3

GEOMORPHOLOGY

CHAPTER 3

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GENERAL

The river Mahi originates from the hills of Madhya Pradesh near Gomanpur at an altitude of about 556 m and flows in a SSE-NNW direction. Draining parts of southwestern Rajasthan, it enters Gujarat near Khedapa in Panchmahal district. In Gujarat it flows in SSW direction and debauches into the Gulf of Cambay. The total area of the Mahi river is around 31,500 km^2 of which 12,050 km^2 falls within the limits of Gujarat. The total length of the Mahi channel is about 500 km from its source upto its mouth. It flows for a considerable distance through a rocky terrain before it enters the alluvial plains. Within the limits of Gujarat state the channel length is around 275 km, of which the upper 165 km is located in the rocky terrain while in the lower reaches the river flows for around 110 km cutting across the Quaternary continental sediments.

The entire Mahi basin shows an array of geomorphic features, which are the reflections of various interrelated processes, depositional, erosional, tectonic and eustatic fluctuations of the late Quaternary. These processes related to tectonism and palaeoclimatic oscillations have given rise to a polygenetic landscape (Bedi, 1978). The investigations carried out by the present author have amply established that the evolutionary history of the Mahi river basin was a complex one involving an early phase of deposition during upper Quaternary followed by tectonic activity that caused a major drainage disruption and development of new river channel.

The Mahi channel reflects a strong structural control, both in the hard rock terrain as well as in the alluvial plains, and the various structural lineaments have helped in the evolution of the river and in the sculpturing of the numerous geomorphic landforms falling within the environs of the river basin. The regional slope of the area is WSW to SW, while the present day channel flows in a SSW direction. This unique behaviour of Mahi throws important light on its evolutionary history. Evidences point to the fact that originally, after emerging from the rocky areas in the east the river flowed due WSW (perhaps following the course of the present day Shedhi river), subsequently changed to follow its course. The Mahi today typically flows along a late tectonic lineament, cutting across and dissecting older fluvial sediment succession. A succession of tectonic events at all stages of the evolution of Mahi river basin has not only significantly modified the river course, but in combination with factors of climate has imparted diversity to the various landforms and topographic features.

The part of Mahi basin in Gujarat on which this study dwells, comprises the following major geomorphic zones (Plate 3.1) :

I. Rocky uplands in the east and north-east (~ 3600 km^2.)

II. Alluvial plain occupying the median part (~7200 km^2)

III Coastal zone (~1250 km^2)

These geomorphic zones are characterised by their distinctive channel morphology. Each of the three zones across which the Mahi river flows show a clearly defined channel, following a zig-zag course with a major portion marked by

