Developing a Disconnection Strategy

A Generalized Plan to Help Connecticut Towns Comply with MS4 Regulations

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A NOTE ABOUT THE AUTHORS

This report serves as a summary of the work done by Nelsen Durkee and Liam Nangle for their Climate Core class in the Spring of 2019. Nelsen is an exchange student from the United Kingdom who spent his third year of undergrad at the University of Connecticut. Liam is completing his undergraduate degrees from the University of Connecticut in May 2019. Both students are passionate about the environment and have brought their unique viewpoints and strengths to the table in this semester-long collaboration. They are grateful for this opportunity to have worked with such amazing individuals (Juliana Barrett, Bruce Hyde, Dave Dickson, Chet Arnold and Amanda Ryan) and are hopeful that their work will help the Town of Norwich and the rest of Connecticut's municipalities.

INTRODUCTION

The Connecticut Department of Energy and Environmental Protection (DEEP) first issued its version of the US EPA General Permit for the Discharge of Stormwater from Small Municipal Separate Storm Sewer Systems (MS4 General Permit) in 2004. A new permit was released in 2016 and became effective on July 1, 2017 and now applies to all CT municipalities within an "urbanized area." Part of the permit addresses stormwater runoff, particularly from directly connected impervious areas (DCIA). DCIA is "impervious area which drains stormwater runoff into catch basins or directly into waterbodies" (nemo.uconn.edu). The MS4 permit requires that each town estimate the amount of DCIA in their boundaries, track changes to the DCIA baseline number, and develop and implement a plan to disconnect 2% of the baseline DCIA by July 1, 2022. The objective of this project was to create a generalized plan for Connecticut towns to develop DCIA disconnection strategies by using the Town of Norwich as a model.

We decided to tackle this task in three phases, with each phase serving to answer a driving question: 1) Data Collection (how much DCIA is in the town?); 2) Data Analysis (how can we understand these numbers?); and 3) Strategy Development (how do we use what we know to make informed and effective decisions about which areas to target for disconnection?). In this report we will explain each of the three phases in hopes that a municipality will want to use the tools we have developed.

1. DATA COLLECTION

Before a town is able to come up with thoughtful and effective plans for disconnecting 2% of their DCIA, they need to know how much DCIA is actually in their town. To figure out how much DCIA is in a town, one first needs to know how much impervious cover (IC) there is, and then classify connectivity of that area. To collect the data and do the calculations needed in an organized, easily adaptable manner, we chose to create a Google Sheet (Fig. 1). We have also created a "cheat sheet" that outlines each section of the spreadsheet, the data that is needed and any tips that we can give or things to keep in mind when a town is going through this phase (Fig. 2). In this section, we will go through the spreadsheet in detail and explain the steps we took to gather all the data for the Town of Norwich.

Columns A-G: Basic Information about Each Basin

CT ECO has developed a comprehensive map of Connecticut MS4 data that includes data layers for stormwater impaired water bodies, and a 1-ft resolution statewide map of impervious surfaces. There is also an “IC by basin” layer which shows the boundaries of all basins in the state and includes data of how much IC is in that basin. We chose to work with the basin layer because basins are the smallest unit of land that drains to a common point, and they are the building blocks of larger watersheds. Since we are dealing with stormwater and runoff, it is useful to think about IC and DCIA in the context of water drainage, which is what the IC by basin layer provides.

To collect data for the entire Town of Norwich we had to get a map of the IC by basin layer that was clipped to the town boundaries because basin geography does not match up perfectly with man-made town lines. Using the clipped map we were able to go through each basin (and basin fragment) and collect the following data:

- Total basin area (acres)
- Total IC, excluding state roads (% of basin and acres)
- IC from buildings
- IC from other
- IC from non-state roads

We then entered this data into the spreadsheet (in columns A-G). We made sure to use the “excluding state roads” values because towns are not responsible for this IC and DCIA since CTDOT has its own MS4 permit that it needs to comply with. When the data for this map layer was collected, it was able to differentiate different surfaces to identify what the impervious cover actually is, whether it be a building, a road or something else like a parking lot or driveway. This portion of Phase 1 is simple but tedious and it provides the information necessary to calculate how much DCIA is in the town.

