

6th Purdue Geotechnical Society
Workshop – April 18, 2008

***Fast-Track Emergency
Replacement of Collapsed Sewer
by Tunneling in Miocene Clay***

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Geotechnics, Foundations, Underground Structures

Project Participants

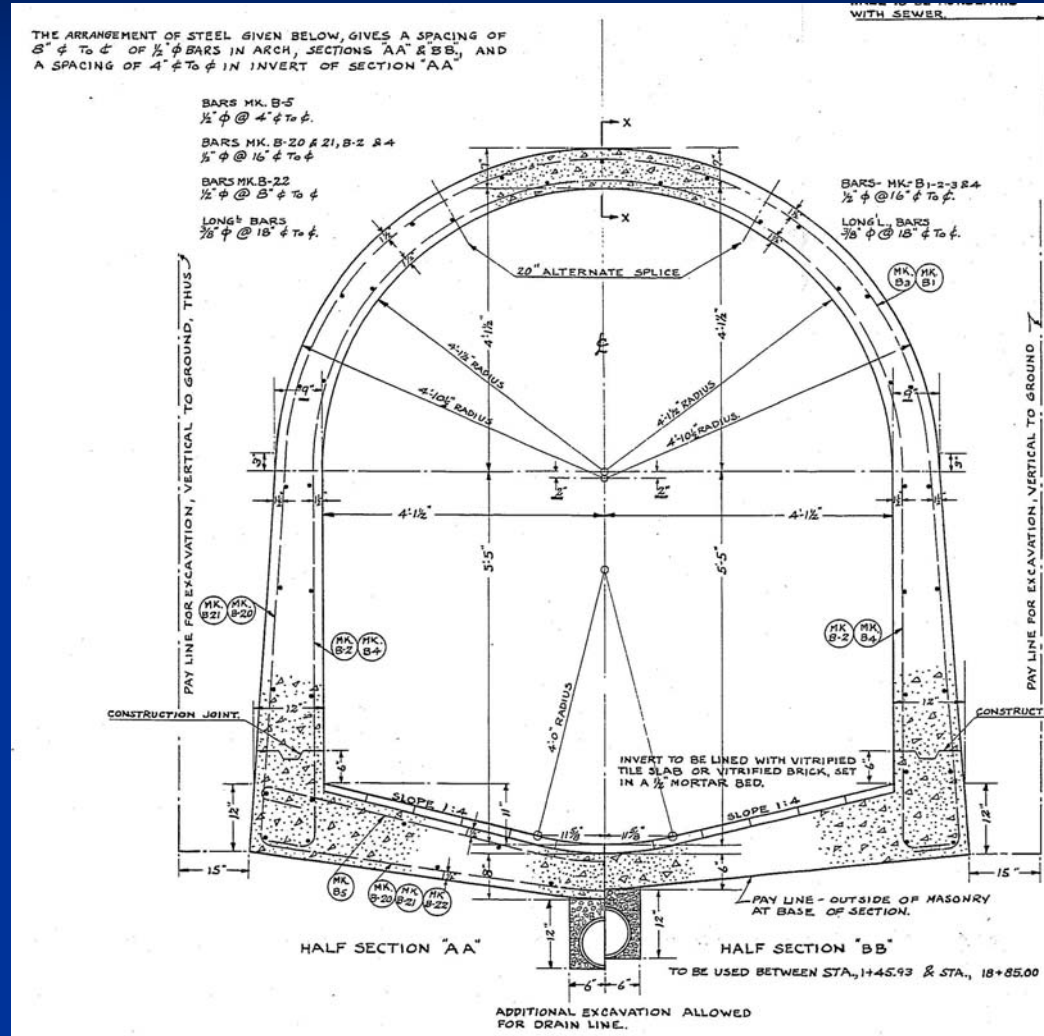
- Greeley and Hansen – sewer facilities design, hydraulics, government relations
- Schnabel Engineering – geotechnical
- Lachel Felice & Associates – tunnel and shaft design, specs, geotechnical contract documents, cost estimating and constructability
- Bradshaw Construction – contractor
- Jacobs Civil – construction management
- City of Richmond, Virginia
- FEMA

Battery Park Sewer – Richmond, VA

- Original Sewer and Historical Changes
- Geotechnical Conditions
- Description of the Problem
- Technical Alternatives
- Selected Solution and Results

Original Arch Sewer/Changes

- 8'-3" wide x 9'-6" Concrete Arch Trunk Sewer built circa 1924 – crown only 9" thick – only slightly buried
- Beginning 1940's – up to additional 100 feet of landfill - Municipal Solid Waste (MSW)



Battery Park Area

Aerial Photo Looking North



Geotechnical Conditions

- Fall Line – Piedmont Geology
- Pre-Cambrian Petersburg Granite – well below project horizon
- Eocene Sand
- Miocene Clay and Silt – Calvert Formation
- Pleistocene Terrace Deposits
- Municipal Solid Waste (MSW)

