Estimation of Conservative Bounding Fill and Infiltration Cap Properties and Determination of Above Grade Fill Extents

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Objective

Source material for use as engineered fill during construction of Comanche Peak Nuclear Power Plant (CPNPP) Units 3 and 4 has not yet been identified. However, hydrogeologic properties of the engineered fill materials are required for use in the postulated accidental release and post-construction groundwater hydrostatic loading analyses. The material properties to be assessed include those for the engineered structural fill (used for both excavation fill and grade build-ups), pipe bedding fill, and the low permeability infiltration cap (placed over areas of excavation fill to limit direct precipitation or stormwater infiltration).

A range of bounding fill properties for hydraulic conductivity (K_h) and effective porosity (η_e) will be used to allow calculation and modeling of post-construction groundwater conditions. Based on descriptions provided in CPNPP Final Safety Analysis Report (FSAR), Revision 2, Subsection 2.5.4.5.4.1.1, a range of particles sizes within the fill can be estimated, thus allowing an estimation of the hydrogeologic properties of hydraulic conductivity (K_h) and effective porosity (η_e). Due to the possible variations in the fill mixtures and placements, it will be assumed for this analysis that all hydrogeologic properties and fill types are homogeneous throughout their in-place volume.

In addition, areas near the plant site that require grade buildup based on a comparison of the post- and pre-construction topographic grading and drainage plans will be addressed.

The material properties and fill extents described in this paper are based on the best available information on post-construction site conditions. Alterations during planning or required for construction will be reviewed and evaluated as needed to assess potential impacts to the final groundwater modeling effort. Parameters and site construction requirements specified in this paper may also change based on ongoing groundwater modeling efforts.

Fill Material Properties

1) Bounding Fill Cap

CPNPP FSAR Revision 2 does not discuss a low permeability capping material with regards to the general requirements for structural fill. The purpose of this cap is to limit surface infiltration from precipitation events into the granular fill.

This section is not intended to specify a design for the low permeability cap, but to specify assumed hydrogeologic properties for the purpose of conservative modeling efforts. Final designs will be reviewed following completion for potential impacts to the assessment.

The cap is assumed to be a compacted low permeability cap similar to a landfill cover.

For conservative analysis, two conditions will be assumed:

- For the conservative analysis using maximum infiltration, no low permeability cap will be assumed with direct exposure of the granular fill at the surface.
- For control of surface infiltration, the low permeability cap is assumed to be an approximate 3-foot thick cap material with a maximum hydraulic conductivity (K_h) of 1×10^{-6} cm/sec and minimum compacted effective porosity (η_e) of 0.04 (EPA 1988).

The low permeability cap will extend beyond the aerial surface of the granular fill to limit infiltration along the edges of the cap.

2) Bounding Fill Materials

CPNPP FSAR Revision 2 Subsection 2.5.4.5.4.1.1 provides a general description for structural fill (both sub-grade and above-grade) as being granular in nature, with a well-graded grain size distribution and less than 25 percent by weight passing standard US Sieve No. 200 (ASTM D422 and D1140), and containing particles no larger than 3 inches in maximum dimension, with less than 15 percent by weight larger than 2.5 in.

It is assumed all particles passing thorough the 200 mesh screen are clay size. Therefore the bounding engineered fill with the smallest grain size (fill type EF-1) would be a mixture of 75% very fine sand (0.075 mm) and 25% clay, evenly mixed, and the bounding engineered fill with the largest grain size (fill type EF-2) would be a mixture of 80% medium gravel (½-inch) and 20% cobbles (3-inch), evenly mixed.

CPNPP FSAR Revision 2 Subsection 2.5.4.5.4.1.1 provides a general description for pipe bedding fill as consisting of granular materials, well graded, with all material passing ½-inch sieve, and at least 95 percent retained on standard US Sieve No. 200 as determined in accordance with ASTM D422. Therefore, the bounding pipe bedding fill with the smallest grain size (fill type PB-1) would be a mixture of 95% very fine sand and 5% clay, evenly mixed, and the bounding pipe bedding fill with the largest grain size (fill type PB-2) would be 100% medium gravel.

