Geological Conditions at the proposed Malir dam Site

Dam Site

GM.01 It is proposed to build an earthen dam about 75-feet high from the river bed and with its crest line at R. L. 360-feet, across the Malir river, at a point near the junction of the Jorando river with the Malir, about a mile upstream of the Dumlottee Gorge. After crossing the Malir and Jorando, the dam line runs due west till it touches the narrow ridge, capped by conglomerate which converges from north upon the Malir river to form the Dumlottee Gorge. This point is less than a mile north of the Gorge. From there the dam line runs on top of the ridge till the Sehwan road is reached. From there turning north east, it extends further for nearly two miles on the same ridge. On the left bank, it touches another isolated hill again capped by conglomerate. After running on top of this hill, it turns east across a gap bottom of which is 318-feet above sea level. Then the line runs north east across another hill for about a mile and a half. Thus, the whole structure runs for more than 6 miles. It covers about half the perimeter of the reservoir thus formed, and encloses it where it is broadest. The dam is designed to hold the entire flow in the normal years of a total rainfall of about 7 inches. (Fig. G.M. II)

GM.02 Topographically, the whole area appears quite flat and plain with only a few low residual ridges and hills being themselves remnants of an older plain, owing their existence to the recent uplift of land and the rejuvenation of cycle of erosion. Streams have excavated their valleys further down and remains of the older plain quite flat on top and carrying even soil cover and vegetation forming the ridges and hills are observable. On the right bank, the ridge is almost continuous, but on the left there is no such

ridge, the entire land surface gradually sloping down southward to the Sukkan valley. Only a few isolated hills are seen on the left bank of the Malir. Further, these ridges and hills seldom rise above R.L.300. These conditions have necessitated building such a long embankment.

Malir River

GM.03 The Malir river is formed by the confluence of the Mol and the Khadeji streams. The Mol river flows in a synclinal valley all its way, but near Dumlottee area it has been gradually shifting to the east occupying the north–south running valleys on weaker strata and now flows along the western side of an anticline, formed of more resistant limestones. The Khadeji river before its confluence with the Mol, 27 miles east of Karachi, crosses this anticline by cutting a gorge nearly 400–feet deep probably facilitated by a fracture line, running oblique to the anticlinal axis. From this point of confluence the Malir river flows obliquely across the synclinal valley.

General Geology of Karachi Basin

GM.04 The Karachi basin comprises the drainage basins of the Malir and the Lyari rivers. It is clearly defined by high scarps of Gaj formations on the east and north west. On the south, the coastline forms the base of this triangular basin, while the apex is formed by the northern extremity of the Mol plateau from where the Mol river starts. In the north these scarps rise abruptly about 1,000–feet above the surrounding plains of upper Nari formations. But southward, they lose in height and ultimately degenerate into broken ridges and hills as they approach Karachi. This basin is essentially a synclinal basin with exposures of the uppermost Tertiary rocks, i.e. the Gaj and the Manchar formations ranging from Miocene to Pliocene in age. The floor of the basin has been mildly folded into a series of asymmetrical folds—anticlines being gentler on the west and steeper on the east—and running north south first and then turning westwards on the approaches of Karachi. These mild and minor folds die out before reaching the Karachi city giving place to two rather broad synclines occupied by the Lyari and the Malir rivers and separated by Drigh Road

anticline. On the east, this basin is flanked by a much more uplifted and somewhat more intensely folded broad tract of Sind Kohistan where much older rocks of Kirthar and Lakki formations of Eocene age have been raised upto 2,000–3,000–feet above sea level. Cretaceous rocks are exposed in the core of Laki Range. On the west, lies the great Pab Range where also much older rocks upto Cretaceous age are exposed.

GM.05 The Karachi drainage basin is hemmed in between the two powerful drainage systems. Indus tributaries, the Baran and others on the east and the Hab river on the west are chief. Both these drainage systems are encroaching upon the Karachi basin from either directions. They are constantly undercutting the Gaj scarps, surrounding this basin which are responding to this process by slowly and gradually receding inwards. Many spectacular changes have occurred in the form of river capture. The Khadeji and the Lyari, owing to their being on the outer margins have lost much of their northern drainage areas through this process. The Mol river valley, lying in the middle still extends far to the north.

