

OWNER

Foundation Design

Calculation



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1. OBJECTIVE

This calculation designs the foundations for the equipment, buildings and structures of the : the filter separator, line heater, pig receiver, meter skid and its canopy, vent stack, liquids tank containment, the two buildings, the generator, transformer and fuel gas skid pads, and the antenna mast. It checks each for bearing, overturning, sliding, uplift and settlement, sizes the reinforcement to ACI 318-19, and screens the anchor rods to ACI 318-19 Chapter 17. The foundations of the pipe supports are designed by type in STR-CAL-004, Pipe Support Foundation Schedule.

2. METHODOLOGY

The station sits on Permian red-bed lean clay of moderate expansion potential. The foundation types were chosen to deal with that clay first and with the loads second. Heavy equipment (the filter separator and the line heater), the buildings and the skid pads rest on stiff reinforced concrete mats bearing on 2 ft of compacted non-expansive select fill. The select fill moves the bearing surface out of the most active part of the clay, and the mat stiffness bridges local heave so that vessel saddles and skid beams stay in plane. A mat was preferred to piers for these items because their loads are spread over long footprints and their equipment is sensitive to differential movement between supports.

Light, concentrated or tall items (the pig receiver saddles, meter skid bearing points, canopy columns, vent stack, antenna mast and the demarcation panel) are carried on straight-shaft drilled piers that extend below the assumed 8 ft zone of seasonal moisture change. A shallow footing for these items would ride the heaving clay; a pier anchored below the active zone does not. The pier length is set by swell uplift rather than by load: the clay grips the upper shaft as it swells, and the pier must be anchored deep enough to resist that grip with only its own weight counted.

Bearing, overturning and sliding use the allowable stress combinations of ASCE 7-22 Section 2.4 with the equipment weights of MEC-LST-002, Equipment List, and the wind, seismic and nozzle loads of STR-CAL-001, Structural Design Loads. Soil pressure under eccentric load follows the rigid-footing distribution, triangular once the resultant leaves the kern. Drilled pier axial capacity follows the alpha method of FHWA GEC 10, lateral capacity follows both IBC 2021 Section 1807.3.2.1 and the Broms method for short piles in clay (the smaller capacity governs), and swell uplift follows the rigid pier method of Nelson and Miller. Reinforcement is designed for strength-level loads: 1.4 times the largest equipment vertical load and 1.67 times the allowable-stress wind moment (the ratio of strength-level to service-level wind). Shear capacity includes the ACI 318-19 size-effect factor.

3. DESIGN INPUTS

The inputs in Table 3-1 govern the calculation. Soil values are assumed pending the geotechnical investigation.

Table 3-1: Design Inputs

Input	Value	Source
Allowable net bearing pressure	2,000 psf, no increase for wind or seismic	 GEN-DB-001; HOLD H-07
Soil	Lean clay (CL), 125 pcf, undrained shear strength 2,000 psf	Assumed; HOLD H-07
Elastic modulus, Poisson ratio	250 ksf, 0.35	Assumed stiff CL; HOLD H-07
Sliding friction, concrete on select fill	0.3	Assumed; cohesion ignored
Active zone depth	8 ft	 CIV-RPT-001; HOLD H-07
Swell pressure	3,000 psf	 CIV-RPT-001; HOLD H-07
Select fill below mats and slabs	2 ft, plasticity index 8 to 20	 CIV-RPT-001
Concrete; reinforcement	$f'_c = 4,000$ psi; ASTM A615 Grade 60	Project specification
Anchor rods	ASTM F1554 Grade 36 (Grade 55 where noted), headed, galvanized	Project specification
Equipment weights	Empty, operating and hydrotest weights	 MEC-LST-002, Equipment List
Nozzle and restraint loads	V-101, H-101, PR-101	 MEC-CAL-004, Piping Flexibility
Wind, seismic, ice, snow	108 mph Exposure C; SDC B	 STR-CAL-001; HOLD H-06
25-year, 24-hour rainfall	6.33 in	 CIV-CAL-002, Hydrology and Drainage

