Stormwater Study Area 'B'

Town of Kure Beach

April 8, 2020

Custom Solutions | Proven Results | Next Door

Prepared by:

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Prepared for:

NORTH CAROLINA PROFESSIONAL SEAL 038624 2020-04-30 ENGINEER JONATHAN D. HINKLE

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April 8, 2020

Mr. Jimmy Mesimer
Public Works Manager
Town of Kure Beach
815 New Bridge Street
Jacksonville, NC 28541

Subject: Stormwater Study – Area 'B'

Dear Mr. Mesimer and Members of Town Council:

LDSI, Inc. (LDSI) is ecstatic to have the opportunity to provide our findings to develop a strategy and analysis of the town's drainage infrastructure which was of concern following the reports to Town Council after Hurricane Florence. While we do not design for Hurricane level storm events, it is important to evaluate and assess infrastructure resiliency following natural disasters. Opportunities like this fuel the passion of our expert engineers, surveyors, planners, and biologists, and projects like this are the foundation of our company. LDSI has a personal interest as many of our team members were also directly impacted by the hurricane and has enjoyed the opportunity to assist the Town in its recovery efforts.

We thank you again for the opportunity to present our findings, analyses, and ideas to make these projects successful for the Town of Kure Beach, its stakeholders, its landowners, and partners.

Sincerely,

Jonathan Hinkle

Jonathan D. Hinkle, PE
LDSI, Inc.

Table of Contents

A. Executive Summary

LDSI was hired by the Town of Kure Beach to survey the existing stormwater infrastructure present within Area A and Area B. The surveyed data was compiled into an online GIS database for the Town to use and add to their records. LDSI was also hired to conduct an analysis of the stormwater drainage network present within Area B. This was done to analyze deficiencies within the network that could lead to improper function or failure of the network. The analysis was completed through in-depth modeling of the existing network under multiple simulated storm conditions. It was found that there are multiple sections of the network that inhibit performance or that cause tailwater effects to upstream portions of the network. Additionally, large portions of the network are inhibited due to sediment gathering within the drainage infrastructure.

B. Background

LDSI, Inc was contracted to collect infrastructure data on Area A (Exhibit A) and Area B (Exhibit B) as well as analyze the watersheds within Area B as seen on the attached booklet (Exhibit B). The engineering team has created advanced stormwater routing models to determine where probable flooding locations are located throughout Area B. Calibration of these models has included adjustment of the soil infiltration rates to account for the rapidly infiltrating sand at Kure beach. On site watershed mapping was done for Area B to supplement the ground elevation data gathered from LiDAR as well as to account for the multiple new or different structures present since the time of LiDAR data collection. This data was digitized so that it could be effectively entered into the stormwater model. This data was then utilized by the stormwater model to determine runoff volumes to each point within the stormwater infrastructure.

B.1 Project Assumptions

As stated at the proposal meeting in the fall of 2019, the Town did not want camera inspections of the pipes nor was that the intent of the LDSI proposal. LDSI would concentrate on and be limited to specific portions of the pipe network in which the Town had received comments from residents that their property had experienced some standing stormwater/flooding/ponding. Portions of the network within Area B that drained to locations outside of Area B were excluded from the modeling phase of the project. After a walk through the networks LDSI noticed several drainage networks that were "clogged" at various levels with sediment, standing water, detrital material, and other debris. Within the modeling phase of the project, LDSI analyzed the maximum performance of the network by modeling it in an unobstructed condition. LDSI made attempts to find the pipe inverts within the analyzed drainage infrastructure, and for the pipes which had accumulated debris, LDSI developed a formula to calculate the inverts based on the surveyed elevation on top of the debris and the percentage of the pipe obstruction. This was calibrated on approximately 25% of the pipes within the study area. (See survey section C for further information).

Additionally, adjustments to the infiltration capacity were made to the hydrologic model based on professional experience, coastal sand dune information, as well as multiple conversations with Town staff. LDSI adjusted the curve number (CN) and rational coefficient (C) values to allow for increased infiltration into the deep sand within the project area. (See hydrology section D for further information).

LDSI obtained climate data from the North Carolina State Climate Office and ran statistical analysis to determine the difference between current published precipitation data and the rainfall events experienced over the last couple of years through 2016. This data does not include Hurricane Matthew and Florence. Granted no engineer would recommend designing to the service level of a Hurricane Matthew, but the statistical analysis of these systems can affect the magnitude of the lower intensity storms if they are occurring on a more frequent basis. In other words, if there is one Hurricane Matthew, statistically it is considered an outlier; however, when you start seeing multiple hurricanes it becomes difficult to statistically prove that it is an outlier. After obtaining the data and performing the analysis LDSI did notice a slight increase in the precipitation depth and intensity from the current NOAA Atlas 14 data, for lower return period storms (see hydrology section D).

C. Survey Efforts

LDSI completed the surveying phase of the project for both Areas A and B. The information gathered includes coordinates, elevations, ground cover, photos, and dimensions of structures, as well as coordinates, dimensions, materials used, % clogged. This information has been digitized into a GIS format that will be transferred to the town for their own records and use. Cross sections for the ditches were collected and used during the modeling phase of the project but this information will not be included within the online GIS database. The GIS database is formatted as a map with pipes and structures superimposed on top of the map imagery. Pipes and structures can be clicked on to reveal their information and a link to a photo taken at their location. During the contract period, LDSI staff noted a large sediment fluctuation within the project area. LDSI noticed that structures that were impacted with sand and debris would have differing amounts the next week depending on the intensity of the storm events and the flushing or influx of sediment into the drainage network.

D. Hydrology

Historic rainfall data for Kure Beach was determined via NOAA's Atlas 14 tool. This rainfall data was used to generate an Intensity Duration Frequency (IDF) chart (Figure B) that would govern the storms simulated within the hydrologic model. The IDF chart was input into the model to simulate a variety of conditions ranging from a 2-yr storm to a 25-yr storm in order to assess the performance of the existing drainage network. Watersheds were individually delineated for each catchment leading into the stormwater system so that a comprehensive analysis could be conducted of each section of the network. As a part of the analysis, rainfall area, percent impervious surface, composite time of concentration, and type of surface flow experienced during a storm event were determined for model inputs. These values were used when calibrating the stormwater model to determine at which points during a storm event any given section of the pipe network would be under maximum load. Determining the maximum load that the network might experience during a storm allows deficiencies in the network to be predicted and analyzed. This also allows for any tailwater effects that might be caused upstream of that section to be determined. The ponds within the network were modeled as interconnected surface water bodies so that the wholistic effects of storage, stormwater attenuation, flood routing, and tailwater could be analyzed. The available maximum volume of the ponds was determined using LiDAR data as well as cross sections and supplemental information recorded by the survey team.

When analyzing the hydrologic conditions of Area B, it was necessary to account for the sandy, rapidly draining soils that are present near Kure Beach. These soils allow for very high stormwater infiltration rates which prevent a significant portion of the stormwater from ever entering the drainage infrastructure. While runoff still occurs during large storm events, it is important to realize that surface flow does not mean that infiltration is not occurring. This means that any stormwater that passes over local soils prior to entering the drainage network will have a portion infiltrated into the soils, thus reducing the amount of water that must be routed through the drainage network. The runoff from the catchments during a storm event was simulated for each individual catchment using the modified rational method. The modified rational method differs from the traditional rational method in that the duration of the storm event can be easily adjusted to calibrate the model. The modified rational method is an advantageous option for hydrologic calculations because it can simulate scenarios where the drainage network is under peak loading.

LDSI performed data validation for the IDF numbers provided by NOAA's Atlas 14 tool prior to implementing them. This was done to account for the changes in coastal storm intensity and frequency over the past few years. After performing an in-depth statistical analysis of rainfall values gathered from site's near Kure Beach, it was determined that an increase in storm intensity has not been accounted for in low-duration, high-recurrence storm events. However, these increases were minor and did not warrant changes in the design criteria or evaluation of the current drainage network. Consequently, the current Atlas 14 values were used in the creation of the IDF.

KURE BEACH						
	Recurrence Intervals					
Duration	2	5	10	25	50	100
1 hour	No Increase	No Increase	No Increase	No Increase	No Increase	No Increase
2 hour	No Increase	No Increase	No Increase	No Increase	No Increase	No Increase
3 hour	No Increase	No Increase	No Increase	No Increase	No Increase	No Increase
6 hour	Increase	Increase	No Increase	No Increase	No Increase	No Increase
12 hour	Increase	Increase	Increase	No Increase	No Increase	No Increase
24 hour	Increase	Increase	Increase	Increase	Increase	No Increase

Figure A: The Results of a Revised Statistical Analysis of Current Rainfall Data

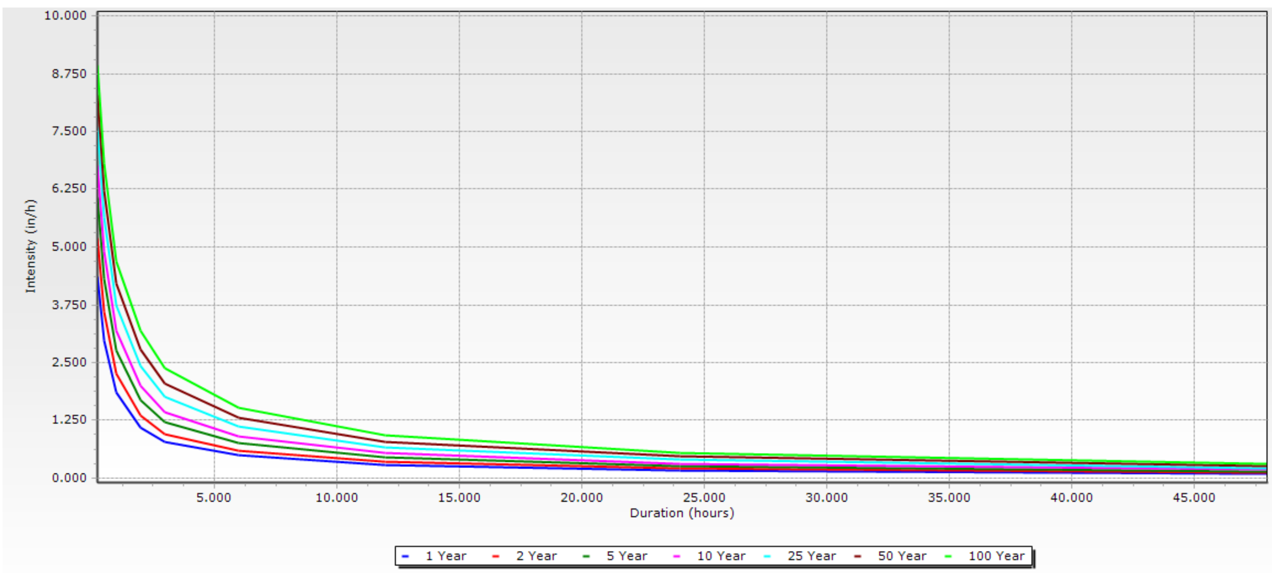


Figure B: The IDF Curve Used to Generate Storm Events within the H&H Model

E. Hydraulics

The rainfall runoff data generated by the simulated storms and watershed parameters was input to the model so that the existing network's hydraulic properties could be analyzed. These properties included Hydraulic Grade Line (HGL), Water Surface Elevation (WSE), maximum flow, and maximum velocity. It was found that there are multiple choke points or restrictions within the existing drainage network. This means that there are multiple locations where downstream pipes are smaller than their upstream pipes. Transitioning from a pipe of a larger diameter to one of a smaller diameter severely restricts the quantity of water that can pass through and results in increased tailwater upstream of that pipe. Additionally, there are junction choke points where multiple pipes all lead into a single pipe that is not capable of adequately handling the volume of water that is provided. These have the same effect of reducing the quantity of water that can pass through and increasing the upstream tailwater. In addition to these choke points, there are several pipe runs throughout the network that are installed at a reverse grade. Water flowing through these sections of pipe must travel "uphill" in order to pass through them which is typical of systems in the flat tidal sections of NC's coastal plain. These sections of pipe require a larger head (driving force) for water to flow through them. This increases the tailwater effects on upstream pipes while reducing flow and increasing the likelihood of surface ponding. The stormwater drainage system at Kure Beach is gravity driven so any pipe runs set on a reverse grade inhibit the functionality of the network, and at low volume levels can even result in reverse flow. Several sedimentation restrictions have also been identified within the existing network including multiple clogs and blockages. It was also noted that there is a high level of sediment flux within the network, meaning that sediment washes into the pipes and a portion of that also washes out at the end of the pipes or settles within the ponds. There were multiple severe blockages due to sedimentation, including several surface exposed pipes that became partially or completely filled with soil. Sedimentation reduces the flow capacity within the pipe network by limiting the available area for water to flow through. Additionally, sedimentation will also reduce storage capacity and stormwater attenuation capability of the ponds within the drainage network.

