THE FORMATION OF LAND BY RIVERS AND TORRENTS IN THE PUNJAB.

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(1) The shape generally assumed by upheavals.—Owing to the fact that the pressure or contractive force, which causes wrinkling of the earth's crust, is *circumferential*, upheavals generally assume a formation in which the hills lie in irregular loops or circuits. Plate I gives a fairly good view of the usual outlines assumed by mountain ranges.

In the evolution of earth structure (T. M. Read) it is shown by photographs, that when composite sheets of clay, plaster and other materials, varying in tenacity and plasticity, are subjected to circumferential (multilateral) compression, they assume shapes very much resembling the mountainous regions of the earth.

A somewhat similar effect can be produced by pushing, from every side, an ordinary starched table cloth, resting upon a *smoothly polished table.*

(2) The result of the shape assumed by upheavals.—As might be expected, the result of the shape assumed by upheavals was that storm water collected in the depressed areas, thus forming numerous lakes of all sizes and depths. There is probably not a river in existence which has not, at some period of its history, had several lakes on its course.

Geologists state that there are indications that the rainfall of the earth was once very much greater than it is at present, also that there is strong evidence that the regions covered by ice and snow were once far more extensive than they are now.

In support of these theories it may be said that very large areas covered by lakes, would increase the rainfall. Also if mountain ranges were once much higher than they are at present, the area under snow would be greater, and arctic conditions would therefore prevail over a wider expanse of country.

Geologists also state that there are signs of certain areas having been submerged and again elevated more than once.

There are also marks of great cataclysms or violent action due to water.

Although fresh upheavals undoubtedly may have caused some of these cataclysms, it is just as probable that the successive bursting of overflowing lakes had a good deal to do with the formation of the gigantic gorges and canyons which we find to-day, often in regions where the rainfall has shrunk to the smallest proportions.

(3) Examples of ancient lakes.—These ancient lakes were certainly far more numerous than is generally supposed. In the valley of the Jhelum River between Srinagar and Baramula, the bed of an old lake is plainly discernible. The existing Wullar and Dal lakes are its remnants.

The whole of the area now occupied by the valleys of the Swat and Kabul Rivers between Jamrud, the Malakand, and Attock, evidently once formed a part of an extensive lake.

It is highly probable also that there was a large lake in the valley of the Jhelum above Rasul. Also above the exit of the Gumal River at Kajuri Kach, and above the exit of the Kurram River near the Indus.

Abbottabad is situated near, and partly in, an old lake basin.

An inspection of the physical map of almost any country will indicate the limits of many of these pristine lakes, some of which attained to the proportions of inland seas.

(4) The General characteristics of old lake basins.—The usual indications of the pre-existence of an ancient lake are :—

(*i*) A deep and fairly uniform deposit of fine clay, often at a much higher level than the surface of the existing rivers in the basin.

(*ii*) Deep ravines and nullahs beds formed in this deposit by the outflow of water, subsequent to the period when the lake was drained (by the erosion of a passage through the encircling barrier).

(*iii*) The presence of a deep rocky gorge at the point where the impounded water of the lake cut its way through the loop or circuit of hills.

(*iv*) Country sloping *towards* the river instead of away from it.

(*v*) The basin usually contains deposits of kunkar, or earth impregnated with lime, on a large scale.

Plate No. 2 shows a cross section of the valleys of the Gumal and Zhob rivers, taken some miles above the gorge at Kajuri Kach. It strongly resembles the cross section of the valleys of the Kabul and Swat rivers.

Isolated peaks are sometimes seen in the midst of lake bottoms. These are generally the highest peaks of a submerged loop or circuit, and are not in reality isolated. They rise abruptly from the plain as if from a sea. The ancient circuit, of which they are members, probably once formed a part of the boundary of an upper lake.

(5) The two methods of forming land.—There are only two main methods in which land is formed by rivers and torrents, *viz* :—

(*i*) The lake basin or deposition method.

(*ii*) The cone or deltaic method.

The former precedes the latter, in the sense that it generally occupies the ground surface in advance of it, although both methods are usually in operation simultaneously, and the cones would, in course of time, advance over the basins and fill the lakes up if the barriers at the exits held good.

For instance, basin dispositions are taking place on the beds of seas at present, while the continental shelf is being formed by the cone method at the same time.

It follows, that in the case of shallow lakes, furnished with hard barriers at the points of outflow, the cones will eventually advance over the whole bed of the lake, and that the velocity of the water at the exit point will thereby be greatly increased. The geological section of the sub-soil and the lie of the country, will usually reveal this method of formation. Thus, there will be a layer of stiff clay at the level of the old lake bed, above which the materials will be arranged in order of specific gravity, as happens in the *cone* method. The lie of the country will disclose the ancient cones, and, unless the barrier has been carved into a gorge, there will be no deep ravines.

(6) The cone or deltaic method of land formation.—Plate 3 gives a typical cross section of the cone method.

The formation of these cones or deltas, is due to a sudden change in velocity, or to a sudden change in the volume of sediment transported, known as the "silt charge." The products of denudation are sifted out and arranged in order of sizes and specific gravities, the finer particles being carried away to form a lake bed or a sea bed (if the cones are being formed in water). Deltaic cones are so well known that there is no need to describe them further, except to say that the ancient cones, adjoining the Himalayas or other mountains, naturally contain far heavier materials (such as large boulders and shingle) than the fine mud and sand of which present day deltas are being formed.

But there are certain points in connection with the deltaic method of formation which are not so well known. These will be referred to below.

