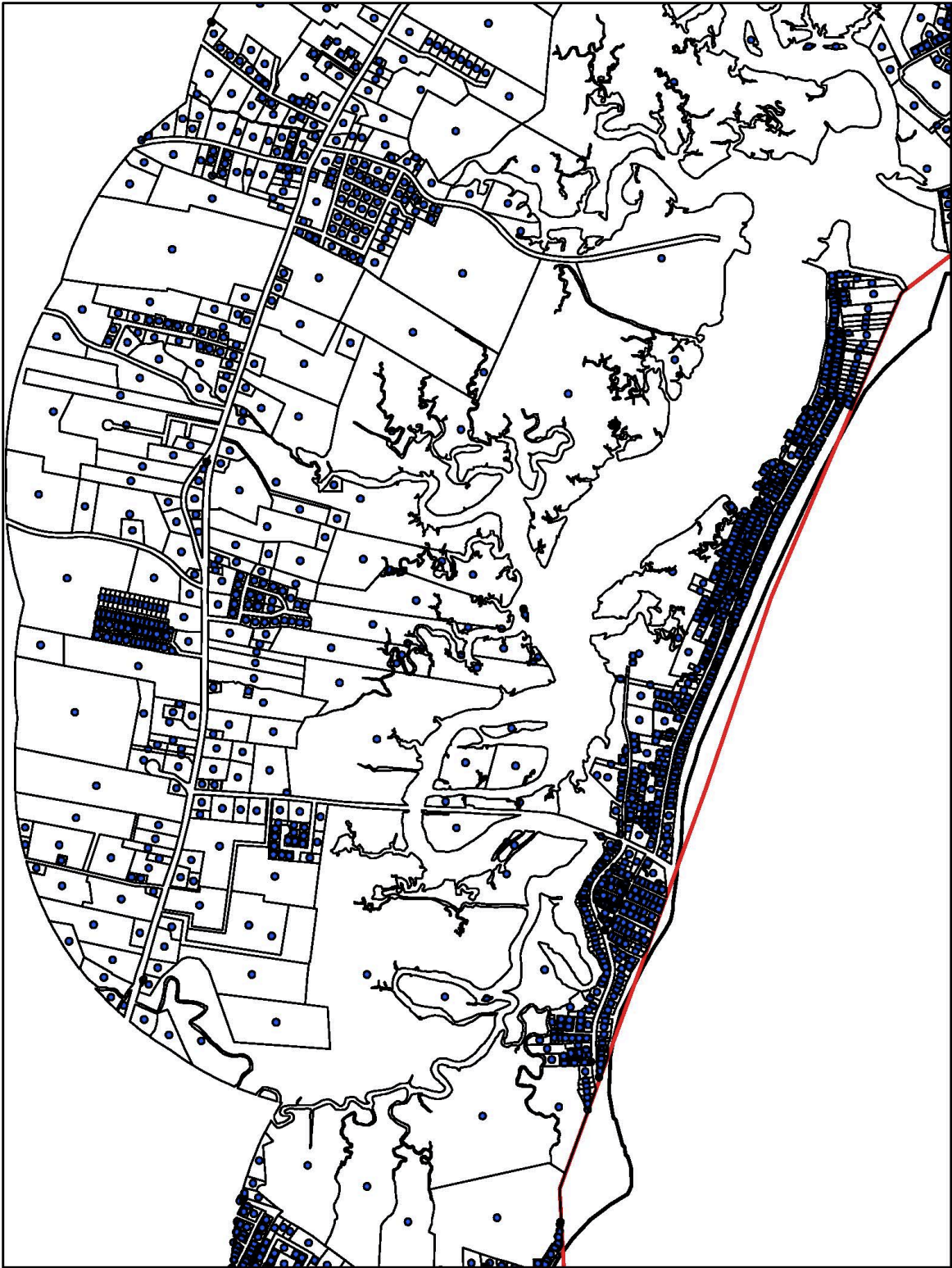


Figure B-11. Centroids within each parcel located in 1000m York County coastal boundary (zoomed in).