The hydraulic properties of the drainage network were analyzed using CivilStorm. Civilstorm was selected for modeling the existing system at Kure Beach because it accurately models the tailwater effects of ponded surfaces through its Interconnected Pond Modeling (ICPM) functionalities. This feature was key in analyzing the impacts that storm events had on the entirety of Area B rather than attempting to analyze one catchment at a time. Using Civilstorm also allowed the same simulation to be run with different recurrence interval storms to see how the existing drainage network would respond to each one. This was used to analyze the network for pipe surcharging (a condition that occurs when the water level within a structure is higher than the top of the pipe) and determine which portions of the network are most at risk or are causing the most issues.

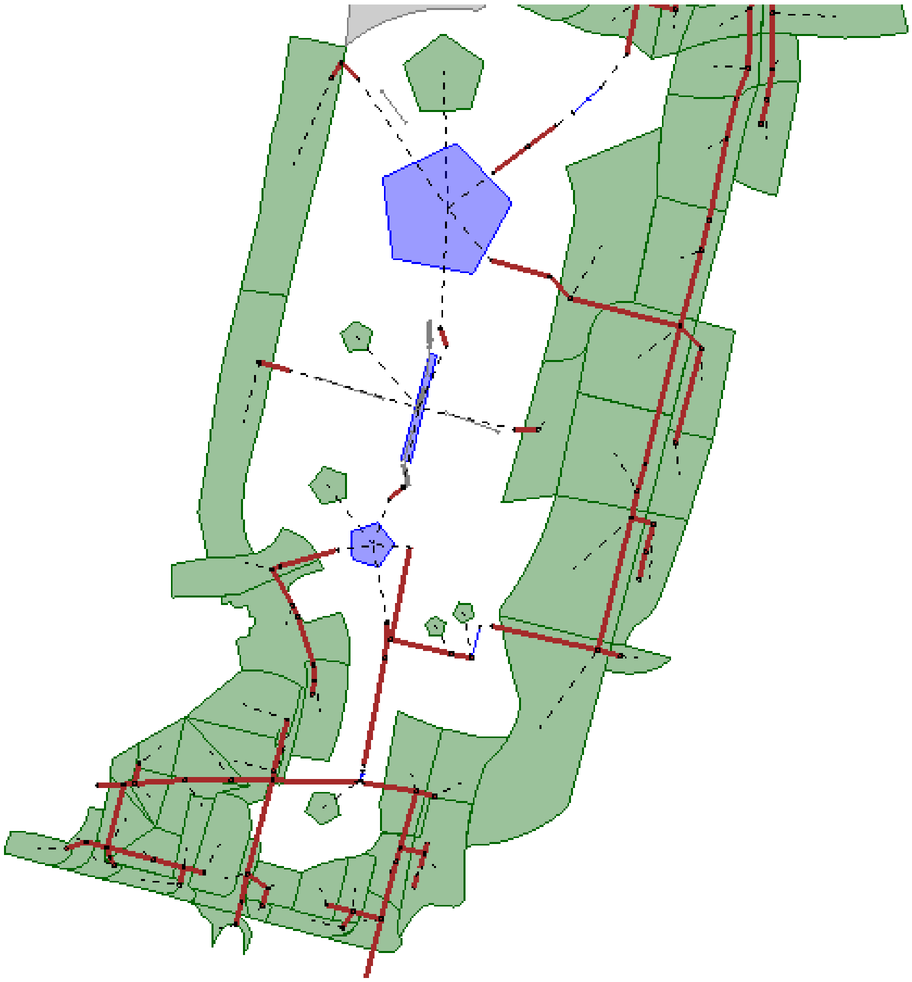


Figure C: A Plan View of the H&H Model Created in CivilStorm

F. Summary of Findings

After analyzing the H&H model, LDSI found that multiple pipes operate under surcharged conditions during storm events at recurrence intervals as low as 2 years. The more intense, higher recurrence interval storms caused more pipes to operate under surcharged conditions as seen in Figure D (note that each recurrence interval includes all pipes from the previous intervals). A surcharged pipe condition is a sign that the pipes in place are likely undersized or are inhibited in some way. This could include pipes being installed at a reverse grade, choke/throttle points within the pipe network, or an excess of pipes being drained through a single outlet.

ADDITIONAL PIPES SURCHARGING BY RECURRENCE INTERVAL			
2-yr	5-yr	10-yr	25-yr
PI-406	PI-596	PI-593	PI-622
PI-405		PI-563	PI-629
PI-404		PI-569	PI-572
PI-602		PI-588	PI-571
PI-565		PI-576	PI-556
PI-507		PI-582	PI-589
PI-409		CO-16	PI-592
PI-597			PI-578
PI-594			CO-15
PI-595			
PI-598			
PI-603			
PI-583			
PI-564			
PI-528			
PI-573			
CO-3			
CO-4			
CO-5			

Figure D: List of Recurrence Levels Where Pipes Become Surcharged

LDSI’s team identified five specific throttle points that are causing restrictions to performance within the drainage network. As seen in Figure E, the inlet box at the corner of K Ave & N 5th Ave has a 15” pipe and an 18” pipe leading into it with only a 12” pipe leading out. However, the H&H model does not show this specific run of pipes as being surcharged at any point within a 25-year storm event. It is likely that the 15” pipe section running into it is larger than it needs to be for the watershed that it is draining. Additionally, the 18” pipe leading into the structure is only a 12” pipe at the other end. This indicates that either the pipe changes diameters at some point along this run, or there are additional pipes feeding into the 18” pipe. Without performing a camera inspection, it was not possible to determine so when modeling the system, the pipe run was treated as a single pipe. The 12” end of the pipe is located in one of the “homemade” style inlet boxes as seen in Figure N.

Figure E: A Choke Point By the Intersection of K Ave & N 5th Ave

The next choke point of concern is behind the fire station on K Ave as seen in Figure F. The point is located upstream of the outlet for the drainage network. A 48" pipe and an 8" pipe feed into a 30" pipe. That 30" pipe has an additional 18" pipe run into it prior to discharging. This configuration significantly reduces the ability of the 48" pipe and under full conditions would cause significant tailwater interferences. However, the H&H model revealed that the interconnected pond network allows for a great deal of stormwater storage and significantly attenuates the volume of water that must be discharged from the network at any given time. The model showed that this junction also does not operate under a surcharged condition during a 25-year storm event. When analyzing severe "worst case" storm events, it was found that the existing network will use the ponds to attenuate stormwater and relieve pressure that would have otherwise been on the lower run of the network. This is advantageous in that it means the configuration shown in Figure X is functional within the current network. However, it poses a potential problem in that a large storm event would cause flooding within the ponded areas prior to reaching the system's maximum outflow capacity.

Figure F: A Choke Point Behind the Fire Station on K Ave

A throttle point, as seen in Figure G, was found on the West side of N 4th Ave in between L Ave & M Ave. This throttle point consisted of an 18" pipe running into a 12" pipe and then into a 15" pipe. This reduction in capcity significantly inhibits the performance of the drainage network. The H&H model revealed that this pipe run, along with portions upstream of it, operate under surcharged conditions during a 2-year storm event.

Figure G: A Throttle Point Along N 4th Ave Between L Ave & M Ave

A significant choke point was identified between N 5th Ave and Settler's Ln as seen in Figure H. Two 24" pipes below a ditch and an additional 24" pipe all run into a single 30" pipe. The capacity of the three 24" pipes far exceeds the capacity of a single 30" pipe. However, it was found that the quantity of water routed through the two 24" pipes is significantly attenuated by the pond network that it drains. Because the upstream ponds store such a large volume of water and only drain through the two 24" pipes, the outflow is throttled by an inlet boundary condition. Due to this, the choke point identified in Figure H does not cause any surcharging within a 25-year storm event.

Figure H: A Choke Point Between N 5th Ave and Settler's Ln

The final significant choke point found during the analysis is located at the intersection of M Ave and N 5th Ave as seen in Figure I. Two 15" pipes along with a 12" pipe feed into a single 18" pipe. The H&H model reveled that during a 25-year storm event the quanitiy of water passing through these pipes is not enough to cause a surcharge condition.

Figure I: A Choke Point at the Intersection of M Ave and N 4th Ave

LDSI's model shows that surface ponding should occur in storm events as low as a 2-yr recurrance interval as seen in Figure J. Surface ponding at a 2-yr recurrance interval likely occurs at DI- 6050 which is located at the the downstream end of the ditch at the corner of L Ave and N 5th Ave. This is due to the fact that the network is configured so that water flows from a channel into a drop inlet with a shallow box. With the level of blockage within the pipe leading to the ditch along with the nature of the configuration, it is likely that ponding that occurs here is insignificant and should be field verified during a storm event. The next overflow does not occur until a 10-yr storm event at DI-6058. This is the structure previously mentioned as a throttle point where an 18" pipe is reduced to a 12" pipe. It is likely that surface ponding reported in this location is indeed valid and will occur during a 10-yr or greater storm. The final overflowing catchbasin shown within the H&H model is structure 9999. Structure 9999 is located West of Settler's Ln near the intersection of 5th Ave, this was the primary point in Area B reported to have surface water ponding issues. LDSI's field crew observed standing water after a storm event that was not draining properly into the "yard style" inlet. This is due primarily to depressions in the surface of the road that allows for slow drainage and slow evaporating storage. The H&H model revealed that during a 25-yr storm event this inlet should experience overtopping meaning that the capacity of the structure will be exceeded by the storm water.

