Memorandum · UTAH DEPARTMENT OF TRANSPORTATION

DATE: October 31, 1980

TO : J. O. Adair, P.E., Chief, Roadway Design

David R Miller For E E Lovelace

FROM : Edwin E. Lovelace, Engineer of Materials and Research

SUBJECT: I-15-4(18)188 - Scipio to Sevier River
Subsurface Investigations for Sinkhole Problem

As recommended by the F.H.W.A. regional office we have conducted a new subsurface investigation concerning the "sinkhole" problem on the proposed I-15 alignment north of Scipio. It was recommended that this investigation include evaluation of strength and saturation characteristics, in-situ density and soil collapse susceptibility.

The problem area is a 3600± foot section of the I-15 alignment, approximately 2 miles north of Scipio, which has several surface subsidence and soil piping characteristics. Where these subsidence areas are intercepted, the existing roadway has undergone considerable differential settlement. Collapse has occurred on two occasions following heavy precipitation and flooding. This problem was previously investigated and covered by a report memorandum dated June 27, 1969.

Relative to the recent subsurface investigation, seven new test holes were drilled to a maximum depth of 42 feet. Undisturbed and standard penetration drive samples were obtained and a series of laboratory tests were conducted.

In order to better determine the cause and nature of the "sinkhole" depressions, test hole 1 was drilled directly in one of the more mature depressions and hole 4 was located on a sinkhole alignment which was not as well developed. Holes 2, 3, 5, 6 and 7 were drilled off to the side of the depressions where the soils appeared to be in a relatively natural or original condition.

All holes were drilled with air as a circulation medium in order to avoid altering the moisture contents of the samples. The soil types found in all seven holes were quite similar - fine sandy silts with varying amounts of clay. A few lenses of more granular soil containing a higher percentage of sand and some gravel were also found. A water table was not found nor were there any zones in which the soil was saturated with water. However, soil samples from test hole 1, drilled in one of the depressions, contained the most moisture; those from hole 2, 132 feet to the south, were also somewhat moist while the others were generally quite dry. Refer to the attached Drilling Logs for further details and location of the holes.

The following laboratory tests were run on selected subsoils samples: consolidation/collapse tests, grading analysis, liquid limit, plastic limit and plasticity index, moisture content, wet (in-situ) unit weight, dry unit weight, specific gravity, vertical permeability, unconfined compressive strength, water soluble salts content and soil chemical analysis. Results of these tests are given in the attached Summary of Test Data Sheets.

Copies of the void ratio vs. log of pressure curves from the consolidation/collapse tests are also attached. In general, these tests show that all samples tested except those from drill hole 1 are susceptible to collapse on contact with water. The samples from hole 2 and those from 19 feet or deeper in holes 4 and 5 are moderately collapse-susceptible and only when subjected to higher than in-situ pressures. It can be seen from the test curves that the collapsible soils at field moisture conditions have considerable strength to resist deformation from pressure but lose this strength and are easily compressed after saturation with water. Several of the specimens were found to be highly susceptible to collapse as shown by immediate reduction in void ratio or volume on contact with water (eg. Test Hole 5 at 7 feet). The wet unit weights of the collapse-susceptible silts are also much lower than normal for soils with similar grain size distribution.

Tests were also conducted on samples wherein the soil was dried and then recompacted at 15% moisture content to approximately 125 pcf wet unit weight. These remolded samples were very stable and strong and had permeabilities which were lower than natural by a factor of nearly a thousand.

CONCLUSIONS

The soils underlying the problem area, as well as adjacent areas are alluvial outwash sediments derived from the hills to the east. They consist mainly of fine sandy silt with some clay. The grains are loosely packed and contain an unusual amount of pore space. These sediments, in their natural state were found to be susceptible to collapse when saturated with water. The mechanism for this collapse upon wetting is probably related to the release of capillary tension or molecular binding forces which are provided by clay particles at low moisture conditions. Clusters of flocculant clay particles probably form miniature butresses or separations between the larger silt and sand grains and provide considerable structural strength as long as the soil remains dry.

