926-10-3

84-360

1984 10 09

Greater Vancouver Water District
2294 West 10th Avenue
VANCOUVER, BC
V6K 2H9

ATTENTION: Mr. Tom Heath, P. Eng.

SUBJECT: **Groundwater/Surface Water Relationships Hixon Creek Alluvial Fan and Indian River Valley**

Dear Sir:

The following descriptions of the hydrogeology of the subject areas are based upon:

1. Surface water flow measurements made by Fisheries and Oceans personnel.
2. Groundwater exploration and testing programs conducted for Fisheries and Oceans in 1972, 1981 and 1982. Two exploration holes were drilled and tested on the Hixon Alluvial Fan in 1972. Six exploration holes and one production well were drilled and tested in the Indian River Valley approximately one mile upstream from the confluence of Hixon Creek and the Indian River. The six exploration holes were drilled and tested in 1981 and 1982 and the production well was completed in late 1982.
3. General experience with the hydrogeology of other similar glaciated valleys in British Columbia.

SURFACE WATER FLOWS

Surface water flows have been measured at several places along both the Indian River and Hixon Creek at various times. The following

...Continued

analyses have used the August 26, 1984 and November 30, 1983 measurements to illustrate the groundwater-surface water relationships during a low water period and a high water period. In each case a diagramatic sketch map is used to help describe these relationships. Surface water flows are shown in solid arrows and groundwater flows derived from the surface water flow measurements are shown in dashed arrows.

The August 26, 1984 surface water flow measurements and the groundwater flows that must exist to maintain a total water balance down the Indian River Valley are shown on Figure 1. Reference to this figure will show:

1. The average August discharge for the years 1913 to 1921, which are the only readings available in the Historical Streamflow Summary of British Columbia, have been used for the flow in the upper reaches of the Indian River. The use of this flow figure in conjunction with the actual flow measurements will not be accurate but it will serve to show the type and magnitude of inter-reaction between surface and groundwater flows in the Indian River Valley.

2. The total surface water flow down the Indian River below Hixon Creek is 241 cfs (195 + 46). This ignores the addition of flows from tributaries between the upper reaches of the Indian River and Hixon Creek which are unknown. Water from these tributaries would dilute the Hixon Creek contribution so that its absence from the water balance places more importance on the Hixon Creek contribution than actually exists.

3. At the lowest station the 241 cfs total Indian River Valley water flow is divided between 133 cfs of surface water flow and 108 cfs of groundwater flow.

4. At the lowest station the total surface water flowing in the Indian River of 133 cfs is made up of

Indian River surface water flow	65 cfs or	49%
Hixon Creek surface water flow	20 cfs or	15%
Groundwater discharge flow	48 cfs or	36%
Total	133 cfs or	100%

5. The total contribution of water (surface and ground) from Hixon Creek amounts to 20% (46/241 x 100) of the total amount of water flowing down the Indian River Valley below the Hixon Creek Alluvial Fan. Since the contribution of waters from

...Continued

tributaries upstream of the Hixon Creek Alluvial Fan are ignored the 20% figure will actually be lower.

The November 30, 1983 surface water flows and their attendent groundwater flows are shown on Figure 2. Reference to the figure will show:

1. At least 62 cfs of groundwater must be flowing beneath the surface water flow of 213 cfs upstream from Hixon Creek to meet the 338 cfs measured at the lowermost station on the Indian River (213 + 62 + 63 = 338).

2. The maximum contribution of Hixon Creek to the surface flow of the Indian River at the lowermost station is 19% (63/338 x 100).

3. The 338 cfs of Indian River surface water flow at the lowermost station has an unknown amount of groundwater flow beneath it.

4. A groundwater discharge of 117 cfs contributes to 35% of the surface water flows at the lowermost station.

HYDROGEOLOGY

Figure 3 shows a sketch map of the Hixon Creek Alluvial Fan and the location of the two groundwater exploration test wells PW-1 and PW-2. Figures four and five show the logs of these test wells and the location of the screens through which the wells were pump tested.

From these figures it will be seen that the alluvial fan of Hixon Creek is composed of silty sands and gravels from ground surface downwards to a maximum depth of approximately 100 feet. These silty sands and gravels overly clean sands and gravels having a maximum thickness of 100 feet which in turn overly a black, organic silt sequence of unknown thickness.

Bedrock is exposed at the apex of the Hixon Creek fan at an approximate elevation of 200 feet above sea level. It lies at an unknown depth below most of the fan but below 200 feet BELOW sea level and rises almost to sea level close to the periphery of the fan. There is therefore a buried river valley cut into the bedrock and filled with almost 200 feet of water-bearing sands and gravels (both silty and clean). This buried river valley runs beneath the eastern side of the Indian River Valley and will allow the surface waters in the Indian River to recharge the groundwater system beneath some parts of the valley. At other places along the valley

...Continued

groundwater will discharge into the surface river waters. Thus a variation in the surface water flows of the Indian River can be expected. Such an interlocking relationship between surface and groundwater within a glaciated and gravel filled valley is a quite natural and common occurrence.

Although no direct measurements of the parameters controlling groundwater movement within the upper silty sands and gravels of the Hixon alluvial fan have been made, reasonable values can be assigned to these parameters by analogy with similar sediments. These parameters and their values are outlined below:

Transmissivity and Permeability - Transmissivity is defined as the amount of water in U.S. gallons that can move through a one foot wide strip of the full thickness of an aquifer in one day under a hydraulic gradient of one to one. It is commonly written as U.S. gpd/ft or as m^2/day (m^3/day per meter) in metric units. As such, transmissivity becomes a field measure of permeability when divided by the thickness of the aquifer that is tested.

The pumping tests run on the clean sand and gravels lying beneath the 30 and 110 feet of silty sands and gravels (Fig. 4 & 5) of the Hixon Creek Alluvial Fan indicate that these sediments have an extremely high transmissivity. In fact the transmissivity was so high that useful readings could not be taken because the system reacted too quickly to the pumping. We considered that the transmissivity must be close to 2,000,000 U.S. gpd/ft.

Pumping tests run on the six wells located approximately one mile upstream from the Hixon Creek Alluvial Fan give the follwing readings for transmissivity.

...Continued

Well	Transmissivity U.S. gpd/ft	Screened thickness (ft)
Pt 82-1	300,000	15
	225,000	15
Well 1	10,000	15
	42,000	15
Well 2	160,000	20
	410,000	20
E1	28,500	15
	36,000	10
E2	220,000	10
E3	33,250	25
	55,000	15

The sands and gravels that must be somewhat silty have low transmissivities that range from 10,000 to 55,000 U.S. gpd/ft over screened thicknesses of 10 to 25 feet. Without detailed instrumentation, it is impossible to assess the thickness of the aquifer that has responded to a pump test. However, in this analysis, the use of the screened thickness will give the highest value of permeability.