4. ASSUMPTIONS

1. The soil parameters in Table 3-1 are typical of stiff red-bed lean clay in County. *Verification required (HOLD H-07).*
2. Groundwater lies deeper than 20 ft, so no buoyancy acts on the foundations. *Verification required (HOLD H-07).*
3. Swell uplift on a pier shaft is taken as 0.15 times the swell pressure over the active zone. The pier is designed to resist it with its own weight and the side resistance below the active zone, with a factor of safety of 1.5. A void form or bond breaker over the top 8 ft reduces the real uplift, but no credit is taken for it.
4. Equipment weights and centers of gravity are the typical values of MEC-LST-002. *Verification required against certified vendor drawings (HOLD H-15).*

5. The meter skid tie-in load (3 kip) and the vent stack relief reaction (1.5 kip at the inlet elbow) are interim values pending the final piping and relief calculations.

5. REFERENCES

1. ASCE/SEI 7-22, Minimum Design Loads and Associated Criteria for Buildings and Other Structures.
2. ACI 318-19, Building Code Requirements for Structural Concrete (Chapters 13, 17, 21, 22, 25).
3. ACI 350-20, Code Requirements for Environmental Engineering Concrete Structures.
4. AISC 360-22, Specification for Structural Steel Buildings; AISC Design Guide 1, 3rd Edition (2024), Base Connection Design for Steel Structures.
5. International Building Code, 2021 Edition, Sections 1806, 1807, 1808 and 1810 (adoption in , HOLD H-11).
6. FHWA-NHI-18-024, Drilled Shafts: Construction Procedures and Design Methods (GEC 10), 2018.
7. Broms, B. B., Lateral Resistance of Piles in Cohesive Soils, ASCE J. Soil Mech. Found. Div., 1964.
8. Nelson, J. D. and Miller, D. J., Expansive Soils: Problems and Practice in Foundation and Pavement Engineering, 1992.
9. GEN-DB-001, Basis of Design.
10. MEC-LST-002, Equipment List; MEC-DS-001, -002, -003, -004, -009 (datasheets).
11. MEC-CAL-004, Piping Flexibility and Stress; MEC-CAL-005, Pipe Supports.
12. STR-CAL-001, Structural Design Loads; STR-CAL-003, Meter Skid Canopy Steel Design; STR-CAL-004, Pipe Support Foundation Schedule.
13. CIV-RPT-001, Civil Design Criteria and Site Report; CIV-CAL-002, Hydrology and Drainage; CIV-RPT-003, T-101 Secondary Containment and SPCC Design Note.
14. STR-DWG-001, Foundation Location Plan (Appendix A).

6. CALCULATION

6.1. V-101 FILTER SEPARATOR MAT

V-101 is a 42 in ID horizontal filter separator with an NPS 24 liquid barrel slung below the shell. It sits on two saddles at X = 78.5 ft (fixed) and X = 89.5 ft (sliding), 11 ft apart, with its centerline 7.3 ft above finished grade. TORUS placed both saddles on one mat, 21 ft by 9 ft by 2 ft, with 2 ft by 5 ft pedestals. Separate footings under each saddle were considered and rejected: they would each be about 7 ft square to meet the frost and select-fill depths, and a common mat costs little more while keeping the two saddles on one rigid plane over the expansive clay. The top of the mat is 6 in below grade, so its underside is 2.5 ft down on the select fill.