Figure B-12. Parcel floating point raster layer produced through kernel density tool.

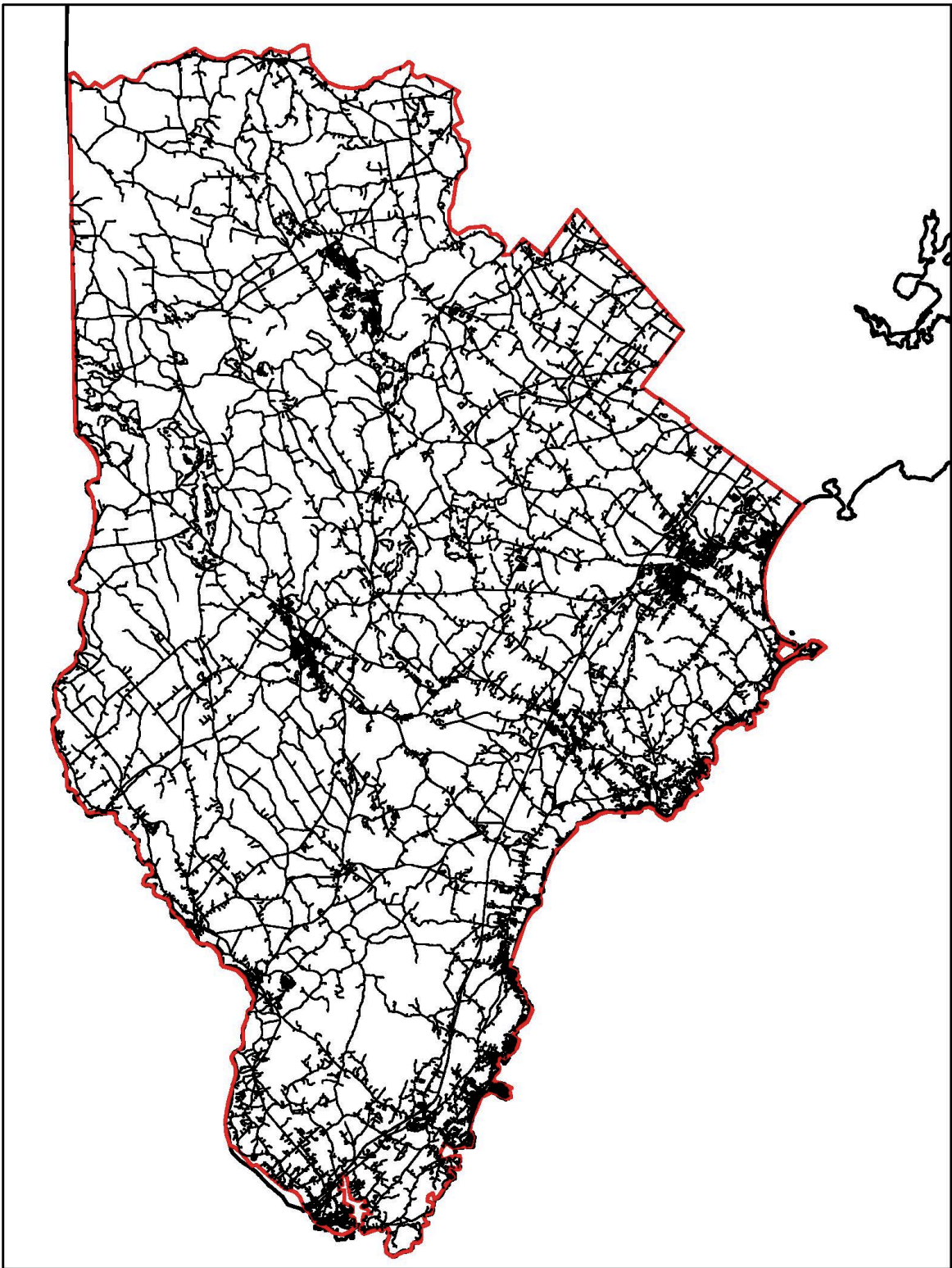


Figure B-13. MEGIS roads file displayed within York County, ME.