From the above, to be conservative, the transmissivity and thickness used to obtain a permeability figure will be

Transmissivity (T) = 60,000 U.S. gpd/ft
Thickness (t) = 15 feet

Therefore permeability (K) = T/t or 60,000/15
= 4,000 U.S. gpd/ft^2

Gradient (I) - The highest gradient possible for the slope of the water table in the Hixon Creek alluvial fan is that which is sub-parallel with the slope of the ground surface from the fan apex to the bottom of the Indian River at the center of the fan periphery. The average slope of the ground surface between these two points is 1 to 20. The average slope of the main part of

...Continued

the fan within the Indian River Valley is 1 to 40. We therefore believe it to be prudent to use a gradient (I) of 1 to 30.

Perimeter - The perimeter of the Hixon Creek alluvial fan, around which the Indian River flows, is measured to be approximately 6500 feet.

The above parameters can be used to calculate the quantity of groundwater that will feed the Indian River during low flow periods when it is assumed that the Indian River will drop to five feet below the water table in the Hixon Creek alluvial fan. Such an event would probably mean that the Indian River would almost stop flowing. Under such conditions the quantity of groundwater would be equal to -

Permeability x Gradient x Thickness x Perimeter or
4000 x 1/30 x 5 x 6500 = 4.33 million U.S. gpd
This is equivalent to
4.33×10^6/1440 minutes in a day x 450 U.S. gpm per cfs
or 6.7 cfs

The effective porosity of sand and gravels can range from 10% to 30% with a generally accepted "rule of thumb" figure of 20% being most often used.

If we assume an effective porosity of 20%, the length of time it will take a drop of water to traverse the 3 000 feet from the apex of the Hixon Creek alluvial fan to the Indian River may be calculated as follows.

Velocity = Permeability in ft^3 per day/ft^2 x Gradient/Porosity
= 4000/7.5 x 1/30 x 1/0.20
= 89 ft per day

Time = Distance/Velocity
= 3000/89
= 34 days

The area of the Hixon Creek alluvial fan is approximately 8.5×10^6 ft^2. Therefore the volume of groundwater contained in the top five feet of the Hixon Creek alluvial fan with a porosity of 20% will be

Volume of Groundwater = 8.5×10^6 x 5 x .2 x 7.5
= 64 million U.S. gallons or 8.5 million cubic feet

...Continued

At a discharge rate of 6.7 cfs or 4.3 million U.S. gallons per day the groundwater held in storage will discharge into the Indian River in

64/4.3 = 15 days

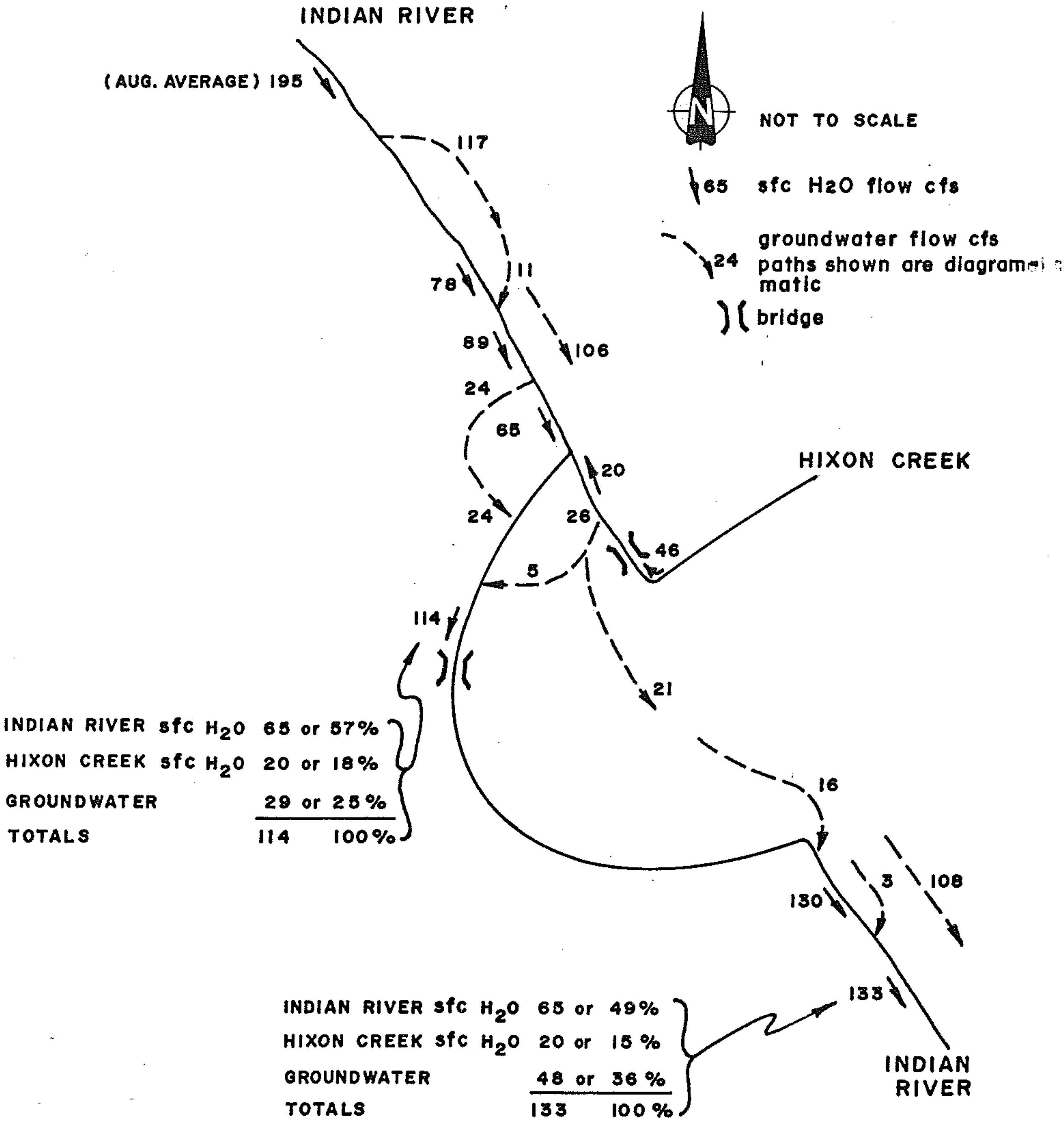
The figures given above are conservative. If they err the error will be on the side of the discussion which will enhance the value of the Hixon Creek water contribution to the waters of the Indian River Valley.

