Advanced Design Workshops

1. Stormwater Basics: Quality vs. Quantity
   August 3, 2016

2. Downstream Analysis
   September 1, 2016

3. Post-Construction BMP
   Exclusions and Infeasibility
   October 6, 2016

4. Wet Detention Pond Design
   November 1, 2016

5. GDOT Post-Construction
   Stormwater Report
   December 1, 2016

More topics to come in 2017......
Downstream Analysis

Source: NCDOT
Why Are We Here?

...to discuss the reasoning and methodology for downstream analysis
Points of Discussion

• What is a downstream analysis?
• Why is a downstream analysis important?
• How is a downstream analysis performed?
Downstream Analysis

Why do we do it?
Performed to ensure no adverse impacts to downstream structures or properties

When is it required?
Required for all projects with a post-developed flow increase or to evaluate effects of water quantity control structures (detention) on peak discharge and timing downstream in the watershed
Downstream Analysis

What is it?

Comparison of hydrographs at:

- Each project outfall
- End of project’s zone of influence in the downstream watershed, either:
  - point where drainage area is 10 times the project site drainage area, or
  - large receiving water (lake, river, estuary)
- Intermediate locations of concern (downstream confluences, structures, conveyances)
Importance & Advantages

- Analysis can reveal potential downstream flood impacts
- Prevent harmful and unnecessary detention
- Reduce high velocity runoff that causes stream erosion
Downstream Analysis

Importance & Advantages

- Identifies necessary downstream improvements
  - Bridges/culverts
  - Increase existing pipe capacity
Downstream Analysis

Importance & Advantages

• Avoid potential legal issues
  - Protect both owner and engineer

• Document and Record Analysis
  - Record Downstream Analysis in MS4 Post-Construction Stormwater Report

• May determine detention is not required due to downstream adverse effects
Downstream Analysis

**Downstream Analysis Process Flowchart**

1. Determine pre-development peak flows ($Q_{p25PRE}$, $Q_{fPRE}$).

2. Determine post-development peak flows ($Q_{p25POST}$, $Q_{fPOST}$).

3. **Is $Q_{p25POST} \leq Q_{p25PRE}$?**
   - **Yes**: No detention required.
   - **No**: Design detention pond so that $Q_{p25POST}$ out of pond ($Q_{p25POND}$) $\leq Q_{p25PRE}$.

4. **Does $Q_{fPOST}$ have safe passage?**
   - **Yes**: Design detention pond so that $Q_{fPOND}$ out of pond ($Q_{fPOND}$) passes safely.
   - **No**: Determine 10% point and identify all confluence points and intermediate structures and conveyances.
Determine $Q_{25PRE}$ at project outfall all confluence points, structures and conveyances to 10% point.

Determine $Q_{p25POND}$ at all confluence points, structures and conveyances to 10% point. Employ reach routing to accurately model timing of basin hydrographs.

**Is** $Q_{p25POND} \leq Q_{25PRE}$ **at all confluence points to 10% point?**

- **Yes** → Analysis complete.
- **No** → Can pond be revised so that $Q_{p25POND} \leq Q_{25PRE}$ **at all confluence points to 10% point?**
  - **Yes** → Revise design and rerun analysis.
  - **No** → Determine all necessary downstream improvements to accommodate flow increases ($Q_{p25POND}$ and $Q_{FPOND}$). This may require coordination with downstream property owners and/or local authority for easements.

Determine $Q_{fPOND}$ at project outfall all confluence points, structures and conveyances to 10% point. Employ reach routing to accurately model timing of basin hydrographs.

**Is** $Q_{FPOND}$ **safely conveyed through all confluence points and structures and conveyances?**

- **Yes** → Analysis complete.
- **No** → Can pond be revised so that $Q_{FPOND}$ **safely conveyed through all confluence points and structures and conveyances?**
  - **Yes** → Revise design and rerun analysis.
  - **No** → Determine all necessary downstream improvements to accommodate flow increases ($Q_{p25POND}$ and $Q_{FPOND}$). This may require coordination with downstream property owners and/or local authority for easements.
• Determine pre- and post-developed basin characteristics (area, CN, Tc)
• Obtain precipitation depth from NOAA website
• Compute pre- and post-developed peak discharges
Downstream Analysis Process Flowchart

- Determine pre- and post-developed basin characteristics (area, CN, Tc)
- **Obtain precipitation depth from NOAA website**
- Compute pre- and post-developed peak discharges
Downstream Analysis Process Flowchart
Downstream Analysis Process Flowchart

- Determine pre- and post-developed basin characteristics (area, CN, Tc)
- Obtain precipitation depth from NOAA website
- Compute pre- and post-developed peak discharges
Downstream Analysis Process Flowchart
Stormwater management facility likely required

Use software for efficient iterative facility design process (Hydraflow Hydrographs, PondPack, HydroCAD, etc.)
Downstream Analysis Process Flowchart

- Determine downstream 10% point
- Note downstream confluences, structures and conveyances and include analysis point at these locations
Downstream Analysis Process Flowchart

- Compute $Q_{p25PRE}$ and $Q_{fPRE}$ at these locations
- Determine hydrographs of downstream basins using software
- Use reach routing to accurately model hydrograph timing

Determine 10% point and identify all confluence points and intermediate structures and conveyances.

