Our Services

With over a half a century of award winning engineering, environmental, construction management and planning expertise, T&M provides a wide spectrum of services to include:

- Green Infrastructure
- Water Resources
- Landscape Architecture
- Site Development / Redevelopment
- Environmental
- Municipal Engineering
- Professional Construction Management
- Geographic Information Systems
- Electrical / Automation
- Energy
- Solid Waste
- Transportation
About Zachary Ranstead, PE, LEED-AP

- Registered Professional Engineer, PA, LEED Accredited Professional
- Over 21 Years of Professional Experience
- Project Management, Planning, Design, Permitting, Construction Management
- Expertise in Stormwater Management, Erosion Control, NPDES and Flood Studies
- Not a Meteorologist!
- Developed Slow Release Stormwater Design Methodology Transitioned into MRC
About Stephen Shiffer, PE

- Registered Professional Engineer, MD
- Over 6 Years of Professional Experience, 4+ Designing GSI in Philadelphia
- Project Management, Planning, Design, Permitting, & Water Quality Crediting
- Expertise in Green Stormwater Infrastructure Planning & Design
- Land Development – Subdivisions, Residential, & Commercial
- Not a Meteorologist either!
Allentown Flooding Aug. 29, 2013

- Hot, humid
- Thunderstorm day before saturated ground
- Unforecast severe thunderstorm with peak lasting 45 minutes
- Flooding of West End Theatre District several feet deep
- Manhole rims popped off structures, dumpsters floated away
- Resident report of over 12” in an open container
Allentown Flooding
Aug. 29, 2013

- Cars pushed onto sidewalks
- Water rescues
- 24,000 people evacuated from Allentown fairgrounds
- Fortunately no injuries
- What happened?!!
Allentown Flooding Aug. 29, 2013

After the fact...

Convergence zone caused moisture to lift and “squeeze out”

Short term models struggle to pick up

Precipitable water in atmosphere was near 2 inches

The cause for this um, ugly bust, in our forecast was a convergence zone (boundary that caused moisture in the atmosphere to lift and squeeze out) that stretched across Eastern Pennsylvania into South Jersey. These mesoscale features are hard to pin down in modeling -- and often times short term modeling struggles to pick this up. While the NAM and HRRR (the HRRR is a pretty reliable piece of guidance) hinted at steadier showers to our west and southwest, the SREF (which I didn't rely on in our forecast as it was a bit of an outlier in precip intensity and amount) had those showers much closer to the region. Other models were less robust in the amount of rain that was projected -- GFS and Euro generally in the quarter to half inch range.

Boundaries matter and small scale features matter when there's a moisture rich environment, which we had today with PWAT's pushing two inches out there. These heavy mesoscale rains have been proven time and time again this summer (see the eight inch rain in Philly a month ago).
<table>
<thead>
<tr>
<th>Event Details:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Event</td>
<td>Flash Flood</td>
</tr>
<tr>
<td>Cause</td>
<td>Heavy Rain</td>
</tr>
<tr>
<td>State</td>
<td>PENNSYLVANIA</td>
</tr>
<tr>
<td>County/Area</td>
<td>LEHIGH</td>
</tr>
<tr>
<td>NWS</td>
<td>PHI</td>
</tr>
<tr>
<td>Report Source</td>
<td>Emergency Manager</td>
</tr>
<tr>
<td>NCEI Data Source</td>
<td>CSV</td>
</tr>
<tr>
<td>Begin Date</td>
<td>2013-08-29 21:30:00.0 EST-5</td>
</tr>
<tr>
<td>Begin Location</td>
<td>15 SSE ECKERT</td>
</tr>
<tr>
<td>End Date</td>
<td>2013-08-29 23:10:00.0 EST-5</td>
</tr>
<tr>
<td>End Location</td>
<td>15 ALLENTOWN</td>
</tr>
<tr>
<td>Deaths</td>
<td>0/0 (fatalty details below, when available...)</td>
</tr>
<tr>
<td>Injuries</td>
<td>0/0</td>
</tr>
<tr>
<td>Property Damage</td>
<td>100,000K</td>
</tr>
<tr>
<td>Crop Damage</td>
<td>0.00K</td>
</tr>
<tr>
<td>Episode Narrative</td>
<td>A cluster of showers and thunderstorms with very heavy rain caused flash flooding in and around Allentown during the evening of the 29th.</td>
</tr>
<tr>
<td>Event Narrative</td>
<td>The second straight day of thunderstorms with very heavy rain caused roadway and small creek flash flooding in Allentown and Whitehall Township. Numerous roadways were flooded with some water rescues from trapped vehicles. A child nearly was swept away in the flood waters before being rescued by an adult. Manhole covers popped. About 43 vehicles were badly damaged in the flooding in the West End of Allentown and several businesses were flooded. Flood damage in the area also occurred to homes, garages and basements. No serious injuries were reported. About 2200 people were sheltered in place at the Allentown Fair off of Liberty Street in the city because the entrances and exits to the fairground were flooded. The Zac Brown Band had to cut their concert short. Fair goers were able to leave later that evening. Damage to the fair was limited to grass and gravel erosion. Elsewhere in the city, vehicles were trapped in flood waters on Summer Avenue, 22nd and Allen Street, 13th and Liberty Street and 18th and Tilghman Street. About ten homes around 22nd and Allen Street had water in their basements and the electricity was turned off for precautionary reasons. Event precipitation totals included 1.20 inches at the Lehigh Valley International Airport.</td>
</tr>
</tbody>
</table>
Cloudburst

