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Study of Meandering Channel

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Abstract — *Meander Characteristics play an important role in location, Design and Maintenance of hydraulic structures such as Bridge, Barrage, Flood embankment and guide bank. A meander forms when moving water in a stream erodes the outer banks and widens its valley and the inner part of the river has less energy and deposits silt. The present paper deals with the study of meander of Narmada River around Bharuch city. The planform geometric parameters such as meander wave length (Lm), meander belt width (B), meander bend (Lb) and radius of curvature (Rc) are measured with the help of available topographical sheets and Google Earth images. In the present study verification of this models is done using data of Narmada River. Statistical Parameters like Percentage Error and D.R. (Discrepancy Ratio) are calculated for comparing the performance of selected models. For such research, data's using Google Earth images from 1984 to 2016, toposheet of year 1971-72 and U.S. army map nf-43-09. Researchers like William G.P. (1986) and Leopold & Wolman (1960) have developed many models correlating various meander features. Morphometric parameters such as Sinuosity Index and Meander Ratio were measured to detect the periodical change.*

Keywords-*Narmada River, River Meandering, Morphometric parameters*

I. INTRODUCTION

A meander is a bend in a sinuous water course or river. A meander forms when moving water in a stream erodes the outer banks and widens its valley, and the inner part of the river has less energy and deposits silt.(3) A stream of any volume may assume a meandering course, alternately eroding sediments from the outside of a bend and depositing them on the inside. The result is a snaking pattern as the stream meanders back and forth across its down-valley axis. When a meander gets cut off from the main stream, an oxbow lake forms. Over time meanders migrate downstream, sometimes in such a short time as to create civil engineering problems.

II. THE PROCESSES OF CREATION AND EVOLUTION OF MEANDERS

River meandering is one of the most predominant, rhythmic geometric phenomenon on the surface of Earth. Meander study is one of the primary subjects of quantitative geomorphology - a science that investigates the shapes, which occur above the ground or beneath it. Numerous studies in this field have proven that the forming processes of the meanders' shape are a lot more elaborate than what appears at first sight(4). Geomorphology gives a clear, detailed image of the meanders' causes and development processes, from their "birth" till their "death".

A single meander is constructed by two arcs attached to each other that create together the shape of the letter S. Each arc is usually larger than 180 degrees. Figure 1 illustrates the general shape of a meander and its main characteristics. The bending of the path is fundamental to meander's development. The speed of the current close to the bank is usually slower than the one in mid-stream, because of the friction with the river bank. When a disturbance to the straight water flow occurs, as a result of an obstacle or a change in soil conditions in different parts, the water detour the obstacle and an arc is formed in the river bed.

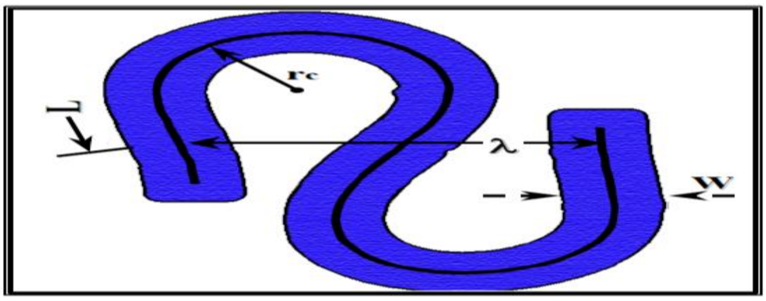

Fig 1 A schematic shape of a meander
W - Width of the river bed; λ - wave length;
L - Length of the river bed; rc - curvature radius

The water flow is accelerated and as a result the alluvium process intensifies in the external side of the arc. In other words: the water flowing towards the concaved bank (looking from mid-river) strikes at it, and bounces back away from it towards the convex bank. The process repeats itself later on to create another arc in the opposite direction. Passing through the inflection point from one arc to the next, all the forces activated in the water, reverse their direction, and the creation process repeats itself in the opposite direction to the previous arc. That concludes the creation of one meander. In this process a centrifugal force develops, which supports the increase of the arc's radius. While the concaved bank withdraws following the alluvium process, the deposits accumulate on the convexes bank. These build-ups create triangular-shape flat ridges, called vertex ridges.