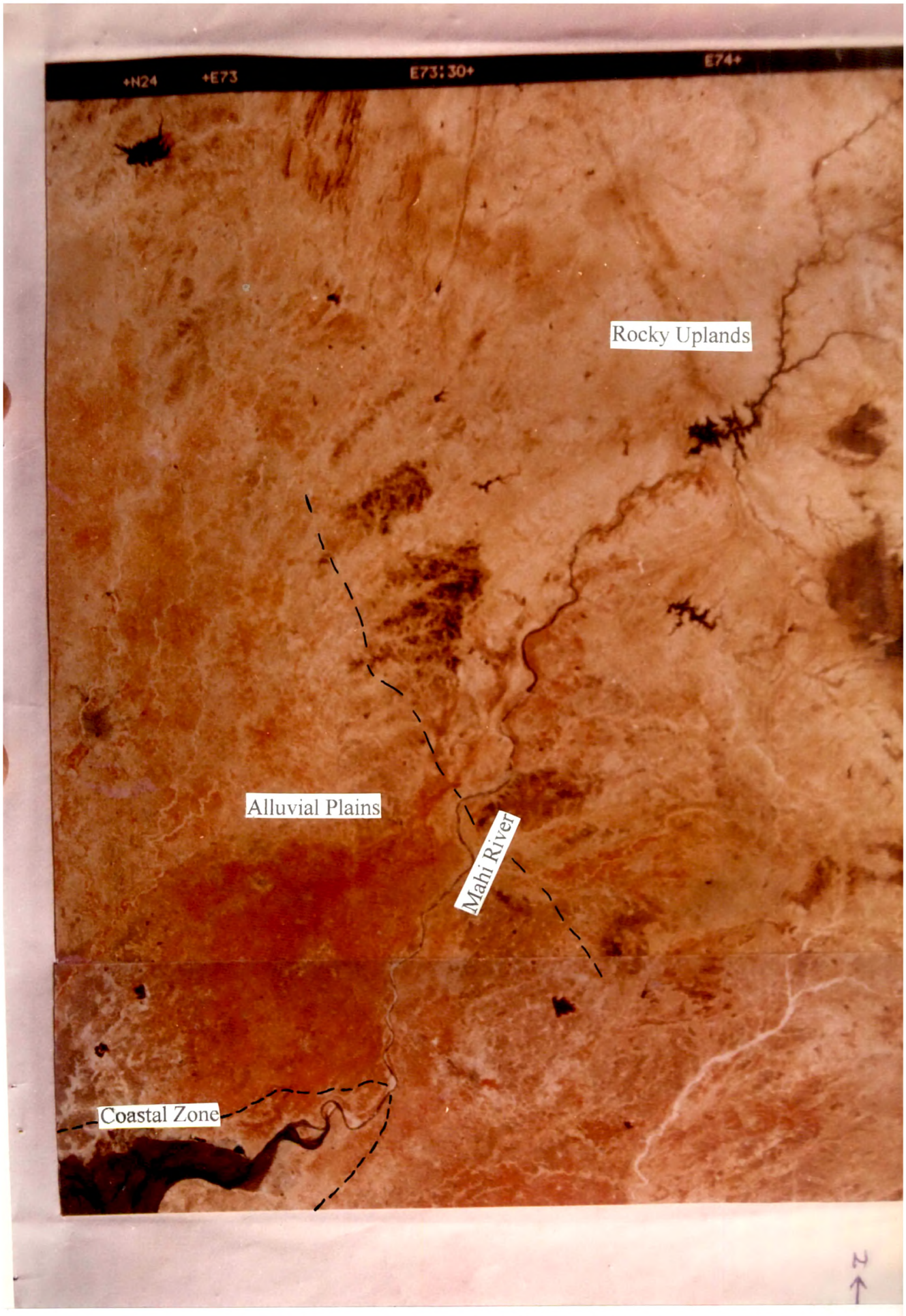

Plate 3.1: IRS FCC image (Band 4) of Mahi basin and adjoining areas, showing major geomorphic features.

a ravine topography. The channel characteristics of Mahi reveal strong tectonic control.

ROCKY UPLANDS

The rocky uplands in the east and northeast through which the river flows comprise rocks dominantly of Proterozoic age viz. Aravalli metasediments like quartzites, phyllites, schists, with associated granites. Along with these occur the Deccan Traps of Cretaceous age (Merh, 1995). These rocks have imparted considerable ruggedness to the terrain. The uplands show a gentle slope that varies between WSW to SW direction. The regional elevation of the uplands ranges between 450 m - 100 m, while between 255 m - 304 m near Kadana, 105 m - 136 m near Balasinor and Vanakbori, 94 m -114 m near Shihora and 80 m -148 m near Kalol, represents denudational features formed due to early erosional processes, being product of tectonism and climatic fluctuations during Quaternary period. These denudational landforms are marked by extensively folded linear hogback ridges of quartzites (Plate 3.2), which at places show rounded tops, at places are marked by escarpments (Plate. 3.3). These tightly folded ridges show sets of several joint patterns trending NNE-SSW, NNW-SSE, N-S and E-W. The NNW-SSE trending Rakhabdev Lineament passing through the area has had a significant geomorphic control on the terrain. The landforms and the channel morphology match well with the structural pattern of the area. The present day channel shows development of point bars, steep cut escarpments in the rocky area, ravines and

Plate 3.2 : Panoramic view of Hogback ridge trending NNE-SSW near Santrampur.