World Meteorological Organization Definition – 4 inches / hour event

Difficult to Predict when, where and how intense

Unique environment required – warm moist air and strong uplift

Small area at resolution limit of current weather models

Short duration

Often missed by official gauge stations
Uplift Processes

Lift processes drive and enhance cloudbursts.

Warm air holds more moisture.

Rising air cools, phase change from vapor to liquid.

Rich, moist parcel of air will rise to great elevation then sudden rapid condensation occurs.

Super-saturated small droplets combine and grow as they fall.

In orographic lift, moist air moves up the windward side of a mountain or a cool, dense body of air. The air cools, forms clouds, and rains, leaving the lee side dry. In convective lift, moist air is warmed as it moves over warm ground. As the warm air rises, it cools and forms rain clouds. In convergent lift, air masses come together and are forced upward. They then cool and form rain clouds.
Historic Extreme Precipitation in Pennsylvania

Photos at 30 minute increments
Emporium, PA 15 fatalities

30.8” in 4.75 hours official measurement, isolated location determined by resident interviews

Better data in rural farm areas than in towns from open containers

Rain fell in rope-like streams rather than drops

Official Stations Recorded 8” or less

July 18, 1942
Emporium, PA Event downstream of Smethport was at top of PMP Estimate

30.8” in 4.75 hours

Near world records
Typical urban storm sewer design capacity for 10-year storm

1-year 45-minute storm
~1.0 in. total precipitation

1000-year 45-minute storm
~3.0 in. total precipitation

### PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)¹

<table>
<thead>
<tr>
<th>Duration (minutes)</th>
<th>Average Recurrence Interval (years)</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>200</th>
<th>500</th>
<th>1000</th>
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<tbody>
<tr>
<td>5</td>
<td>0.324</td>
<td>0.386</td>
<td>0.454</td>
<td>0.507</td>
<td>0.566</td>
<td>0.610</td>
<td>0.656</td>
<td>0.691</td>
<td>0.719</td>
<td>0.767</td>
<td>0.803</td>
</tr>
<tr>
<td></td>
<td>(0.289–0.399)</td>
<td>(0.348–0.427)</td>
<td>(0.405–0.502)</td>
<td>(0.455–0.557)</td>
<td>(0.505–0.623)</td>
<td>(0.542–0.673)</td>
<td>(0.560–0.724)</td>
<td>(0.589–0.716)</td>
<td>(0.598–0.712)</td>
<td>(0.656–0.803)</td>
<td>(0.603–0.854)</td>
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<tr>
<td>15</td>
<td>0.618</td>
<td>0.676</td>
<td>0.725</td>
<td>0.780</td>
<td>0.837</td>
<td>0.894</td>
<td>0.956</td>
<td>1.011</td>
<td>1.079</td>
<td>1.138</td>
<td>1.200</td>
</tr>
<tr>
<td></td>
<td>(0.485–0.757)</td>
<td>(0.558–0.882)</td>
<td>(0.652–0.880)</td>
<td>(0.722–0.887)</td>
<td>(0.802–0.999)</td>
<td>(0.859–1.071)</td>
<td>(0.917–1.187)</td>
<td>(0.969–1.222)</td>
<td>(1.030–1.324)</td>
<td>(1.056–1.460)</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>1.004</td>
<td>1.080</td>