Columns H-L, M and N: Classifying Basin Connectivity Level and Calculating DCIA

Now that the amount of impervious cover is known, the next step is figuring out how much IC is directly connected to the stormwater system or waterbodies based on the area’s connectivity level. The connectivity level of an area can fall into five categories from “Fully Connected” where all IC in the area is directly connected to the MS4 system, to “Slightly Connected” where only a small portion of the IC is directly connected. Though these categories are qualitative, they each have a corresponding equation which essentially converts the %IC value into a %DCIA value, giving you the percentage of an area (an individual basin in our case) that is directly connected impervious cover. These equations were developed by Southerland and adapted by CT DEEP (Fig. 3).

To classify the connectivity level of each basin, we needed to see the configuration of stormwater infrastructure within an area. In other words, we used Google Maps street view to travel around the Town of Norwich and look for things like street curbs, storm sewers and gutter spouts to get an idea of how stormwater would travel in that area. If we saw that most roads in a basin were curbed with frequent storm drains and that most of the gutters on buildings and homes lead right onto the street, we would classify that basin as “Fully Connected.” If we saw that only some roads were curbed while others were not and that most gutter spouts lead onto grassy areas, we would classify the basin as “Moderately Connected” because the stormwater falling on the IC there would have more opportunity to go into the ground instead of into the stormwater system.

We wanted to create a system that would allow us to easily classify each basin in the town and have the spreadsheet perform the calculation of %DCIA by using the corresponding Southerland equation. Columns H-L allow the user to enter a connectivity level by putting a “1” in the corresponding column, and column M does the correct calculation. If the connectivity level needed to be changed for a basin for some reason, we could simply move “1” to the correct column and column M would then use the different equation. Column N takes the %DCIA value that column M calculates and converts it into an actual area basin on the total area in that basin.

This portion of Phase 1 is arguably the most important because it is where the town wide amount of DCIA is actually calculated, but it also takes the largest amount of time and requires consistency of judgement. The rest of the process is essentially dependent on the values gathered here, so it is crucial that the connectivity level of the basins are classified accurately.

Columns O-T: Categorical DCIA Breakdown
Based on the IC data, we can also estimate how much DCIA is from buildings, roads and other surfaces. Breaking the total DCIA amount down into these three categories will be helpful in the next two phases for understanding where the DCIA is and how to best address these areas.
The breakdown is based on the ratio of the IC breakdown. In other words, if we gathered data for a basin that had 8% IC and 4% was buildings, 2% was roads and 2% was from other, we would know that half of that total IC was from buildings, a quarter from roads and the remaining quarter from other surfaces. We took these ratios for each basin and applied them to the DCIA value we calculated. We then converted the % value for each category into an actual acreage based on the total area in the basin.

The spreadsheet does these calculations automatically when the connectivity level is entered.

Columns U-X: Land Use Classification
To further our understanding of where the DCIA in a town is located, we thought it would be important to relate DCIA to land use. To do this we looked at the zoning map of the Town of Norwich, which showed each of the properties within the town and the roads. Using this map, we were able to determine what zone the majority of the DCIA in a basin was located in. Some basins had multiple zones within it, but we based our land use classification on where the DCIA actually was. For instance, if a basin was half residential and half recreational, we would classify

it as residential because that is where the IC and DCIA is located. This portion is also a judgement call, but it is less tedious than determining the connectivity level.

Column Y: Connectivity Level Reasoning

This column on the spreadsheet is a space designated for explaining how the decision was made to classify each basin's connectivity level. This section was included to provide justification to the Town of Norwich in the context of this project, though it could be useful for other towns to record the reasoning for their determinations as well since this portion is opinion-based.

2. DATA ANALYSIS

Though we did a lot of work on this phase summarizing the data and creating pie charts, if towns use this method in the future they will not have to do much more than look at the charts we have set up that the spreadsheet will automatically create.

All the pie charts are included in the same workbook at the spreadsheet from Phase 1, and all the charts are based on this data. There are two spreadsheet pages for this phase, the first is designed to be a quick numerical summary of the data collected in Phase 1, and the other formats this summary so that Google Sheets can make pie charts. Since everything in the workbook is linked, making a change in the Data Collection spreadsheet will ripple through the Data Analysis and Chart Data spreadsheets and the change will then be reflected on the pie charts themselves. Each pie chart is meant to provide a visual summary of different aspects of and relationships within the data so that it can be understood more clearly and holistically.

