अध्ययन प्रतिवेदन

नवीन किच्चा बैराज के उपयुक्त निर्माण स्थल के चयन हेतु किच्छा नदी की रीवर मोर्फोलोजी अध्ययन

प्रस्तावक
मुख्य अभियंता (शारदा), बरेली
सिंचाई एवं जल संसाधन विभाग, उत्तर प्रदेश

राष्ट्रीय जल विज्ञान संस्थान, रुड़की - 247667, उत्तराखंड

दिसंबर, 2024

Report

on

Study of Kichcha River Morphology for Identification of new site for Kichcha Barrage

Study Proposed by

Chief Engineer (Sharda), Bareilly
Irrigation and Water Resources Department,
Uttar Pradesh

NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE – 247 667 UTTARAKHAND
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Study of Kichcha River Morphology for Identification of new site for Kichcha Barrage

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Acknowledgement

The study group at NIH has made its best efforts in carrying out the study entitled **“Study of Kichcha River Morphology for Identification of new site for Kichcha**” carried out on the request of the Chief Engineer (Sharda), Irrigation Department, Bareilly, UP. The study is taken up under the work program of CFMS, Patna for the year 2023-24. The study is based on satellite images and field data and information provided by UPID.

I express gratefulness towards the officials of UPID for providing help and support for the study. The cooperation and logistic arrangement made by the officials during the site visit is of immense help and informative. I am also thankful to the Director National Institute of Hydrology, Roorkee for his support and encouragement to carry out the study.

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1 ABOUT THE PROJECT

1.1 Background

National Institute of Hydrology, Roorkee received a proposal from the Chief Engineer (Sharda), Irrigation Department, Uttar Pradesh (IDUP), Bareilly to carry out river morphology study of Kichha river for identification of new site for Kichha barrage (Annexure-I). The need for new site for barrage has arisen damage of Kichha barrage on 18-19 October 2021. The letter briefly described the event of failure of barrage. The Kichha barrage is located on Kichha river (also known as Gaula/ Gola river) 40 km downstream of the Gaula barrage. The average monsoon flow in Kichha river is of the order of 125000-150000 cusec. CWC has estimated the 1:100 design flood as 113254 cusec (3207 cumecs) and 1:500 design flood as 141258 cusec (4000 cumecs), respectively. On the date of failure, the Gaula barrage discharged 82869 cusecs and aggravated by intense rainfall in the intermediate catchment, the flood level at Kichha barrage reached to level RL 680 ft (207.264 m) which is 6 ft (1.8 m) higher than the design HFL of 674 ft (205.44 m). The IMD recorded rainfall at Naintal, Haldwani and Pantanagar as 401 mm, 325 mm and 403.99 mm, respectively on 18 October 2021. Due to rise of water level above left marginal bund; the left abutment of barrage, head regulator of canal and main canal in a stretch of 100 m was completely washed away. In the above background IDUP has asked NIH to study morphological behaviour of Kichha river for identification of new barrage site in the vicinity of old site. In response, NIH submitted the study proposal with the following scope of work.

1.2 Scope of Study

The morphological study of Kichha river would be carried out that will include:

1. The reconstruction of planform changes using high resolution (spatial resolution <=30 m) historical satellite images for about last 40 years (using Landsat 4 since 1982 and other satellite images onwards, depending on the data availability).
2. The baseline condition for fluvio geomorphological changes would be developed using the earliest possible map/ image. The pre-monsoon satellite images would be used to reconstruct the river morphology and planform dynamics for the last ~40 years at appropriate time intervals.

3. Additional analysis with few specific years’ images would also be used to document the river morphological changes due to the large flood. The specific years would be finalized after checking the data availability in consultation with the project authority (IWRD, UP) officials.

4. Considering the planform dynamics and morphological classification, stable / suitable river reach would be identified for new barrage site.

2 DESCRIPTION OF STUDY AREA

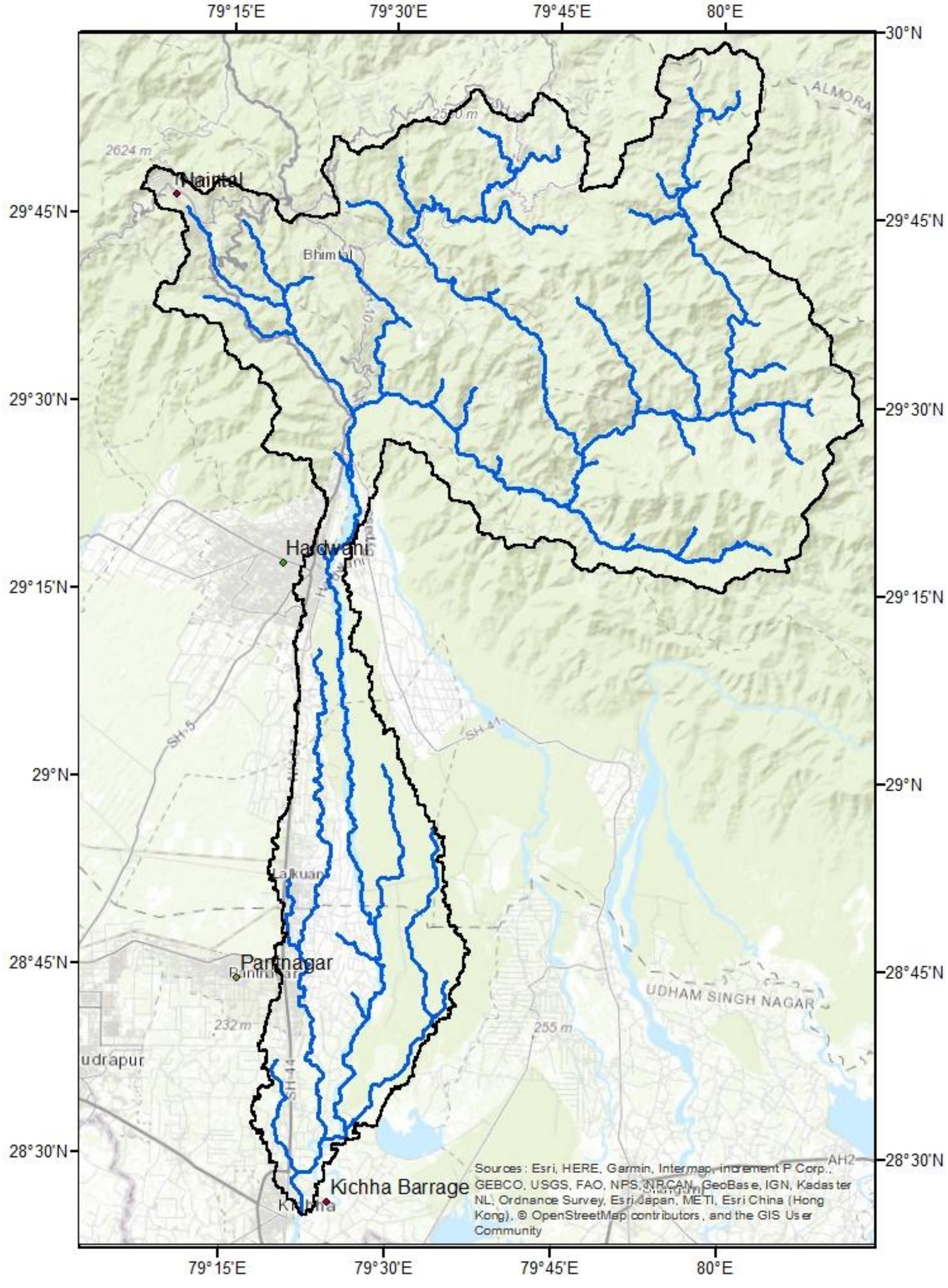
2.1 General

The Kichha river, also known as Gola River, originates in the Lesser Himalayas, of Kumaun hills of Uttarakhand and flows through Kathgodam, Haldwani, Kichha and Shahi, and finally joining the Ramganga River about 15 km northwest of Bareilly in Uttar Pradesh. It is mainly a spring fed river and river Gola is major source of drinking and irrigation water. The Kichha barrage has been constructed in 1964 (IndiaWRIS, 2023) near Kichha town (Kichha Tahsil) in Udham Singh Nagar in Uttarakhand and is used mainly for irrigation purpose. The baragge was function till September 2021. Figure 2.1 shows the Barrage photograph as on March 31, 2021 (source: Internet) and the pre damage condition of the barrage is visible in satellite image dated 27 Feb 2021 as shown in Figure 2.2. The figure shows that each components of the barrage and canal headwork is intact and flow in canal is clearly visible. The catchment boundary map of of Kichha river extracted using ALOS PALSAR online DEM (ALOS PALSAR, 2023) above Kicha barrage is shown in Figure 2.3. The map also shows the location of the rainguage stations in the upstream and location of Kichha barrage. The catchment area is computed as 831.50 km^2. The slope of the longest flow path is computed as (m/m).

Following the heavy rainfall on 18-19 October 2021 in the catchment and release of heavy discharge from Gaula barrage, the left marginal bund of Kichha barrage, head regulator and Kichha canal (partially) is washed away completely. The field photograph of the Kichha dam after the incident is shown in Figure 2.4 while the satellite image showing the extent of damage is illustrated in Figure 2.5.

Figure 2.1: Kichha Dam photographs (courtesy: youtube posted by Yoga & Ayurved, Mar 31, 2021)

Figure 2.2: Satellite image of Kichha Dam (courtesy: Google Earth, Feb 27, 2021)



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), © OpenStreetMap contributors, and the GIS User Community

Figure 2.3: Catchment area map of Kichha river above Kichha barrage.

Figure 2.4: Kichha barrage after the devastating flood event of 19 October 2021.

Figure 2.5: Satellite image showing damaged Kichha barrage as on 26 October 2021.

2.2 Data Used

Satellite images available at USGS and online DEM from EARTHDATA website are used in the study. The details of images downloaded and used in the study are as follows:

Date of Acquisition	Satellite	Sensor	Application
09-12-1993	Landsat 5	Thematic Mapper (TM)	Multispectral image for river bank line delineation
14-10-1996	Landsat 5	Thematic Mapper (TM)	
15-10-1999	Landsat 7	Enhanced Thematic Mapper (EMT)	
23-10-2002	Landsat 7	Enhanced Thematic Mapper (EMT)	
15-10-2005	Landsat 7	Enhanced Thematic Mapper (EMT)	
23-10-2008	Landsat 7	Enhanced Thematic Mapper (EMT)	
13-10-2010	Landsat 7	Enhanced Thematic Mapper (EMT)	
18-10-2012	Landsat 7	Enhanced Thematic Mapper (EMT)	
08-10-2014	Landsat 8,9	Oriental land Imager & Thermal Infrared Sensor (OLI_TIRS)	
29-10-2016	Landsat 8,9	Oriental land Imager & Thermal Infrared Sensor (OLI_TIRS)	
03-10-2018	Landsat 8,9	Oriental land Imager & Thermal Infrared Sensor (OLI_TIRS)	
16-10-2020	Landsat 8,9	Oriental land Imager & Thermal Infrared Sensor (OLI_TIRS)	
27-10-2021	Landsat 7	Enhanced Thematic Mapper (EMT)	
14-10-2022	Landsat 8,9	Oriental land Imager & Thermal Infrared Sensor (OLI_TIRS)	
09-10-2023	Landsat 8,9	Oriental land Imager & Thermal Infrared Sensor (OLI_TIRS)	
09-03-2007	ALOS PALSAR •	L-Band (Hi-Res Terrain Corrected)	DEM for terrain anaysis
08-05-2007	ALOS PALSAR •	L-Band (Hi-Res Terrain Corrected)	

3 METHODOLOGY

3.1 BIS Recommendations Regarding Siting of Barrage

The IS 7720 code of Practice for Investigation Layout and Planning of Barrage describes the various requirement for siting of barrage. The followings are extract from BIS code pertaining to suitable location of barrage and its allied structures:

1. A barrage or weir normally comprises a deep pocket of under sluice portion in front of the canal head regulator on one or both the sides and the remaining river bays or spillway bays separated from the under sluice bays by divide walls. In addition guide bunds on the upstream and downstream of the barrage or the weir and sediment excluding devices such as silt excluders in the barrage and silt ejectors in the canal are provided. Location for a barrage or weir should be decided on considerations of suitability for the barrage or weir proper, the under sluices and the canal head regulators. An ideal location is that which satisfies the requirements for all the three.

2. The river reach should, as far as possible, be straight so that velocities may be uniform and the sectional area of the river remains fairly constant. The banks should preferably be high, well defined and in-erodible. This will obviate oblique approach as well as non-uniform distribution of flow on to the barrage. If such a site is available, it may need very small or practically no guide bunds. In case of high banks, the country side will not be submerged during high floods and a considerable saving in the cost of flood protection embankment can be effected.

3. In the case of a meandering river the barrage or weir should be located at the nodal point. A slight curvature at the site may be advantageous from point of which when located on the downstream end of the outer curvature will have the advantage of drawing less sediment. However cross currents maybe produced due to curvature and may endanger the foundation. Moreover, if canals take off from both the banks, the canal taking off from the inner side of the curve will draw comparatively more sediment. Therefore, proper judgement should be exercised while deciding the location of a barrage or weir in a curvature reach of the river.

4. River training works for barrages and weirs are required to: (a) prevent out flanking of the structure, (b) minimize cross flows through the barrage or weir which may endanger the structure and protection works, (c) prevent flooding of the riverine lands upstream of the barrages and weirs, (d) provide favourable curvature of flow at the head regulator from the point of sediment entry into the canal, and (e) guide the river to flow axially through the barrage or weir.

5. If the river flows in a wide alluvial belt, it is necessary to narrow down and restrict its course through the barrage or weir constructed across it. The guide bunds are constructed to arrest the meandering tendency, obliquity of flow and to maintain deep channels through the under sluice bays adjacent to the canal off-takes. Proper alignment of guide bunds is essential to ensure satisfactory flow conditions on to the barrage. In case of wide alluvial banks the length and curvature of head of guide bunds should be kept such that worst meander loop is wide away from either the canal embankment or the approach embankment. If the alluvial bank is close to the barrage, the guide bunds maybe tied to it by providing suitable curvature, if necessary. If there are any out-crop of hard strata on the banks it is advisable to tie the guide bunds to such control points.

3.2 Regime Theory of Stable Alluvial River Channel

The two extreme channel pattern of the alluvial river are braided and meandering. In the braided river, a network of interconnected threads seperated by island or bars is developed. The flow (water and sediment) is bifurcated and may reunite downstream. In meandering pattern, the river flows through a (primary) single thread that follow curve path. Both patterns can be observed on the same alluvial river at different reaches and may coexist on the same alluvial surface. The alluvial rivers are well-known for pattern transitions in space and time. Some identified drivers for the river pattern change are river slope, river bed material, water and sediment supply, sediment particle size or riparian vegetation (Leopold et al., 1957; Parker, 1976; Schumm, 1985; Tal and Paola, 2007; M´etivier and Barrier, 2012). Several empirical and theoretical studies have been attempted to explain the initiation and development of braided and meandering rivers.

Based on the field observation data of stream slope of various braided and meandering rivers at bankfull discharge Leopold et al. (1957) suggested the following relationship:

$$S_t = 0.06 Q_{bf}^{-0.44}$$

Where, S_t is the threshold slope and Q_{bf} is the bankfull discharge. The rivers having slope more than the threshold slope are braided in nature while lower slope are meandering in nature. Lacey's regime theory states that the width of a natural channel at bankfull flow is proportional to the root of the discharge. The equation is composed of physical and measurable parameters which agree with field observations. The equation hinges on the fact that the velocity at bankfull discharge is a sole function of the bed material. At bankfull discharge the average velocity is no longer a function of the discharge, as is assumed in regime theory. At discharges below bankfull level the stream velocity is a function of the discharge to the power 1/6. There is a bed-shaping flow velocity that has just sufficient power to lift the bottom material to the natural levee. This velocity is a function of the bed material. However at bankfull discharge a singularity occurs where the water slope is forced on the slope of the natural levees. The velocity of flow associated with this slope is fully determined by the bed material, and is independent of the discharge. Above bankfull level a new situation occurs, with a different slope (the valley slope), a different width (the valley width) and a new stage discharge relation. For stages below the bankfull level the equilibrium cross-section, where B and h are directly proportional to each other, does not occur. It is possible that within the river channel different (combinations of) temporarily stable cross-sections occur with a total stream width smaller than the bankfull width, i.e. the width that corresponds with the bed-shaping discharge. Cao and Knight (1996) presented that width B; average depth h and average flow velocity over the cross-section U are power functions of the discharge with the following exponents: 0.5, 0.33 and 0.17. The first corresponds with Lacey's equation; the second follows from the combination of Lacey's equation with Chezy's equation (stating that the flow velocity U is proportional to the root of the depth of flow h); and the third follows by definition (Lacey et. al., 1963). Cao and Knight (1996) presented that width B; average depth h and average flow velocity over the cross-section U are power functions of the discharge with the following exponents: 0.5, 0.33 and 0.17. The first corresponds with Lacey's equation; the second follows from the combination of Lacey's equation with Chezy's equation (stating that the flow velocity U is proportional to the root of the depth of flow h); and the third follows by definition Q=BhU.