RECURRANCE INTERVALS FOR CATCHBASIN OVERFLOW			
2-yr	5-yr	10-yr	25-yr
DI- 6050		DI- 6058	9999

Figure J: Recurrance intervals for catchbasin overflow

Figure K: Dual Grate Outlet Drain for Pond Network

Figure L: 18" Pipe Within Ditch Connecting the Ponds

Figure M: Obstructed Inlet Grate

Figure N: "Homemade" Yard Inlet

G. Conclusions and Town Hall Meeting Responses

The primary throttle points within the drainage network for Area B have been identified and documented. These include points where multiple pipes or structures lead to a single pipe or structure that is incapable of handling the flow provided as well as points where pipes suddenly decrease in size and flow capacity. Multiple pipes have been identified as having a reverse grade. However, most of these pipes are downstream of the ponds and the flow that they will be handling is significantly attenuated by the ponds. This means that the primary issue caused by the reverse grades downstream of the ponds is sediment accumulation.

Turning downspouts so that stormwater runs over pervious surfaces could significantly reduce the load placed on the drainage network. Although it may not be obvious, even when water is flowing over the top of a pervious surface such as grass, a portion of that water is being infiltrated into the soil and will never reach the drainage network. The infiltration rate lessens over the course of a storm event as the soil becomes saturated with water, but infiltration still occurs. Preventing a "short circuit" from rooftops into the drainage network could have significant impacts on the function of the stormwater infrastructure while also providing water quality benefits. The soils present within Area B would be especially effective in reducing the load on the drainage system and providing water quality benefits because of their high infiltration rate. Sandy dunes have been found to have infiltration rates higher than 200 in/hr in some locations. A coastal town such as Kure Beach would potentially see a much larger impact than an area in Raleigh where the soil infiltration rates are typically 0.5 – 2.0 in/hr.

Finally, the stormwater infrastructure within Area A has been surveyed and uploaded to the GIS database but has not been analyzed for its effectiveness.

Recommended Next Steps

LDSI recommends the following next steps to further analyze the concerns of the Town Council and residents of Kure Beach:

- Analyze the sediment storage capacity of the ponds within the drainage network
- Perform an alternatives analysis for Area B
- Perform an analysis of the existing drainage network (and alternatives) in Area A
- Perform an ordinance audit and assess options to lower the drainage volume and network demand
- Remove the 18" pipe seen in Figure L
- Perform vacuum maintenance on the existing drainage network to remove sediment
- Replace the 12" pipe seen in Figure G
- Perform micro-grading near Structure 9999 to ensure drainage and prevent surface ponding

Exhibit A

(Area 'A' Maps)

FEAT	POINT_	SURFACE	ELEV	Invert	NOTES
CB-	6200	Asphalt	15.94	11.97	
CB-	6201	Asphalt	15.9	12.25	
CB-	6259	Grass	9.6	<Null>	
CI-	0	*	9.77	<Null>	
DDI-	6216	Grass	10.38	7.05	25
DDI-	6217		12.42	<Null>	
DDI-	6221	Grass	12.37	9.53	
DDI-	6224	Grass	10.2	7.7	
DDI-	6258	Grass	10.15	<Null>	
DDI-	6260	Concrete	9.94	<Null>	
DI-	6121	Other	17.15	13.1	
DI-	6125	Grass	16.5	12	10' WEST OF SINKHOLE
DI-	6126	Asphalt	16.15	12.48	25% CLOGGED
DI-	6127	Concrete	16.41	12.67	
DI-	6128	Asphalt	16.86	12.44	
DI-	6129	Asphalt	16.78	12.5	
DI-	6130	Concrete	15.21	11.41	25% CLOGGED
DI-	6131	Concrete	16.57	11.18	25% CLOGGED
DI-	6132	Asphalt	16.68	12.27	25% CLOGGED
DI-	6133	Asphalt	16.56	12.39	
DI-	6134	Grass	16.97	13	
DI-	6135	Asphalt	16.39	13.39	
DI-	6136	Asphalt	16.51	13.72	
DI-	6137	Grass	17.39	11.23	
DI-	6138	Grass	16.08	11	DOGHOUSED INTO 30' HDPE/FIBERGLASS. CA
DI-	6139	Concrete	16.29	10.97	
DI-	6140	Asphalt	15.82	11.57	
DI-	6155	Asphalt	15.82	11.24	10 DIP WATERLINE IN BACK OF BOX
DI-	6170	Other	16.54	6.56	IN TREES. 50% CLOGGED
DI-	6171	Grass	13.65	6.62	50% CLOGGED
DI-	6172	Other	13.46	7.06	MULTIPLE LARGE CACTI ON GRATE
DI-	6173	Asphalt	15.11	10.89	
DI-	6174	Asphalt	15.11	11.02	
DI-	6175	Grass	12.74	6.99	CRUSHED PIPE. 50% CLOGGED
DI-	6176	Grass	12.6	6.8	50% CLOGGED
DI-	6177	Grass	13.12	6.71	50% CLOGGED. IN TREES
DI-	6188	Asphalt	12.37	6.93	50% CLOGGED
DI-	6189	Asphalt	12.41	6.85	25% CLOGGED
DI-	6190	Asphalt	11.83	6.99	50% CLOGGED
DI-	6191	Asphalt	12.65	7.3	25% CLOGGED
DI-	6192	Asphalt	12.87	10.04	
DI-	6193	Asphalt	13.78	7.66	25% CLOGGED
DI-	6194	Asphalt	12.18	8.69	25% CLOGGED
DI-	6195	Asphalt	12.75	9.23	25% CLOGGED
DI-	6196	Asphalt	12.06	9.37	25% CLOGGED
DI-	6197	Grass	15.08	10.63	
DI-	6198	Grass	15.4	13.45	25% CLOGGED
DI-	6199	Grass	15.28	12.54	25% CLOGGED. UNDER FNC
DI-	6202	Grass	12.13	9.28	
DI-	6203	Grass	12.25	9.42	25% CLOGGED
DI-	6204	Grass	12.09	10.87	YARD DRAIN
DI-	6205	Grass	12.67	10.77	25% CLOGGED
DI-	6206	Grass	12.75	10.12	25% CLOGGED
DI-	6207	Grass	11.12	9.6	25% CLOGGED
DI-	6208	Grass	10.6	9.22	25% CLOGGED
DI-	6209	Grass	10.69	8.84	25% CLOGGED
DI-	6210	Grass	10.79	8.61	50% CLOGGED
DI-	6211	Grass	11.03	8.85	25% CLOGGED
DI-	6212	Grass	10.79	8.64	25% CLOGGED
DI-	6213	Grass	10.67	8.32	25% CLOGGED
DI-	6214	Grass	10.45	8.08	25% CLOGGED
DI-	6215	*	10.17	<Null>	
DI-	6219	Grass	12.36	9.56	50% CLOGGED
DI-	6220	Concrete	13.05	10.22	
DI-	6222	Grass	13.13	10.69	50% CLOGGED
DI-	6223	Grass	12.63	9.55	50% CLOGGED
DI-	6225	Concrete	10.3	7.35	25% CLOGGED
DI-	6226	Grass	9.86	7.86	25% CLOGGED
DI-	6227	Other	13.57	11.85	ROUND DI 18 25% CLOGGED
DI-	6276	GRASS	13.17	<Null>	NONE
DI-	6277	GRAVEL	12.64	<Null>	NONE
DI-	6278	GRASS	12.25	<Null>	NONE
DI-	6279	GRASS	13.25	<Null>	DOGHOUSED INTO 15 RCP
DI-	6280	GRASS	12.89	<Null>	100% CLOGGED CAN NOT SEE INVS
DI-	6281	GRASS	13.4	<Null>	HOLE IN NORTH SIDE OF BOX
DI-	6282	GRASS	12.73	<Null>	NONE
DI-	6157	Asphalt	15.33	<Null>	
DI-	6168	Concrete	16.61	<Null>	
DI-	6169	Grass	14.31	<Null>	60 VERT CMP
DI-	6254	Grass	11.14	<Null>	25% CLOGGED
DI-	6255	Grass	11.2	<Null>	25% CLOGGED
DI-	6256	Grass	11.83	<Null>	OBSTRUCTED NO DATA
DI-	6257	Grass	12.31	<Null>	
DI-	6261	Concrete	10.03	<Null>	4 WL RUNNING EAST WEST
DI-	6228	Grass	13.51	<Null>	25% CLOGGED
DI-	6229	Gravel	13.39	<Null>	25% CLOGGED
DI-	6231	Grass	16.4	<Null>	CONC-GRASS/50% CLOGGED
DI-	6232	Grass	16.18	<Null>	CONC-GRASS/50% CLOGGED/AT&T LINE OR S
DI-	6233	Grass	15.44	<Null>	25% CLOGGED
DI-	6234	Grass	15.32	<Null>	CONC-GRASS/25% CLOGGED
DI-	6235	Grass	13.27	<Null>	25% CLOGGED/WATER LINE OR AT&T LINE IN
MH-	6122	Grass	18.72	12.67	
MH-	6123	Other	18.55	12.6	IN HOLLY BUSH
MH-	6124	Grass	17.92	12.25	
MH-	6218	Gravel	13.61	8.96	75% CLOGGED

LDSI

Date: 2/17/2020

Legend

- Stormwater Structure
- Stormwater Pipe

KURE BEACH STORMWATER STUDY

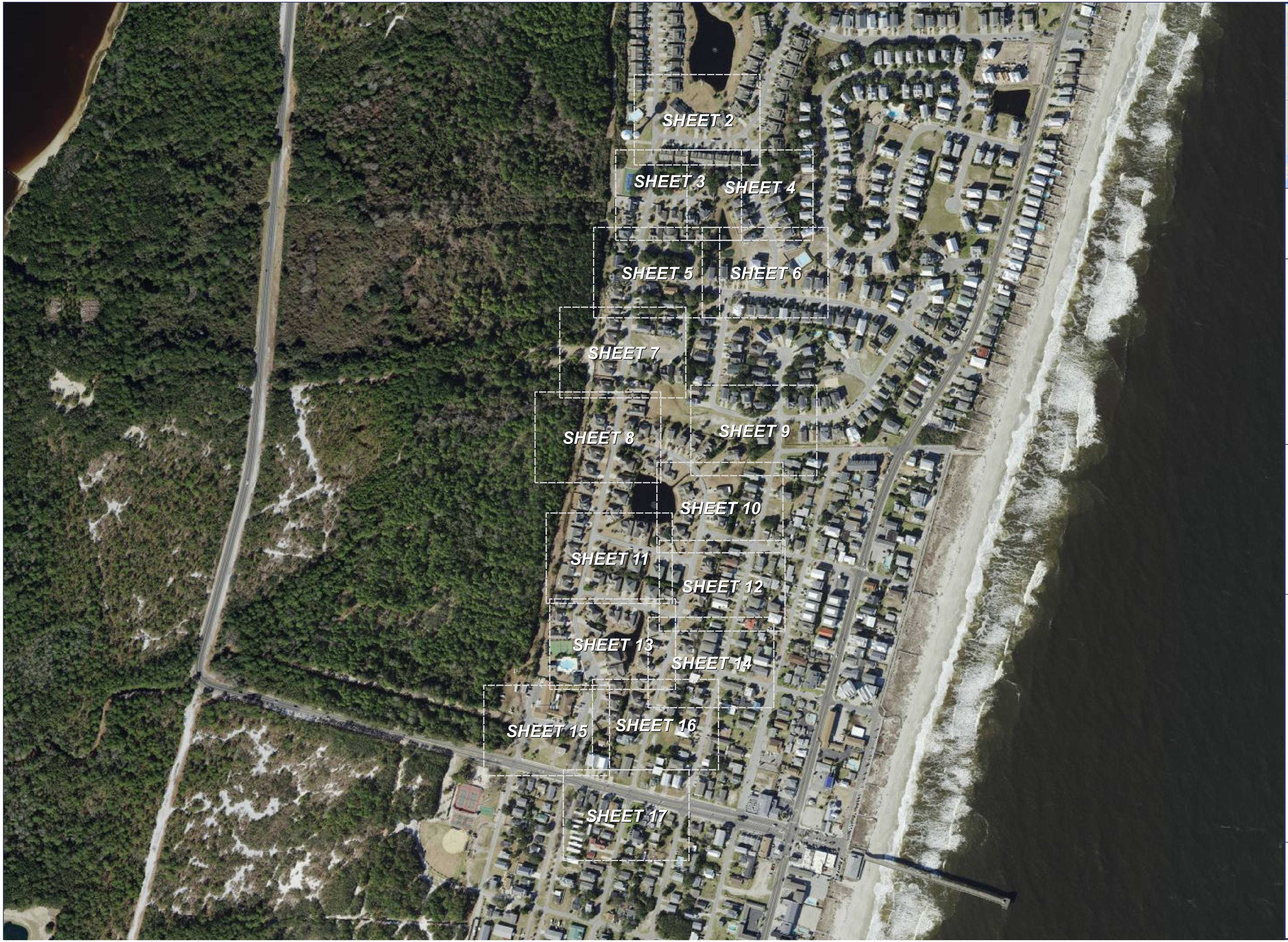
AREA "A"