3) Fill Material Placement and Layering

The type of structural fill used in the excavations will depend on the amount of pipe bedding fill used. Pipe bedding fill is not used in structure excavations (turbine, reactor, and auxiliary buildings) or the ESW pipe tunnel (piping within a concrete structure).

In those excavations where piping is installed without a concrete lined piping tunnel (e.g., the circulating water piping), CPNPP FSAR Revision 2 Subsection 2.5.4.5.4.1.1 provides a general description for installation of the pipe bedding fill where the height of the fill is at least at the centerline of the pipe, or preferably 12 inches above the top of the pipe. Therefore, three fill scenarios are anticipated within the onsite excavations (low permeability cap as per Section 1):

- Subgrade structures and concrete lined pipe tunnels (ESW Piping Tunnel) – 100% EF-1 or EF-2 (Figure 1).
- Buried piping, minimum pipe bedding – PB-1 or PB-2 to the piping centerline, remainder EF-1 or EF-2 (Figure 2).
- Buried piping, maximum pipe bedding – PB-1 or PB-2 to the 12 inches above the top of the piping, remainder EF-1 or EF-2 (Figure 2).

4) Engineered Fill Material Properties

The sources of engineered fill materials (structural, pipe bedding, capping) have not been determined; however, conservative values of K_h and η_e will be assumed to allow for quantitative assessment of the groundwater pathways, travel times, and maximum groundwater elevation within the engineered fill surrounding the reactor and auxiliary buildings.

The assumed values of K_h and η_e will be chosen to provide the most conservative value dependant on the calculation required. For the maximum groundwater elevation within the fill to be calculated, the assessment would require use of fill material properties that would result in the slowest groundwater transport; therefore, the smallest K_h and the largest η_e would be assumed. For the postulated accidental release analysis, the assessment would require use of fill material properties that would result in the fastest groundwater transport within the fill; therefore, the highest K_h and the smallest η_e would be assumed.

Fill type EF-1 is assumed to be a mixture of 75% very fine sand and 25% clay, evenly mixed, texturally classified as a sandy clay loam. The estimated saturated K_h value for sandy clay loam is 1.99 $x10^2$ m/yr (ANL 1993). $K_h = 1.99 \times 10^2$ m/yr = 6.31×10^{-4} cm/s. The estimated η_e value for sand ranges from 0.16 to 0.46 with an arithmetic mean of 0.32. Addition of clay into the sand would tend to lower the η_e values (η_e of clay ranges from 0.01 to 0.18). The conservative value would tend toward higher porosities (slower groundwater movement); therefore, the η_e value for the sandy clay loam will be estimated at 0.32.

Fill type EF-2 is assumed to be a mixture of 80% medium gravel (½-inch) and 20% cobbles (3-inch), evenly mixed. The estimated saturated K_h value for medium gravel poorly sorted with coarse gravel is 52 $x10^3$ m/yr (ANL 1993). $K_h = 5.2 \times 10^4$ m/yr = 0.165 cm/s. The estimated η_e value for medium gravel ranges from 0.17 to 0.44 with an arithmetic mean of 0.24. Addition of 20% 3-inch cobbles would not tend to greatly affect the overall porosity of the fill material. The conservative value would tend toward lower porosities (faster groundwater movement); therefore, the η_e value for the poorly sorted medium gravel will be estimated at 0.24.

Fill type PB-1 is assumed to be a mixture of 95% very fine sand and 5% clay, evenly mixed, texturally classified as very fine sand. The estimated saturated K_h value for well sorted, very fine sand is 3 $x10^3$ m/yr (ANL 1993). $K_h = 3 \times 10^3$ m/yr = 9.51×10^{-3} cm/s. The estimated η_e value for sand ranges from 0.16 to 0.46 with an arithmetic mean value of 0.32. Although this mixture has very little clay, the η_e value for the very fine sand will be estimated at 0.32.

Fill type PB-2 is assumed to be 100% medium gravel. The estimated saturated K_h value for well sorted medium gravel poorly sorted with coarse gravel is 45 $x10^3$ m/yr (ANL 1993). $K_h = 4.5 \times 10^4$ m/yr = 0.143 cm/s. The estimated η_e value for medium gravel ranges from 0.17 to 0.44 with an arithmetic mean value of 0.24. The conservative value would tend toward lower porosities (faster groundwater movement); therefore, the η_e value for the medium gravel will be estimated at 0.17.

