Alberta Research Council
Open File Report 1965-10

EVALUATION OF THE GRANDE PRAIRIE ALLUVIAL-TERRACE WATER SUPPLY

by

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Edmonton, Alberta
July 1965

Alberta
RESEARCH COUNCIL

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SUMMARY

This report presents the general conclusions from a detailed study of the available aquifer-test and recharge-test data for a number of test sites along the Wapiti River south of Grande Prairie. Each test is reported on individually. The results as a whole suggest that the alluvial terrace on the north side of the river which is presently used as a source of water supply for Grande Prairie is unsuitable for that purpose under natural conditions. Under natural conditions water cannot be induced to flow into the aquifer from the river when water is pumped from the aquifer and, consequently, it is not possible to reduce the high iron concentration which has been a continual problem during the two years that the city has made use of the aquifer. River water can be introduced artificially into the aquifer by pumping it into a recharge pit but, although there is a tendency for iron concentration to be reduced, the reduction may not be sufficient. In addition, the costs of operating this artificial-recharge system might be excessive, because, besides the additional pumping installations required, there would be a need for periodic cleaning and maintenance of the recharge pits. An infiltration gallery projecting out under the river is a possible alternative but test results indicate that a layer of fine sediment permeates the sands and gravels of the river bottom. Such a layer would tend to inhibit the free flow of river water into the gallery and there could be major maintenance costs associated with its operation.

It is suggested that an alternative well worth investigation is the groundwater potential in the bedrock underlying the alluvial terrace. A successful bedrock supply could eliminate or minimize treatment problems. Such supplies have proved successful

elsewhere in Alberta under similar conditions. If a bedrock supply is not feasible, experiments could be made with an infiltration gallery or an attempt could be made to design an efficient artificial-recharge system. The possibilities of direct intake from the river or from an oxbow lake located at the north side of the terrace are ignored in the report but they might take precedence over the infiltration gallery or artificial recharge. The investigation of a bedrock supply should, however, be given prime consideration.

INTRODUCTION

Since the summer of 1963 the water supply for the city of Grande Prairie has been obtained from a number of wells completed in the alluvial sand and gravel deposits of a terrace adjacent to and on the north side of the Wapiti River. The well site and a treatment plant lie approximately 8 miles to the south of the city. At the present time ten wells have been completed and eight of these are connected to the treatment plant but not all of the eight are producing.

Difficulties were experienced with the alluvial-terrace supply within the first year of operation and have been more or less chronic since that time. There are two principal problems:

1) it has not been possible to produce from the wells at rates as high as those that were originally anticipated, and

2) the water produced has an undesirable high iron content (generally in the range 6-9 ppm*).

It was expected at the time of installation of the system that the amount of iron would gradually reduce with time because of the infiltration of river water into the

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* parts per million

terrace. Eventually the iron content should have approached that of the river (0.05-1.2 ppm) but, during approximately two years of operation, no perceptible change attributable to river-water infiltration has been noted.

The problem of iron reduction is the primary one. If any or all of Grande Prairie's water is to come from this terrace, iron in the water produced from it will have to be appreciably decreased. Greater production rates are desirable if the iron problem should be overcome, especially at times of low river stage. During these periods groundwater levels in the terrace are also low and well production rates are reduced.

PURPOSE AND SCOPE OF THIS REPORT

This report presents the broad conclusions arrived at from a detailed study of the available aquifer-test and recharge-test data for a number of test sites along the Wapiti River south of Grande Prairie (Table 1). Most of the sites were on the alluvial terrace in which the city's wells are now completed. This terrace is referred to, for convenience, as the north terrace. The first test listed in table 1, however, was for a similar terrace on the south side of the river and about 1 mile to the west. This terrace is referred to as the south terrace.

Table 1

Summary of Wapiti River Test Data

Test	Started		Stopped		Duration	Remarks
	Day	Hour	Day	Hour	(min.)	
A	Aug.20, 1960	0900	Aug.21, 1960	1115	1,575	Pumping test, recovery observed
B	Oct.20, 1961	1300	Oct.23, 1961	1200	4,260	Pumping test, recovery observed
C	Apr.21, 1964	1100	Apr.24, 1964	1600	4,620	Pumping test, recovery observed
D	Jan.24, 1965	1200	Feb.16, 1965	0938	32,978	Pumping test, recovery not observed
E	Mar.21, 1965	1430	June 16, 1964*	1430	125,280*	Recharge-pit test

*Time of last available reading. Test terminated during last week in June.

