Image by JBG Companies

Louis *at the* **14**th

Washington D.C.

Image by JBG Companies

Russell Voigt | **April 16, 2014** | **Construction Option** | **Dr. Ed Gannon**
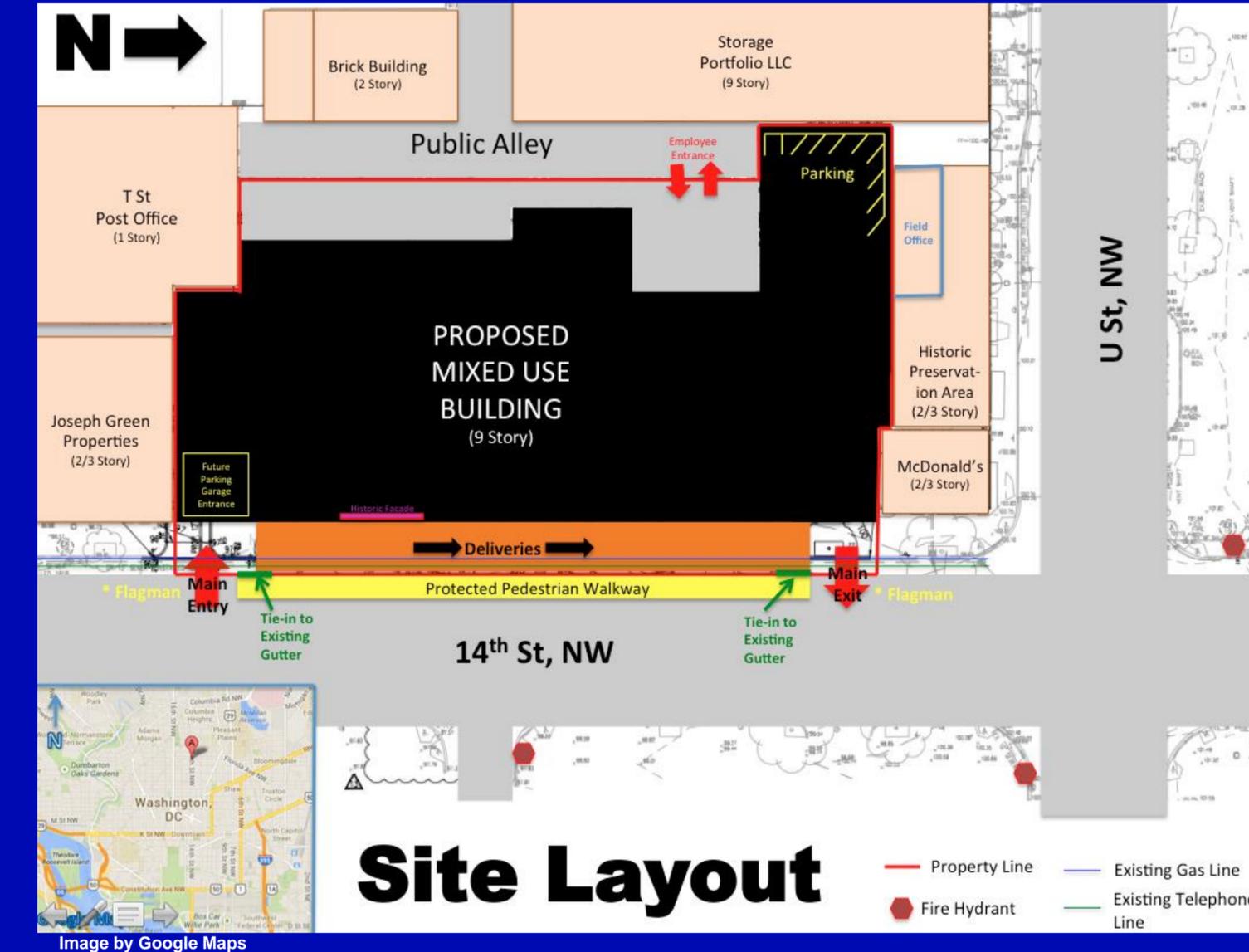
Louis at the 14th

Background Information

- $47M
- 9 stories
- 267,000 SF (GFA)
- 268 rental units
- Ground floor retail tenants
- Design-Bid-Build
- Construction: March 2012 - March 2014

U.S. GREEN BUILDING COUNCIL — LEED SILVER — USGBC

THE JBG COMPANIES

LOUIS. AT 14TH/U

Balfour Beatty Construction

Site Layout

N ➡

Brick Building (2 Story)

Storage Portfolio LLC (9 Story)

T St Post Office (1 Story)

Public Alley

Employee Entrance

Parking

Field Office

Joseph Green Properties (2/3 Story)

PROPOSED MIXED USE BUILDING (9 Story)

Historic Preservation Area (2/3 Story)

Future Parking Garage Entrance

McDonald's (2/3 Story)

Deliveries

Main Entry

Protected Pedestrian Walkway

Main Exit

Flagman

Tie-in to Existing Gutter

Tie-in to Existing Gutter

14th St, NW

U St, NW

Washington DC

Property Line — Existing Gas Line
Fire Hydrant — Existing Telephone Line

Image by Google Maps

Louis at the 14th

Prevention Through Design

"The fatality rate for excavation work is 112% higher than the rate for general construction."

Photo by Balfour Beatty Construction

Key Takeaways

- means & methods selection by contractor
- supervision & inspection
- thorough geotech. investigation
- effective communication b/w engineers & contractor
- *Design-Build* delivery method recommended