GM.06 Some more morphological changes have occurred during the Glacial period and afterwards. During the glaciation, when the sea level became low, streams were rejuvenated; their down cutting action was renewed and accelerated; deep valleys were excavated. Later, during the Post-Glacial phase of transgression, the streams became aggrading and the valleys were filled with bolders, gravels and sands. The deep gravel-fill of the Malir river, which has been yielding sweet water for Karachi citizens so generously, owes its existence to such a process and may perhaps be a headache to the dam makers. In still later period, there has been vertical uplift of land relative to the sea level and as a consequence, the streams are again degrading their channels. In almost all the streams, we can notice the valley-in-valley conditions, and nicks or breaks in stream profiles which are working upstream in the form of minor falls of rapids and may prove dangerous to a dam upstream, if not taken care of.

Conditions at the Dam Site

GM.07 As already stated, the area where dam is to be built is

is a plain area, mostly covered by alluvium. Even residual hills and ridges above described are fossil plains. Consequently, the rock exposures are few and far apart. They are seen only in the cliffs of these hills and ridges, facing the Malir river and other streams. Other slopes of these hills are covered by detritus. On the geological map of the Geological Survey of India, of 1 inch to a mile scale, the whole area east of the junction of the Bazar river with Malir has been shown as occupied by the Miocene Gaj formations. From the exposures in these hills and the area further north it appears that this section is a continuation of the same syncline which is occupied by the Mol river further upstream the confluence. The axis of the syncline runs roughly south-south-west close to the Dumlottee Gorge with a probable slight pitch in this direction. The dam line between points A and B runs transverse to the synclinal trough which is a favourable condition. The strata in the ridge west of the Jorando nallah and north of the Sehwan Road show south easterly dips, while in the low ridges east of Jorando they dip in a westerly direction at an angle 1–2°. In the hill on the left bank about a mile upstream of the Dumlottee Gorge, the strata dip west by north at about 2°.

Stratigraphy and Texture of Roc

Surface Exposures

GM.08 Sections of Gaj formations in the vicinity have been examined and described by Blanford in his "Memoir on the Geology of Western Sind". The total thickness of this formation was estimated at 800–feet at Sawaji a few miles north of Khadeji and 500–feet is exposed at the Gorge of Rahuja stream further north. At Khar in the Hab valley, 500–feet of it, was seen all composed of light coloured limestones. In the Khadeji Gorge about 400–feet white and pale coloured limestones have been cut without reaching the base. These limestones form the lower part of the Gaj formation. The upper part consists of alternating bands of sandstone and clay with occasional thin bands of limestone. In this area, from the Dumlottee Gorge to a little east of Goth Radho only the clays and sandstones and one band of hard limestone 4-5 feet thick forming the upper part of Gaj formation were seen.

Further east, the lower limestones forming an anticlinal fold are exposed.

(i) **Cliffs at Dumlottee Gorge :**

GM.09 The cliffs on either side of the Dumlottee Gorge are composed of sub-recent conglomerates from top to base. This conglomerate is composed of pebbles of Gaj limestones only partly rounded. The matrix is gravel and sand again of Gaj limestone. The cementing material, where present, also appears to be calcareous. This conglomerate is rather compact near the base. But upwards, it is rather weak and large; rounded pebbles are fewer. The mass of it is of coarse river gravel and not very compact. Bedding planes are open and vertical joints are also developed, the conglomerate falling out in cuboidal blocks. In the eastern scarps of the northern ridge of the Dumlottee Gorge, a thick bed of coarse grey limestone is exposed. The sandstone is soft and jointed. This ridge continues northwards for a mile and turns north-west till the Sehwan Road is reached. In the later half, it runs in the direction of the dip of the strata. From Sehwan Road, it turns north-north-east and becomes a strike ridge throughout capped by sub-recent conglomerate, and the older strata are mostly sandstones outcropping in the eastern underscarps. In the western scarps still older rocks clays, limestones and sandstones are exposed. They dip south east.

(ii) **Hills near the junction of the Jorando and the Malir rivers :**

GM.10 On this point, the narrow ridge on the north is again composed of sub-recent conglomerates. On the western slope, grey sandstone was observed, but on the east, in the cliffs cut by the Jorando, clay is exposed which extends to the east of Jorando nallah to the base of another ridge east of Jorando. In the southern hill a bed of hard limestone 2-feet thick was seen near the base. It is the same bed which is seen in the ridge crossed by Sehwan Road at mile 26th. It breaks into blocks about 3-feet by 2-feet by 2-feet. Downwards, it gives way to broken impure limestone. It is succeeded upwards by a thick bed of pale grey coarse sandstone, jointed and porous. These beds show a westerly dip of about 2°.