KURE BEACH, NORTH CAROLINA

0 50 100 200 Feet

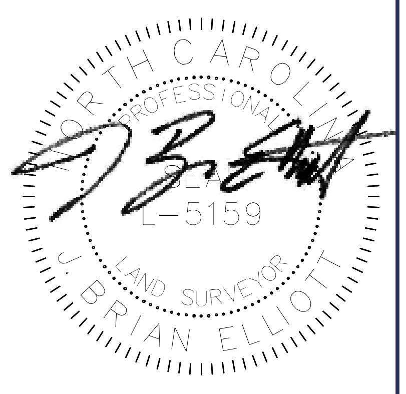
Exhibit B

(Sealed Area 'B')



Vicinity Map: Not to scale

"I, J. Brian Elliott, certify that this project was completed under my direct and responsible charge from an actual ground survey made under my supervision; that the original data was obtained between October 2019 and February 2020; and all coordinates are based on NCState Plane, NAD83"



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SCALE: 1 in = 400 ft
DATUM: NCSP83FT
DATE: 4/29/2020-PAGE 1 OF 18
PROJECT NO: 4519045
MAP BY: belliott

KURE BEACH

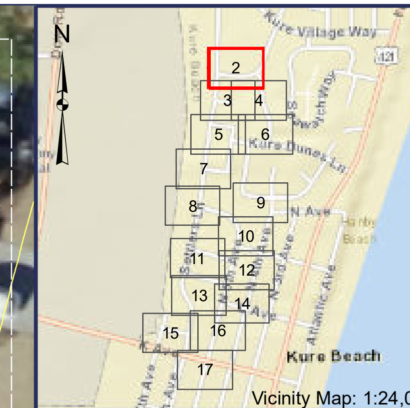
STORMWATER STUDY

NEW HANOVER COUNTY

NORTH CAROLINA

Client: Town of Kure Beach

Path: G:\2019\4519045\04-GIS\AreaB_Booklet\BookletIndex.mxd



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SCALE: 1 in = 40 ft
DATUM: NCSP83FT
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PROJECT NO: 4519045
MAP BY: belliott

KURE BEACH

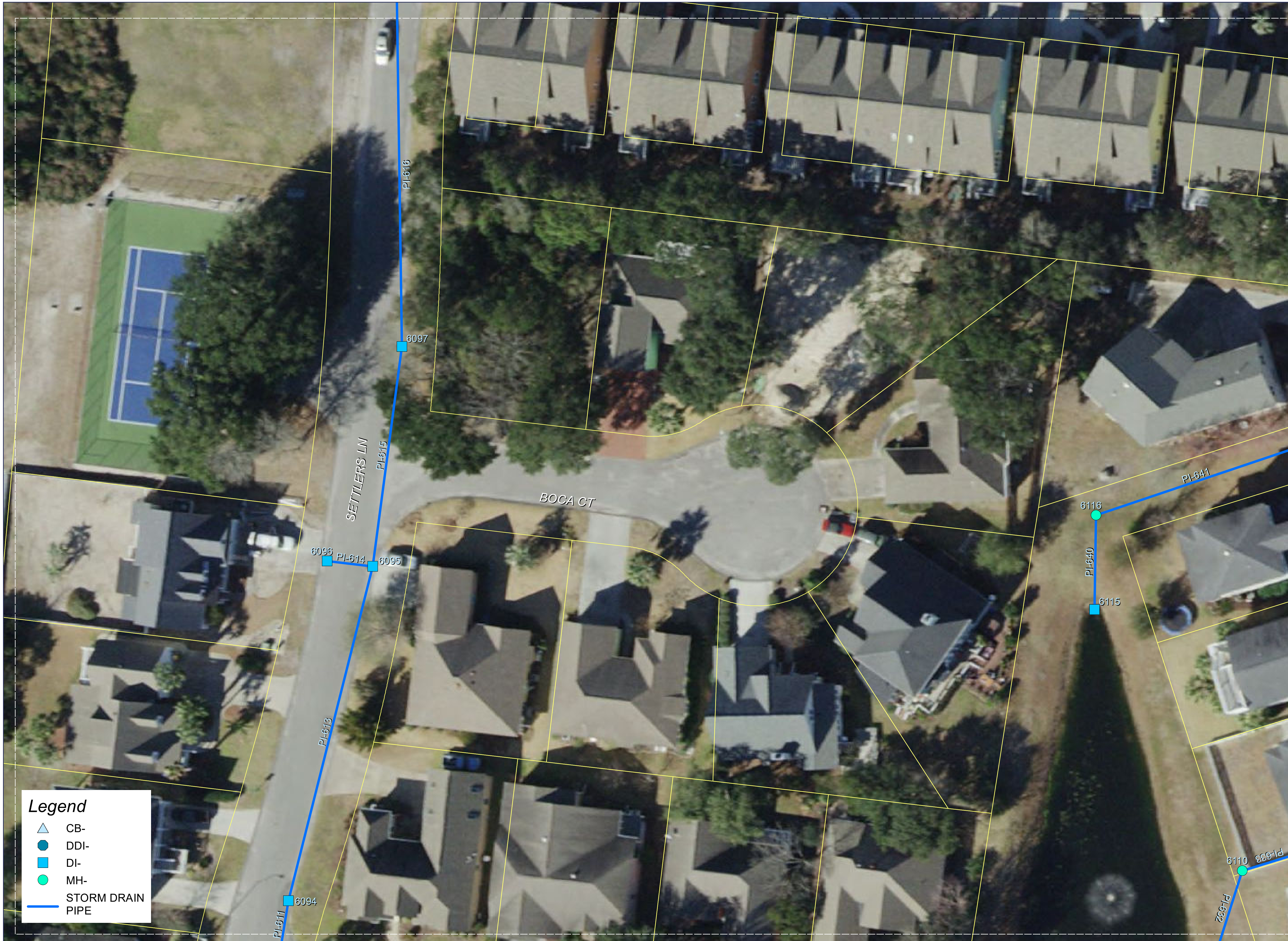
STORMWATER STUDY

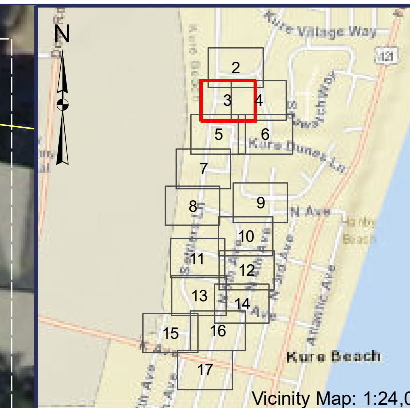
NEW HANOVER COUNTY

NORTH CAROLINA

Client: Town of Kure Beach

Path: G:\2019\4519045\04-GIS\AreaB_BookletSealedMaps.mxd





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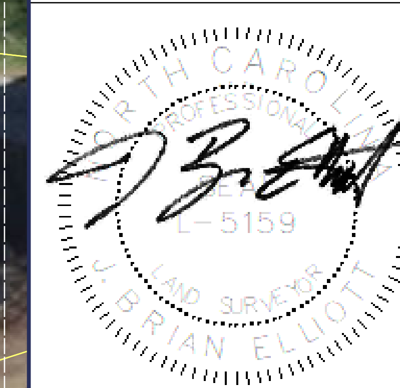

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KURE BEACH

STORMWATER STUDY

NEW HANOVER COUNTY

NORTH CAROLINA

Client: Town of Kure Beach

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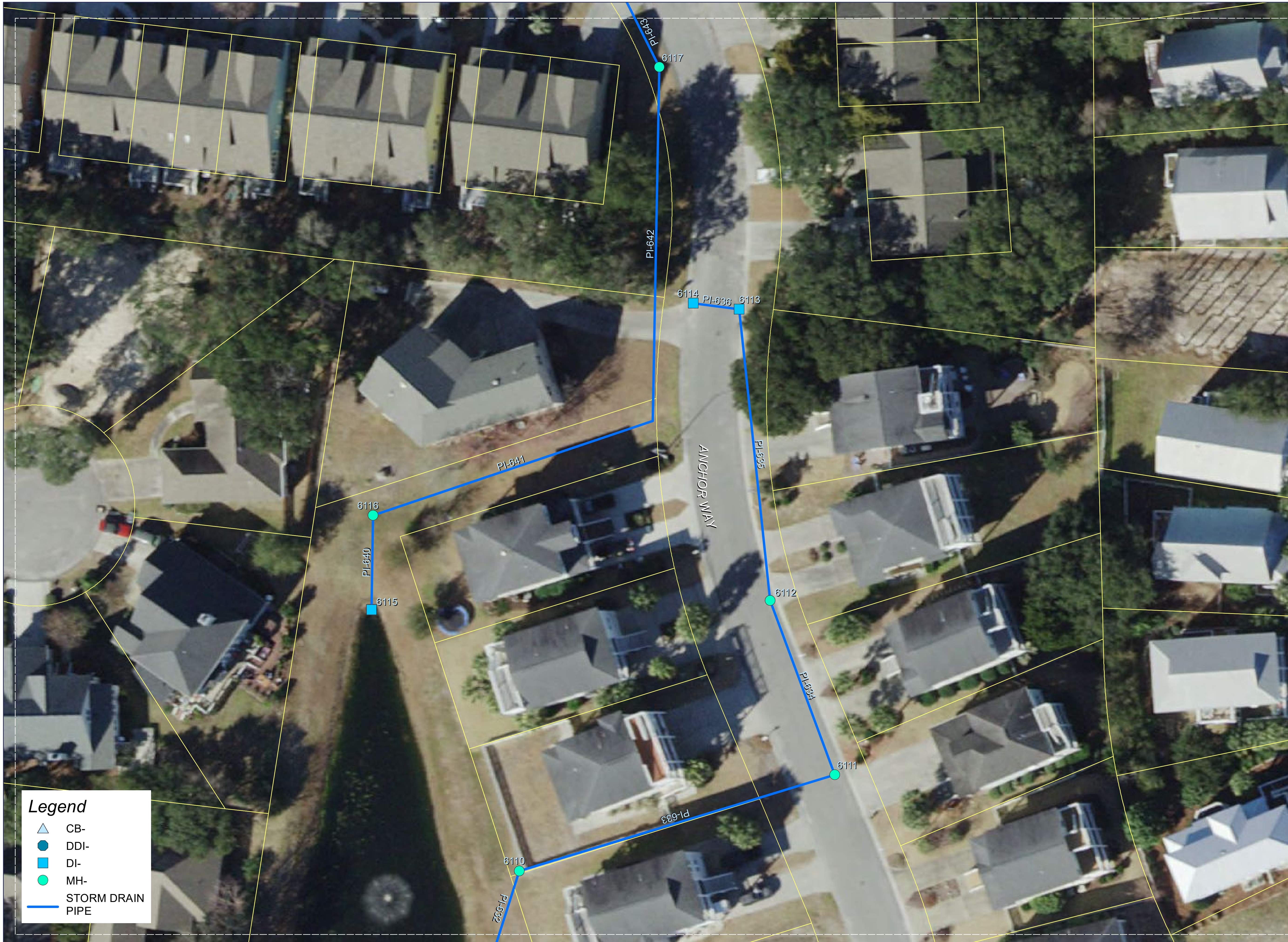