Schumm and Khan (1972) and Paola (2001) reported that bedload is the major driver for river pattern transformation and the stream slope seems to act as a dependent variable rather than an independent one. Further investigation reported that sediment size is an important parameter that controls the pattern changes of alluvial rivers (Osterkamp and Hedman, 1982; Carson, 1984; and Ferguson, 1987). The study suggested that the majority of rivers that are composed of fine-grained sediments are likely to meander, while rivers composed of coarse-grained sediments are often braided. Gaurav et al., 2014 carried out field measurement and satellite based studies for Indian rivers originating from Himalaya. The field measurements of width, depth, slope and discharge across individual threads of braided and meandering rivers shows that trends of the scaling relationships are well predicted by the threshold channel theory. Further, the study used the satellite images to obtain a reasonable estimate of the formative discharge of rivers which are comparable to the mean annual discharge from historical records of gauging stations.

3.3 Hierarchical River Classifications

Recent approaches for river classification focus on watershed analysis related to land management and stream restoration, using a hierarchical approach that nests successive scales of physical and biological conditions and allows a more holistic understanding of basin processes. One of the most widely used hierarchical channel classification systems was developed by Rosgen (1985, 1994, 1996) for mountain basins. His approach involves four scales of analysis, ranging from broad-scale delineation of landform and valley type to small-scale measurements of physical processes (e.g., bed load transport, bank erosion) and biological inventories (vegetation, aquatic organisms). In practice, the classification is focused on delineating reach-scale morphologies and recognizes eight major stream types based on entrenchment (ratio of floodplain width to channel width), width-to-depth ratio, and sinuosity (Figure 12). A sinuosity range straight 1.1, sinuous 1.1–1.5, and meandering >1.5 (Leopold et al., 1964). A primary goal of the Rosgen (1994, 1996) method is ‘‘natural channel design’’ for use in stream restoration. The lower the entrenchment ratio, the more vertical containment of flood flows exists. Higher entrenchment ratios depict more floodplain development.

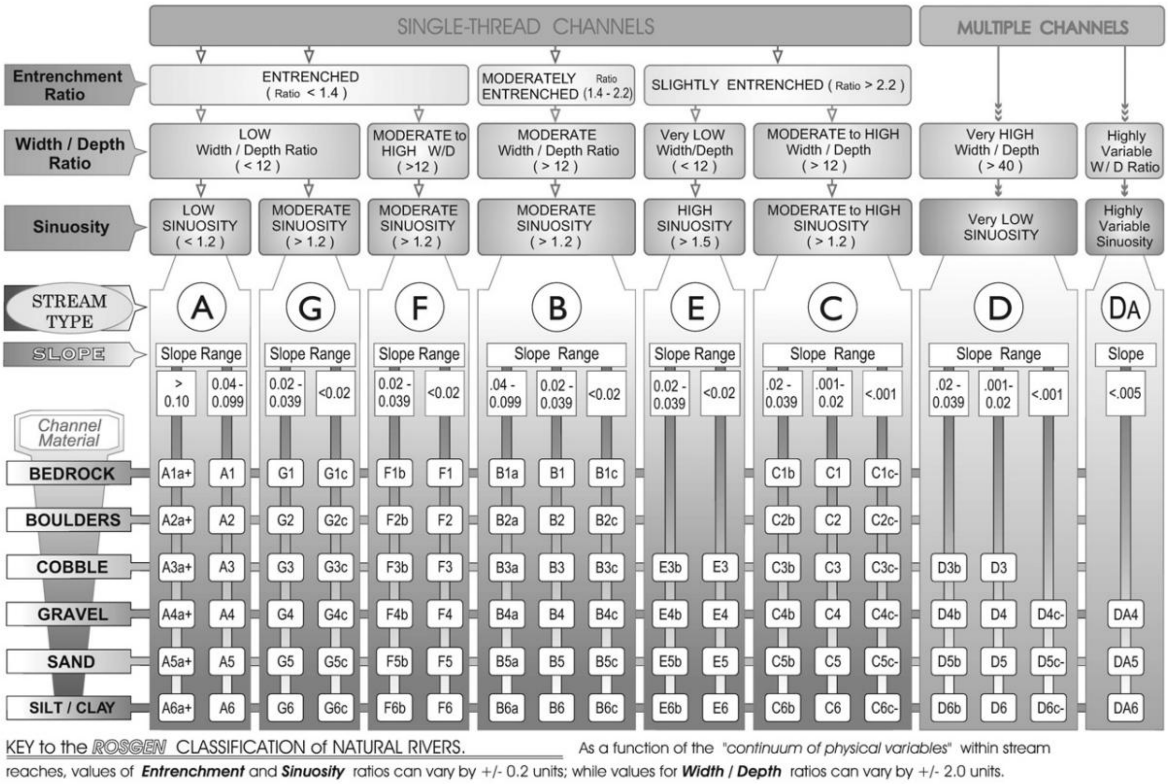


Figure 3.1: Stream type classification as proposed by Rosgen (1994, 1996b)

3.4 Study of River Morphology

The temporal shifts of alluvial river channels and river erosion have been the core areas of study in geomorphology. The measurement of riverbank line and channel shifting are made using various methods, such as using historical river planform map analysis, periodic cross-section profiling, erosive pins and sediment data analysis, and temporal photogrammetric/ satellite image analysis. According to the earlier research on riverbank change, four core techniques are divided into field measurement, remote sensing, historic data, and paleo (Yang et al. 2015). Each of these methods has its advantages and disadvantages as far as its size, precision, accessibility, and repeatability are concerned in change in river morphology (Grabowski et al. 2014). Remote sensing data give a direct, integrated, and synoptic view of a wider area in comparison with other methods. This approach is quite distinct from traditional methods, such as sedimentation, historical graphs, and cross-profiling, which are usually localized in extent. Remote sensing is an accurate and multi-temporal approach, which has been used to determine the change in riverine morphology in different rivers. Morphometric parameters, such as sinuosity index, channel surface area, channel erosion/deposition, channel centreline and channel width have been utilized in various studies to examine the river morphology with the help of remote sensing (Yang et al. 2015).

3.5 Method Adopted in the Study

In this study, detailed the temporal satellite images from 1993 to 2023 have been used to map the river bank line of Gaula stream in a stretch of about 37 km, 12 km downstream and 25 km upstream of existing Kichha barrage site. Historical satellite imagery has been downloaded from USGS website and river course has been delineated and digitised. The cloud free images are identified and downloaded and image analysis and processing is carried in the image processing ArcGIS and finally the river bank line is delineated. The flow chart of the methodology is shown in Figure 3.2. The study stretch is divided into 6 reach for detailed morphological analysis. The spatial position of the bank line is computed with respect to a permanent linear feature (railway line) at every 200 m and its shifting pattern has been quantified. Further, the active river width and floodplain width of river in each reach have been estimated and entrenchment ratio is computed using satellite image of the year 2023. The stream slope is also estimated for each reach. Thus the stream slope, sinuosity index and entrenchment ratio in each reach are estimated and the river is classified. The temporal bank line shifting is used to identify the river stretch where minimum river shifting is observed and this may be considered as the stable channel and might be a probable site for near barrage.

Further, analysis of stable river channel would be carried out after obtaining the field data from the project authority.

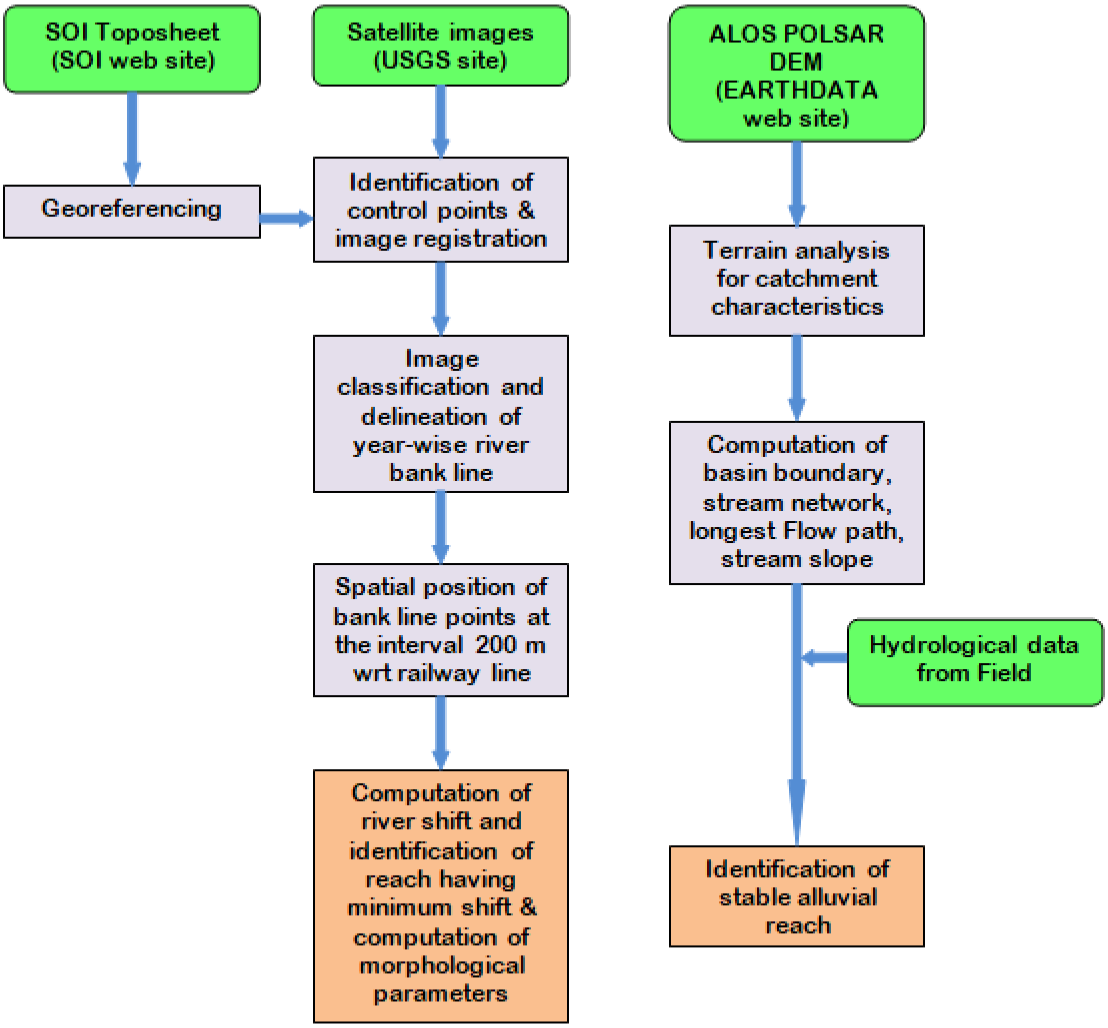


Figure 3.2: Flow chart of methodology used in the study.

4 ANALYSIS AND RESULTS

4.1 Longitudinal Profile of River and Stream Slope

The longest flow path is derived from the terrain analysis and the elevation of the points (at the regular interval of 200 m) along the stream is extracted. The longitudinal profile of the stream is then plotted, as shown in Figure 4.1, using these point elevations. The figure shows the location of Guala and existing Kichha barrage. The morphological characteristics of the river in the stretch of about 30 km (25 km upstream of Kichha barrage and 5 km downstream of Kichha barrage) have been evaluated. As the river slope and planform are highly variable in the stretch, this stretch is further divided into 8 reaches for detailed analysis. The location and extent of each reach is also shown in the figure.

4.2 River Bank Line Extraction and Estimation of River Shifting

The river bank line is extracted from the temporal satellite images and year-wise river course is developed. These year-wise river courses are superimposed over each other to visualize the shifting pattern of the river as shown in Figure 4.2. The figure shows the river course at various years during last 15 years, from 1993 to 2023. As stated earlier, the extent of river stretch is about 30 km long, for clarity in visualization, the entire stretch of river is divided into smaller stretch (section), and altogether 8 sections have been created as shown in Figure 4.2. Using 2023 image, the sinuosity and entrenchment ratio of each section is computed as given in Table 4.1. This table also shows the slope of the stream computed from ALOS PALSAR derived longitudinal profile.

Table 4.1: Morphological parameters of stream in various reach.

Reach ID	Sinuosity	E Ratio	Slope (m/m)
Section 1	1.13	12.50	0.0038
Section 2	1.17	7.14	0.0019
Section 3	1.53	3.85	0.0014
Section 4	1.023	2.27	0.0023
Section 5	1.20	2.70	0.0007
Section 6	1.28	3.45	0.0030
Section 7	1.62	2.56	0.0018
Section 8	1.25	2.86	0.0010

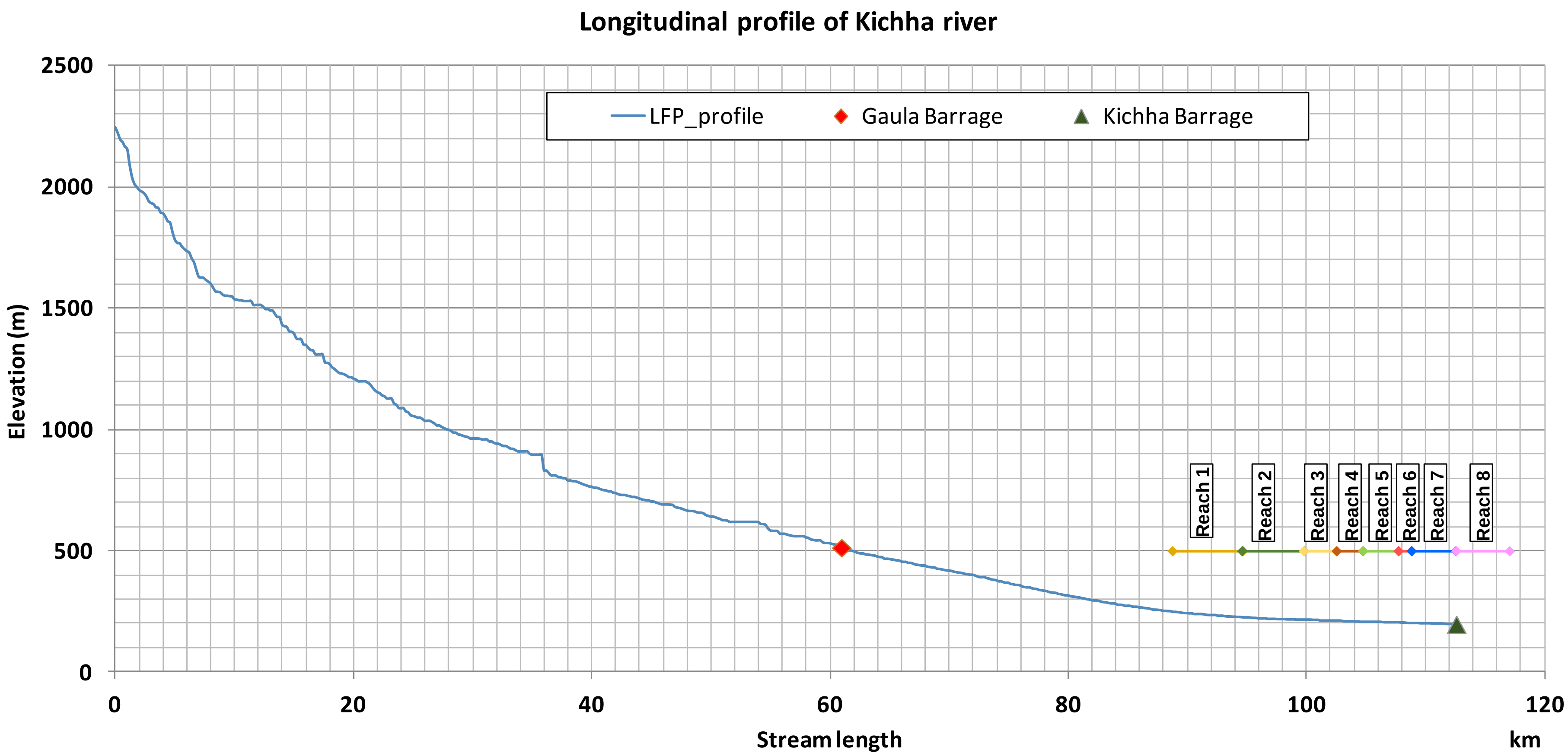


Figure 4.1: Longitudinal profile of river.