Further downstream of the Malir bank, this sandstone is seen overlying a brown clay unconfirmably. The sandstone bed contains a lenticular band of coarser sandstone hard and full of marine fossils. The whole pale grey sandstone bed may probably represent the base of the Manchar group. All these three strata are then covered unconfirmably by the sub-recent conglomerate.

Evidence from Borings:

(i) The Ridges:

GM.11 The boreholes have been sunk to investigate into the sub-surface conditions in the area. Three of them are located on the northern ridge of the Dumlottee Gorge and three at the junction of Jorando and Malir, one each on the hills on either side and one in the bed near the junction. Borehole No. 1 near the Dumlottee Gorge passed through 42-feet of conglomerate and 30-feet of sandstone before striking 31-feet of thick clay bed at R. L. 245.5. In hole No. 2 further north 90-feet of conglomerate and sandstone was penetrated before touching a clay bed at R. L. 226.3. Only 5-feet of clay was pierced. For the last 20-feet of sandstone no core was obtained. The borehole No. b, the 3rd on the ridge also got a silty clay about 91-feet below surface. This borehole is located at R. L. 335.

GM.12 At the junction of Jorando and Malir, the borehole No. 3 on the northern hill penetrated 51-feet of conglomerate and sandstone before reaching 24-feet hard clay bed at R. L. 275.96. This clay was succeeded by 10-feet of hard sandstone, 5-feet of clay and 6-feet of sandstone before reaching another 19-feet of clay bed at R. L. 230.96. Borehole No. 4 on the southern hill passed through 9-feet of upper conglomerate, 31-feet of sandstone and 17-feet of thin beds of limestone, sandstone and clay, until a 27-feet of sandy clay bed, for which no core was obtained. It was reached at R. L. 264. Then after a 6-feet of sandstone band, another sandy clay bed of 10-feet was met at R. L. 231, but again no core was obtained.

(ii) Conditions in the Malir bed:

GM.13 Borehole No. 5 was put down in the bed near

the confluence of the Jorando and the Malir. It passed through 62-feet of river gravel and sand then 13-feet of sandstone and a clay bed 26-feet thick at R. L. 221. Below this again, sand full of water was met at R. L. 195.

GM.14 K. R. Bhide, Special Engineer, Karachi Municipal Corporation carried out hydrographical surveys and investigations in the Malir valley and the results are given in the note No. 4 of 7th April 1939. 25 borcholes were put down in the Malir bed from the confluence of the Mol and Khadeji to the Dumlottee Gorge at regular intervals of 1,000-feet. The boreholes were located in the middle of the channel to determine the depth of the water bearing river gravel, sand and bolders in the river channel upto the bed rock.

GM.15 It was found that the depth of this water bearing material from the Dumlottee Gorge to a distance of about 2 miles upstream ranged from 60 to 90-feet. At one point 8,000-feet upstream of the Gorge, the depth was 120-feet. At another point 6,000-feet from the Gorge (very close to the proposed dam site) bed rock was struck at a shallow depth of only 17-feet. This proba ly struck some buried rocky island in the channel. At this point, a borehole was taken down to a depth of 225-feet below the river bed in 1937 and the section has been given in D.A. Howell's report of September 1937.

Section of Tubewell No. 2—18,000-feet downstream of the confluence of Mol and Khadeji

293	R.L. — Bed of the river				
283	Gravel	10 feet	193	Blue clay	44 feet
271	Clay, gravel and stones	12 feet	173	Sandstone	20 feet
260	Sandstone	11 feet	123	Soft Sandstone	50 feet
256	Gravel, clay and stones	4 feet	118	Black Sticky Clay	5 feet
252	Hard Mooram	4 feet	93	Soft Sandstone	25 feet
243	Blue clay	9 feet	90	Hard Rock	3 feet
237	White clay	6 feet	68	Soft Sandstone	22 feet