Miocene Clay

- Mineralogy – 55% smectite, 25% mica
- Typical SPT N-values 10-22
- Older foundation practice involved pile foundations to rock
- Arthur and Leo Casagrande studied the properties in the 1960's – consolidation and triaxial tests
- Foundations since have been shallower mats and caissons (belled where required)

Casagrande Correlation

SPT – In situ Shear Strength

		SPT N-value, blows/ft		
		2-4	4-8	8-15
T&P	Consistency	Soft	Medium	Stiff
	Qu, tsf	0.25-0.5	0.5-1.0	1-2
Richmond	Consistency	Firm	V Stiff	Hard
	Qu, tsf	0.5-1.0	2-4	> 4

Miocene Clay Properties

Property	Range	Mean
Natural Wet Density, pcf	95.0 - 98.9	96.6
Natural Moisture Content, %	61.2 - 89.7	68.6
Liquid Limit, %	61 - 128	105
Plastic Limit, %	23-76	49
Plasticity Index, %	38-71	56
Percent Passing #200 Sieve	78.6 - 96.6	88.8
Specific Gravity of Solids	2.53 - 2.56	2.55
Undrained Shear Strength	1944 - 4078	3011
USCS Symbol	MH & CH	N.A.

Miocene Clay

- Past ground level higher – sediments eroded
- Dessicated by sea-level fluctuations
- Dilatometer Testing - K_0 values 2.0 ranging down to 1.0 at greater depths
- Volume change concerns upon excavation?
- Expected good stand-up time and support characteristics for tunnels and shafts

The Emergency

- Labor Day Weekend – 2006
- Tropical Storm Ernesto dumps 10 inches of rain
- A serious hidden problem was disclosed