Relating DCIA Categories to Land Use

As mentioned before, our goal was to understand where the DCIA in the town was, both in the context of type of DCIA (buildings, roads, other) and the setting (residential, commercial, municipal, industrial). Relating these two contexts painted a clearer picture of what kinds of surfaces contribute the most to the town's DCIA baseline total. For example, though we know that approximately 35% of the DCIA in Norwich is from buildings, we do not know whether these are primarily people's houses or the rooves of industrial buildings (Fig 4a). By combining this data with our land use classifications, however, we can see that most of the DCIA from buildings is in residential zones in Norwich (Fig 4b).

3. STRATEGY DEVELOPMENT

In the final phase we are trying to now use what we know about a town to make informed, impactful decisions based on our priorities. We decided to break Phase 3 down into three steps: 1) Identifying areas of interest, 2) Matching up LID practices, and 3) Plans for Incentivization. The following sections of this report will explain each step in Phase 3 and why it is important. Towns should think of the steps in Phase 3 as cumulative, meaning that each one leads into the next, similarly to the larger phases of this project.

Step 1: Identifying Areas of Interest

This step is meant to provide towns with a way to think about what their priorities are and what issues they want to address while complying with this part of the MS4 permit. This part of the process is the most town-specific as the priorities, needs, and abilities of one town can be, and most likely are, very different from those of another. Since the goal of this project was to create a generalized plan for towns to adopt and use, we tried to construct a flexible, question-based framework for identifying areas of interest (Fig. 5).

This sheet is also in the DCIA workbook and it is essentially a questionnaire with room for additional questions that the town can go through to identify their areas of interest (AOI). Filling out the questionnaire is as easy as thinking about each question and ranking the various types of DCIA. Looking at the total of each column at the bottom of the sheet will give towns an idea of where to focus their efforts based on which type of DCIA best answers the most questions/fits the most needs. Depending on the scale chosen for ranking each question, towns can give more consideration to certain factors than others.

Step 2: Matching Up LID Practices

There are numerous resources available that describe various Low Impact Development (LID) practices for disconnecting DCIA. In particular, the Whole Building Design Guide provides a thorough compilation and comparison of a number of common LID practices. Based on the overall rankings from Step 1, towns can easily look for LID practices that match their needs.

Step 3: Plans for Incentivization

It is one thing to know what to do, but it is another thing to do it. This is especially true when completing the task involves getting other people to engage with the activity. There are various ways to incentivize various groups of people, and town governments can get creative with this part of the process.

Some suggestions include the following:

- Outreach programs
- Educational campaigns
- Disconnection tracking and friendly competitions between neighborhoods
- Discounts on residential building permits for implementing a LID practice to disconnect DCIA during their construction/renovation
- Updated regulations for construction and renovation projects that require that no DCIA be added, even with the addition of impervious cover due to new construction

Of course, each town is unique and has a unique set of challenges, considerations and strengths. Generally, by being sure to present information about DCIA and the MS4 permit in a relatable way will be crucial for getting people to incorporate disconnection strategies into the infrastructure around them, and into the town's culture.

