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GRANITE CANYON AREA
CLEARWATER RIVER

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GEOLOGY OF THE GRANITE CANYON AREA, CLEARWATER RIVER

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GEOLOGY OF THE GRANITE CANYON AREA, CLEARWATER RIVER

Physiography

Granite Canyon extends along the Clearwater River from about 4½ to 6 miles upstream from the confluence of the North Thompson and Clearwater Rivers. The river valley in the general canyon area, as at the Hemp Creek damsite, consists of a wide, flat-bottomed outer valley and a relatively narrow, roughly V-shaped inner valley in which the river now flows. The inner valley lies on the extreme west side of the outer valley and has been cut to a depth of about 800 feet below the outer valley floor. As at the Hemp Creek site, a sediment-infilled, basalt-capped pre-glacial valley lies to the east of the present river in this area. In the canyon the river flows southward at an average gradient of about 30 feet per mile, varies considerably in width, and contains several small bedrock islands, the largest of these being located near its upstream end. The canyon, which forms the lower part of the inner valley in this area, consists of nearly vertical rock walls ranging in height from a few feet to a maximum of about 300 feet. The right wall is generally somewhat lower than the left. Between the relatively low canyon rim and the rim of the inner valley on the left bank, the ground surface slopes at an average angle of about 17 degrees and is broken intermittently by relatively narrow short benches and by irregular hillocks and gullies in its downstream section (see Fig. 1). About one-half mile upstream from the river island located near the head of the canyon, the flat outer valley floor lies only a few feet east of the river and a vertical basalt cliff extends from this floor almost to the river. This cliff decreases in elevation southward and its south end is shown on Figure 2. A high vertical basalt cliff occurs relatively near the river at the foot of the canyon on the left bank and lower vertical basalt cliffs occur along the rim of the inner valley east of and well above the canyon (see Fig. 1). A small basalt cliff occurs about 800 feet east of and about 300 feet above the river about 2,000 feet upstream from the foot of the canyon on the left bank. Above the canyon rim on the right bank from near the centre of the large river island southward to the foot of the canyon, the ground surface is flat or rises very gently westward to the base of the steep main west valley rock wall. The width of this flat or gently sloping ground generally increases southward, and near the foot of the canyon is about one-quarter mile wide.

Bedrock

The distribution of bedrock outcrops in the general canyon area is shown on Figures 1 and 2. The bedrock forming the canyon walls and river islands is similar to the granite and granodiorite exposed at the Hemp Creek site. At Granite Canyon these rocks are light buff in colour, generally equigranular, and medium to very coarse grained. Locally they contain dark grey, partially digested inclusions of metamorphosed sedimentary rocks. A relatively large inclusion is exposed along the east side of the island near the head of the canyon (<u>see</u> Fig. 2). These rocks are cut by joints generally spaced more than 1 foot apart and locally coated by limonite or calcite. Three main sets appear to predominate: a set striking north 10 degrees east and dipping vertically to 60 degrees east, a set striking east-west and dipping about 45 degrees north, and a set striking east-west and dipping about 45 degrees south. Seven trenches were made by a bulldozer on the left inner valley wall above and near the upstream end of the canyon (<u>see</u> Figs. 1 and 2), and a jeep road was constructed from the Wells Grey Park road about 1 mile east of the river down to near the canyon rim. Four of the trenches, and sections of the road encountered granite which was exposed to a maximum height of about 300 feet above river level in this area. Much of the rock exposed in the trenches and along the road is cut by narrow clay gouge-filled faults, and the rock is generally highly altered, soft, and crumbly. The bulldozer was able to cut well into the granite with little difficulty in several places. Similar faults and altered granite are visible along the steep canyon walls (<u>see</u> Fig. 2) where, however, they could not be closely examined due to the steepness of the cliffs. The alteration of the granite near faults is similar to that encountered at the Hemp Creek site and consists mainly of the development of carbonates, clay minerals, and minor iron oxides and chlorite. Fine talus resulting from the weathering of this altered rock occurs locally along the inner valley wall above the canyon rim.

The basalt exposed upstream, downstream, and above the canyon rim on the left bank is, as in other areas of the Clearwater Valley, flat lying and consists of a sequence of relatively thin flows separated by scoriaceous layers locally containing open cavities to several feet in diameter. Steep talus slopes composed of semi-angular basalt blocks to several feet in diameter occur at the base of all the basalt cliffs in the area and immediately upstream from the canyon a very large quantity of this talus occurs relatively near the river. The contact between the granite and the overlying basalt is shown very approximately on Figures 1 and 2. The contact was plotted from the few rock outcrops, the bedrock exposed in the bulldozer trenches and along the road, and from the distribution of fine granite talus.