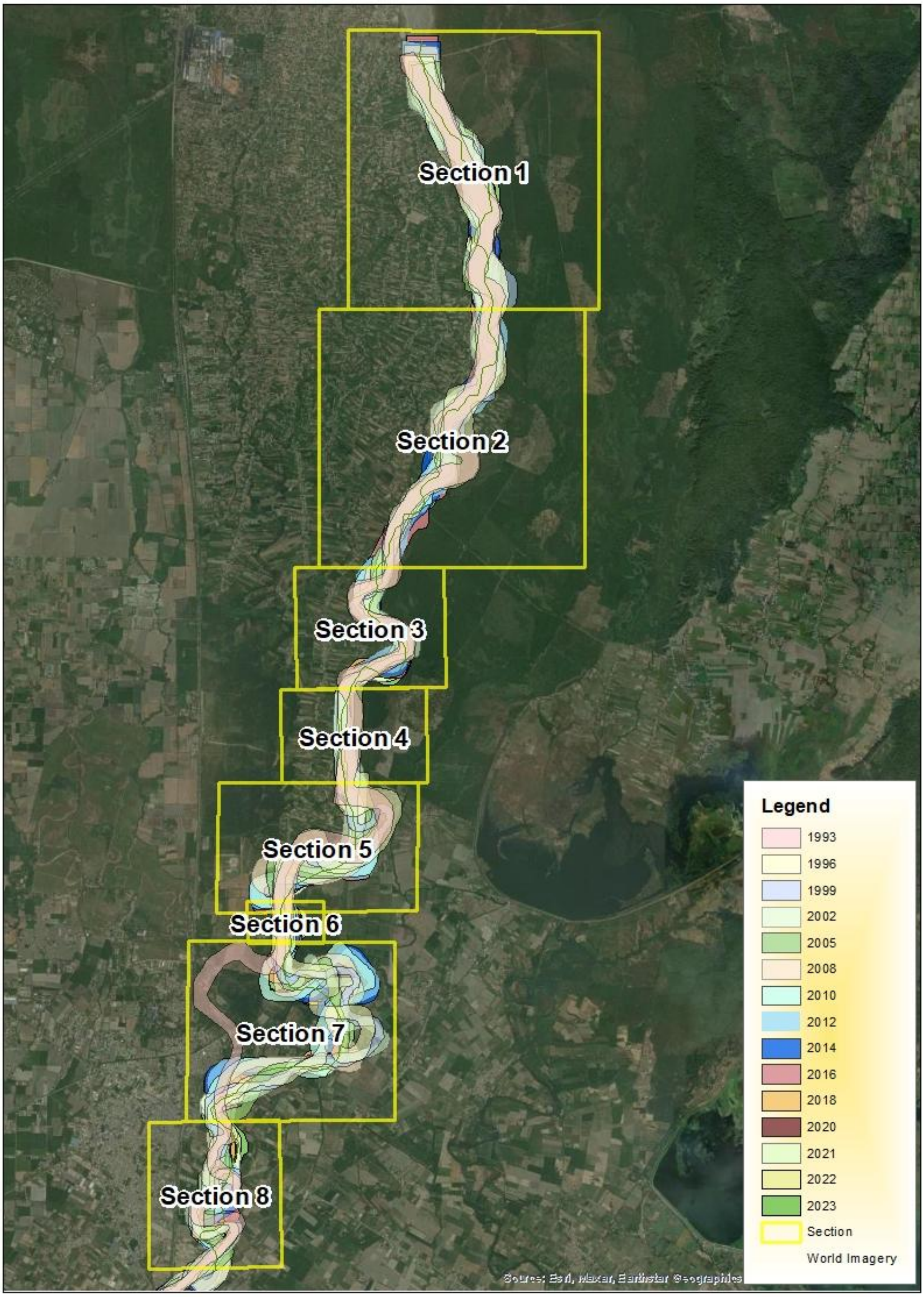


Figure 4.2: Year-wise river course extracted from satellite image and superimposed over each other.

The river course in various years in each section is mapped and shifting is evaluated as shown in Figure 4.3 to Figure 4.10.

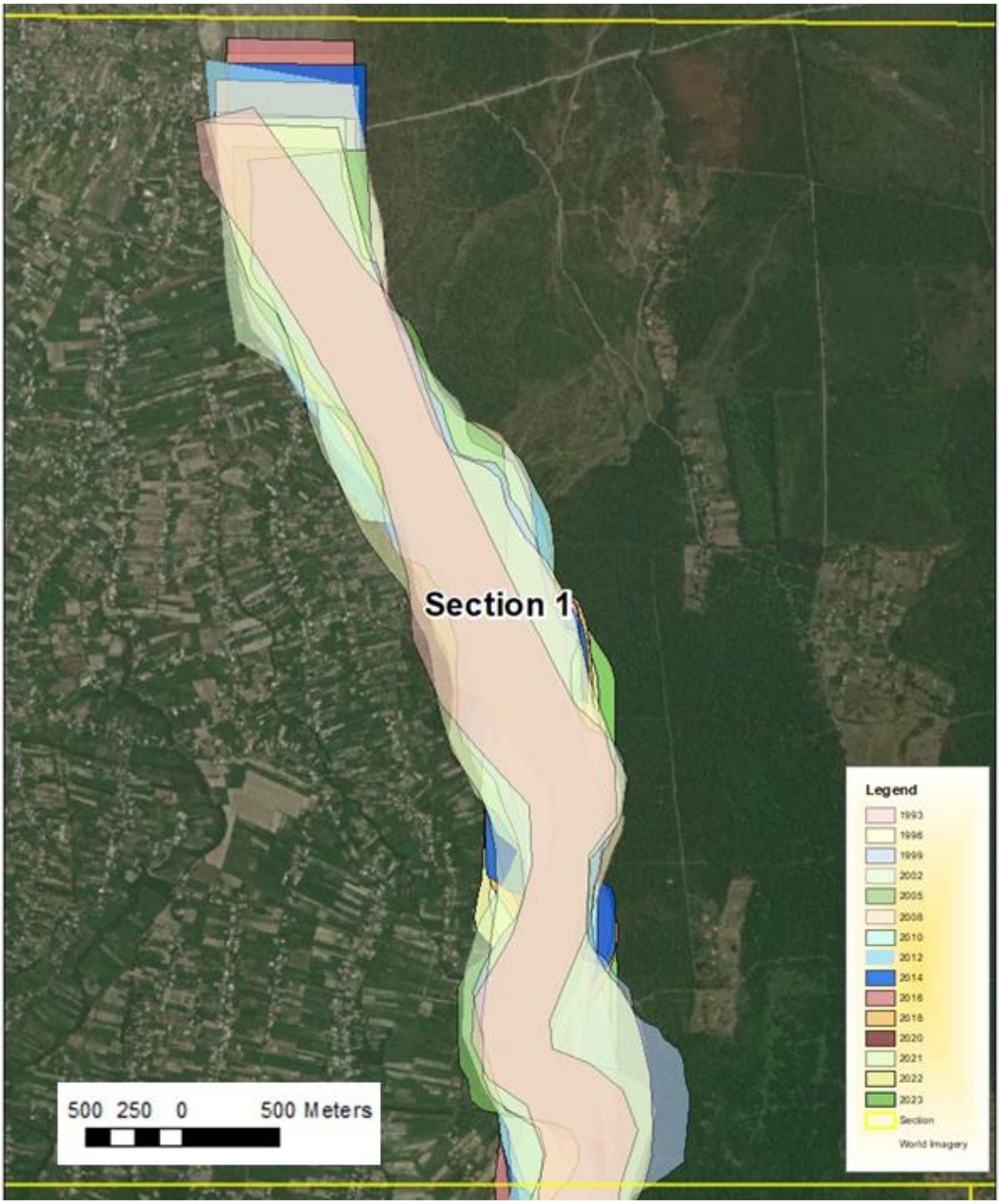


Figure 4.3: Year-wise shifting of river course River in section (reach) 1.

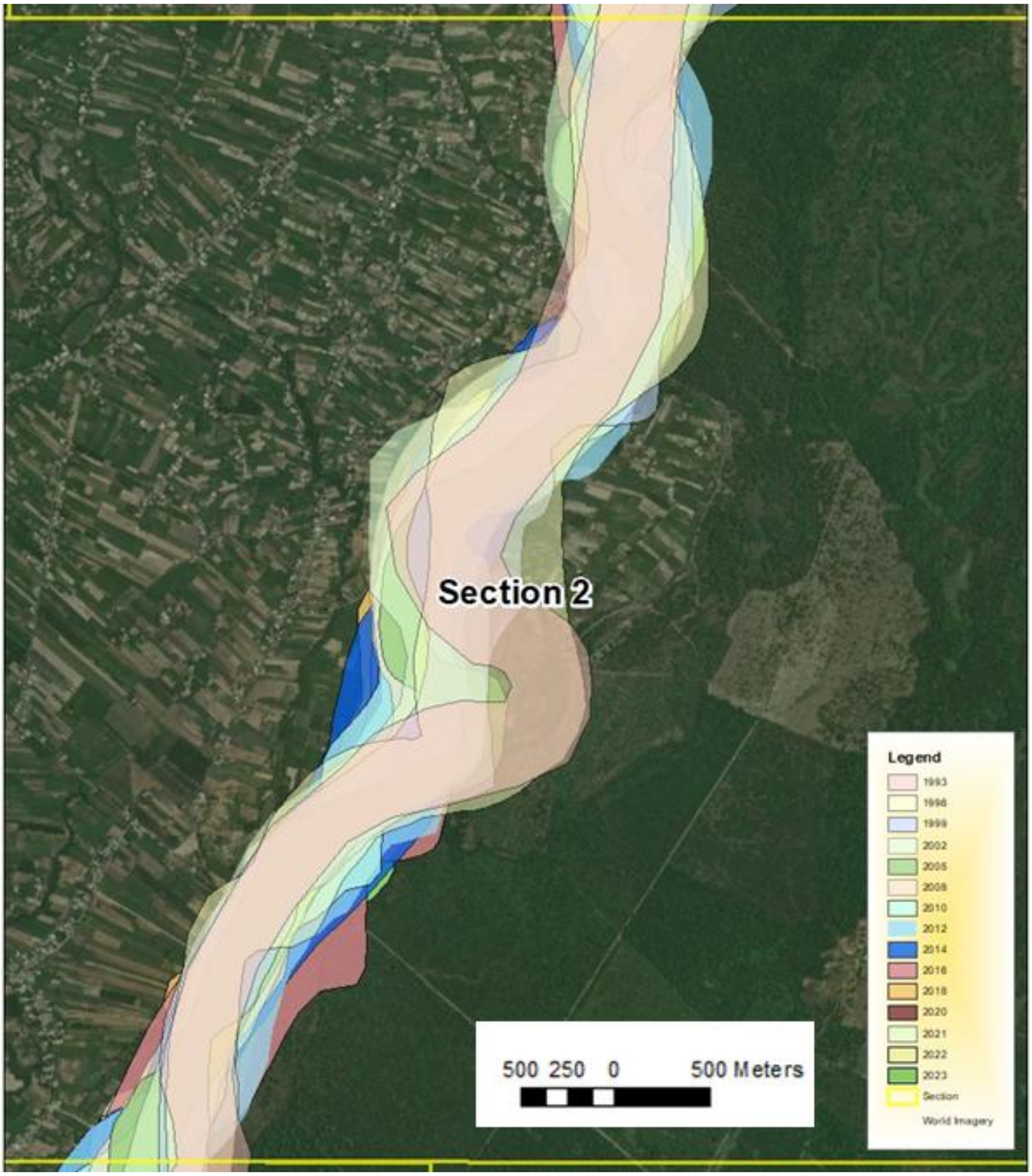


Figure 4.4: Year-wise shifting of river course River in section (reach) 2.

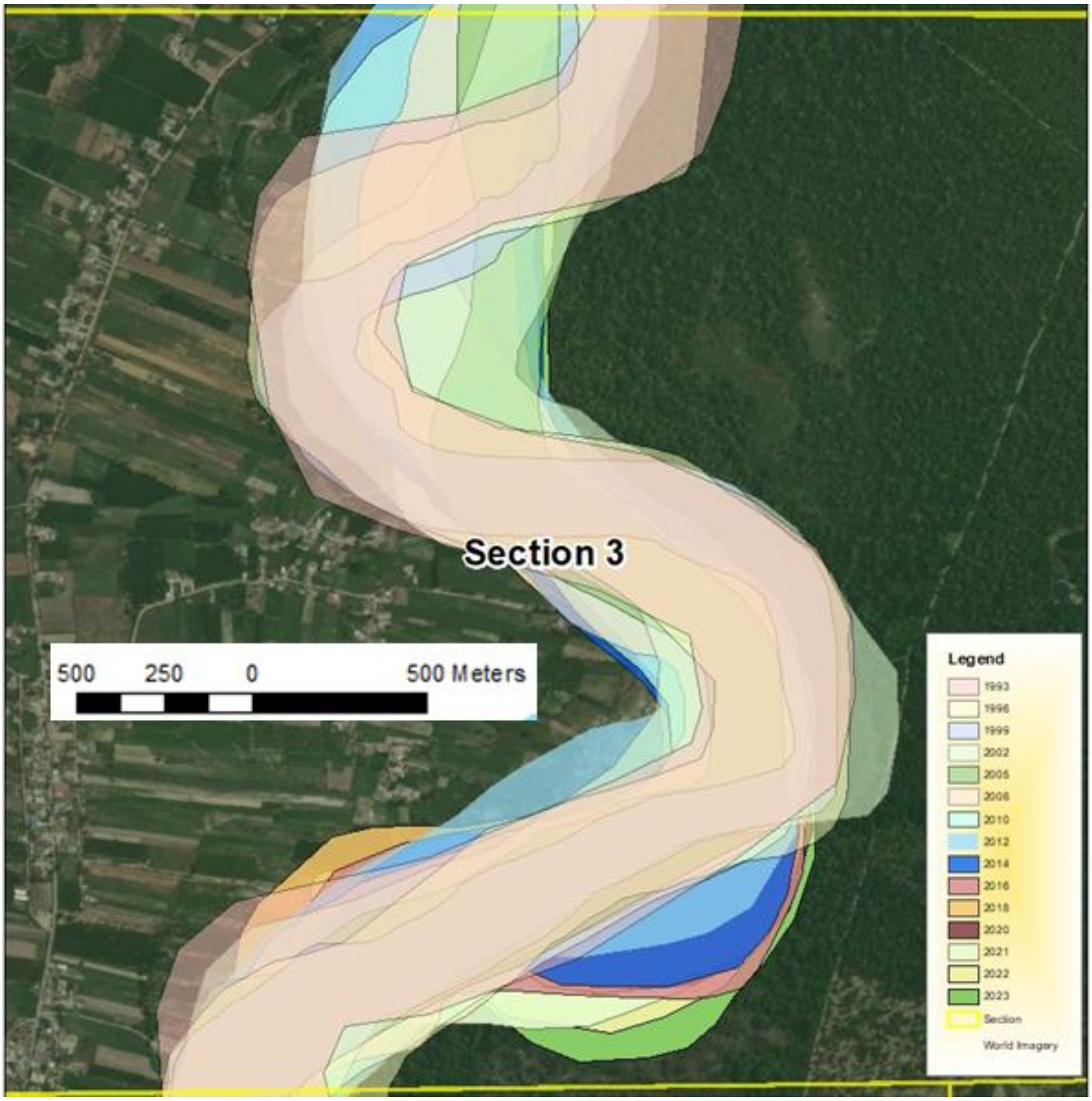


Figure 4.5: Year-wise shifting of river course River in section (reach) 3.

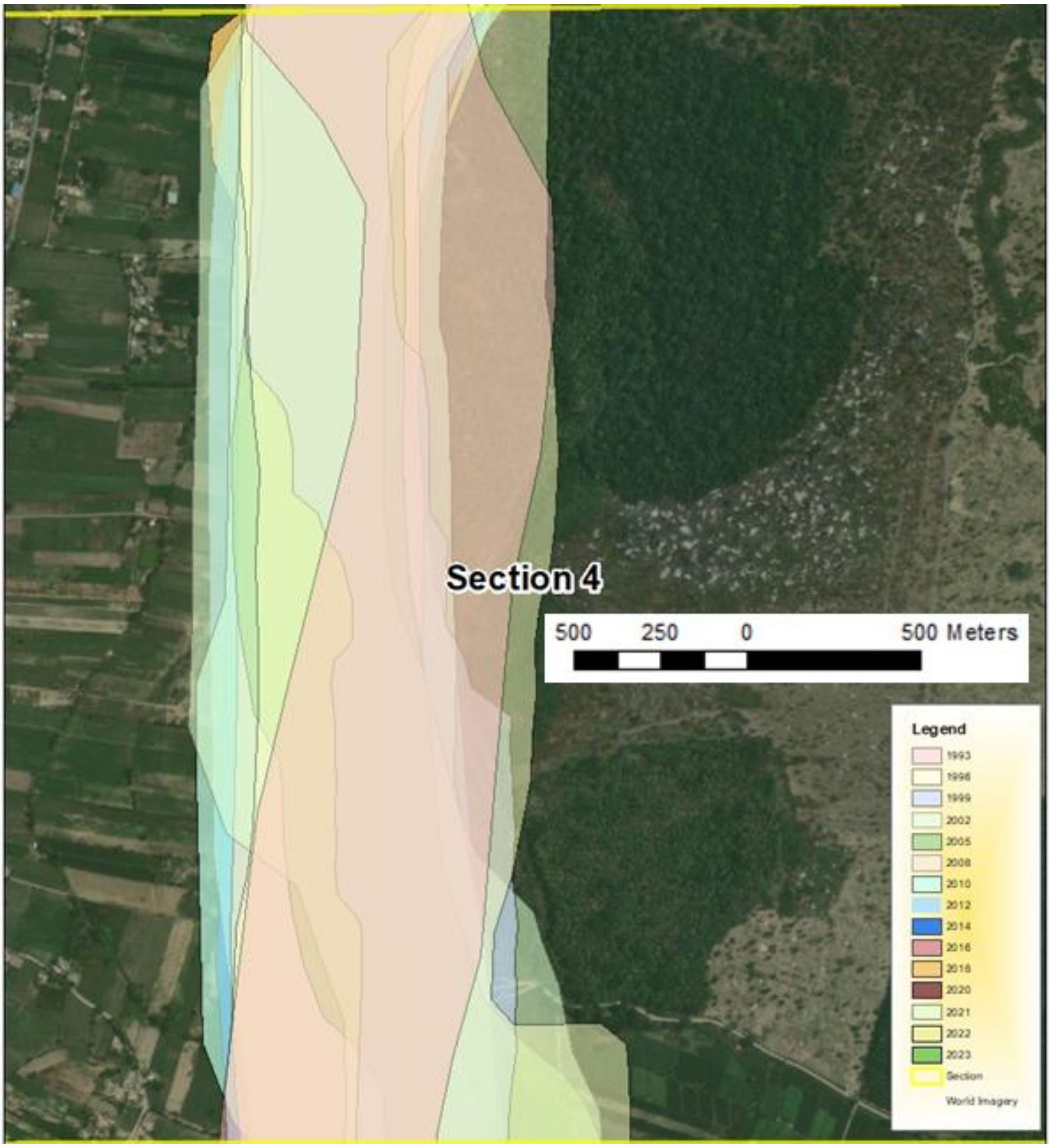


Figure 4.6: Year-wise shifting of river course River in section (reach) 4.