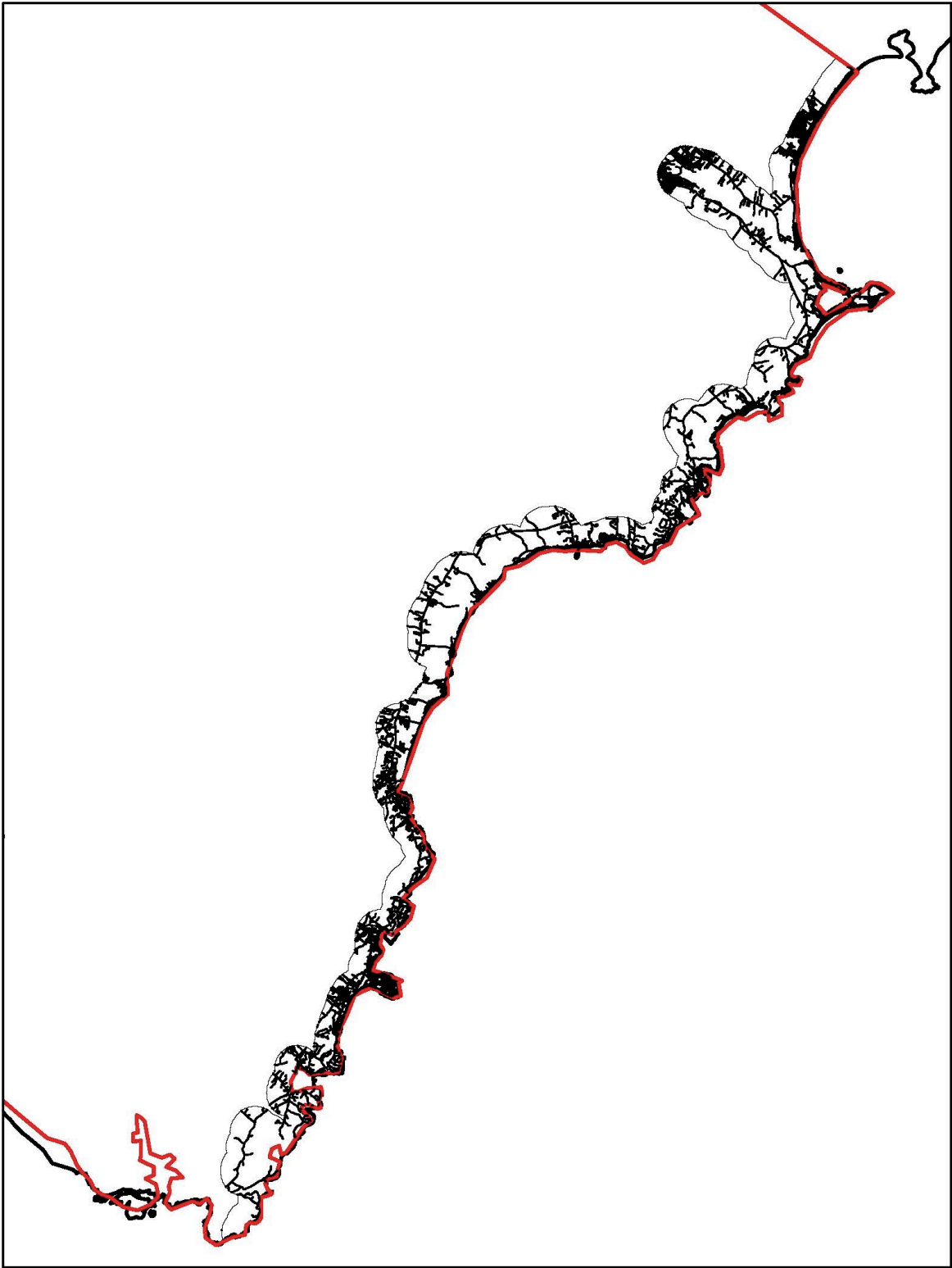


Figure B-14. MEGIS roads file displayed within 1000m York County, ME coastal boundary.



