International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081 (Online)
An Online International Journal Available at http://www.cibtech.org/jgee.htm
2013 Vol.3 (3) September-December, pp.30-39/Subrata Jana
Research Article

RIVERINE GEOMORPHOLOGY, SEDIMENTOLOGY AND SUB-SURFACE WATER POTENTIALITY- A CASE STUDY ALONG THE SECTION OF DWARKESWAR RIVER, ONDA, BANKURA, WEST BENGAL

***Subrata Jana**
Department of Geography and Environment Management, Vidyasagar University, Midnapore- 721102, West Bengal, India
**Author for Correspondence*

ABSTRACT

Fluvial hydro-geomorphology and sedimentological features of any riverine tract is significantly influenced by flood regime in the tropical monsoon dominated environment. The fluvial geomorphology, sedimentology and sub-surface water potentiality are the significant issues to understand the temporal fluvial dynamism in any channel section. Both the macro and micro geomorphological landforms are identified and measured with their some sedimentological variation in this study. Significant micro landforms features like sand splay, mid-stream bar, various depositional surfaces, ripple marks, braided channels are measured with quantitative aspects. Those landforms are very much associated with river gradient, flood energy conditions in the study area. The sub-surface litho logical sediment structures dominated with sand size sediment about >97% except top portion of the lithologs that influenced on about 887.519×10-5 m3/day water yield potentiality is estimated in this present work. Through remote sensing image analysis, it is clear that the critical pattern of braided channel, positions of ripple marks with their necessary geometric measurements. The geomorphic features are positively related with the flood regime. The sub-surface water is very potential condition in respect to extraction for drinking water supply purpose in the surrounding areas.

Key Words: *Fluvial hydro-geomorphology, Micro landforms, Sand splay, Braided channel, Flood, Water yield potentiality, Lithologs*

INTRODUCTION

The geomorphological setup of any middle section riverine tract is dominated by the upstream contribution of water, sediment load and energy potentiality, carrying by the river.

The middle section of the Dwarkeswar River, particularly in the present study sector is dominated by the fluvio-geomorphological features like braided channels, mid-stream sand bar, point bars, thickly deposited sand bodies, ripple marks, sand splays etc. the sand splays are normally formed due to the high magnitude flood with over bank river discharge during peak rainy season (Mukhopadhyay, 2010).

Stream flow side point bars are formed with the effects of locally concentration of bed load sediment and suspended sediments with lag of water current energy along the channel during peak river discharge and stored temporarily in the outer side of the river meander bend (Chang, 1984).

Channel middle mid-stream sand bars are formed due to the sudden high flood discharge with high load of coarser and unsorted sediments deposited in the middle of the channel with the change of river gradient or the expansion of the channel water carrying capacity (Joshi and Gaikhe, 2009).