(7). Rivers periodically swing across their cones in order to cause the base of the cone to advance uniformly.—To show that this is the case, let an experiment be made by pouring a stream of water down the side of a soft earthen bank. A delta will immediately begin to form at its base. As long as the stream is continued, the delta will continue to grow, its slopes gradually becoming flatter and flatter. The shape of the base of the cone is influenced by a variety of circumstances (which need not be discussed here) but if the direction, which the stream takes down the cone, be closely watched *for several hours*, it will be observed that it is very thorough and systematic in its action. No deep windings or undulations of the surface of the cone will be permitted. The stream will occasionally swing completely across its delta in order to level up a hollow which exists on the opposite side. Additions to the cone are made from the base upwards, and will be seen climbing the surface of the cone, apparently in the very teeth of the current. While the delta is steep, these oscillations are rapid and frequent ; but as it becomes longer and flatter, they are more deliberate and less frequent.

In his *Report on The Hydrology of the Irrawady River*, Mr. Robert Gordon mentions that the Hoangho, which has a delta of 100,000 square miles, has passed over its delta nine times during the last 2,500 years. It makes a high bed, then abandons it for the low country at the sides.

In *Egyptian Irrigation* Sir William Willcocks, writing of the Nile delta, says that it is a common occurrence to find dry

beds possessing all the characteristics of the existing channels. In some cases these dry beds are of such dimensions as to leave no doubt that they are deserted beds of the main stream.

A recent example of a river which has tilted to one side of its cone is that of the Colorado river, which, assisted by a puny irrigation cut, suddenly poured its whole volume into a depression one hundred miles to its right.

It appears clear, therefore, that many of the oscillations which occur in the stream of a river, are due to the presence of an undulation or irregularity in the surface of its cone, which the attractive force of gravity compels the river to fill up as the cone alters its proportions.

(8). Rivers often sweep away large parts of the cones which they have made in former years.—If we return to the experimental earthen bank referred to above, and by placing a piece of waterproof sheeting under the falling water, arrange that it shall reach the delta in an *uncharged* condition (*i. e.* free from sediment) we shall find that a deep excoriation is immediately made in the cone. This excoriation continues until the clear water has picked up sufficient silt to charge itself.

Similarly the deep ravines, which are found in lake basins, have been referred to above as mainly caused by the increased velocity (and therefore the increased transporting power) due to the lowering or total destruction of the barrier at the exit gorge.

It may be said that deltaic cones would be somewhat similarly affected under similar circumstances but there is an additional cause at work, *viz. the clear water of the winter supply of perennial streams.*

The Punjab rivers are perennial, and the surplus transporting power of their winter supplies undoubtedly performs work which lowers their beds.

Every Canal Engineer is probably familiar with the amount of silt which the clear water of the Rabi (winter supply) automatically removes from certain canal channels. This clear water charges itself with as much silt as it is able to transport.

It follows, that in the case of torrents which are *dry* throughout the winter, and carry nothing but heavily-charged

storm water during the summer, this cause is not at work. But it affects them indirectly if they are short, and if they discharge into a perennial stream ; for the lowering of the bed of the perennial stream, by increasing their indrop, induces a higher velocity in them, which effects a lowering of their beds also.

The sandy *Chos* of the Hoshiarpur District appear to be of the nature of torrents which are forming cones *not* subject to subsequent erosion from any cause.

In *The Chos of Hoshiarpur* (B. H. Baden Powell), a description is given of the damage done by the advancing cones of these *chos ;* they had then buried 35,000 acres of good land with sand.

(9). Cross Sections of Doabs.—Some interesting cross sections of the Doabs of the Punjab are given in plates 4, 5, 6 and 7.

They show the cone formation, but in each case there has been considerable erosion of the original cone. In the case of the Beas the original cone has been entirely destroyed. There are river terraces marking the gradual lowering of the river beds. the probable surfaces of the original cones have been indicated by means of dotted lines.

The cones in question are 500 to 700 ft. above sea level, and 200 to 300 miles in length, measured from the base of the hills.

A longitudinal section of the Chenab-Jhelum-Doab is also given, (Plate 6) in which the river terraces again appear.

It seems probable that a rocky barrier existed across the Indus at Sukkar for some considerable time, and that it was not eroded away until the original cones of the Punjab Rivers had extended almost up to it.

The geological sections of these regions, during the construction of canals, showed 14 to 24 ft. of fine clay at the surface, then 80 to 96 ft. of sand, increasing in specific gravity. At a depth of 100 to 120 ft. from the ground surface, the water-table was met with. Probably the clay bottom of a pristine lake or sea would be encountered if borings were carried further.

(10). A knowledge of the methods of formation of land by rivers and torrents is useful to the Engineer.—It will be obvious that a knowledge of the manner in which a country has obtained its configuration is of practical service to the Engineer.

When he is working in "cone" lands, he will know that if he can raise water to the level of the original cones, he will find the lie of the country favourable for the construction of canals, since it has been laid out by flowing water in the first instance. He would naturally seek to place his canal on the highest lines of the cones. These would be situated on the truncated margins, nearest to each parent river. The Railway or Road Engineer would also find his work made easier by following the cone lines.

An Engineer operating in "basin" lands would be certain of good stiff soil in the bed or central plain, most probably containing kunkar deposits, and of a girdle of cones advancing on the lake bottom from the hills forming the circuit. He would know that a rocky bed could be obtained for a crossing at the exit gorge, also that a masonry dam, erected at that site, would partially or wholly restore the old order of things. In the case of a threatened oscillation on the part of a river, he would be in a position to investigate its nature, and to take measures to prevent or encourage it, as suited his purpose.

A knowledge of the causes which lead to the formation and destruction of deltaic cones, would lead him to endeavour to bring into operation the particular cause which would work *for* him on the desired lines. He would know, for instance, that water with a low silt charge will cut through a cone which has been formed by water carrying a high silt charge, and would endeavour by afforestation, impounding reservoirs, or other means, to reduce the silt charge of the water which he desired to harness.

Similarly, if constructing works in the vicinity of the hills, he would seek to locate the boulder cone, or the shingle cone, or the gravel cone, as affording him more secure foundations for his works than coarse sand.

