Town of Nags Head
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TO: Mayor and Commissioners
FROM: Cliff Ogburn
DATE: March 9, 2018
RE: Stormwater Capital Project Presentations

At your Capital Improvement Workshop, consultants from WithersRavenel will present five stormwater projects for your consideration. Funding opportunities will also be presented.

As part of the Stormwater Master Plan process 13 individual projects were identified to cover various problem areas. Working with the committee, staff and the consultants discussed five of these projects that are part of the first phase. What will be presented are (5) individual projects in a single presentation consisting of the following project areas;

1. Gallery Row
2. Nags Head Acres
3. Village at Nags Head
4. Wrightsville Ave.
5. North Ridge Subdivision

At least two concept solutions will be provided for each individual project with associative concept costs. The Board will need to consider which of the preferred concepts to move forward with, a schedule for the work (over single or multiple years), project prioritization, and project financing.

The Stormwater Committee is schedule to meet Monday, March 12 and their comments will be incorporated into the presentation on Friday at the Workshop. Staff will provide additional supplemental materials to insert into your CIP notebooks on Tuesday, March 13.

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Date: March 13, 2018

To: Board of Commissioners

From: David Ryan, P.E.

RE: Town of Nags Head Stormwater Capital Improvement Project Conceptual Designs

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Since the summer of 2017, Town staff has been working with the team of WithersRavenel and Moffat & Nichol on the second phase of the Towns Stormwater Master Plan Update. The focus of the current scope of work has been the development of a stormwater Capital Improvement Plan in support of Town wide drainage system improvements. This planning has been fast-tracked for inclusion in this year's CIP.

Town staff has been compiling data related to existing drainage problem areas via field observations from stakeholders, resulting in 18 individual problem areas which have been synthesized into 13 potential CIP projects. The project listing was then ranked, utilizing a consistent set of criteria in relation to other projects to determine their relative importance. The information was then shared with our consulting engineers for project development.

Due to the accelerated nature of the planning, only five of the thirteen projects are being brought forward for Board consideration at this time. Staff requests that the Board consider the remaining eight for FY 19/20.

The project development framework includes a problem statement which identifies existing drainage deficiencies, existing constraints and design considerations, and a minimum of (2) conceptual designs alternatives for each project area. Hydraulic and hydrologic models were created, to closely simulate field observations and evaluate project performance as measured by rainfall amount and depth of flooding. Construction cost estimates for the conceptual alternatives have been included for reference.

Due to the accelerated nature of planning, staff would request that the Board consider this is several parts: with the first part being the consideration of the project proposals and the second part concentrating on project funding. Staff would request that a second CIP workshop be scheduled to discuss project funding and scheduling.

WithersRavenel
Our People. Your Success.

MEMORANDUM

To:	David Ryan, PE, Town of Nags Head
From:	Hunter Freeman, PE, WithersRavenel
Date:	March 13, 2018
Project:	Nags Head Stormwater Master Planning
Subject:	Phase Two Conceptual Design Alternatives Summary

Executive Summary and Overall Approach

This memorandum summarizes the preliminary conceptual design and results for five drainage projects located in the Town of Nags Head.

WithersRavenel's approach was to develop simple models to represent complex and unique hydrologic challenges. Each conceptual design is intended to improve the quality of life of Nags Head residents by reducing the detrimental impacts of standing water most often present after rainfall events.

After discussion with Town staff and a presentation to the Stormwater Committee, five sites were selected and prioritized for further study and development of stormwater models. The models were developed to help understand the hydrologic components existing in the present conditions, and also understand how the physical site conditions were affected by rainfall events. Once the existing conditions models were calibrated to more closely match field observations from Town staff and citizens, we began developing proposed conditions models and retrofit options.

WithersRavenel modeled the five project areas using PondPack software. Both physical (i.e., upgrade infrastructure) and mechanical (i.e., lowering groundwater through pumping or add emergency pumping) options were considered. Metrics presented for each project area include the depth of roadway flooding and time for floodwaters to recede. Projected performance of the proposed design alternatives was compared to existing conditions using these metrics to gauge their effectiveness in addressing the concerns noted by the stakeholders.