The geologic setting and influence of faulting on the movement of subsurface water was discussed in the 1969 report. We believe that fault controlled concentrations of surface and perched ground water in contact with the collapsible soils has caused localized volume reductions and formation of cavities and conduits for water migration. Soil piping is then initiated which in turn brings more water in contact with the collapsing soils and perpetuates the process by enlargement of the cavities. Progressive subsidence and eventual collapse further act to concentrate surface water in these "channels" and the vicious cycle continues.

The collapse and piping phenomena appear to be confined to the upper 15 to 25 feet of sediments. Water can apparently move vertically down through the collapsible soils to a denser, much less permeable zone at depths of 15 to 20 feet. The water then begins moving near horizontally and progressively increases its flow capacity by forming interconnected cavities and piping conduits.

The large sinkhole system to the right of Station 896± NBL shows indications that some of the soil may also have been lost by piping along fault fractures to greater depths, in addition to the horizontal piping. However, the limited lateral extent of the sinkholes indicates these are not caused by the collapse of solution caverns in limestone underlying the valley, as proposed by Bjorkland and Robinson in the U.S. Geological Survey "Water-Supply Paper 1848", published in 1968.

RECOMMENDATIONS

It is recommended that corrective measures be taken to prevent water from saturating the foundation soils underlying the proposed roadway and that existing unstable conditions already created by piping and collapse phenomena be corrected. We believe the most practical means of accomplishing these goals available at this time are as follows:

1. Excavate the native soils along the alignment of the "sinkholes" to an average depth of 15 feet. The locations of known sinkholes which should be excavated are:

Sta. 873 + 30 SBL and 875 + 10 NBL
Sta. 877 + 30 SBL and 880 + 60 NBL
Sta. 886 + 65 SBL and 888 + 90 NBL
Sta. 892 + 72 SBL and 894 + 85 NBL
Sta. 899 + 75 SBL and 901 + 50 NBL
Sta. 905 + 50 SBL and 908 + 25 NBL

The excavation trenches should extend from the east to the west right of way line and should be at least 12 feet wide at the bottom with 1:1 side slopes for the safety of workmen. Some trial and error or direction adjustments of the excavations should be expected in order to stay on course of the sinkhole trends. In addition, isolated vertical type sinkholes were noted near southbound lane Stations 880+90 and 882+90. These are not on apparent fault trends; however evidence of connection to other sinkholes or subsidence trends may develop as the excavation of adjacent soils progresses. In that case excavation should intercept these sinkholes also and provide a drainage outlet for subsurface water. If no connection with other sinkholes or piping conduits is found, these isolated sinkholes as well as any others that may be found during construction should be filled with granular borrow and compacted in accordance with standard specifications.

2. The bottom of the excavations should be compacted with a vibratory roller in order to densify any very soft underlying soils and fill all possible voids remaining below 15 feet. Several passes will probably be required to effect the readjustment of soil grains and filling of small caverns. The bottom of the excavation should be finished to provide a 1% slope from east to west.

3. Perforated underdrain pipe should be placed at the bottom of each compacted excavation to expedite the transmission of runoff water from existing subsurface conduits on the east side of the right of way to the west side. This is needed to reduce the possibility of water infiltration into the uncollapsed soils. The inlet of the underdrain should be installed in line with the predominant piping conduit exposed at the upper end of the excavation. The inlet of the underdrain pipe should be protected from infiltration of silt by covering with a perforated cap and two layers of filter fabric (such as Mirafi 140). The outflow from the existing natural piping conduits should be collected and channeled into the underdrain by means of a "French drain" collection basin backfilled with underdrain granular backfill. The collection basin should also be enclosed with a filter fabric such as Mirafi 140 in order to prevent infiltration of silts. The outlet end of each underdrain should be carried beyond the existing US-91 roadway to keep the water as far away as possible from soils underlying the new roadway and to protect the existing road which must carry I-15 traffic until the new facility is completed. We recommend that 8 inch slotted (corrugated) plastic underdrain pipe encased in filter fabric be used because of its cost effectiveness and proven durability.

4. The side slopes and bottom of the excavations should be protected from water infiltration by spraying with catalytically blown asphalt or covering with polyethylene film or other suitable plastic membrane.