Louis at the 14ᵗʰ
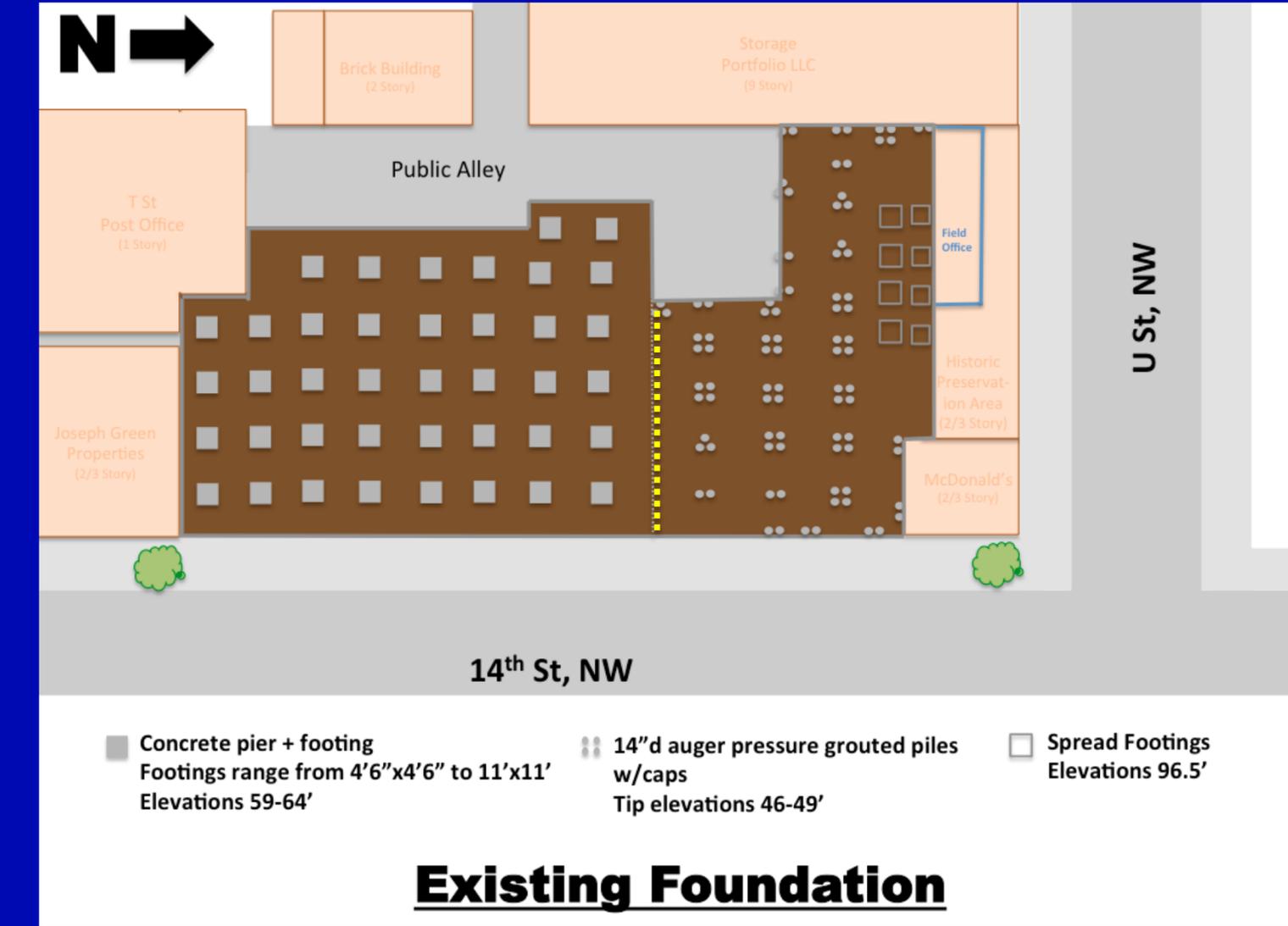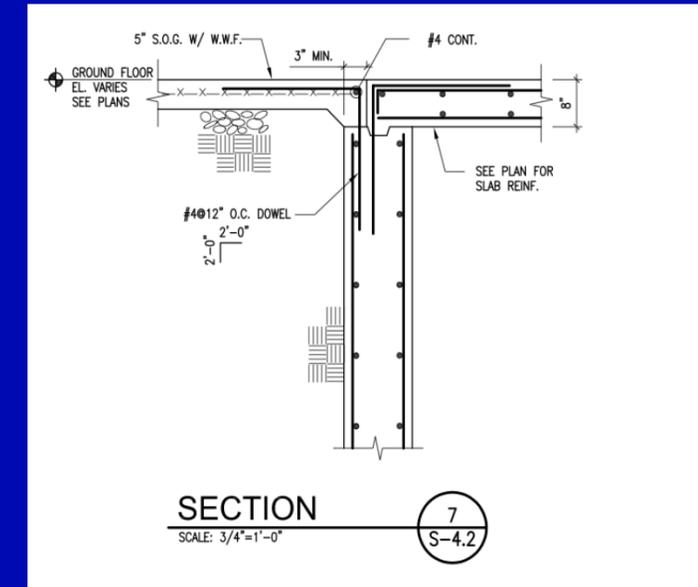
Foundation System

As-Built
North: Capped APG Micropiles (9-stories)
South: Piers on Spread Footings (6-stories)

Geotech. Report
•clays & sands
•estimated a 4-5' thick mat slab
•underpinning concerns
•budget concerns

SECTION   7
SCALE: 3/4"=1'-0"   S-4.2

N ➡

Public Alley

U St, NW

14ᵗʰ St, NW

■ Concrete pier + footing
Footings range from 4'6"x4'6" to 11'x11'
Elevations 59-64'

▌▌ 14"d auger pressure grouted piles
w/caps
Tip elevations 46-49'

☐ Spread Footings
Elevations 96.5'

Existing Foundation
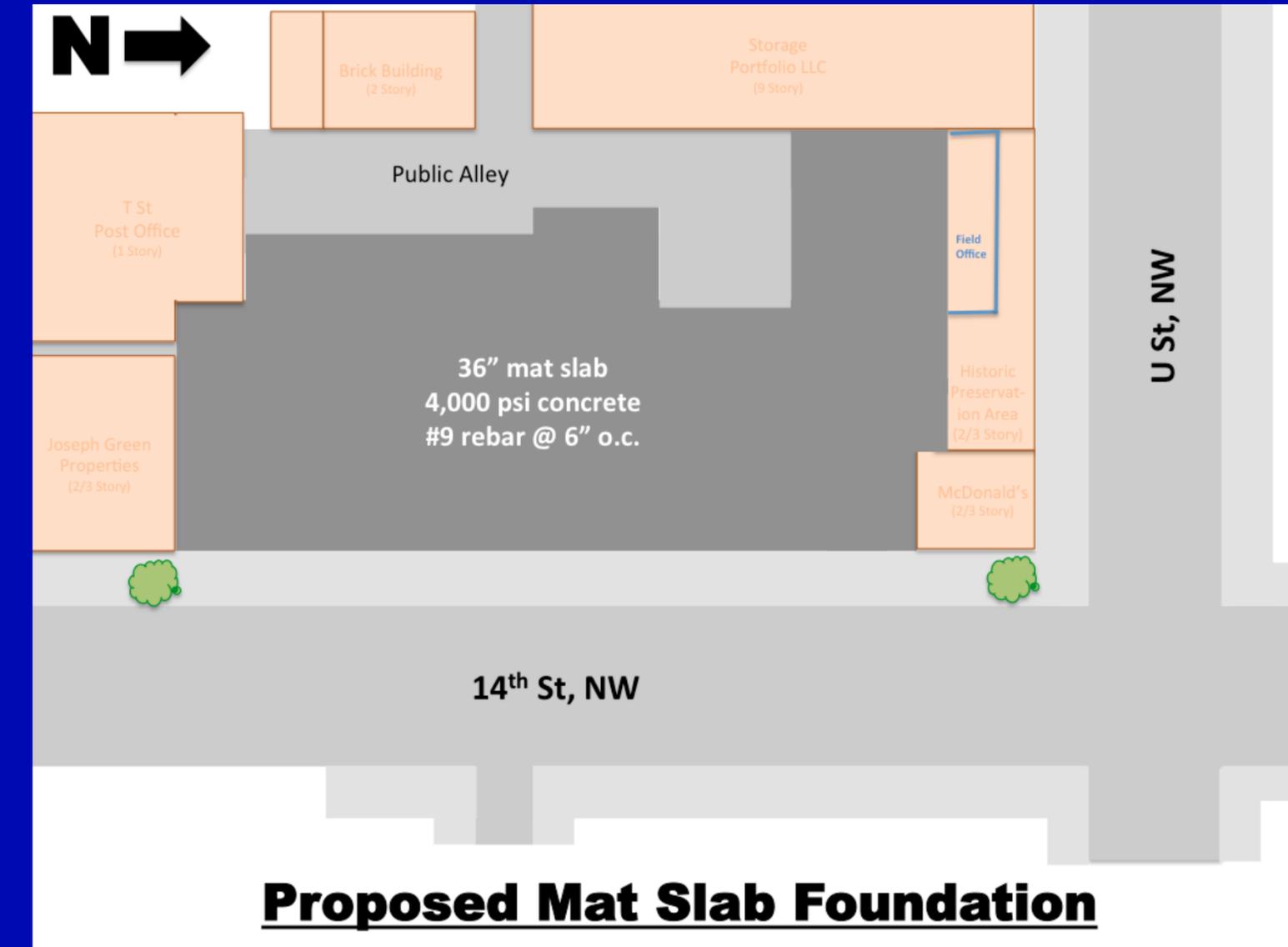
Louis at the 14th

Structural Breadth

Constraints
•soil bearing capacity: 2,000 psf
•slab area: 44,175 SF
•slab perimeter: 900 LF
•largest column load: 1,100 kips (18x24)
•Total building loads:
North: 20,770 kips   South: 35,230 kips