Soils

Two generalized subsurface profiles through the canyon in the vicinity of the main upstream river island are shown on Figure 3. The shallowness of the granite exposed along the road and in the trenches and the relatively wide distribution of the fine granite talus on the left bank, suggest that the overburden soils are relatively thin on this bank from the canyon rim at least up to the basalt talus slopes. Generally clean, well stratified, locally dense sandy gravel, sand, and sandy bouldery gravel locally containing basalt fragments were exposed in some of the trenches and along the road.

Bedrock is clearly visible under the river, especially in the wider parts of the canyon, indicating that little or no unconsolidated sediments overlie bedrock along the river in this area. Five seismic lines were run along the right bank on the flat and gently sloping ground above and to the west of the canyon rim (see Figs. 1 and 2). The depths to bedrock recorded by this work varied from 25 feet to over 70 feet indicating in general a very gentle westward rise of the bedrock surface for at least several hundreds of feet in this area (see Sections A-A' and B-B', Fig. 3). A few exposures of the sediments overlying bedrock along the right bank suggest that they are mainly sands and gravels.

FIG. 3
GRANITE CANYON DAMSITE
— SECTIONS —

DAMSITE NO. 141, CLEARWATER RIVER

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DAMSITE NO. 141, CLEARWATER RIVER

Introduction

The damsite is located on the Clearwater River 2½ miles upstream from its confluence with the North Thompson River, and just over 1 mile upstream from the highway bridge. From March to May, 1962, fourteen drill holes, totalling 2,219 feet, of which 1,335 feet was in bedrock, were put down at the site to test foundation conditions for a dam of an approximate head of 80 feet. Also, seismic exploration to determine bedrock depth was carried out at various localities on the left bank. This report summarizes the data obtained from the drilling, the seismic exploration, and the geological mapping of the site.

The drill hole locations and the seismic lines are shown on the accompanying plans, Figure 1, Sheets 1, 2, and 3 and sections through certain areas of the site, on Figure 2. Detailed logs of individual holes have been submitted separately to the Fraser River Board and do not accompany this report.

(A) General Geology of the Area

(I) Physiography

The damsite is located at the head of a narrow 1,200-foot long, rock-walled, southwest trending canyon. Downstream from the canyon, the river widens to between 300 and 400 feet and flows in a general southerly direction between banks of gravel to its confluence with the North Thompson River. From the upstream end of the canyon to the downstream end of Granite

Canyon, 2 miles distant, the river is between 100 and 150 feet wide and flows in a general southerly direction between banks of gravel and minor bedrock.

The short canyon in which the site is located consists of steep rock walls rising on both banks to a maximum height of about 120 feet above river level. Above the right canyon rim, the ground surface rises very gently northwestward for about 1 mile to the base of the steep west rock wall of the main valley. Above the upstream end of the left canyon rim, the ground surface rises to form a short southeastward trending ridge which reaches a maximum elevation of about 1,525 feet about 700 feet southeast of the river. This ridge then slopes down to the northwest side of Dutch Lake, located about one-third of a mile southeast of the site. Irregular, hummocky ground, lying between the lake and the river, locally pitted by deep glacial kettles extends for one-half mile south from this ridge and is terminated on its south end by a low alluvial flat. This flat extends from the river to the west side of Dutch Lake. A pronounced depression about 500 feet wide, with a maximum surface elevation of about 1,440 feet and sloping gently southeastward borders the ridge to the northeast and extends from the river immediately upstream from the canyon to Dutch Lake. This depression is bordered to the north by very gently undulating ground averaging about 1,500 feet in elevation which extends northward for three-quarters of a mile to the base of steep rock bluffs and from the river, between the site and Granite Canyon, eastward up the North Thompson Valley.

This area is part of the North Thompson Valley lowlands, into which the degrading rivers are presently downcutting in this area. Immediately to the north of the depression described above, this plain is pitted by several deep glacial kettles trending in general parallel to the depression.