For the proposed groundwater lowering scenarios, WithersRavenel looked at the net result of the pumping to assess the effect on floodwater levels during small storm events. This approach removed the need to design and model specific pumping options for the time being. This level of detail will be added in the final design if the scenario reaches that stage. The hydrologic models simulate the change in soil properties due to elevated and lowered water tables within each drainage area. Existing conditions (e.g., no groundwater pumping operation) were considered to be saturated, resulting in the loss of infiltration capacity as a starting boundary condition. To simulate the effect of the groundwater lowering operation, the soil type within the project area was revised to reflect the available absorptive capacity of the dewatered soil to infiltrate a portion of rainfall. This reflects WithersRavenel assumption that prior to a rainfall event the soil would be functioning sandy, high infiltration-capacity soils that exist at the coast.

For the larger storms where emergency pumping operations were applicable, WithersRavenel worked under the presumption that the storm event itself was less important to quality of life than the aftermath of the storm. This starting condition was arrived at after lengthy discussion with stakeholders as well as initial storm modeling, which indicated that the rate and total volume of floodwater inflow, both from rainfall and storm surge, was so high that any reasonably affordable pumping design would be able to maintain a non-

flooded condition during or immediately after major storms. Therefore, the starting condition in the model was a flooded condition and the hydrologic model was used to analyze the ability of the retrofit scenario to dewater the flooded land faster than in the existing scenario.

This approach was intended to address the primary impacts to quality of life voiced during community meetings. It should be noted that we are not attempting to quantify the results using traditional engineering metrics (peak flow, inches of runoff, level of service based on XX-year storm), but rather evaluating these scenarios within a framework that quantifies how each option will improve day-to-day quality of life. If a more traditional engineering reporting is requested, we can add this type of analysis to the report.

Preliminary Results & Cost Estimates

*Note: the cost estimates below do not include potential costs of easements or land acquisition.

Project Area #1 - Gallery Row

Problem Statement

Flooding at the Gallery Row outfall, specifically along Memorial Avenue from Driftwood to Baltic Street, is due to a combination of an insufficient outfall pipe capacity, low-lying properties, and elevated groundwater. Additionally, the cross-pipe draining a primary ditch in the drainage area is approximately 18" higher than the downstream ocean outfall, which reduces capacity, available storage in the ditch, and may be inadvertently preventing the groundwater table from receding.

Existing Constraints and Design Considerations

The Gallery Row ocean outfall pipe is insufficiently sized to handle large flow rates but cannot be upgraded due to existing NCDOT regulations; additionally, replacing the cross-pipe will require NCDOT coordination.

Project Area 1 Conceptual Designs

Conceptual Design Alternative #1 – Lower cross-pipe at Virginia Dare Trail

Goal: Create additional soil and ditch storage by lowering the upstream cross-pipe invert to more closely match pipe inverts in junction box that leads to ocean outfall.

Assumptions: High groundwater simulated by modeling soils as saturated, Hydrologic Soil Group (HSG) D soils. A constant tailwater elevation of 0.00 (sea level) was applied.

Design: Upgrade cross-pipe to 36" pipe and lower upstream invert by 18".

Preliminary Engineer's Cost Opinion: **$50,000 - $100,000**

Conceptual Design Alternative #2 – Pump water from Gallery Row ditch

Goal: Pump water from primary ditch across Virginia Dare Trail (Beach Road) to junction box that leads to ocean outfall. Gradual groundwater lowering (low-flow option) and emergency pumping (high-flow option) to be assessed.

Assumptions: Lowered groundwater simulated by modeling soils as HSG A soils. Emergency pumping option considered soils to be saturated and added a constant pumping rate of 5 cfs (2,250 gpm). Emergency pumping option only modeled for 25-year storm. It was assumed that the pumps would be activated in advance of anticipated large storm events. A constant tailwater elevation of 0.00 (sea level) was applied for both low flow and high flow options.