The hydrotest governs the vertical load. The vessel full of water weighs 41.6 kip, and the mat, pedestals and soil above the mat add 70.3 kip:

ASCE 7-22 Section 2.4; rigid footing, load within the kern

$$q = \frac{P}{BL} \left(1 + \frac{6e}{L} \right) = \frac{111.9}{21 \times 9} \left(1 + \frac{6(0.034)}{9} \right) = 606 \text{ psf}$$

Transverse wind while operating, with the nozzle loads from MEC-CAL-004 acting in the same direction, gives the largest overturning moment. The horizontal load of 2.17 kip acts 9.8 ft above the underside of the mat, and the nozzle moment adds 2.7 kip-ft:

Overturning and sliding, allowable stress combination D + 0.6W

$$FS_{OT} = \frac{P(L/2)}{M} = \frac{101.4(4.5)}{24.0} = 19.0 \geq 1.5, \quad FS_s = \frac{\mu P}{H} = \frac{0.30(101.4)}{2.17} = 14.0 \geq 1.5$$

Table 6-1 lists every load combination. The largest soil pressure is under a third of the allowable, which confirms that the mat is sized by stiffness and depth, not by bearing.

Table 6-1: V-101 Mat, Load Combinations

Case	Combination	P, kip	H, kip	M, kip-ft	q max, psf	FS overturning	FS sliding
S1	De+Fo	101.4	0.0	0.0	540	-	-
S4	De+Fo+Ab+0.6W transverse	101.4	2.2	24.0	620	19.0	14.0
S4	De+Fo+Ab+0.6W longitudinal	101.4	1.5	14.8	560	> 50	20.1
S6	De+Fo+0.7E	103.2	0.8	8.2	580	> 50	37.0
S7	0.6De+0.6W	59.9	1.0	9.7	350	27.8	18.1
S9	De+Ft+0.6Wt (test)	111.9	0.4	3.8	610	> 50	> 50

Note 1: P includes the mat, pedestals and soil. M is taken about the underside of the mat. A dash means the check does not apply.

For the V-101 mat, the factored net soil pressure is 487 psf. With an effective depth of 19.9 in, the governing moment is 3.90 kip-ft per foot, which needs 0.04 in² per foot of bottom steel. The minimum of 0.0018 *bh* (0.52 in² per foot, top and bottom together) governs, and #6 @ 12 in bottom EW, #5 @ 12 in top EW provides 0.75 in² per foot. One-way shear at *d* from the loaded area is 1.14 kip per foot against $\phi V_c = 9.1$ kip per foot (size-effect factor $\lambda_s = 0.82$). The immediate settlement under the sustained load is 0.10 in. Along the mat, the two saddle loads on a uniform soil reaction give 3.86 kip-ft per foot, well within the same reinforcement. The pedestals carry 8 #5 verticals hooked into the mat, with #4 ties at 12 in and three ties at 3 in at the top to act as anchor reinforcement for the saddle rods.

6.2. H-101 LINE HEATER MAT

The 6.0 MMBtu/h line heater is 34 ft by 9.5 ft overall and weighs 98.0 kip operating, most of it bath water. It rests directly on a 38 ft by 13.5 ft by 2 ft mat, 2 ft larger than the skid all round for grout pads and anchor edge distance. The top of the mat is 6 in above grade to keep the skid out of standing water. The governing case is transverse wind on the heater body and stack, with the coil outlet nozzle load of 5.0 kip and 6.0 kip-ft from MEC-CAL-004: $P = 251.9$ kip, $M = 79.7$ kip-ft, giving a peak soil pressure of 560 psf and factors of safety of 21.3 against overturning and 7.4 against sliding. Table 6-2 gives the full set.

Table 6-2: H-101 Mat, Load Combinations

Case	Combination	P, kip	H, kip	M, kip-ft	q max, psf	FS overturning	FS sliding
S1	De+Fo	251.9	0.0	0.0	490	-	-
S4	De+Fo+Ab+0.6W transverse	251.9	10.2	79.7	560	21.3	7.4
S4	De+Fo+Ab+0.6W longitudinal	251.9	6.7	45.1	500	> 50	11.3
S6	De+Fo+0.7E	256.4	2.6	17.8	520	> 50	29.2
S7	0.6De+0.6W	119.5	5.2	39.9	270	20.2	6.9
S9	De+Ft+0.6Wt (test)	255.2	2.1	15.8	510	> 50	37.1