Figure B-15. Roads floating point raster layer produced through kernel density tool.

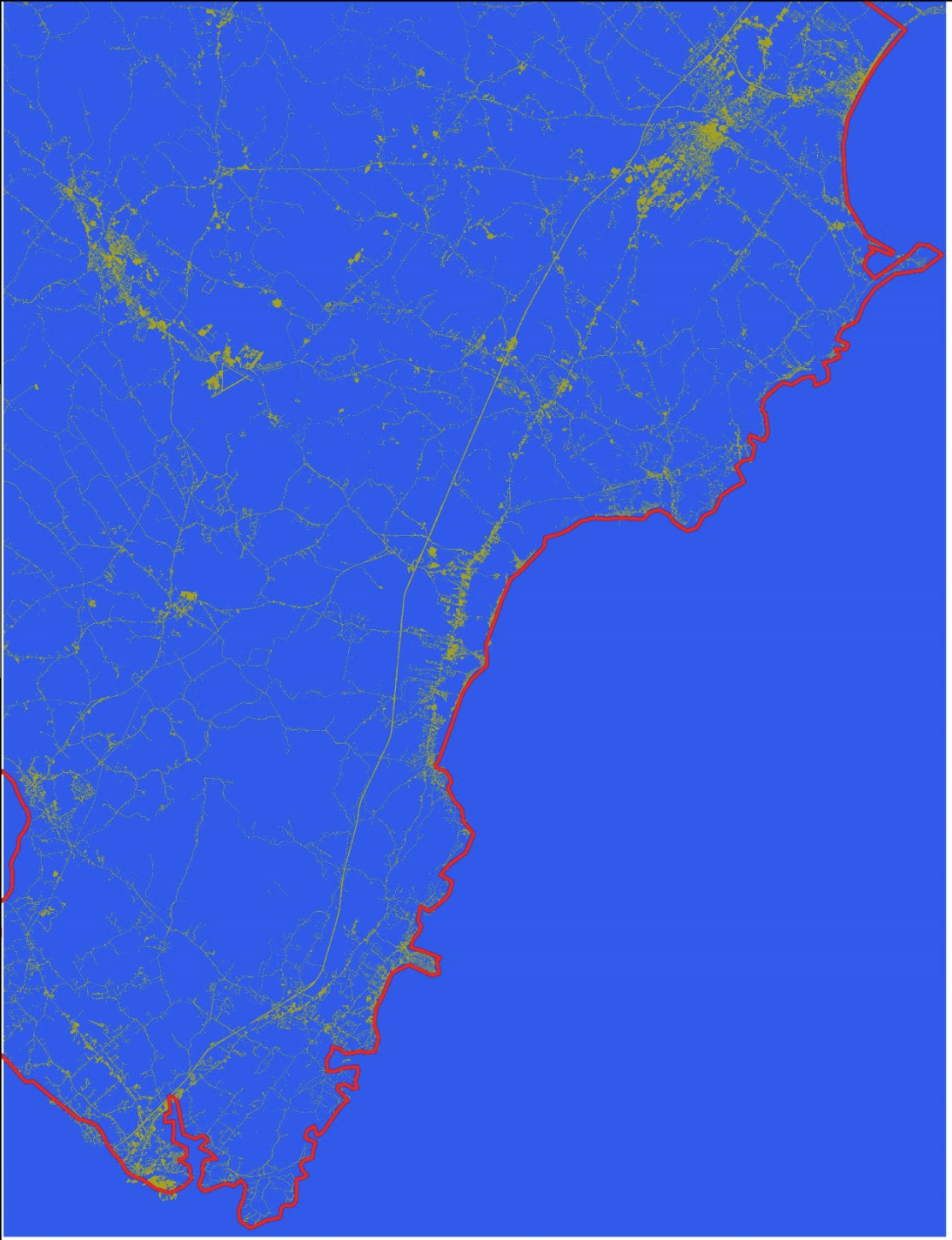


Figure B-16. Impervious surface binary raster clipped to York County, ME.

