Using a Flow Dynamics 2D Model to Develop Street Flooding Solutions in a Highly Transited Urban Area

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<u>Outline</u>

- <u>Study Motivation</u>
- Description of the Study Area
- Data Collection
- Design Criteria
- Model Setup
- Simulation Results
 - Existing and Proposed Conditions
- <u>Conclusions</u>

Study Motivation

• Recurrent street flooding in a highly transited area



Need to evaluate flooding solution measures

- Use of 2D Overland Model over other approaches:
 - Traditional 1D Catchment Modeling not suited for analysis
 - Spread Analyses
 - Each CB requires calculation of its own tributary area => time consuming
 - Not direct visualization of flooding extents

Study Area

Flow into

Private Property



- LU: Residential/Commercial Area
- Pipe has leftover capacity, thus flooding induced by limited inlet capacity
- Low laying Area
- Low Curbs

Data Collection

- CB Field investigations:
 - Single & Double Grate
 - 10" Lead Pipes



- LiDAR terrain data, impervious, and soil type GIS layers:
 - Used to assign Zone roughness coefficients for pervious/impervious areas, and infiltration parameters
- Building Footprint, and Road GIS Layers

Design Criteria

Design Solution Scenarios to Limit Flooding to within Right-of-Way.

Reduce Damaging Flooding into Private
 Property

Design 'short-burst' Storm: 1.5 in/hour, 1-hour



Numerical Model

•Existing Conditions Model

- •Citywide InfoWorks ICM Model
- •Underground sanitary and storm drain 1D model
- •Calibrated to Recent Metering Data
- Integrated 1D/2D Overland Flow Model
 - •Covers ~70 Acres
 - •Existing and Proposed Conditions
 - •Uses HEC-22 (Urban Drainage Design Manual) Equations to model CB Hydraulics
 - •Model Checks:
 - Against 1D model,
 - Mesh sensitivity

Numerical Model

1D Model 1D/2D Overland Model Rain on Mesh mpervious Zone Subcatchment Properties Roughness Infiltration zone zone Infiltration, Roughness, 2D Imperviousness TKIKIKIKIK <u>UKUKUKUK</u>

1D

+

Numerical Model

Mesh sensitivity analysis



Evaluation of Existing Conditions



Simulated ground surface flooding during the 1.5 in/hour – 1 hour design storm under Existing Conditions.



Simulated flow pathways into Ashburton Place during peak of the 1.5 in/hour – 1 hour design storm under Existing Conditions



Simulated Peak HGL along Essex St. during the 1.5 in/hour – 1 hour design storm under existing conditions.

Evaluation of Flooding Solution Measures

Results: Solution Scenario (Cont.)

Maximized CB Inflows

• New CBs were placed at lowest points



Added CB: Initial Location Added CB: Optimized Location

<u>Results: Solution Scenario</u> (Cont.)



Pavement Resurfacing

Results: Solution Scenario (Cont.)



Simulated ground surface flooding during the 1.5 in/hour – 1 hour design storm under Proposed Conditions

Results: Solution Scenario (Cont.)



Simulated ground surface flooding during the 2.5 in/hour – 30 min design storm under Proposed Conditions

Summary & Conclusions

- <u>Under Existing Conditions</u>,
 - Street flooding is primarily attributed to limited inlet capacity,
 - The simulated peak flood depths in the area of interest rise well above 6-in,
 - Flood waters reach into driveways, building fronts, and backyards, while
 - The underground drain system has leftover capacity,

Summary & Conclusions (Cont.)

- <u>Under Solution Scenario</u>, several flooding control measures were evaluated:
 - Double-grating of existing inlets,
 - Adding single and double grate inlets,
 - Upsizing lead pipes,
 - Grating of Manhole
 - Raising of cross-walks and back of sidewalks, and
 - Pavement resurfacing

Summary & Conclusions (Cont.)

- Advantages of the 1D/2D Integrated Model
 - Allows Identification/Visualization of flow pathways into area of interest
 - Allows evaluation of multiple control measures either separately or in combination in a fast and cost effective manner