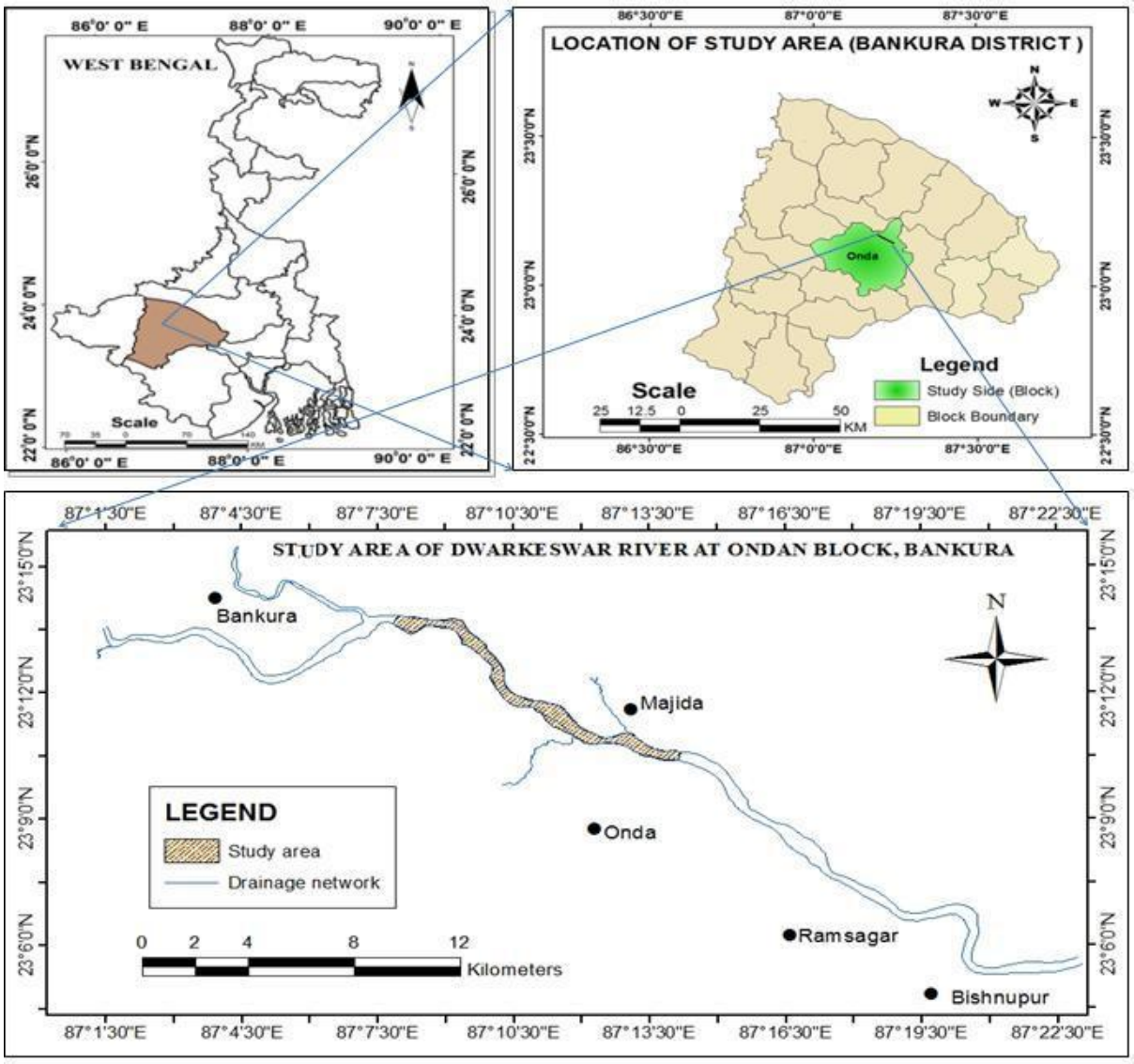

Figure 1: Location Map of the study area.

The underlying geology is the imprint about the past record of the fluvial hydrology and sedimentology of a particular river. The stratigraphical records through bore holes can give us a clear cut idea about the past environmental conditions of a specific region. The bore holes sedimentological lithologs depict dominance of the late-Pleistocene glacial melting, through the signatures of the gravels and pebbles size rock fragments dominated bed remain in a certain depth (about 15m)from the present river bed (Project Report, 2013).

Sedimentological grain size analysis of the mid-stream bar section of different stratigraphical lithologs through sieve test analysis and identifying the dominant phi (ϕ) scale with layer wise variation (Mukherjee, 2003; Mukhopadhyay, 2010).

The micro-geomorphological landforms are shifted their position with every flood. Formation of newly deposited sand splays over channel side with high magnitude river flood is very problematic function in this study area. The sub-surface water storage and flow characteristics are dominated by the underlying sedimentological structures. The distribution of the well sorted sedimentological layers depicts the storage

and flow capacity of the sub-surface water and its degree of potentiality. During the pre-monsoon phase the river bed almost remain dry. But, the sub-surface water can remain in the potential stage. Huge extraction of ground water will not sustain the permanent ground water table; therefore sub-surface water will play a vital role in near future. This paper contains the following objectives:

i. To find out the micro and macro geomorphological landforms associated with flood regime.
ii. To study the sub-surface water potentiality in response to sedimentological structures.