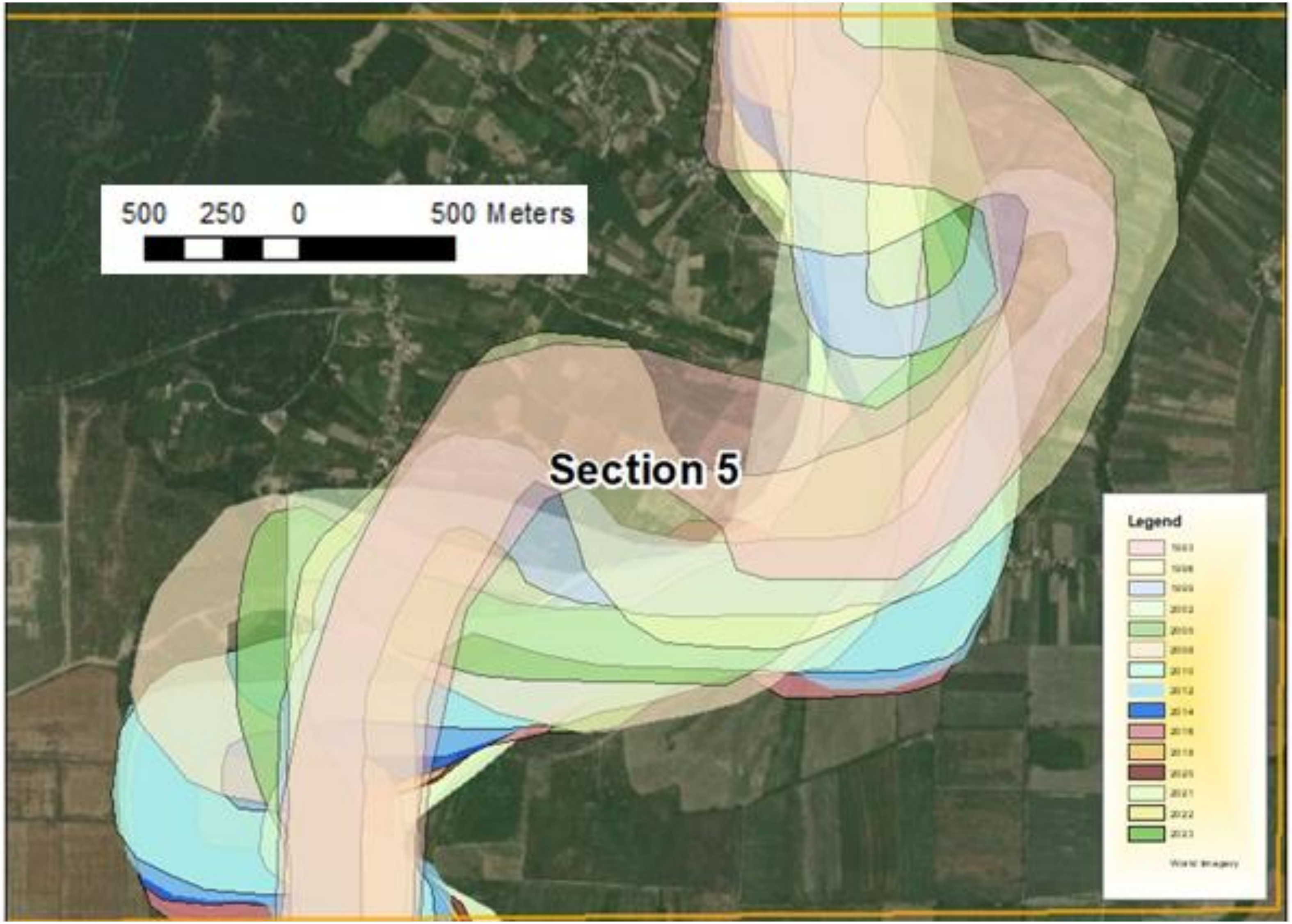


Figure 4.7: Year-wise shifting of river course River in section (reach) 5.

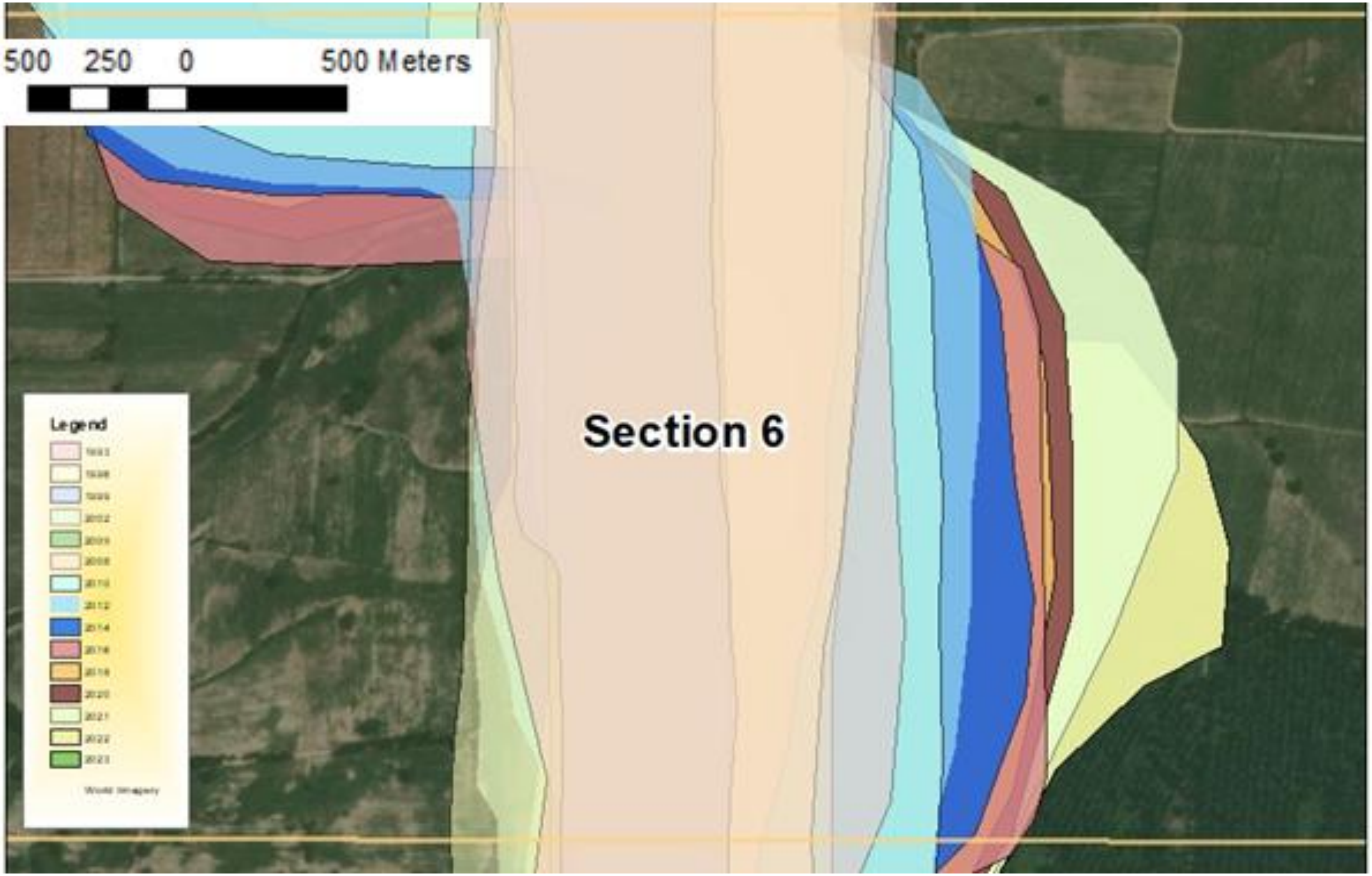


Figure 4.8: Year-wise shifting of river course River in section (reach) 6.

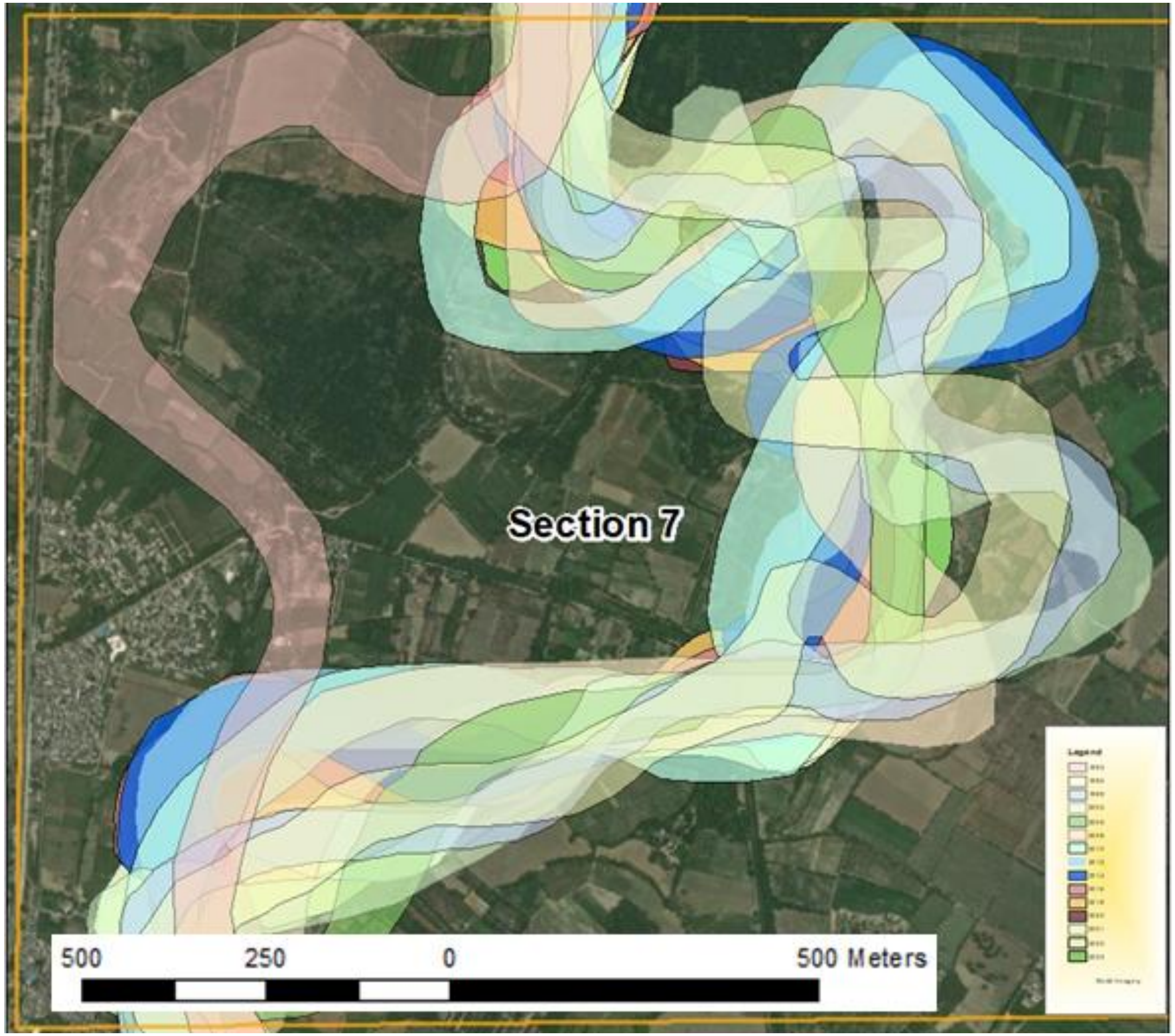


Figure 4.9: Year-wise shifting of river course River in section (reach) 7.

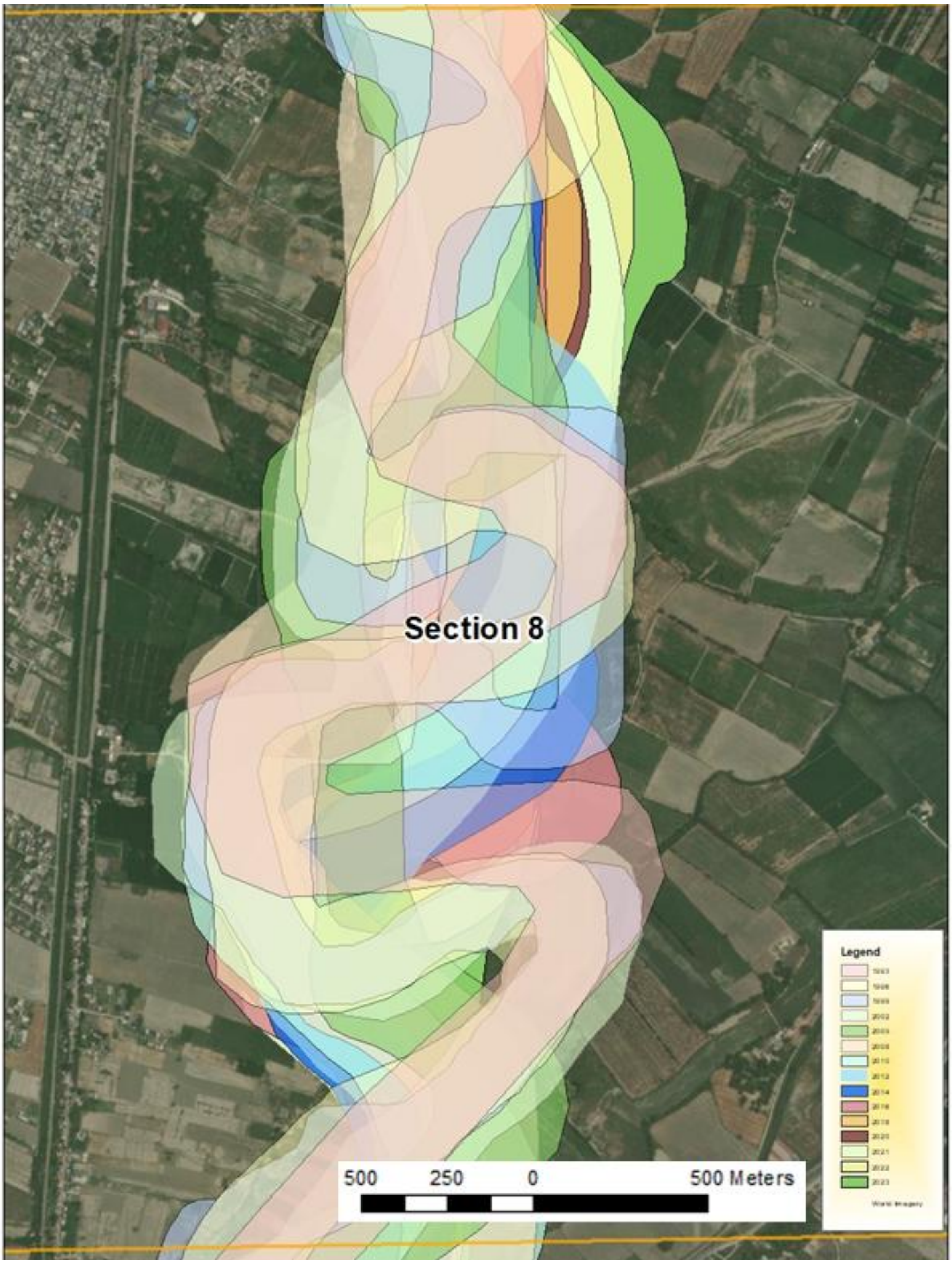


Figure 4.10: Year-wise shifting of river course River in section (reach) 8.