For the H-101 mat, the factored net soil pressure is 415 psf. With an effective depth of 19.9 in, the governing moment is 1.87 kip-ft per foot, which needs 0.02 in² per foot of bottom steel. The minimum of 0.0018 bh (0.52 in² per foot, top and bottom together) governs, and #6 @ 12 in bottom EW, #5 @ 12 in top EW provides 0.75 in² per foot. One-way shear at d from the loaded area is 0.56 kip per foot against $\phi V_c = 9.1$ kip per foot (size-effect factor $\lambda_s = 0.82$). The immediate settlement under the sustained load is 0.21 in. The heater skid is anchored with 8 x 1 in rods; the end away from the coil connections has slotted holes for the 0.2 in of thermal growth of the skid.

6.3. DRILLED PIERS

Every drilled pier is checked for axial capacity, swell uplift, lateral load and flexure with the equations below. Side resistance is counted only below the active zone, with the bottom one diameter excluded; the base resistance uses the bearing factor 9 for clay.

FHWA GEC 10, alpha method; factors of safety 2.0 on side and 3.0 on base

$$Q_{all} = \frac{0.55 c_u \pi D (L - z_a - D)}{2.0} + \frac{9 c_u \pi D^2 / 4}{3.0}$$

Nelson and Miller, rigid pier in expansive clay

$$U = 0.15 p_s \pi D z_a, \quad FS_U = \frac{0.55 c_u \pi D (L - z_a) + W_p}{U} \geq 1.5$$

Broms (1964), short free-head pile in clay; top 1.5D ignored



$$H_u \left(e + 1.5D + \frac{f}{2} \right) = 2.25 D g^2 c_u, \quad f = \frac{H_u}{9 c_u D}, \quad L = 1.5D + f + g$$

IBC 2021 Section 1807.3.2.1, nonconstrained embedment

$$d = 0.5A \left(1 + \sqrt{1 + \frac{4.36h}{A}} \right), \quad A = \frac{2.34P}{S_1 b}$$

6.3.1. PR-101 Fixed Saddle Pier

The fixed saddle of the pig receiver takes the barrel restraint load from the connected piping, 9,978 lb (MEC-CAL-004), in addition to its share of the hydrotest weight. The horizontal load of 10.1 kip acts at the barrel centerline, 3 ft above grade. A 24 in pier has ample lateral capacity, but its 4 x 1 in anchor rods would sit only 7 in from the pier face, where concrete breakout in shear governs. The pier was therefore increased to 36 in, which puts the rods 9.5 in from the face. For this pier:

$$U = 0.15(3.0)\pi(3.0)(8) = 33.9 \text{ kip}, \quad FS_U = \frac{51.8 + 13.8}{33.9} = 1.93$$

With $e = 3.0$ ft, the Broms ultimate lateral load is 80 kip, a factor of safety of 7.9, and IBC 1807.3.2.1 needs only 12.3 ft of embedment against the 13 ft provided. The strength-level moment in the shaft is 130 kip-ft against a capacity of 364 kip-ft for 12 #6 bars.

6.3.2. VS-101 Vent Stack Pier

The NPS 8 vent stack stands 25 ft on a base plate. Its natural frequency is about 3.6 Hz, which puts the vortex-shedding lock-in wind near 9 mph, a speed that occurs often. The stack therefore carries three-start helical strakes on its top 8 ft. The strakes suppress lock-in but raise the drag: with a drag coefficient of 1.2 on 1.2 times the diameter over the strake length, the strength-level base moment rises to 5.3 kip-ft from 3.4 kip-ft. Together with an interim relief reaction of 1.5 kip at the inlet elbow, the pier sees 1.71 kip and 6.0 kip-ft at grade (allowable stress level). A 30 in by 14 ft pier gives a lateral factor of safety of 54 and a swell uplift factor of 2.20; the length is set by uplift, and the diameter by the 8-rod bolt circle.