5) Summary

Conservative values of K_h and η_e to be used in calculations and modeling efforts are presented in Table 1.

Table 1
Engineered Fill Properties

Location		(K_h) (cm/s)	(η_e) (unitless)
Low Permeability Cap	max	N/A	N/A
	min	$1x10^{-6}$	0.04
Subgrade Fill and Above Grade Fill	min (EF-1)	$6.31x10^{-4}$	0.32
	max (EF-2)	0.165	0.24
Pipe Bedding	min (PB-1)	$9.51x10^{-3}$	0.32
	max (PB-2)	0.143	0.17

The following fill placements will be assumed for the bounding conditions:

Hydrostatic loading analysis (slowest groundwater transport)

- PB-1 to centerline of piping
- Remainder EF-1
- Low permeability cap not installed

Postulated accident analysis (fastest groundwater transport)

- PB-2 to 12 inches above piping
- Remainder EF-2
- Presence of low permeability cap not significant

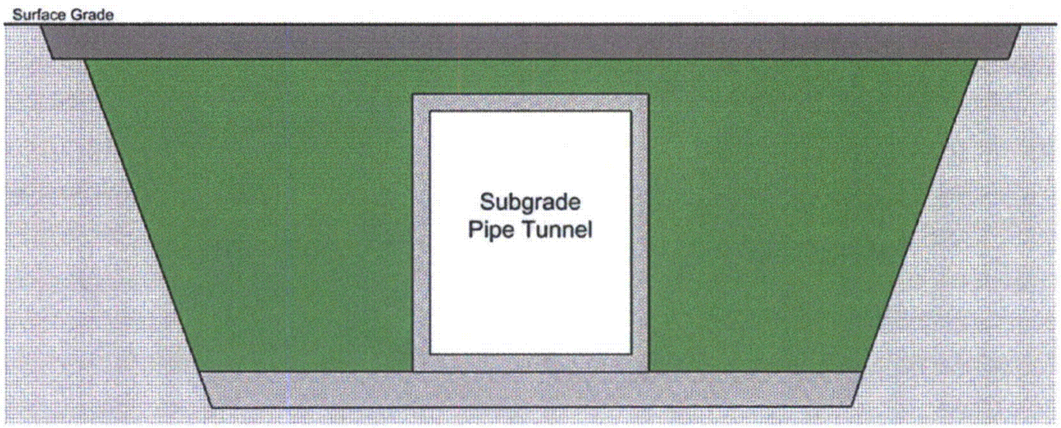
Areas of Above Grade Fill

The topographic elevations depicted on the post-construction grading and drainage plan (Rev H) were compared to the pre-construction topographic elevations. Areas requiring above grade fill build up to support construction operations are depicted in blue outlines on Figures 3 and 4.

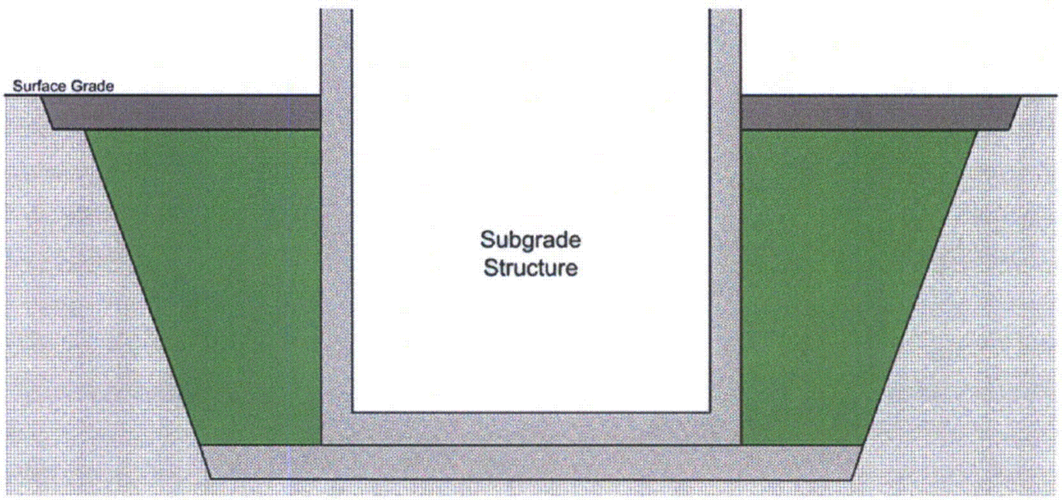
References

(ANL, 1993) Argonne National Laboratories, Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil, Website, http://web.evs.anl.gov/resrad/documents/data_collection.pdf, Accessed 11/2/2011