The meanders extend the watercourse of the river, and while doing so, cause a local reduction in its slope and a reduction of the flowing speed in this part of the river. As a result, there is a gradual tapering off the centrifugal force until it diminishes altogether. In this state the curvature radius stops growing. Therefore the curvature radius does not grow beyond a certain size, which depends on the slant of the mountain's slope, the width of the river and the amount of water in this part of the river. When the curvature radius reaches its maximum size, the meander is called a mature meander.

III. NEED OF THE STUDY

The behavior of river flow is greatly affected by the flow characteristics and river bank character which affects its alignment greatly during its course. The process of meandering is highly dynamic which depends upon number of hydrological i.e., discharge in stream, run off etc. and hydraulic variables like flow velocity, depth of bed, slope of bed etc. Hence meander geometry is significantly affected by the nature of strata through which it flows. The behavior of river is required to be known as it is directly related with transportation, agriculture, power generation, recreational and many other uses. The main characteristics of a meandering river are - the shape, size and mobility of meander loops. All these characteristics play an important role in location, design and maintenance of hydraulic structures such as bridges, barrages, flood embankments and guide banks.

Narmada is the largest west flowing river in India. Narmada River known for occurrence of large floods due to influence of depressions from catchment areas surrounding from Narmada River. Western margin of Indian subcontinent in the lower reaches of a significant River Narmada, which flows from East to West for 1289 km, across the Indian Peninsula, under the influence of Southwest Indian Monsoon (SwIM).

At the time of flood in Narmada River, Bharuch city and surrounding regions are most affected. The Bharuch city has face many floods in Narmada River. Present study on river Narmada is undertaken to find the characteristics and past behavior of river meandering and compare the meander characteristics using the empirical formulae developed by researchers and to understand effect of flood on meandering.

IV. OBJECTIVE OF THE STUDY

The objective of present study is to analyse relationship between various planimetric variable for the meandering portion of river Narmada from Kabirvad to Ambali around Bharuch City and to develop the model for various planimetric variable for the meandering portion of river.

- To study planform geometric parameters of the Narmada River meander from the Topo-sheets and Google images.
- To measured planform geometric parameters using AUTCAD software.
- To study interrelationship between meander future.
- To compare the observed data with computed data.
- To developed the model for various planimetric variable for the meander portion of Narmada River.

V. REVIEW OF PAPERS

Williams G.P (1986)[5] studied an enlarged data set to (1) compare measured meander geometry to that predicted by the Langbein and Leopold (1966) theory, (2) examine the frequency distribution of the ratio radius of curvature/channel width, and (3) derive 40 empirical equations (31 of which are original) involving meander and channel size features. The Langbein-Leopold sine-generated-curve theory for predicting radius of curvature agrees very well with the field data (78 sites). The ratio radius of curvature/channel width has a modal value in the range of 2 to 3, in accordance with earlier work; about one third of the 79 values is less than 2.0. The 40 empirical relations, most of which include only two variables, involve channel cross-section dimensions (bank full area, width, and mean depth) and meander features (wavelength, bend length, radius of curvature, and belt width),having very high correlation coefficients, most being in the range of 0.95~.99.

Leopold L.B. & Wolman M.G., 1957[1], studied channel pattern which is used to describe the plan view of a reach of river and found that the meander wavelength, or twice the distance between successive riffles, is from 7 to 12 times the channel width and also concluded that the mechanics which may lead to meandering operate in straight channels. The points of inflection are also shallow points and correspond to riffles in the straight channel. This distance, which is half the wavelength of the meander, varies approximately as a linear function of channel width. Natural channels characteristically exhibit alternating pools or deep reaches and riffles or shallow reaches, regardless of the type of pattern. The length of the pool or distance between riffles in a straight channel equals the straight line distance between successive points of inflection in the wave pattern of a meandering river of the same width.