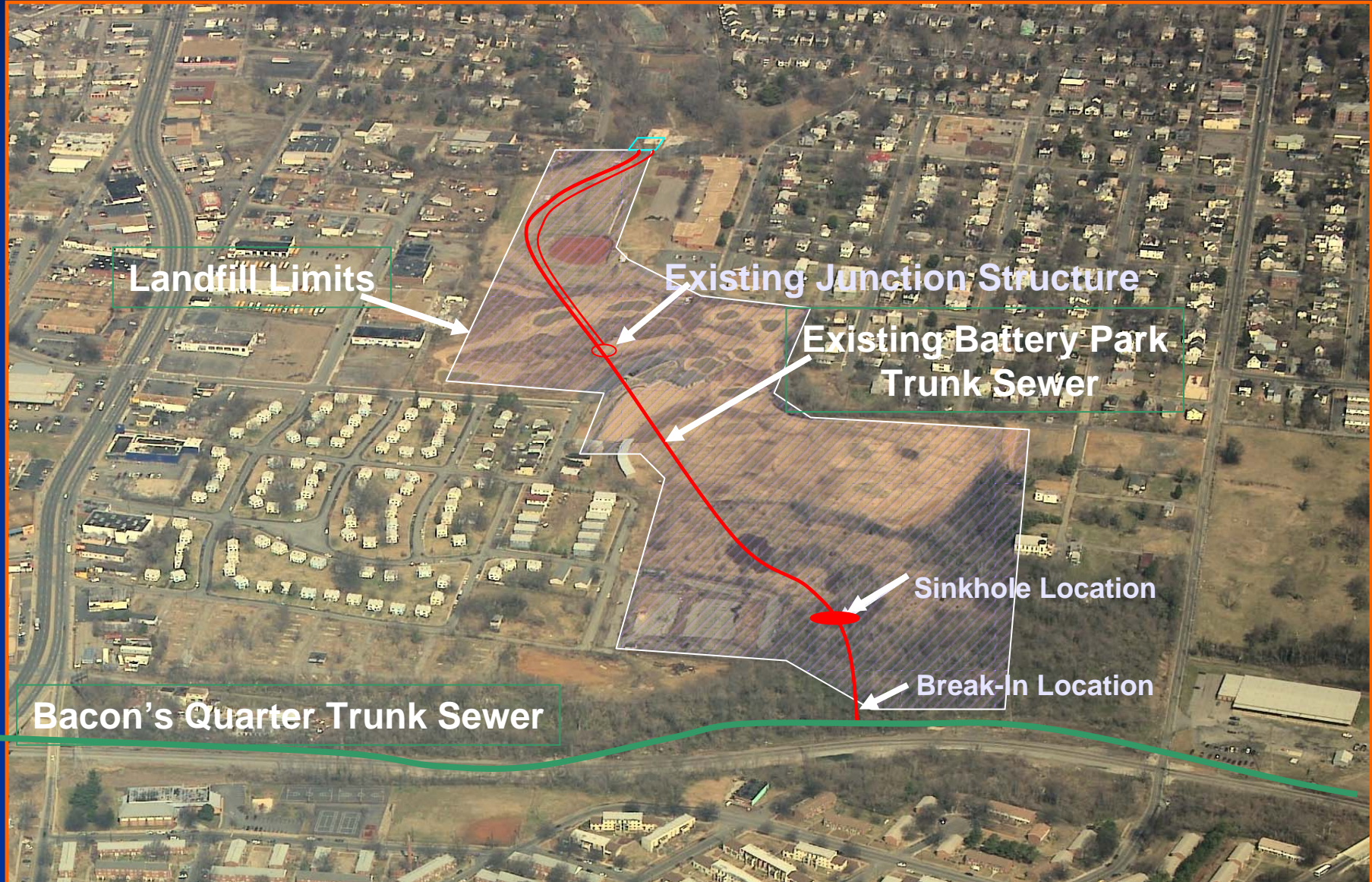
The Sinkhole





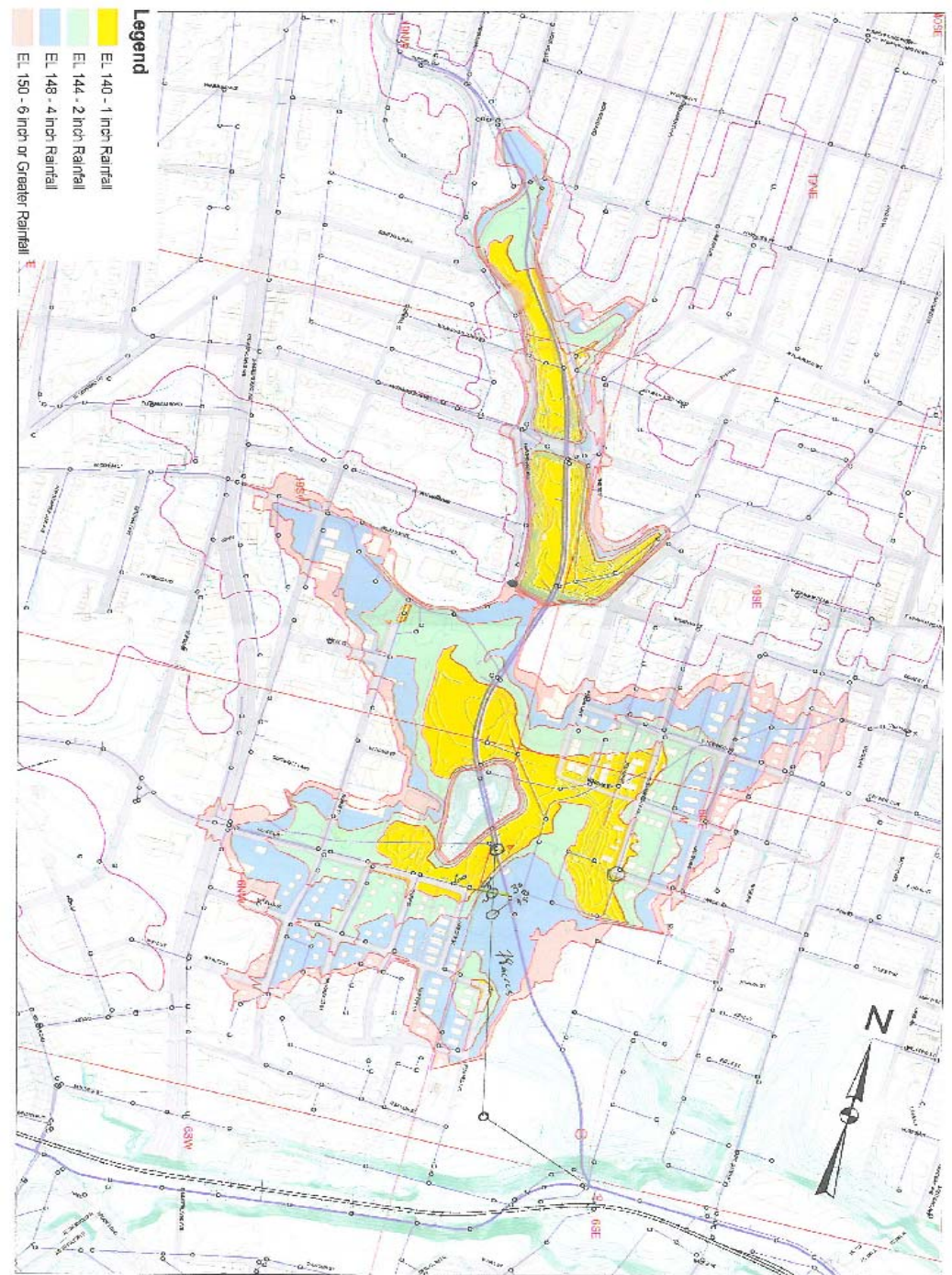
Battery Park Area

Aerial Photo Looking North



Flooding due to Blockage

- Yellow = 1" Rainfall
- Lt. Blue = 2" Rainfall
- Blue = 4" Rainfall
- Purple = 6" or > Rainfall



The Magnitude of the Problem

- Flooding developed at night 8/31/06
- 150 homes evacuated – > 20 later condemned
- 80+ acres flooded with sewage

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Misery in Battery Park

Some fight foul-smelling water -- and now rats
BY MEREDITH BONNY
TIMES-DISPATCH STAFF WRITER
Tuesday, September 5, 2006

On top of the stench of sewage and standing water, Battery Park residents yesterday said they were plagued with rats and feelings of loss and devastation.