(EPA, 1988) U.S. Environmental Protection Agency, Determination of Effective Porosity of Soil Materials, EPA/600/S2-88/045, September, 1988



a) ESW Piping Tunnel Excavation Fill



b) Subsurface Structure Excavation Fill

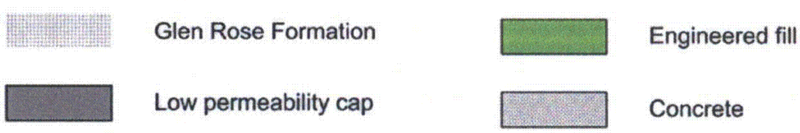
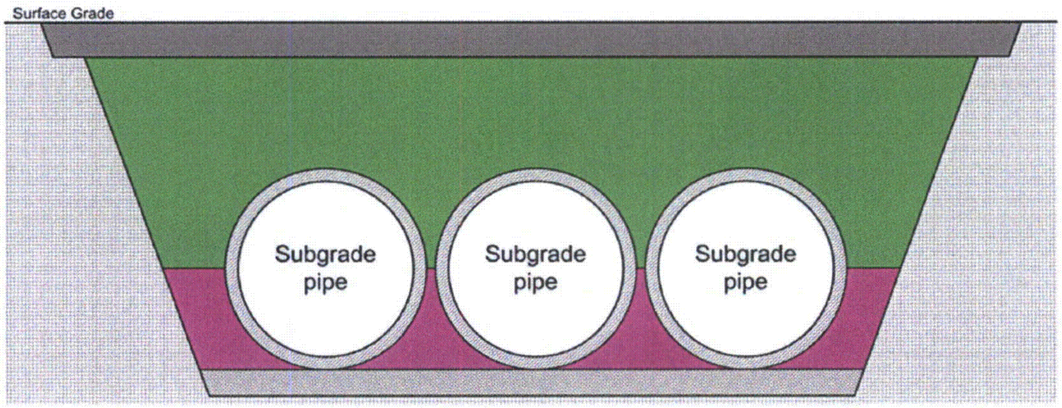
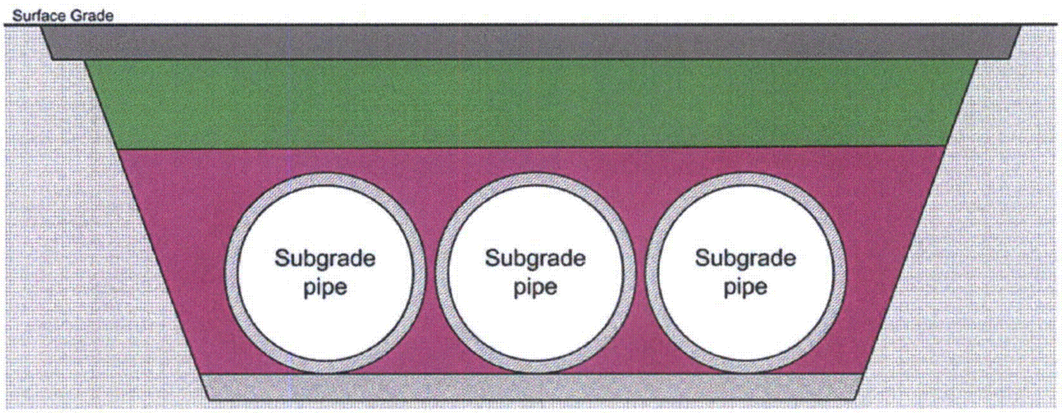


Figure 1 – Structural Fill Placement



a) Piping Excavation Fill, minimum pipe bedding.



b) Piping Excavation Fill, maximum pipe bedding.