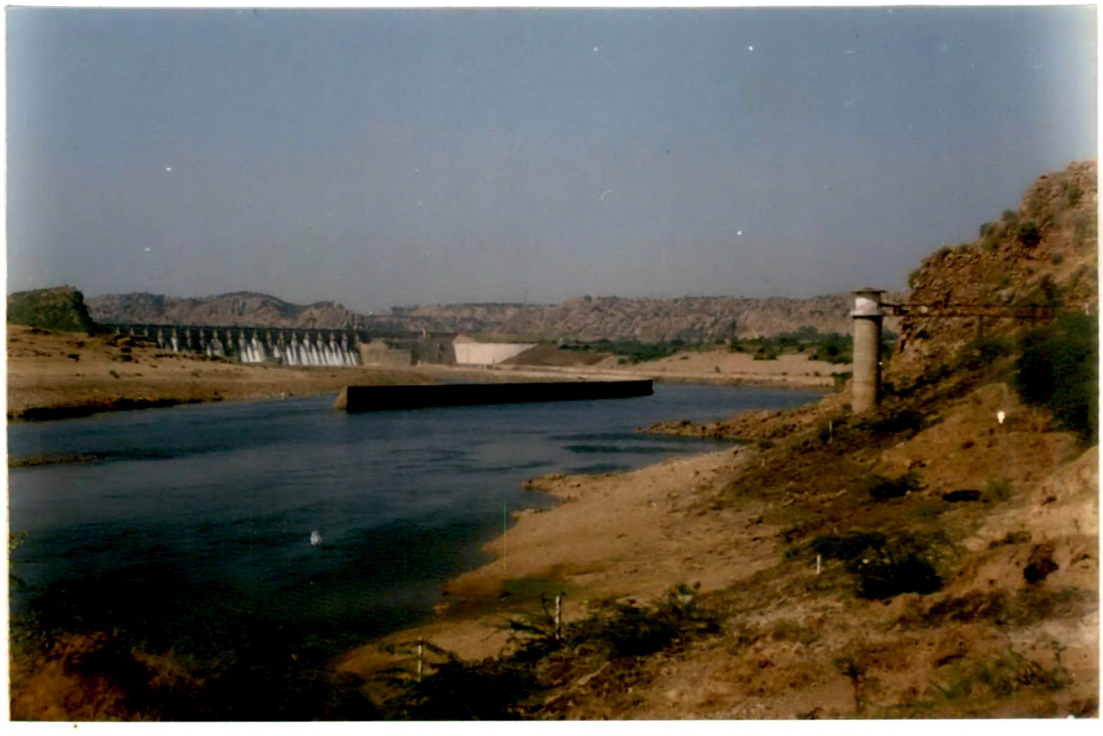

Plate 3.3 : Hogback ridge showing escarpment near Kadana.

channel cut-off. The Quaternary deposits are confined to the valley portion overlying the quartzites, granites, phyllites and schists of Precambrian age, while in the lower reaches they rests over the Deccan basalts of Cretaceous age. These alluvial sediments comprise mainly semi-consolidated silts, sands and gravels.

The present day river channel has incised Quaternary sediments forming cliffy banks ranging in height from 15 m - 30 m. The exposed sediment succession in the cliffs show well developed buried soils and at places are capped by the aeolian sediments. The fractures related to the Precambrian trends have controlled the flow of the channel and its tributaries. The NNW-SSE and E-W trending lineaments and related fractures played important role in the evolution of the present day landforms in the uplands. The Quaternary tectonism that shaped the basin is well evidenced by several geomorphic features (Fig. 3.1). The reactivation of E-W trending fractures caused truncation of the meander loop giving rise to an abandoned channel cut-off near Kadana. The major tributaries that join Mahi on its left bank are Anas and Panam rivers, while Jakam, Som and Erau river join on right alongwith some other smaller streams. The rocks are extensively folded and faulted. Most of the tributaries as also the uppermost portion of the main channel in the uplands show distorted meanders and a rectangular drainage pattern; the tributaries and streams joining the Mahi at almost right angles, or take U-turns before joining it. This type of drainage pattern typically indicates that they flow along the fold troughs or faults or joints and ideally reveal the structural control (Howard, 1967; Pant and Chamyal, 1990). The main channel of Mahi as also those