• <u>Recommend Maintenance (e.g., clogging)</u>







Additional

Sample CB Spread Analysis

| 1 PROJECT: Essex STREET SEWER SEPARATION | | | DATE: | | Variables & Units | | | | | | | | | | |
|---|---|--|--|---|---|--|--|---|--|---|--|---|--|---|---|
| 2 | DESCRIPTION: CB SPREAD REV.#2 | | | BY: YAC | | | | | | | | | | | |
| 3 | NEW CBs RESULTING FROM REV#1 | | | CHECKEDIMODI | FIED: YC 10/14 | Site Conditions | | Flow Analysi | s | | | | | | |
| 4 | | | | | | H _{outter} = gutter height | ft | C = drainage | coefficient | # | | | | | |
| 5 | Static Variables | Value | | Units | | L _{autter} = gutter length | ft | K _{GRATE} = grate | e minor loss coefficient | # | | | | | |
| 6 | | | | | | L _{ourb} = curb length | ft | Q _{Rain} = rain fl | DW | ft ³ /s | | | | | |
| 7 | Flow Analysis | | | | | H _{crown} = crown height | ft | Q _{Total} = cumu | ative flow to CB | ft ³ /s | | | | | |
| 8 | R = runnoff yeld | 3.00 | | ft ³ / s * acre | | L _{crown} = crown length | ft | Q _{Grate} = max o | apacity through CB | ft ³ /s | | | | | |
| 9 | | | | | | L _{lane} = lane width | ft | Q _{int} = flow act | tually intercepted by CB | ft ³ /s | | | | | |
| 10 | Resultant Ponding | | | | | A _T = total catch basin area | acres | Q _{Bvp} = flow bypassing CB | | ft ³ /s | | | | | |
| 11 | n = Manning's coefficient | 0.016 | | # | | S _L = longitudinal gutter slope | # | Q _{Avail} = remai | ning CB capacity | ft ³ /s | | | | | |
| 12 | D _{MAX} = max allowable ponding depth | 0.25 | | ft | | ST = transverse gutter slope | # | | | | | | | | |
| 13 | T _{MAX} = max allowable ponding width | 6.0 | | ft | | A = total catch basin area | ft ² | Orifice Perfo | ormance | | | | | | |
| 14 | | | | | | | | G _A = open ar | ea of grate | ft ² | | | | | |
| 15 | Orifice Performance | | | | | Resultant Ponding | | W = grate wid | Ith | ft | | | | | |
| 16 | Co = orifice constant | 0.60 | | # | | D = depth of road ponding | ft | X = averaged | head acting on CB orifices | ft | | | | | |
| 17 | g = gravitational acceleration | 32.20 | | ft ² /s | | T = width of road ponding | ft | Q _{Orifice} =cumu | lative flow through CB orifi | ft ³ /s | | | | | |
| 18 | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | |
| 20 | FORMULA BANK | | | | ERROR | NEEHAH | "RECT. SLOT (TRADITIONAL)" | | | | | | ERROR | | |
| 21 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 22 | | This name cor | nvention does not | apply any longer | | | | | | | S | TE CONDITIC | ONS | | |
| 22 | Contibuting Area | CB Number | NEW CB | apply any longer | Spread | Manufacturer | Grate Type | Δ. | Gutter | | S | | own | L. | |
| 23 24 | Contibuting Area | CB Number | NEW CB | street | Spread Flag | Manufacturer | Grate Type | AT | Gutter H _{gutter} | Lgutter | S L _{curb} | ITE CONDITIC Crown H _{crown} | own L _{crown} | L _{lane} | _ |
| 22 23 24 25 | Contibuting Area | CB Number | NEW CB | Street | Spread Flag | Manufacturer | Grate Type | A _T | Gutter H _{gutter} | L _{gutter} | L _{curb} | ITE CONDITIC Crown H _{crown} | own L _{crown} | L _{lane} | - |
| 22 23 24 25 26 | Contibuting Area | CB Number | NEW CB CB-1 | Street | Spread Flag OK | Manufacturer NEEHAH | Grate Type | A _T | Gutter H _{gutter} 53.54 | L _{gutter} 42.77 | L _{curb} | Herown 43 | UNS UND L _{crown} 42.77 | L _{lane} 13 | |
| 22 23 24 25 26 27 | Contibuting Area | CB Number CB-1 NA | CB-1 CB-87 | Street New New | Spread Flag OK OK | Manufacturer NEEHAH NEEHAH | Grate Type "RECT. SLOT (TRADITIONAL)" "RECT. SLOT (TRADITIONAL)" | A _T 0.5755 0.0978 | Gutter H _{gutter} 53.54 42.77 | L _{gutter} 42.77 33.04 | 225 200 | Hcrown 43 42.40 | CNS Communication Lorown 42.77 33.04 | L _{lane} 13 13 | |