5. The bottom five feet of each excavation should be backfilled with granular borrow in order to provide a stable replacement material. The granular borrow should also enhance the migration of water, not collected by the underdrains, and help carry it beyond the roadway.

The excavated native soil may be used for backfill above the bottom five feet. This material should be moistened to near the optimum moisture content and compacted in accordance with standard specifications.

6. It is extremely important to provide positive drainage of surface water with adequate culverts. This is particularly important for water which is channeled by the sinkhole depressions. Naturally, the surface drainage water should not be allowed into the underdrain system.

7. It is also recommended that water from the underdrains be disposed of by transporting by culvert far enough west to daylight with open ditches.

An alternate recommendation for disposing of water from the underdrains is to dump it into vertical drains approximately 75 feet deep. These underground disposal drainage systems could be constructed by auger drilling 2 foot diameter or larger holes, placing slotted plastic pipe and filling the anulus with underdrain granular backfill material. The capacity of these drains would be limited to water picked up by the underdrains only. Surface drainage should be kept completely separate from the underdrain system.

8. Subexcavation and backfill between the above mentioned sinkhole trends is not recommended unless additional sinkholes are discovered during construction.

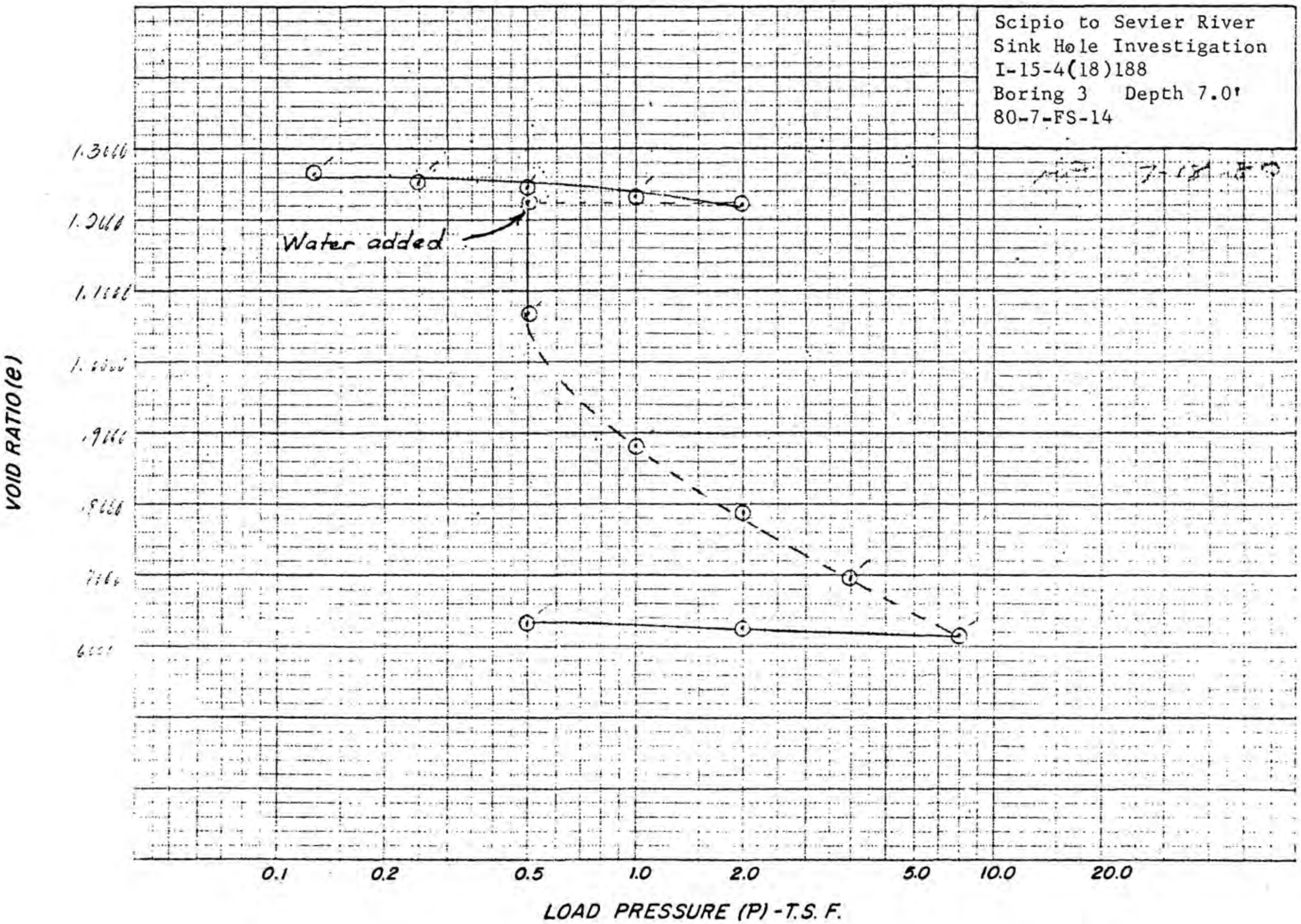
An alternate method of corrective treatment for the sinkholes which was considered is that of using water to prewet the collapsible soils and allow collapse or hydrocompaction to take place prior to the main construction. This could be accomplished by preparing the near surface soils for more efficient water penetration by deep "chiselling" with a ripper and continuous sprinkling with fine spray rainbird-type sprinklers. It is estimated that this could require as much as 3 months sprinkling time for sufficient penetration. The main objection to this method is the scarcity of water in this area which apparently makes it impossible to obtain permits from water-user associations to use Sevier River water from approximately a 6.2 mile distance. The utilization of underground water, which appears to be inadequate in any case, is also restricted by water-user associations.

