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An Investigation into the Nature and Origin of the Inland High Sand Reef Located at Rose Hall - Port Mourant in East Berbice, Guyana

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Abstract:- Guyana's flat coastal plain is interspersed with large shore-parallel lines of well-compacted inland sand dunes. These sand dunes are called 'high sand reefs' in the local vernacular as these reefs are above mean high tide level. It is believed that these reefs are of coastal origin forming from ancient beaches that were left behind when sea level fell in the geological past. Over years of human occupancy of Guyana's coast, some reefs were used for habitation, agriculture, cemeteries and sand-extraction, while others were left to flourish with flora and fauna. Due to the paucity of studies on these reefs, this research aims to uncover some aspects of their origin and nature, to determine current and future uses as a coastal resource and to suggest ways for further investigation.

Analyses were done on samples of materials collected from the sand reef located about 2 km inland of the Rose Hall Town-Port Mourant shoreline to ascertain their physical and chemical properties. Comparison was made with materials collected and analyzed from the tidal shore beaches in the area to compare with the sand reef materials. The sand reef material was found to have seashells and salinity and dissolved salts content similar to materials from the tidal beaches, indicating their coastal nature, though located on dry land 2 km behind the shoreline.

Further research using radiometric dating could be done to determine the age of the reef sand and deep-core borings made to ascertain the soil profile of the reefs. This work attempts to add to the knowledge pool of Guyana's coastal resources as the country moves into the petroleum-extraction industry.

Keywords:- *High sand reef; marine alluvium; salinity; pH; total dissolved solids; acidity-alkalinity.*

I. INTRODUCTION

Along the 260-km cultivated coastal plain of Guyana, from the East Berbice Coast to the Essequibo Coast, there exist great natural inland sand dunes, locally called high sand reefs, which are located within 0.25 to 10 km of the shoreline. These reefs run parallel to the shore line and are to some extent elevated above the surrounding lower areas and so are not prone to flooding even at high spring tides. They are recognizable by the yellowish-brownish colour of their fine soil, which drains well and remains firm even when saturated with water, and by the presence of broken seashells in them.

Over the years of human habitation of the Guyana coast, many of these dunes have been occupied by housing and used for agricultural activities. Some of the better-known ones are at Rose Hall Town, Port Mourant, Albion, Belvedere, Hampshire and Leeds-Number 51 in Berbice, Annandale, Cottage, Zeskinderen, Victoria and Hope in Demerara, and the Supenaam to Lima Sands reefs in Essequibo.

Unoccupied dunes are exploited for the fine high-quality sandy material which is extracted and removed for construction purposes. These dunes are therefore an important coastal resource which ought to be managed efficiently and sensibly, especially those that are unoccupied and exploited for their sand, for these dunes carry significant ecosystems and may also act as means of coastal protection from flooding. New housing projects can be established on large uninhabited sand reefs where they are less susceptible to flooding, unlike lands at lower elevation on the coastal plain.

It is believed that these sand dunes were formed by various coastal processes such as sea retreat, land uplift and sedimentation dynamics. Little investigative work has been done in investigating the nature and origin of these sand dunes and their importance to the coastal environment. One local study in this area which the researcher has so far found is "Coast Erosion Protection Works on the Case System in British Guiana" by G. O. Case, 1920. A series of sand reef surveys done in 1976 is mentioned in Earth Matter in the Guyana Chronicle, 2012, but the reporter noted that "information on the outcome of these surveys has proven difficult to obtain." Since then, there has been a paucity of work in this area. The researcher hopes that this investigation will be a start in filling this gap in our knowledge of our coastal resources and so enable better planning and more efficient and environmentally-friendly use to be made of said resources.

The main focus of the research activities will be the high sand reef located at Rose Hall Town, Corentyne, Berbice, Latitude 6°15'44.28"N; Longitude 57°21'2.06"W (Figure 1). This coastal feature extends approximately 1 mile (1.6 km) in length and 1/3 mile (0.5 km) in breadth. Less than half of it is occupied by housing in the Rose Hall Town portion and the rest in the Port Mourant section is unoccupied and covered with vegetation. The unoccupied portion is exploited for its sandy material for road-building and land-filling purposes (Figure 2).