Study Area

The present study area of Dwarkeswar River, between latitudinal extension of 23°10′19″N to 23°13′52.30″N and longitudinal extension of 87°07′44.30″E to 87°14′20″E comprising an area of 6.16km^2(figure 1). This are comes under the Onda block of Bankura district, West Bengal and in the middle course with wide (average about 400m), shallow depth (about 3.8m) channel bed and relatively low gradient (about 1:0.0017) along with various erosional and depositional hydro-geomorphic features of the Dwarkeswar River.

In the geological point of view, this study area is situated in the fringe area of the dissected lateritic belt of Chhota Nagpur plateau. The river valley, in the study area is formed by the Quaternary sediments and recent alluvium deposits of sand silt and clay (unoxidised or occasionally oxidised) like soft sediments with dominance of soft mottled clay.

MATERIALS AND METHODS

The final base map for the current study has been prepared from the satellite image (LISS-III) of1st February, 2011. The various geomorphological maps also prepared from that image and final maps are prepared through Arc GIS 10.1 software. The various geomorphological units are observed and measurements have been done with geoscientific methods. The topographical Digital Elevation Model (DEM) map has been prepared through SRTM data processing through GIS software. To study the sedimentological parameters, sediment samples are collected from various layers with different geomorphological units. The bore holes lithological samples are also taken through boring activities across the study area. The boring activities have been done with methodological way of 500m interval along the river long profile and about 50m (average) interval along the river cross profile. Therefore, total 204 number of slim bores are bored (an average depth of 15m) and sediment samples are collected from each different layers with the variation of depth and sediment characters. All the sediment samples are analysed through sieve test with specific mesh sizes. The analysed data are arranged in logical statistical way and the diagrams are drawn. The sub-surface water potentiality is analysed through 72 hours continuous pump test activities with spatial variation. And the discharge records are collected and analysed those data with relation to sedimentological characteristics.

RESULTS AND DISCUSSION

Geomorphological and Hydrological Characteristics

The geomorphological landforms in the middle Dwarkeswar River valley are formed with the interaction of natural physical setup, hydrology and sedimentology of the valley area. The river valley, in the study area (Onda section), lying in between 80m to 60m above sea level (ASL) with 1:0.0017channel gradient within the 12km river stretch (figure- 2). The study area is located in the typical monsoonal tropics type of climate. About 90% of the total rainfall arrives during the monsoon season (June to October), after a long dry phase of about seven months (November to May) generally. Also the most of the portion of the monsoon rainfall arises within 30 to 45 rainy days with torrential rainfall that caused for the high magnitude of soil erosion and high volume of water and energy are concentrated with the peak water discharge occurring severe flood events. The high magnitude of flood discharge contributes huge amount of suspended and bed load sediments with high current energy and with interaction both the parameters there are various geomorphological micro and macro landforms are developed (figures- 3, 4 and 5). After the storm monsoon discharge, in the dry phase there has been remain some imprints of past flood event.

Table 1: Various micro-geomorphological setup and their quantitative aspects

Sl. No.	Geomorphological units	No. of signatures in each geomorphological units	Total length (m)	Total area (m^2)
1	**Sand splays**	03	-	231437.89
2	**Mid-stream sand bar**	01	-	106873.70
3	**Sand bodies**	18	-	4603265.92
4	**Ripple marks**	87	3010.50	-
5	**Various depositional surfaces within the river bed**			
5.1	1st Depositional surfaces	02	-	578730.52
5.2	2nd Depositional surfaces	12	-	2297749.10
5.3	3rd Depositional surfaces	07	-	370173.15
5.4	4th Depositional surfaces	03	-	101326.43
5.5	5th Depositional surfaces	01	-	45202.74
5.6	6th Depositional surfaces	01	-	65812.76
6	**Braided channels**	270	64854	-