Also, in grading canal channels and designing rapids and falls in that region, he would be prepared to recommend steeper beds slopes, and less costly downstream protection than would be advisable in the lighter soils further down the cones, especially if the shingle and gravel were compacted with clay. In this latter case he would also be sure of being comparatively free from difficult wet conditions in foundations, as such strata are usually water-tight.

PLATE 1.

PLAN SHOWING THE DOABS OF NORTH-WESTERN INDIA AN
THE LINES ALONG WHICH CROSS SECTIONS ARE GIVEN.

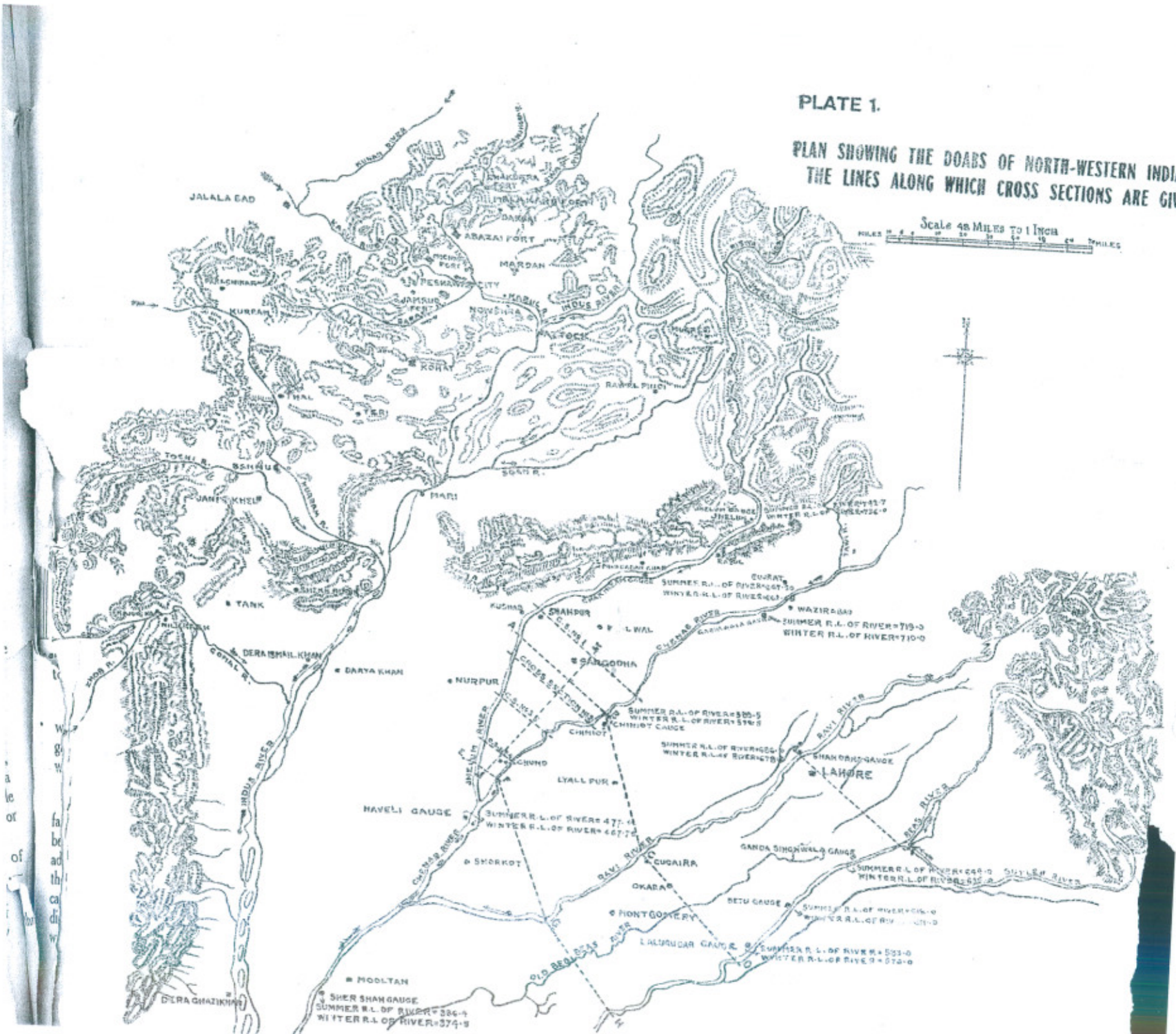


PLATE 2

CROSS SECTION
OF
THE VALLEY OF THE GUMAL AND ZHOB RIVERS
ABOVE GUMAL GORGE. BALUCHISTAN

SCALES { HOR: 1/500
VER: 1/1000

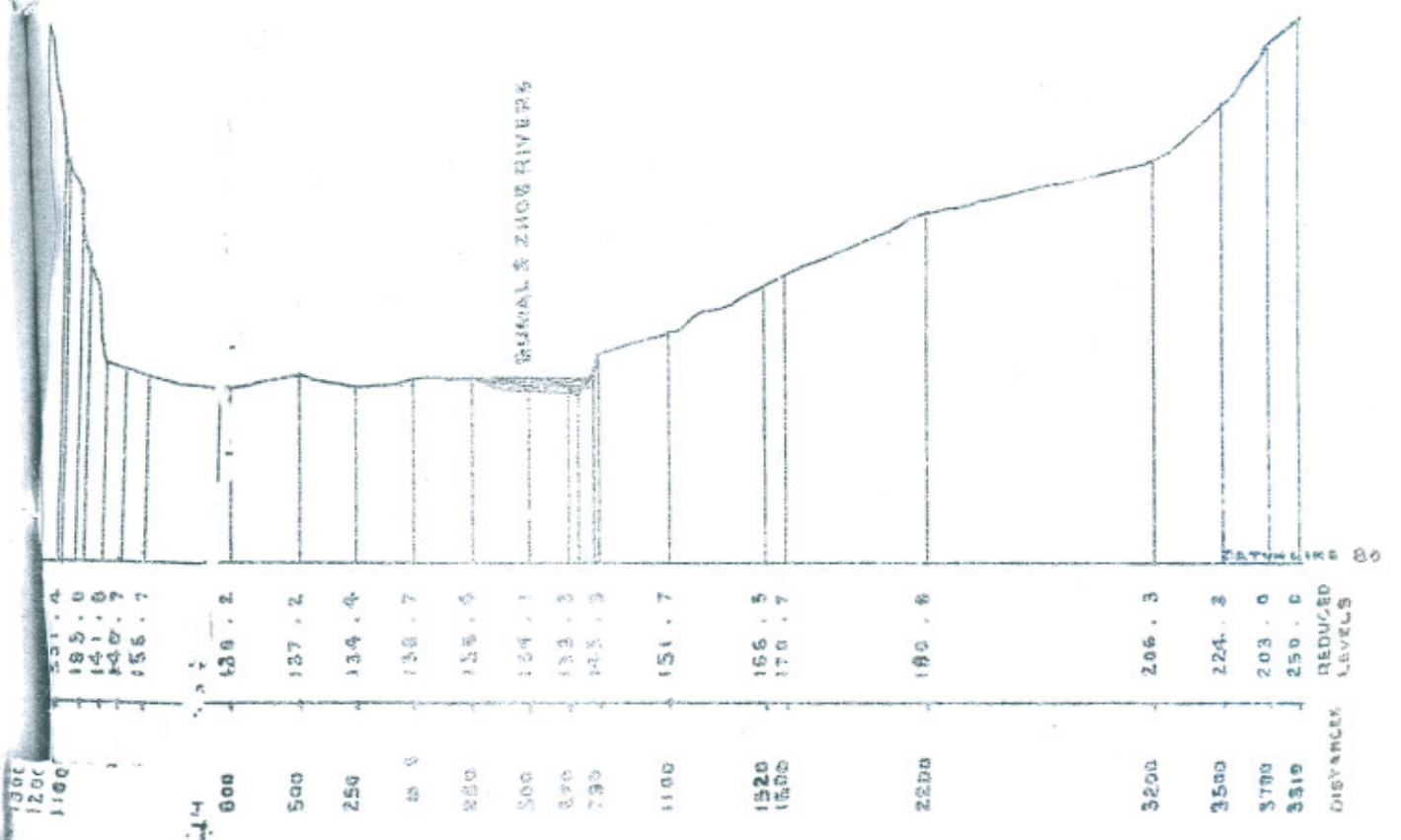
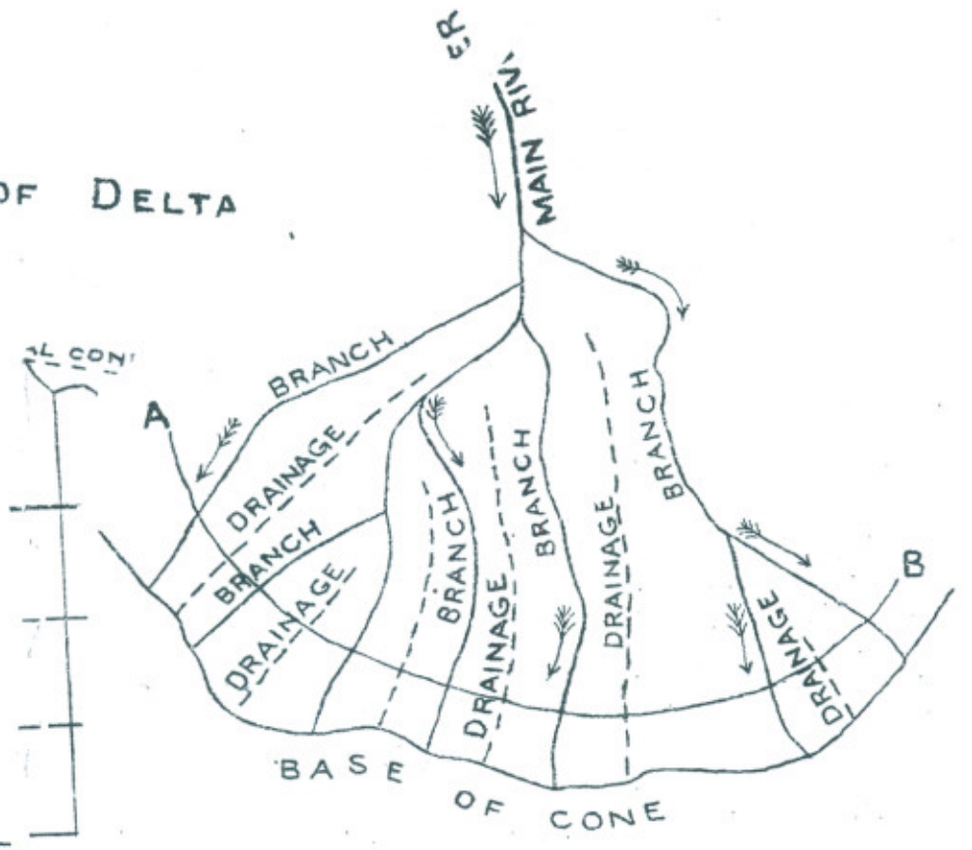