Other disadvantages to this method are the risk of water penetrating the soils underlying the existing roadway and rendering it unfit to carry the traffic during construction. There is also a possibility that considerable time would be required after sprinkling was complete before sufficient strength could be gained by the soils to support heavy equipment and permit continuing on with construction. There is also a possibility of creating a ground-water dam by collapsing the silty soils and consequent reduction in permeability. Large quantities of soil could also possibly be eroded and carried away with water piping to considerable depths vertically along fractures in some sinkholes (particularly the one near Station 896). Because of these drawbacks this method is not recommended at this time.

Other corrective treatments which could be considered are dynamic compaction methods. These methods include either the vibro-replacement procedure where a VIBROFLOT vibrating probe is used for compaction of the silts and replacement with granular materials; weight-drop methods effecting great compactive energies have also been used. The dynamic compaction methods have been found effective for compacting soils to depths of about 25 feet and show promise of considerable cost savings in compacting collapsible silts. The only drawback visualized is again that of creating a ground water dam by the compacted soils which would be much less permeable. The impoundment of subsurface water behind the I-15 roadway could cause long term problems through future collapse of adjacent soils underlying sections outside of the present problem area.

It should be recognized that the corrective treatment here recommended may not prevent future differential settlement and even collapse in the areas not treated. It is quite likely that horizontal piping conduits and cavities exist without any apparent surface identification. The recommended treatment should, however, provide reasonable assurance of an adequate design for the known conditions.

Attachments
LHRausher/nmt
cc: Sheldon McConkie
Alex E. Mansour
James C. Nelson
Woodrow A. Burnham
George W. Bohn, FHWA