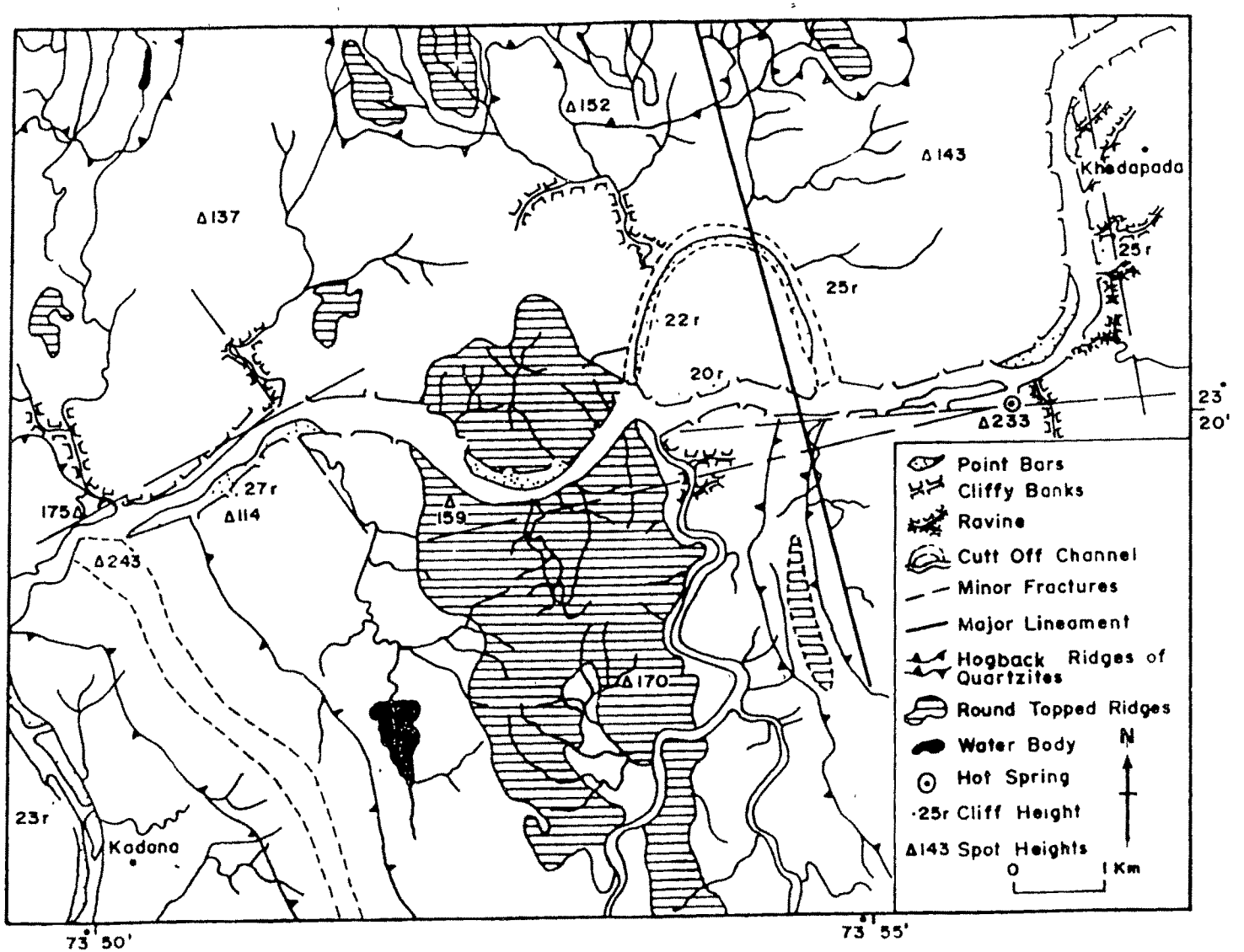

Fig. 3.1 : Morphotectonic map of the uplands around Kadana.

of its major tributaries Anas and Panam show interesting sequence of horse-shoe shaped trends during their flow within the rocky terrain. This feature very ideally illustrates development of river channels along three lineaments namely NNW-SSE, NE-SW and NNE-SSW, the last one conforming to this new trend of Mahi. This phenomenon is confined to the rocky portion only and is not seen in the alluvial plains.

ALLUVIAL PLAINS

The lower part of the Mahi flows across the alluvial plains for a distance of 80 km starting from Shihora and extending upto Umeta, where it comes under the influence of the coastal marine processes (Fig. 3.2).

The channel cuts the alluvial plains in a zig-zag manner consisting of bends and curves simulating meanders. All along, the river course is characterised by steep cliffy banks exposing sedimentary sequence. The channel has an altitude of 60 m at Balasinor where it emerges from the rocky terrain and progressively falls to almost 20 m at Umeta. The present day Mahi carries insignificant sediment load except during floods when some debris comes from the hilly provenance and the rest consists of eroded bank material.

The river at present exhibits an asymmetrical basin development, such that it has no tributaries on the right banks; only a few streams meet the river on the left bank. The major tributaries that join Mahi on the left bank are Karod and Mesri river joining near Shihora and Mini river at Singrot, while other small streams that

