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Settlement Experienced at a Recently Licensed Nuclear Station

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ABSTRACT The settlement experienced at a recently licensed nuclear station demonstrated the need for coordination among geologists, geotechnical engineers and structural engineers to ensure that essential geological knowledge and experience is applied to the design and construction of the structures. The nuclear station had been under construction for a number of years when unexpected settlements were noticed which caused significant concrete cracking of the nuclear service water intake structure. The "seismic Category I" intake structure has an internal dimension of 12 feet wide by 15 feet high, a length of 167 feet with the thickness of walls and roof varied from 2 feet 6 inches to 3 feet.

This paper describes the details of the problem including the original exploration and design, the extent of investigation following the discovery of the structural cracks, the evaluation of the causes of settlement and conclusions.

INTRODUCTION

The nuclear service water pumphouse and intake structure are located on the west side of a man-made lake as shown in Figure 1. Profiles through these structures, the embankment slope, and foundation soils are shown in Figure 2. The intake structure has an internal dimension 12 feet wide by 15 feet high and a length of 167 feet with the wall and roof thicknesses varying from 2 feet 6 inches to 3 feet. The pumphouse has a plan dimension of 70 x 80 feet with a height about 80 feet.

The subsurface condition in the vicinity of the pumphouse and intake structure, prior to construction of the embankment, was disclosed by drilling five test borings. Samples obtained from these borings were tested for soil identification and consolidation. The compacted fill was also tested in a laboratory for compression characteristics. Based on the results of this investigation, settlement at the pumphouse was estimated to be about 4 inches, and at the intake structure, about 2 inches over the life of the plant. The intake structure was expected to undergo a linear differential settlement with no significant bending in the longitudinal direction. A settlement monitoring program was established prior to construction to measure the actual settlement at various locations on the pumphouse.

During construction, in August 1977, settlement exceeded the predictions at the settlement points. Two weeks later, cracks were discovered in the walls and roof of the intake structure. These cracks were widest in the roof and disappeared near the bottom of the vertical walls. The cracks penetrated the full thickness of the walls and the roof slab (Fig. 3). The largest observed crack had a maximum width of 1/8 inch.

Soon after the settlement and cracks were observed, construction of the pumphouse and surrounding fill was temporarily halted while the cause of the settlement was investigated. This investigation consisted of additional borings, settlement monitoring instrumentation, laboratory tests and settlement analyses. Based on the results of the investigation, the expected settlement of the pumphouse was revised upward from 4 inches to about 14 inches. A program was begun to reduce the settlement. Preloading of the subsurface materials was accomplished by placing extra fill around the structure and by filling the pump chamber in the pumphouse with water to accelerate the settlement of the soils under the pumphouse. After removal of the preload fill, the cracks, now up to 0.2 inches wide, in the intake structure were pressure grouted. The service water pond was filled about five weeks after the completion of grouting in the intake structure.

DISCUSSION

The settlement potential for the pumphouse and intake tunnel was apparently not at an early stage, possibly due to the engineer's unfamiliarity with the geologic terms used in describing the site. Some of the apparent causes of the settlement problem follow.

The residual soils or saprolite that supported the pumphouse and intake structures are known to be highly variable and difficult to classify into engineering units with distinct properties and boundaries. Soil compression characteristics and reasonably accurate residual soil profiles are essential for the determination of anticipated settlement. In the original investigation, however, consolidation test samples of saprolite were obtained from borings located over one-thousand feet away from the pumphouse and intake structure. These samples did not represent the soil conditions beneath the structures and therefore did not provide sufficiently reliable information for a geotechnical engineering evaluation of the foundation performance for this site.

Excavated residual soils were used as fill material to raise the foundation bearing grade for the pumphouse and intake structure. Due to inclement weather conditions during construction, fill material was placed under these structures with moisture content higher than originally specified. The high moisture content resulted in undercompaction of the fill which was discovered by a later investigation to have caused a few inches of settlement.

The subsurface profile along the intake structure as revealed by later investigation (Fig. 4) indicates that the fill thickness varies from 20 to 30 feet and the saprolite thickness varies from 17 to 35 feet; this later profile contrasts with the original assumption of about 10 feet of fill and no saprolite underneath the pond end of the intake structure. To locate potential settlement areas, the highly variable nature of saprolite requires a more precise subsurface profile than was provided initially.

With foreknowledge of potential settlement problems, verified perhaps with adequate testing and evaluation of soil parameters, the design of the intake structure could have included longitudinal reinforcement to mitigate the effects of differential settlement and embankment loadings.