6.3.3. ANT-201 Antenna Mast Pier

ANT-201 is a 50 ft monopole located at (150, 22). It has an engineered breakpoint at 30 ft: the pole is deliberately weaker there than below, so an overload folds the top 20 ft over rather than toppling the full height. The fall radius is therefore 20 ft or less, and the nearest items, G-101 at 30 ft and R-1 at 30 ft, lie outside it. The pole is designed by its vendor. TORUS set the foundation loads from ASCE 7-22 wind on a representative pole (NPS 12 XS to 30 ft, NPS 8 XS above) carrying a typical antenna load: a 900 MHz Yagi and two LTE panels near the top, side-arm mounts and the coaxial cables on the pole face. The strength-level base moment is 30.2 kip-ft, and the representative pole works at 0.15 of its flexural capacity at the base and 0.08 at the breakpoint. Its tilt at the top under a 60 mph service wind is 0.17 degrees, within the 1 degree that a Yagi link tolerates.

The base plate is 22 in square by 1-1/2 in with 8 x 1 in rods on a 20 in bolt circle. The pier is 36 in by 14 ft with 9 #7 bars; at the allowable stress level it carries 0.63 kip and 18.1 kip-ft at grade, with a lateral factor of safety of 51 and a swell uplift factor of 2.27.

6.3.4. Summary of Equipment and Structure Piers

Table 6-3 summarizes every pier other than the pipe support piers. Every pier passes; the smallest margins are on swell uplift, which confirms that the clay, not the load, sets pier length.

Table 6-3: Equipment and Structure Drilled Piers

Mark	Supports	D (in) x L (ft)	P / Qall, kip	FS uplift	H, kip / M, kip-ft	FS lateral	Bars
FD-03A	PR-101 sliding saddle X 28.0	24 x 13	9.7 / 29.2	1.80	1.05 / 3.1	> 50	6 #6
FD-03B	PR-101 fixed saddle X 37.5	36 x 13	16.9 / 52.8	1.93	10.13 / 30.4	7.9	12 #6
FD-03C	PR-101 closure-end pig tray support	18 x 13	4.8 / 19.7	1.73	1.00 / 2.5	> 50	6 #5
FD-04	SK-110 skid pier (typ. of 8)	24 x 14	13.2 / 32.7	2.12	1.15 / 1.1	> 50	6 #6
FD-05	Canopy column pier (typ. of 8)	30 x 14	16.9 / 44.6	2.20	1.14 / 6.2	> 50	9 #6
FD-06	VS-101 vent stack pier	30 x 14	11.7 / 44.6	2.20	1.71 / 6.0	> 50	9 #6
FD-18	ANT-201 antenna mast pier	36 x 14	18.5 / 58.0	2.27	0.63 / 18.1	> 50	9 #7
FD-19	JB-W01 panel post	12 x 13	1.9 / 11.6	1.66	0.06 / 0.2	> 50	4 #5

Note 1: Loads at the allowable stress level at the top of the pier. FS lateral is the Broms ultimate load divided by H.

Note 2: Ties are #4 at 12 in for piers 24 in and larger and #3 at 12 in for smaller piers, with 3 in cover.

The meter skid bears on eight 24 in piers in four lines at 14 ft, which keeps the skid main beams within their L/720 deflection limit (MEC-DS-009). Each pier carries 6.5 kip in the hydrotest, which includes a 1.25 factor for the uneven weight of the meters and valves. The skid is anchored at its west line and slotted elsewhere so that it can grow freely. The canopy columns stand on eight separate 30 in piers so that no canopy load or vibration reaches the meter tubes. Four skid piers are 2.1 ft clear of the canopy piers; adjacent shafts shall be drilled and concreted at least 24 h apart.

6.4. T-101 SECONDARY CONTAINMENT

Liquids tank T-101, 9 ft 6 in in diameter by 8 ft, stands inside a 24 ft by 24 ft reinforced concrete containment at X = 18 to 42 ft. The containment holds 110 % of the tank shell capacity plus the 25-year, 24-hour rainfall falling on it, with 6 in of freeboard. This exceeds the federal requirement (the full shell capacity plus freeboard for precipitation), which the Owner preferred for a tank handling produced liquids.