Design: Low-flow option – approximately 0.5 cfs pumping rate throughout the drainage area to lower groundwater table between storm events. High-flow option employs emergency pump of 5 cfs and only simulated for the 25-year storm.

Preliminary Engineer's Cost Opinion: Groundwater lowering option - **$250,000 - $300,000**
Emergency pump option - **$75,000 - $100,000**

Project Area 1 Preliminary Results

Under existing conditions, Virginia Dare Trail and the surrounding roadways are modeled to flood 0.25" and nearly 6" during the 1-year and 25-year storm, respectively. During the 1-year storm, the time to recede from the peak water surface elevation below the edge of the road is 6 hours. This number increases to over 2 days for the 25-year storm.

With the pipe lowered by 18" (Design Alternative #1), there is projected to be no roadway flooding during the 1-year storm; roadway flooding during the 25-year storm reduces to 1.5". Additionally, the time to recede is less than 6 hours.

Under the low-flow and high-flow pumping options (Design Alternatives #2A and #2B), there is also no simulated roadway flooding during the 1-year storm and 3-4" of flooding over the roadway during the 25-year storm. The time for floodwaters to recede is reduced by 16 to 18 hours compared to existing conditions.

A tabulated summary of performance is given below.

Table 1. Projected depth of roadway flooding and time to recede for Project Area 1

SCENARIO	DEPTH OF ROADWAY FLOODING (IN)		TIME TO RECEDE (HR)	
	1-YR	25-YR	1-YR	25-YR
EXISTING	0.25	5.75	6.00	54.00
ALTERNATIVE #1	None	1.50	N/A	4.25
ALTERNATIVE #2 - LOW FLOW	None	3.00	N/A	35.75
ALTERNATIVE #2 - HIGH FLOW	-	3.75	-	37.25

Project Area #2 – Nags Head Acres/Vista Colony

Problem Statement

Inadequate drainage infrastructure, coupled with high groundwater and a lack of a gravity-fed outfall, is causing severe flooding in both subdivisions. The downstream invert of a 15" pipe draining Bridge Lane is approximately 12" lower than the ditch along US Highway 158 that it drains to and thus bubbles out of a grate that can get clogged. Additionally, the primary outlet crossing US Highway 158 to drain the ditch is over 12" higher than the grate, so there is standing water in the ditch.

Existing Constraints and Design Considerations

The downstream boundary condition is the US Highway 158 cross-pipe elevation which causes the bypass to act as a dam. Because of this, upstream controls via pumping of the ditch is likely required.

Project Area 2 Conceptual Designs

Conceptual Design Alternative #1 – Pump water across US 158 at US 158 swale

Goal: Pump water to cross-pipe at US 158 to de-water swale along US 158 more quickly. Gradual groundwater lowering (low flow option) and emergency pumping (high flow option) to be assessed.

Assumptions: Lowered groundwater simulated by modeling soils as hydrologic soil group A soils. Emergency pumping option considered soils to be saturated and added a constant pumping rate of 5 cfs (2250 gpm). Emergency pumping option only modeled for 25-year storm. It was assumed that the pumps would be activated in advance of anticipated large storm events. The swale along 158 was modeled as an interconnected pond with the downstream nodes associated with Project Area #1 to account for tailwater conditions. Water pumped across 158 was assumed to enter directly into downstream nodes at Project Area #1.

Design: Low-flow option – approximately 0.5 cfs pumping rate throughout the drainage area applied to lower groundwater. High-flow option employs emergency pump at 5 cfs.

Preliminary Engineer's Cost Opinion: Groundwater lowering option - **$100,000 - $150,000**
Emergency pump option - **$50,000 - $75,000**

Conceptual Design Alternative #2 – Pump water to existing discharge point of groundwater lowering project

Goal: Pump water to the west to discharge point of existing groundwater lowering project. Gradual groundwater lowering (low flow option) and emergency pumping (high flow option) to be assessed.