Results:
•36" thick w/ #9 rebar @ 6" o.c.
•4,000 psi concrete
•5,300 CY & 300 tons rebar
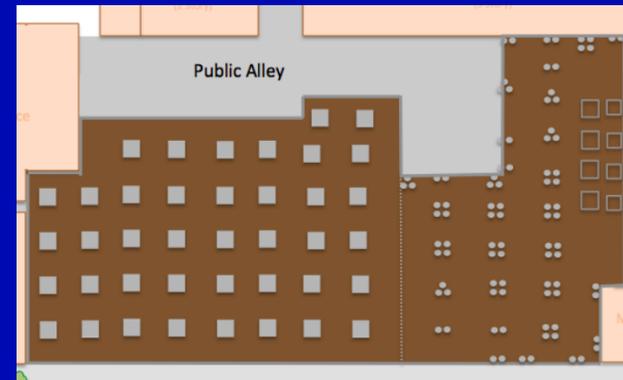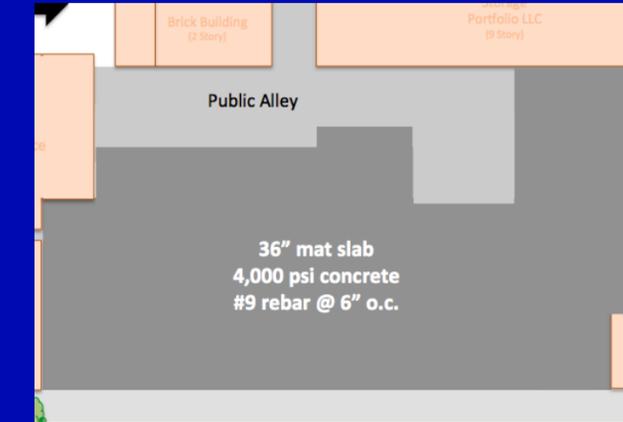•3-4" work mat included

Proposed Mat Slab Foundation

Louis at the 14th

Total Cost (O&P excluded)

Concrete: $1,412,185
Rebar: $751,026

$2,163,211

Public Alley

36" mat slab
4,000 psi concrete
#9 rebar @ 6" o.c.

Public Alley

Actual Cost

North (micropiles): $450,000
South (spread footings): $300,000

$750,000

Total Duration

Concrete Placement: (24 workdays w/2 pump crews)
                                500 truckloads
                                1-day pour

Rebar Install: 26 workdays w/ 20 rodmen

27 workdays

Actual Duration

North (micropiles): **90 workdays** w/ 1 drill rig crew

South (spread footings, fdtn walls, strap beams):
                                35 workdays

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Dewatering System

Actual Plan:

Modifications:

• 28,500 SF larger area

• 10' shallower South, 10' deeper North

• 4 extra wells (11)

• each well 40-50' deep (actual: 60')

• extra standby temporary pumps
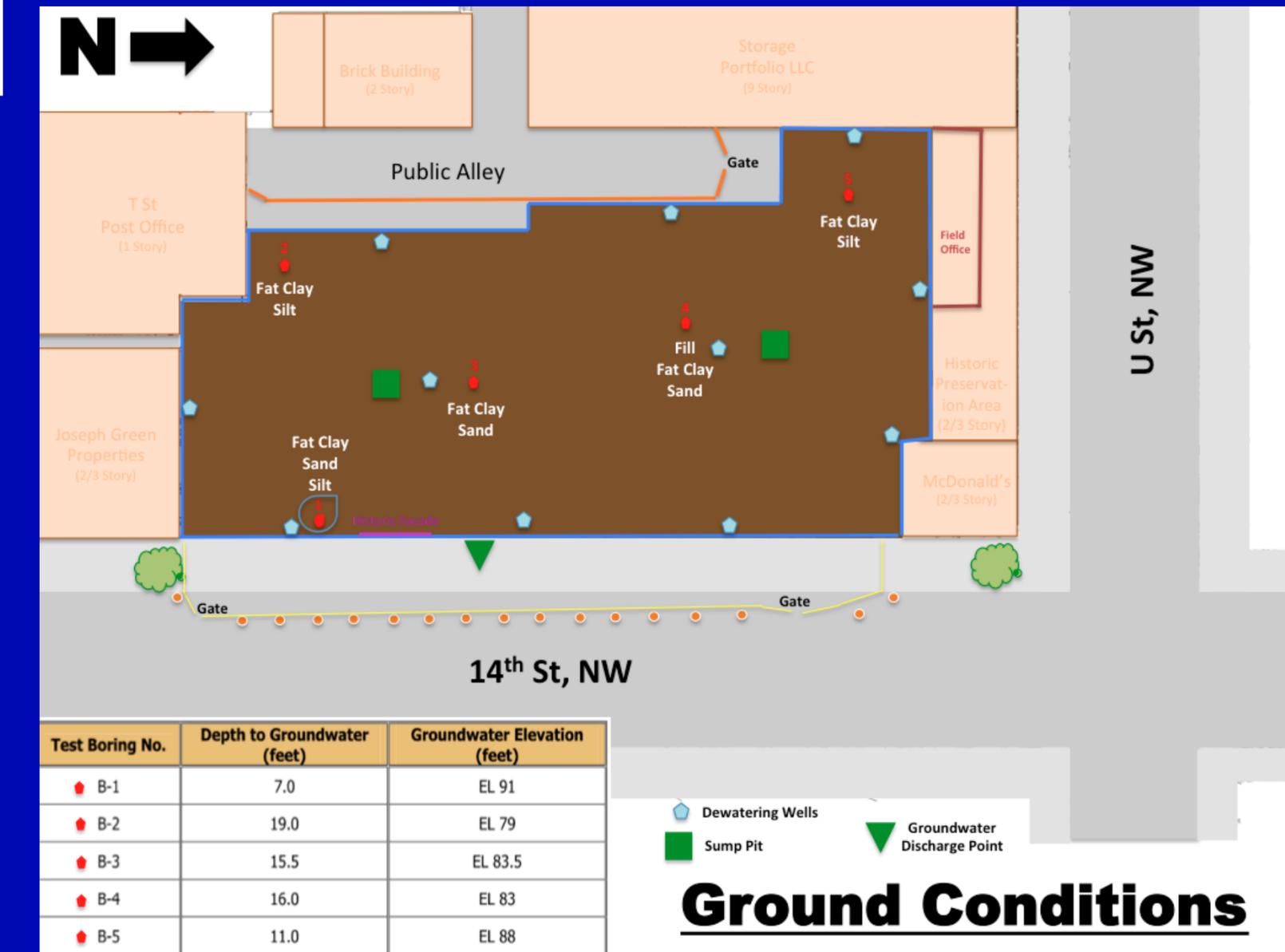
Test Boring No.	Depth to Groundwater (feet)	Groundwater Elevation (feet)
B-1	7.0	EL 91
B-2	19.0	EL 79
B-3	15.5	EL 83.5
B-4	16.0	EL 83
B-5	11.0	EL 88