40 CFR 112.8(c)(2), with the project's 110 % criterion

$$h = \frac{1.10 V_{shell} + A P_{25}}{A - A_{tank}} = \frac{1.10(567.1) + 576(6.33/12)}{576 - 70.9} = 1.84 \text{ ft}$$

With 6 in of freeboard the wall is 30 in above the slab, which holds 9,446 gal below its top. The 8 in walls act as cantilevers retaining liquid to their full height. The factored moment is 228 lb-ft per foot against $\phi M_n = 5.0$ kip-ft per foot for #4 bars at 12 in each face. The service steel stress is 1.9 ksi, well under the 20 ksi limit that ACI 350 uses to control cracking in liquid-retaining concrete. The reinforcement ratio of 0.42 % meets ACI 350 for a 24 ft panel between joints. A PVC waterstop seals the wall-to-slab joint, and the interior receives a chemical-resistant epoxy lining.

An empty tank in a flooded containment would float. The buoyancy at full wall height is 11.1 kip against a tank weight of 3.8 kip, a net uplift of 8.8 kip with 0.6 of the dead load counted. Four anchor chairs with 3/4 in rods hold the tank down; each rod sees 3.5 kip at the strength level, an interaction ratio of 0.24. The soil pressure under the full tank is 652 psf. The truck hose connection is on the north wall, over a 16 ft by 6 ft curbed drip pad at the edge of the truck stand. CIV-RPT-003 sets out the containment's regulatory basis.

For the tank full of liquid, seismic governs its horizontal load rather than wind: $V = C_s W = 0.0384 \times 39.1 = 1.50$ kip (strength level), against 0.83 kip of wind. Acting at the center of the liquid mass, 3.9 ft above the base, it gives an overturning factor of safety of 28.3 with 0.9 of the operating weight and a sliding factor of 9.4 on the sand cushion (friction 0.40), so the tank needs no seismic anchorage beyond the flotation chairs. Each chair sees 0.38 kip of seismic shear, well within the 6.0 kip shear capacity of its rod. The containment itself, at 118 kip of concrete, cannot slide under this load.

6.5. BUILDING AND EQUIPMENT SLABS

The analyzer shelter, control building, generator, transformer and fuel gas skid rest on slabs over 2 ft of select fill. The two buildings have 12 in by 24 in thickened edges that reach 18 in below grade for frost and carry the building anchors. The transformer pad follows the electric cooperative's standard (HOLD H-10). Table 6-4 gives the governing case for each slab; wind uplift on the buildings is carried by the slab weight with a large margin.

Table 6-4: Building and Equipment Slabs

Item	Slab (ft x ft x in)	Equipment weight, lb	q max, psf	FS overturning	FS sliding	Reinforcement
B-101	14 x 12 x 8 in	7,500	240	14.5	3.8	#4 @ 12 in B, #4 @ 12 in T, each way
B-102	26 x 14 x 8 in	19,000	280	11.8	3.1	#4 @ 12 in B, #4 @ 12 in T, each way
G-101	12 x 7 x 12 in	3,400	230	9.8	3.4	#5 @ 12 in B, #5 @ 12 in T, each way
XF-101	6 x 6 x 8 in	2,600	200	9.8	3.1	#4 @ 12 in B, #4 @ 12 in T, each way

Item	Slab (ft x ft x in)	Equipment weight, lb	q max, psf	FS overturning	FS sliding	Reinforcement
FG-101	10 x 8 x 12 in	3,800	220	17.5	5.9	#5 @ 12 in B, #5 @ 12 in T, each way

6.6. ANCHOR RODS

Anchor rods were screened to ACI 318-19 Chapter 17 for steel strength, pullout, concrete breakout and side-face blowout in tension, and for steel strength and breakout in shear, in cracked concrete. Pedestals and piers carry ties and verticals within half the embedment of the rods so that they act as anchor reinforcement. Table 6-5 shows the results; every group is within the combined tension and shear interaction of 1.2.