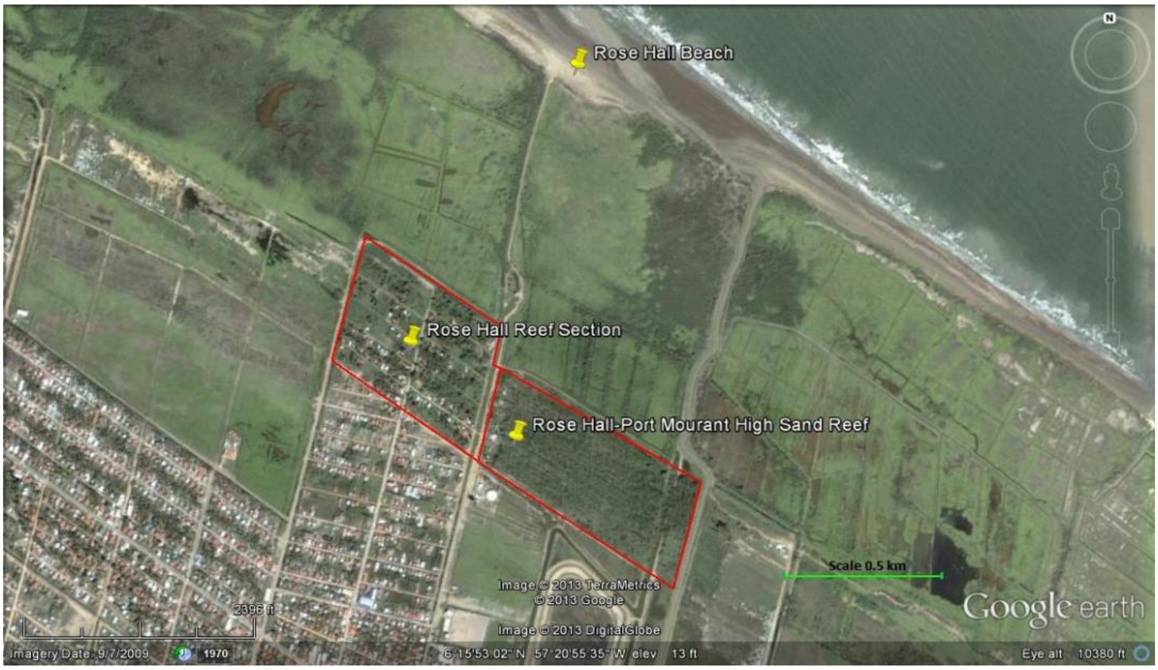

Fig. 1: Rose Hall Town-Port Mourant High Sand Reef

Fig. 2 Excavation made by mechanical shovel at Port Mourant Sand Reef

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II. LITERATURE REVIEW: FORMATION OF THE COASTAL LAND OF GUYANA

The existence of the high sand reefs or sand dunes is attested to by Case, 1920:

"The Coast region of British Guiana forms a plain of marine alluvium which is traversed in places by lines of sand dunes. The deposits were undoubtedly derived from the silt brought down by the Amazon and carried along the coast by currents until it was finally deposited. By this means a tract of land was formed ten to thirty miles wide of exceptional fertility, most of it from 3 to 4 feet below the level of the sea at spring tides. The country in its physical features bears a close resemblance to Holland."

Case then refers to Prof. Harrison, Government Geologist, in a report to the Sea Defense Commission, who describes the geological condition of the coast line and mentions the presence of the sand dunes:

"From the vicinity of Point Kokali to the River Mariwyne there existed a vast bay or indentations of the land apparently of greatest depth and of broadest extension southward near the present Corenyne River. It was probably the estuary of a great South American river or more probably rivers possibly flowing from the Amazon region as well as from the districts which are now drained by the Essequibo group of rivers. The evidence afforded by the recently made deep borings shows that this indentation or bay was gradually silted up by the deposition of great beds showing evidence that their constituents were derived from a nearby area of granitic or gneissose rocks. In the course of geological ages an uplift of the area occurred, the lines of river flow were changed and the coastland was bordered by vast areas of windblown sand dunes."

Case then ends his description of the formation of the coastal land, thus:

"There is no doubt that the coastlands of British Guiana at one time formed an immense area of foreshore, covered by the sea at high tides and dry at low water. A shell barrier was then formed and in course of time marsh land and tidal forests were formed behind. At the time of the first occupation of the country by Europeans the coast line was no doubt more or less stable except near the mouths of the rivers which cut through the natural shell barrier."