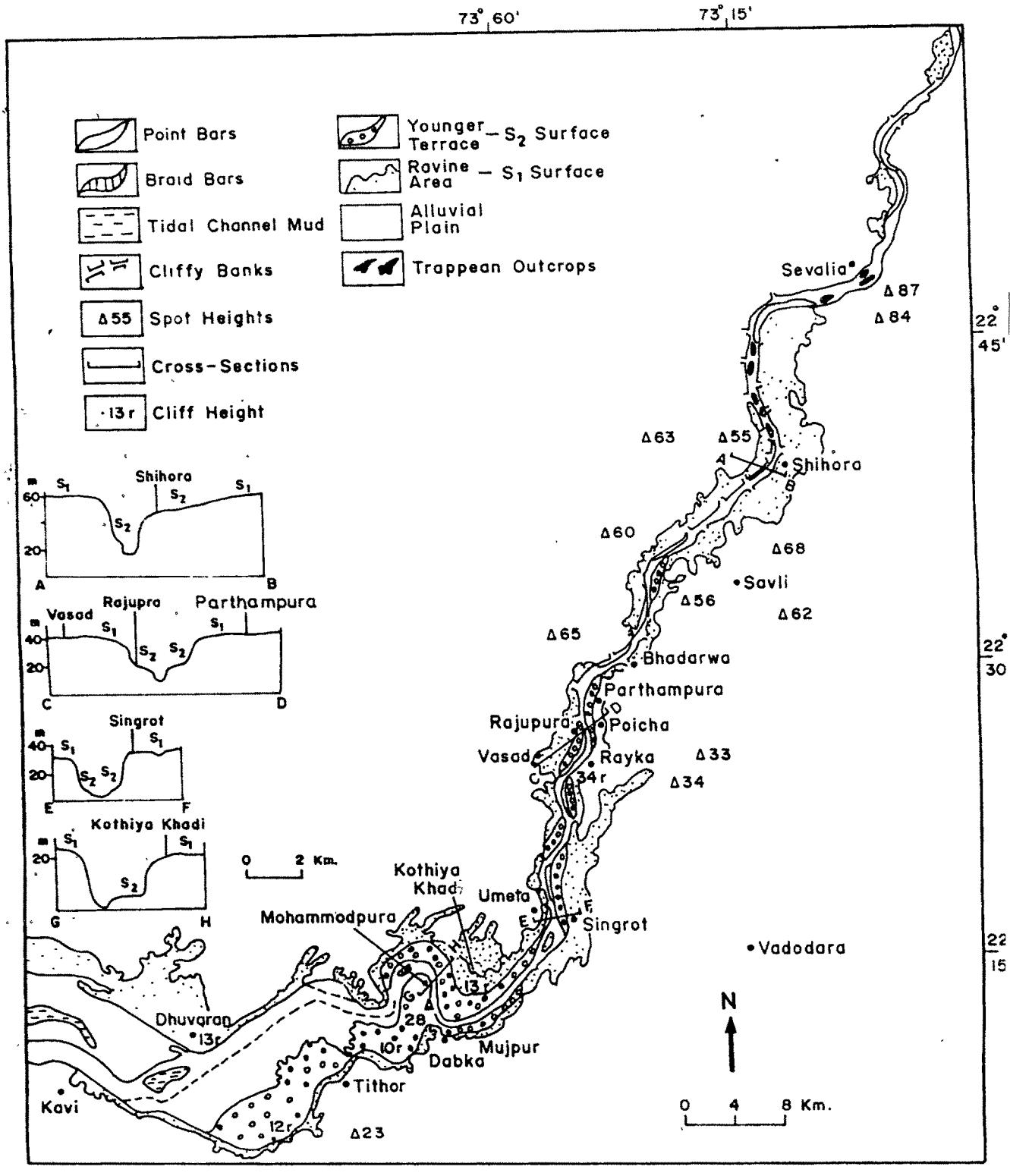

Fig. 3.2 : Geomorphic map of the alluvial plain and the coastal zone.

meet Mahi on its left bank are Desma Nadi near Bilitha, Kun Nadi and Mahia Nadi near Bamna.

The youngest geomorphic landforms are both erosional and depositional. They include depositional features like point bars, sand bars, braid bars and distinct unpaired terraces. The erosional processes has given rise to cliffy banks and gully erosion marked by a badland topography developed due to headward erosion by the smaller streams. The badland topography is characterised by the branching networks of minor tributaries and related streams. The ravines comprise a very prominent erosional feature of the alluvial plains; they extend even upto the coastal zone. In alluvial plains, the gully erosion downstream of Balasinor seen on both the banks, but dominantly it is seen on the left bank. Around Shihora on the left bank the ravines extend inland upto 1.5 km to 2 km from the bank, and show typical linear trends in NNE-SSW, N-S and NW-SE, that confirms the control of regional fracture trends.

The Mahi basin sediments show two distinct surfaces, which have been categorized on the basis of their diagnostic geomorphic features (Fig. 3.2). The older aggradational surface representing the main aggradational fluvial phase over which aeolian deposition took place. Near the banks of the river within the valley portion it is marked by highly dissected ravine erosion. This surface marked by badland topography is categorized as S_1 surface, that represent the degradational phase which was affected by the gully erosion process giving rise to 3 m to 18 m high gullies (Plate 3.4). This surface S_1 must have developed due to steep cutting of

Plate 3.4 : View of older aggradational surface showing deep ravines near Singrot.

older aggradational surface by the present day Mahi channel flowing along the new fractures and related tectonic uplifts which is well indicated by the deep headward gully erosion. It appears that the present day channel was responsible for the deposition of the surface- S_2, in the form of bank attached bars which marks younger the aggradational phase. Later due to subsequent uplift and related incision by the bank attached bars formed unpaired terraces confined to the convex banks of the present day channel and ranging in height from 3 m - 8 m (Plate 3.5). This S_2 - surface is not affected by the ravine erosion. The landforms of this segment have been categorized on the basis of diagnostic geomorphic features as under :

Description of Geomorphic landforms	Average elevation in m from the river level	Surface
Unpaired terraces devoid of ravine erosion occurring on the convex banks of present day channel meanders.	3.5-8	S_2
Highly dissected surface marked by ravine erosion (badland topography) occurring along the valley.	20-35	S_1

COASTAL ZONE

This segment marks the funnel shaped estuarine river mouth. It comprises a drowned valley occupying an area of about 1250 km^2 (Plate 3.1). Its tidal limit broadly extends upstream upto the village Singrot, and during very high tides, sea water travels upto Angadh. This part of the Mahi river is characterised by cliffy