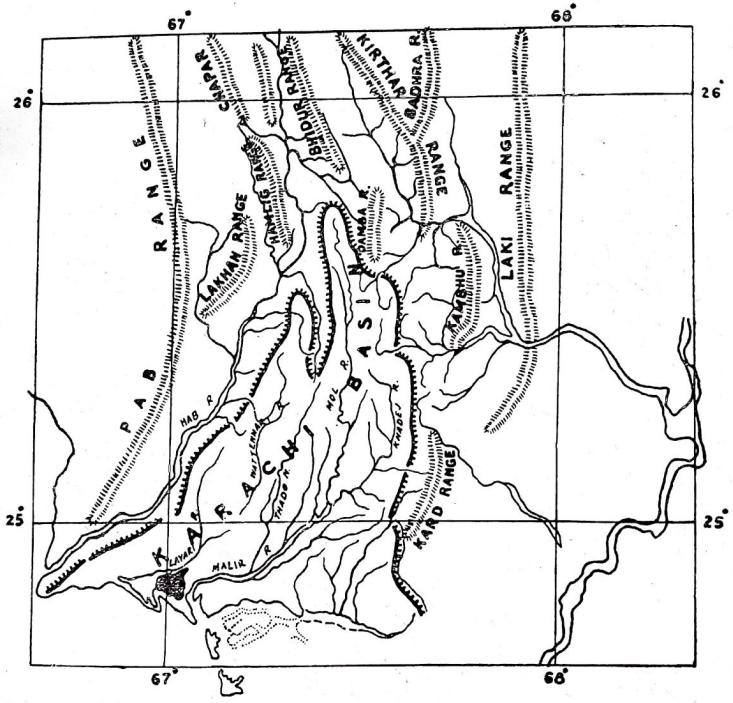
GM.16 This Tubb well ends in a sticky black clay. For 100-feet below the surface, the borehole was lined with 13 inches diameter pipe and the lower part was unlined. In this borehole a band of 44-feet blue clay is succeeded downwards at R. L. 193 by two thick beds of sandstone 70-feet thick. Also in the borehole No. 5, recently drilled in the bed, sandstone, charged with water was met at nearly the same level below a 27-feet clay bed. From the section given above, it is clear that the alternating bands of clay and permeable sandstones continue to a considerable depth below the gravel fill in the channel. The dips here being westerly, these strata must be cropping out under the gravel and also alluvium further to the east and to the north.

GM.17 Another important point to be noted is that the permeable beds below the river gravels and sands were found charged with water under pressure of greater load of water than alluvium, and the water level rose upstream as the boring progressed downwards. At that time, water table was 33-feet below the river bed rose with the progressive depths of boreholes, as follows :

Depth of bore-hole	Level of water surface below the bed of the river	Depth of bore-hole	Level of water surface below the bed of the river
33 feet	33 feet	130 feet	21–1/6 feet
56 feet	29½ feet	134 feet	20–5/12 feet
101 feet	25½ feet	179 feet	18–1/3 feet
120 feet	22–1/3 feet	203 feet	17–1/3 feet

(iii) Gaps between the Hills and Ridges :

GM.18 A big gap is situated on the south of the Malir river east of the point B. Its lowest point is at R. L. 318, while the level of borehole 5 in the bed is 296. This gap is filled with alluvium, no solid rock outcropping anywhere. It is, at places thickly covered by Babul growth and cultivation is also going on. It appears to be an old channel of the Malir river now silted up. The alluvial and gravel fill here must be quite deep and thoroughly permeable. An under current of fresh water southward from Malir already exists, as is evidenced from the well situated in the gap



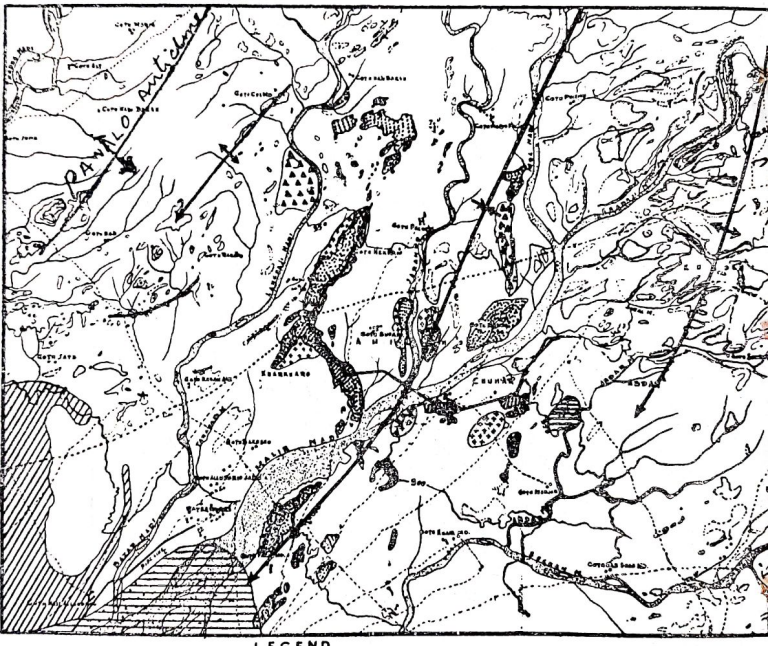
KARACHI DRAINAGE BASIN

GAJ-SCRAP DEMARCATING THE BASIN : .....