The prime purpose of the report is the evaluation of the north terrace water supply and of the possibilities for increasing the quantity and improving the quality of the water produced from the terrace. Alternative supplies involving development of other aquifers or use of other methods of inducing infiltration from the river are, however, briefly considered. Direct intake from the river, another possible alternative, or from any other surface source is beyond the scope of this report.

GENERAL OBJECTIVES AND PROCEDURES FOR THE TEST ANALYSES

Improvement of water quality -- that is, iron reduction - and production of water in the quantities required to satisfy Grande Prairie's growing needs both depend on the infiltration of water in significant quantities from the river into the alluvial terrace. The objective in the analysis of the data from tests A to D in table 1 was, therefore, to determine whether induced infiltration takes place at all and, if so, to establish its relative importance. There are a number of indicators that are useful for this purpose:

1) drawdown trends in the pumped well and any observation wells as pumping progresses,
2) recovery trends in these wells after pumping ceases,
3) temperature changes in the pumped well, and
4) changes in iron concentration in the pumped well.

If induced infiltration is effective, drawdowns (and, therefore, water levels) should tend to stabilize as pumping progresses. When pumping ceases water levels should rise and eventually return to their undisturbed values. If induced infiltration is not effective, water levels will not stabilize during pumping and will tend to values somewhat lower than their undisturbed values after pumping ceases. This latter effect

Whether or not induced infiltration takes place -- that is, whether or not what is known as a hydraulic connection exists between the aquifer and the river - varying river levels will commonly be observed to give rise to varying groundwater levels in the alluvial terrace. If there is a hydraulic connection, water moves from the river into the terrace when the river stage is high, and from the terrace into the river when it is low. If there is no hydraulic connection, any increase in river stage results in an increase of pressure on that part of the aquifer underlying the river. As a result water is squeezed out toward those parts of the aquifer forming the river banks and water levels rise in the terrace aquifer. This correspondence between river and groundwater fluctuations cannot then be taken as evidence for a hydrologic connection between river and terrace. It is, however, a factor that must be corrected for if test results are to be interpreted correctly. The recommended procedure is to make a series of measurements of both river and groundwater levels prior to the test for as wide a range of river fluctuation as possible.

TEST A - AUGUST 1960

This test was conducted by the Research Council of Alberta and lasted a little more than a day. The test site was a terrace on the south side of the river about one-quarter mile west of Grovedale Bridge. No pumping-well data were obtained but water-level measurements were made in three observation wells, 40 feet east, 100 feet west, and 100 feet south of the pumping well. Recovery measurements were also made in these three wells. The pumping rate was 70 igpm*.

This test suffered from two shortcomings: it was too short, and the river effect was not determined. No quantitative analysis of the data could be made but the following points were noted:

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*imperial gallons per minute

1) drawdowns did not stabilize or tend to stabilize during the pumping period,

2) recovery data indicated that stabilized recovery levels would be slightly lower than the levels existing before pumping started, and

3) temperature of the pumped water remained constant throughout the test.

All three observations suggest that no significant infiltration took place during the 1,575 minutes of the test and, in fact, that the aquifer was partly dewatered. Declining river levels during the pumping and recovery periods, if these existed, could have masked the effects of infiltration on drawdown and recovery but should not have made any difference to the temperature results.

None of the pumped water was analyzed chemically.

TEST B - OCTOBER 1961

This test was financed by the city of Grande Prairie, conducted by the Research Council of Alberta, and lasted almost three days. It was the first test on the terrace now used by the city. The test site was very close to the location of the existing treatment plant. Drawdown and recovery measurements were obtained for the pumped well and for five observation wells located 50 feet south, 100 feet north, 100 feet east, 100 feet west, and 500 feet east of the pumped well. The pumping rate was about 65 igpm*.

As was the case for Test A, this test was too short and the river effect was not determined. River levels, however, were measured during the course of the test and were observed to drop significantly during the later stages. The total drop at the end of the test was almost 0.9 feet, sufficient in size to give rise to appreciable declines in the groundwater levels. Since the river effect had not been determined, correction could not be made for the drop in river level and, as before, no quantitative analysis of the data was possible.