A contemporary Guyanese geographer-historian, Ishmael, 2005, also gives a brief description of the formation of the coastal land and makes mentions of the high sand reefs:

"Much of the coastal plain was built up by alluvial deposits from the rising Atlantic Ocean during the period ranging from 17,000 to 6,000 years ago. Large rivers which were formed also brought huge deposits of silt from the continental interior and dumped them into the ocean. These silt deposits formed part of the alluvium which helped to create the coastal plain. There were periods when the rising waters stabilised allowing mangrove forests to develop. As the waters rose at a later time, these forests were destroyed and were covered over with silt on which new forests grew during different periods. As the coastland built up, the sea retreated but left behind a series of parallel sand and shell beaches, now known as sand reefs, up to about 10 miles inland."

Early Amerindian settlements along the coast of Guyana also made use of the high sand reefs. According to Ishmael:

"Because of the swampy nature of the land, some Amerindian communities constructed huge earth mounds of over 20,000 square yards (18,000 square metres) about 2 metres above swamp level on which they built their houses. These houses, grouped together, were surrounded by wide ditches. Their agricultural plots were also created on similar types of mounds. Dennis Williams' studies, based on the evidence of ceramic patterns, indicate that an early form of this settlement was at Joanna, (in the Black Bush Polder area on the Corentyne), going back to about 1,500 years ago."

"Probably because it was felt that it was too energy-consuming to maintain these mounds over a number of generations, settlements later graduated to the sand reefs which were themselves somewhat elevated over the swampy areas. The farm plots, on which cassava was the main crop, were kept on the swamp borders and also on clearings on the sand reefs, even though the latter areas possessed relatively poor soils. A series of settlements sprang up along these reefs from the Corentyne to the North West District."

Hence, since prehistoric times, the sand reefs of the Guyana coast have been an important natural resource for the human inhabitants providing a safe living space above high water level and agricultural lands.

III. THEORY AND PHYSICAL PRINCIPLES INVOLVED

The main objective of this research is to conduct an investigation into the nature and origin of sand dunes (high sand reef) located at Rose Hall Town, Corentyne, Berbice and to determine their importance to the coastal environment. The researcher collected data for the sodium chloride content (salinity), total dissolved solids (TDS) and acidity-alkalinity (pH) of representative soil samples from the selected area.

The basic concept is that since it is believed that these sand reefs are of marine origin as described earlier, then they should exhibit some remnants of their earlier marine origin, viz., high salinity due to the presence of sodium chloride, high TDS due to the presence of all dissolved salts and an alkaline pH due to the presence of carbonates from the exo-skeletons of dead marine shelled organisms.

Sea water, on average, has a TDS of 35,000 parts per million (or 35 parts per thousand or 35 grams per litre) (Skinner & Turekian, 1973). Hence, coastal soils which were once covered by the sea should have TDS around this value, or more likely, less, due to leaching by rainwater or overland fresh water flow (Fanning & Fanning, 1989).

Strahler, 1973, gives the composition of sea water as shown in Table 1.

Name of Salt	Grams per 1000 g of water (Equivalent to g/L or ppt)
Sodium chloride (NaCl)	23
Magnesium chloride ($MgCl_2$)	5
Sodium sulfate (Na_2SO_4)	4
Calcium chloride ($CaCl_2$)	1
Potassium chloride (KCl)	0.7
With other minor ingredients, to total (TDS)	34.5

Table 1: Composition of Sea Water

Note: The units for salinity (NaCl) and TDS (total dissolved solids) used in this research are grams per litre (g/L) or parts per thousand, which are equivalent units, i.e., 1 g/L = 1 ppt.

From Table 1, Strahler's and Skinner's & Turekian's values for TDS are in agreement. It is also evident that NaCl is 66% of the TDS present in sea water, i.e., the NaCl/TDS percentage is (23/35)*100% = 66% for sea water.

According to Tan, 1998, "The process of accumulation of soluble salts in these soils is called salinization. The salts are mostly NaCl, Na_2SO_4, $CaCO_3$, and $MgCO_3$ … Salinization can also occur locally and develop the intrazonal type of saline soils, e.g., soils reclaimed from the sea bottom, and soils in coastal areas affected by the tide."

Hesse, 1972, too, reported, "The coastal soils of Israel had oceanographic salinity and the desert salinity was caused by wind-borne salts."

It is therefore expected that the soil sampled from the high sand reefs, being on the coastal region of Guyana, will display the characteristic of marine origin as described above.

However, some amount of leaching due to rainfall and the flow of fresh ground-water, as mentioned earlier, may reduce the salinity of the sand reef soil, and so change its characteristics, particularly in the zone of leaching (Montgomery, 1992).