Vertical rock cliffs extend from about 500 feet to about one-half mile upstream from the head of the canyon on the right bank about 150 to 200 feet west of the river. These cliffs reach a maximum elevation of about 1,450 feet, increase in height northward, and have created steep talus slopes which extend from their base to the river. Similar vertical cliffs extend from about 300 feet to about one-half mile downstream from the head of the canyon on the right bank about 100 to 500 feet northwest of the river. From about 1,500 feet to about one-half mile downstream from the proposed centreline these cliffs and their talus slopes form the western boundary of a 500-foot wide alluvial flat of elevation 1,370 feet bordering the river.

(II) Bedrock Geology

A sequence of metamorphosed sedimentary rocks consisting of thin-bedded argillite, massive and banded chert, and lesser fine-grained quartzite and quartz-chlorite-sericite-phyllite, intercalated with andesite and porphyritic andesite flows (?) are exposed along the canyon walls at the site. These rocks have been mapped by Walker* as possibly Pre-Cambrian. At

*Walker, J. F.: Geol. Surv., Canada, Sum. Rept., 1930, Pt. A, Clearwater River and Foghorn Creek Map-area, Kamloops District, B.C.

the centreline on the right bank, these rocks have been intruded by a relatively thick diorite dyke which has contact metamorphosed the adjoining argillite creating a relatively hard biotite hornfels. This diorite may be of Triassic age. Overlying in part all of the above rocks on the right bank are flat-lying vesicular basalt lava flows of late Pleistocene age.

In the canyon the metamorphosed sediments and intercalated volcanics strike east or southeast and dip generally at moderate angles to the south or southwest. These rocks and the later diorite are cut by faults, most of which appear to be narrow and of small offset. However, a southwest striking, steeply west dipping fault which has considerably offset and dragfolded these rocks cuts through the centre of the canyon. All of the rocks are cut by joints spaced from less than an inch in argillite and chert members to several feet in local areas of the intrusive diorite.

(III) Glacial Geology

Prior to Pleistocene time, the Clearwater River flowed southward in a valley west of the present canyon. The centre of this valley is possibly one-half mile west of the canyon and is no doubt considerably deeper than the present river channel. The few short drill holes put down into this buried valley near the canyon wall indicate that its base slopes about 15 degrees westward in this immediate area. At the Granite Canyon site the pre-glacial valley lies to the east of the present river indicating that the centre of this valley crosses the present valley at some point along the gravel reach between these two sites. The depression extending from the present river valley to Dutch Lake immediately upstream from the canyon on the left bank marks the location of a buried pre-glacial or interglacial valley. Its postulated shape as suggested by a few drill holes put down into and near it and a few seismic soundings taken along its north and south sides is shown on Sections C-C' and D-D', Figure 2. The relationship between this short valley and the probably considerably larger buried valley lying to the west of the canyon was not established by the limited drilling and seismic work done.

Two drill holes possibly encountered glacial till at the site. Dense, poorly to well graded sandy gravels and gravelly sands, thought to be glacial till deposited by an advancing ice sheet, were encountered overlying bedrock for 36 feet in drill hole 8, drilled on the ridge south of the short depression described above (see Section A-A', Fig. 2). About 25 feet of mainly clayey sandy gravel till directly overlying bedrock was encountered in drill hole 10, also drilled south of the depression (see Section C-C', Fig. 2).

Vast amounts of glacial outwash sands and gravels were deposited on till and bedrock in this area during the wasting of the last ice sheet to occupy the area. The outwash reaches an elevation of well over 1,500 feet within the map-area and was penetrated in drill hole 4 down to an elevation of

1,240 feet (see Section C-C', Fig. 2). It probably extends to the bottom of both buried valleys. The numerous deep kettles between the present river and Dutch Lake were formed when stagnant ice blocks, buried by outwash sediments, melted causing collapse of the sediments into the vacated space.

During a late stage in the deposition of the outwash, the flat lying basalts were deposited on this outwash in the western part of the valley in the map-area. The rock ridge through which the canyon has been cut possibly acted as a dam to confine the lava flow between this ridge and the steep main west valley wall. From this area the lava turned southwest and flowed for some distance down the North Thompson Valley.

Following the deposition of the basalt the present Clearwater River proceeded to cut down through the bedrock ridge following the eastern margin of the basalt in the map-area. It has cut down into the ridge for a maximum depth of about 160 feet.

(B) Geology of the Damsite

(I) Bedrock

A total of 1,335 feet of diamond drilling was done in bedrock in ten holes at the site. Pumping tests were carried out continuously in bedrock and the reader is referred to the logs of individual holes for detailed descriptions of the formations encountered and to the logs and to Figure 2 for the results of the pumping tests.