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| 22 23 24 25 26 27 28 29 30 | Contibuting Area New-Northwest1 Larch-Northwest2 Larch-Northeast1 Larch-Northeast2 Larch-Softwest1 | CB-1 CB-1 NA CB-2 NA CB-3 | CB-1 CB-87 CB-2 CB-88 CB-3 | New New New New New New New | Spread Flag OK OK OK FLOODED OK | Manufacturer NEEHAH NEEHAH NEEHAH NEEHAH | Grate Type "RECT. SLOT (TRADITIONAL)" "RECT. SLOT (TRADITIONAL)" "RECT. SLOT (TRADITIONAL)" "RECT. SLOT (TRADITIONAL)" | A _T 0.5755 0.0978 0.202 1.0126 0.1002 | Gutter H _{gutter} 53.54 42.77 53.34 42.16 52.81 | Lgutter 42.77 33.04 42.16 33.02 46.61 | 225 200 200 200 100 | 43 42.40 16.82 46.87 | All | L _{lane} 13 13 13 13 13 13 | |
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| 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 38 39 40 | Contibuting Area New-Northwest1 Larch-Northwest2 Larch-Northwest2 Larch-Sothwest1 Larch-Sothwest1 Larch-Sothwest3 Larch-Sothwest3 Larch-Sothwest4 Larch-Sotheast1 Grozier-Northeast1 Grozier-Northwest1 Grozier-Southwest1 Grozier-Southwest1 | This name cor CB Number CB-1 NA CB-2 NA CB-3 CB-4 CB-6 CB-6 CB-6 CB-6 CB-7 CB-7 CB-8 CB-9 CB-12 CB-12 CB-12 CB-12 CB-12 | CB-1 CB-87 CB-87 CB-2 CB-88 CB-3 CB-4 CB-6 CB-8 CB-6 CB-8 CB-7 CB-7 CB-9 CB-10 CB-11 CB-13 | Apply any longer Street New New New New New New New New New Grozier Grozier Grozier Grozier | Spread Flag OK OK FLOODED OK FLOODED OK FLOODED OK OK OK | Manufacturer NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH | Grate Type "RECT. SLOT (TRADITIONAL)" | Aτ 0.5755 0.0978 0.202 1.0126 0.1002 0.1795 2.1763 0.3017 0.1167 0.3127 0.2243333 0.1424 0.1382417 0.063225 | Gutter Figure 53.54 42.77 53.34 42.16 52.81 46.61 48.03 51.33 52.42 51.17 47.31 48.62 48.62 48.62 | Lgutter 42.77 33.04 42.16 33.02 46.61 44.10 44.10 44.03 44.87 44.47 44.47 43.76 43.78 43.76 48.56 48.56 48.56 | 225 200 200 200 100 60 100 382 150 506 150 150 150 40 40 | Herown 43 42.40 42.40 16.82 46.87 45.44 44.36 48.29 45.13 44.73 44.08 44.08 48.86 48.86 48.86 | DNS Dwm Lerown 42.77 33.04 42.16 33.02 46.61 45.18 44.10 48.03 44.87 44.47 43.76 48.56 48.56 | L _{lane} 13 13 13 13 13 13 13 13 13 13 | |
| 222 23 24 25 26 27 28 29 30 31 32 33 33 33 33 33 33 33 33 33 33 33 33 | Contibuting Area New-Northwest1 Larch-Northwest2 Larch-Northwest1 Larch-Northwest1 Larch-Sothwest1 Larch-Sothwest3 Larch-Sothwest3 Larch-Sothwest4 Larch-Sotheast1 Larch-Sotheast1 Grozier-Northwest1 Grozier-Northwest1 Grozier-Southwest1 Grozier-Southwest1 Grozier-Southwest1 Grozier-Southwest1 | This name cor CB Number CB-1 NA CB-2 NA CB-2 NA CB-2 NA CB-2 NA CB-3 CB-4 CB-5 CB-7 CB-8 CB-9 CB-12 CB-13 | CB-1 CB-87 CB-2 CB-87 CB-2 CB-88 CB-3 CB-4 CB-6 CB-3 CB-4 CB-6 CB-7 CB-7 CB-7 CB-10 CB-11 CB-13 CB-14 | Apply any longer Street New New New New New New New Grozier Grozier Grozier Grozier Grozier | Spread Flag OK OK OK FLOODED OK FLOODED OK FLOODED OK OK OK OK OK | Manufacturer NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH NEEHAH | Grate Type "RECT. SLOT (TRADITIONAL)" "RECT. SLOT (TRADITIONAL)" | At 0.5755 0.0978 0.202 1.0126 0.1002 0.1795 2.1763 0.3017 0.1167 0.3127 0.2243333 0.1424 0.332471 0.063225 0.0784 | Gutter Hgutter 53.54 42.77 53.34 42.16 52.81 46.61 48.03 51.33 52.42 51.17 47.31 48.62 48.62 48.66 | Lgutter 42.77 33.04 42.16 33.02 46.61 45.18 44.10 45.18 44.10 45.18 44.87 44.87 44.87 43.78 43.76 43.76 48.56 47.88 | S Leurb 225 200 200 200 200 200 200 200 200 200 | Herown 43 42.40 42.40 46.87 45.44 44.36 48.29 45.13 44.73 44.08 48.86 48.86 48.18 | DNS Dwm Lerown 42.77 33.04 42.16 33.02 46.61 45.18 44.10 48.03 44.87 44.47 43.78 43.76 48.56 47.88 | Liane 13 13 13 13 13 13 13 13 13 13 | |







Simulated flow pathways into Ashburton Place during peak of the 1.5 in/hour – 1 hour design storm under Existing Conditions



Simulated flow pathways into Ashburton Place during peak of the 1.5 in/hour – 1 hour design storm under Existing Conditions