Ground Conditions

Louis at the 14th

Excavation Support & Workflow

Anchored Sheet Piling
22' depth
equiv. fluid pressure: 1320 psf
cost: $565,290

Advantages:
- fast installation
- structural capabilities
- seepage control
- maximizes useable space (<1" thick)
- little risk of blowout
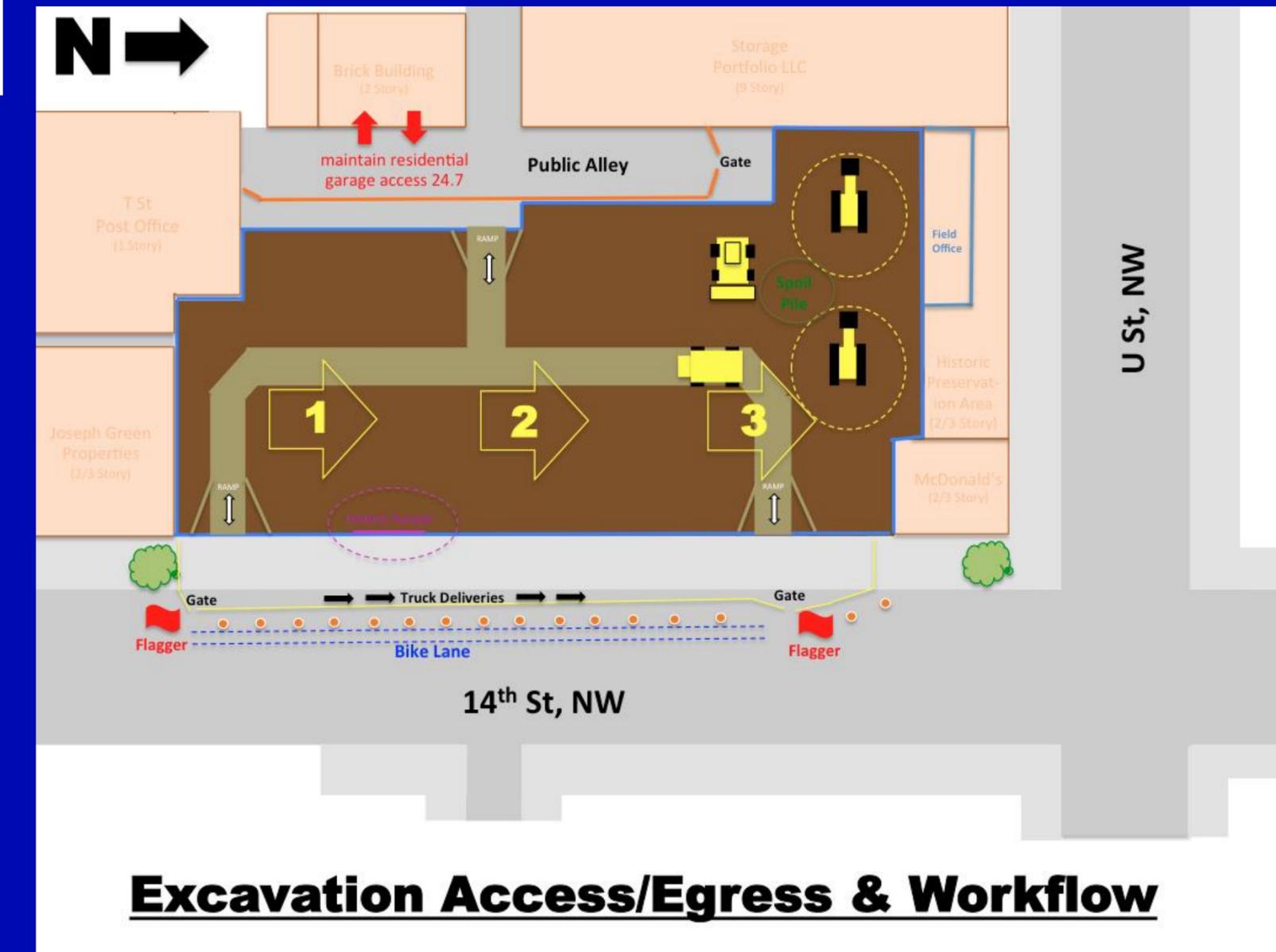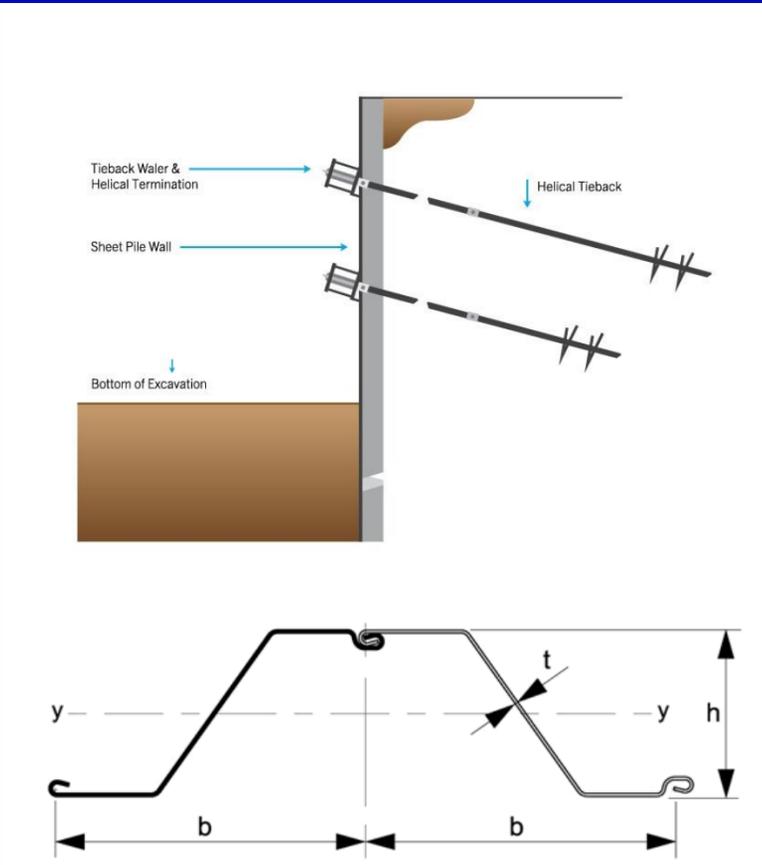
Excavation Access/Egress & Workflow

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Existing Ground Floor System:

• water-to-air
• serves 13,020 SF
• 93 nominal tons heating/cooling
• (14) water source heat pumps
• (2) 5 SF direct outdoor air intake louvers
• (2) 5 SF relief/exhaust louvers
• (2) 712.5 MBH boilers
• (1) 155-ton cooling tower

Image by Gipe Associates, Inc.