Yours truly,

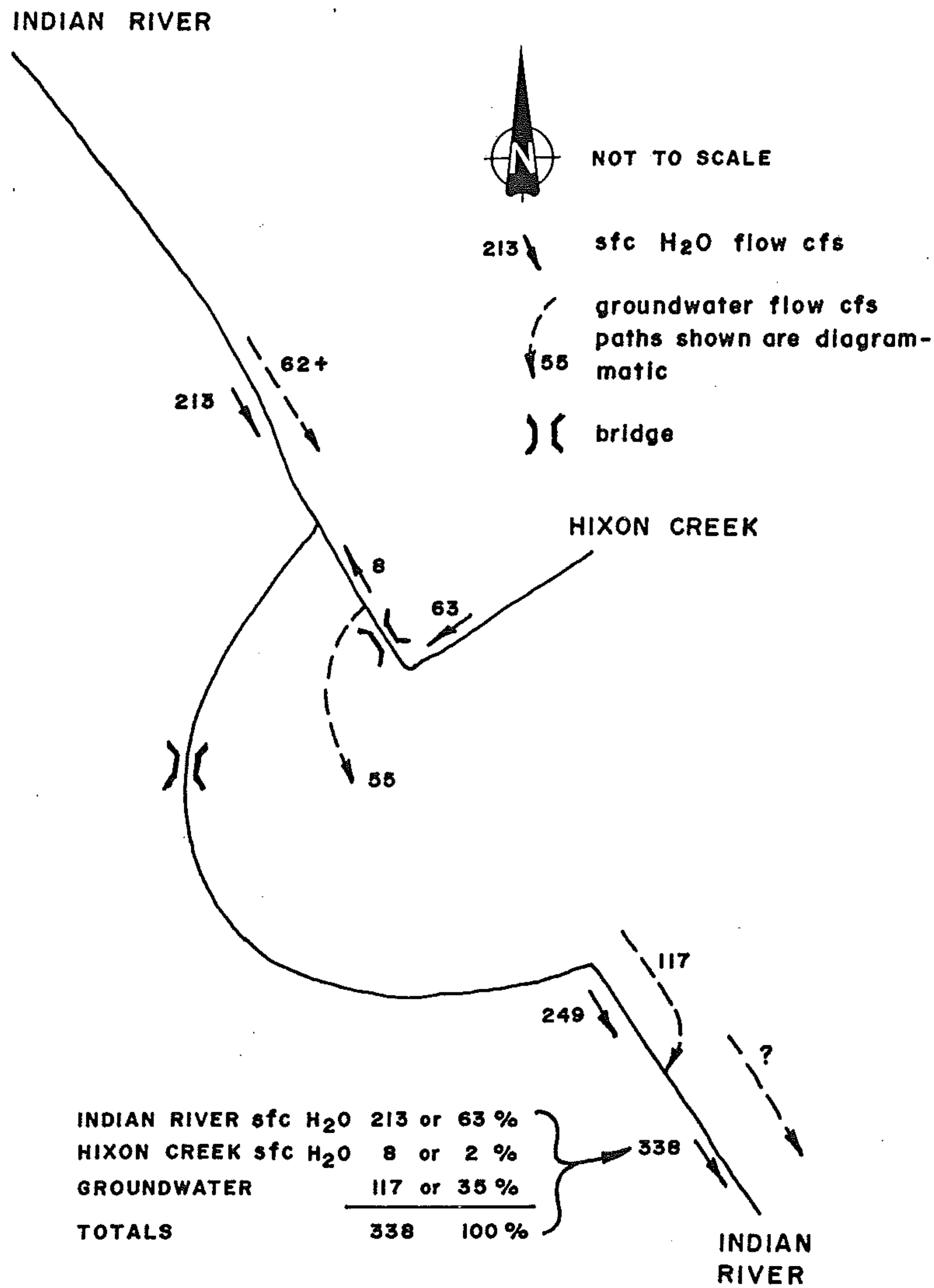
BROWN ERDMAN & TURNER, LTD.

W.L. Brown, P. Eng.

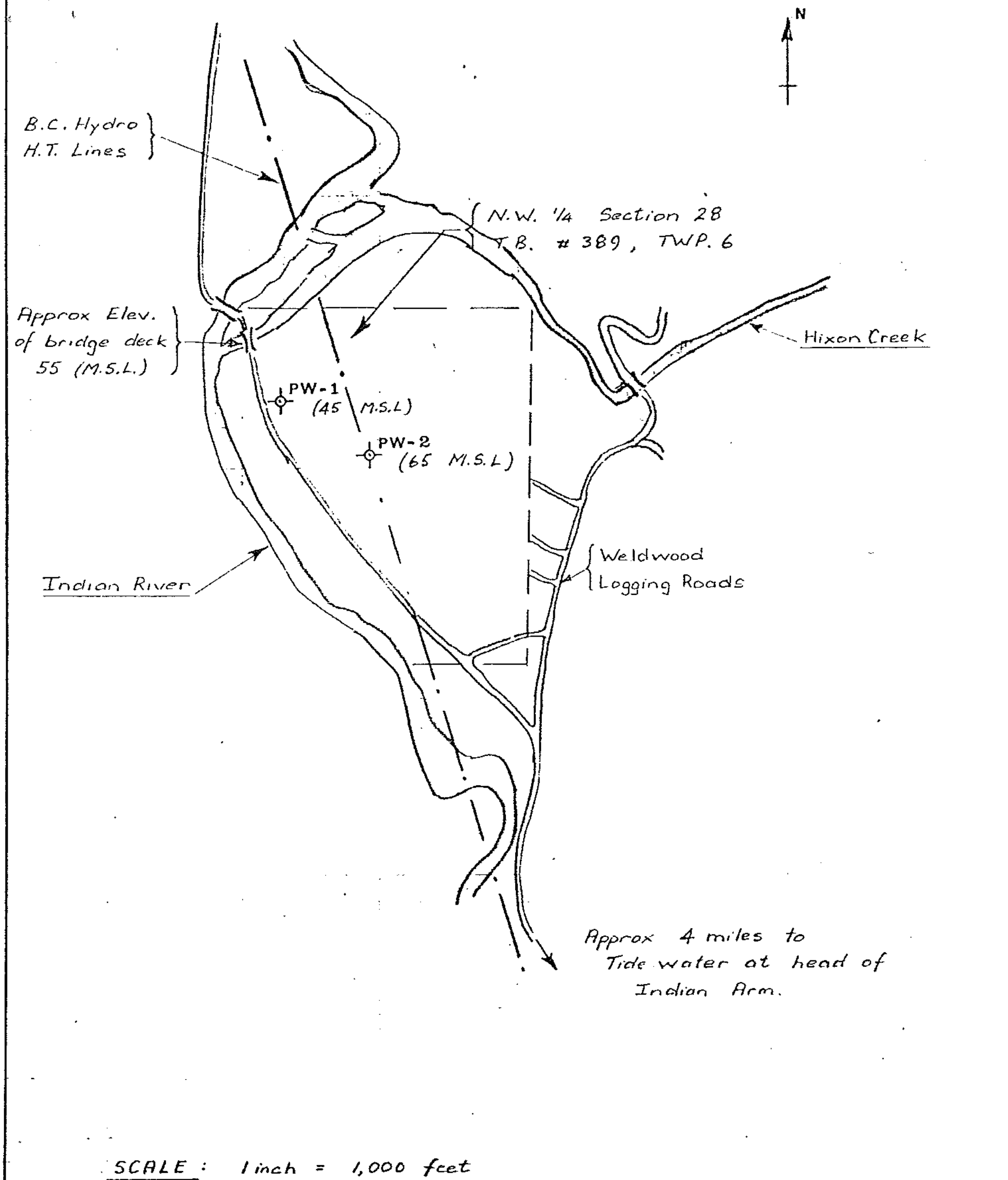
WLB/pv



GREATER VANCOUVER WATER DISTRICT	HYDROLOGIC BALANCE INDIAN RIVER VALLEY AUG. 26, 1984 READINGS (SEE TEXT)	BROWN, ERDMAN & TURNER LTD. INTERNATIONAL GROUNDWATER CONSULTANTS NORTH VANCOUVER, CANADA		
INDIAN RIVER HIXON CREEK		SEPT. 1984	W L B	FIG. 1