GEOLOGICAL FORMATIONS

AT & NEAR THE PROPOSED MALIR DAM SITE

Scale: 1 Mile.



LEGEND

ALLUVIUM OF THE LOWER MALIR VALLEY.

SUB-RECENT CONGLOMERATES & CONSOLIDATED RIVER GRAVELS COVERING THE FLAT HILLS.

MANCHAR FORMATIONS.

AREA OF GAJ FORMATIONS PARTLY COVERED BY ALLUVIUM.

ARTICLINAL AXIS

SINCLINE.

STRIKES AND DIPS OF THE STRATA.

CLAY.

LIME-STONE.

CLAY UNDERLYING.

DAM SITE

and fitted with number of engines. Water is continuously pumped into an open channel which brings surface flow of Malir through this gap to Deh Darsano, where a considerable tract of land is under irrigation. After the completion of the diaphragm under the Dumlottee Gorge in 1939, the water level rose upstream of it and wells south of the Malir river got the benefit due to greater seepages through this gap and others to that side.

GM.19 Another broad valley parallel with the Jorando and west of it, joins the Malir close to the Dumlottee Gorge. It is very green with considerable cultivation and apparently good sub-soil water conditions. The alluvium in this valley must also obviously be deep. It appears to be the old channel of the Mol river. It is at present drained by an insignificant stream. In this valley a little north of Malir, an attempt was made to dig a well by local zamindars, but it was abandoned due to the coming in of the coarse gravel and sand. From this dry well, it is evident that this coarse and thorougly permeable gravel and sand is quite deep.

Faulting in the Reservoir Area

GM.20 The fracture line mentioned in connection with the Khadeji Gorge appears to be trending in the direction of the Dumlottee Gorge. The disturbance in the strata is noticeable upto Goth Radkho. Beyond this the whole area is covered by alluvium and no trace of it is to be found, but the semi-artesian head in the Tertiary strata below, indicates that there are no open fissures under the bed. Further investigations are necessary.

Conclusions

(1). 21 The dam line between points A and B runs transverse to a synclinal structure, strata dipping inward at a low angle. This is a favourable condition for the dam. (Fig. G.M. II)

(2). 22 The ridges and hills on either side of the river, upon which the dam will be raised to a fairly good height, with their upper conglomerates and underlying grey sandstone, cannot be relied upon for their resistance against permeability, and considerable percolation is likely to take place through them. The conglomerates with limestone pebbles and calcareous matrix and cement, and

also with their beddings and joint planes, will prove particularly weak. With the passage of time, the pores and passages will be enlarged by solution and abstraction. They can be made impermeable by giving a lining of impermeable material on their inner side upto some suitable clay bed underneath.

(3).23 The depth of the gravel and sand in the river bed was 62-feet in bore No. 5 and below this again a 13-feet bed of sandstone was met. Therefore, the impervious core will have to be taken down at least to 75-feet below the river bed to check the leakages under the dam. Even, beyond the Malir river bed, the dam cannot be built just on the surface. In the valley between the ridge, north of the Dumlottee Gorge and the Jorando river, the gravel deposits are quite deep. Similarly the 3/4 mile broad gap on the left bank is still more serious, but nevertheless, within the ingenuity of the Engineers.

(4).24 The Tertiary strata below the river gravels consists of alternating beds of clays and sandstones. Some of these permeable sandstones must be exposed upstream in the reservoir area. Percolation losses through these sandstones could be possible. But due to the semi artesian conditions in the strata as proved in Tubewell No. 2, we can expect that the downward percolation losses may not be very great.

(5) 25 Building materials are locally available. Limestone for pitching is available within the reservoir area and also outside within a short distance. Clays for coring are extensively exposed in the area on the surface as well as in the scarps of the hills. But within the reservoir area, the removal of the clays should not be carried out indiscriminately, otherwise the exposure of the porous sandstone beds on the surface will increase the percolation losses.