Vertical Closed-Loop Geothermal Well System
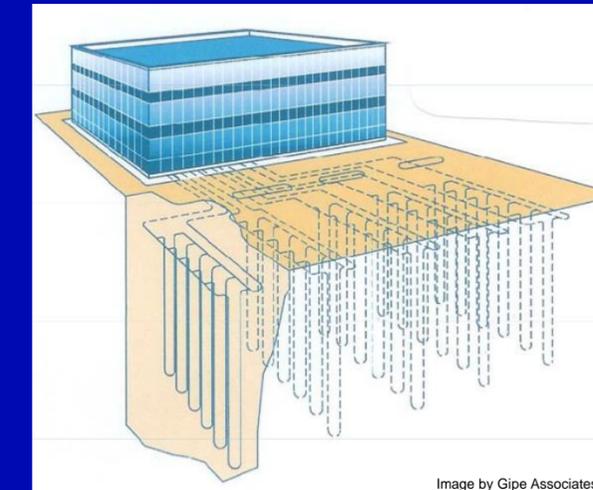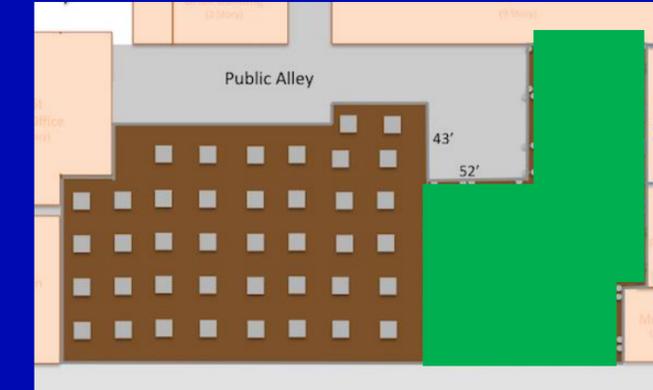
• north footprint well field: 17,000 SF
• well spacing: 15' d
• 46 wells @ 300' deep, 1 well @ 150'
• 1 ¼" U-tube pipe
• 10% antifreeze
• 436 gpm (includes head loss)
• (1) 244 MBH boiler
• (1) 63-ton cooling tower

Typical ground-source heat pump system applied to a commercial facility
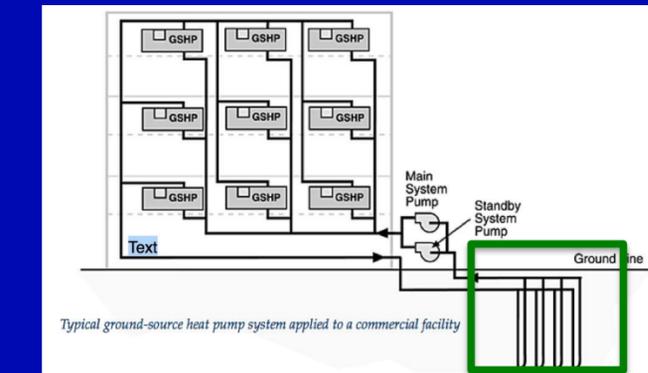
Image by ghpsystems.com

Louis at the 14ᵗʰ

Constructability Issues

Geothermal well typical detail:

MINIMUM HORIZONTAL BURY DEPTH 4 FT
TO BUILDING
GROUT ENTIRE ANNULAR SPACE AND VERTICAL U-TUBE WITH BENTANITE GROUT.
TYPICAL BORE DEPTH 200-300 FT
TYPICAL VERTICAL U-TUBE 1" DIAMETER
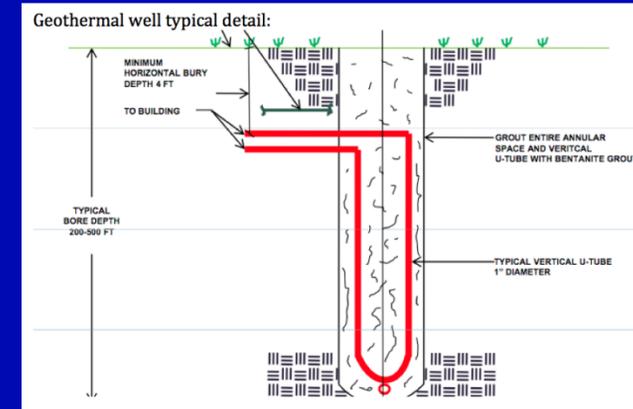
• spacing & depth adjustments

• micropile coordination

• soil conductivity interference

• tenant negotiation

• ongoing research:
  foundation-encased wells

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T St. Post Office (1 story)

Joseph Green Properties (2/3 story)

43'

52'

Field Office

U St, NW

Historic Preservation Area (2/3 story)

Concrete pier + Footings range Elevations 59-6...

...ead Footings ...vations 96.5'

McDon... (2/3 story)

Louis at the 14th

Cost Impact

Total Cost (O&P excluded)

R.S. Means Assembly: **$105,555** (excludes GSHPs)
$23-$45/SF: **$299,460 - $585,900**
$1,500-$3,000/ton capacity: **$139,500 - $279,000**

Cooling Tower & Boiler Downsize: $52,376 savings

Energy Costs (annual):   **$10,416 - $14,322**
Maintenance Costs (annual):   **$1,302**

Schedule Impact

Image by Balfour Beatty Construction

Total Duration

• 1.5 wells / drill rig / day

• 47 wells with 2 drill rigs
  = **35 workdays**

• actual micropiles
  = 4 months with 1 drill rig

• equipment mobilization advantage

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Conclusion

Depth #1
(Prevention through Design research)

Depth #2
Foundation Redesign
Recommended for Quality
Not Recommended for Budget

Depth #3
Site Specific Safety Plan
Permanent Sheet Piling, Dewatering System, Workflow

Depth #4
Geothermal Loop System
Not Recommended

Image by Russell Voigt

Louis at the 14th

Acknowledgements

Balfour Beatty Construction

Alex Ward
Will Siegel

Penn State AE Faculty

Dr. Ed Gannon
Dr. Craig Dubler
Dr. Walt Schneider

**My Family, Friends, &
AE Classmates**

Image by JBG Companies

Floors

Concrete						
No Sub Sequence						
	CONCP305	Pour Footings & Strap Beams - East	8	8	08-Aug-12	17-Aug-12
	CONCP320	Pour Footings & Strap Beams - North	10	10	10-Aug-12	23-Aug-12
	CONCP310	Pour Footings & Strap Beams - South	7	7	15-Aug-12	23-Aug-12
	CONCP315	Pour Footings & Strap Beams - West	5	5	20-Aug-12	24-Aug-12
	CONCP325	Form/Reinf/Place Foundation Walls/Col P3 to	5	5	20-Aug-12	24-Aug-12
	CONCP350	Form/Reinf/Place Elevator/ Sump Pits	5	5	20-Aug-12	24-Aug-12