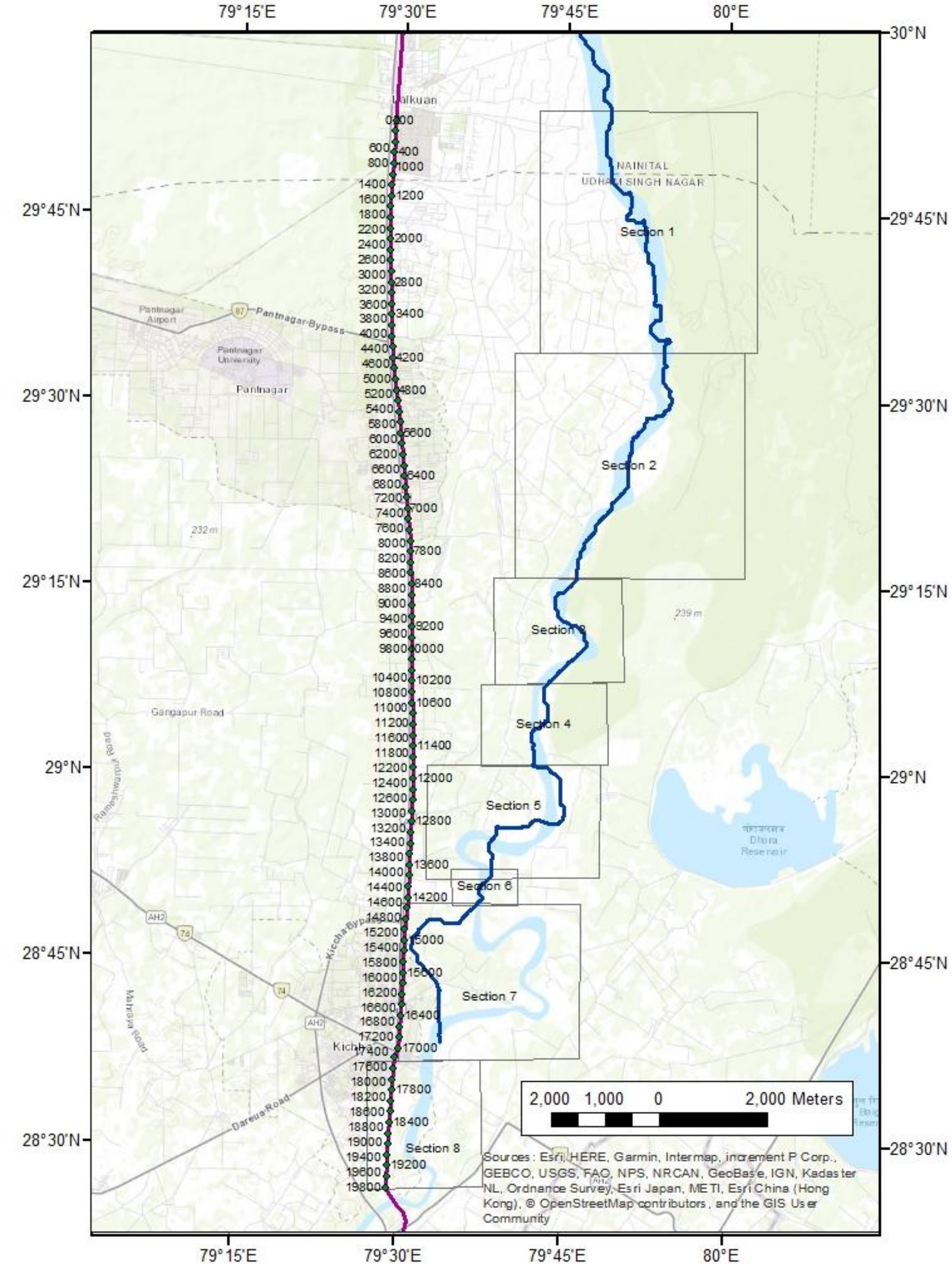
Further, the sinuosity of the stream in the year 1993, 1995, 2000, 2005, 2010, 2015 and 2020 are also computed for each section. The year-wise variation of sinuosity is shown in Table

4.2. The maximum, minimum, average and standard deviation of sinuosity is also shown in this table. The table shows that the variation of sinuosity is lowest for section 4 with average sinuosity of 1.04 and standard deviation (SD) of 0.03. This infers that section 4 remained comparatively more stable for the period of evaluation.

Table 4.2: Temporal variation of sinuosity of Kichha river.

Reach ID	**Sinuosity**								**Average**	**Max**	**Min**	**SD**
Year	**1993**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2023**				
Section 1	1.12	1.15	1.12	1.18	1.17	1.18	1.09	1.13	1.14	1.18	1.09	0.03
Section 2	1.21	1.12	1.17	1.23	1.20	1.06	1.07	1.17	1.15	1.23	1.06	0.06
Section 3	1.77	1.72	1.58	1.37	1.43	1.48	1.49	1.53	1.55	1.77	1.37	0.14
Section 4	1.08	1.05	1.06	1.04	1.03	1.01	1.01	1.02	1.04	1.08	1.01	0.03
Section 5	1.65	1.90	1.26	1.44	1.52	1.67	1.69	1.20	1.54	1.90	1.20	0.23
Section 6	1.07	1.01	1.06	1.00	1.24	1.39	1.35	1.28	1.17	1.39	1.00	0.16
Section 7	1.53	1.98	2.31	1.79	2.47	2.50	1.82	1.62	2.00	2.50	1.53	0.38
Section 8	1.63	1.68	1.68	1.27	1.21	1.22	1.18	1.25	1.39	1.68	1.18	0.23

Further to quantify the magnitude of shifting of left and right bank, a fictitious reference line (railway line running parallel to Bareilly- Nainital road) is identified. Along this reference line, points at regular interval of 200 m is digitized and the perpendicular distance of the river bank (left and right bank separately) is computed in GIS data base. The location of the reference points is shown in Figure 4.11. The distance of the bank line (left and right) extracted from satellite images of various years/ dates are measured. Considering the river bank line position extracted from 1993 satellite image, the change in the bank line in successive years are computed and analysed. Hence, the positions of the left and right bank line for each year with reference to 1993 bank line are computed and plotted as shown in Figure 4.12. In the figure the continuous line shows the positions of left bank while the dashed line is used to illustrate right bank positions. The colour of the left and right bank position is kept same for any specific year. For detailed visualization, the section-wise shifting of left bank and right bank are also plotted as given in Figure 4.13 to Figure 4.20. Further, the trend of maximum shifting in section 4 along left and right bank are also plotted and given in Figure 4.21. The figure shows that the minimum and maximum shifting of left bank is estimated as 140 m and 384 m, respectively for section 4. Similarly, for right bank, the minimum and maximum shifting is 170 m and 299 m, respectively.



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), © OpenStreetMap contributors, and the GIS User Community

Figure 4.11: Reference points at interval of 200 m from which the distance of river bank is computed.

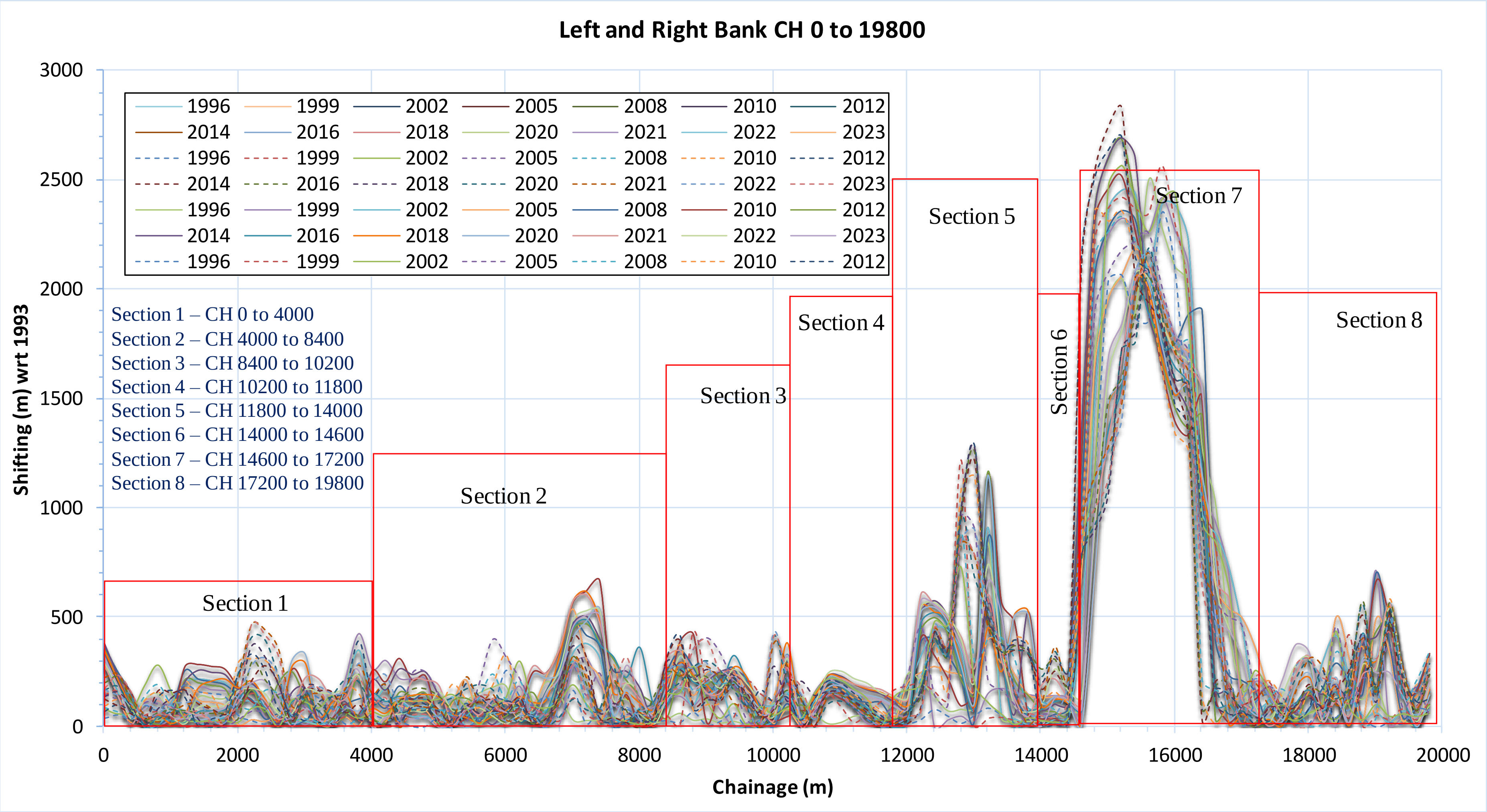


Figure 4.12: Year-wise bank line position in various years, the continuous line shows the left bank while the dashed line shows right bank.

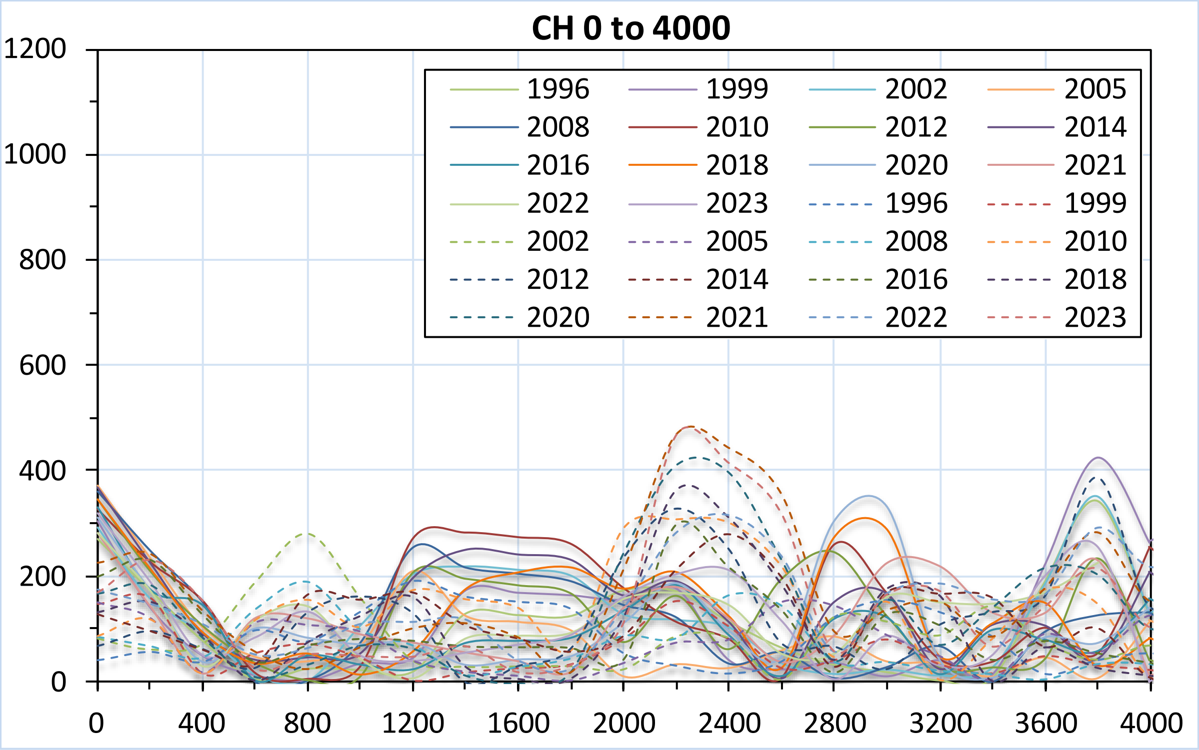


Figure 4.13: Year-wise bank line position for Section 1.

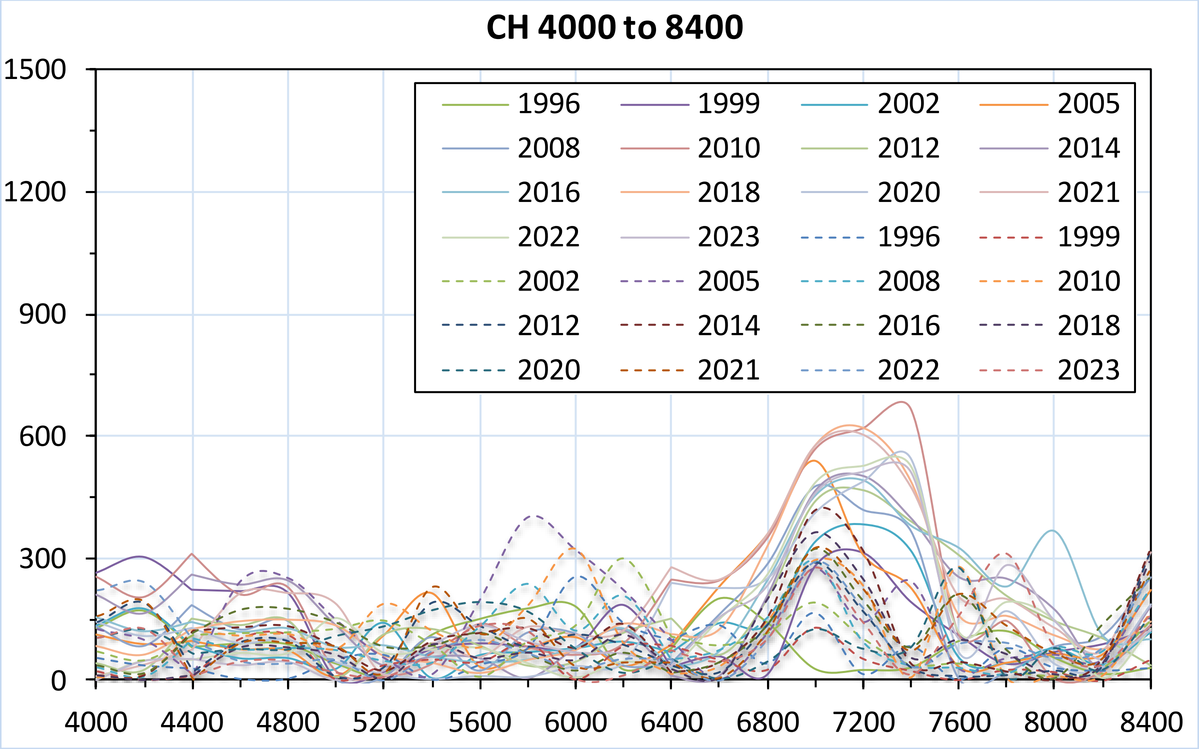


Figure 4.14: Year-wise bank line position for Section 2.