Source: Estimated by author

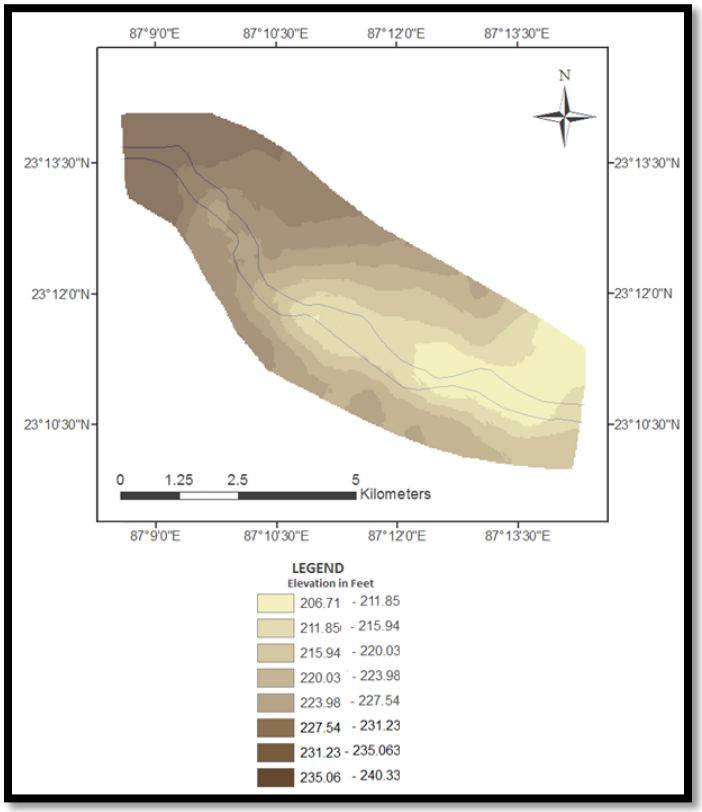

Figure 2: DEM Map in an around the study area of Dawrakeswar River at Onda, Bankura, West Bengal

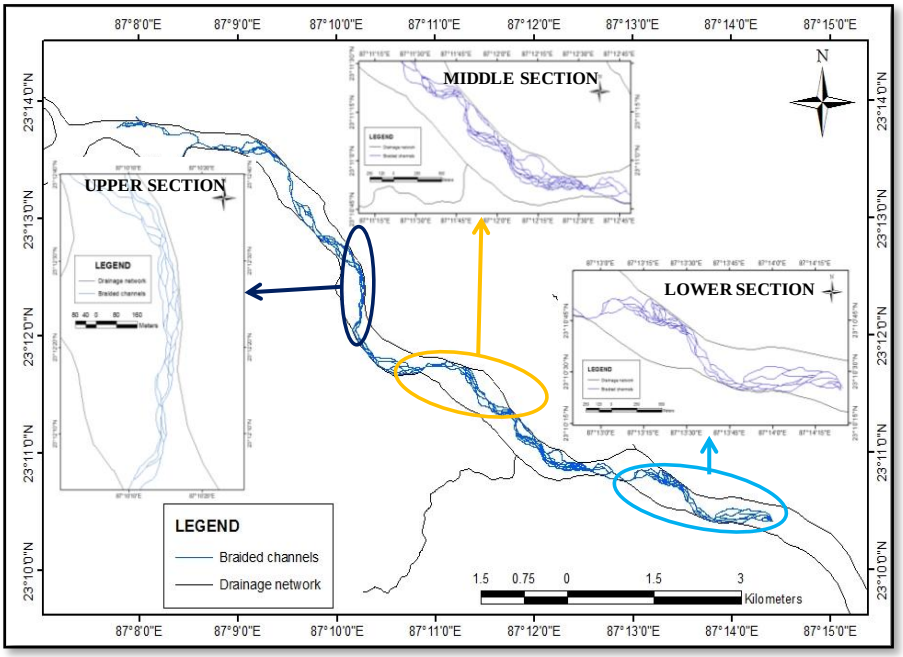

Figure 3: Nature of braided channel patter in the study area.