*imperial gallons per minute

Observations concerning drawdowns, recoveries, and water temperature were similar to those for Test A. Water samples for chemical analysis were taken and the iron concentration was found to remain substantially unchanged. An examination of the drawdown data suggests, however, that correction for the river effect would have led to corrected drawdowns showing a slight stabilizing trend in the last day or so of the test. This indicates that any recharging of the alluvial-terrace aquifer, whether by induced infiltration or from some other source, takes at least a day to produce any measurable effect. The slight amount of recharge, however, was not enough to prevent dewatering of the terrace.

No other test was made of the terrace now used for the city supply until after the construction of the pipe line and treatment plant and the initiation of production. As indicated above, however, Test B failed to provide adequate information for the evaluation of the groundwater potential of the terrace. The initial analysis of the results from Test B led to a recommendation for further testing involving a protracted pumping period and special attention to variation in iron concentration with time. No such test was run until January 1965 (Test D).

TEST C - APRIL 1964

This test was conducted by Hi-Rate Drilling Company Limited for the city's consulting firm, Stanley, Grimble, Roblin Limited. It was supervised by the Research Council of Alberta and lasted a little more than three days. The test site was again on the north terrace from which the city's present supply is derived. Drawdown and recovery measurements were obtained for the pumped well and for six observation wells located 40 feet north, 40 feet east, and 56, 96, 146, and 171 feet west of the pumped well. The average pumping rate for the test as a whole was 61 igpm but there were some rather extreme fluctuations in rate during the early part of the test.

Test C, like Tests A and B, was too short and the river effect was not determined. River levels were measured during the test but, as before, no corrections could be made for their changes. A few temperature measurements were taken but not enough to justify the drawing of any conclusions for or against induced infiltration. No water samples were taken.

The meager information provided by this test once more suggests that there was no appreciable recharge from induced infiltration or other sources until a day or more of testing had been completed. There is some slight indication of aquifer dewatering.

TEST D -- JANUARY-FEBRUARY 1965

This test was conducted by Stanley, Grimble, Roblin Limited and lasted almost 23 days. The test site was on the north terrace to the east of the treatment plant. Drawdown but not recovery was measured for the pumped well (Terrace Well No. 5) and for ten observation wells located 45 and 90 feet north, 45 and 80 feet south, 38, 80, and 430 feet east, and 43, 83, and 405 feet west of the pumped well. The two wells to the south are of particular interest because both were completed in gravels underlying the river bed. If induced infiltration is a significant factor there should be little or no drawdown observed in these two wells.

The average pumping rate during the test was 48 igpm and fluctuations in the rate were small.

The length of the test in this case was more than adequate. River effect, however, was not determined prior to the test. This omission could have presented a serious obstacle to the quantitative analysis of the data. Fortunately, however, a relatively rapid rise in river level during the seventh day of the test provided a means of roughly estimating the river effect. Similar but smaller rises were observed in all groundwater levels shortly thereafter and correlation of groundwater rise with river rise led to a value of the river effect for each well. This permitted the correction of observed drawdowns for river fluctuations and it was possible to put the test data in a form suitable for quantitative analysis.

The two most distant wells (405 feet west and 430 feet east) were unaffected by pumping of the test well. The well in the river gravels 45 feet to the south of the pumped well was affected, at the most, only slightly. The corrected water levels in all other wells, including the one in the river gravels 80 feet to the south, drew down significantly during the test. In all cases a stabilizing trend was evident after about a day of pumping. A source of recharge was therefore indicated and it remained to be established whether or not the source was induced infiltration from the river.

A standard analytical method based on the assumption that induced infiltration was taking place was used to determine aquifer properties and infiltration characteristics. Agreement between drawdowns predicted on the basis of the results of such an analysis and observed drawdowns would indicate the assumption to be valid; disagreement would be strong evidence against induced infiltration. There is, in this case, a marked disagreement between predicted and observed drawdowns and it can only be concluded that induced infiltration from the river is negligible, at least along that stretch of the river in the vicinity of the test site. River water may, however, be able to infiltrate the terrace gravels at more remote locations, such as the far ends of the terrace.