FIGURES

Unique Basin Number	Basin Area (Acres)	Total IC ESR		IC Buildings (%)	IC Other (%)	IC Roads (%)	Connectivity Level					Total DCIA		DCIA Buildings		DCIA Other		DCIA Roads		Land Use			
		%	Acres				1 (F)	2 (W)	3 (M)	4 (S)	5 (SI)	%	Acres	%	Acres	%	Acres	%	Acres	R	C	M	I
Example	150	20	30	8	8	4			1			8.94	13.42	3.58	5.37	3.58	5.37	1.79	2.68			1	
(C) 3800-00-5-R14	35	6	2	2	3	1			1			1.47	0.51	0.49	0.17	0.73	0.26	0.24	0.09	1			
(C) 3800-13-1	1018	2	23	0	1	1				1		0.13	1.32	0.00	0.00	0.06	0.66	0.06	0.66	1			
(C) 3804-00-2-R5	57	0.23	0.13	0.23	0	0								0.00	0.00	0.00	0.00	0.00	0.00				
(C) 3804-05-1	125	0.62	0.78	0.62	0	0								0.00	0.00	0.00	0.00	0.00	0.00				
(C) 3800-00-5-R15	178	5	9	2	3	0								0.00	0.00	0.00	0.00	0.00	0.00				
3800-14-1	970.8	5	49.85	1	2	2			1			1.12	10.85	0.22	2.17	0.45	4.34	0.45	4.34	1			
(C) 3800-00-5-R16	168	12	20	3	7	1								0.00	0.00	0.00	0.00	0.00	0.00				
3800-15-1	440.9	6	25.65	2	2	2			1			1.47	6.48	0.49	2.16	0.49	2.16	0.49	2.16	1			
(C) 3804-04-1	343	2	5	2	0	0								0.00	0.00	0.00	0.00	0.00	0.00				
3900-11-1-L1	746.8	1	8.47	0	0	1			1			0.10	0.75	0.00	0.00	0.00	0.00	0.10	0.75	1			
3800-13-1-L1	67.8	6	4.39	1	2	3			1			1.47	1.00	0.24	0.17	0.49	0.33	0.73	0.50	1			
3800-15-1-L1	55.5	4	2.05	1	1	2				1		0.42	0.23	0.11	0.06	0.11	0.06	0.21	0.12	1			
3800-15-1-L2	87.5	0.5	0.47	0	0.5	0					1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1			
(C) 3800-00-5-R17	572	24	138	9	11	4								0.00	0.00	0.00	0.00	0.00	0.00				
(C) 3900-10-1	201	10	20	10	0	0								0.00	0.00	0.00	0.00	0.00	0.00				
3900-12-1	441.3	13	59.3	3	8	3		1				8.69	38.33	2.00	8.85	5.34	23.59	2.00	8.85		1		
3900-11-1	267.5	9	23.63	3	4	3			1			2.70	7.22	0.90	2.41	1.20	3.21	0.90	2.41	1			
3900-13-1-L1	483.4	4	20.96	1	2	2			1			0.80	3.87	0.20	0.97	0.40	1.93	0.40	1.93	1			
3800-18-1-L1	177.6	9	16.28	2	3	4			1			2.70	4.80	0.60	1.07	0.90	1.60	1.20	2.13	1			
3800-18-1	461.5	11	49.79	3	5	2				1		2.36	10.88	0.64	2.97	1.07	4.95	0.43	1.98	1			
3900-14-1	339.8	10	33.63	3	4	3			1			3.16	10.75	0.95	3.22	1.26	4.30	0.95	3.22	1			
3900-13-1	272.6	11	29.27	3	5	3			1			3.65	9.95	0.99	2.71	1.66	4.52	0.99	2.71	1			
3800-00-6+L3	272.8	8	21.55	2	3	3			1			2.26	6.17	0.57	1.54	0.85	2.31	0.85	2.31	1			
(C) 3800-00-5-R18	39	29	11	5	21	3								0.00	0.00	0.00	0.00	0.00	0.00				
(C) 3800-00-6+R1	28	7	2	1	5	1																	
3800-19-1	340.1	12	40.31	3	5	3				1		2.73	9.30							1			
(C) 3800-00-6+R2	98	1	1	1	0	0																	
(C) 3900-00-4-R5	53	6	3	1	3	2								0.00	0.00	0.00	0.00	0.00	0.00	1			
3900-00-4-R6	1563.1	15	242.21	4	6	6			1			5.81	90.81	1.55	24.22	2.32	36.32	2.32	36.32		1		
3900-11-2-R1	111.4	35	38.69	7	17	11			1			20.71	23.07	4.14	4.61	10.06	11.20	6.51	7.25	1			
3900-004-R7	324.5	16	51.08	4	7	5			1			6.40	20.77	1.60	5.19	2.80	9.09	2.00	6.49	1			
3900-13-2-R1	49.3	21	10.45	6	11	1				1		7.08	3.49	2.02	1.00	3.71	1.83	0.34	0.17	1			
3900-00-4-R8	1162.4	27	308.46	7	13	5			1			14.03	163.08	3.64	42.28	6.75	78.52	2.60	30.20	1			
3800-00-6+L4	125.9	5	6.45	0.33	3.24	2.88					1	0.25	0.31	0.02	0.02	0.16	0.20	0.14	0.18			1	
3800-00-6+R4	1764.3	23	413.95	7	10	5		1				17.22	303.88	5.24	92.49	7.49	132.12	3.74	66.06	1			
3800-00-6+R3	72.7	12	8.9	4	5	4			1			4.16	3.02	1.39	1.01	1.73	1.26	1.39	1.01	1			
(C) 3001-005-1														#DIV/0!		#DIV/0!		#DIV/0!					
3001-07-7-L1	966.3	12	111.21	3	4	4				1		2.73	26.41	0.68	6.60	0.91	8.80	0.91	8.80	1			
3001-09-01	322	30	96.14	8	17	4			1			16.43	52.91	4.38	14.11	9.31	29.98	2.19	7.05	1			
(C) 3000-00-6+R1														#DIV/0!		#DIV/0!		#DIV/0!					
3001-08-01	765.4	13	97.3	2	5	2			1			4.69	35.88	0.72	5.52	1.80	13.80	0.72	5.52		1		
C 3001-05-02-R1														#DIV/0!		#DIV/0!		#DIV/0!					
C 3001-00-3-R1														#DIV/0!		#DIV/0!		#DIV/0!					
3001-07-2-R1	65.5	11	7.45	3	4	3					1	1.21	0.79	0.33	0.22	0.44	0.29	0.33	0.22	1			
(C) 3001-00-3-L1														#DIV/0!		#DIV/0!		#DIV/0!					
(C) 3001-00-3-R3														#DIV/0!		#DIV/0!		#DIV/0!					
(C) 3000-00-6+R2														#DIV/0!		#DIV/0!		#DIV/0!					
(C) 3003-09-1-L1														#DIV/0!		#DIV/0!		#DIV/0!					
ADD														#DIV/0!		#DIV/0!		#DIV/0!					
TOTAL	15633.7	12.87	2012.8	27.67	46.68	23.46	0	2	18	6	3	5.42	846.82	11.64	225.72	19.64	377.64	9.87	203.43	26	3	1	0