<td>1.160</td>
<td>1.240</td>
<td>1.320</td>
<td>1.400</td>
<td>1.480</td>
<td>1.560</td>
<td>1.640</td>
<td>1.720</td>
<td>1.800</td>
</tr>
<tr>
<td></td>
<td>(0.794–0.976)</td>
<td>(0.926–1.118)</td>
<td>(1.017–1.143)</td>
<td>(1.051–1.212)</td>
<td>(1.080–1.175)</td>
<td>(1.127–1.269)</td>
<td>(1.169–1.355)</td>
<td>(1.206–1.313)</td>
<td>(1.239–1.428)</td>
<td>(1.257–1.633)</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>1.510</td>
<td>1.590</td>
<td>1.670</td>
<td>1.750</td>
<td>1.830</td>
<td>1.910</td>
<td>1.990</td>
<td>2.070</td>
<td>2.150</td>
<td>2.230</td>
<td>2.310</td>
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<tr>
<td></td>
<td>(0.989–1.222)</td>
<td>(1.201–1.408)</td>
<td>(1.345–1.631)</td>
<td>(1.453–1.907)</td>
<td>(1.564–2.057)</td>
<td>(1.625–2.197)</td>
<td>(1.685–2.357)</td>
<td>(1.776–2.517)</td>
<td>(1.867–2.657)</td>
<td>(1.958–2.797)</td>
<td></td>
</tr>
</tbody>
</table>

¹ Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parentheses are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be less than the upper bound (or more than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.
Translated from NOAA Radar Data

User friendly graphical output for current storm events

Not available for viewing past events

Not always a complete record of NOAA data
NOAA NCEIClimate Toolkit

Export of radar data to Shapefile, Arc/Info, ASCII Grid, Gridded NetCDF and Google Earth kmz

Radar product inventory dating back to 1991

Precipitation depth estimates from algorithms of radar reflectivity
NEXRAD Radar Limitations

Greater distance from radar less coverage due to scan angle

Algorithms from base reflectivity – many assumptions

Missing data records – maintenance during events

Not official, but useful tool to correlate specific storms to official gauge data

Lowest beam can overshoot low topped storms and underestimate events in Lehigh Valley

Note that rainfall estimates from klix radar has been grossly underdone as the radar beam has overshot the core of these very low-topped showers (e.g., Beam height at 0.5 degree tilt can't see anything below 6,000 ft mean sea level out toward the Lehigh valley).
NOAA Official Rain Gauges

Regional map of rain gauges with official totals 8/29/13

LVI Airport 1.3 in
Schnecksville 0.5 in
Kutztown 0.2 in
Alburtis 0.8 in

Does Not Add Up!
USGS Stream Gauge
Little Lehigh Creek

Little Lehigh Creek
Water Surface Rise of 1.0 ft

Does Not Add Up!
USGS Stream Gauge
Little Lehigh Creek

Little Lehigh Creek
Water Surface Rise of 1.0 ft

Does Not Add Up!
USGS Stream Gauge
Jordan Creek

Jordan Creek
Water Surface Rise of 1.3 ft

Does Not Add Up!
USGS Stream Gauge
Jordan Creek

Jordan Creek
Water Surface Rise of 1.3 ft

Does Not Add Up!
10:29 PM
NEXRAD

11:03 PM
Heat Island Effect?

- High Imperviousness
- Dark Rooftops
- Blacktop Pavement

Little vegetation or evaporation causes cities to remain warmer than the surrounding countryside.
Heat Island Effect?