Determine $Q_{p25PRE}$ at project outfall all confluence points, structures and conveyances to 10% point.

Determine $Q_{fPRE}$ at project outfall all confluence points, structures and conveyances to 10% point.
Downstream Analysis Process Flowchart

- Develop post-developed conditions model (with detention)
- Compare to pre-developed model at confluences, structures and conveyances

Determine $Q_{p25POND}$ at all confluence points, structures and conveyances to 10% point. Employ reach routing to accurately model timing of basin hydrographs.

Determine $Q_{FPOND}$ at all confluence points, structures and conveyances to 10% point. Employ reach routing to accurately model timing of basin hydrographs.
Downstream Analysis Process Flowchart

- Check hydrographs for downstream adverse impacts
- Pond designed to meet outflow requirements at site...

Is $Q_{p25POND} \leq Q_{p25PRE}$ at all confluences to 10% point?

Yes $\rightarrow$ Analysis complete.

Is $Q_{FPOND}$ safely conveyed through all confluence points and conveyances?

Yes $\rightarrow$ Yes

No $\rightarrow$ No

At project outfall

Pre-developed
Post-developed
(with detention)
• Check hydrographs for downstream adverse impacts
• Pond designed to meet outflow requirements at site...
Downstream Analysis Process Flowchart

- Check hydrographs for downstream adverse impacts
- Pond designed to meet outflow requirements at site...

Is $Q_{P25POND} \leq Q_{P25PRE}$ at all confluences to 10% point?

- Yes: Analysis complete.
- No:

Is $Q_{FPOND}$ safely conveyed through all confluence points and structures and conveyances?

- Yes
- No:

At project outfall

At downstream culvert

Pre-developed
Post-developed (with detention)

At 10% analysis point
Downstream Analysis Process Flowchart

- If adverse impacts exist, consider alteration of pond outlet control structure to mimic pre-development conditions
Consider the following to mitigate impacts of detention:
- Upgrade of downstream infrastructure
- Additional drainage easements from affected property owners

Ensure there are no adverse effects on FEMA-regulated floodplain.
Example Problem

1. Define Downstream Analysis Points and Obtain Basin Characteristics
2. Calculate Downstream Basin Time of Concentration (Tc)
3. Compute Peak Flows/Hydrographs at Analysis Points
4. Assess Downstream Impacts

Example Project:
Roadway widening project in Gwinnett County, Georgia
Project Outfall Basin Area: 4.7 acres
Example Problem

1. Define Downstream Analysis Point(s) and Obtain Basin Characteristics
2. Calculate Downstream Basin Time of Concentration (Tc)
3. Compute Peak Flows/Hydrographs at Analysis Points
4. Assess Downstream Impacts

Basin Characteristics:

- **Drainage Area:** LIDAR, USGS topo maps, DEM
- **Land Use:** Aerial Photography, GIS datasets
Downstream Analysis Process Flowchart

Example Problem

1. Define Downstream Analysis Point(s) and Obtain Basin Characteristics
2. Calculate Downstream Basin Time of Concentration (Tc)
3. Compute Peak Flows/Hydrographs at Analysis Points
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<table>
<thead>
<tr>
<th>Downstream Basin</th>
<th>Area (Acres)</th>
<th>CN</th>
</tr>
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<tbody>
<tr>
<td>Commercial and business (Soil Type B)</td>
<td>43.22</td>
<td>92</td>
</tr>
<tr>
<td>Woods - grass combination - Good condition (Soil Type B)</td>
<td>3.96</td>
<td>58</td>
</tr>
<tr>
<td>Total</td>
<td>47.18</td>
<td>89</td>
</tr>
</tbody>
</table>
Example Problem

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**Downstream Basin**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>3189.6</td>
<td>Flow Length (ft)</td>
</tr>
<tr>
<td>CN</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>9.8</td>
<td>Watershed Slope (%)</td>
</tr>
<tr>
<td>S</td>
<td>1.22</td>
<td>Maximum Retention (in)</td>
</tr>
<tr>
<td>Tc</td>
<td>0.311</td>
<td>Hours</td>
</tr>
<tr>
<td>Tc</td>
<td>18.7</td>
<td>Minutes</td>
</tr>
</tbody>
</table>

*In this case, lag method was used to calculate Tc*
For this example, there is not a significant increase in flow rates at the downstream analysis study point between pre- and post-development conditions. The existing drainage system has enough capacity to handle the small increase in flow rates.
Questions

Any Questions?
Course Feedback

Please complete the course feedback forms before leaving so this course can continue to be improved!
Contact Information

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