Figure 1. Screenshot of the “1. Data Collection” sheet in the DCIA Google Sheets workbook. Colored boxes correspond to the sections in Figure 2.

Column	Description	Data From...	Notes
A-G	Basic information about each basin	CT ECO MS4 Mapviewer	-Make sure to use "excluding state roads" values -The category breakdown does not always add up to the total IC%
H-L	Classifying basin connectivity level	Google Maps and street view, CLEAR MS4 Guide	-Judgement call, try to be consistent -Collecting lots of data in order to explain and justify
M	Based on the connectivity level, what % of the basin is DCIA?	Formulas from MS4 Guide, based on Southerland's equations	Cell formula is nested if statements so one can easily switch the connectivity level
N	Total DCIA area in basin	Multiplying Basin Area (column B) by the % in M	Areas are mostly for easier conceptualization
O-T	DCIA breakdown into categories	%'s = Ratio of IC in each category and total IC in basin Acres = % multiplied by Basin Area (B)	Helpful for pinpointing where the DCIA problem areas are
U-X	Land Use Classification	Town Zoning Map	-Make sure to focus on areas with IC -Useful for further specifying where the DCIA is

Figure 2. Color coordinated "cheat sheet" for filling out the "1. Data Collection" sheet.

NOTE: %IC = percent impervious cover

Column	Connectivity Level	Description of Contributing Area	Land use type	Column M Equation	Example for a watershed with 20% impervious cover (IC)
H	1. Fully Connected (default)	100% storm sewered with all IC	High density mixed use, commercial	None. DCIA% = IC%	20% DCIA
I	2. Wicked Connected	Mostly storm sewered with curb and gutter, residential rooftops connected to MS4	High density residential, commercial, industrial, institutional	DCIA%=0.4(%IC)^1.2	0.4(20)^1.2 = 14.6% DCIA
J	3. Moderately Connection	Mostly storm sewered with curb and gutter, residential rooftops NOT connected to MS4	Medium density residential, commercial, industrial, institutional, open land	DCIA%=0.1(%IC)^1.5	0.1(20)^1.5 = 8.9% DCIA
K	4. Sorta Connected	50% storm sewered with some infiltration and residential rooftops not connected to MS4	Low density residential, open land	DCIA%=0.04(%IC)^1.7	0.04(20)^1.7 = 6.5% DCIA
L	5. Slightly Connected	Small % of urban area storm sewered or mostly infiltration	Agricultural, forested, natural areas	DCIA%=0.01(%IC)^2	0.01(20)^2 = 4% DCIA