PLATE 4

PLATE 3

SKETCH
SHOWING
TYPICAL DELTAIC FORMATION

LAN OF DELTA



CROSS SECTION OF DELTA ON A.B

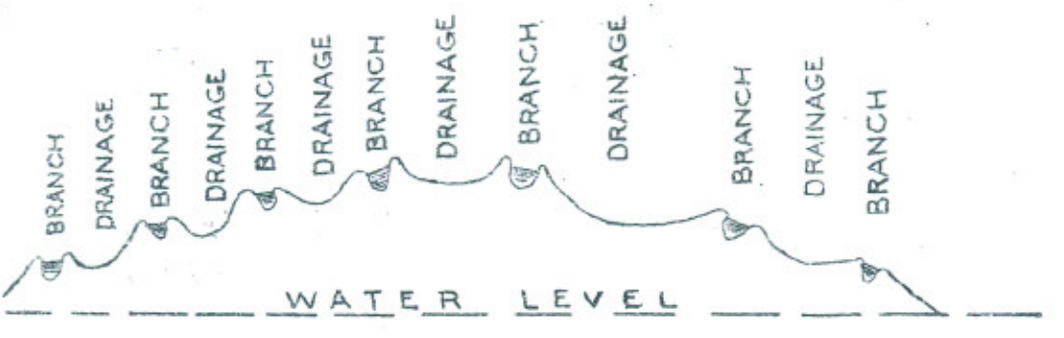


PLATE 4

CROSS SECTION I.K

RAVI - SUTLEJ DOAB

SCALES { HOR: 1 IN = 12 MILES