Leopold L.B. & Wolman M.G. (1960)(2) observed that the most river curves have nearly the same value of the ratio of curvature radius to channel width, in the range of 2 to 3. Meanders formed by melt water on the surface of glaciers, and by the main current of the Gulf Stream, have a relation of meander length to channel width similar to rivers. Because such meanders carry no sediment, the shapes of curves in rivers are evidently determined primarily by the dynamics of flow rather than by relation to debris load. Velocity distributions along river curves provide a generalized picture of flow characteristics. Evidence on flow resistance in curved channels suggests that a basic aspect of meander mechanics may be related to the distribution of energy loss provided by a particular configuration or curvature. No general theory of meanders is as yet satisfactory, however; in fact, present evidence suggests that no single theory will explain the formation and characteristics of all meanders and that few of the physical principles involved have yet been clearly identified.

VI. METHODOLOGY

The total basin area of the river is 97,410 square kilometer comprising 85,858 square kilometer in Madhya Pradesh, 1658 square kilometer in Maharashtra and 9894 square kilometer in Gujarat. The basin covers large areas in the states of Madhya Pradesh (81%), Gujarat (12%) and a comparatively smaller area (4%) in Maharashtra, (2%) in Chhattisgarh and (1%) in Andhra Pradesh. The drainage area up to dam site is 88,000 square kilometer. The mean annual rainfall in the basin is 112 centimeters.

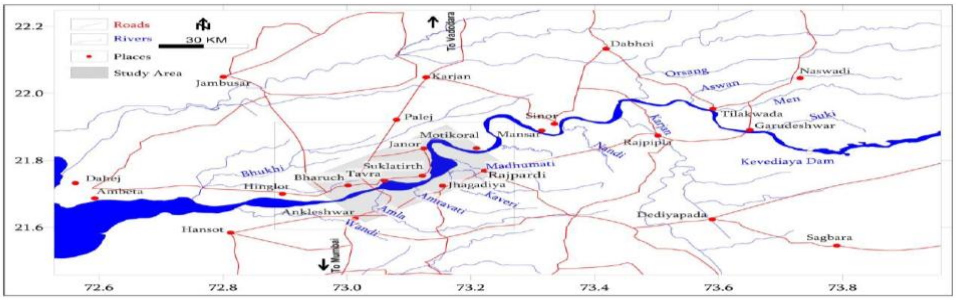

Fig 2 Location map of study area

It lies between 72°38’ to 81°43’ east longitudes and 21°27’ to 23°37’ north latitudes. It is bounded by the Vindhyas on the north, by the Maikala range on the east, by the Satpuras on the south and by the Arabian Sea on the west. The hilly regions are in the upper part of the basin, and lower middle reaches are broad and fertile areas well suited for cultivation. The catchment area encompasses important regions in Madhya Pradesh, Gujarat, and Maharashtra.

For the proper study of the present study, Google earth images as well as toposheet and us army map was studied (figure 3). AutoCAD has been used for calculation of Belt width, Bad length, Radius of curvature and wave length which is major parameters for the calculation of the sinuosity index and meander ratio which are described in the figure-4 to figure-7 with 5 year span.