"It's a disaster," said Yvonka Hill, who lives on Overbrook Road with her husband and four children under the age of 11.

"There is raw sewage floating around. I have rats running through my home," she said, explaining how she had to put rat poison on her kitchen counters to keep the rodents from getting into the food.

RELATED

"I don't know what to do," she said.

MORE SLIDESHOWS
Take a photo tour of **Battery Park.**



Neighbor Adolph White used a plastic flower pot to empty water from Louise Crawley's basement, flooded by the remnants of tropical depression Ernesto.

P. KEVIN MORLEY/TIMES-DISPATCH

Flooding

- Picture taken at North Diversion Structure location above landfill extent
- Marker points to 26-foot level



Emergency Bypass Pumping

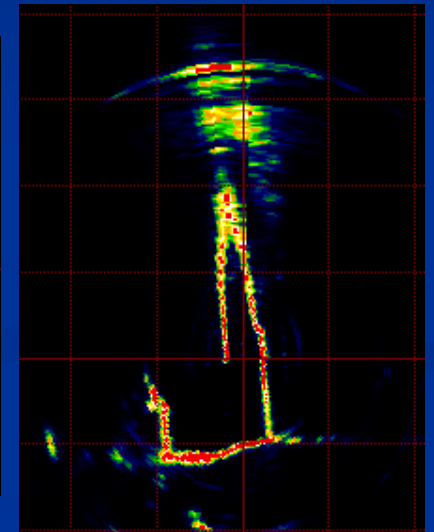
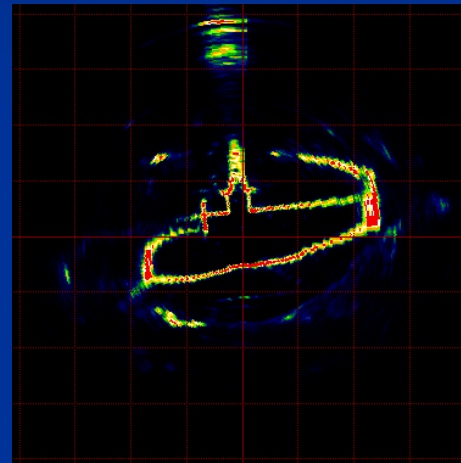
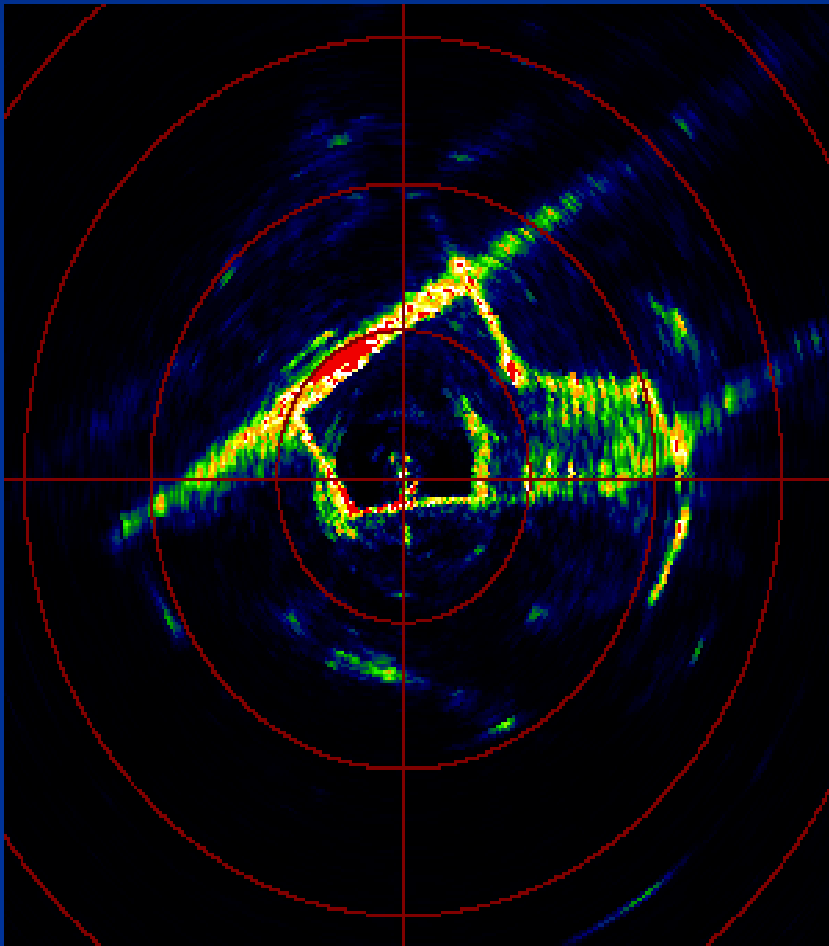