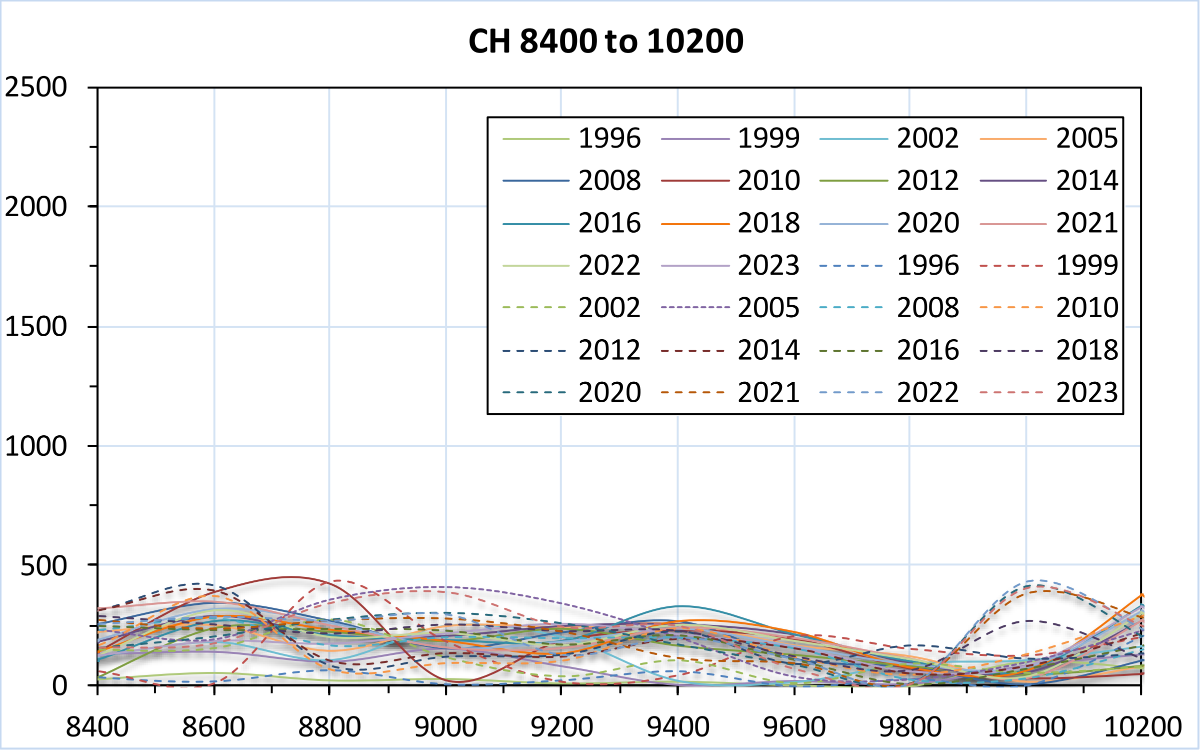


Figure 4.15: Year-wise bank line position for Section 3.

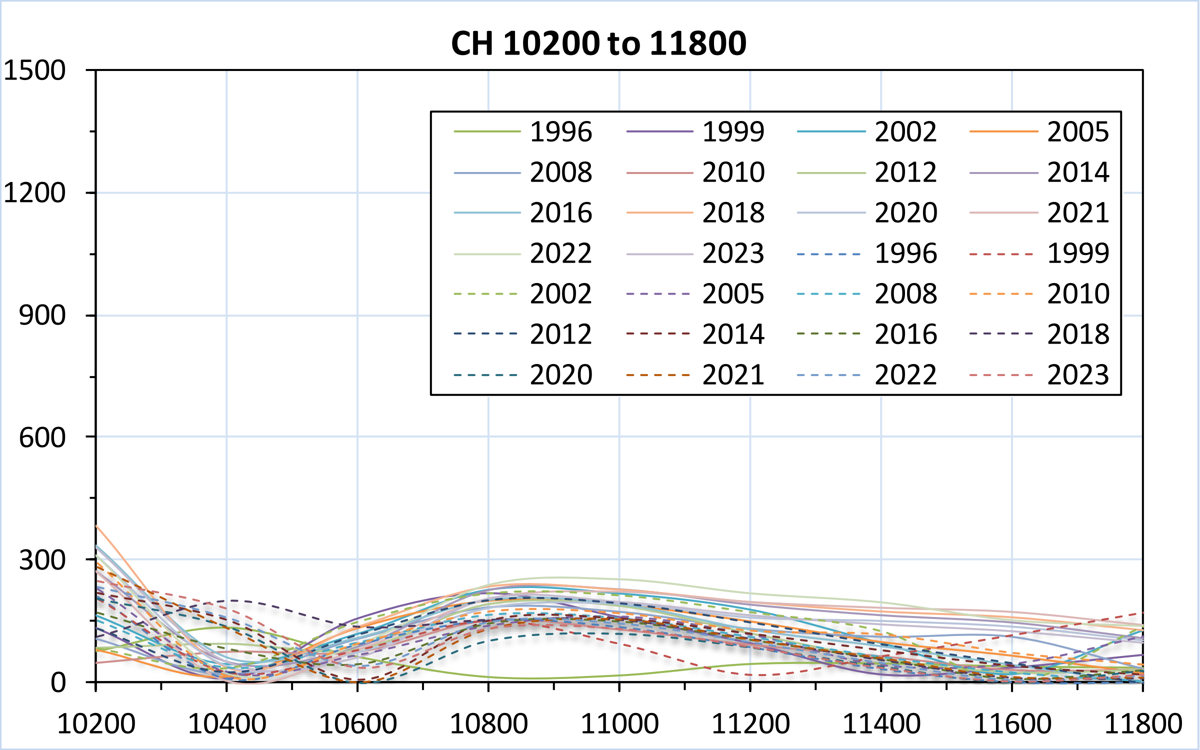


Figure 4.16: Year-wise bank line position for Section 4.

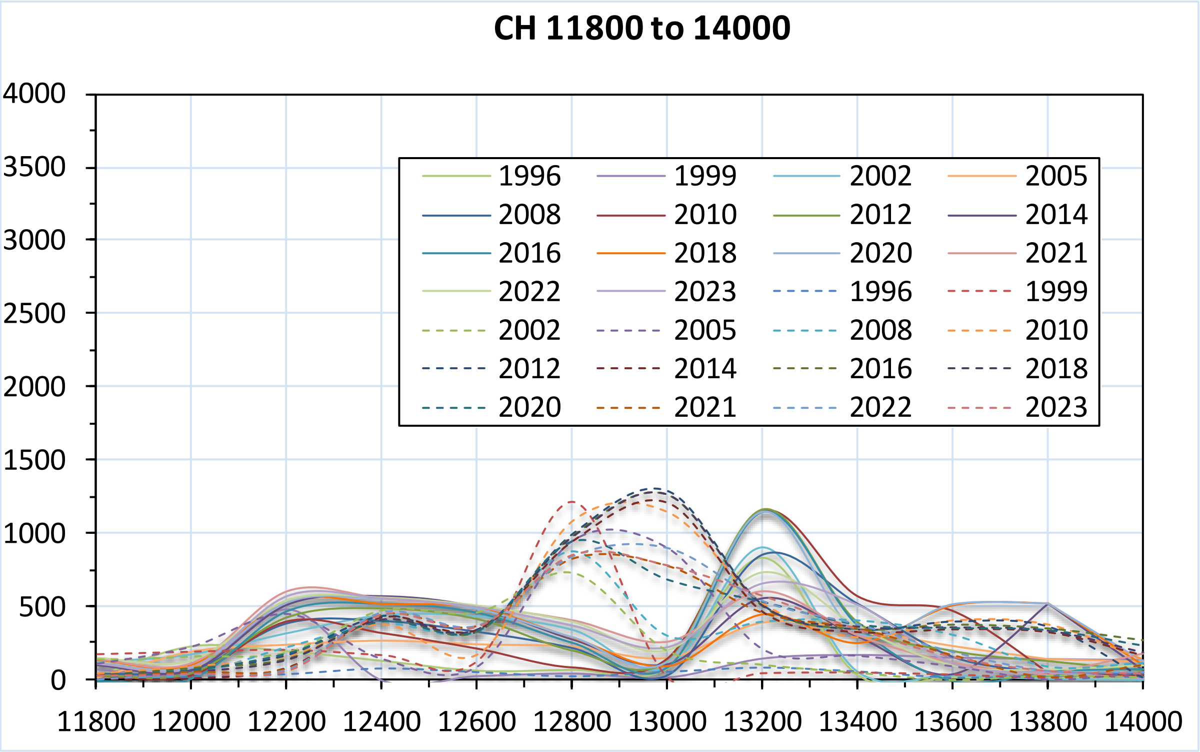


Figure 4.17: Year-wise bank line position for Section 5.

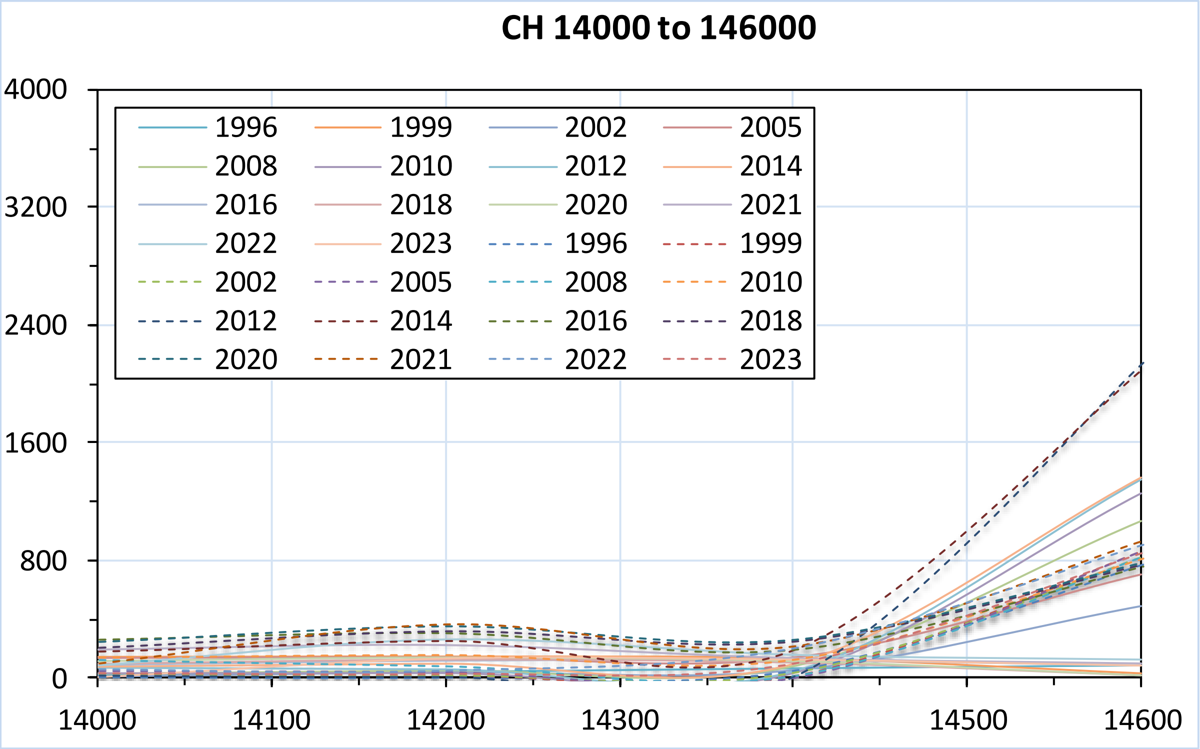


Figure 4.18: Year-wise bank line position for Section 6.

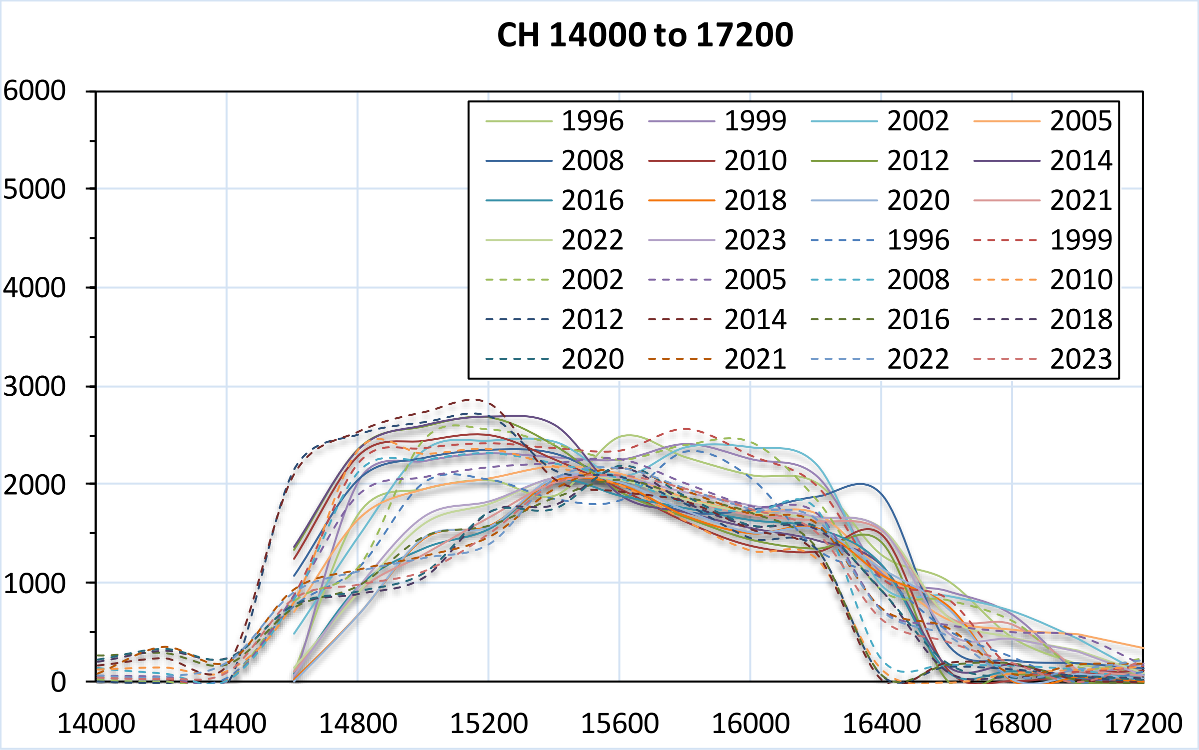


Figure 4.19: Year-wise bank line position for Section 7.

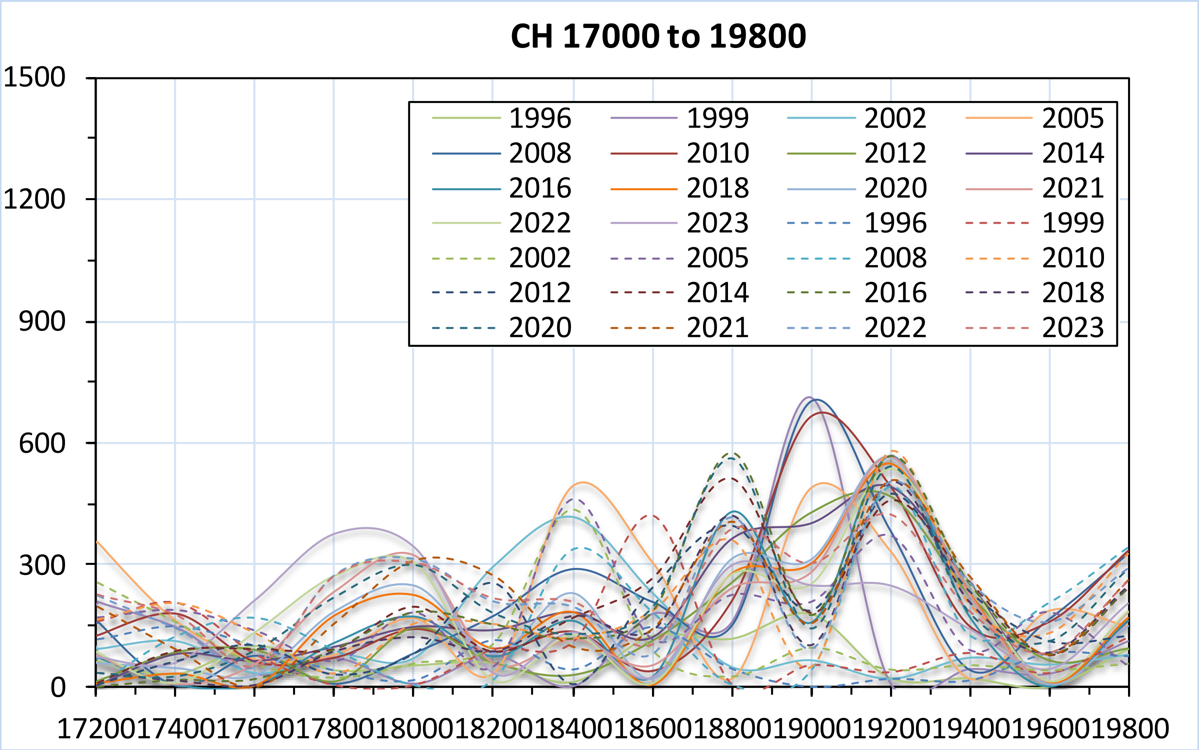


Figure 4.20: Year-wise bank line position for Section 8.