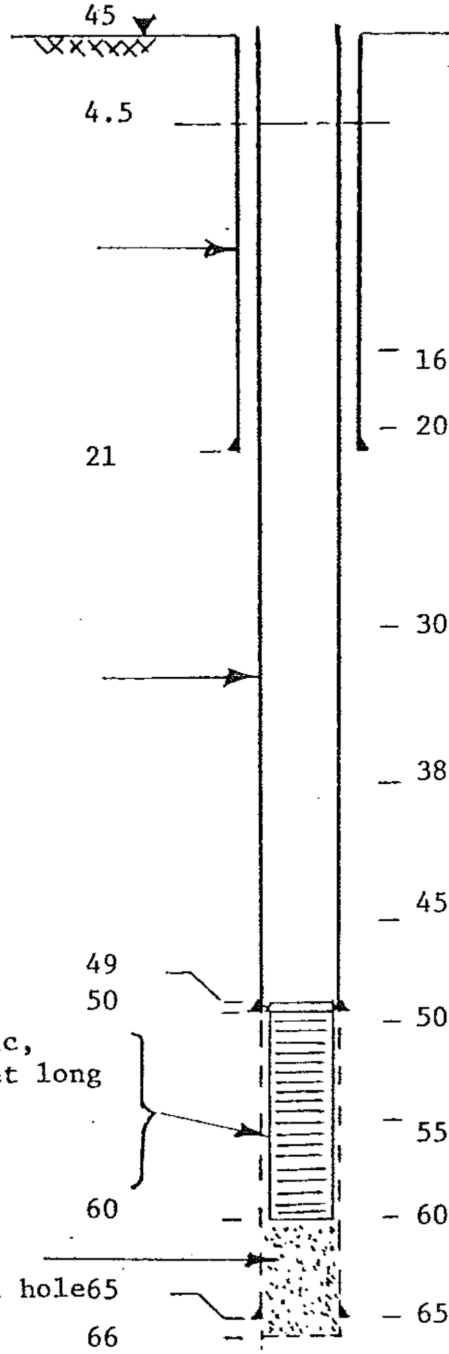
GREATER VANCOUVER WATER DISTRICT	HYDROLOGIC BALANCE INDIAN RIVER VALLEY	BROWN, ERDMAN & TURNER LTD. INTERNATIONAL GROUNDWATER CONSULTANTS NORTH VANCOUVER, CANADA		
INDIAN RIVER HIXON CREEK	NOV. 30, 1983 READINGS (SEE TEXT)	SEPT. 1984	W L B	FIG. 2



UNDERWOOD, MCLELLAN & ASSOCIATES LTD.	WELL LOCATION SKETCH MAP INDIAN RIVER	ROBINSON, ROBERTS & BROWN LTD. CONSULTING GROUNDWATER GEOLOGISTS NORTH VANCOUVER, CANADA
HATCHERY SITE CHEAKAMUS RIVER		April, 1972 / Fig : 3

WTN 71324

Elevation of ground surface (approx) MSL 45



Well construction	Depth	Material	Description
Static water level	4.5	GRAVEL:	Sand, silt and boulders
12-inch diameter casing			
		GRAVEL:	Sand and boulders, W.B.
Bottom of 12-inch	21	SAND:	Silty, fine to coarse
8-inch diameter casing		SAND:	Fine to coarse; some gravel W.B.
		SAND:	Gravel, no fines, W.B.
		GRAVEL:	Coarse, little fines
Top of Lead Packer	49		
Bottom of 8-inch casing	50		
SCREEN: 8-inch telescopic, stainless steel, 10 feet long with 200/1000 inch slot openings		SAND:	Fine to coarse, gravel, W.B.
		GRAVEL:	Coarse, few fines W.B.
Bottom of Screen	60	SAND:	Silty, some gravel
Back filled hole			
Bottom of original cased hole	65		
Total Depth	66	BEDROCK:	

SCALE
Vertical: 1-inch = 10 feet
Horizontal: N.T.S.

Notes

1. All depths given to existing ground surface.
2. W.B. = water-bearing
3. Screen removed.

UNDERWOOD, McLELLAN & ASSOCIATES LTD.	L O G	ROBINSON, ROBERTS & BROWN LTD. CONSULTING GROUNDWATER GEOLOGISTS NORTH VANCOUVER, CANADA	
HATCHERY SITE INDIAN RIVER, B. C.	Test Well No : 1 Indian River	April 1972	Fig: 4