CONCLUSIONS

The lesson to be learned from this experience with residual soils is that the unexpected should always be expected. The geologist and engineer should work together to recognize the inherent variability of residual soils and they should be thorough at the early stages of site development and in the design process so that everyone is aware of the uncertainties involved. Limiting conditions, such as potential settlement, should be defined early so that construction strategies or design features can be developed to cope with the limitations.

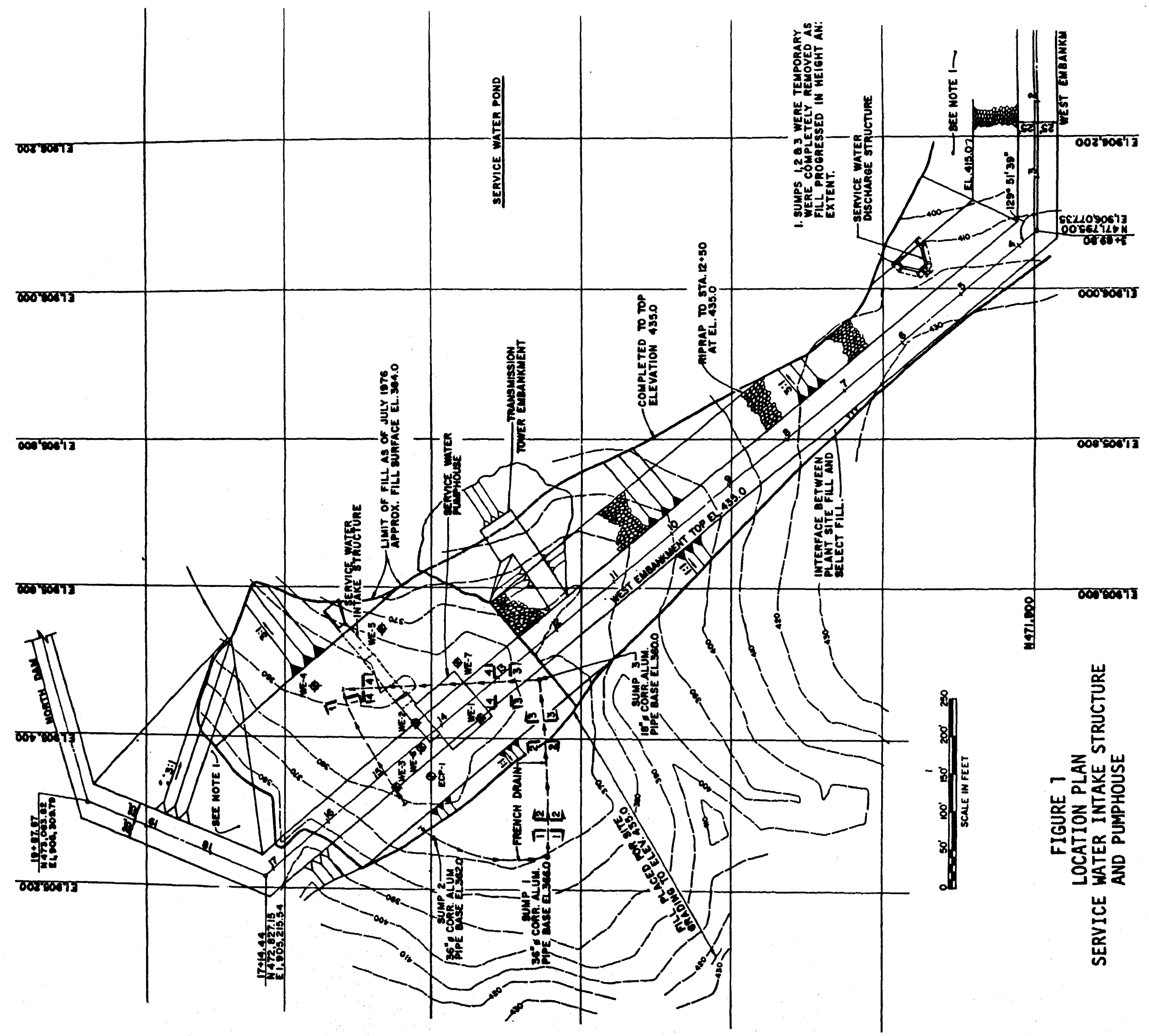


FIGURE 1
LOCATION PLAN
SERVICE WATER INTAKE STRUCTURE
AND PUMPHOUSE

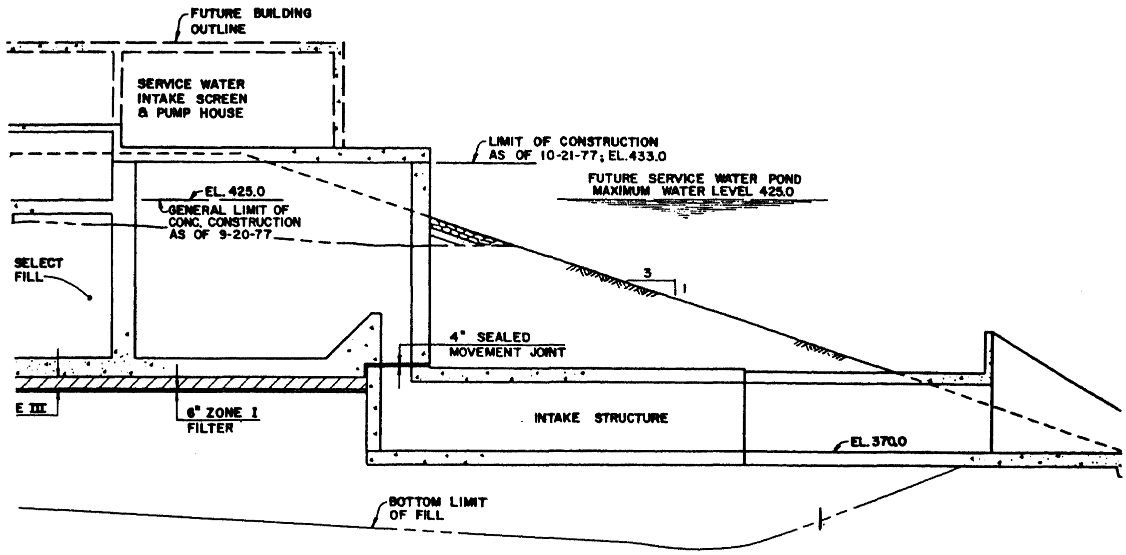


FIGURE 2
SECTION PROFILE
SERVICE WATER INTAKE STRUCTURE
AND PUMPHOUSE

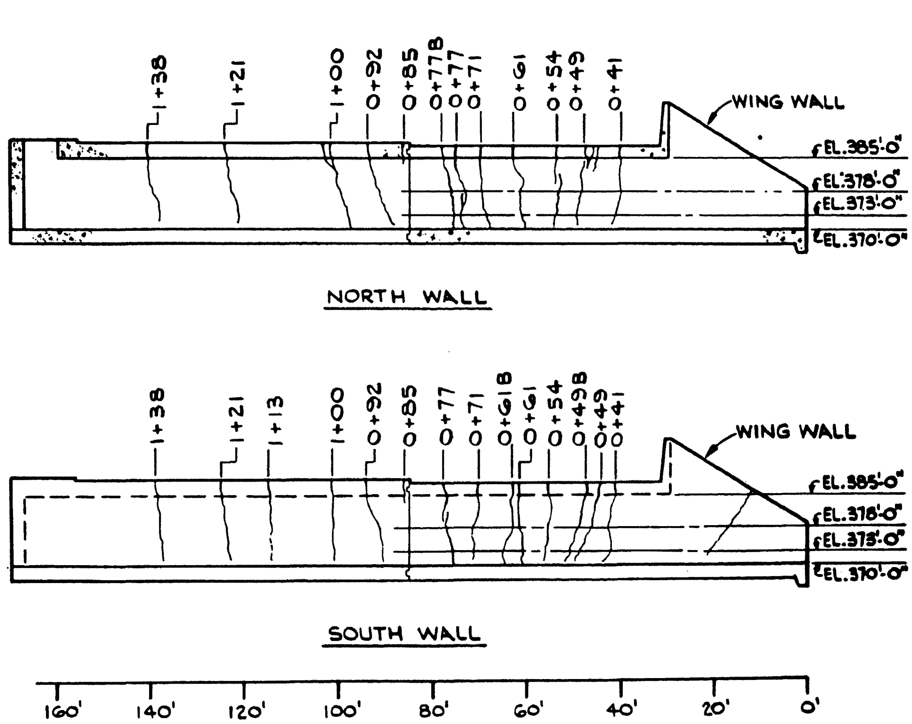
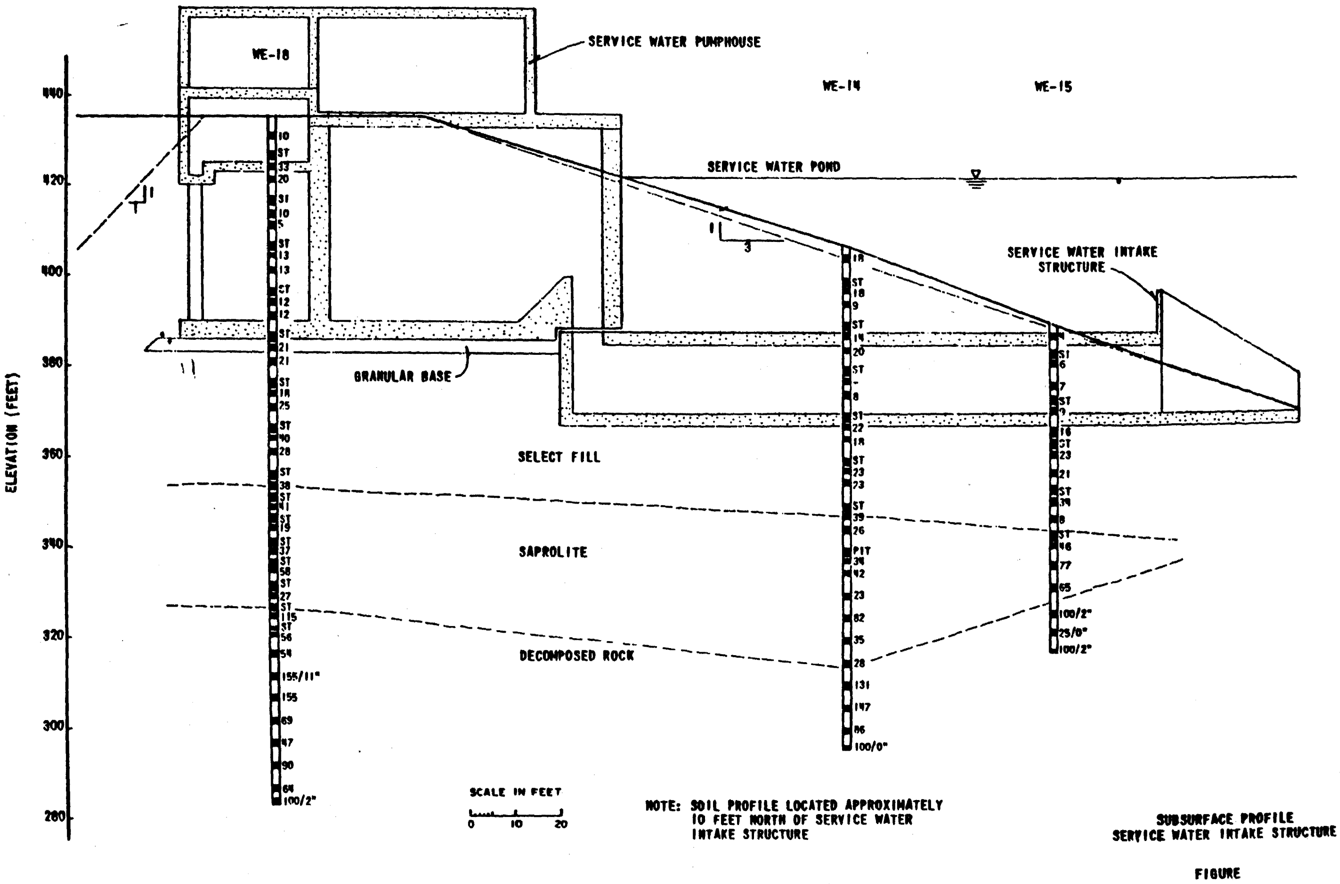


FIGURE 3
CRACKING SURVEY DATA TO DECEMBER 5, 1977
SERVICE WATER INTAKE STRUCTURE


SERVICE WATER PUMPHOUSE
WE-18
WE-14
WE-15
SERVICE WATER POND
SERVICE WATER INTAKE STRUCTURE
GRANULAR BASE
SELECT FILL
SAPROLITE
DECOMPOSED ROCK
ELEVATION (FEET)
440
420
400
380
360
340
320
300
280
SCALE IN FEET
0
10
20
NOTE: SOIL PROFILE LOCATED APPROXIMATELY 10 FEET NORTH OF SERVICE WATER INTAKE STRUCTURE
SUBSURFACE PROFILE
SERVICE WATER INTAKE STRUCTURE
FIGURE