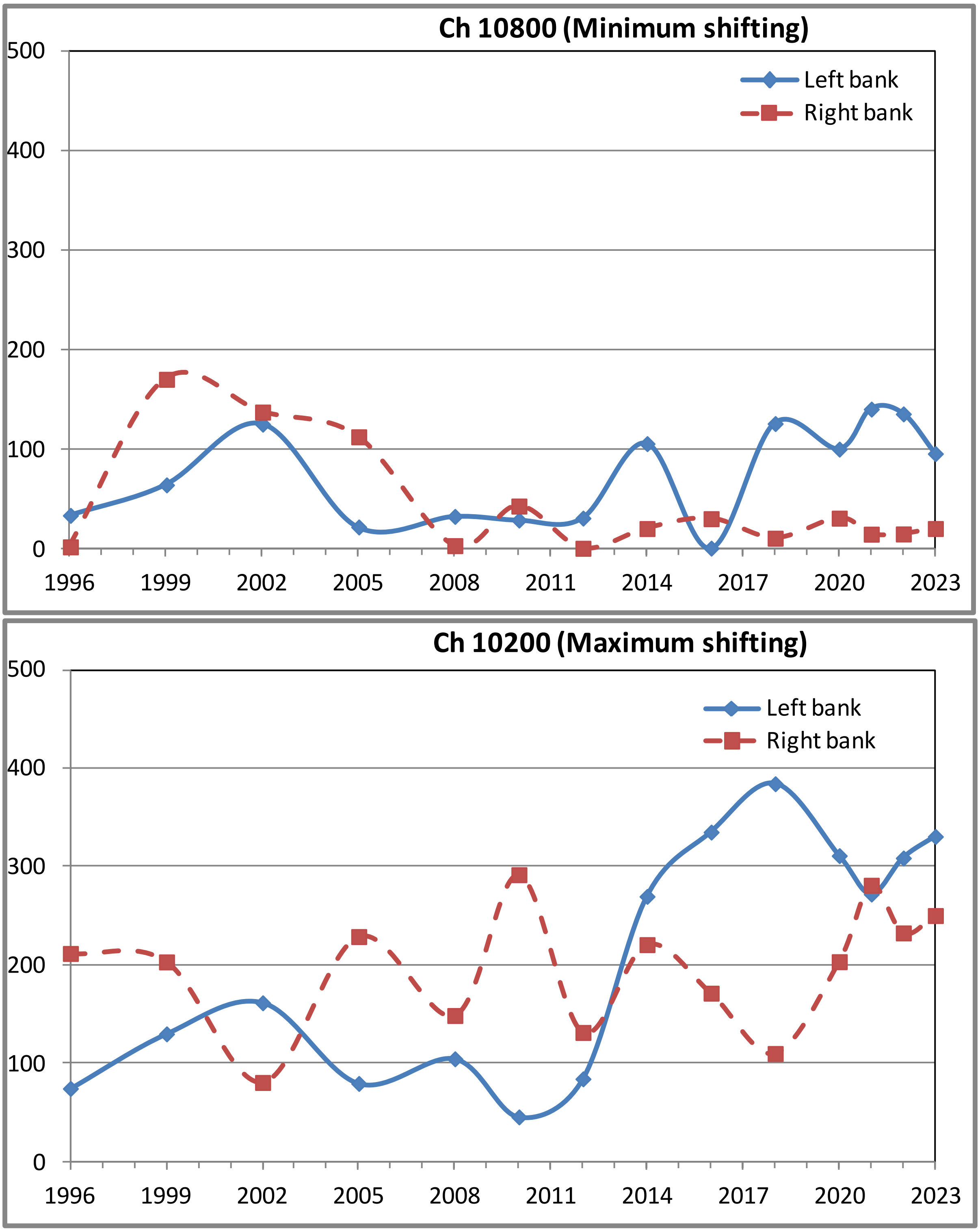


Figure 4.21: Trend of minimum and maximum river shifting in Section 4.

4.3 Dynamic Hydrological and Morphological River Behaviour at barrage site

As per India WRIS web site, the construction of the Kichha barrage was completed in 1964 with the design discharge of 70,000 cusecs (1,982.18 Cumec). Accordingly, the width of the barrage (91.25 m), its crest level (201.47 m) and pond level (202.23 m) were decided. However, the letter received from the Chief engineer states that the average monsoon flow in the Kichha river is of the order of 125000-150000 cusec. Thus it is evident that the hydrology of the river at Kichha barrage site has changed to great extent since its construction. With the increased average monsoon flow, the existing barrage length became insufficient causing excessive ponding/ inundation upstream of the barrage. In case of alluvial rivers, the constriction of flow may increase the siltation which in turn aggravates the meandering behaviour. The temporal variation of the river course near the barrage (in upstream reach) is shown in Figure 4.22. The figure shows that the Gaula river bends 90 degree on the right hand side just upstream of the barrage. Except for the year 1993, river has tendency to shift on the left bank. This is grossly because the alluvial river erodes its outer bank at the bends and has tendency to deposit silt on the inner bank. The shifting on the left bank has also endangered the stability of left bank canal. The major shifting of the river course in 1993 has caused the damage to the right bank canal. The river course shows that the existing barrage location became inappurtenant (Figure 4.22). However, the river was trained to its original course through various engineering measures and the barrage remained functional till 2021. However, the structures need to be re-designed in view of the changes in the river hydrology as evident from the average monsoon flow.

Thus, it is inferred that the existing location of the barrage can be utilized using suitable and adequate engineering interventions. The use of existing location of the barrage will also be beneficial as the existing canal alignments can be used without any loading for the new land acquisition. However, the revised design of the barrage is to be carried out considering the following points:

1. The barrage is to be designed for the revised design flood. The length of the barrage, the crest level and the pond level of the barrage would be modified accordingly. Considering the new barrage width, the design of the head works may also be revised.
2. The alignment of the barrage and upstream training works should be decided based on the model study. The model study would help in planning and design for various river

training structures, afflux and guide bunds to train the river at the barrage. The extent of model study is marked in Figure 4.22.

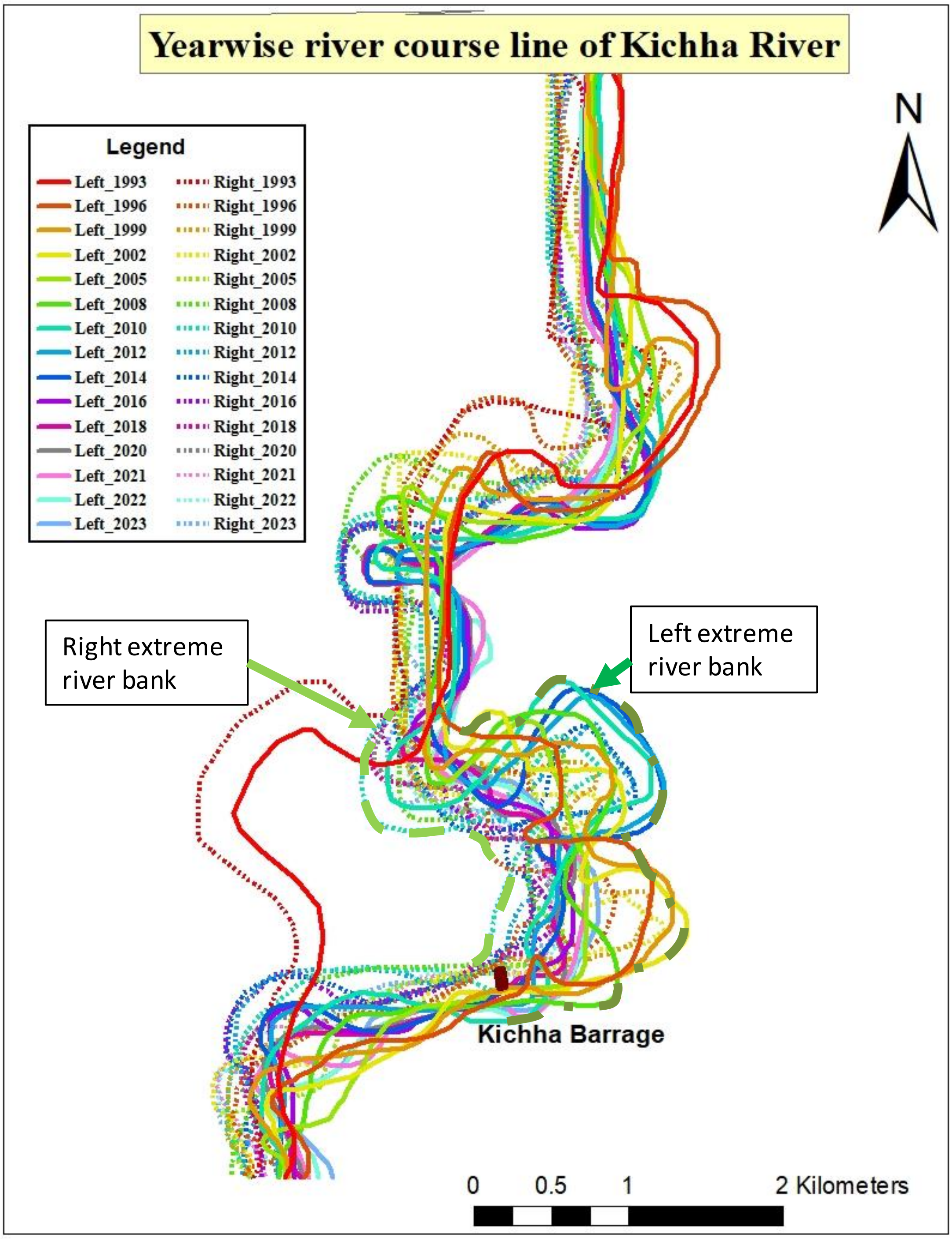


Figure 4.22: Yearwise river course near the existing Kichha bridge.

4.4 Site Visit and Discussion with UPID

After completing the analysis for dynamic Hydrological and Morphological River Behaviour at the barrage site a joint team consisting of Scientists of NIH and Engineers of Irrigation and Water Resources Department, UP visited the site to look into various aspects to finalise the location for barrage. It was informed that the study for revision of design flood has been carried out by the CWC. The revised 100- and 500- yr return period floods estimated by CWC are 3207 m^3/s and 4000 m^3/s, respectively and the new barrage would be designed accordingly. Further, the Irrigation and Water Resources Department, UP expressed that the availability of land is a major constraint for alternate location of the barrage. The land availability, extending the canal network up to the new barrage site etc. are some of the major concern raised by the Irrigation and Water Resources Department, UP.

5 CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

Based on the study, following conclusions can be drawn:

1. Using the ALOS PALSAR DEM data the drainage line and watershed boundary for Kichha river has been extracted and the catchment area is computed as 831.50 km^2 while the length of longest flow path up to the existing Kichha barrage site is computed as 112.34 km.
2. The morphological characteristics of the river in the stretch of about 30 km (25 km upstream and 5 km downstream of the existing Kichha barrage) have been evaluated. This stretch is further divided into 8 Sections (reaches) where the stream slope varies in the range of 0.0007-0.0038.
3. The sinuosity and entrenchment (E) ratio of the stream in 8 reaches (sections) are estimated using satellite image of the year 2023. The minimum sinuosity and E ratio is computed for Section4 as 1.023 and 2.27, respectively. This infers that the river is almost straight and well developed in this reach. The river slope in this reach is computed as 0.0023 m/m.
4. The temporal change in the sinuosity of the river is also computed using the satellite image of the year 1993, 1995, 2000, 2005, 2010, 2015 and 2020. The results shows that average sinuosity is minimum (1.04 with standard deviation of 0.03) for reach 4. The year-wise sinuosity for this reach varies in the range of 1.01-1.08. This analysis also that section 4 is more stable. Year-wise trend for the maximum shifting in section 4 is computed for left and right bank. The analysis shows that the maximum shifting on left and right bank are 348 m and 299 m, respectively.
5. The gross alignment of the river near the existing barrage location after 1993 shows that the engineering interventions remained successful in training the river. However, increase in the annual average flow in the river compared to the barrage design flood has progressively induced the excessive river shifting upstream of the barrage and failure of the structures in 2021.

6. The barrage needs to be redesigned considering the updated design discharge. If adequate land is available for the revised barrage and its allied structures, the existing location may be used with appropriate river training works. The model study should be carried out to plan and design of river training works, afflux and guide bunds. Based on the model study, the alignment and structural design of the various river training works should be finalized.

5.2 Recommendations

Based on the study, the following recommendations are made:

1. If the other site condition permits, the barrage should be located in stable river reach. Considering the most stable reach and vicinity of the exiting Kichha barrage, site Section 4 is identified as the most suitable reach. The maximum shifting of left and right bank of Kichha barrage is computed as 348 m and 299 m, respectively during the period of analysis of 1993 to 2023. Thus it is recommended to consider for the river training works at least in the river width covering this shift. However, this recommendation should further be evaluated in light of availability of land in this reach.
2. The existing locations of the Kichchha barrage may also be considered as adequate land is available for the revised barrage design considering the updated design flood. This would be a cost effective approach as the existing canal alignment in full potential can be utilized without overburdening the land acquisition cost. However, the model study is highly recommended to plan the design of river training works, flow diversion, afflux and guide bunds. Based on the model study alignment and structural design of the river training works should be evaluated.

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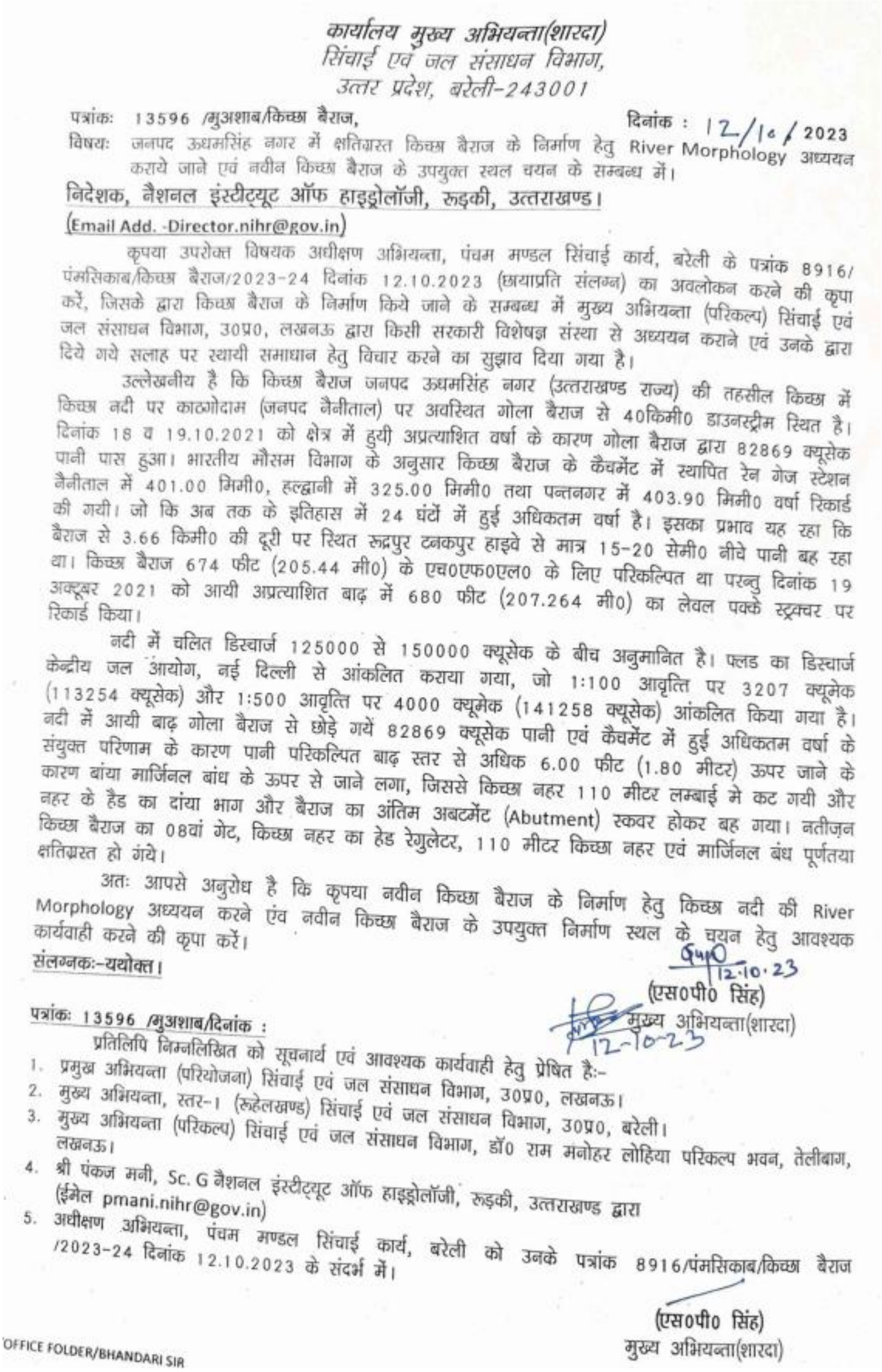
Annexure



कार्यालय मुख्य अभियन्ता(शारदा)
सिंचाई एवं जल संसाधन विभाग,
उत्तर प्रदेश, बरेली-243001

पत्रांकः 13596 /मुअशाब/किच्छा बैराज, दिनांक : 12/10/2023

विषयः जनपद ऊधमसिंह नगर में क्षतिग्रस्त किच्छा बैराज के निर्माण हेतु River Morphology अध्ययन कराये जाने एवं नवीन किच्छा बैराज के उपयुक्त स्थल चयन के सम्बन्ध में।

निदेशक, नैशनल इंस्टीट्यूट ऑफ हाइड्रोलॉजी, रुड़की, उत्तराखण्ड।
(Email Add. -Director.nihr@gov.in)

कृपया उपरोक्त विषयक अधीक्षण अभियन्ता, पंचम मण्डल सिंचाई कार्य, बरेली के पत्रांक 8916/पंमसिकाब/किच्छा बैराज/2023-24 दिनांक 12.10.2023 (छायाप्रति संलग्न) का अवलोकन करने की कृपा करें, जिसके द्वारा किच्छा बैराज के निर्माण किये जाने के सम्बन्ध में मुख्य अभियन्ता (परिकल्प) सिंचाई एवं जल संसाधन विभाग, उ0प्र0, लखनऊ द्वारा किसी सरकारी विशेषज्ञ संस्था से अध्ययन कराने एवं उनके द्वारा दिये गये सलाह पर स्थायी समाधान हेतु विचार करने का सुझाव दिया गया है।