Assumptions: Lowered groundwater in the drainage area was simulated by modeling soils as HSG A soils. Emergency pumping option considered soils to be saturated and added a constant pumping rate of 5 cfs (2250 gpm). Emergency pumping option only modeled for 25-year storm. It was assumed that the pumps would be activated in advance of anticipated large storm events. It was assumed water pumped from the swale was deposited in an upstream infiltration area and did not interfere with downstream nodes in Project Area #1. The infiltration area was assumed to have an infiltration rate of 8 in/hr. Water that was not pumped and instead drained by gravity to Project Area #1 was modeled as an interconnected pond with the downstream nodes.

Design: Low-flow option – approximately 0.5 cfs pumping rate throughout the drainage area applied to lower groundwater. High-flow option employs emergency pump at 5 cfs. Existing infiltration area from Vista Colony to be used as discharge point.

Preliminary Engineer's Cost Opinion: Groundwater lowering option - **$75,000 - $125,000**
Emergency pump option - **$50,000 – 75,000**

Project Area 2 Preliminary Results

Under existing conditions, roadways in the neighborhood were modeled to flood 2.50" and nearly 10.50" during the 1-year and 25-year storm, respectively. Due to the downstream boundary conditions of Project Area #1, the time to recede was nearly 12 hours for the 1-year storm and 39 hours for the 25-year storm.

For both groundwater lowering projects (low flow alternatives), neighborhood flooding during the 1-year storm was eliminated and nearly cut in half for the 25-year storm. The time for floodwaters to recede was also reduced by approximately half a day.

Under both the emergency pumping options (high flow options), the depth of flooding remained close compared to that of existing conditions, but overall length of flooded conditions was reduced by 4 to 13 hrs.

None of the proposed designs significantly impacted downstream infrastructure at the Gallery Row ditch.

Table 2. Projected depth of roadway flooding and time to recede for Project Area 2

SCENARIO	DEPTH OF ROADWAY FLOODING (IN)		TIME TO RECEDE (HR)	
	1-YR	25-YR	1-YR	25-YR
EXISTING	2.50	10.50	11.75	39.00
ALTERNATIVE #1 - LOW FLOW	None	6.00	N/A	26.25
ALTERNATIVE #1 - HIGH FLOW	-	9.25	-	26.25
ALTERNATIVE #2 - LOW FLOW	None	5.75	N/A	25.00
ALTERNATIVE #2 - HIGH FLOW	-	10.25	-	36.50

Project Area #3 – Village at Nags Head/Seven Sisters

Problem Statement

High groundwater, insufficient drainage infrastructure and variations from proposed drainage infrastructure (i.e., at Seven Sisters, lot imperviousness increased and swale section never constructed), has caused roadway flooding throughout the project area.

Existing Constraints and Design Considerations

Mismatched infrastructure (i.e., dual 24" RCPs reduce to a single 30" RCP), negative pipe gradients, and undersized cross-pipes.

Project Area 3 Conceptual Designs

Conceptual Design Alternative #1 – Pump water to existing permeable pavement lot

Goal: Pump water across Virginia Dare Trail (Beach Road) to existing permeable pavement lot, which would be converted to a storage and infiltration area.

Assumptions: It was assumed only the top third of the drainage area was pumped/diverted to the permeable pavement infiltration area. Pumping to the infiltration area was assumed to cause lowered groundwater, which was simulated by modeling soils in the drainage area to the permeable pavement as HSG A soils. The storage area was assumed to be filled with aggregate (40% void space) and have an infiltration rate of 8 in/hr. When the capacity of the permeable pavement was overwhelmed, it was assumed flow in the drainage area traveled downstream as interconnected ponds.

Design: 8,000 sf of permeable pavement with approximately 4.5' of aggregate storage area below the pavement surface. 0.5 cfs pumping rate utilized to carry water to the permeable pavement area. Constant tailwater of 0.00 (sea level) applied.