- *Bypass Pumping - 90 MGD - Cost \$600,000/month*
- *2-3 inches of rain would still cause flooding (sewage)*

Initial Solution Considered

- Emergency repair – attempt to salvage sewer pending replacement
 - Bypass pumping
 - Dewater collapsed arch sewer
 - Support arch sewer with steel ribs/timber lagging for safety, and tunnel through collapsed zone
 - Add shotcrete liner to re-establish flow conveyance
- Follow up with permanent solution – construct bypass tunnel to North Junction Structure
- Slow and expensive! Subject to more flooding in the interim during heavy rainfall events

Sonar Survey of Damaged Sewer



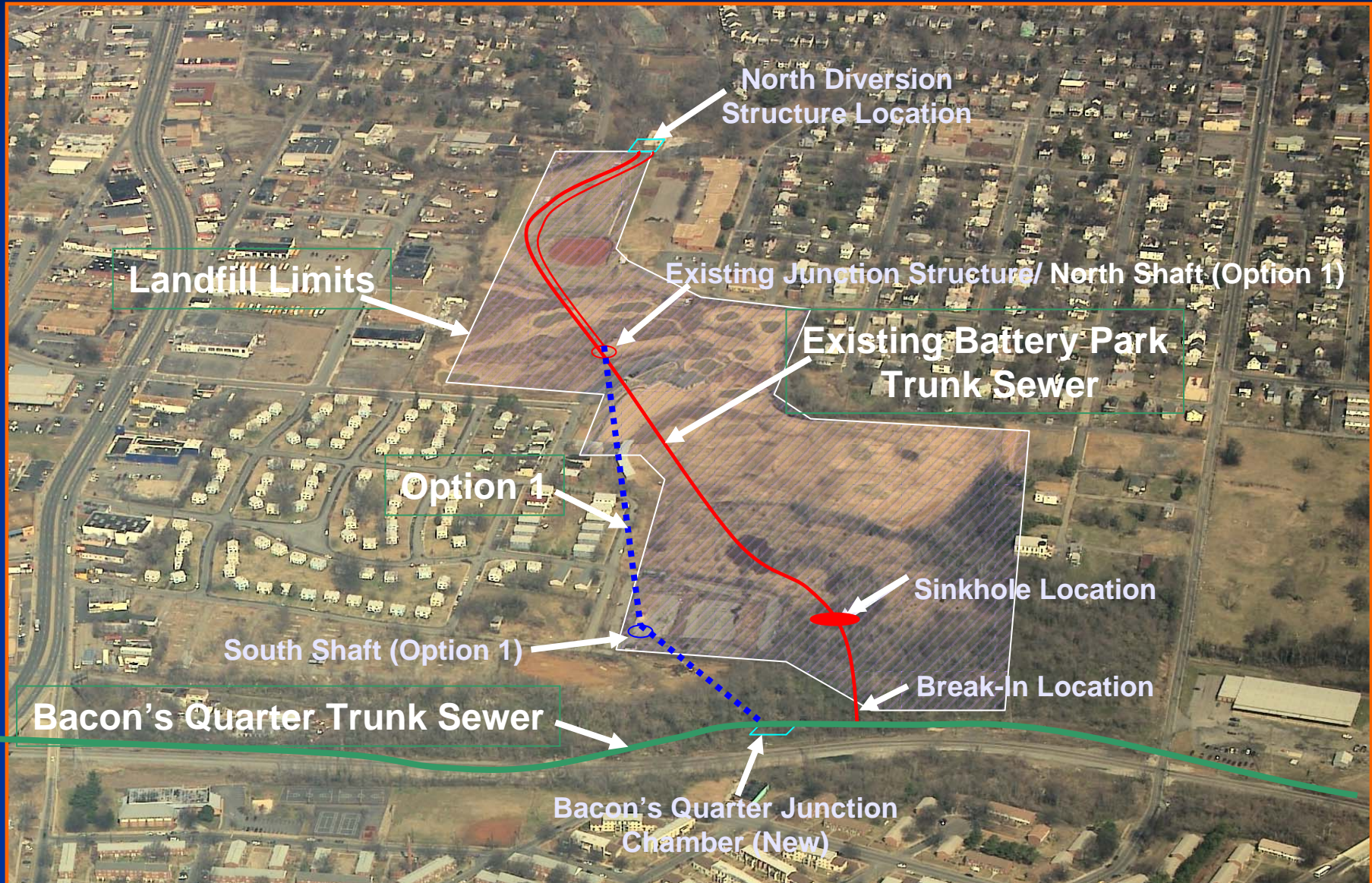
More accidents
waiting to happen!