It is expected that the soil samples from the sand reef will have the characteristics of marine origin with respect to relatively high salinity, high TDS and alkaline pH.

After millennia of undergoing these natural processes, the reef sand has acquired a yellowish-brownish colour, is fairly fine and non-cohesive, does not contain a significant amount of clays, drains well and does not become muddy when saturated with water, instead remaining firm. These properties make it a highly valued material for laying foundations for roads and buildings and for building up low-lying housing lands.

IV. EXPERIMENTAL PROCEDURE

- **Soil sampling and analyses:** Top soil samples were collected from the high sand reef at Rose Hall – Port Mourant along three parallel lines, named by the researcher as North, Middle and South paths of the sand reef (Figure 3). These were most easily accessible, as they are paths regularly used by persons to access the sand reef. Other areas of the sand reef are mostly covered in dense vegetation, including coconut trees, and were not accessed by the researcher. The sampled parallel lines extended for 50% of the total of 740 m length of the uninhabited and vegetated section. Soil samples were also collected from the Rose Hall Beach located 950 m north of the sand reef and also from the Wellington Park Beach, Latitude 6°10'53.11"N; Longitude 57°14'8.49"W, located 16 km East of Rose Hall for comparison purposes (Figure 4). Photographs of the sample areas were taken and maps of the sample areas were obtained using satellite imagery from Google Earth Satellite Maps.

Analyses of the soil samples collected were done using the laboratory equipment and facilities available at the John's Science Centre, University of Guyana, Berbice Campus. The samples were analysed for pH, total dissolved solids (ppt, g/L), and salinity (ppt, ppm). Comparison was made between the samples collected from the Rose Hall Beach and the sand reef in order to achieve the objective of the research.

To render the soil samples into a form suitable for analysis, the soil paste method as described by Hesse, 1972, was modified and used.

- The soil was sieved using a 1 mm size sieve, as it was of a fairly fine and even texture, in order to remove grass roots, other vegetable matter present in it and any large broken seashells present.
- Fifty (50) grams of soil was massed on a digital electronic balance.

- The measured soil was mixed thoroughly with 25 mL of distilled water measured by a burette. The mixing was done in a 50 mL beaker until a soil paste was formed.
- A pH-TDS-salinity digital meter (Figure 5) was used to measure the required quantities present in the soil paste, based on the instructions in its manual. This was done for all samples collected, as they were of a fairly fine, even and regular texture, to maintain constant conditions. The data were recorded in tabular form for ease of analysis.

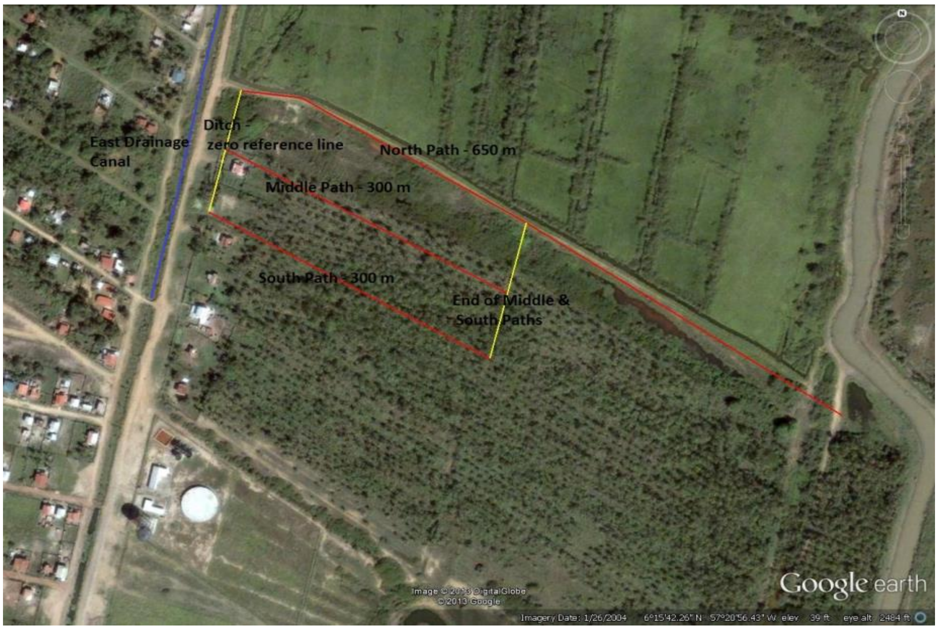

Fig. 3: North, South & Middle Paths of the High Sand Reef

Fig. 4: Rose Hall Beach to Wellington Park Beach

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Fig. 5: pH-TDS-salinity meter EXTECH Instruments ExStik II EC 500

The measurements obtained from soil samples taken from the Rose Hall Beach are given in Table 2.