Preliminary Engineer's Cost Opinion: $275,000 – $325,000

Conceptual Design Alternative #2 – Add additional pipe infrastructure

Goal: Add additional pipe infrastructure along Virginia Dare Trail (Beach Road) to improve conveyance and infiltration capacity.

Assumptions: Pipe infrastructure added to Virginia Dare Trail was considered to be additional storage within each respective drainage area. Additionally, perforated pipe was utilized to increase infiltration capacity; an infiltration rate of 8 in/hr was applied to the footprint of the pipe. Storage areas were modeled as interconnected ponds. Constant tailwater of 0.00 (sea level) applied.

Design: Install1600 LF of 24" HDPE slotted pipe at 0% slope.

Preliminary Engineer's Cost Opinion: $125,000 - $175,000

Project Area 3 Preliminary Results

Under existing conditions, Virginia Dare Trail and adjacent roadways were modeled to flood up to 2" and nearly 8" during the 1-year and 25-year storm, respectively. The time to recede was less than 4 hours for the 1-year storm and less than 10 hours for the 25-year storm.

Diverting a portion of the drainage area to the permeable pavement storage area eliminated flooding during the 1-year storm and decreased the time to recede to 6.50 hours for the 25-year storm.

Adding additional perforated pipe infrastructure increased storage and infiltration capacity such that length of flooded conditions was reduced by approximately 2 hours for both the 1-year and 25-year storms.

Table 3. Projected depth of roadway flooding and time to recede for Project Area 3

SCENARIO	DEPTH OF ROADWAY FLOODING (IN)		TIME TO RECEDE (HR)	
	1-YR	25-YR	1-YR	25-YR
EXISTING	2.00	7.75	3.50	9.25
ALTERNATIVE #1	None	6.50	N/A	6.50
ALTERNATIVE #2	0.50	8.25	1.25	7.50

Project Area #4 – Wrightsville Avenue

Problem Statement

Insufficient drainage infrastructure, along with low-lying properties and elevated groundwater, are causing flooding along Wrightsville Avenue from Bonnett Street to Bainbridge Street.

Existing Constraints and Design Considerations

The capacity of the Curlew Street outfall to which the area drains is affected by ocean tailwater.

Project Area 4 Conceptual Designs

Conceptual Design Alternative #1 – Replace existing infrastructure along Wrightsville Avenue with perforated pipe

Goal: Replace drainage infrastructure along Wrightsville Avenue with perforated pipe.

Assumptions: Perforated pipe infrastructure added to the drainage area was considered to be additional storage. An infiltration rate of 8 in/hr was applied to the footprint of the pipe. Storage areas were modeled as interconnected ponds to point of analysis at eastern end of Wrightsville Avenue. Constant tailwater of 0.00 (sea level).

Design: Install 2,250 LF of 24" HDPE slotted pipe added along Wrightsville Avenue, Bonnett Street, and Bittern Street (approximately 450 LF new pipe, remaining 1800 LF to replace existing 15" CPP). Inverts lowered to reflect expanded pipe size.

Preliminary Engineer's Cost Opinion: $250,000 - $300,000

Conceptual Design Alternative #2 – Upgrade cross-pipe draining to Curlew Street outfall

Goal: Upgrade cross-pipe draining to Curlew Street outfall.

Assumptions: Constant tailwater of 0.00 (sea level) applied. Point of analysis at the eastern end of Wrightsville Avenue. Additional drainage area from the point of analysis to the Curlew Street outfall was not modeled.

Design: Replace 1590 LF of existing 30" and 36" pipe with 42" RCP. Invert lowered by 12".

Preliminary Engineer's Cost Opinion: $250,000 - $300,000

Project Area 4 Preliminary Results

Under existing conditions, depth of flooding in the project area was projected to be approximately 3" for the 1-year storm and nearly 6" for the 25-year storm. Time to recede was 4.25 hours and 20 hours for the 1-year and 25-year storms, respectively.