There have been formed various micro-geomorphic landforms in the river bed, like water pools with the scouring effects of flood water, braided channels (figure- 3), ripple marks (figure- 5) etc. and in the bank margin area of river valley some small size levees, thick deposition of finer sediments with desiccation cracks etc. There is some macro-geomorphic landform features also found in the river bed, like mid-stream sand bar, thick deposition of coarser sands with various depositional surfaces (table 1; figure- 4) etc. and in channel water side deposited features, like point bars, sand splays (figure- 5) etc. are common. The micro-geomorphological units are plays a dominant role in response to past flood magnitude. In maximum cases the micro-geomorphological landforms are may shifted, abolished or reformed with every major flood events (Molla, 2011).

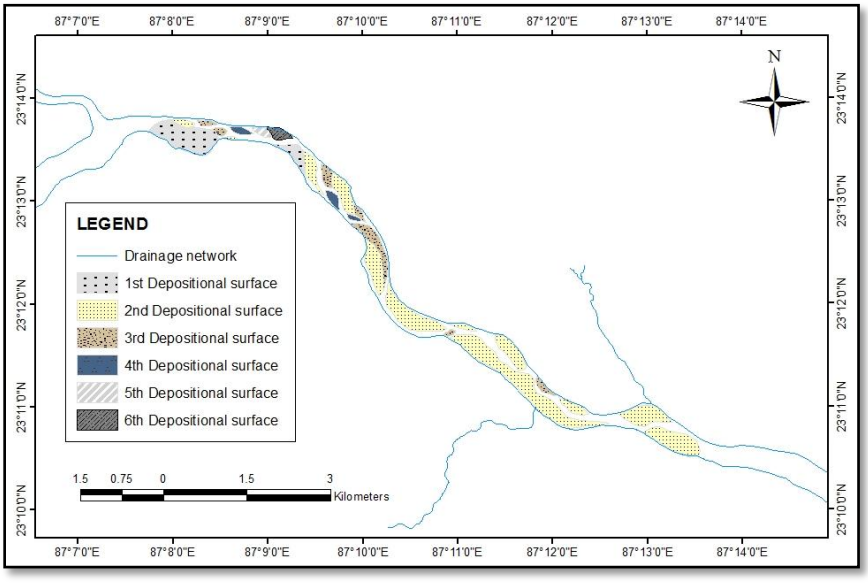

Figure 4: Various fluvio-depositional surfaces within the channel bed

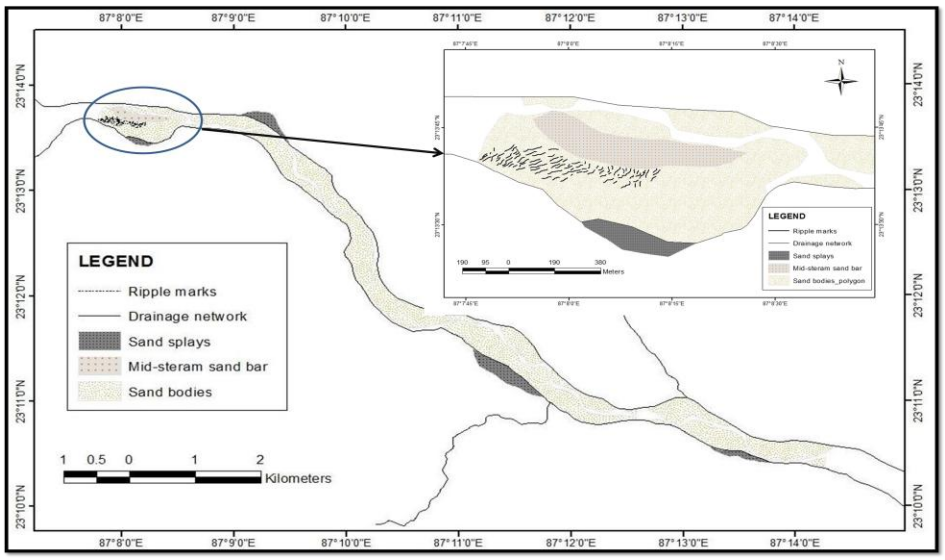

Figure 5: Different micro-geomorphological landforms in response to fluvial hydro-dynamics within the river bed