Option 1 Tunnel Solution

- Pro
 - Skip repair – construct bypass tunnel – 1,750 ft
 - Shortest time to eliminate flooding and health risks
- Con
 - Existing North Junction Chamber in MSW
 - 250 ft tunneling required in MSW
 - Additional vulnerable old sewers below landfill upstream of junction chamber
- Half a solution! Risk not eliminated.

Battery Park Area

Aerial Photo Looking North

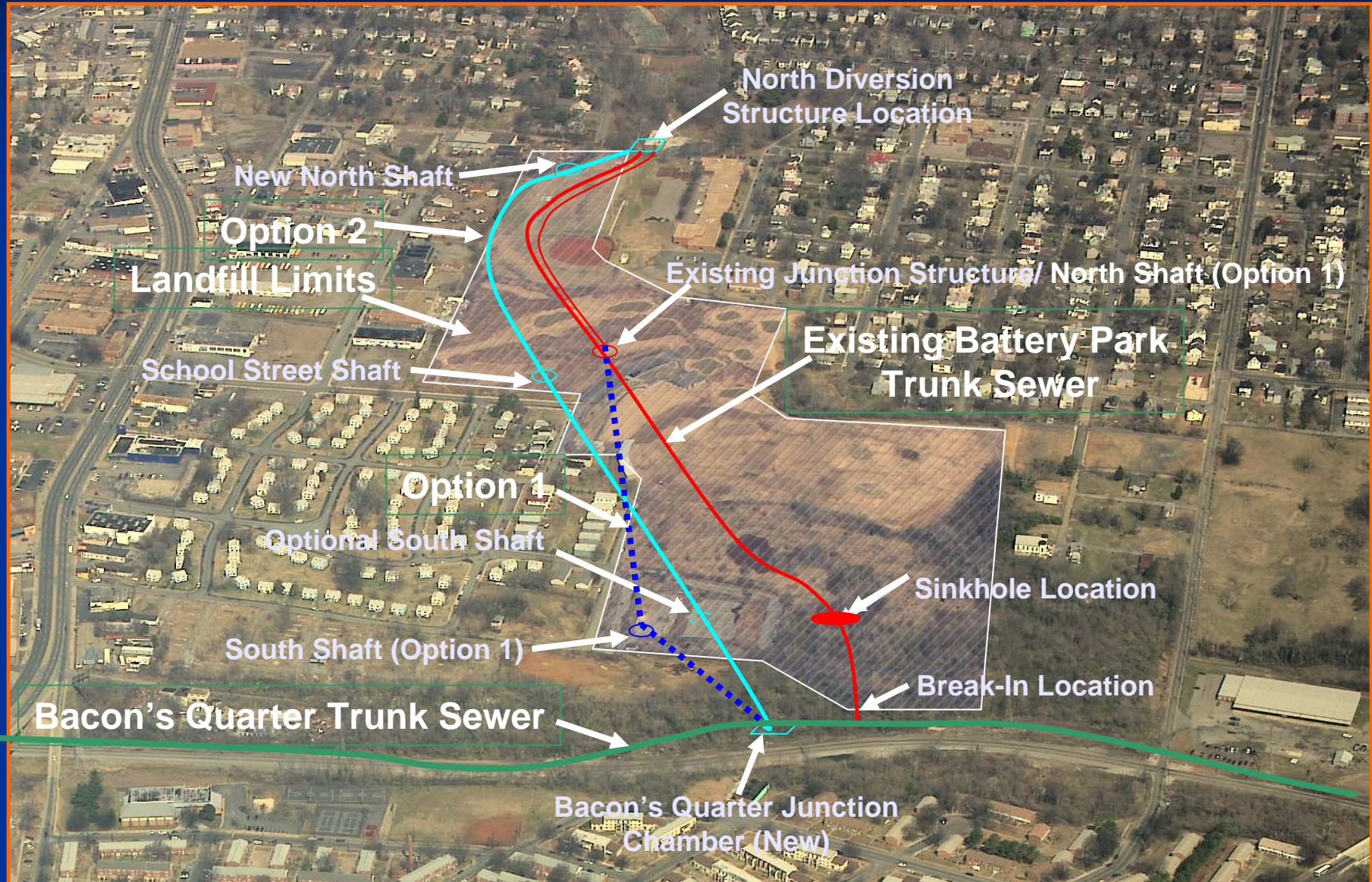


Better Solution – Option 2

- Longer tunnel – past landfill – 3,300 ft
- Move tunnel further into valley wall
- Maximize tunneling in Miocene clay
- Eliminate tunneling in MSW
- Bypass risk of additional collapse and backup
- Challenge – FEMA rules and funding basis
 - Replacement – 95%, cover change orders
 - Improvement – 75%, change orders borne by local government