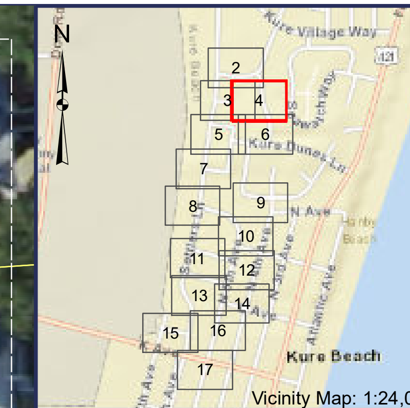

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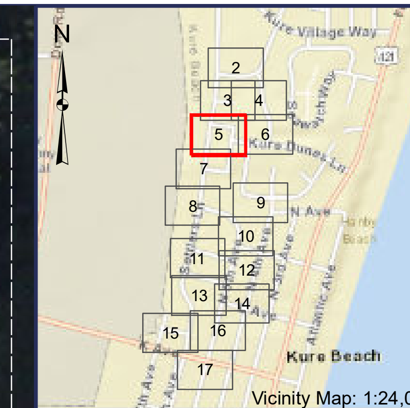
KURE BEACH
STORMWATER STUDY
NEW HANOVER COUNTY
NORTH CAROLINA
Client: Town of Kure Beach



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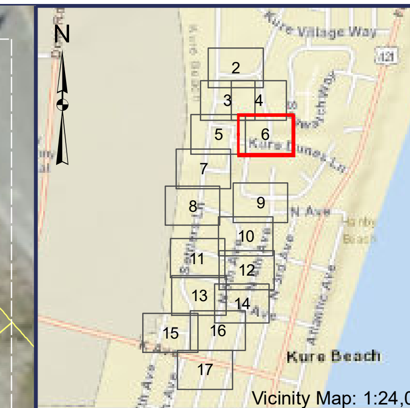

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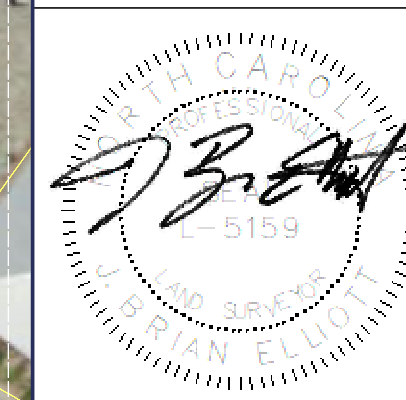

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STORMWATER STUDY

NEW HANOVER COUNTY

NORTH CAROLINA

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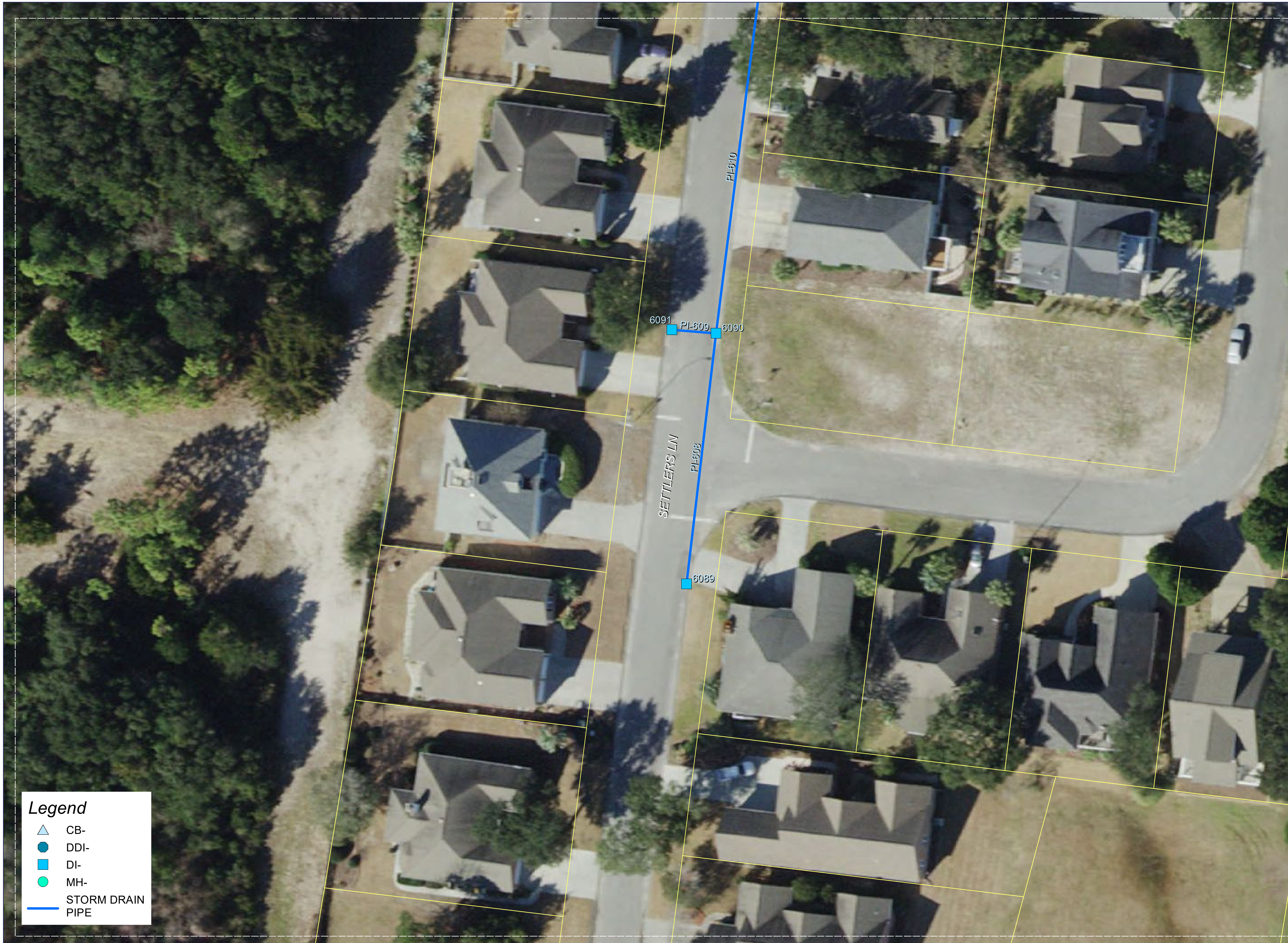

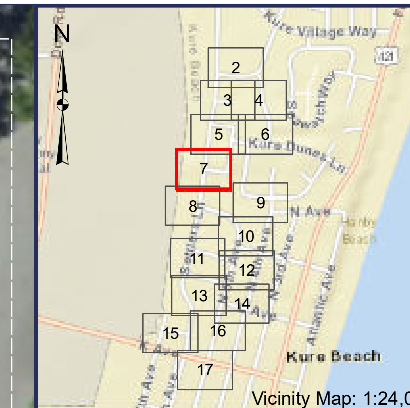

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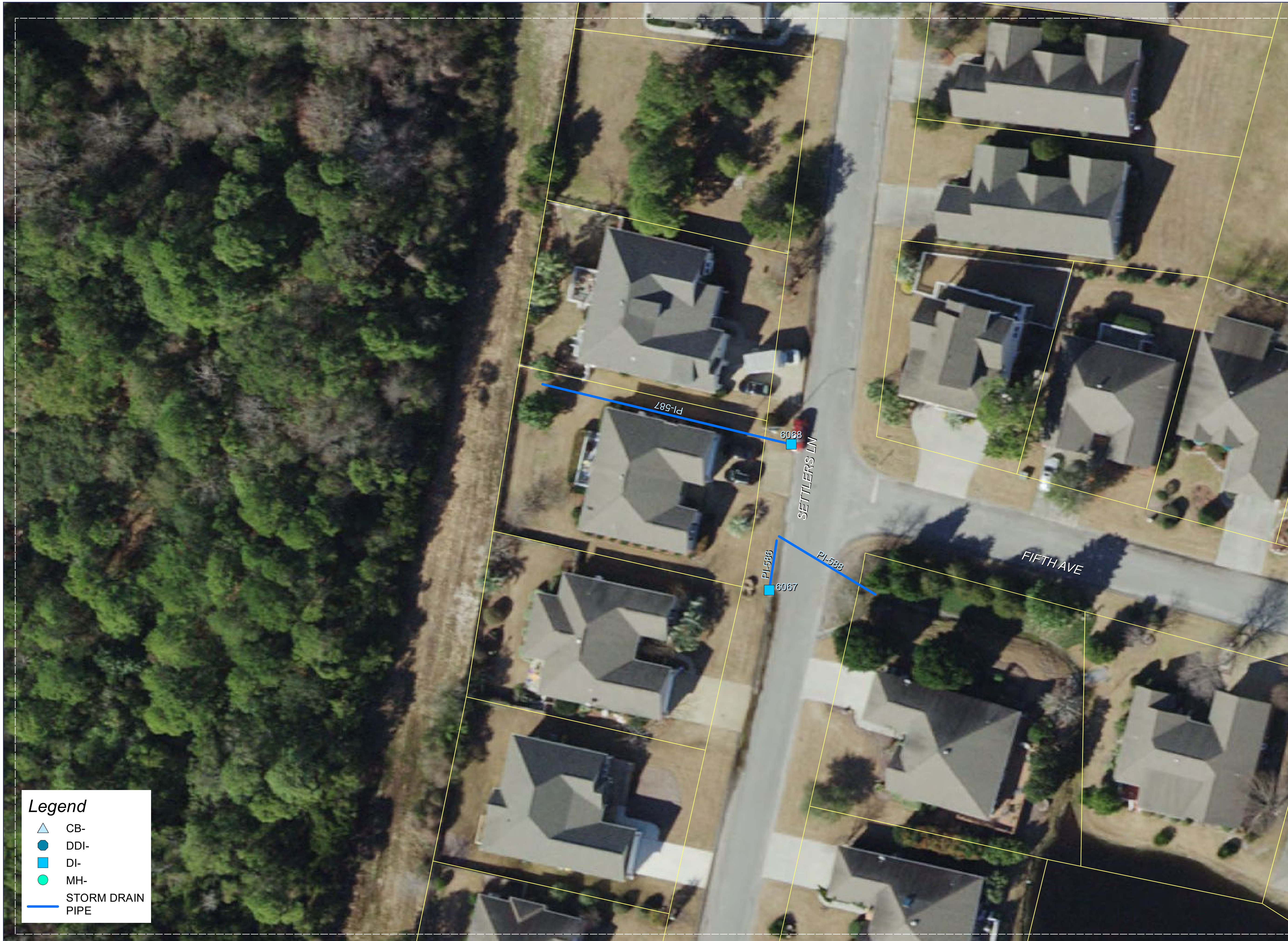