Scipio to Sevier River
Sink Hole Investigation
I-15-4(18)188
Boring 3 Depth 7.0'
80-7-FS-14
Water added
VOID RATIO (e)
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0.2
0.5
1.0
2.0
5.0
10.0
20.0
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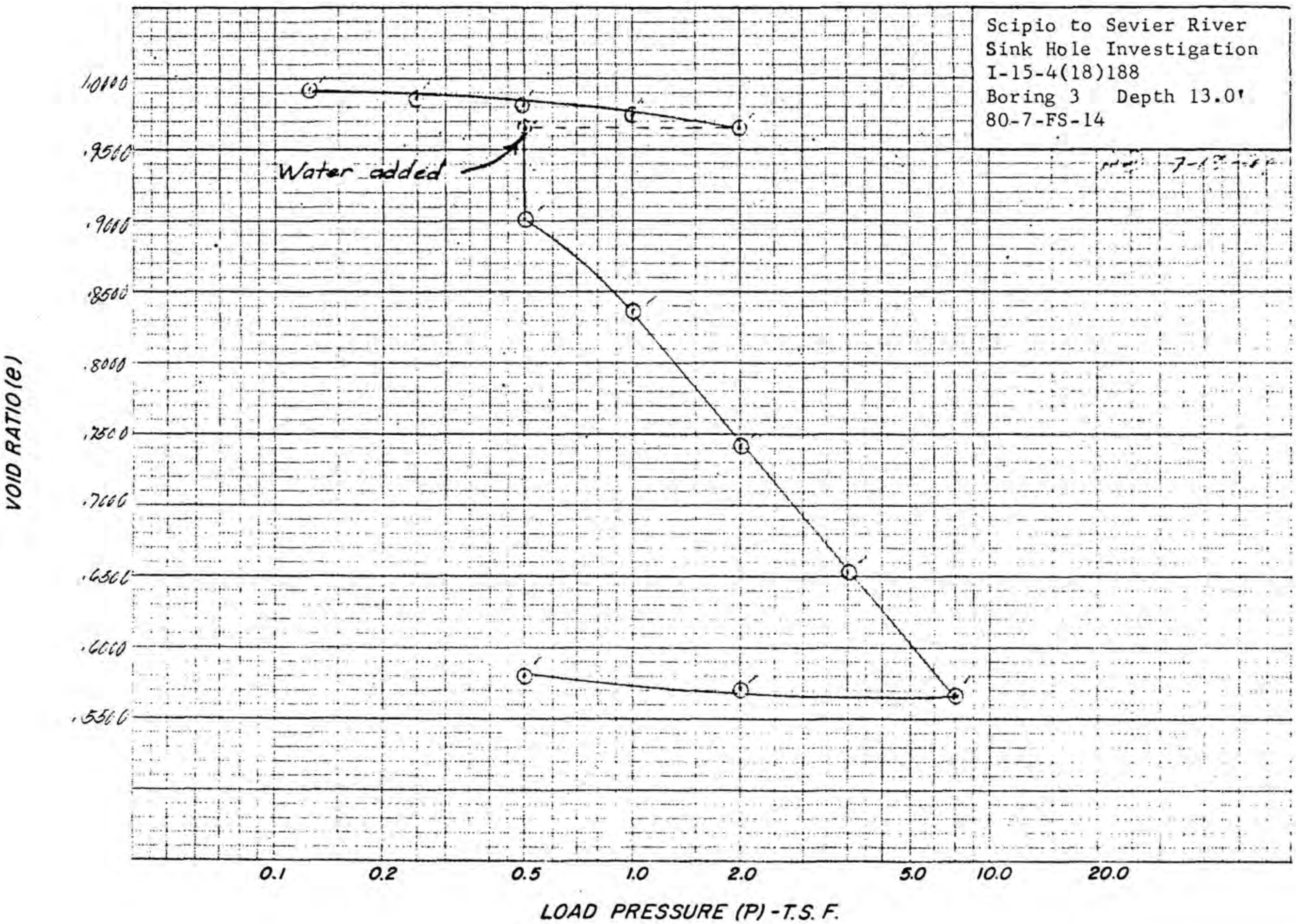
Scipio to Sevier River
Sink Hole Investigation
I-15-4(18)188
Boring 3 Depth 13.0'
80-7-FS-14
VOID RATIO (e)
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.8500
.8000
.7500
.7000
.6500