Temperature increase from rural to urban areas
**Heat Island Effect?**

Urban area becomes small low pressure system with rising heat

Draws moisture in from surroundings

Urban air pollutants act to bind water droplets

Peak radiation in evening
Typical Ground-Level Conditions

High Imperviousness

Little Vegetation

Dark Surfaces
Impervious Coverage

Mapping from PASDA - PSU

IMPNLCD01 Percentage of impervious area determined from NLCD 2001 impervious dataset 84 percent
NEXRAD
Downtown
Allentown
8:33 PM
NEXRAD
Downtown
Allentown

8:39 PM
NEXRAD
Downtown
Allentown

8:44 PM
NEXRAD
Downtown
Allentown
8:50 PM
8:56 PM

NEXRAD
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Allentown
NEXRAD
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9:02 PM
NEXRAD
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9:35 PM
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9:35 PM
NEXRAD Downtown Allentown

9:46 PM
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9:46 PM
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9:50 PM
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Downtown
Allentown

9:50 PM
9:54 PM

NEXRAD
Downtown
Allentown
Heat Island Effect!

1. In big cities, heat-absorbing roofs, blacktop pavement and auto exhaust trap the sun’s rays and warm the air.
2. Late in the day, the accumulated heat starts to be released. The lighter, warmed air begins to rise.
3. In cities near large bodies of water, moist air flows in toward the rising urban air.
4. The moist air and warm city air collide and drive each other higher, hitting the cooler layer of air above and creating clouds and rain.
5. The prevailing wind blows the clouds. Areas downwind of cities get more rain than those upwind.
Allentown, Pa. – Angry Allentown residents are blaming the city for late August flooding that damaged homes and destroyed dozens of cars in their West End neighborhoods.

“This is not a natural disaster. This is not environmental.”

“This is the city not taking care of drainage. This is negligence.”

“Don’t sit there and tell us that you have no responsibility. You have all the responsibility.”

A west end resident reported more than 12-inches of rain collected in a large trash bin.
Downtown Allentown Topographic Setting

Built on hilltop between Jordan Creek to North and Little Lehigh Creek to South

Streets constructed down historic natural drainageways - StreamStats
500-year storm typically contained within overbanks

Less runoff from undeveloped tributary area
Developed Channel Section

Roadway built over historic stream flanked by buildings. Same flow – runoff depth of 2-3 feet

Increased flow rate from unmitigated impervious areas

Installing large storm sewer to replicate pre-existing channel capacity infeasibly costly

With unmitigated runoff will move the problem downstream to others
Livingston Storm Sewer Analysis

Detailed dynamic model
2.25 square miles 500 nodes, 248 catch basins

Most infrastructure from early 20th century

Model of existing drainage system showed capacity for only 1-2 year storm event

Alternatives for moderate upgrades for $200k – $400k, but not widespread relief up to millions for new trunkline
Cloudburst Resiliency

Daylight and restore pre-existing drainage ways

Require redevelopment to sequester runoff in lower level vaults

Provide inlet grates with maximum capture efficiency

Storm Sewer Upgrades – additional inlets

Green infrastructure
GSI & the Heat Island Effect

Green Roofs

Vertical Greening Systems

Tree Pits & Vegetated Surfaces (Bumpouts etc.)

Parks
Schuylkill River West Trail

Photo near the Trailhead

Layout minimized disturbances

Extensive Green Infrastructure

Amended Soils
Infiltration Berms

Designed to become naturalized within the environment.
Schuylkill River West Trail

2018 PA APA Award Winner

Final Naturalization
Monday Morning Quarterback

- Allentown: 84% Impervious
- Meetings resulted in some limited improvements
- Lowering of Albright Avenue at Andrew Street Intersection to reduce ponding
- A Stormwater fee program was since implemented – projected 2019 budget of $6 Million
- A 10% increase in green cover equates to a roughly a 5.4 °F decrease in peak temperatures!
Cloudburst
Resiliency

Alternative Green
Infrastructure
Concept...
Cloudburst Resiliency in the Future

Global Warming – more heat equals more evaporation

Every 1°F rise in air temperature allows atmosphere to hold an additional 4% of water vapor

Expect cloudbursts to be more frequent and intense

Weather modelling computing power and resolution to improve forecasting ability
QUESTIONS
THANK YOU

Presenters

Zachary Ranstead, PE, LEED -AP
Supervising Engineer
T&M Associates
zranstead@tandmassociates.com | 610.625.2999

Stephen Shiffer, PE
Senior Staff Engineer
T&M Associates
sshiffer@tandmassociates.com | 215.282.7850