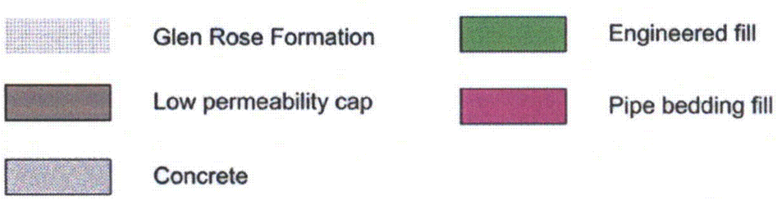


Figure 2 - Pipe Bedding Fill Placement

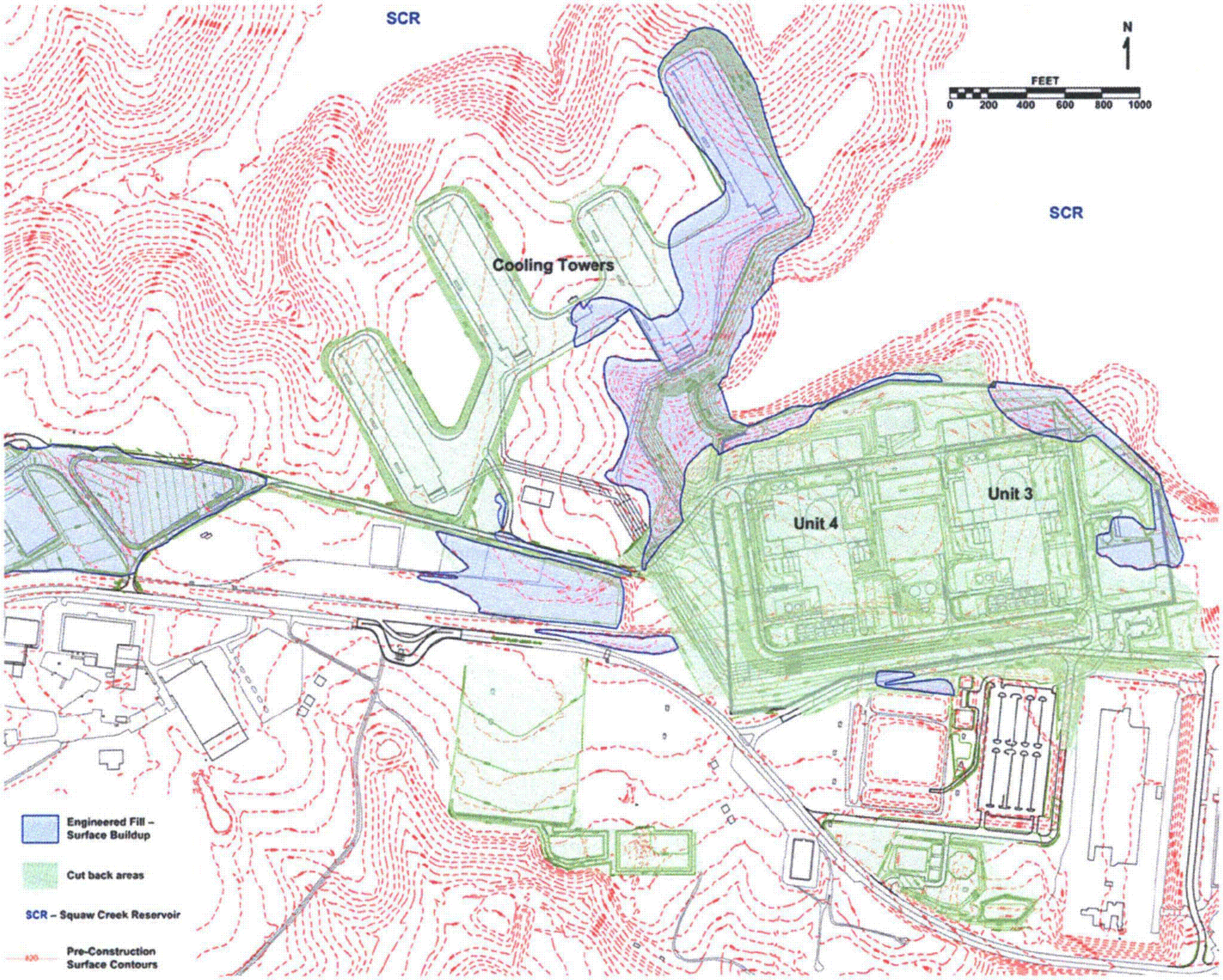