VER: 1/300

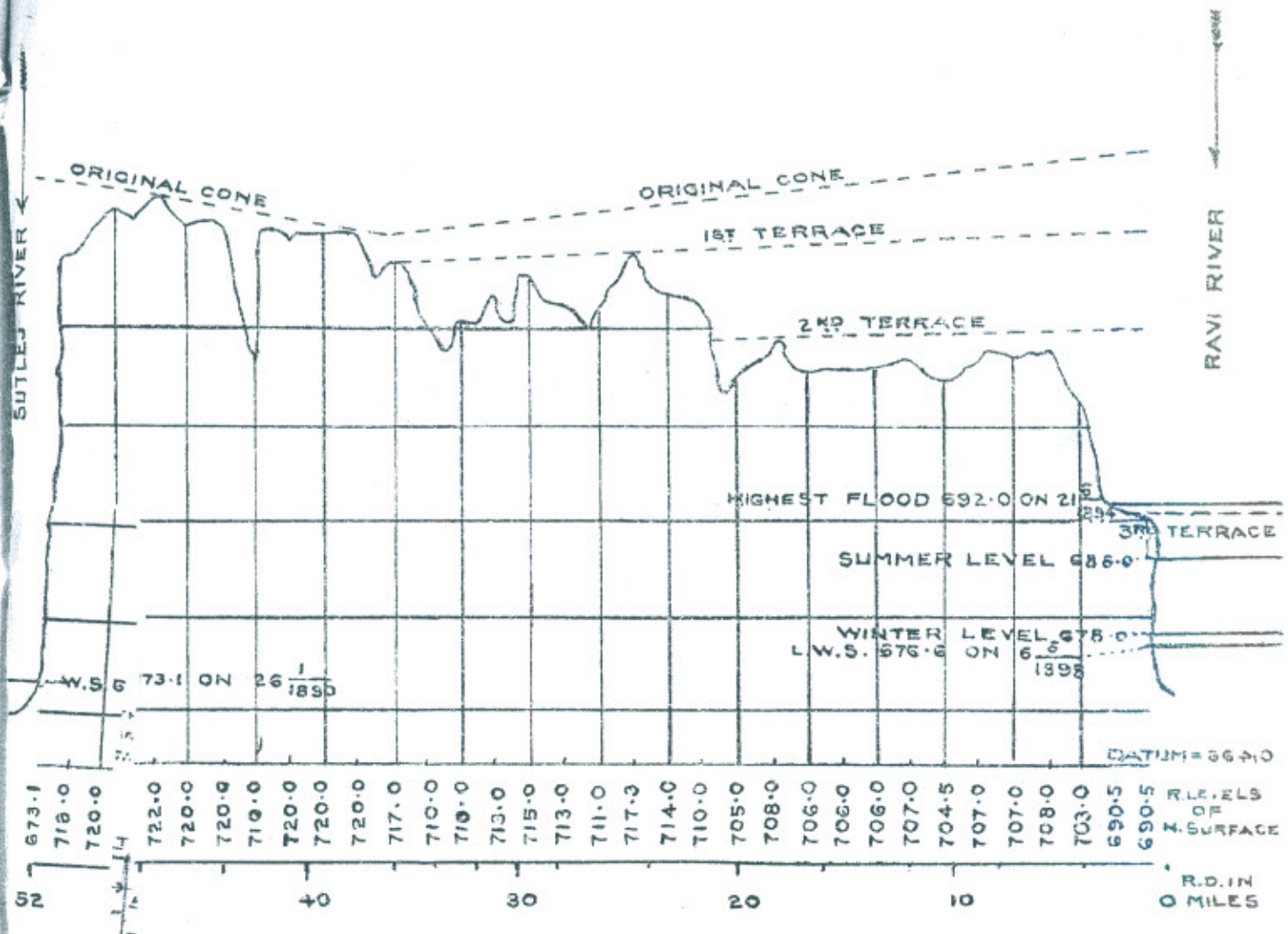


PLATE 5

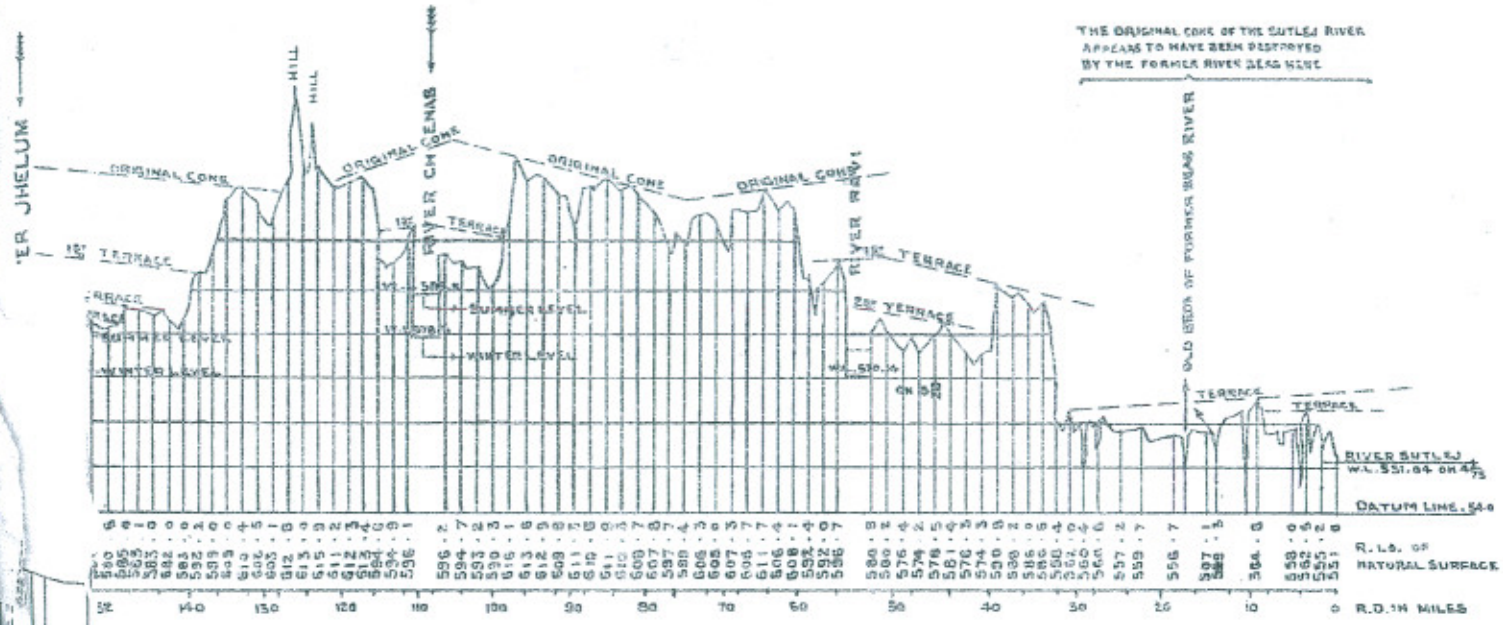
CROSS SECTION

THROUGH

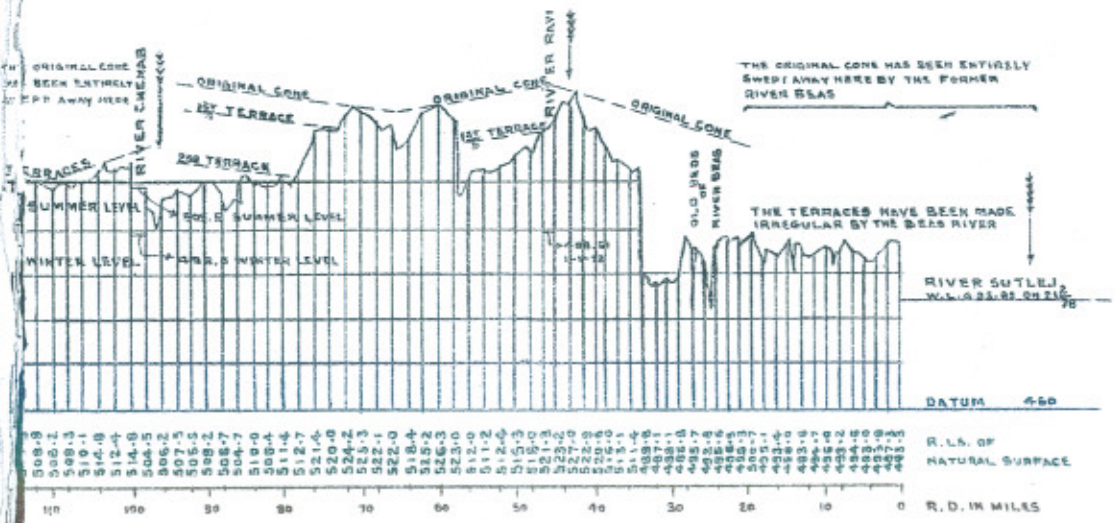
SUTLEJ-RAVI RAVI-CHENAB & CHENAB-JHELUM DOABS