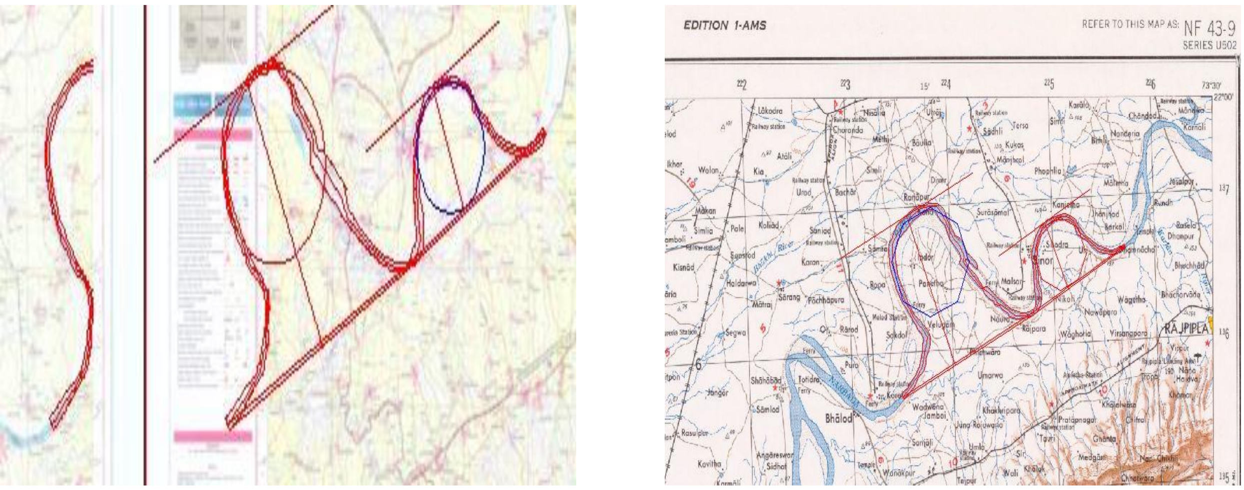

Fig 3 Toposheet and US Army Map for Study Area

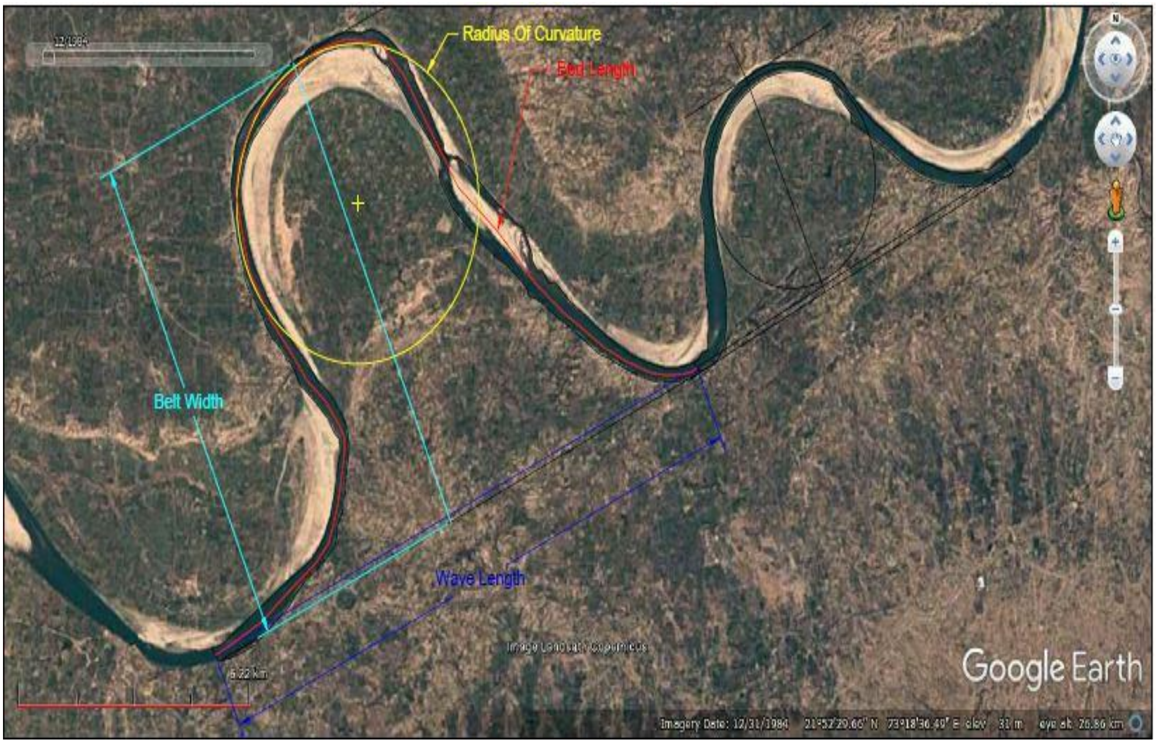

Fig 4 Image of Narmada River Meandering in AutoCAD (Year 1984)

Fig 5 Images of Narmada River Meandering in AutoCAD (Year 1990 and 1995)

Fig 6 Images of Narmada River Meandering in AutoCAD (Year 2000 and 2005)

Fig 7 Images of Narmada River Meandering in AutoCAD (Year 2010 and 2016)

VII. RESULTS

For the calculation of different parameters which can be used to maintain graphs for the sinuosity index and meander ratio via help of AutoCAD images, Different parameters were calculated through which sinuosity index and meander ratio can be calculated.