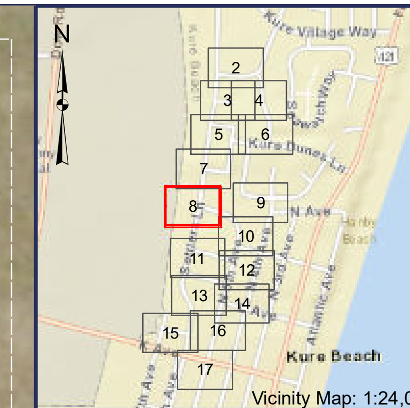

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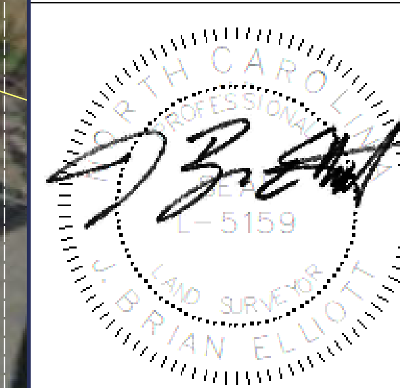

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NEW HANOVER COUNTY
NORTH CAROLINA
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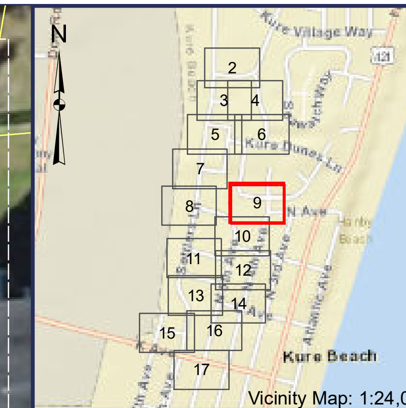

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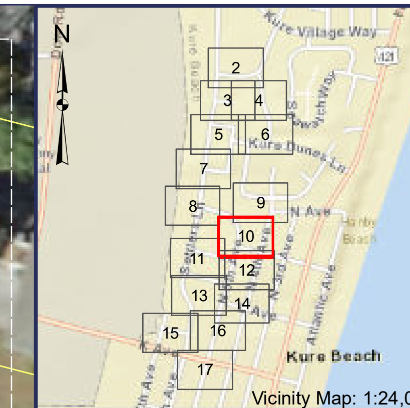

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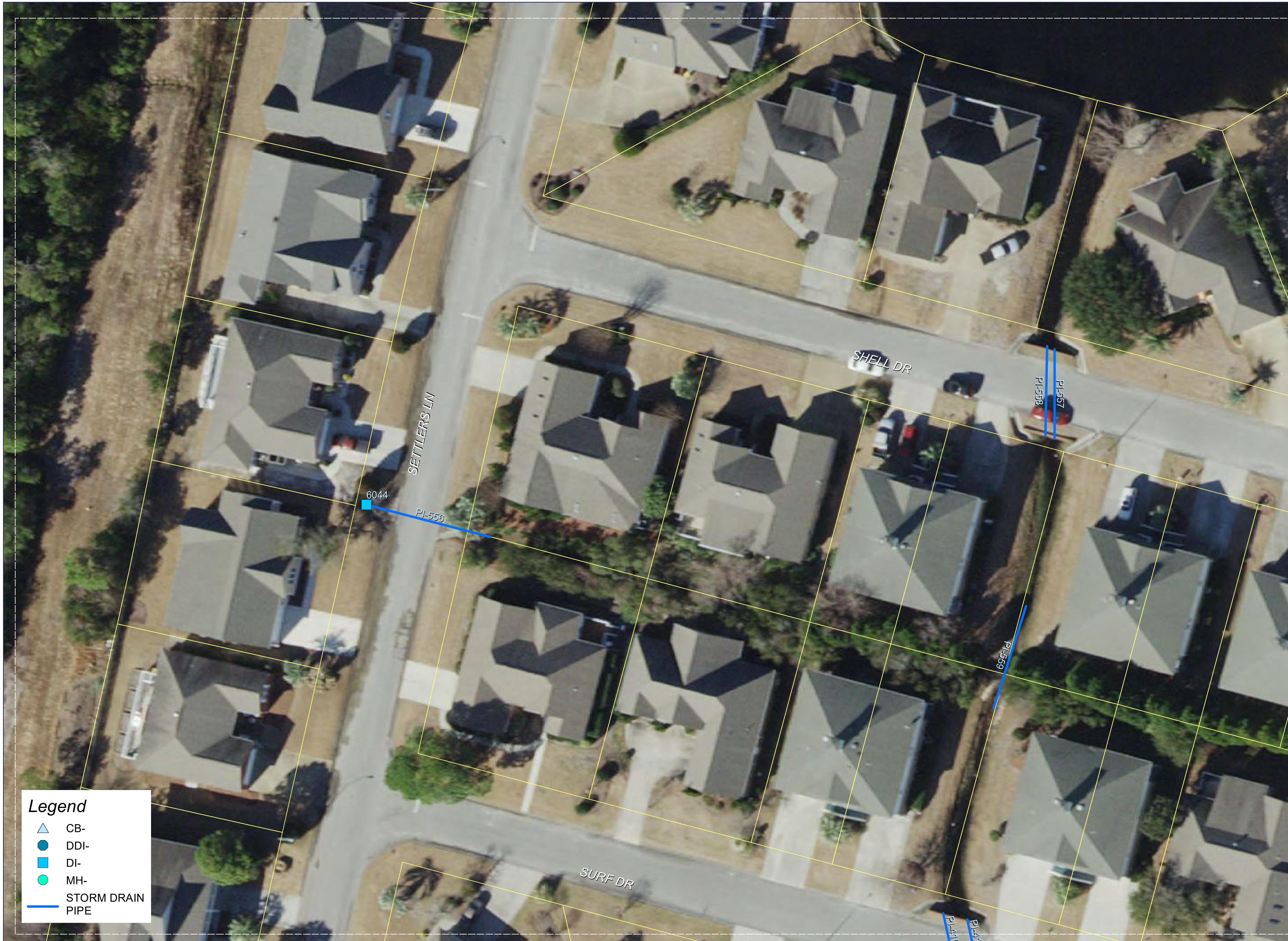

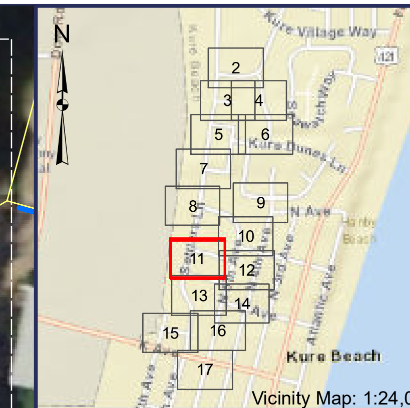

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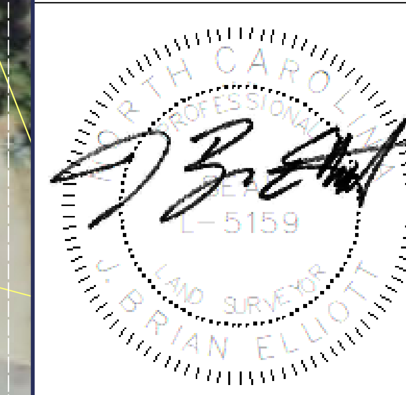

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KURE BEACH

STORMWATER STUDY

NEW HANOVER COUNTY

NORTH CAROLINA

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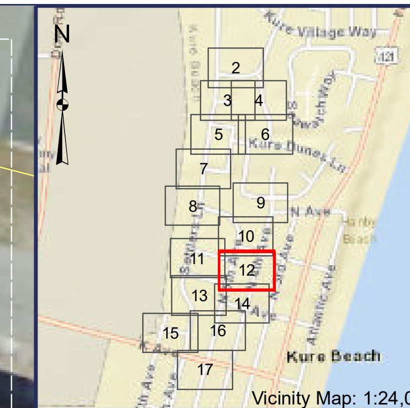

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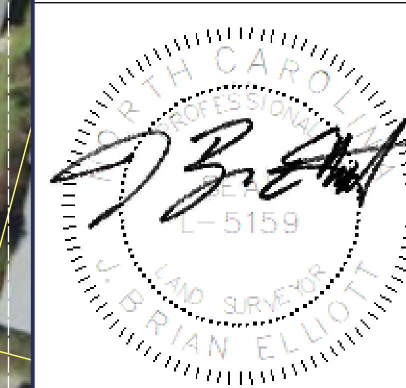

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NEW HANOVER COUNTY

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DATE: 4/29/2020-Page 12 of 18

PROJECT NO: 4519045

MAP BY: belliott

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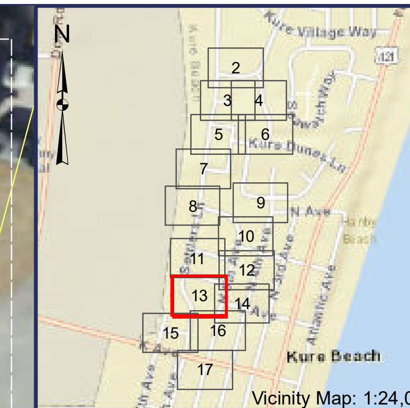

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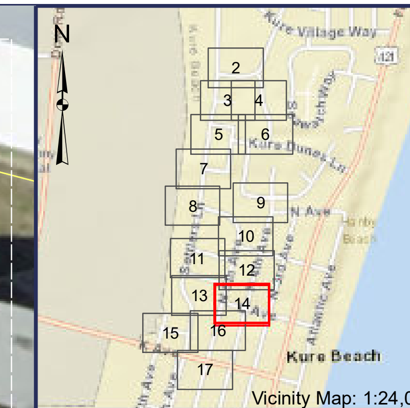