No temperature measurements were taken but water samples were collected regularly and analyzed. The iron concentrations found in these samples varied somewhat during the test but there was no evidence for a reduction in iron as the test progressed. The chemical evidence, then, also supports the contention that no significant infiltration took place during the test. This result, of course, was hardly surprising since two years of production from the terrace has failed to produce any reduction in iron concentration.

Just one set of results for Test D seem to contradict the conclusion that no significant induced infiltration takes place. These are the results for the well supposedly completed in the aquifer beneath the river bed and located 45 feet south of the pumping well. It was remarked above that drawdowns in this well were small, a result that would be anticipated for a river well if river waters were infiltrating into the aquifer as a result of pumping. However, if there is indeed no induced infiltration, it must be because there is a layer of low permeability between the river and the aquifer. It is suspected that such a layer has been formed by the deposition of fine material on the river bed and along its banks and the settling of this material into the interstices between the sand and gravel particles. In this case it can be assumed that the well 45 feet south of the pumping well failed to penetrate through the silted-up low-permeability layer, whereas the well 80 feet to the south, which behaved more normally during the test, did penetrate this layer.

The test results indicate that Well No. 5 (the pumped well) could be pumped continuously on a long-term basis at about 55 igpm, which is slightly above the test rate of 48 igpm. They also indicate that a separation of about 500 feet between wells would be sufficient to eliminate interference between producing wells. Interference between wells, that is, drawdown in one producing well as a result of production from a neighboring well, reduces production rates and is to be avoided.

As remarked above, the drawdown results indicate a source of recharge. Infiltration close to the test site has been eliminated as a possible source. Other possibilities are:

1) infiltration remote from the test site, possibly at one or both ends of the terrace,

2) movement of water upward from the bedrock formation underlying the alluvial gravels,

3) precipitation, and

4) runoff.

Conjectures may be made about the relative likelihood of each of these four possibilities.. They would be of importance if the rate of production were the principal concern. It is probable, for instance, that high rates of production could not be maintained if precipitation and runoff were the only sources of recharge. High iron concentration, however, is the real problem and it is believed that this is a natural consequence of a relatively long residence time in the sands and gravels of the terrace. In other words, any water remaining in the sands and gravels or travelling though them slowly or for relatively great distances will pick up iron from them and the iron concentration will eventually reach the high level that is characteristic of the terrace groundwater. This will be true, no matter what the source or the original iron concentration. In the cases of the four recharge possibilities listed above, it is unlikely that pumping will cause recharge water to move fast enough to prevent high iron concentration.

A number of conclusions may be drawn from the results of Test D, all of which are in general agreement with the results from the first three tests:

1) there is no induced infiltration, at least along the stretch of the

river in the vicinity of the test site, and there is, therefore, no hope for iron reduction through induced infiltration,

2) there is evidence for recharge from some source other than induced infiltration in the vicinity of the test site but worthwhile reductions in iron concentration are unlikely for any of the possible alternate sources,

3) long-term continuous production rates at different sites on the terrace will undoubtedly vary, depending on local varations in aquifer and well characteristics and on river stage, but the estimated rate of 55 igpm for Terrace Well No. 5 can probably be taken as a representative low-water average, and

4) 500 feet is a suitable well spacing for the minimization of interference between producing wells.

One significant point remains to be made about the results of the analysis of this test and that is that the unsuitability of the alluvial-terrace aquifer for the municipal water supply could have been established by just such a test before the construction of the pipe line and treatment plant.

TEST E -- MARCH-JUNE 1965

This test was conducted by Stanley Grimble, Roblin Limited and lasted about three months. The test site was the same as for Test D, the pumped well was again Terrace Well No. 5, and water-level measurements were made in all the observation wells of Test D, with the exception of the two south wells completed in the gravels underlying the river bed. For the purposes of the test a recharge pit was constructed, the center point of which lies about 140 feet to the north of Well No. 5. The pit has sloping sides and is about 27 feet square at the bottom and about 83 feet square at ground surface. It penetrates below the top of the sands and gravels to a depth of almost 2 feet. The sands and gravels are overlain by about 10 feet of a relatively impermeable sand, silt, and clay mixture. A lip was built up around the pit and above the terrace level to prevent surface water from draining into the pit. The pit therefore holds about 14 feet of water. [illegible]