Table 1 represents the different parametric values for Belt Width, Wave length, Radius of Curvature and Bed Width through which Sinuosity Index and Mender Ratio were calculated and then graph were plotted for Loop 1.

Table 1 Different Parameters for Loop 1

For Loop 1											
Sr No.	Year	Belt Width(B)		Wave Length(meander Length)(Lm)		radius of curvature(Rc)		Bed width(Lb)		Sinousity Index(S.I)	Meander Ratio(MR)
		AutoCAD distance	Orignal distance	AutoCAD distance	Orignal distance	AutoCAD distance	Orignal distance	AutoCAD distance	Orignal distance		
1	1950	0.691	10.406	0.853	12.854	0.229	3.449	1.868	28.141	2.704	2.189
2	1972	8.110	10.284	10.481	13.291	2.628	3.333	22.152	28.091	2.731	2.114
3	1984	6.295	10.199	8.712	14.115	1.997	3.235	17.693	28.668	2.811	2.031
4	1990	6.273	10.165	8.714	14.118	1.997	3.236	17.810	28.857	2.839	2.044
5	1995	6.307	10.218	8.713	14.117	1.995	3.232	17.676	28.640	2.803	2.029
6	2000	6.286	10.185	8.710	14.113	1.996	3.233	17.532	28.406	2.789	2.013
7	2004	6.287	10.186	8.711	14.113	1.996	3.234	17.683	28.651	2.813	2.030
8	2005	6.268	10.155	8.712	14.115	1.996	3.234	17.605	28.525	2.809	2.021
9	2006	6.281	10.176	8.718	14.125	1.990	3.224	17.581	28.486	2.799	2.017
10	2007	6.273	10.164	8.709	14.110	1.982	3.212	17.525	28.395	2.794	2.012
11	2008	6.270	10.158	8.712	14.116	1.994	3.231	17.582	28.487	2.804	2.018
12	2009	6.271	10.161	8.714	14.118	1.991	3.226	17.629	28.564	2.811	2.023
13	2010	6.291	10.192	8.711	14.115	1.993	3.229	17.563	28.456	2.792	2.016
14	2011	6.295	10.199	8.712	14.115	1.995	3.232	17.533	28.407	2.785	2.013
15	2012	6.277	10.170	8.711	14.115	1.997	3.236	17.517	28.383	2.791	2.011
16	2013	6.269	10.158	8.716	14.123	1.996	3.234	17.503	28.359	2.792	2.008
17	2014	6.291	10.194	8.716	14.122	1.996	3.234	17.494	28.344	2.781	2.007
18	2015	6.265	10.151	8.715	14.120	1.997	3.235	17.487	28.334	2.791	2.007
19	2016	6.269	10.157	8.718	14.125	1.994	3.231	17.643	28.586	2.814	2.024
	AVERAGE		10.176		14.117		3.231		28.503	2.801	2.019