Sedimentological Characteristics

The sediments of the river bed and the sub-surface Sedimentological layers are studied in this work. Within the study area there are several places with the coarser to medium grain size of sediments are dominated (table 4). During the high magnitude flood, the river energy can carried these types of sand size sediments with the suitable depositional environment. There are total 204 number of slim bores are bored with an average depth of about 12m. The varying Sedimentological grained of coarser size sand, gravels, and medium size sands dominated along the studied river stretch along with the presence of thin discontinuous mud layer (table 2; figure 6). The stratigraphical Sedimentological analysis depicts that there is the dominance of the gravels (60.70% among the total) in the upstream region from the initial point of boring site. But, in the lower stretch of the river, there are the dominance of coarser to medium size sands. In the overall study area there is a minimum concentration of finer and very finer sediments (table 2).

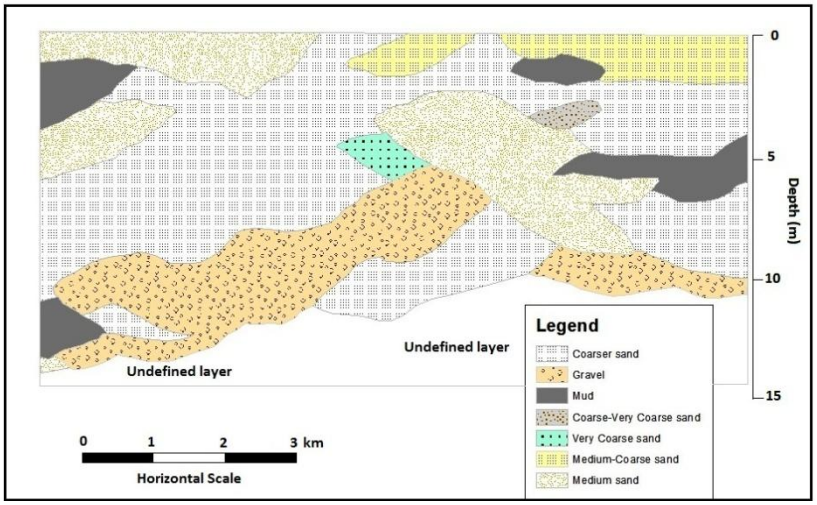

Figure 6: Detailed Lithologs along the Dawrakeswar River (Onda), Bankura district

Table 2: Depth wise variation of sediment texture of bore whole lithologs within the study area

Samples	Textural Analysis				Fractional Analysis of Sand %					
	Sand %	Silt %	Clay%	Texture	Gravel %	VC %	C %	M %	F %	VF %
Depth: 0-6m	17.5	51.8	30.7	sicl	-	1.8	1.8	1.8	7.6	4.5
Depth: 6-8m	99.2	0.3	0.5	s	20.7	24.3	43.6	29.5	1.8	-
Depth: 8-10m	97.7	0.5	1.8	s	60.7	76.3	19.4	1.9	0.1	-
Depth: 10-12m	97.6	1.6	0.8	s	22.7	28.1	42.3	22.4	4.3	0.5

Source: Anlysed and estimated by author

Table 3: Texture, Porosity and Specific yield of sediments of Onda, Dwarkeswar River

Sl. No.	Material types	% of material content	Porosity (%)	Specific yield (%)
1	Coarse gravel	2	28	23
2	Medium gravel	2	32	24
3	Fine gravel	2	34	25
4	Coarse sand	70	39	27
5	Medium sand	10	39	28
6	Fine sand	4	43	23
7	Silt	2	46	8
8	Fine-grained sandstone	4	33	21
9	Clay	1	42	3
10	Medium-grained sandstone	3	37	27

Source: Unpublished project report, (PHE), 2013

Table 4: Layer wise variation of sediment grains character in the mid-stream sand bar section