Both design alternatives resulted in a depth of flooding that remained relatively consistent to existing conditions. Replacing the downstream pipe with a 42" RCP (Design Alternative #2) reduced total flooded time by 2 hours for the 1-year storm and 9 hours for the 25-year storm.

Table 4. Projected depth of roadway flooding and time to recede for Project Area 4

SCENARIO	DEPTH OF ROADWAY FLOODING (IN)		TIME TO RECEDE (HR)	
	1-YR	25-YR	1-YR	25-YR
EXISTING	2.75	5.25	4.25	20.00
ALTERNATIVE #1	2.50	5.25	3.75	19.25
ALTERNATIVE #2	2.00	4.75	2.00	11.00

Project Area #5 – North Ridge

Problem Statement

Property flooding is caused by insufficient drainage infrastructure and high groundwater. Additionally, US Highway 158 is acting as a dam during storm events, which causes backwater onto cul-de-sac properties.

Existing Constraints and Design Considerations

Potential need for land and easement acquisition; groundwater from Jockey's Ridge moving eastward towards neighborhood.

Project Area 5 Conceptual Designs

Conceptual Design Alternative #1 – Add additional infrastructure throughout neighborhood

Goal: Improve conveyance infrastructure in the neighborhood and add flap gates to existing cross-pipes draining to US Highway 158 swale.

Assumptions: Constant tailwater of 2.50 ft applied, equivalent to downstream invert across US Highway 158.

Design: Add 4,450 LF of infiltration swales throughout neighborhood. Swale cross-section 1.5' deep at 3:1 side slopes. Add driveway culverts for connectivity. Add flap gates to cross-pipes draining to US Highway 158 swale.

Preliminary Engineer's Cost Opinion: **$175,000 – 225,000**

Conceptual Design Alternative #2 – Pump water from US Highway 158 swale to upland infiltration area.

Goal: Pump water from swale along US Highway 158 to upland infiltration areas and/or storage area acquired by the Town.

Assumptions: Lowered groundwater in the drainage area was simulated by modeling soils as HSG A soils. Emergency pumping option considered soils to be saturated and added a constant pumping rate of 5 cfs (2,250 gpm). Emergency pumping option only modeled for 25-year storm. It was assumed that the pumps would be activated in advance of anticipated large storm events. It was assumed water pumped from the swale was deposited in an upstream infiltration area and did not interfere with downstream nodes. Water that was not pumped and instead drained by gravity across US Highway 158 was modeled as an interconnected pond with upstream and downstream nodes.

Design: Low-flow option – approximately 0.5 cfs pumping rate throughout the drainage area applied to lower groundwater. High-flow option employs emergency pump at 5 cfs. Location of upstream infiltration area to be determined.

Preliminary Engineer's Cost Opinion: Groundwater lowering option - **$75,000 - $125,000**
Emergency pump option - **$50,000 - $75,000**

Project Area 5 Preliminary Results

Under existing conditions, roadway flooding through North Ridge was minimal for the 1-year storm but increased to nearly 5 inches for the 25-year storm. The time for floodwaters to recede was modeled to be nearly 24 hours.

Adding swales throughout the neighborhood reduced the time for floodwaters to recede by 1 to 2.25 hours.

Pumping water to an upstream infiltration area reduced overall flooding depths and decreased the time for floodwaters to recede by 7 to 8.25 hours.

Table 5. Projected depth of roadway flooding and time to recede for Project Area 5

SCENARIO	DEPTH OF ROADWAY FLOODING (IN)		TIME TO RECEDE (HR)	
	1-YR	25-YR	1-YR	25-YR
EXISTING	0.75	4.75	2.00	21.00
ALTERNATIVE #1	0.25	4.50	1.00	18.75
ALTERNATIVE #2 - LOW FLOW	None	1.25	N/A	12.75
ALTERNATIVE #2 - HIGH FLOW	-	3.75	-	14.00

Upcoming Work

WithersRavenel intends to compile conceptual design alternatives into 1-page exhibits for each project area to graphically represent design goals and results.