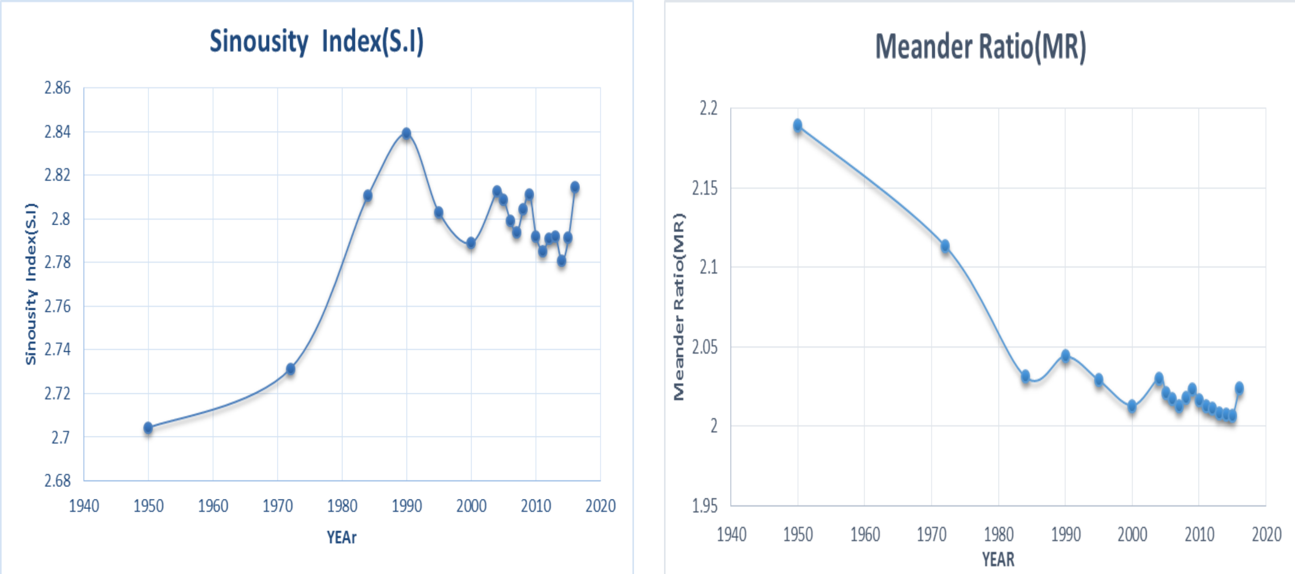

Fig 8 Graph of Sinousity Index and Meander Ratio Vs Year

For the calculation of percentage error and discrepancy ratio, above values were used and compared with papers of author Williams G.P which are shown in below table.

Table 2 Percentage Error and Discrepancy Ratio for Loop 1

Year	Lm=1.25 Lb	Lm=1.63B	Lm=4.53Rc	Wave Length(Lm)	% Error For			Discrepancy Ratio(D.R) For		
					Lm=1.25 Lb	Lm=1.63B	Lm=4.53Rc	Lm=1.25 Lb	Lm=1.63B	Lm=4.53Rc
1950	0	16962.049	15624.611	12853.700	-100	31.962	21.557	0	1.320	1.216
1972	0	16763.706	15096.809	13290.950	-100	26.129	13.587	0	1.261	1.136
1984	0	16624.409	14656.03	14115.182	-100	17.777	3.832	0	1.178	1.038
1990	0	16568.156	14657.498	14118.423	-100	17.351	3.818	0	1.174	1.038
1995	0	16655.573	14642.819	14116.965	-100	17.983	3.725	0	1.180	1.037
2000	0	16600.904	14646.489	14112.914	-100	17.629	3.781	0	1.176	1.038
2004	0	16602.753	14650.159	14113.238	-100	17.640	3.804	0	1.176	1.038
2005	0	16553.366	14650.159	14115.182	-100	17.273	3.790	0	1.173	1.038
2006	0	16586.907	14606.12	14125.066	-100	17.429	3.406	0	1.174	1.034
2007	0	16567.892	14548.136	14109.998	-100	17.420	3.105	0	1.174	1.031
2008	0	16557.856	14636.213	14115.507	-100	17.303	3.689	0	1.173	1.037
2009	0	16562.081	14614.194	14118.261	-100	17.310	3.513	0	1.173	1.035
2010	0	16613.581	14628.139	14114.696	-100	17.704	3.638	0	1.177	1.036
2011	0	16623.881	14639.149	14115.344	-100	17.772	3.711	0	1.178	1.037
2012	0	16577.135	14658.966	14114.534	-100	17.447	3.857	0	1.174	1.039
2013	0	16557.064	14650.159	14122.798	-100	17.236	3.734	0	1.172	1.037
2014	0	16615.43	14650.159	14122.312	-100	17.654	3.738	0	1.177	1.037
2015	0	16546.235	14656.03	14120.367	-100	17.180	3.794	0	1.172	1.038
2016	0	16555.743	14636.213	14124.580	-100	17.212	3.622	0	1.172	1.036
Average	0	16615.512	14713.055	14007.3694	-100	18.706	5.142	0	1.187	1.051

Table 3 represents the different parametric values for Belt Width, Wave length, Radius of Curvature and Bed Width through which Sinuosity Index and Mender Ratio were calculated and then graph were plotted for Loop 1.