Battery Park Area

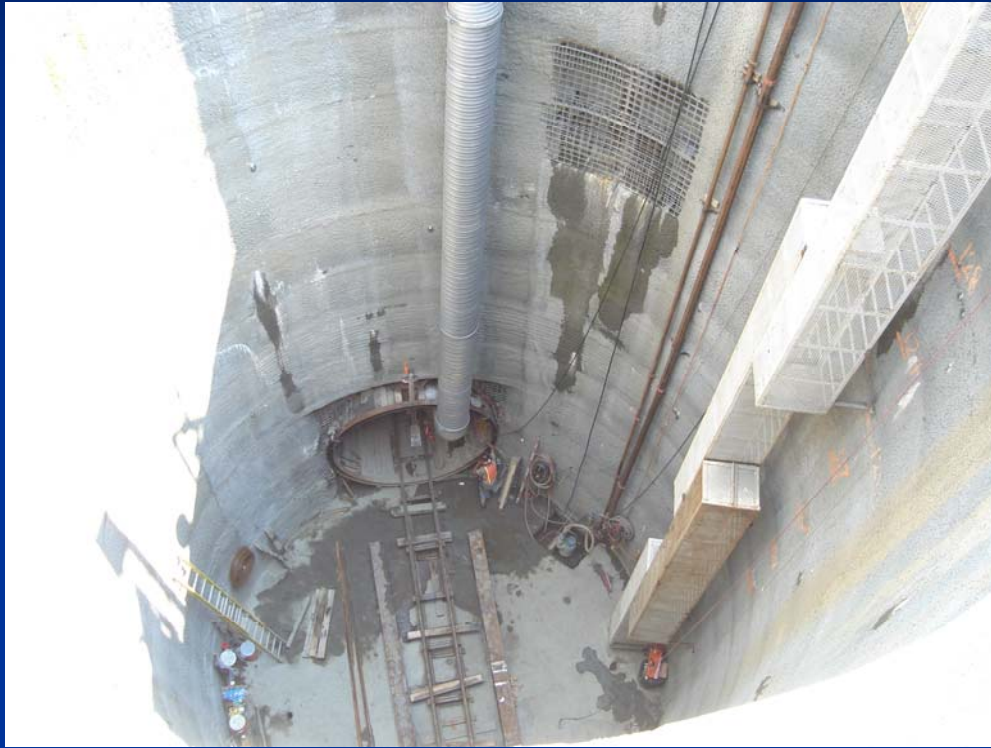
Aerial Photo Looking North



Bid Results

- Option 1
 - \$20,600,000
 - 1,750 feet of new 108" Sewer
 - 108" Liner Pipe installed by November 2007
- Option 2
 - \$25,500,000
 - 3,300 feet of new 108" Sewer
 - 108" Liner Pipe installed by November 2007
- FEMA gives Option 2 the Green Light !

N.A.T.M. Shafts



Components:

- Steel Lattice Girders
- Welded Wire Fabric
- Shotcrete

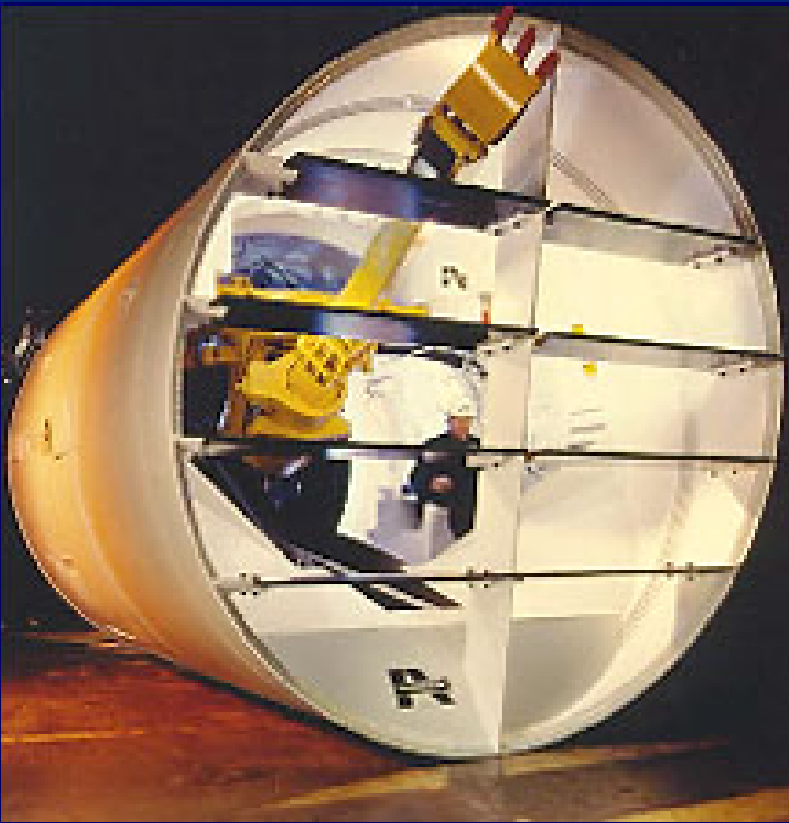


Tunnel Initial Support

- 12 Foot Diameter
- 6" Steel Ribs on 5 Foot Longitudinal Centers
- Oak Lagging (4 x 4)