The distribution of outcrops of the various rock types is shown on Figure 1. The metamorphosed sedimentary rocks consist of dark grey, very fine-grained, generally very thin-bedded, locally pyritic and/or siliceous argillite, lesser grey to light buff, massive or banded chert grading into very fine-grained quartzite locally, and a few relatively thin interbeds of grey, very fine-grained, weakly schistose chlorite-sericite-quartz phyllite. Intercalated with the sediments are fine-grained volcanic flows (?) which reach a maximum thickness of almost 100 feet in this immediate area (<u>see</u> Fig. 1). These flows (?) consist of fine to locally medium-grained, dark greenish grey, massive, partially altered, locally weakly limy andesite and dark grey, massive andesite porphyry composed of generally angular feldspar phenocrysts to one-quarter inch in a fine-grained altered matrix. Contacts with the enclosing sediments are tight and conformable and no obvious metamorphism of the sediments along contacts was observed. However, small fragments of argillite occur in andesite locally near irregular welded contacts suggesting that some of this rock may be intrusive. A narrow biotite lamprophyre dyke was encountered in one drill hole. All of these rocks strike in a general east-west direction and dip at moderate angles south or downstream. The bedding is accentuated along the canyon walls by more rapid weathering of the softer members. The sedimentary rocks are generally finely fractured, the argillites locally breaking down to very small, needle-like or platy fragments. Much of the core obtained from these rocks was badly broken along joints and bedding. The volcanic rocks tend to be somewhat less fractured, especially the thicker flows (?) and in general can be considered to be more competent structurally than the sedimentary members. Several narrow faults of small offset and containing clayey fault gouge are visible cutting these rocks along the canyon wall. Several of these faults were encountered in drill holes but most of them appear to be relatively water tight. A larger fault striking southwest and dipping steeply northwest cuts these rocks along the left bank. It appears to cut across the river near the centre of the canyon and was possibly intersected by angle drill hole 6 at a depth of about 200 feet (see Fig. 1 and Sections A-A' and B-B', Fig. 2). A pronounced gully has been developed along this fault along the left bank. The rocks to the northwest of this fault have been displaced northward in relation to the rocks to the southwest and dragfolding of argillites along this fault can be seen near the downstream end of the canyon on the left bank.

The relatively thick diorite dyke forming the very steep canyon wall on the right bank near the upstream end of the canyon and penetrated by drill holes 2 and 6 is a dark green, massive, hard, locally somewhat altered rock cut by three sets of relatively widely spaced joints (see Fig. 1). It varies in texture from fine grained near contacts to coarse grained near its centre. The attitude of this rock was not determined although its near vertical contact with argillites on the island immediately upstream from the canyon suggests it may be as steeply dipping as shown on Section A-A', Figure 2. Its contact with the enclosing rocks is sharp and welded and the adjoining argillites have been metamorphosed for various widths (see Fig. 1) to a relatively hard, flinty, biotite hornfels.

The dark grey, fine-grained, fresh olivine basalts exposed near the site are, as in other areas of the Clearwater Valley, flat lying and consist of a sequence of relatively thin flows separated by scoriaceous layers containing, locally, open cavities up to several feet in diameter. The flows are highly vesicular near contacts becoming less vesicular toward their centres. They are cut by numerous conchoidal fractures and break to relatively large, rectangular talus fragments.

(II) Soils

A total of 884 feet of drilling was done in unconsolidated sediments at the site. Pumping tests were carried out at approximately 5-foot intervals in most of the holes and the reader is referred to the logs of holes 1, 4, 7, 8, 9, 10, 11, 12, 13, and 14, prepared by the Water Resources Branch, for the results of pumping tests, for detailed descriptions of the soils penetrated, and for the results of certain laboratory tests carried out on selected samples taken from the holes.

The glacial till encountered in drill hole 10 overlying bedrock is mainly a very dense, grey, impermeable clayey sandy gravel of low plasticity, while the doubtful till encountered in drill hole 8 overlying bedrock is as previously stated deficient in the clay- and silt-sized particles.

The unconsolidated outwash sediments underlying the basalt along the right bank penetrated by drill holes 9 and 14 consist mainly of silty sand, some clean sand, and locally minor gravel. These sediments are generally dense and where exposed under the basalt on the canyon wall about 750 feet downstream from the head of the canyon are well stratified and stand vertically. Pumping tests done in them suggest that they are in general less permeable than the outwash sediments infilling the buried valley extending from the river to Dutch Lake on the left bank.