Beginning on March 21, water was pumped from a stilling well directly connected with the river into the pit at an initial rate of about 194 igpm. On March 22, after the pit became partially filled, pumping from Well No. 5 began at a rate which, after a short period of adjustment, was fixed at 66 igpm. The recharge rate to the pit was subsequently reduced to 159 igpm when the pit filled. During the first 16 days of the test the recharge rate was readjusted to 178 igpm and that for Well No. 5 to 85 igpm. Between April 8 and April 30 the test had to be suspended because of faulty equipment. When the test was resumed, Well No. 5 was operated continuously with minor adjustments in rate (85-100 igpm) whereas the recharge pump was allowed to operate for only a portion of each day.

Infiltration rates for movement of water from the pit into the aquifer were determined for three different periods during the test: (1) the period prior to the start of pumping for Well No. 5, (2) the 15-day period between March 22 and April 8, and (3) a 12-day period from June 3 to June 15 Infiltration rates during the first period may be considered to be natural infiltration rates. They were observed to vary with depth of water in the pit. The maximum measured rate was 114 igpd/ft^2* for a water depth of 9.3 feet. It was estimated that the rate could have gone as high as 130 igpd/ft^2 for a water depth of 13.3 feet.

Infiltration rates during the second and third periods depended on the rate of production from Well No. 5, as well as on the depth of water in the pit. Two

* Imperial gallons per day per square foot.

rates were calculated for the second period, the first being 187 and the second 209 igpd/ft^2. Consideration of the observed responses of water levels in the pit and in Well No. 5 to changes in recharge and production rates led to an estimated maximum infiltration rate of 390 igpd/ft^2. All three of these rates are in the lower range of values reported for recharge pits elsewhere.

Eight rates were calculated for the third period. They ranged from 37 to 64 igpd/ft^2, appreciably lower than the calculated rates for the second period. The reduction is believed to be caused by silt deposition on the bottom of the pit. Considerable deposition was noted after drainage and exposure of the pit bottom at the conclusion of this test. Frequent draining and servicing of recharge pits would be required if silt deposits build up this rapidly. The problem might be avoided or minimized if the silt load in the water pumped into the recharge pit could be reduced.

Although the use of recharge pits would introduce additional maintenance and servicing problems, the test results indicate that higher production rates could be achieved and that the water produced would improve in quality. Production rates could be increased in two ways: (1) each producing well could be pumped at a higher rate and (2) the spacing between wells could be decreased. Stipulating that the maximum depth of water in the recharge pit should be 13.8 feet and that the water level in Well No. 5 should not be allowed to drop below the top of the screen, it can be estimated that the maximum rate of production from Well No. 5 would be about 100 igpm, an increase of about 80 per cent over the maximum permissible rate of 55 igpm without the recharge pit. For this production rate, the pit must be recharged at about 390 igpm. The data from Test E are unfortunately not adequate for any prediction of the reduction in well spacing. Percentage production increases of about 80

* Imperial gallons per day per square foot.

per cent might also be anticipated at other sites along the terrace, if recharge pits were introduced adjacent to them.

Production increases are important, but whether or not the north alluvial terrace will be suitable for Grande Prairie's water is still primarily a question of an adequate reduction in iron concentration. Analyses of the water samples taken during the recharge-pit test do indicate some reduction. Concentrations varied irregularly from 7 to 9 ppm during the first nine days of the test but began to drop below 7 ppm after this period. Subsequent water analyses showed an irregular downward trend in iron concentration, the lowest reported value being 3.3 ppm for a sample collected on June 10. Only one later analysis is available, for a sample taken on June 14, and the reported iron concentration for this sample is 5.0 ppm. The analyses discussed here were all performed by Western Industrial Laboratories. Reported concentrations for a number of samples collected during the later part of the test and sent to the Provincial Analyst are less precise but suggest higher concentrations than those found by Western Industrial Laboratories. Most of the iron concentrations are reported by the Provincial Analyst as 5+ ppm, but one is given as 5 ppm.

The conclusions to be drawn from the results of Test E are:

1) the introduction of system of recharge pits will boost production from the north terrace and reduce iron concentration but will lead to added expense for maintenance and periodic cleaning of the pits,

2) some of the boost in production will result from the possibility of reducing well spacing but the amount by which spacing might be reduced cannot be determined from the results of the present test,

3) the precise amount of iron reduction during the test is not firmly

established and even if the most favorable figure of 3.3 ppm is accepted it cannot be said with any certainty that there would be any reduction much below this figure on a long-term basis.