▬ Actual Work   ◆ ◆ Milestone
▬ Remaining Work
▬ Critical Remaining Work

J Street - Baseline revised 4-18

ty ID	Activity Name	Original Duration	Remaining Duration	Start	Finish
	CONCP355	Form/Reinf/Place Elevator Shaft	3	3	24-Aug-12	28-Aug-12
	CONCP330	Form/Reinf/Place Foundation Walls P3 to	5	5	24-Aug-12	30-Aug-12
	CONCP340	Form/Reinf/Place Foundation Walls/Col P3 to	5	5	24-Aug-12	30-Aug-12
	CONCP335	Form/Reinf/Place Foundation Walls/Col P3 to	5	5	27-Aug-12	31-Aug-12
	CONCP345	Install Underdrain/Prep & Pour SOG A-D.5	5	5	04-Sep-12	10-Sep-12
	CONCP360	Form/Reinf/Place Stairwell to P2	2	2	11-Sep-12	12-Sep-12
	CONCP365	Install Underdrain/Prep & Pour SOG D.5-J	5	5	11-Sep-12	17-Sep-12
	CONCP300	Form/Reinf/Place Elevated Slab A-D.5	5	5	11-Sep-12	17-Sep-12
	CONCP370	Form/Reinf/Place Elevated Slab D.5-J	5	5	18-Sep-12	24-Sep-12
	CONCP220	Form/Reinf/Place Foundation Walls/Col P2 to	4	4	18-Sep-12	21-Sep-12
	CONCP260	Form/Reinf/Place Stairwell to P1	5	5	18-Sep-12	24-Sep-12
	CONCP210	Form/Reinf/Place Foundation Walls/Col P2 to	4	4	24-Sep-12	27-Sep-12
	CONCP230	Form/Reinf/Place Foundation Walls/Col P2 to	4	4	24-Sep-12	27-Sep-12

Item/Activity	Quantity	Unit	Crew	Daily Output	Labor Hours	Total Hours	Total Days
Concrete Placement:							
Foundation mats, over 20CY,							
direct chute, pumped	5317	CY	C-20	110	0.582	3094	48
						2 crews:	**24**
*crew C-20 includes:							
1 labor foreman, 5 laborers, 1 cement finisher, 1 equip operator, 2 gas engine vibrators, 1 concrete pump							
Rebar Placement:							
Slab on grade, #3 to #7	300.4	Ton	4 Rodm	2.3	13.913	4179	131
(#9 not available)						**20 Rodm:**	**26**
					Mat Slab Total Work Days:		**50**

03 30 53.40 Concrete In Place			**Cost Each**		
Item/Activity	Unit	Material	Install	Equipment	Total
Foundation mat (3000psi), over 20 CY	CY	178	87	0.58	265.58
	5317			Cost:	$1,412,185
Reinforcing Steel	ton		general rule of thumb:		
#9 rebar	300.4		$2500/ton		
				Cost:	$751,026
				TOTAL COST:	**$2,163,211**

Sheet Piling System Costs (per SF)

Perimeter	Depth	SF					
900	22	19800					
			Material	**Labor**	**Equipment**	**Total**	**Total + O&P**
20' deep excavation, 27 psf, left in place			$21.50	$3.07	$3.98	$28.55	$32.50
		Cost:	$425,700	$60,786	$78,804	$565,290	$643,500

Slab Area = 44,175 ft
Perimeter = 900 LF

ϕ = 0.9 for flexure ϕ = 0.75 for shear

Maximum soil contact pressure = 2,000 psf

Total load at top of footing for all columns = 56,000 kips

(20,770 kips northern footprint
35,230 kips southern footprint)

$$\frac{total\ gravity\ load}{building\ area} \leq soil\ bearing\ capacity$$

$\frac{56,000\ kips}{44,175\ SF} \times 1,000\ \frac{lbs}{kip} = 1,268\ psf \leq 2,000\ psf$ ✓

Largest Columns Loads: southern footprint = 1,100 kips, 18x24, column #46

northern footprint = 810 kips, 16x24, column #107

Calculate Q:

P = 1,100 kips P_D = 500 kips P_L = 600 kips

P_u = 1.2 P_D + 1.6 P_L = 1560 kips

$Q = \frac{P_u}{A} = \frac{1,560}{270} = 5.77\ ksf \rightarrow 5.77\ ksf \times 1,000\ lbs/kip \times (1'/12")^2 = 40.12\ psi$

Calculate V_c:

$V_c = \phi 4\sqrt{f_c'}$

$V_c = 0.75(4)\sqrt{4,000} = 190\ psi$ (4,000 psi concrete to be used)

To calculate the size of the mat slab, column #46 is used to evaluate punching shear with a tributary area of 20' x 13.5' that represent the largest column and the largest bay of the structure.

Calculate d:

$d^2(V_c + \frac{q}{4}) + d(V_c + \frac{q}{2})w = \frac{q}{4}(BL - W^2)$

V_c = 190 psi   q = 40.12 psi   W = 24"   B = 162" or 13.5'   L = 246" or 20' 6"

$d^2(190 + \frac{40.12}{4}) + d(190 + \frac{40.12}{2})w = \frac{40.12}{4}(162 \times 246 - 24^2)$

d = 33.5"

Calculate h:

h = d + 3 + $d_{b/2}$

h = 36.875 → 40"

d with clearance adjustment: d = 40 – 3 – 0.375 = 36.625"

Calculate ℓ:

$\ell = \frac{L - column\ width}{2} = \frac{20.5 - 2}{2} = 9.25'$

Calculate ϕM_n using #6 bars @ 12" spacing:

$$\phi M_n = \phi A_s(60\ ksi)(d - \frac{a}{2})$$

$$\phi M_n = 0.75A_s(60\ ksi)\left(d - \frac{1.96A_s}{2}\right)$$

$$\phi M_n = 98.8\ ft \cdot k$$

Calculate M_u (maximum moment):

$M_u = \frac{q \times \ell/2}{2} = \frac{5.77 \times 9.25/2}{2} = 246.9\ ft \cdot k$

$\frac{M_u}{4d} = \frac{246.9}{4(36.625)} = 1.679\ in^2 \rightarrow$ use #9 rebar size

$\phi M_n \rightarrow 310.86\ ft \cdot k > 247\ ft \cdot k$ ✓

a = 1.96(2) = 3.92"

$C = \frac{3.92}{0.85} = 4.611"$

$\varepsilon = \frac{0.003}{4.611}(36.5 - 4.611) = 0.0207\ \frac{in}{in} > 0.005$ ✓ for ϕ = 0.9

Final Result: 36" thick mat slab; 4,000 psi concrete w/ #9 rebar @ 6" o.c.