Plate 3.5 : Panoramic view of of S_1 and S_2 surfaces at Kothiyakhad.

banks on both sides ranging in height between 7 m - 8 m. The main part of the present day channel is seen cutting an older fluvial sediment succession. This coastal segment which more or less forms the unusually wide E-W trending estuary may represent the mouth of an older river that deposited the main bulk of the sediments seen in the cliffy banks (S1 surface). Sedimentary structures, especially depositional current directions points to a west flowing river to have formed this estuarine river mouth. Two well developed sand bars, one of about 2.5 km in length and 0.75 km wide near Umeta, and the other 1.5 km in length and 0.25 km wide near Mohommadpura characterize the river mouth. This sand bar is confined by numerous straight to meander tidal channels. This type of funnel shape and straight-meander-straight morphology is typical example of tide-dominated estuary. It resembles the model envisaged by Dalrymple *et al.* (1992), according to whom a funnel shaped geometry develops when there is a rapid filling or sedimentation in a deeper and wider parts, under both river and marine influences.

The features related to the present day channel are mostly depositional. They consist of a younger set of fluvio-marine terraces (S_2 surface) and channel sand bars, that rise 1 m - 2 m above the present day high-waterline. The actual river channel tends to become increasingly tidal, gets dissected into straight to meandering tidal channel and flows within the tidal flats. This last feature is more or less confined between the high and the low waterline. Also the occurrence of younger surface (S_2) in the form of terrace is confined to the convex banks of the present day channel. Sediments of this (S_2) surface suggest that they were deposited

under fluvio-marine and marine (mainly tidal) environment and consist mainly of very fine sand, silt and mud. This younger terrace is seen well developed between Singrot and Kavi marked by tidal sedimentation. This surface is comparable with the (S_2) alluvial terrace in the upstream.

Striking occurrences of relicts of an abandoned channel belonging to the older river are ideally seen around Singrot, Kothiyakhad, Mohommadpura and Jaspur. The older aggradational surface (S_1) and younger terrace (S_2) is well seen at Kothiyakhad (Plate 3.5). This abandoned channel is about ~500 m wide and is marked by 3 m to 4 m high cliffs. From this relict channel pattern, clearly the straight-meander morphology matches well with the present day channel. From the satellite imageries, topographical sheets and field check it is seen that the channel segment from Singrot further downstream migrated southwestward by 1 km to 2.5 km. This shifting could be related to the formation of the new Mahi channel.

DRAINAGE CHARACTERISTICS

The present day Mahi basin morphology has preserved relicts of the older channel. The channel flow directions in the rocky terrain has not changed much but the sediment record and palaeocurrent data of the exposed Quaternary sediments in the alluvial plain suggest that the present day channel was not responsible for the deposition of the older aggradational surface.

The Mahi basin exhibits two distinct surfaces (Fig. 3.3) and the channel has incised the Quaternary succession in the form of high cliffy banks in alluvial plain.

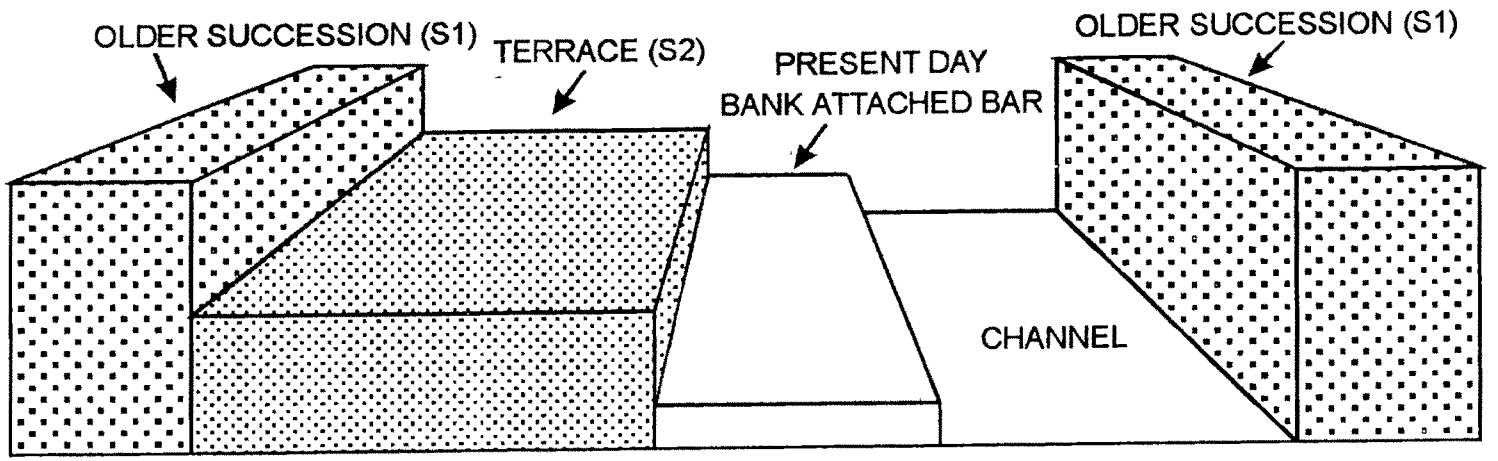

Fig. 3.3 : Schematic diagram showing evolution of older (S_1) and younger surface (S_2) in the Mahi valley.