WTN 71325

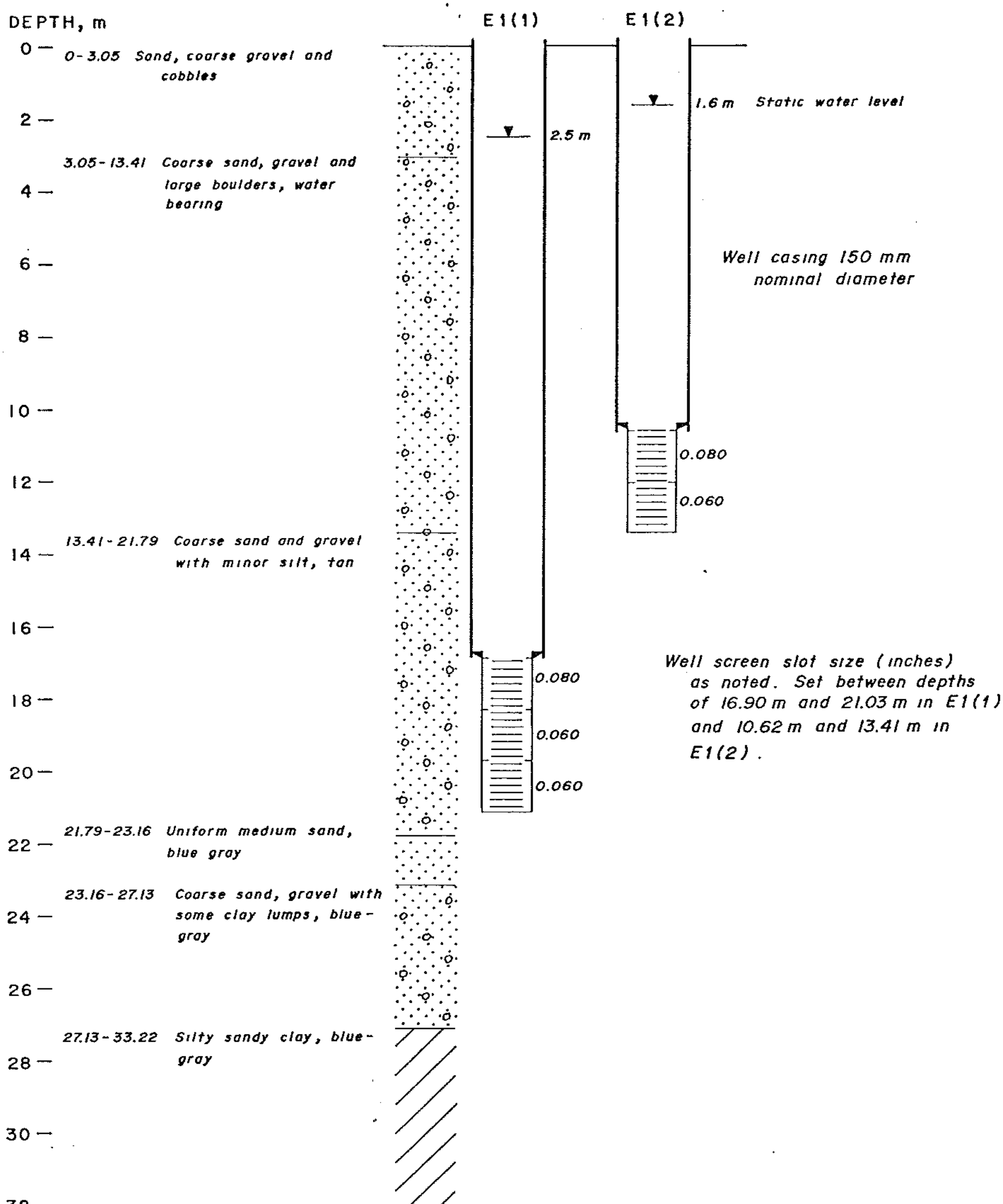
Elevation of ground surface
65 MSL

Static Water Level
27.92

Depth	Material	Description
0		Top Soil & Fill
4		Silty sand & gravel
93	SAND:	md/crs, gravel clean water-bearing fe stained
105	SAND:	fn/crs some silt
110	SAND:	fn/crs some gravel - water-bearing
130	GRAVEL:	to 2" some sand W.L. 15' water-bearing
142	SAND:	fn/crs some gravel - water-bearing
170	GRAVEL:	to 2" some sand md/crs - silty layers fe stained water-bearing
188	SAND:	fn/crs - silty layers of gravel crs
202	SAND:	md/crs - few pebbles, trace silt water-bearing
225	SILT:	& organic materials, black
260 T.D.		

8" stainless steel Test Screen 200/1000 slot → 175–185

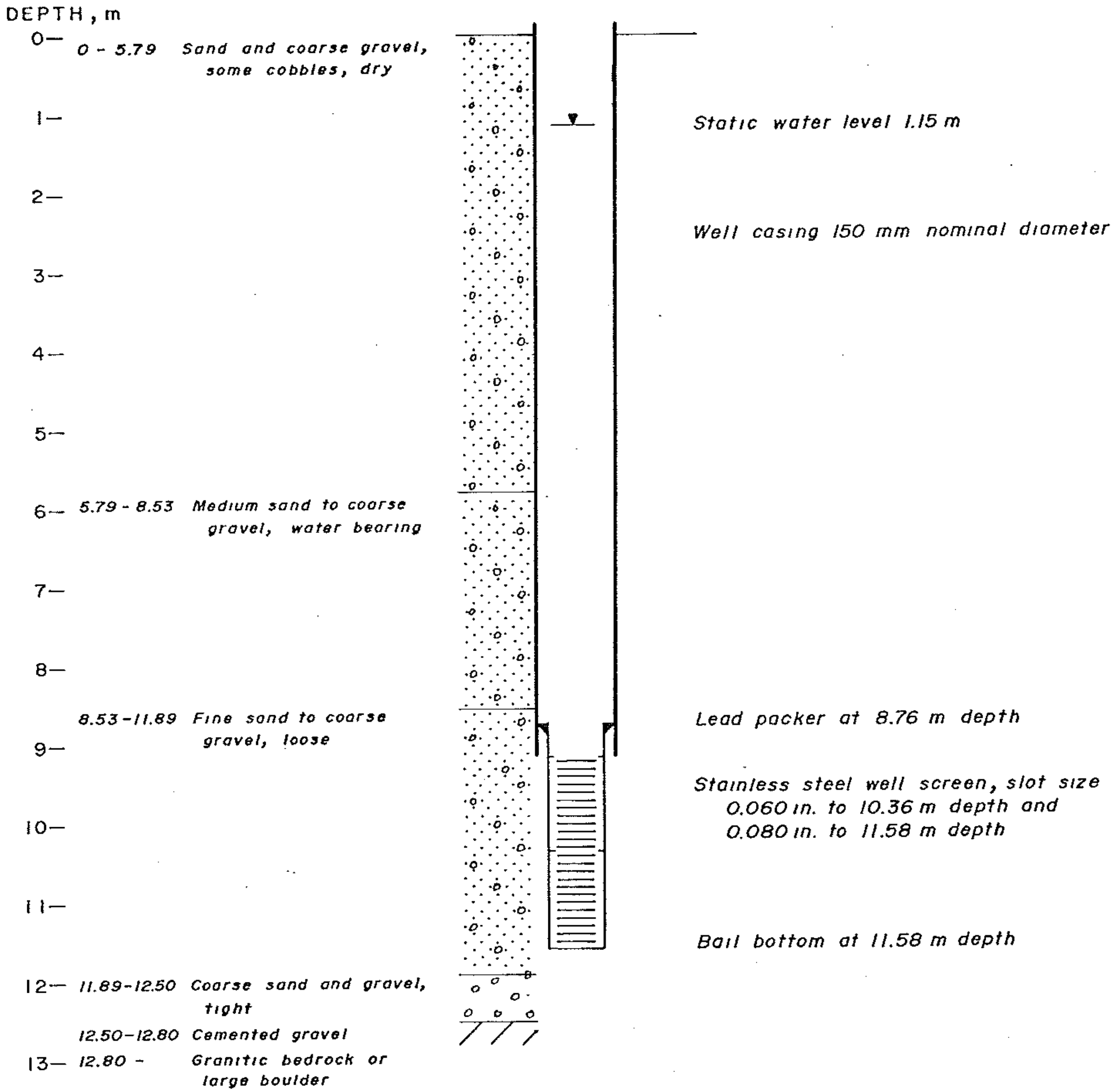
INDIAN RIVER	Log Test Well #2	ROBINSON, ROBERTS & BROWN LTD. CONSULTING GROUNDWATER GEOLOGISTS NORTH VANCOUVER, CANADA
Underwood, McLellan & Associates Ltd.		March 1972 | Fig 5