OTHER SOURCES OF SUPPLY

If the alluvial terrace on the north side of the Wapiti River is unsuitable as a source of supply for the city of Grande Prairie without recharge pits, and is of dubious value if recharge pits are introduced, what alternatives does the city have? Apart from direct intake from the river or other surface source, which is beyond the scope scope of this report, there seem to be two: (1) an infiltration gallery extending out under the river bed and (2) wells taking groundwater from the bedrock underlying the terrace.

It has been demonstrated by the results of Test D that there seems to be a low-permeability layer formed by the deposition of fine material on the river bottom. This layer forms an effective barrier between the river and the aquifer and prevents the occurence of induced infiltration. This layer will surely cause difficulty in the operation of an infiltration gallery. Periodic scarification of the river bed would probably be necessary and high-iron problems might again develop if the river bed could not be kept reasonably clear of fine material. Thorough testing should most certainly precede any installation of a permanent infiltration gallery for municipal-supply purposes.

Wells taking water from bedrock should eliminate the high-iron problem and reduce hardness, although the water quality might be less desirable in other respects. Nevertheless, there is a good chance that potable water will be obtained to depths of some hundreds of feet below the terrace levels. The rates at which water might be produced from bedrock can only be conjectured on the basis of the meager information now available. The river terraces are known to be underlain by approximately 1,200 feet of Wapiti Formation. This formation outcrops along the banks of the Wapiti River in the vicinity of Grovedale Bridge and the north and south terraces. The outcrop materials have good permeability, suggesting the formation has good potential as an aquifer. Evaluation of the potential of the bedrock deposits would require the drilling of a test hole, perhaps to a considerable depth. Waters from promising aquifers would be collected and analyzed and the aquifers themselves would be pump-tested. A similar procedure has paid off in three instances in central Alberta. In each case water supply from an alluvial terrace or direct river intake proved, for one reason or another, to be unsatisfactory and a good supply was found in bedrock deposits similar to those found in the Grande Prairie area. For this reason, as well as because a good bedrock supply would substantially reduce or eliminate treatment costs, drilling and testing of bedrock, to a considerable depth if necessary, seems to be a gamble well worth taking.

CONCLUSIONS

1) The alluvial terrace now being used by the city of Grande Prairie as a source of water supply is unsuitable for this purpose, unless recharged artificially by a system of recharge pits. Water cannot be induced to flow into the terrace from the river under natural conditions and the iron concentration in the water remains much too high as a result.

2) Even if a system of recharge pits is introduced, the suitability of the terrace is doubtful. An increase in production rates and some reduction in iron concentration would take place but operation costs would certainly go up, partly because of the additional pumping facilities and partly

because of the periodic cleaning and maintenance of the pits which would be required.

3) An infiltration gallery projecting out from the terrace under the river bed would probably also encounter difficulties because of silt deposition on the river bed. This would retard infiltration, and periodic maintenance would again be required, though probably not as frequently as with recharge pits. Thorough testing should precede any permanent infiltration-gallery installation.

4) A bedrock supply might provide the answer to Grande Prairie's water-supply problem but a testing and sampling program is necessary to establish the potential of the bedrock aquifers. The expense involved is small compared to the amounts already invested, however, and could lead to a supply requiring a minimum of treatment. Experience elsewhere in Alberta in similar situations suggests there is a reasonable chance of success.

5) It is suggested that the following course of action be followed in attempting to solve the Grande Prairie water-supply problem.

   a) Drill and test the bedrock below the north alluvial terrace.
   b) If bedrock proves to be unsatisfactory, experiment with an infiltration gallery running out from the terrace beneath the river bed.
   c) If the infiltration gallery proves to be unsatisfactory, attempt to design an efficient recharge-pit and well system.

The above course of action ignores the possibilities of direct intake from the river or from the oxbow lake to the north of the terrace. Either of these might be preferable to c) above, and perhaps to b) as well. It is firmly believed, however, that the drilling and testing of bedrock should be carried out first of all in preference to any other possible alternative.

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July, 1965.