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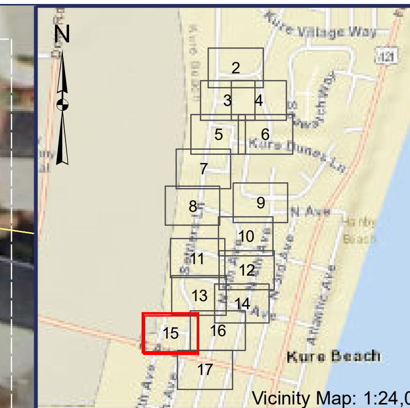

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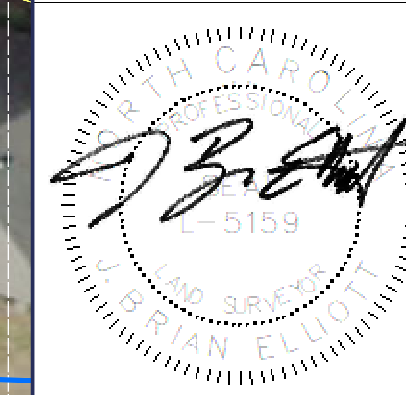

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KURE BEACH

STORMWATER STUDY

NEW HANOVER COUNTY

NORTH CAROLINA

Client: Town of Kure Beach

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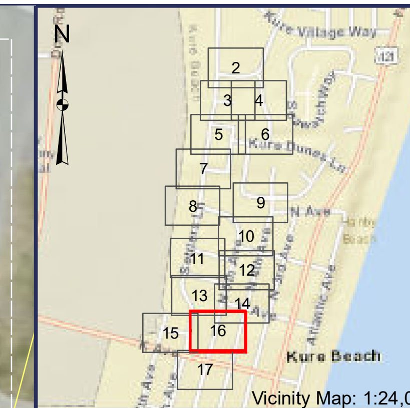

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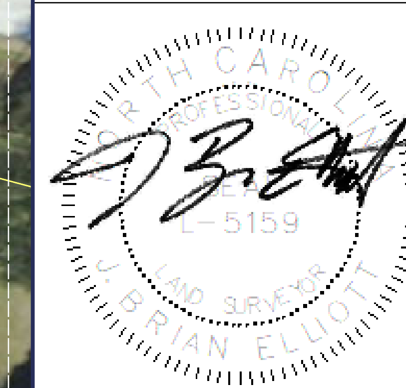

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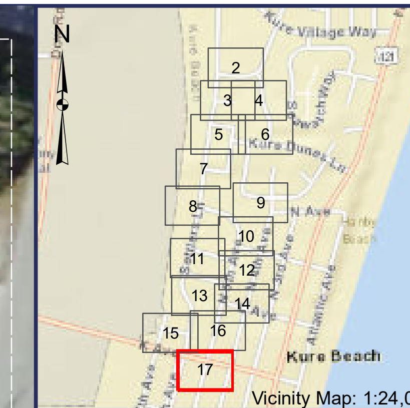

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KURE BEACH

STORMWATER STUDY

NEW HANOVER COUNTY

NORTH CAROLINA

Client: Town of Kure Beach

Path: G:\2019\4519045\04-GIS\AreaB_Booklet\SealedMaps.mxd

POINT_NUMB	DESC_	ELEV	Invert
6000	01-CATCH_BASIN	23.83	14.65
6001	01-CATCH_BASIN	23.13	19.85
6002	02-DROP_INLET	22.51	18.8
6003	08-DBL_DROP_INLET	24.35	20.79
6004	08-DBL_DROP_INLET	22.78	20.7
6005	08-DBL_DROP_INLET	22.57	20.92
6006	01-CATCH_BASIN	23.49	21.4
6007	02-DROP_INLET	23.76	14.79
6008	01-CATCH_BASIN	23.55	20.04
6009	02-DROP_INLET	23.01	15.03
6010	08-DBL_DROP_INLET	22.70	15.2
6011	02-DROP_INLET	22.63	16.17
6012	01-CATCH_BASIN	22.78	18.9
6013	01-CATCH_BASIN	22.81	19.86
6014	08-DBL_DROP_INLET	23.34	18.42
6015	04-MANHOLE	23.53	19.16
6016	01-CATCH_BASIN	23.80	20.28
6017	08-DBL_DROP_INLET	21.65	19.66
6018	01-CATCH_BASIN	23.28	20.7
6019	02-DROP_INLET	21.07	17.1
6020	02-DROP_INLET	21.04	17.08
6021	08-DBL_DROP_INLET	21.82	19.88
6022	08-DBL_DROP_INLET	21.67	19.46
6023	01-CATCH_BASIN	23.24	20.88
6024	08-DBL_DROP_INLET	22.00	19.55
6025	02-DROP_INLET	22.34	20.74
6026	02-DROP_INLET	21.89	19.64
6027	02-DROP_INLET	21.60	18.63
6028	02-DROP_INLET	21.65	19.41
6029	02-DROP_INLET	23.05	21.13
6034	02-DROP_INLET	22.68	20.03
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6038	02-DROP_INLET	22.97	20.46
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6054	02-DROP_INLET	22.20	20.56
6055	02-DROP_INLET	22.52	20.56
6056	02-DROP_INLET	22.53	20.79
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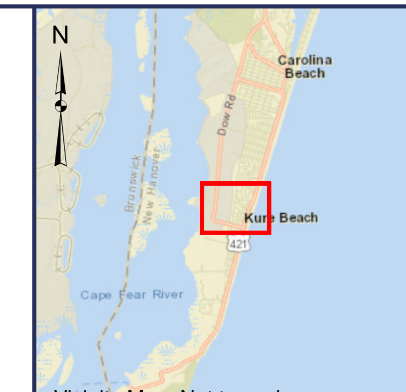
6058	02-DROP_INLET	21.98	20.61
6059	02-DROP_INLET	22.15	20.53
6060	02-DROP_INLET	23.34	20.09
6061	02-DROP_INLET	23.60	21.51
6062	02-DROP_INLET	22.45	20.93
6063	02-DROP_INLET	21.52	18.82
6064	02-DROP_INLET	21.70	18.4
6065	01-CATCH_BASIN	23.28	20.08
6066	04-MANHOLE	23.99	20.59
6067	02-DROP_INLET	22.13	0
6068	02-DROP_INLET	22.11	21.11
6069	02-DROP_INLET	20.74	17.67
6070	02-DROP_INLET	20.70	17.51
6071	02-DROP_INLET	22.39	18.9
6072	02-DROP_INLET	22.38	18.61
6073	02-DROP_INLET	21.66	16.31
6074	02-DROP_INLET	21.35	15.76
6075	02-DROP_INLET	21.08	14.6
6076	02-DROP_INLET	20.98	14.8
6077	02-DROP_INLET	20.81	15.26
6078	02-DROP_INLET	20.89	17.93
6079	02-DROP_INLET	21.94	19.92
6080	02-DROP_INLET	22.68	20.48
6081	02-DROP_INLET	22.56	20.69
6082	02-DROP_INLET	20.74	16.64
6083	02-DROP_INLET	20.80	16.29
6084	02-DROP_INLET	20.79	16.79
6085	02-DROP_INLET	21.90	19.45
6086	02-DROP_INLET	23.85	22.05
6087	02-DROP_INLET	23.78	21.23
6088	02-DROP_INLET	22.68	20.53
6089	02-DROP_INLET	22.85	17.63
6090	02-DROP_INLET	21.83	17.13
6091	02-DROP_INLET	22.02	17.24
6092	02-DROP_INLET	20.28	15.36
6094	02-DROP_INLET	20.06	15.21
6095	02-DROP_INLET	19.30	14.3
6096	02-DROP_INLET	19.56	15.16
6097	02-DROP_INLET	19.39	14.55
6098	02-DROP_INLET	20.86	15.56
6099	04-MANHOLE	18.11	14.3
6100	02-DROP_INLET	17.61	14.06
6101	02-DROP_INLET	21.87	17.73
6102	02-DROP_INLET	22.17	18.02
6103	02-DROP_INLET	21.91	17.71
6104	02-DROP_INLET	22.02	19.08
6105	02-DROP_INLET	21.94	18.79
6106	02-DROP_INLET	21.95	18.06
6107	02-DROP_INLET	23.17	17.44
6108	02-DROP_INLET	23.59	18.69
6109	02-DROP_INLET	23.48	19.3
6110	04-MANHOLE	21.86	14.61
6111	04-MANHOLE	23.78	15.28
6112	04-MANHOLE	21.86	15.75
6113	02-DROP_INLET	18.87	15.7
6114	02-DROP_INLET	18.64	15.84
6115	02-DROP_INLET	18.40	14.98
6116	04-MANHOLE	20.23	14.93
6117	04-MANHOLE	18.36	13.94
6118	04-MANHOLE	17.78	13.98
6119	02-DROP_INLET	17.16	13.59
6120	02-DROP_INLET	17.06	14.21
6121	02-DROP_INLET	17.06	13.7