INDIAN RIVER NO. E1

BROWN, ERDMAN & ASSOCIATES LTD.
80-181 HWR 24-12-81

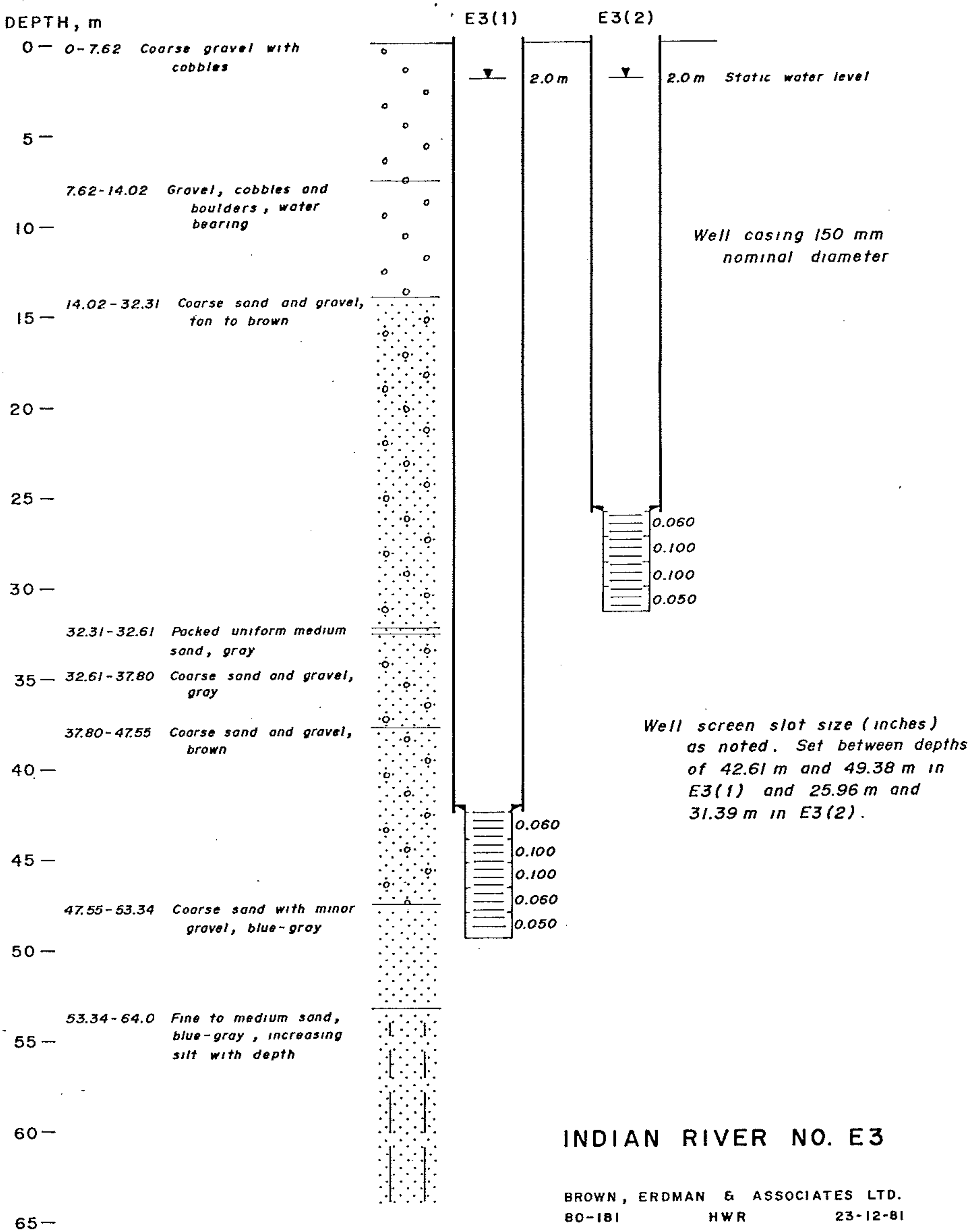
FIGURE 6



INDIAN RIVER NO. E2

BROWN, ERDMAN & ASSOCIATES LTD.
80-181 HWR 8-10-81

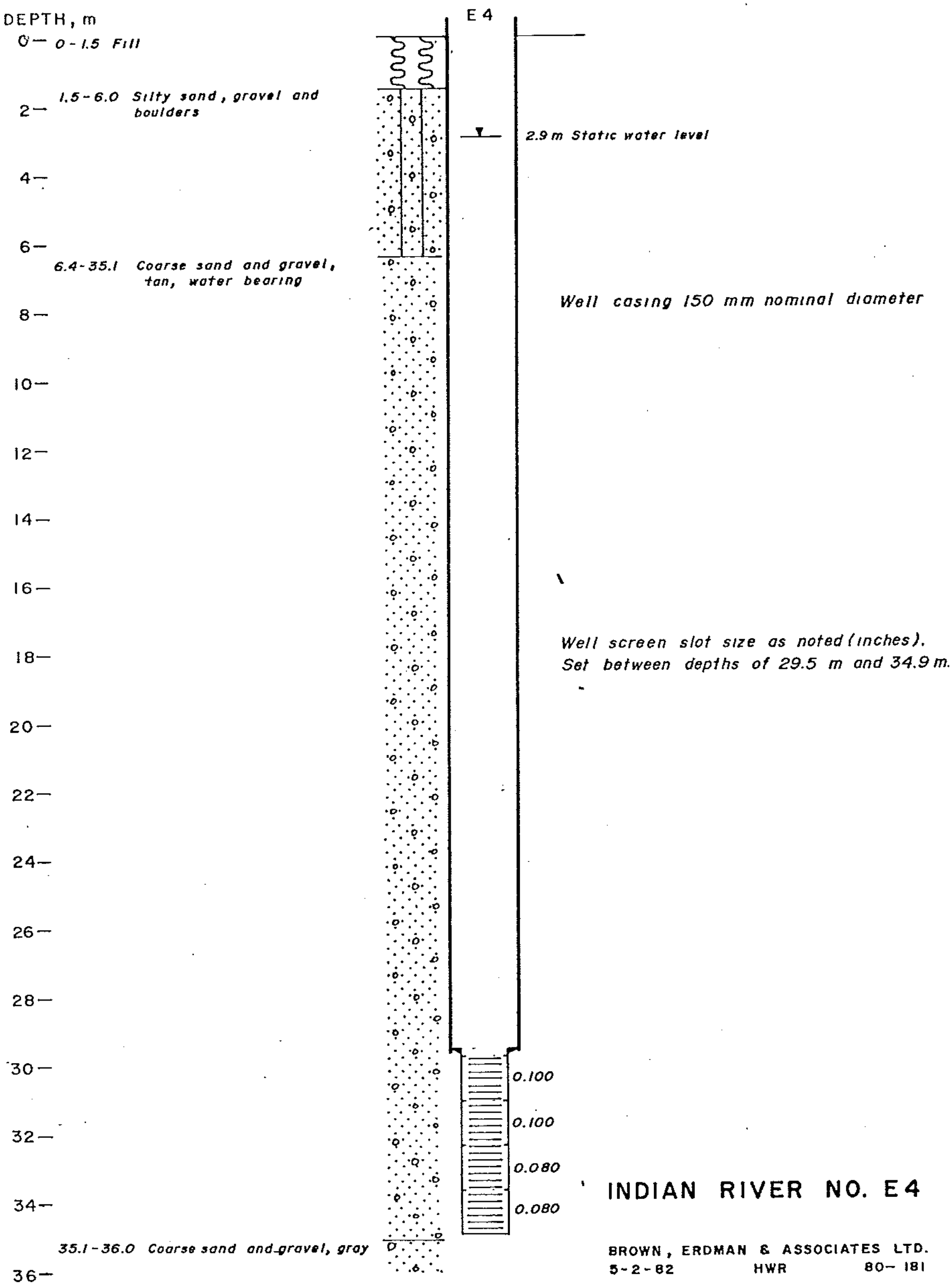
FIGURE 7



INDIAN RIVER NO. E3