उल्लेखनीय है कि किच्छा बैराज जनपद ऊधमसिंह नगर (उत्तराखण्ड राज्य) की तहसील किच्छा में किच्छा नदी पर काठगोदाम (जनपद नैनीताल) पर अवस्थित गोला बैराज से 40किमी0 डाउनस्ट्रीम स्थित है। दिनांक 18 व 19.10.2021 को क्षेत्र में हुयी अप्रत्याशित वर्षा के कारण गोला बैराज द्वारा 82869 क्यूसेक पानी पास हुआ। भारतीय मौसम विभाग के अनुसार किच्छा बैराज के कैचमेंट में स्थापित रेन गेज स्टेशन नैनीताल में 401.00 मिमी0, हल्द्वानी में 325.00 मिमी0 तथा पन्तनगर में 403.90 मिमी0 वर्षा रिकार्ड की गयी। जो कि अब तक के इतिहास में 24 घंटों में हुई अधिकतम वर्षा है। इसका प्रभाव यह रहा कि बैराज से 3.66 किमी0 की दूरी पर स्थित रूद्रपुर टनकपुर हाइवे से मात्र 15-20 सेमी0 नीचे पानी बह रहा था। किच्छा बैराज 674 फीट (205.44 मी0) के एच0एफ0एल0 के लिए परिकल्पित था परन्तु दिनांक 19 अक्टूबर 2021 को आयी अप्रत्याशित बाढ़ में 680 फीट (207.264 मी0) का लेवल पक्के स्ट्रक्चर पर रिकार्ड किया।

नदी में चलित डिस्चार्ज 125000 से 150000 क्यूसेक के बीच अनुमानित है। फ्लड का डिस्चार्ज केन्द्रीय जल आयोग, नई दिल्ली से आंकलित कराया गया, जो 1:100 आवृत्ति पर 3207 क्यूमेक (113254 क्यूसेक) और 1:500 आवृत्ति पर 4000 क्यूमेक (141258 क्यूसेक) आंकलित किया गया है। नदी में आयी बाढ़ गोला बैराज से छोड़े गयें 82869 क्यूसेक पानी एवं कैचमेंट में हुई अधिकतम वर्षा के संयुक्त परिणाम के कारण पानी परिकल्पित बाढ़ स्तर से अधिक 6.00 फीट (1.80 मीटर) ऊपर जाने के कारण बांया मार्जिनल बांध के ऊपर से जाने लगा, जिससे किच्छा नहर 110 मीटर लम्बाई मे कट गयी और नहर के हैड का दांया भाग और बैराज का अंतिम अबटमेंट (Abutment) स्कवर होकर बह गया। नतीज़न किच्छा बैराज का 08वां गेट, किच्छा नहर का हेड रेगुलेटर, 110 मीटर किच्छा नहर एवं मार्जिनल बंध पूर्णतया क्षतिग्रस्त हो गये।

अतः आपसे अनुरोध है कि कृपया नवीन किच्छा बैराज के निर्माण हेतु किच्छा नदी की River Morphology अध्ययन करने एंव नवीन किच्छा बैराज के उपयुक्त निर्माण स्थल के चयन हेतु आवश्यक कार्यवाही करने की कृपा करें।

संलग्नकः-यथोक्त।

ह0
12.10.23
(एस0पी0 सिंह)
मुख्य अभियन्ता(शारदा)
12-10-23

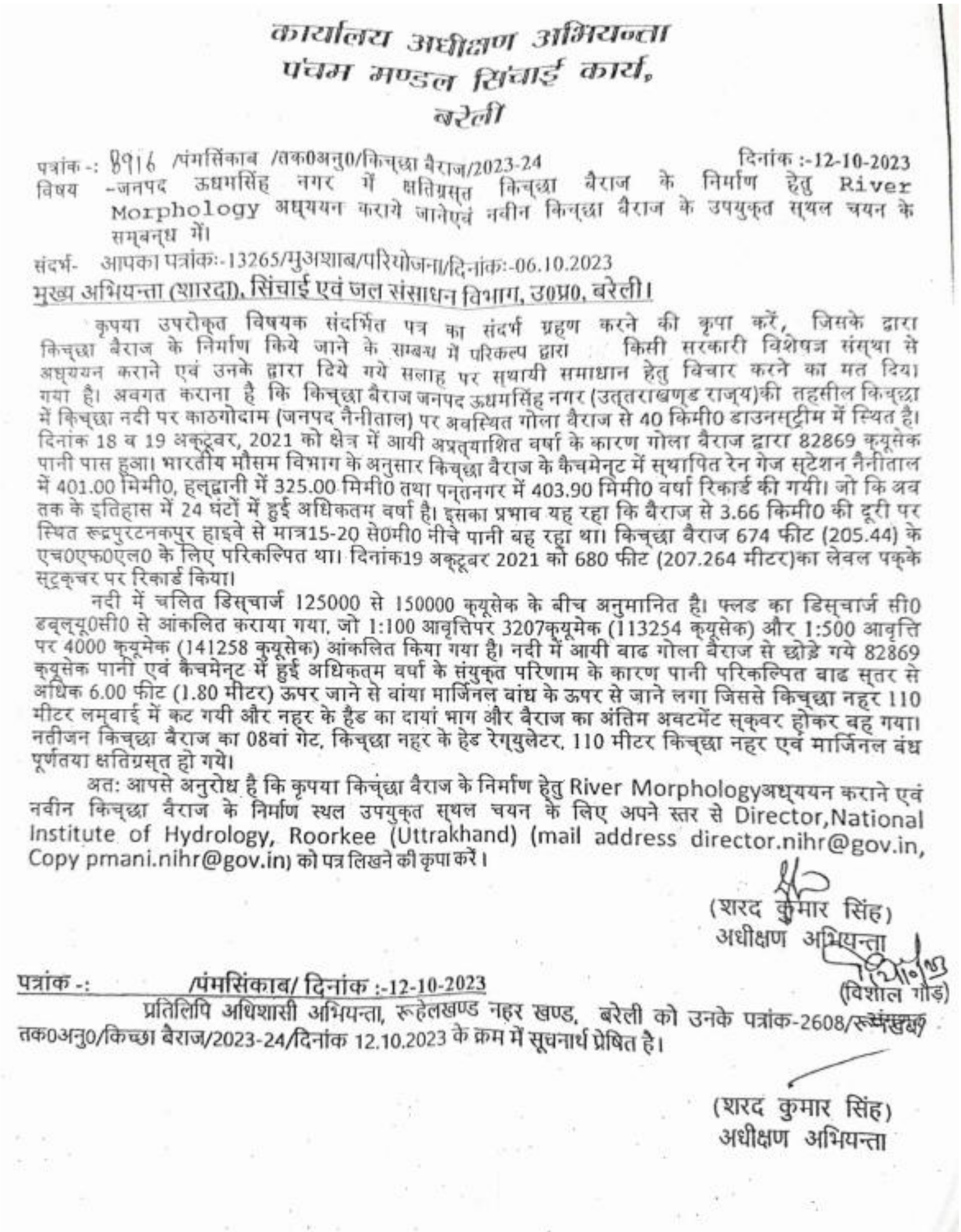
पत्रांकः 13596 /मुअशाब/दिनांक :

प्रतिलिपि निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित हैः-

1. प्रमुख अभियन्ता (परियोजना) सिंचाई एवं जल संसाधन विभाग, उ0प्र0, लखनऊ।
2. मुख्य अभियन्ता, स्तर-1 (रूहेलखण्ड) सिंचाई एवं जल संसाधन विभाग, उ0प्र0, बरेली।
3. मुख्य अभियन्ता (परिकल्प) सिंचाई एवं जल संसाधन विभाग, डॉ0 राम मनोहर लोहिया परिकल्प भवन, तेलीबाग, लखनऊ।
4. श्री पंकज मनी, Sc. G नैशनल इंस्टीट्यूट ऑफ हाइड्रोलॉजी, रुड़की, उत्तराखण्ड द्वारा (ईमेल pmani.nihr@gov.in)
5. अधीक्षण अभियन्ता, पंचम मण्डल सिंचाई कार्य, बरेली को उनके पत्रांक 8916/पंमसिकाब/किच्छा बैराज/2023-24 दिनांक 12.10.2023 के संदर्भ में।

(एस0पी0 सिंह)
मुख्य अभियन्ता(शारदा)

OFFICE FOLDER/BHANDARI SIR



कार्यालय अधीक्षण अभियन्ता
पंचम मण्डल सिंचाई कार्य,
बरेली

पत्रांक -: 8916 /पंमसिंकाब /तक0अनु0/किच्छा बैराज/2023-24 दिनांक :-12-10-2023

विषय -जनपद ऊधमसिंह नगर में क्षतिग्रस्त किच्छा बैराज के निर्माण हेतु River Morphology अध्ययन कराये जानेएवं नवीन किच्छा बैराज के उपयुक्त स्थल चयन के सम्बन्ध में।

संदर्भ- आपका पत्रांकः-13265/मुअशाब/परियोजना/दिनांकः-06.10.2023

मुख्य अभियन्ता (शारदा), सिंचाई एवं जल संसाधन विभाग, उ0प्र0, बरेली।

कृपया उपरोक्त विषयक संदर्भित पत्र का संदर्भ ग्रहण करने की कृपा करें, जिसके द्वारा किच्छा बैराज के निर्माण किये जाने के सम्बन्ध में परिकल्प द्वारा किसी सरकारी विशेषज्ञ संस्था से अध्ययन कराने एवं उनके द्वारा दिये गये सलाह पर सथायी समाधान हेतु विचार करने का मत दिया गया है। अवगत कराना है कि किच्छा बैराज जनपद ऊधमसिंह नगर (उत्तराखण्ड राज्य)की तहसील किच्छा में किच्छा नदी पर काठगोदाम (जनपद नैनीताल) पर अवस्थित गोला बैराज से 40 किमी0 डाउनस्ट्रीम में स्थित है। दिनांक 18 व 19 अक्टूबर, 2021 को क्षेत्र में आयी अप्रत्याशित वर्षा के कारण गोला बैराज द्वारा 82869 क्यूसेक पानी पास हुआ। भारतीय मौसम विभाग के अनुसार किच्छा बैराज के कैचमेन्ट में स्थापित रेन गेज स्टेशन नैनीताल में 401.00 मिमी0, हल्द्वानी में 325.00 मिमी0 तथा पन्तनगर में 403.90 मिमी0 वर्षा रिकार्ड की गयी। जो कि अब तक के इतिहास में 24 घंटों में हुई अधिकतम वर्षा है। इसका प्रभाव यह रहा कि बैराज से 3.66 किमी0 की दूरी पर स्थित रूद्रपुरटनकपुर हाइवे से मात्र15-20 से0मी0 नीचे पानी बह रहा था। किच्छा बैराज 674 फीट (205.44) के एच0एफ0एल0 के लिए परिकल्पित था। दिनांक19 अक्टूबर 2021 को 680 फीट (207.264 मीटर)का लेवल पक्के स्ट्रक्चर पर रिकार्ड किया।

नदी में चलित डिस्चार्ज 125000 से 150000 क्यूसेक के बीच अनुमानित है। फ्लड का डिस्चार्ज सी0 डब्ल्यू0सी0 से आंकलित कराया गया, जो 1:100 आवृत्तिपर 3207क्यूमेक (113254 क्यूसेक) और 1:500 आवृत्ति पर 4000 क्यूमेक (141258 क्यूसेक) आंकलित किया गया है। नदी में आयी बाढ गोला बैराज से छोड़े गये 82869 क्यूसेक पानी एवं कैचमेन्ट में हुई अधिकतम वर्षा के संयुक्त परिणाम के कारण पानी परिकल्पित बाढ स्तर से अधिक 6.00 फीट (1.80 मीटर) ऊपर जाने से बांया मार्जिनल बांध के ऊपर से जाने लगा जिससे किच्छा नहर 110 मीटर लम्बाई में कट गयी और नहर के हैड का दायां भाग और बैराज का अंतिम अबटमेंट स्कवर होकर बह गया। नतीजन किच्छा बैराज का 08वां गेट, किच्छा नहर के हेड रेग्युलेटर, 110 मीटर किच्छा नहर एवं मार्जिनल बंध पूर्णतया क्षतिग्रस्त हो गये।

अतः आपसे अनुरोध है कि कृपया किच्छा बैराज के निर्माण हेतु River Morphologyअध्ययन कराने एवं नवीन किच्छा बैराज के निर्माण स्थल उपयुक्त स्थल चयन के लिए अपने स्तर से Director,National Institute of Hydrology, Roorkee (Uttrakhand) (mail address director.nihr@gov.in, Copy pmani.nihr@gov.in) को पत्र लिखने की कृपा करें।

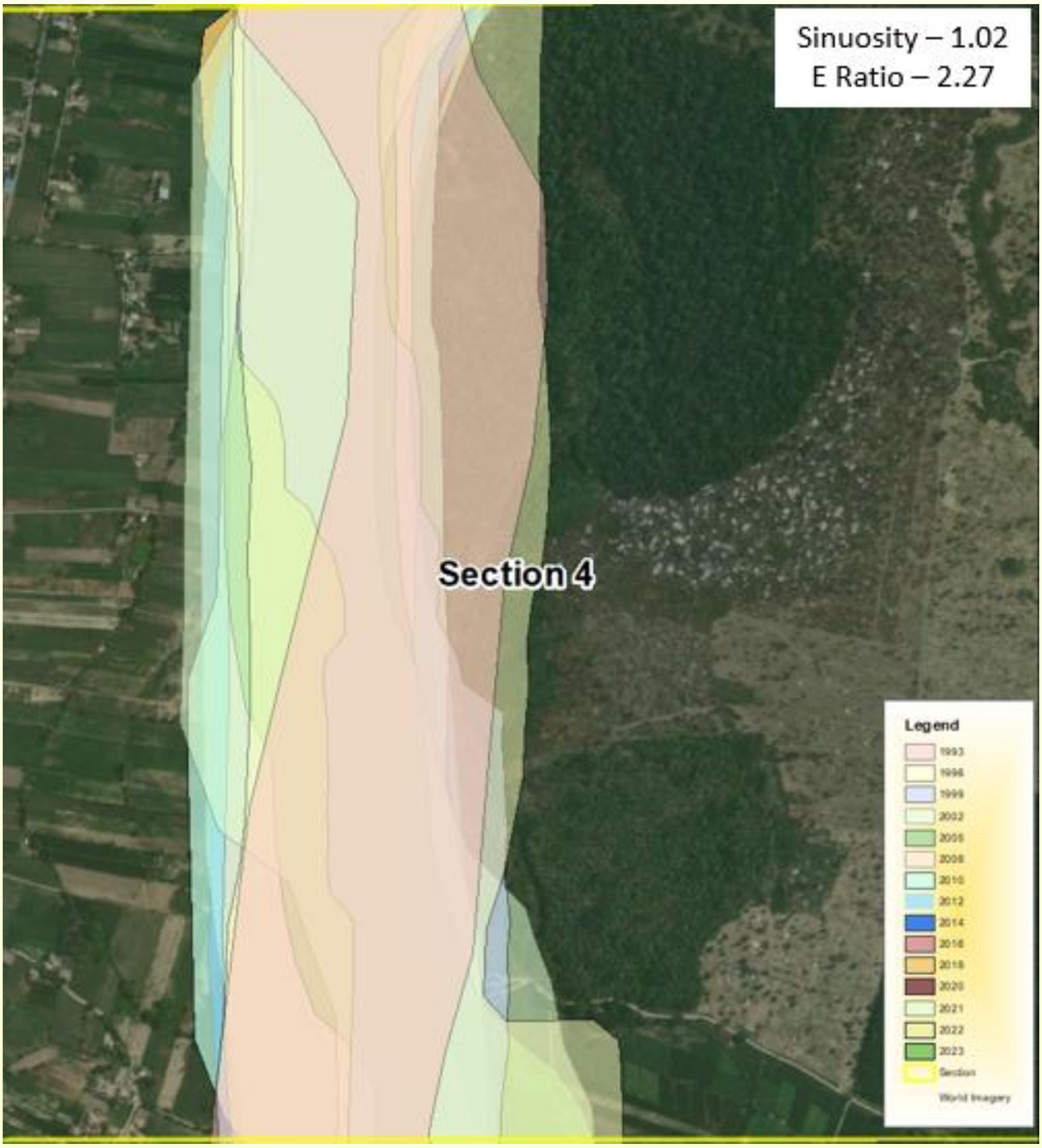
(शरद कुमार सिंह)
अधीक्षण अभियन्ता

पत्रांक -: /पंमसिंकाब/ दिनांक :-12-10-2023

12/10/23
(विशाल गौड़)

प्रतिलिपि अधिशासी अभियन्ता, रूहेलखण्ड नहर खण्ड, बरेली को उनके पत्रांक-2608/रू[illegible]/तक0अनु0/किच्छा बैराज/2023-24/दिनांक 12.10.2023 के क्रम में सूचनार्थ प्रेषित है।

(शरद कुमार सिंह)
अधीक्षण अभियन्ता



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