Figure 3 - Cut and Fill Areas

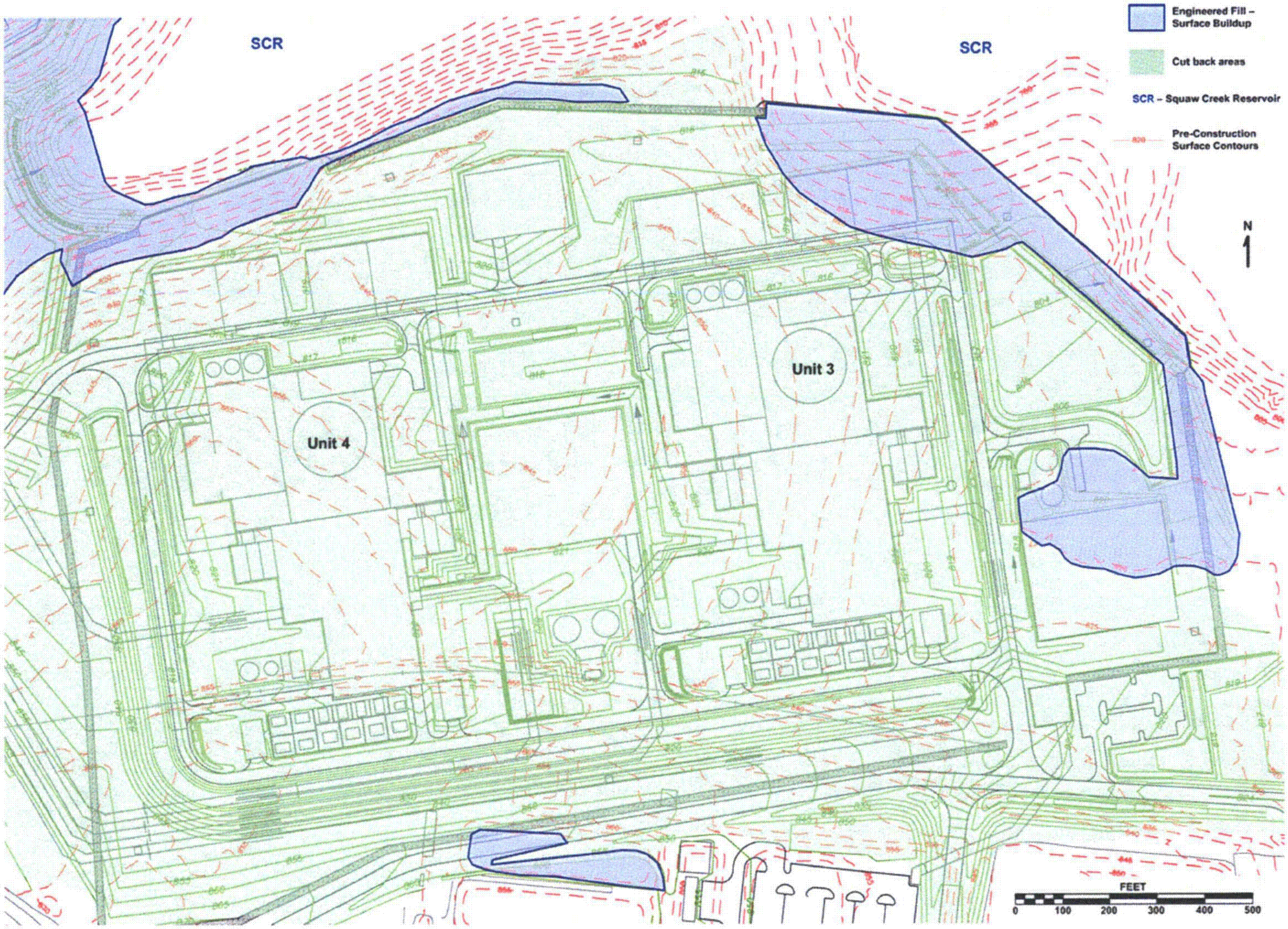


Figure 4 - Cut and Fill Areas in the Vicinity of Units 3 and 4