BROWN, ERDMAN & ASSOCIATES LTD.
80-181 HWR 23-12-81

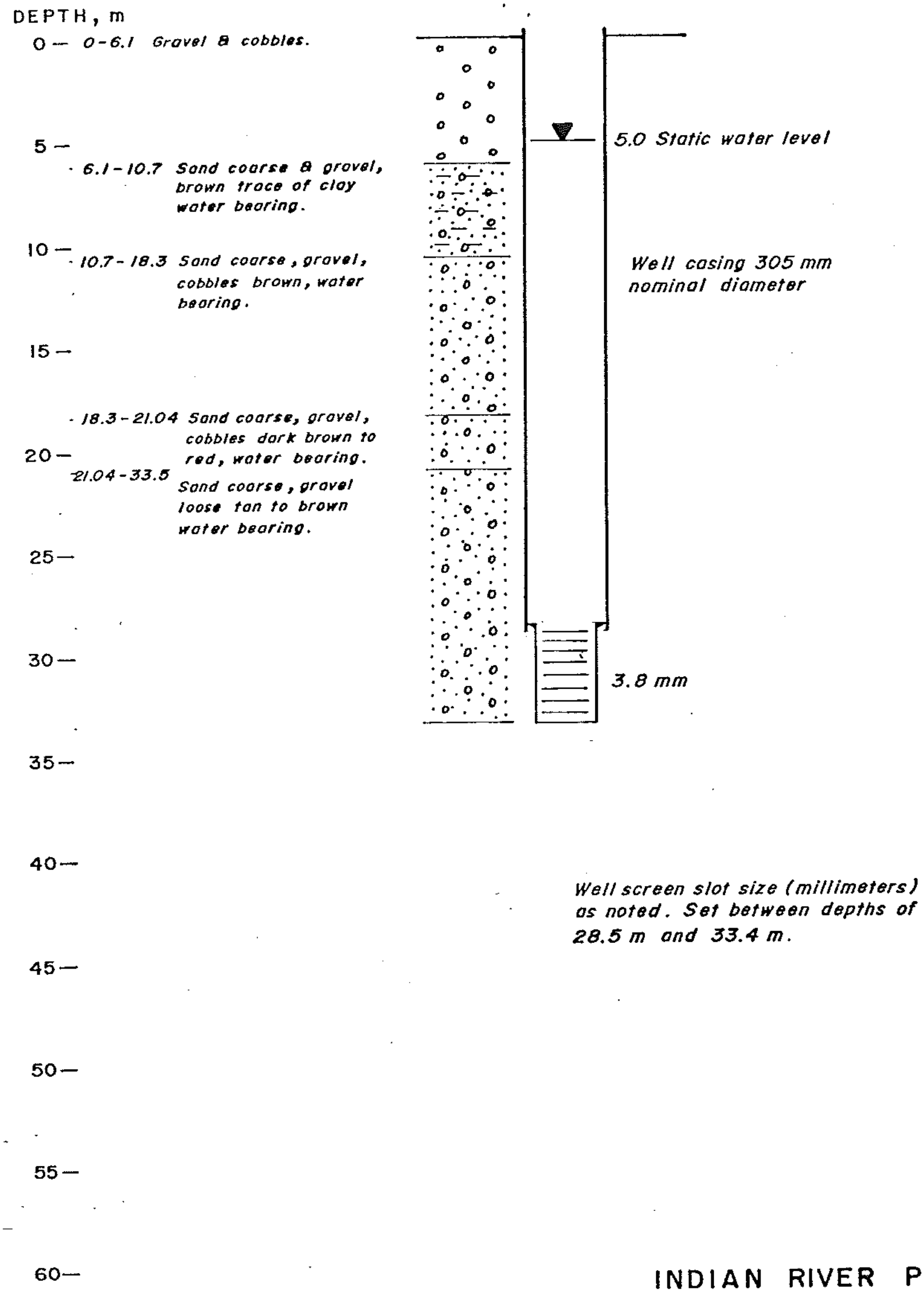
FIGURE 8



INDIAN RIVER NO. E4

BROWN, ERDMAN & ASSOCIATES LTD.
5-2-82 HWR 80-181

FIGURE 9



INDIAN RIVER Pt 82-1

BROWN, ERDMAN & ASSOCIATES LTD.
82-505 RBE 04-1-83