SCALES { HOR: 1 INCH = 24 MILES
VER: 1/500

CROSS SECTION MARKED A.B.C.D. ON PLAN



CROSS SECTION MARKED E.F.G.H ON PLAN

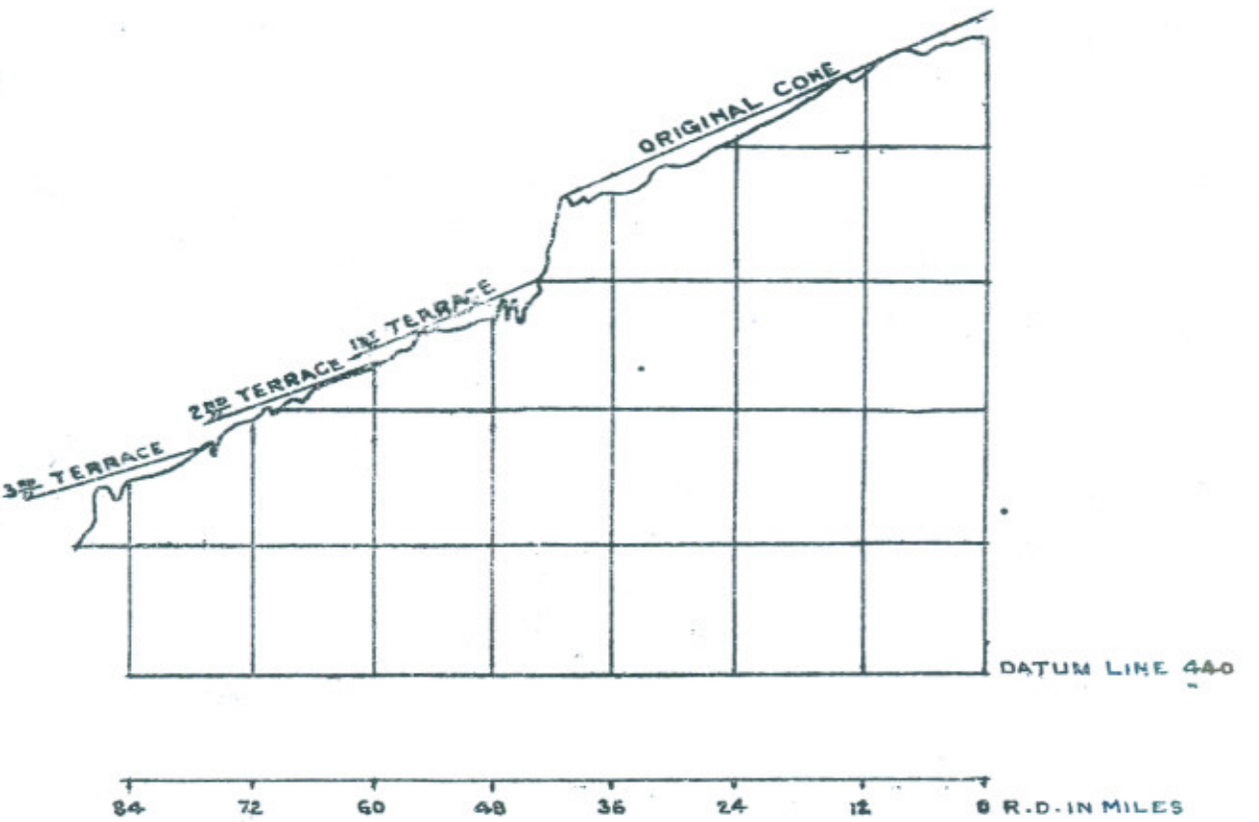


CHENAB JHELUM DOAB

LONG^{L} SECTION DOWN DOAB ALONG DOTTED LINE L.M

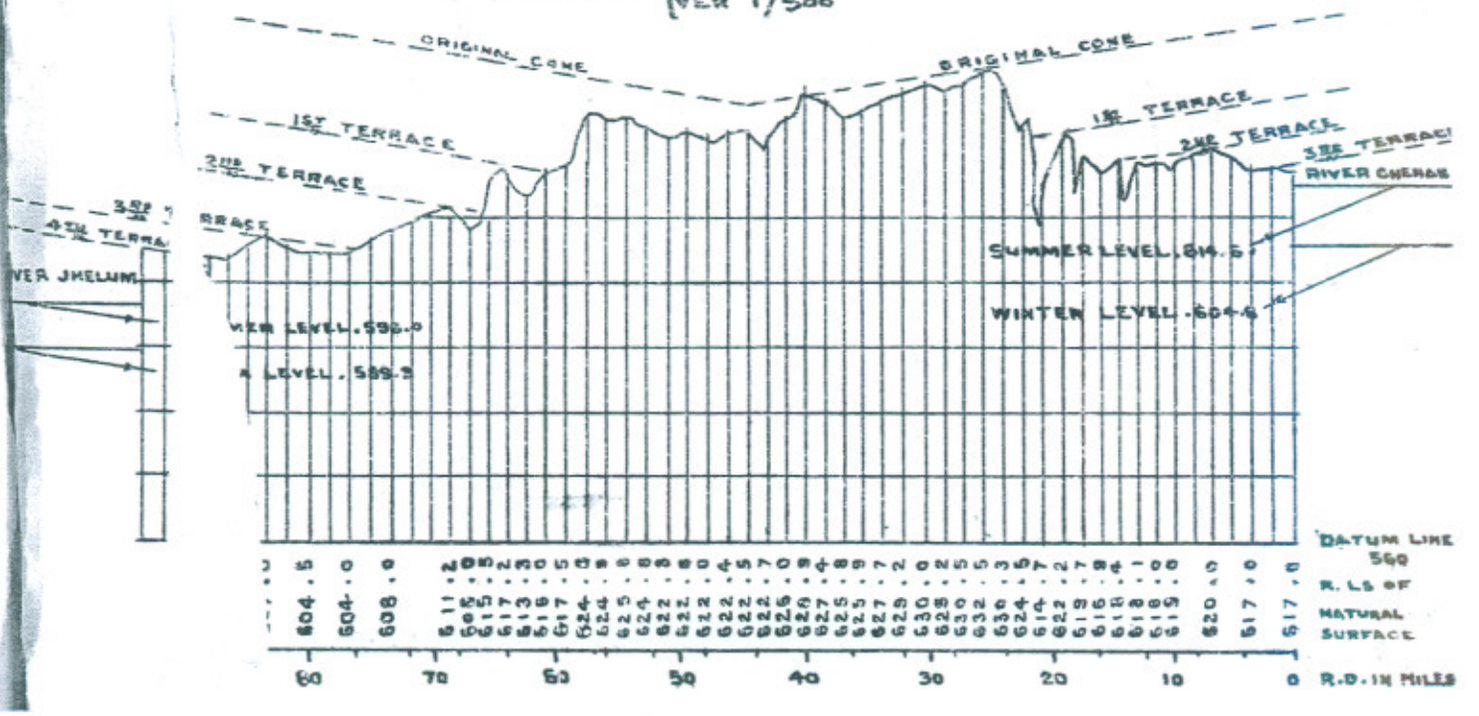
SHOWN IN PLAN