From the morphology of the S_2 - surface (younger terrace) it appears that this terrace is characterised by aggradational as well as the degradational features of the present day channel. This S_2 - surface occurs in the form of cliffs ranging in height between 3.5 m - 12 m in alluvial and the coastal zone and are confined to convex banks.

The river channel shows moderate to high sinuosity (1.25) with low gradient, flows in a flat valley ranging in width between 0.5 km to 1.5 km. The channel width in the uplands is narrow, ranging between 0.5 km to 0.65 km. In the upland the Mahi river in Gujarat shows flow trends NNE-SSW, ENE-WSW, N-S and NNW-SSE, where NNE-SSW and ENE-WSW are the major flow trends, and the tributaries join from both the banks (Fig. 3.4). The tributaries that join Mahi from its right bank are Erau and Som. The Erau river flows in a NNE-SSW direction, a trend almost opposite to that of the Mahi, before joining it, while Som river flows almost W to E and swings to SE (with its tributary Jakam) joins Mahi near Jogpura. Near Jogpura the Mahi after flowing due SSE-NNW, swings due NNE-SSW.

The other two major tributaries in uplands that join Mahi on its left bank are Anas and Panam, both these rivers follow the trend of Mahi i.e. SSE-NNW and then swings due NNE-SSW direction. The Anas river joins Mahi near Khedapa, having a channel width of about 0.35 km. The Panam river meets Mahi near Lunavada, having a channel width of about 0.25 km flows in an angular manner, at places it flows at almost right angles. Downstream of Lunavada Mahi channel