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.5500
Water added
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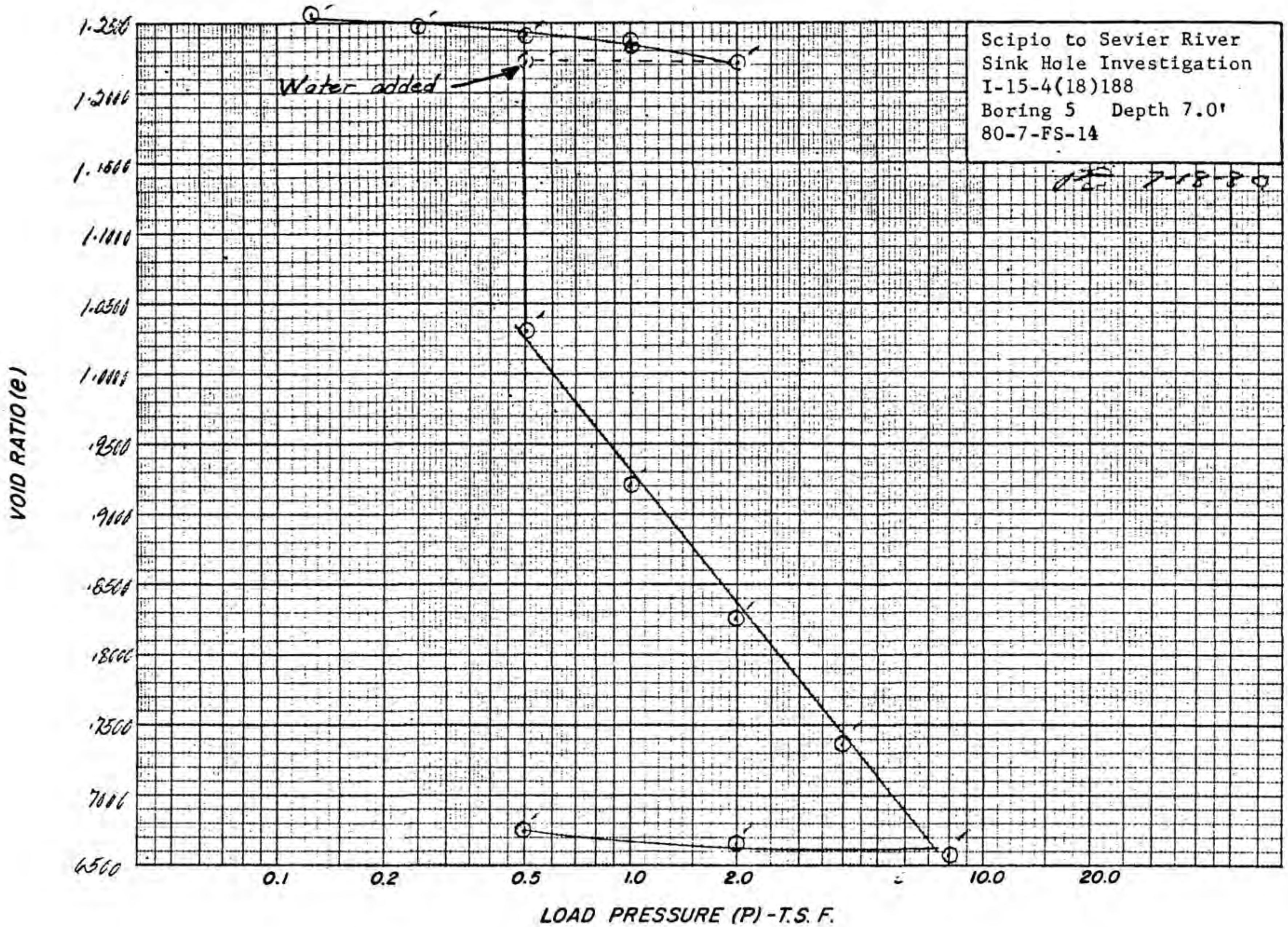
0.2
0.5
1.0
2.0
5.0
10.0
20.0
LOAD PRESSURE (P) - T.S.F.



Scipio to Sevier River
Sink Hole Investigation
I-15-4(18)188
Boring 5 Depth 7.0'
80-7-FS-14
Water added
7-18-80
VOID RATIO (e)
1.2500
1.2000
1.1500
1.1000
1.0500
1.0000
.9500
.9000
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.8000
.7500
.7000
.6500
0.1
0.2
0.5
1.0
2.0
10.0
20.0
LOAD PRESSURE (P) - T.S.F.