Table 3 Different Parameters for Loop 2

Sr No.	Year	Belt Width(B)		Wave Length(meander Length)(Lm)		radius of curvature(Rc)		Bed width(Lb)		Sinousity Index(S.I)	Meander Ratio(MR)
		AutoCAD distance	Orignal distance	AutoCAD distance	Orignal distance	AutoCAD distance	Orignal distance	AutoCAD distance	Orignal distance		
1	1950	0.311	4.687	0.605	9.118	0.152	2.292	0.928	13.983	2.983	1.534
2	1972	3.793	4.810	7.750	9.828	1.756	2.227	11.722	14.865	3.090	1.512
3	1984	2.971	4.813	5.744	9.306	1.380	2.235	8.804	14.265	2.964	1.533
4	1990	2.943	4.768	5.745	9.309	1.374	2.225	8.922	14.455	3.032	1.553
5	1995	2.950	4.780	5.743	9.305	1.374	2.227	8.778	14.222	2.975	1.528
6	2000	2.951	4.782	5.744	9.307	1.374	2.226	8.726	14.138	2.957	1.519
7	2004	2.934	4.754	5.747	9.312	1.379	2.234	8.812	14.278	3.004	1.533
8	2005	2.934	4.753	5.747	9.311	1.379	2.234	8.805	14.266	3.001	1.532
9	2006	2.942	4.767	5.738	9.297	1.378	2.232	8.725	14.137	2.966	1.521
10	2007	2.928	4.745	5.749	9.315	1.380	2.235	8.736	14.155	2.983	1.520
11	2008	2.926	4.741	5.742	9.304	1.379	2.234	8.716	14.122	2.979	1.518
12	2009	2.926	4.741	5.744	9.307	1.380	2.236	8.772	14.213	2.998	1.527
13	2010	2.940	4.764	5.747	9.311	1.375	2.227	8.689	14.078	2.955	1.512
14	2011	2.940	4.764	5.747	9.311	1.375	2.228	8.691	14.082	2.956	1.512
15	2012	2.940	4.764	5.747	9.311	1.376	2.229	8.713	14.117	2.963	1.516
16	2013	2.939	4.762	5.749	9.315	1.380	2.236	8.739	14.159	2.973	1.520
17	2014	2.955	4.788	5.748	9.313	1.377	2.230	8.767	14.205	2.967	1.525
18	2015	2.948	4.777	5.751	9.317	1.380	2.235	8.731	14.146	2.961	1.518
19	2016	2.939	4.761	5.745	9.309	1.382	2.239	8.789	14.240	2.991	1.530
	AVERAGE		4.766		9.310		2.232		14.193	2.978	1.525