Drill hole 1, drilled vertically into the buried valley on the left bank about 300 feet from the river, encountered loose, unstratified, relatively highly permeable gravelly sand down to an elevation of about 1,400 feet and soft, medium dense, stratified, fine silty sand and minor sandy silts of relatively low permeability from 1,400 feet down to 1,322 feet. From 1,322 feet to the bottom of the hole at elevation 1,246 feet, coarse, open-work gravel, containing a little sand and boulders to several feet in diameter, was encountered. Pumping tests done in this gravel reveal that it is highly permeable although the permeability varies considerably within relatively short vertical distances. Drill hole 4, drilled into this buried valley about 800 feet southeast of drill hole 1, encountered coarse boulders containing minor sand and gravel from the collar at elevation 1,399 feet down to 1,335 feet. No pumping tests were done in this material but it is probably highly permeable. Clean, dense, poorly to well-graded sandy gravels and gravelly sands were penetrated from elevation 1,335 feet to bedrock at elevation 1,240 feet. Pumping tests done in these latter sediments indicate them to be relatively highly permeable and very high water losses were recorded locally for a few feet. Drill hole 10, drilled on the south bank of the depression about 500 feet southwest of drill hole 4 and 600 feet from the lake encountered poorly to well-graded, locally stratified, generally medium dense sandy gravel, gravelly sand, and lesser silty sand and sandy silt from its collar at elevation 1,443 feet to the top of the till at about elevation 1,325 feet. Water losses during pumping tests varied widely and local highly permeable interbeds were encountered. However, in general these sediments are somewhat less permeable than those encountered in drill holes 1 and 4. No definite correlation was established between the various very permeable horizons encountered in these few relatively widely spaced drill holes. Drill hole 7, drilled on the right bank about 400 feet northwest of and 110 feet above the river, encountered generally medium dense, well-graded, locally bouldery gravelly silty sand

and lesser sandy and silty gravel from its collar at elevation 1,450 feet to bedrock at elevation 1,384 feet. Pumping tests indicate that these sediments are considerably more permeable than those encountered in drill hole 9 underlying the basalt.

Drill holes 11, 12, and 13, drilled into the low alluvial flat about 600 feet downstream from the canyon on the right bank, encountered silt, sand, gravel, and boulders in various proportions to depths of up to 37 feet. These sediments which are stratified, medium dense to dense, and of relatively low permeability are believed to have been capped once by basalt which has been eroded away in this area by recent river down-cutting.

(C) <u>Foundation Conditions</u>

(I) <u>Bedrock</u>

The profile through the upstream end of the canyon in the general area of the proposed dam is shown on Section A-A', Figure 2. Drill holes 2 and 3 were angled northwesterly at -35 degrees below horizontal and southwesterly at -30 degrees below horizontal respectively under the river from the island immediately upstream from the site. These holes remained in bedrock for their entire lengths of 285 feet and 220 feet, except for a few feet of gravel near the collars indicating that little or no unconsolidated sediments overlie bedrock in the river at the site. Drill hole 3, drilled approximately down the dip of the relatively soft argillites under the left side of the river recovered 81 per cent of the core in generally very short drill runs. Drill pressures were generally light and the core very badly broken along the bedding and closely spaced fractures. Despite this however, only relatively minor water losses were recorded to a depth of about 40 feet (1,320 feet elevation) during pumping tests indicating the joints and bedding to be tight. Drill hole 2, drilled into argillite, hornfels, and diorite under the right side of the river recovered 90 per cent of the core in generally longer drill runs. Drilling pressures tended to be harder in the 60 feet of argillite penetrated than in drill hole 2 although the core was also badly broken. Generally high core recoveries were obtained in the 170 feet of hornfels penetrated by this hole and drilling pressures tended to be medium indicating this rock to be somewhat harder and stronger than the unmetamorphosed argillite. One hundred per cent of the core was recovered in relatively long runs in the firm diorite penetrated between -140 feet and -201 feet. Insignificant water losses were recorded during pumping tests in the argillites penetrated but moderate water losses were recorded in the upper hornfels from the argillite-hornfels contact down to an elevation of about 1,270 feet. From here to the bottom of the hole at elevation 1,175 feet insignificant water losses were recorded. Drill hole 5, drilled vertically into the left abutment encountered argillite and minor andesite porphyry, chert, phyllite, and lamprophyre. Only 72 per cent of the core was recovered in generally short drill runs. Drilling pressures were erratic and the core generally badly broken. Moderate water losses, mainly through open fractures, were recorded intermittently throughout the length of the hole and the drilling wash water was lost from a depth of about -140 feet to the bottom of the hole. Drill hole 6, angled 30 degrees below horizontal northwesterly into the diorite dyke forming the right abutment, recovered almost 100 per cent of the core in relatively long drill runs. Drilling pressures were medium to hard and this rock generally cored very well. Water losses were recorded only between elevations 1,409 feet and 1,395 feet.