Table 6-5: Anchor Rod Screening

Anchor group	Rods	Embedment / edge, in	N _{ua} per rod, lb	V _{ua} per rod, lb	ϕN_n , lb	ϕV_n , lb	Interaction
V-101 fixed saddle	2 x 1.0 in	18 / 12.0	0	1,222	23,662	10,648	0.11
H-101 skid	8 x 1.0 in	12 / 12.0	0	2,020	26,051	10,966	0.18
PR-101 fixed saddle	4 x 1.0 in	18 / 9.5	0	3,991	12,089	6,129	0.65
SK-110 skid bearing	2 x 0.75 in	12 / 8.0	0	931	10,516	5,796	0.16
VS-101 base plate	4 x 0.75 in	18 / 8.0	4,156	345	12,324	5,434	0.34
ANT-201 mast base	4 x 1.0 in	24 / 11.0	8,683	131	15,134	7,646	0.57
T-101 anchor chair	1 x 0.75 in	6 / 12.0	3,522	300	14,529	6,044	0.24
B-101 building	2 x 0.75 in	6 / 6.0	0	322	13,385	3,765	0.09
B-102 building	2 x 0.75 in	6 / 6.0	0	525	14,529	3,765	0.14
G-101 enclosure	2 x 0.75 in	6 / 6.0	0	358	14,529	3,765	0.10
FG-101 skid	2 x 0.75 in	6 / 6.0	0	401	14,529	3,765	0.11
PF-2 stanchion base (SG-1)	4 x 1.0 in	18 / 9.5	17,686	3,094	26,051	6,129	1.18
PF-4 stanchion base (SV-1)	4 x 0.75 in	12 / 7.0	4,324	694	8,432	4,066	0.51

Note 1: Demands at the strength level per rod. Capacities are the governing mode per rod.

Note 2: For the guided pipe supports at the shutdown valves, the concrete breakout is replaced by 2 #5 hairpins per rod designed as anchor reinforcement (ACI 318-19 17.5.2.1); see STR-CAL-004.

7. RESULTS AND CONCLUSIONS

Table 7-1 lists the foundations designed in this calculation, with their locations, sizes and top-of-concrete elevations. Their locations are shown on STR-DWG-001 (Appendix A).

Table 7-1: Foundation Schedule, Equipment and Structures

Mark	Description	X, Y (ft)	Size	TOC, ft	Concrete, CY
FD-01	V-101 mat with 2 saddle pedestals	84.0, 40.0	21'-0" E-W x 9'-0" N-S x 2'-0"	1151.71	15.2
FD-02	H-101 mat	192.0, 140.0	38'-0" E-W x 13.5' N-S x 2'-0"	1151.13	39.1
FD-03A	PR-101 sliding saddle X 28.0	28.0, 40.0	24 in dia x 13 ft	1152.27	1.6
FD-03B	PR-101 fixed saddle X 37.5	37.5, 40.0	36 in dia x 13 ft	1152.17	3.6
FD-03C	PR-101 closure-end pig tray support	21.0, 40.0	18 in dia x 13 ft	1152.34	0.9
FD-04-1	SK-110 skid	63.0, 91.0	24 in dia x 14 ft	1152.17	1.7
FD-04-2	SK-110 skid	63.0, 103.0	24 in dia x 14 ft	1152.23	1.7
FD-04-3	SK-110 skid	77.0, 91.0	24 in dia x 14 ft	1152.03	1.7
FD-04-4	SK-110 skid	77.0, 103.0	24 in dia x 14 ft	1152.10	1.7
FD-04-5	SK-110 skid	91.0, 91.0	24 in dia x 14 ft	1151.89	1.7
FD-04-6	SK-110 skid	91.0, 103.0	24 in dia x 14 ft	1151.95	1.7
FD-04-7	SK-110 skid	105.0, 91.0	24 in dia x 14 ft	1151.75	1.7
FD-04-8	SK-110 skid	105.0, 103.0	24 in dia x 14 ft	1151.82	1.7
FD-05-1S	Canopy column	58.0, 87.0	30 in dia x 14 ft	1152.20	2.7