Geothermal Loop Appendix
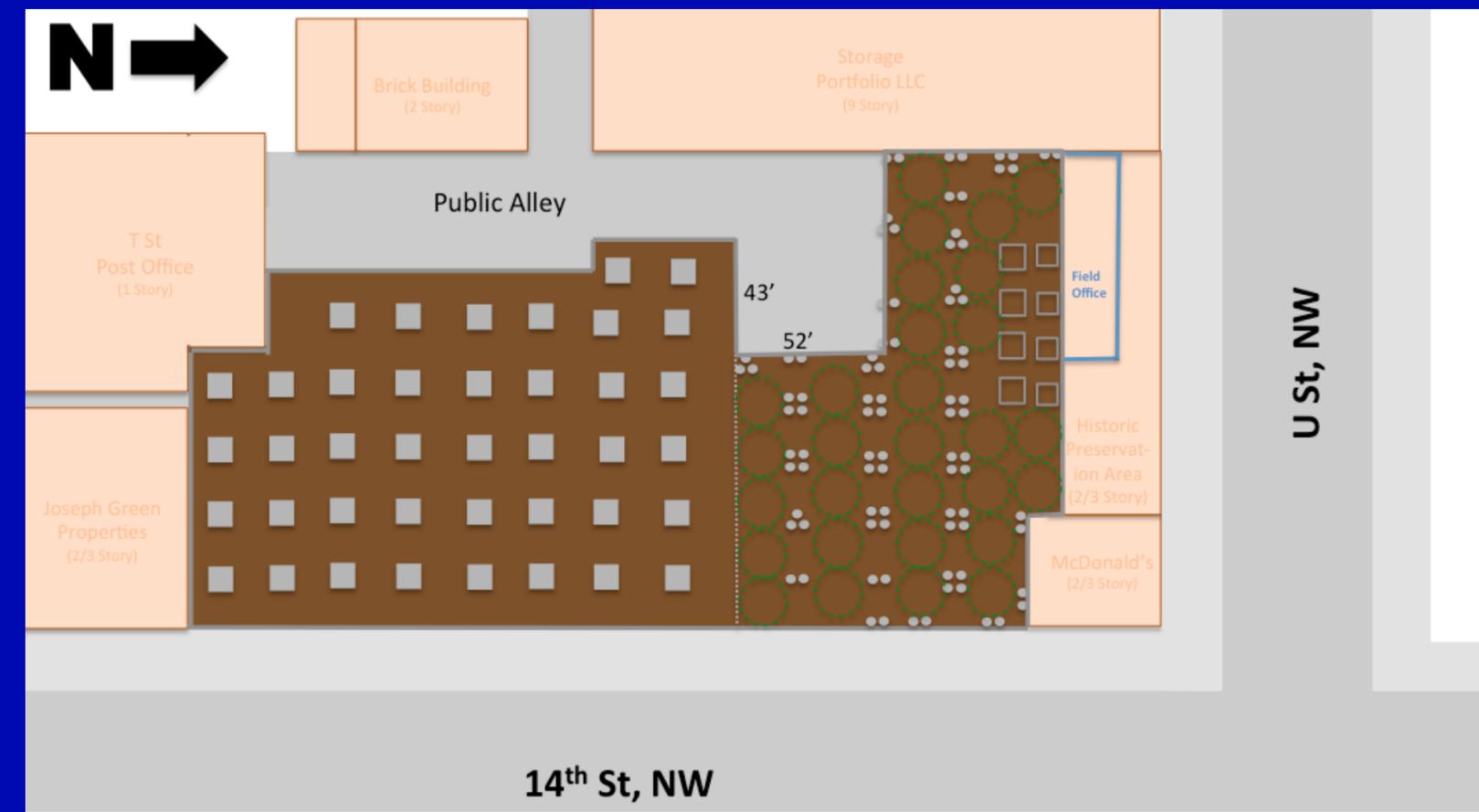
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Storage Portfolio LLC (3 Story)

Public Alley

T St Post Office (1 Story)

43'

52'

Field Office

U St, NW

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Historic Preservation Area (2/3 Story)

McDonald's (2/3 Story)

14th St, NW

■ Concrete pier + footing
Footings range from 4'6"x4'6" to 11'x11'
Elevations 59-64'

⠿ 14"d auger pressure grouted piles w/caps
Tip elevations 46-49'

☐ Spread Footings
Elevations 96.5'

Spacing: 20'd   # Wells: 29
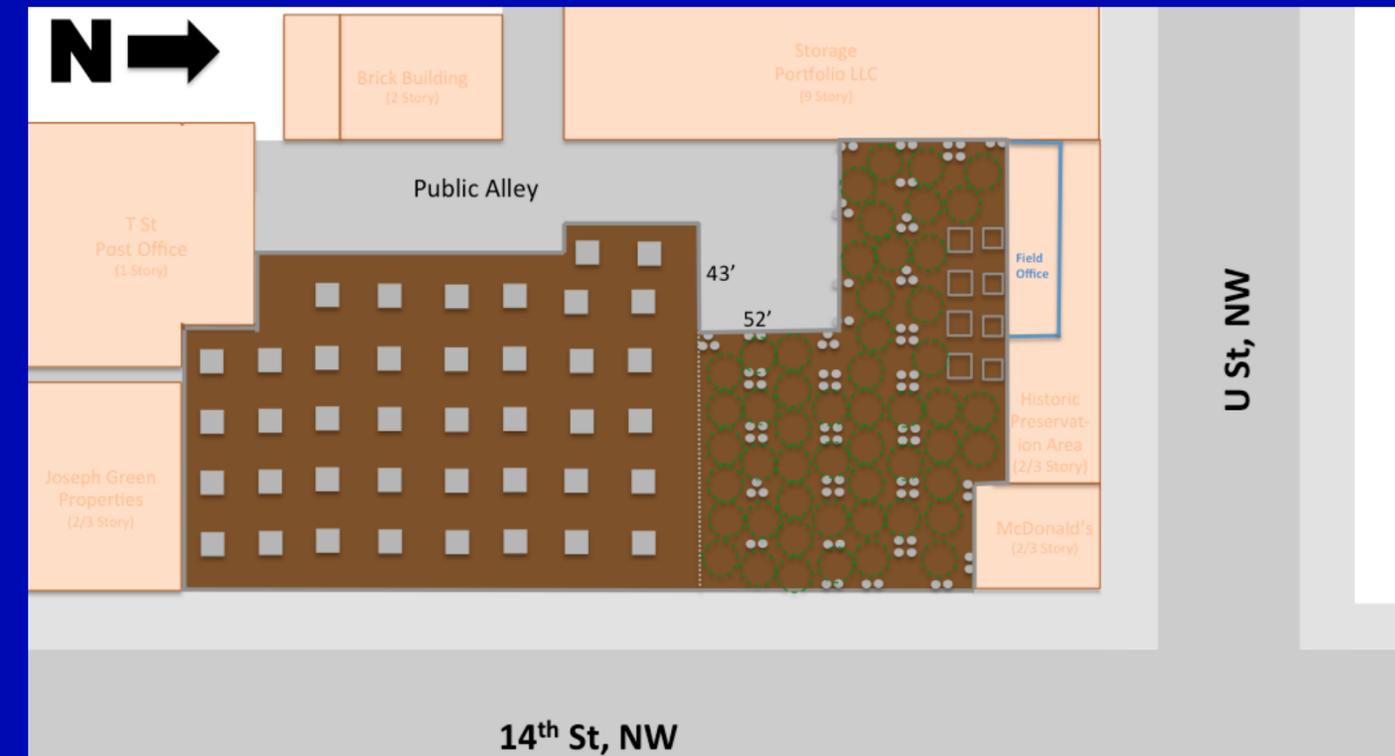
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Tip elevations 46-49'

☐ Spread Footings
Elevations 96.5'

Spacing: 15'd   # Wells: 52

ROOF

ROOF

MECH ROOM WALL

ASI#6 ADDED GLYCOL SYSTEM, SEE MSK-0.6 11/27/12 LR

RFI 0016.1 PROVIDE SHOT FEEDER AS INDICATED IN SPEC 232500 3.B.5. B/1, AF

MECH RM FLOOR

MAKE-UP CONNECTION

SHOT FEEDER

CT-1

ROOF DECK

RFI 0108 PIPE DOES NOT REQUIRE INSULATION. 8/25/12 LR

ASI#6 REMOVED AIR SEPERATOR DETAIL AND ADDED GLYCOL LINE. 11/27/12 LR

8 WATER SOURCE LOOP SCHEMATIC
SCALE: NOT TO SCALE

NOTES:
1. EXPANSION TANK SHALL BE BLADDER TYPE.
   TANK VOLUME = 100 GALLONS
   ACCEPTANCE VOLUME = 80 GALLONS
2. SYSTEM FILL PRESSURE SHALL BE SET AT 45 PSIG.