From the drilling done at the site and from an examination of the rocks exposed along the canyon walls, it is concluded that the site is suitable for the relatively low concrete structure planned. Obviously, little grouting will be required in the highly competent diorite forming the right abutment but a deep grout curtain will be required under most of the river section and in the left abutment to prevent possible high pore pressures from building up along the bedding planes and joints in the argillite. The relatively low surface of the old sedimentary and volcanic rocks underlying the right bank suggest that, if possible, tunnels should be confined to the left bank where this surface is considerably higher (see Sections A-A' and B-B', Fig. 2). Some support will probably be required during the driving of a tunnel through the highly fractured argillite and chert members but the intercalated volcanic rocks should stand well. It should be assumed that tunnels driven into these rocks will have to be lined. Prior to tunnel driving under the left bank, the major fault zone underlying the deep gully along the downstream end of the canyon (see Fig. 1 and Section B-B', Fig. 2) should be investigated by drilling.

(II) Soils

When the reservoir is filled, seepage will occur through the unconsolidated outwash sediments filling the buried valleys on both the left and right banks. Part of the seepage from the reservoir through the buried valley on the left will flow around the bedrock into which drill hole 8 was drilled and flow southwestward toward the river downstream from the canyon and part will flow southeastward toward Dutch Lake. Observations of ground water levels in drill holes and two water wells southwest of the canyon, and the surface level of the river upstream and downstream of the canyon and Dutch Lake and the geology of the general area suggest that the widespread unconsolidated sediments greatly increase in depth downstream and southeast of the canyon. Consequently much of the seepage flowing from the reservoir into this vast groundwater reservoir will probably emerge along the Clearwater River well downstream from the bridge and even in the North Thompson River. A major factor controlling the quantity of seepage which will flow through the infilled valley on the left bank is its cross-sectional area at its narrowest part. Its narrowest part is possibly its upstream end, shown on Section D-D', Figure 2. In order to determine the amount of seepage which may flow through this valley, radial flow nets were constructed and seepage computations carried out.

Assuming a maximum reservoir elevation of 1,420 feet, an average depth of the buried valley in the general vicinity of drill holes 1 and 4 to be 180 feet, an average coefficient of permeability of these sediments to be 2.4 X 10^{-3} ft./sec. (maximum calculated from pumping tests done in drill holes 1, 4, and 10, neglecting a few erratic very high values), it is estimated that up to 30 c.f.s. may flow through these sediments when the reservoir is filled. Seepage paths will be very long suggesting that piping will not occur. Insufficient drilling was done to delineate the extent of the thick bed or lens of very permeable gravel penetrated in the lower part of drill hole 1. Although this type of deposit is often of limited lateral extent, it is conceivable that it could be continuous from the river upstream of the dam to the ground surface somewhere downstream of the canyon in which case very large seepage losses could occur upon filling the reservoir. Consequently the extent of this gravel should be thoroughly investigated prior to construction. For the purposes of preliminary cost estimating, it should be assumed that a cement injection grout curtain or some other type of cut-off will be required across this buried valley near its upstream end.

Upon filling the reservoir seepage will occur also through the buried valley to the east of the site. As little is known about the extent and nature of the sediments infilling this valley in this immediate area, seepage quantity calculations could not be carried out. However, the results of the pumping tests done in these sediments in drill hole 9 and at the Hemp

Creek site suggest that they are considerably less permeable than the sediments infilling the valley on the left bank. The elevation of the surface of the argillites and volcanic rocks immediately downstream from the diorite dyke on the right bank was not determined. If it is considerably below reservoir level, seepage could flow from the reservoir and emerge on the river bank along this area. Seepage paths would be short and failure by piping could occur. Consequently it should be assumed that a cut-off wall will be required through the outwash sediments to bedrock extending from the right abutment to possibly somewhere between drill holes 7 and 9. Ideally, the seepage in this area should be controlled such that the minimum seepage path would be from the reservoir to the embayment about 200 feet southwest of drill hole 14 (see Fig. 1), in which case, piping would be very unlikely to occur.