PipeID	InvIn	InvOut	DiameterIn	MaterialIn
CO-4	16.29	15.26	15	
CO-5	16.79	16.29	18	
PI-401	18	17.5	24	
PI-404	17.36	16.86	18	
PI-405	16.8	15.3	36	
PI-406	15	14.77	36	
PI-409	19.9	19.1	15	
PI-410	16.01	15	36	0
PI-411	0	0	36	
PI-500	14.76	14.59	30	RCP
PI-502	19.86	18.83	18	CPP
PI-503	14.8	14.66	30	RCP
PI-504	20.8	20.11	15	RCP
PI-505	20.59	20.13	15	RCP
PI-506	20.47	20.27	15	CPP
PI-507	20.93	18.81	15	RCP
PI-508	20.8	20.85	15	RCP
PI-509	21.41	21.01	15	RCP
PI-510	20.93	20.81	15	RCP
PI-511	20.13	18.4	8	PVC
PI-512	15.09	15.5	48	RCP
PI-513	15.21	15.04	48	RCP
PI-514	16.18	15.25	48	RCP
PI-515	19.02	18.81	15	CPP
PI-516	16.7	16.23	30	RCP
PI-517	18.43	16.42	18	RCP
PI-518	19.94	19.01	15	CPP
PI-519	19.67	19.81	15	RCP
PI-520	19.27	18.43	15	RCP
PI-521	20.37	19.34	15	RCP
PI-522	20.72	19.98	15	RCP
PI-523	18.64	17.63	24	RCP
PI-524	17.09	16.89	24	CMP
PI-525	17.15	16.84	24	CMP
PI-526	13.41	17.07	24	CMP
PI-527	17.11	17.11	24	CMP
PI-528	18.74	17.86	18	CPP
PI-531	19.89	19.5	15	RCP
PI-532	19.47	19.56	15	RCP
PI-533	20.89	20.19	15	RCP
PI-534	19.93	19.84	12	CPP
PI-535	20.88	19.6	12	RCP
PI-536	19.64	18.8	18	RCP
PI-537	19.42	18.8	24	RCP
PI-538	22.74	21.27	12	RCP
PI-539	21.18	21.14	15	CPP
PI-541	21.41	21.37	12	CPP
PI-546	20.16	19.7	12	HDPE
PI-547	19.85	20.09	12	HDPE
PI-548	20.11	20.08	12	HDPE
PI-549	20.22	20.14	12	HDPE
PI-550	20.47	20.26	12	HDPE
PI-551	20.52	20.48	12	HDPE
PI-552	20.81	20.6	12	HDPE
PI-553	0	19.94	0	
PI-554	21.3	0	6	PVC
PI-555	21.86	21.17	6	PVC
PI-556	18.93	19.24	18	RCP
PI-557	17.72	17.28	30	CMP
PI-558	17.36	17.79	30	CMP
PI-559	16.79	16.61	18	RCP
PI-563	18.49	19.14	18	CMP
PI-564	18.78	18.83	18	CMP
PI-565	19.66	18.77	18	RCP
PI-566	21.5	21.44	15	CMP
PI-568	0	20.93	0	
PI-569	20.57	20.74	12	RCP
PI-570	0	21.71	0	
PI-571	20.7	20.82	12	RCP
PI-572	20.8	20.65	12	RCP
PI-573	19.02	20.72	15	RCP
PI-575	20.55	20.67	18	RCP
PI-576	20.62	20.54	12	RCP
PI-577	20.59	20.21	15	RCP
PI-578	20.02	18.96	18	RCP
PI-579	22.05	20.09	15	
PI-580	21.54	20.15	12	RCP
PI-581	20.94	21.52	12	RCP
PI-582	18.92	18.46	18	CMP
PI-583	18.41	17.91	18	CMP
PI-584	20.43	20.51	18	RCP
PI-586	21.1	20.32	6	PVC
PI-587	21.05	0	6	DIP
PI-588	20.32	19.53	6	
PI-589	17.81	17.55	36	CMP
PI-590	17.83	17.65	36	CMP
PI-590	17.65	16.47	36	CMP
PI-592	17.52	16.54	36	CMP
PI-593	18.92	18.65	18	RCP
PI-594	18.61	17.66	18	RCP
PI-595	14.88	16.16	48	
PI-596	15.77	16.84	48	RCP
PI-597	17.94	17.68	18	RCP
PI-598	20.03	18.02	18	CMP
PI-599	20.8	19.97	12	RCP
PI-601	20.69	20.48	12	RCP
PI-602	16.66	16.3	24	RCP
PI-603	19.46	17	18	RCP
PI-604	20.11	19.88	18	CMP
PI-605	20.62	20.33	15	RCP
PI-606	22.1	21.33	15	RCP
PI-607	21.41	20.54	15	RCP
PI-608	17.44	17.1	15	RCP
PI-609	17.26	17.25	15	RCP
PI-610	17.1	15.44	15	RCP
PI-611	15.45	15.18	15	RCP
PI-611	15.18	15.16	15	RCP
PI-613	15.14	14.81	24	RCP
PI-614	15.06	14.85	15	RCP
PI-615	14.32	14.52	30	RCP
PI-616	14.47	14.3	30	RCP
PI-617	15.62	14.68	15	PVC
PI-620	14.31	13.99	30	RCP
PI-621	14.1	0	30	RCP
PI-622	17.74	17.75	15	RCP
PI-623	18.02	17.92	15	RCP
PI-625	19.09	18.85	15	RCP
PI-626	18.79	18.3	18	RCP
PI-627	18.07	18.1	24	RCP
PI-628	18.42	18.1	24	RCP
PI-629	18.69	17.45	18	RCP
PI-630	19.31	18.91	15	RCP
PI-631	17.5	0	24	
PI-632	15	0	18	
PI-633	15.33	14.61	18	RCP
PI-634	15.82	15.3	18	RCP
PI-635	15.85	15.47	18	RCP
PI-636	15.97	15.95	18	RCP
PI-640	15.19	14.99	15	RCP
PI-641	14.91	0	15	RCP
PI-642	0	0	0	
PI-643	14.01	13.93	15	RCP
PI-644	13.88	13.75	15	RCP
PI-645	15.05	14.07	15	CMP
PI-646	13.08	13.83	12	HDPE
PI-647	0	0	18	PVC



Vicinity Map: Not to scale

"I, J. Brian Elliott, certify that this project was completed under my direct and responsible charge from an actual ground survey made under my supervision; that the original data was obtained between October 2019 and February 2020; and all coordinates are based on NCState Plane, NAD83"

NORTH CAROLINA PROFESSIONAL SEAL L-5159 LAND SURVEYOR J. BRIAN ELLIOTT

LDSI, Inc.
201 West 29th Street
Charlotte, NC 28206
(704) 337-8329
www.ldsi-inc.com

SCALE: 1 in = 400 ft
DATUM: NCSP83FT
DATE: 4/29/2020-PAGE 18 OF 18
PROJECT NO: 4519045
MAP BY: belliott

KURE BEACH
STORMWATER STUDY
NEW HANOVER COUNTY
NORTH CAROLINA
Client: Town of Kure Beach
Path: G:\2019\4519045\04-GIS\AreaB_Booklet\Tables.mxd

Exhibit C

(Surcharge Maps)

PLAN VIEW

(1" = 100' HORIZ.)

No.	DATE	DESCRIPTION	BY	APVD	SEAL
		NOT FOR CONSTRUCTION			

DSGN: JDH DR: NAE CHK: JDH APVD: JDH DATE: 2020/03/20

TOWN OF KURE BEACH
STORMWATER STUDY
AREA B

2-YR DESIGN STORM SURCHARGE

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WWW.LDSI-INC.COM NC FIRM #: C-1925

SCALE AS SHOWN

VERIFY SCALE

BAR IS ONE INCH ON ORIGINAL DRAWING

0 1"

DATE: 2020/03/20

PROJ: 4519045

DWG: SURCHARGE MAPS

SHEET: 1 of 4

PLAN VIEW
(1" = 100' HORIZ.)

TOWN OF KURE BEACH
STORMWATER STUDY
AREA B

5-YR DESIGN STORM SURCHARGE

NOT FOR CONSTRUCTION

No.	DATE	DESCRIPTION	BY	APVD	SEAL

DSGN: JDH DR: NAE CHK: JDH APVD: JDH DATE: 2020/03/20

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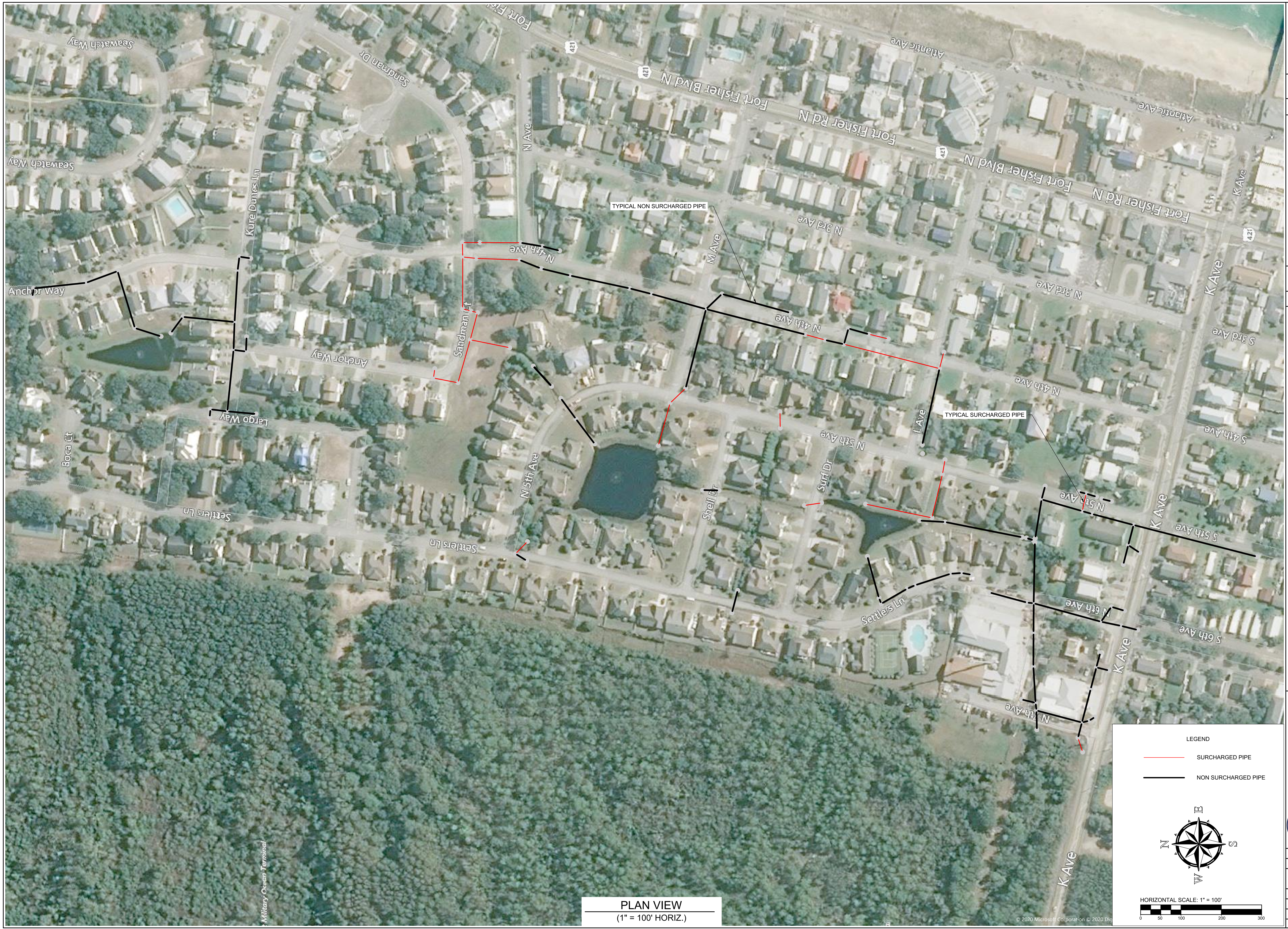
WWW.LDSI-INC.COM NC FIRM #: C-1925

SCALE AS SHOWN
VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING
0 1"

DATE: 2020/03/20
PROJ: 4519045
DWG: SURCHARGE MAPS
SHEET: 2 of 4



PLAN VIEW
(1" = 100' HORIZ.)

No.	DATE	DESCRIPTION	BY	APVD	SEAL
		NOT FOR CONSTRUCTION			

DSGN: JDH | DR: NAE | CHK: JDH | APVD: JDH | DATE: 2020/03/19

TOWN OF KURE BEACH
STORMWATER STUDY
AREA B

10-YR DESIGN STORM SURCHARGE

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SCALE AS SHOWN

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0 1"

DATE: 2020/03/20
PROJ: 4519045
DWG: SURCHARGE MAPS
SHEET: 3 of 4

PLAN VIEW

(1" = 100' HORIZ.)

No.	DATE	DESCRIPTION	BY	APVD	SEAL
		NOT FOR CONSTRUCTION			

DSGN: JDH | DR: NAE | CHK: JDH | APVD: JDH | DATE: 2020/03/20

TOWN OF KURE BEACH
STORMWATER STUDY
AREA B

25-YR DESIGN STORM SURCHARGE

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WWW.LDSI-INC.COM NC FIRM #: C-1925

SCALE AS SHOWN

VERIFY SCALE

BAR IS ONE INCH ON ORIGINAL DRAWING

0 1"

DATE: 2020/03/20

PROJ: 4519045

DWG: SURCHARGE MAPS

SHEET: 4 of 4