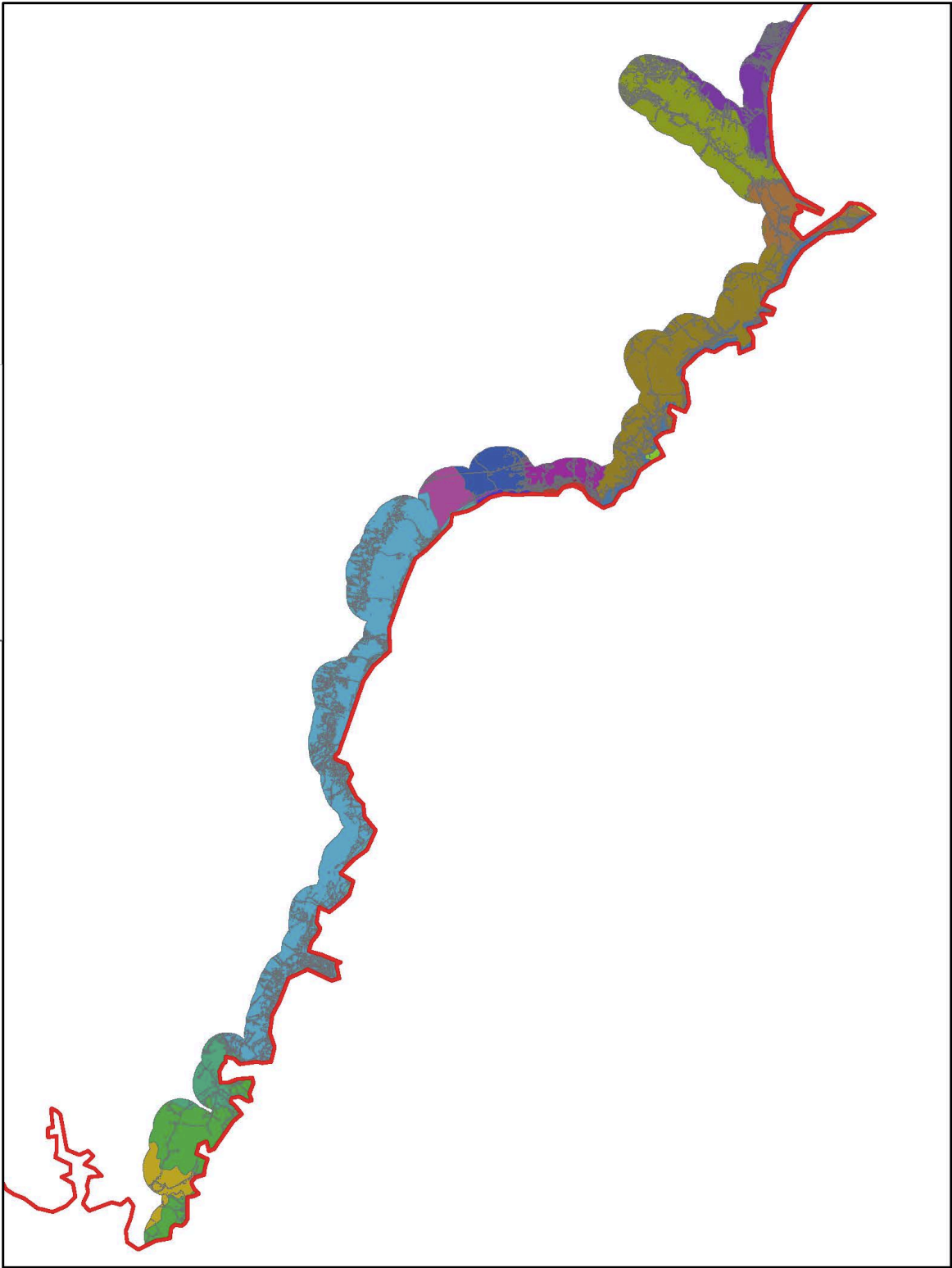


Figure B-17. Impervious surface binary raster clipped to 1000m York County coastal boundary layer interested with 12 digit HUC layer.