Mark	Description	X, Y (ft)	Size	TOC, ft	Concrete, CY
FD-05-1N	Canopy column	58.0, 107.0	30 in dia x 14 ft	1152.31	2.7
FD-05-2S	Canopy column	75.3, 87.0	30 in dia x 14 ft	1152.03	2.7
FD-05-2N	Canopy column	75.3, 107.0	30 in dia x 14 ft	1152.13	2.7
FD-05-3S	Canopy column	92.7, 87.0	30 in dia x 14 ft	1151.86	2.7
FD-05-3N	Canopy column	92.7, 107.0	30 in dia x 14 ft	1151.96	2.7
FD-05-4S	Canopy column	110.0, 87.0	30 in dia x 14 ft	1151.68	2.7
FD-05-4N	Canopy column	110.0, 107.0	30 in dia x 14 ft	1151.79	2.7
FD-06	VS-101 vent stack	40.0, 160.0	30 in dia x 14 ft	1152.75	2.7
FD-07	T-101 containment slab and walls + loadout drip pad	30.0, 100.0	24'-0" x 24'-0" x 8" slab, walls 8" x 30" high	1152.30	29.1
FD-08	B-101 slab	118.0, 118.0	14'-0" x 12'-0" x 8"	1151.76	6.9
FD-09	B-102 slab	215.0, 25.0	26'-0" x 14'-0" x 8"	1150.32	13.3
FD-10	G-101 slab	185.0, 22.0	12'-0" x 7'-0" x 12"	1150.61	3.2
FD-11	XF-101 slab	240.0, 8.0	6'-0" x 6'-0" x 8"	1149.99	0.9
FD-12	FG-101 slab	95.0, 55.0	10'-0" x 8'-0" x 12"	1151.67	3.1
FD-18	ANT-201 50 ft breakpoint monopole	150.0, 22.0	36 in dia x 14 ft	1150.96	3.8
FD-19	JB-W01 demarcation panel post	214.0, 197.5	12 in dia x 13 ft	1151.20	0.4
FD-20	DW-101 deep anode wellhead pad 4 x 4 x 6 in with AJB-101 pedestal	285.0, -45.0	4'-0" x 4'-0" x 6", #4 @ 12 EW, + 18 in pedestal 4 #4	1147.42	0.6

Note 1: Coordinates are on the station grid, origin at the southwest fence corner. TOC is the top of concrete, feet NAVD88.

TORUS draws the following conclusions:

1. Every foundation meets the bearing, overturning, sliding, uplift and strength criteria with the equipment weights of MEC-LST-002. Soil pressures are at most a third of the 2,000 psf allowable.
2. The expansive clay governs the design. Mats bear on 2 ft of select fill, and drilled piers are 13 to 14 ft long, set by swell uplift rather than load. A deeper active zone or higher swell pressure in the geotechnical report would lengthen the piers by about 0.8 ft per foot of added active zone.
3. The PR-101 fixed saddle and the guided pipe supports at the shutdown valves carry large horizontal restraint loads and need 36 in piers.
4. T-101's containment wall is 30 in high, and the tank shall be anchored against flotation.
5. VS-101 shall carry helical strakes on its top 8 ft, and ANT-201's pier is sized for a representative breakpoint monopole; both designs shall be confirmed against the vendors' data.
6. The foundations in Table 7-1 need 159 CY of concrete. With the pipe support foundations of STR-CAL-004 and the bollards, the station total is 378 CY of concrete and 45,763 lb of reinforcement.

The following items remain open: the geotechnical report, which governs every value in this calculation (HOLD H-07); certified vendor weights, centers of gravity and anchor patterns (HOLD H-15); site-specific hazard data (HOLD H-06); and the utility's transformer pad standard (HOLD H-10).



APPENDIX A. FOUNDATION LOCATION PLAN