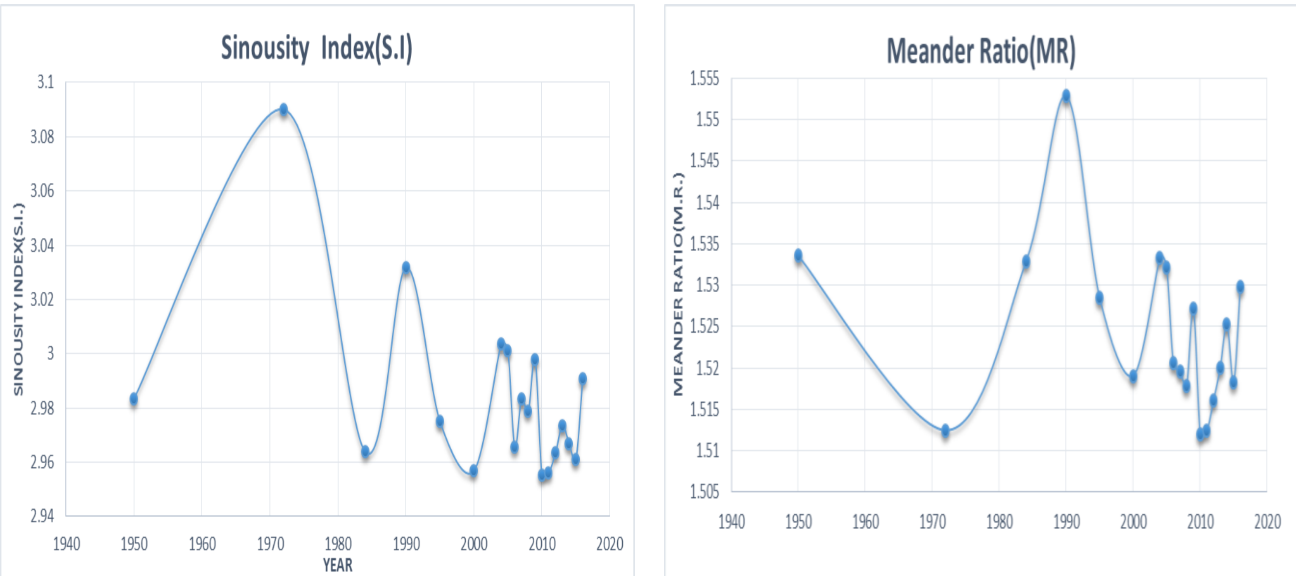

Fig 9 Graph of Sinousity Index and Meander Ratio Vs Year

For the calculation of percentage error and discrepancy ratio, above values were used and compared with papers of author Williams G.P which are shown in below table.

Table 4 Percentage Error and Discrepancy Ratio for Loop 2

Year	Lm=1.25 Lb	Lm=1.63B	Lm=4.53Rc	Wave Length(Lm)	% Error For			Discrepancy Ratio(D.R) For		
					Lm=1.25 Lb	Lm=1.63B	Lm=4.53Rc	Lm=1.25 Lb	Lm=1.63B	Lm=4.53Rc
1950	0	7640.165	10384.567	9118.385	-100	-16.211	13.886	0	0.838	1.139
1972	0	7840.702	10088.092	9828.212	-100	-20.222	2.644	0	0.798	1.026
1984	0	7845.141	10126.665	9306.425	-100	-15.702	8.814	0	0.843	1.088
1990	0	7771.457	10081.159	9308.856	-100	-16.515	8.296	0	0.835	1.083
1995	0	7791.792	10087.764	9304.967	-100	-16.262	8.413	0	0.837	1.084
2000	0	7793.905	10084.829	9307.397	-100	-16.261	8.353	0	0.837	1.084
2004	0	7748.480	10121.527	9311.772	-100	-16.788	8.696	0	0.832	1.087
2005	0	7747.951	10119.325	9311.448	-100	-16.791	8.676	0	0.832	1.087
2006	0	7769.608	10111.252	9297.190	-100	-16.431	8.756	0	0.836	1.088
2007	0	7733.690	10126.665	9314.527	-100	-16.972	8.719	0	0.830	1.087
2008	0	7727.880	10120.059	9303.833	-100	-16.939	8.773	0	0.831	1.088
2009	0	7727.616	10128.133	9306.749	-100	-16.968	8.826	0	0.830	1.088
2010	0	7765.382	10088.498	9311.448	-100	-16.604	8.345	0	0.834	1.083
2011	0	7764.854	10094.370	9311.448	-100	-16.610	8.408	0	0.834	1.084
2012	0	7764.854	10095.838	9311.448	-100	-16.610	8.424	0	0.834	1.084
2013	0	7761.685	10127.399	9315.013	-100	-16.676	8.721	0	0.833	1.087
2014	0	7804.205	10103.912	9313.230	-100	-16.203	8.490	0	0.838	1.085
2015	0	7786.774	10126.665	9317.281	-100	-16.427	8.687	0	0.836	1.087
2016	0	7761.157	10143.547	9309.018	-100	-16.628	8.965	0	0.834	1.090
Average	**0**	**7765.647**	**10124.225**	**9326.771**	**-100**	**-16.727**	**8.573**	**0**	**0.833**	**1.086**

VIII. CONCLUSION

From the study of above results, following points can be concluded:

1. William G.P. model predicts well for the meander features Lm & B and Lm & Rc with discrepancy ratio 1.187 and 1.051 for loop 1.
2. William G.P. model predicts well for the meander features Lm & B and Lm & Rc with discrepancy ratio 0.833 and 1.086 for loop 2.
3. The best predictability of the Leopold & Wolman model is observed for the relation between Lm & Rc with the D.R. 1.0074 which is nearly for both the loop 1 and 2.

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