FIGURE 10

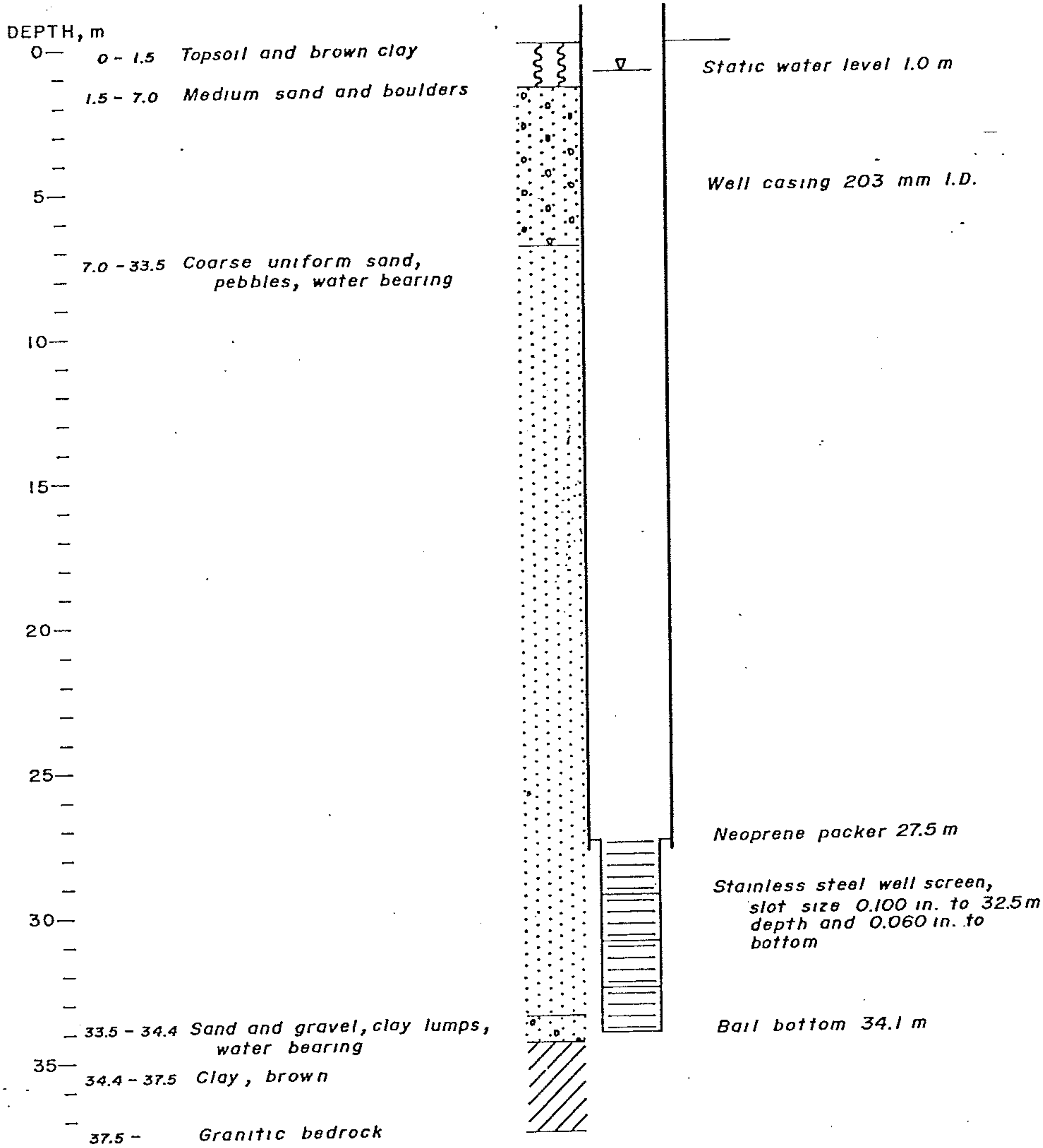


FIGURE 11

INDIAN RIVER NO. 2

BROWN, ERDMAN & ASSOCIATES LTD.
HWR 12 - 5 - 81

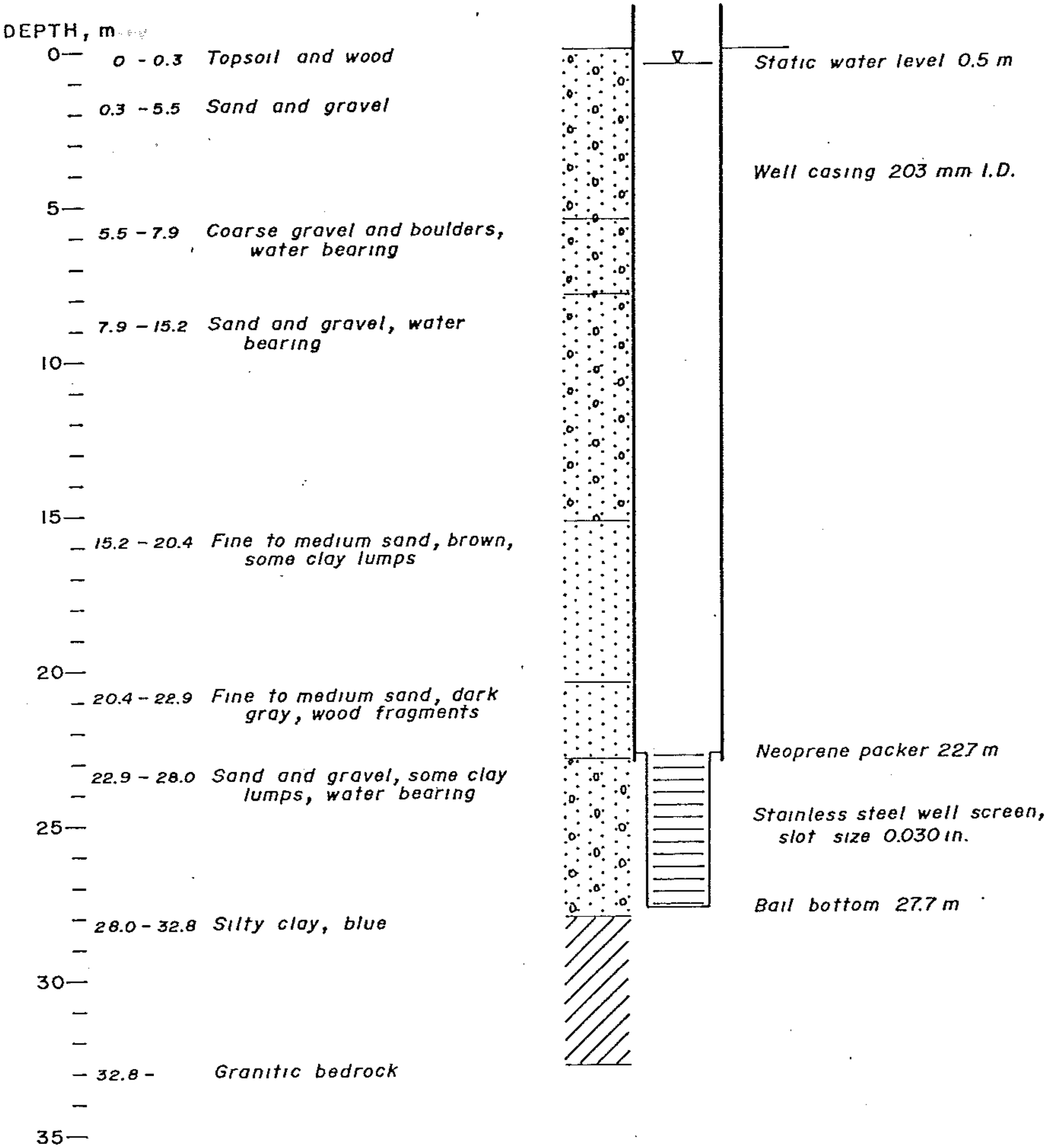


FIGURE 12

INDIAN RIVER NO. 1

BROWN, ERDMAN & ASSOCIATES LTD.

HWR 11 - 5 - 81