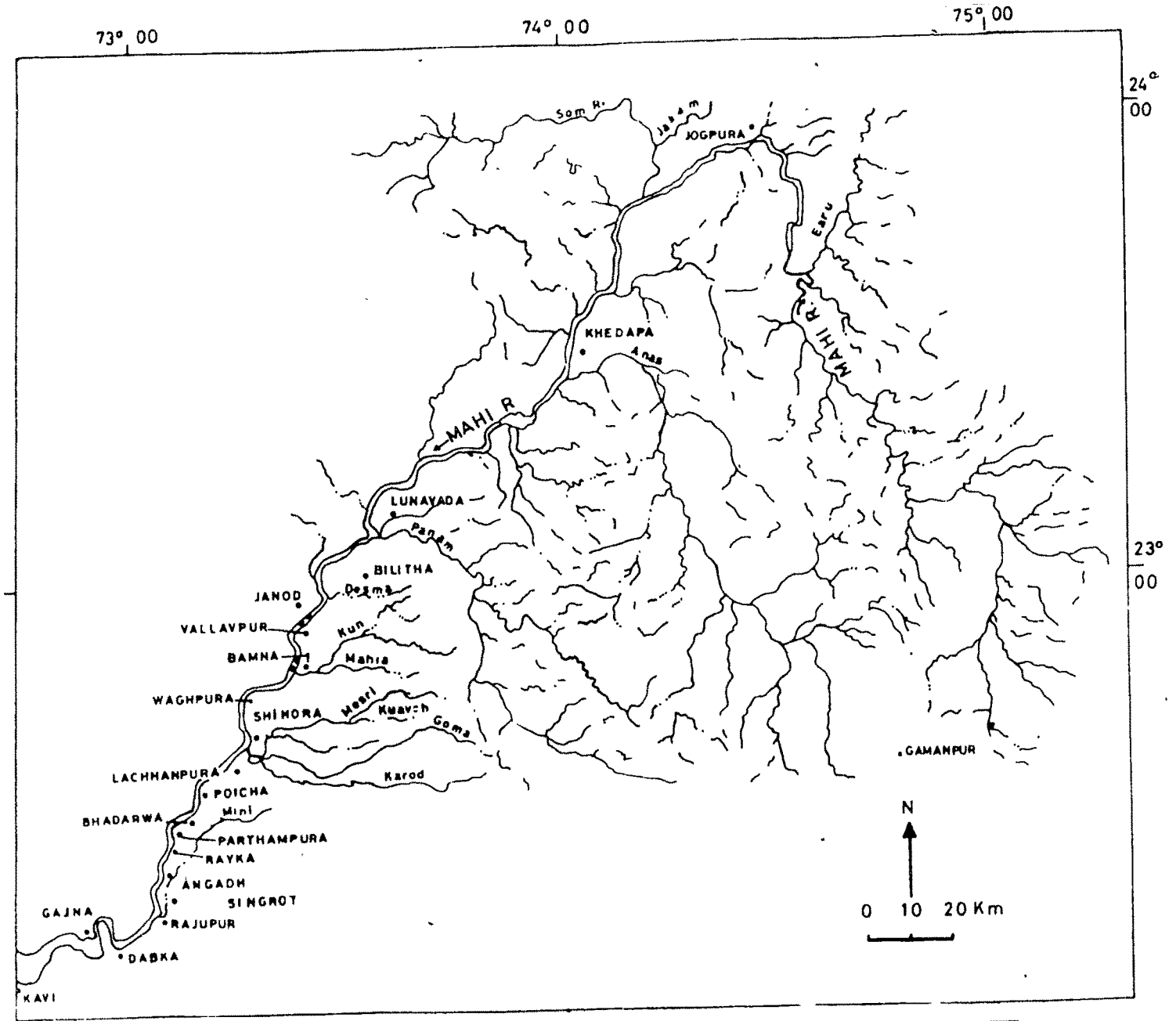

Fig. 3.4 : Drainage map of Mahi Basin.

becomes broader. Near Janod on the right bank a well developed shoal is located, which is about 3 km long and 0.25 km wide. The right bank area is slightly elevated, show an elevation of about 100 m which suddenly falls by 20 m near the valley marked by 80 m contour. This elevated portion shows extensive development of ravines which occurs on the convex right bank of the channel. The variation in the altitude and ravine formation suggest a relative upliftment. Near Bilitha, Desma river meets Mahi on its left bank. Little downstream of Janod the river changes its direction and flows towards SSW for a stretch of about 11 km upto Chhapra, and show braidation upto Vallavpur.

Downstream of Vallavpur it starts developing point bars on the alternate convex side of channel. This moderately meandering Mahi channel flowing in NNW to SSE direction also show cliffy banks ranging in height between 12 m - 20 m. At Bamna (located on left bank) Kun and Mahia rivers join Mahi on the left bank at almost right angles. After this confluence Mahi starts flowing in an almost E-W direction and shows well developed braid bars and broad channel width ranging between 1 km -1.75 km for a stretch of about 10.5 km. Again near Waghpura it takes a 90° turn and flows in a N-S direction for about 13 km (Fig. 3.4). Here the area on its left bank shows extensive ravine development. Around Shihora (located on the left bank) two west flowing major tributaries of Mahi, Mesri (0.2 km wide channel) and Karod (0.2 km - 0.25 km wide channel) along with their tributaries Kuvach and Goma respectively meet Mahi after taking 'U' shaped turns. From the extensive ravine topography it appears that the eastern block

has been considerably uplifted. At the confluence, the Mahi channel width is < 0.5 km, but a little downstream near Lachhanpura channel widens to almost 1 km, where well developed sand bars, braid bars and point bars are seen developed. For a distance of about 9 km from Poicha upto Bhadarwa it flows due NNE-SSW. The channel on both the banks between Lachhanpura to Bhadarwa is marked by ravines, but they are not as extensive as seen near Shihora in the upstream.

Downstream of Bhadarwa near Parthampura the channel takes a turn and flows almost in an N-S direction upto Rayka. Between Parthampura to Rayka, the left bank is marked by ravines and cliffs on both the banks show identical heights ranging between 28 m - 34 m. After Rayka upto Phajalpur it flows in a ENE-WSW direction. Similar trend of flow i.e. N-S and ENE-WSW is repetitively seen upto Angadh. The most conspicous feature observed is that downstream of Shihora upto Singrot no tributaries meet Mahi on its either banks (Fig. 3.4). Further downstream of Angadh upto Rajupura the channel flow in NNW-SSE direction. The Meni river, tributary of Mahi, emerging from the trappean highlands in the east flows in a ENE-WSW direction takes turn near Ratyapura and flows parallel to Mahi in N-S trend and joins Mahi at Rajupura. Downstream of Singrot the channel shows well developed shoal in 1.5 km wide channel, but the western portion of the channel exists as an abandoned channel. This part of channel flows almost straight for about 12.5 km upto Dabka in ENE-WSW direction. The channel is broad (1 km wide) and becomes slightly narrow near Dabka. After Dabka, the channel becomes sinuous, for about 11 km upto Gajna. From Gajna the channel shows a funnel

shaped estuary. The width of the estuary at Gajna is about 3.5 km - 5 km and it becomes wider further downstream ranging between 9.5 km - 10.5 km upto Kavi. Here the channel shows well-developed tidal channel bars and braid bars.