Lithological layers	Thickness (m)	Material content	Colour	Dominated grain size	Dominated Phi (ϕ) scale.
1st layer	0.45	Medium to finer sand	Whitish Brown	425-250 micron	+1to +2
2nd layer	0.06	Finer sand with alluvium	Brownish grey	250-150 micron	+2 to +3
3rd layer	0.13	Coarser sand	Yellowish grey	500-150 micron	+1 to +3
4th layer	0.18	Coarser size sand with gravels	Yellowish brown	3.35 mm	-1.75
5th layer	0.22	Medium size sand	Yellowish brown	450-75 micron	+1.25 to +3.75
6th layer	0.53	Finer sand	Yellowish	500-150 micron	+1 to +2.75

Source: Anlysed and estimated by author

The Sedimentological characteristics at the mid-stream bar section there is a thick layer of medium to finer sediments in the upper section as the signature of recently flood deposition. But, beneath that layer, there are the corresponding layers of finer size sand, coarser size sand, and mixed gravels with coarser size sand (18cm thick), then up to river bed section again medium to finer size sand dominated layers is found (table 4). The gravel deposition at that section is the signature of the very high energy riverine discharge has been occurred in the past. The total amount of sediment is coming up from the upper catchment area of the fringed of Chhota Nagpur plateau with the concentration of silica particles.

At the point bar section, the Sedimentological layers with the thick deposition of finer sand and silt size sediments. During the peak flood discharge this type of sediment is being deposited with the sudden reduces of the current after the increasing of channel width or water carrying capacity. But, after that, beneath the upper layer there is similar condition of lithological stratigraphy remains, as found in the mid-stream bar section.

The channel margin bank Sedimentological lithologs are dominated with thick finer alluvium in the top most section, where productive agricultural activities are practices. After that layer, the finer sand dominated in the lower stratigraphic section up to the normal flood limit of the river Dwarkeswar at study site.

Sub-surface Water Potentiality

During the monsoon, rivers of tropical monsoon areas contribute the highest riverine discharge. But in the post-monsoon and pre-monsoon seasons the most of the same rivers are carries minimum amount of water as surface flow. In case of Dwarkeswar River, at the study section these types of riverine flow characteristics have also been found. But, during the pre-monsoon season are not found any surface flow over the river bed (table 5). Though there is sufficient storage of sub-surface water within the sand bed. The storage capacity of sub-surface water very much depends on the porosity of the sedimentary layers (table 3).

Table: 5 Estimation of the soil-water interacted parameters in test wells and observatory wells (OW) in the study area

Well No.	Transmissivity (m^2/day)		Average Transmissivity (m^2/day)	Storability	Thickness of aquifer (m)	Permeability (m/day)	Yield of well (m^3/day)	Radius of influence (m)	Static water level (m)	Pumping water level after 72 hrs. pumping	Drawdown (m)
	Jacob's Method	Theim's Method									
Test well	306.65	855.39	581.02	-	6	51.11		-	0.914	1.646	0.732
OW-1	361.16	-	361.16	1.69	6	60.19		37.98	0.914	1.463	0.549
OW-2	492.49	-	492.49	2.39	6	82.08	887.519×10^{-5}	37.29	0.914	1.493	0.579
OW-3	560.42	-	560.42	0.87	6	93.4		75.79	0.914	1.219	0.305
OW-4	601.93	-	601.93	0.94	6	100.32		65.74	0.914	1.25	0.336

Source: Unpublished project report, (PHE), 2013

The water potentialities of the sub-surface aquifers in the study area have been estimated through the pump test data analysis along with sedimentological study. The water storability, aquifer thickness, average transmisivity, permeability, yield of well, static water levels is estimated in this study section (table 5). The recuperation rate of sub-surface water also been calculated on the basis of spatio-temporal variation after the continuous 72 hours of water pumped. The rate of water discharge during 72 hours continuous pump test have been estimated as 877.519m^3/day at lower section, 852.011m^3/day at middle section and 825.609m^3/day at upper section of the study site (Project report, 2013).