SCALES { HOR 1 INCH = 24 MILES
VER 1/1000



CROSS SECTION No 1

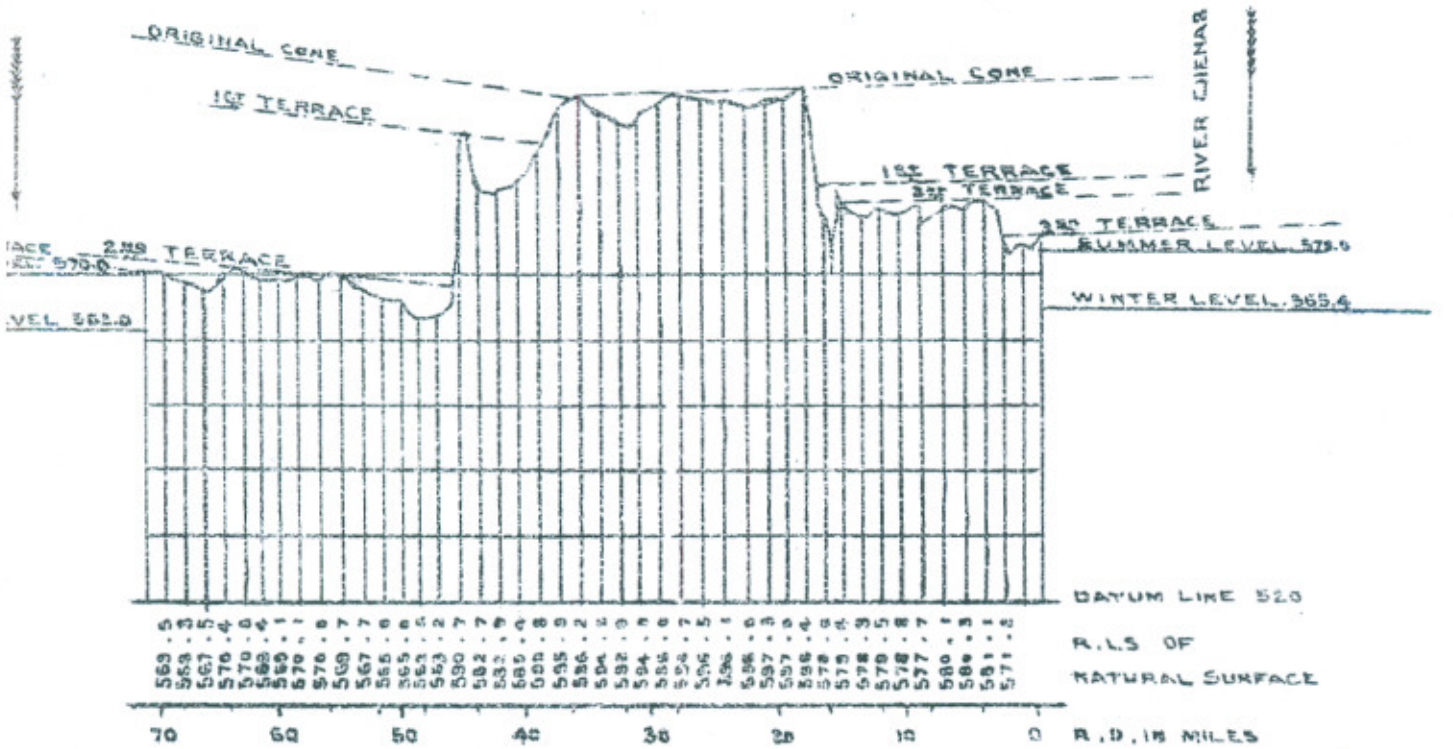
SCALES { HOR 1 INCH = 24 MILES
VER 1/500



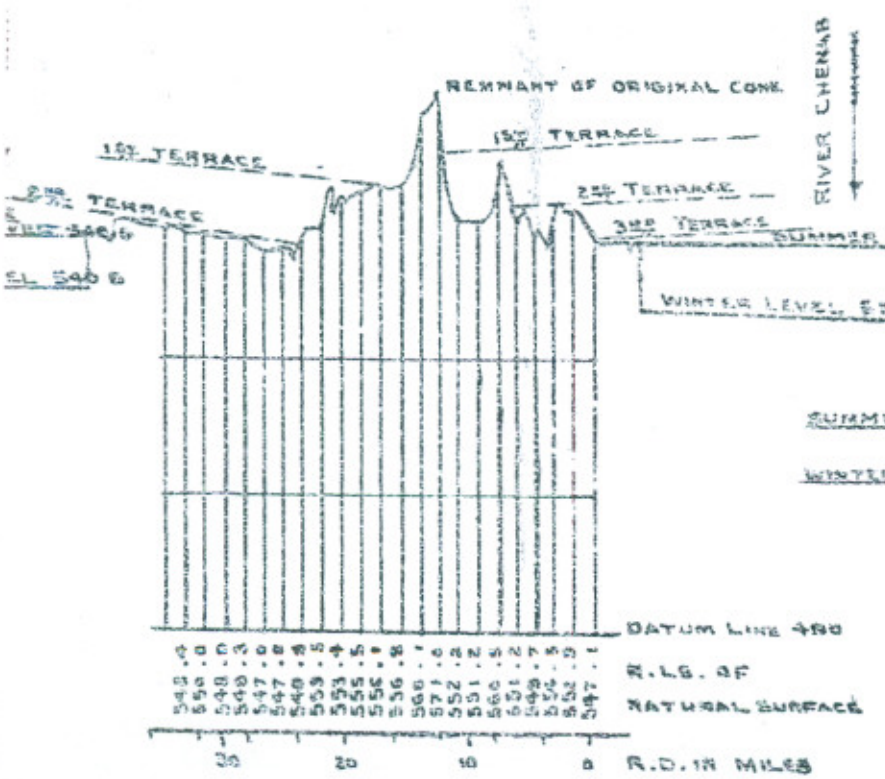
JHELUM CHENAB DOAB

CROSS SECTION No. 2

SCALES { HOR 1 INCH = 24 MILES
VER 1/500



CROSS SECTION No. 3



CROSS SECTION No. 4