This table was adapted by CT DEEP from EPA guidance on DCIA.

Figure 3. Southerland's Equations for converting IC to DCIA. Spreadsheet columns included. Chart from https://nemo.uconn.edu/ms4/tasks/mapping.htm

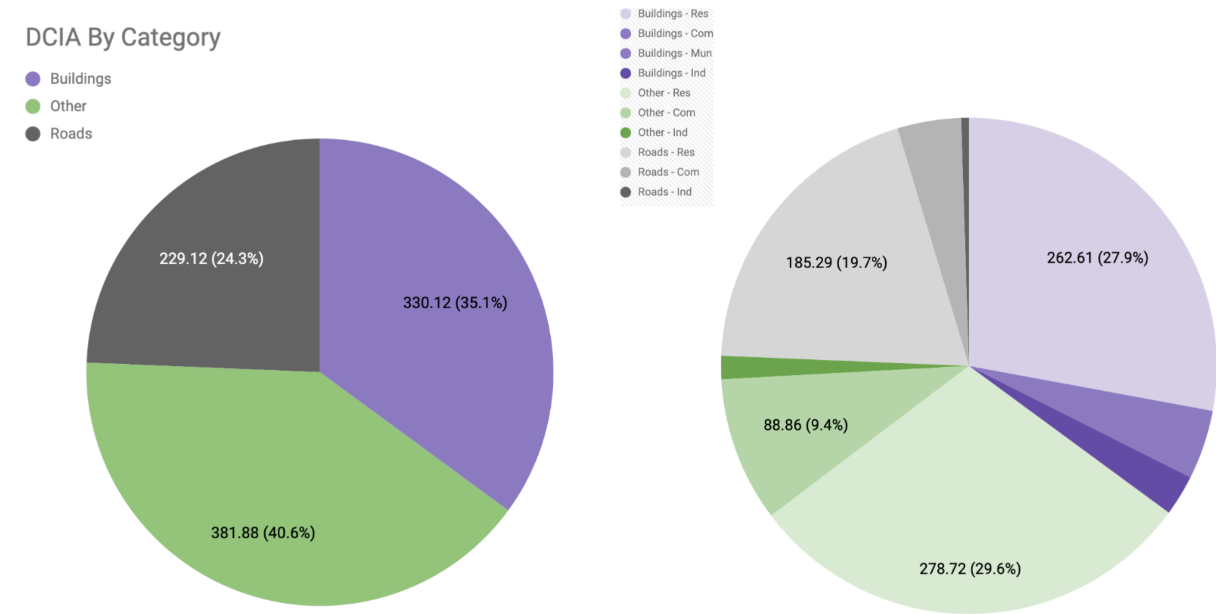

Figure 4. a) Pie chart of DCIA in each category (buildings, other and roads), b) Pie chart of the relationship between DCIA category and land use.

	Residential			Commercial			Municipal			Industrial		
	B	O	R	B	O	R	B	O	R	B	O	R
Where is the most DCIA?	2	1	3	5	4	6	10	10	10	7	8	9
What could be address the quickest?	2	2	2	3	3	3	1	1	1	4	4	4
What is the most environmentally beneficial?	2	2	2	1	1	1	3	3	3	1	1	1
What is most cost effective?	1	3	3	1	7	7	1	2	2	1	7	7
...												
	7	8	10	10	15	17	15	16	16	13	20	21

Figure 5. Identifying areas of interest questionnaire. This chart is included in the Workbook as sheet “3. 1) AOI” and can be easily changed based on a town’s needs. The numbers filled in are for example and do not have any meaning.