Tunnel Excavated with Digger Shield



Installing 108" FRP Final Liner Pipe

- Fiberglass Reinforced Polymer (FRP) Pipe
- Relatively lightweight and easy to handle
- Speeds installation
- High corrosion resistance equals long service life
- Lower Manning's n – improved flow



Lowering of Carrier Pipe into Tunnel



Pipe Blocked in Place for Grouting



Grouting Annular Space from Ground Surface



Structures

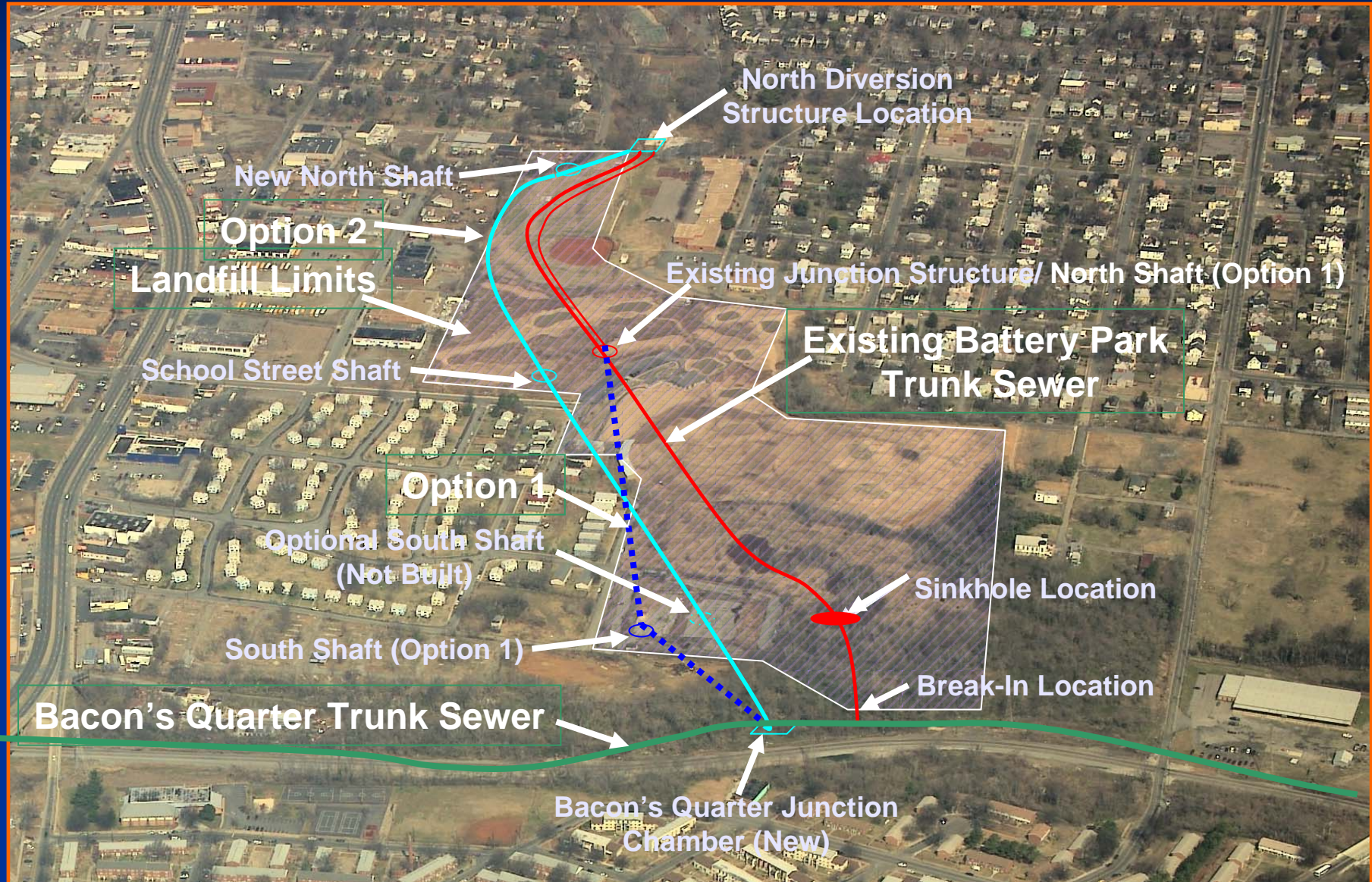


Successful Project

- Fast-track approach was not derailed - 18 Months from catastrophe to completion
- Evolutionary Design Process
 - Initial reactions (good money after bad) vs. right answer
 - Owner correctly supported repeated geotech field recon efforts as situation evolved and changed – provided sound basis for contracting
 - Kept FEMA engaged to gain support and funding for most economical solution

Battery Park Area

Aerial Photo Looking North



The Light at the End of the Tunnel



Questions?