In this present study section of Onda (Upstream), the yield of water is much more (average 851.713m^3/day) than the yield of water (average 769.710m^3/day) at Joypur (20km downstream form Onda) section of same river (Project report, 2013). It indicates the average transmissivity of water through sub-surface sediment layers is more than the downstream section that depends on the sediment grain size distribution. More than 97% of sand to coarser sand size sediment distributed in sub-surface lithologs in the present study section. This potential water yield condition may complement the demand of ground water through supplying irrigation as well as drinking water supply in an around the surrounding study area.

Conclusion

Regarding the geomorphological point of view, the micro-geomorphological signatures are dominated within the study area. The six depositional surfaces are the signatures of the stage wise flood discharge during monsoon with high to low chronological order (table 1). The braided channel pattern is dominated throughout the study channel section during river's lean phase (figure 4). The dominance area of point bars, sand splays, mid-stream sand bar, ripple marks are the significance features of geomorphic landform units (figure 5). There are ripple marks over the higher (1^{st}) depositional surface as the signature of sudden high energy water flow over that surface (figure 5).

The geological condition of the study area is dominated by Late-Quaternary deposits of soft sand, silt and clay over that area. The sub-surface lithologs of the river bed is dominated by the coarser size sandy layer. Monsoon flood plays a classic role in the concentration, distribution and deposition of the riverine sediments along the submerged areas of floodings. Like other rivers of the tropical monsoon, the Dwarkeswar River plays a vital role in the context of sedimentology. The section wise sedimentological characteristics demarcated that, medium to coarser size sands are concurred grained sediment over the study site. That denotes river's high energy concentration during peak discharge. The Sedimentological facies depositional landforms of mid-stream sand bar indicates the highly correlation between the energy concentration and sediment grain distribution (table 4). Sand splays depositional surfaces are subjugated by the finer sand size sediments.

There is a higher potentiality of sub-surface water condition in the study channel reaches. The porosity and permeability status of the sub-surface sediment layers plays a significant role in the context of storability of sub-surface aquifers to reoccupy the vacuumed space by water after extraction of sub-surface water by pumping. From the channel and channel's surrounding areas there are several numbers of pumps ate extracting huge volume of water for irrigational water in the cultivated lands.

In spite of various influencing factors, the river current plays a vital role in the energy distribution also the sediment distribution over the flooded areas. The Dwarkeswar River (particularly in that study section) is well preserved every kind of geomorphological and sedimentological signatures with due response of fluvial hydro-dynamics. The potential sub-surface water can easily distributed over the large surrounding area through well organized piped water as drinking water after some qualitative treatments.

ACKNOWLEDGEMENT

The author is very thankful to PHE, Government of West Bengal for providing project. The author is also grateful to all the members of research team of the very particular project.

REFERENCES

Chang HH (1984). Meandering of under fit streams. *Journal of Hydrology* **75** 311-322.

Joshi VU and Gaikhe SN (2009). Geomorphic characteristics of a pint bar and a mid-stream bar in a semi arid rivers: a case study along Karha River, Maharashtra. In: *Geomorphology in India*, edited by Sharma HS and Kale VS, Prof. Savindra Singh Felicitation Volume, Prayag Pustak Bhavan, Allahabad 359-380.

Molla HR (2011). Embankment and changing micro-topography of lower Aloy basin in Eastern India. *Ethiopian Journal of Environmental Studies and Management* **4**(4) 50-61.

Mukherjee M (2003). Flood and land degradation- a study in the lower Ajoy basin. Land degradation and desertification (Ed). Rawat Publication, India 374-381.

Mukhopadhyay S (2010). A geo-environmental assessment of flood dynamics in lower Ajoy River inducing sand splay problems in Eastern India. *Ethiopian Journal of Environmental Studies and Management* **3**(2) 96-110.

Project Report (PHE) (2013). Hydro-geological study of sub-surface water flow/storage water characteristics for creation of Sustainable source on rain - fed river for semi – arid and fluoride affected blocks in connection with comprehensive water security plan under Purulia, Bankura & Birbhum district, Sanctioned by Govt. of West Bengal.