Geothermal Loop Appendix

WATER SOURCE HEAT PUMP SCHEDULE (PROVIDED BY TENANT)

TAG	CFM	NOMINAL TONS	ESP IN WG	HYDRONIC COOLING FLOW RATE GPM	MAX WPD FEET	EAT (DB/WB)	EWT °F	SENSIBLE MBH	TOTAL MBH	HYDRONIC HEATING FLOW RATE GPM	MAX WPD FEET	EWT °F	TOTAL MBH	MANUFACTURER	MODEL OR SERIES	WCA AMPS	WDCP AMPS	VOLTAGE	NOTES
WSHP-1-3	2,000	5.0	0.4	16	—	80/67	47.7	58.4	18	—	70	66.3	WMMOTH	WHSP D62	—	—	480/3/60	1-6
WSHP-4-14	2,800	7.0	0.4	22	—	80/67	68.0	83.8	22	—	70	96.1	WMMOTH	WHSP D84	—	—	480/3/60	1-6

SCHEDULE AS EXAMPLE ONLY WSHP'S BY TENANT.

NOTES
1. UNITS SHALL BE EQUIPPED WITH EC'M MOTORS.
2. R-410 REFRIGERANT ONLY.
3. COORDINATE ALL ELECTRICAL REQUIREMENTS PRIOR TO ORDER.
4. PROVIDE UNIT WITH MERV 8 FILTER.
5. WSHP'S SUPPLIED BY TENANT.
6. TENANT TO PROVIDE HOT GAS REHEAT DEHUMIDIFICATION AS REQUIRED.

(1. SELECT UNITS WITH ALLOWANCE FOR 20% PROPYLENE GLYCOL SOLUTION.)

ASHI ADDED NOTE 11/27/12 LR

Table 3
RECOMMENDED LEVELS OF ANTIFREEZE SOLUTIONS FOR GCHP SYSTEMS

Recommended % Volume of Propylene Solutions

Coil Type	Pitch Ft. pipe/Ft.trench	% by Volume 60 to 63°F Ground	% by Volume 52 to 59°F Ground	% by Volume 44 to 51°F Ground
Slinky	10	10	15	20
6-Pipe or Eqv. Slinky	6	10	15	20
2-Pipe	2	10	15	20
Vertical (3/4" Pipe)	2	0	10	20
Vertical (1 1/4" Pipe)	2	0	10	20

Warning more antifreeze will be required if loops are shorter than those recommended in Tables 1 and 2.

Table 1. Recommended Lengths of Trench or Bore Per Ton For GCHPs
Multiply length of trench by pitch to find required length of pipe.
See Tables 4 and 5 for Thermal Conductivity of Soils and Rocks.

Coil Type (See Figure 1 for Details)	Pitch Ft. of Pipe per Ft. Trench (or Bore)	Ground Temperature - °F 44 to 47°F	48 to 51°F	52 to 55°F	56 to 59°F	60 to 63°F	64 to 67°F	68 to 70°F
Horz. 10-Pitch Slinky	10	125	120	115	120	125	150	180
Horz. 6-Pipe/6-Pitch Slinky	6	180	160	150	160	180	200	230
Horz. 4-Pipe/4-Pitch Slinky	4	190	180	170	180	190	220	260
Horz. 2-Pipe	2	300	280	250	280	300	340	400
Vertical U-tube (3/4" Pipe)	2	180	170	155	170	180	200	230
Vertical U-tube (1" Pipe)	2	170	160	150	160	170	190	215
Vertical U-tube (1¼" Pipe)	2	160	150	145	150	160	175	200

Table 1 based on k=0.6 Btu/hr-ft-°F for horizontal loops and k=1.2 Btu/hr-ft-°F for vertical loops and an annular fill/grout conductivity of 0.85 in vertical loops. For other conditions:

Item/Activity	Quantity	Unit	Material	Install	Total
Original Design:					
162 ton Forced-Draft Type Cooling Tower					
	1	TonAC	172	9.95	181.95
					29,476
1,460 MBH Gas/Oil Fired Boiler					
	2	Ea	28400	6300	34700
					69,400
Proposed Design:					
300 MBH Gas/Oil Fired Boiler					
	1	Ea	10400	2675	13075
					13,075
91 ton Stainless Steel Induced Draft Cooling Tower					
	1	Ea	32100	1325	33425
					33,425
Total Savings:	**52,376**				

Mechanical Assemblies Estimate

Code	Element	Quantity	Unit	Material	Install	Total
1480	Unit Heater 5032 MBH 67		SF	4.35	3.52	7.87
		267000		$1,161,450	$939,840	$2,101,290
1080	Boiler 1088 MBH		Ea	14900	6500	21400
		2		$29,800	$13,000	$42,800
1300	Closed Loop Water Cooled		SF	3.45	3.1	6.55
		267000		$921,150	$827,700	$1,748,850
1440	Split System with Air Cool		SF	2.91	3.49	6.4
		267000		$776,970	$931,830	$1,708,800
				TOTAL HVAC COST:		**$5,601,740**
Other:						
1320	Cooling Tower Systems		SF	7.33	8.1	15.43
		267000		$1,957,110	$2,162,700	$4,119,810
1280	Rooftop Units		SF	10.7	4.93	15.63
		267000		$2,856,900	$1,316,310	$4,173,210
					Actual Cost:	**$4,365,000**

Geothermal Heat Pump System 50 Ton, Vertical Loops, 200 LF Per Ton
System D3050 248 1000

Item/Activity	Quantity	Unit	Material	Install	Total
Mobilization Excavator	2	Ea		544	544
Mobilization crew and equipment	2	Ea		377	377
Mobilization drill rig	2	Ea		169	169
Drill wells 6" diameter	100	CLF		68300	68300
Pipe loops 1 1/2" diameter	200	CLF	28000	38800	66800
Pipe headers 2" diameter	1600	LF	3696	3840	7536
U-fittings for pipe loops	50	Ea	225.5	857.5	1083
Header tee fittings	100	Ea	1410	2900	4310
Header elbow fittings	10	Ea	63.5	182.5	246
Excavate trench for pipe header	475	BCY		3534	3534
Backfill trench for pipe header	655	LCY		1873.3	1873.3
Compact trench for pipe header	475	ECY		1168.5	1168.5
Circulation pump 5 HP	1	Ea	9825	835	10660
Pump control system	1	Ea	1350	635	1985
Pump guages	2	Ea	79	44	123
Pump gauge fittings	2	Ea	151	44	195
Pipe insulations for pump connection	12	LF	33.84	81	114.84
Pipe for pump connection	12	LF	203.4	364.92	568.32
Pipe fittings for pump connection	1	Ea	32	187.7	219.7
Install thermostat wells	2	Ea	15.6	114.28	129.88
Install guage wells	2	Ea	15.6	119.42	135.02
Thermometers, stem type	8	Ea	308	750.72	1058.72
Gauges, pressure or vacuum	1	Ea	860	278	1138
Pipe strainer for pump	1	Ea	165	283	448
shut valve for pump	1	Ea	630	305	935
Expansions joints for pump	2	Ea	660	224	884
Heat pump 50 tons	1	Ea	40000	13200	53200
Total:			$87,723	$140,012	$227,735
Adjusted			**$19,723**	**$86,922**	**$105,555**

300 LF/ton; excludes heat pumps & mobilization

Schedule