Sample No.	Description of sample location	pH	TDS (ppt)	TDS (g/L)	Salinity (ppt)
1	In tidal range at eroded shoreline	8.08	7.50	**7.70**	**4.05**
2	In tidal range 15 m south of eroded shoreline	8.25	OL	OL	OL
3	In tidal range 45 m south of eroded shoreline	7.95	OL	OL	OL
4	At beach entrance, 60 m south of eroded shoreline	7.52	OL	OL	OL
5	Near abandoned pump house, 700 m south of beach	7.00	OL	OL	OL
	Average	**7.76**	-	-	-
	Standard Dev.	**0.54**	-	-	-
	Range	**7.00-8.25**	-	-	-

Table 2: Rose Hall Beach – pH, TDS and Salinity

The digital meter gave overload (OL) readings for four samples, as the salinity and TDS levels for those samples exceeded the possible maximum 20 g/L or 20 ppt of the digital meter, meaning these samples have higher salinity and TDS than 20 g/L. Direct measurement of sea water with the meter also gave OL readings as sea water has salinity and TDS in excess of 20 g/L. The NaCl/TDS percentage from the single available measurement is 53%, which is less than the value of 66% given by Strahler and Skinner & Turekian for sea water.

Next, the measurements obtained from samples taken at the Wellington Park Beach are given in Table 3.

Sample No.	Description of sample locations	pH	TDS (ppt)	TDS (g/L)	Salinity (ppt)
1	Surface beach sand in tidal range	8.10	12.15	12.15	6.71
2	Surface beach sand in tidal range	8.55	2.01	2.01	1.13
3	Broken surface shells in tidal range	9.36	0.16	0.16	0.09
4	Sand 23 cm below surface seashells	9.64	0.29	0.29	0.16
	Average	**8.91**	**3.65**	**3.65**	**2.02**
	Standard Dev.	**0.71**	**1.53**	**1.53**	**0.85**
	Range	**8.10-9.66**	**0.16-12.15**	**0.16-12.15**	**0.09-6.71**

Table 3: Wellington Park Beach (16 km East of Rose Hall Beach) – pH, TDS and Salinity

The readings obtained here are within the range of the digital meter, and along with the readings from the Rose Hall Beach, will serve as a baseline with which the sand reef soil can be compared. The average NaCl/TDS percentage calculated from Table 3 is 55%, not significantly different from the 53% found from Table 2.

The measurements obtained from soil samples taken from the North, Middle and South Paths are given in Tables 4, 5 and 6. The distances were measured relative to a ditch which was taken at the zero-reference line. The ditch itself is 25 m east of the Rose Hall East Drainage Canal (Figure 3).

Using the formula function in MS Excel, the average values, standard deviations and ranges were calculated for the measurements obtained for each path and set out below each table.

Sample No.	**Description**	**Distance/m**	**pH**	**TDS (ppt)**	**TDS (g/L)**	**Salinity (ppt)**
1	From East Drainage Canal to ditch 25 m	0	6.71	0.16	0.16	0.88
2		20	6.63	6.54	6.53	3.51
3		40	7.02	11.57	11.58	6.31
4		60	7.92	4.50	4.50	2.48
5		80	6.80	5.60	5.60	3.10
6		100	6.65	4.00	4.00	2.21
7		120	6.33	7.50	7.45	4.14
8		140	6.69	3.51	3.51	1.98
9		160	6.91	9.22	9.22	4.99
10		180	6.61	5.77	5.78	3.18
11		200	6.86	5.04	5.04	2.80
12		220	6.61	4.21	4.21	2.32
13		240	6.15	5.06	5.05	2.81
14		260	6.24	4.96	4.95	2.74
15		280	6.17	3.39	3.46	1.88
16		300	6.33	5.10	5.08	2.92
17		375	7.23	6.58	6.57	3.64
18		400	7.26	4.46	4.47	2.46
19		650	7.89	8.18	8.07	4.46
		Average	**6.79**	**5.54**	**5.54**	**3.10**
		Standard Dev.	**0.51**	**2.45**	**2.44**	**1.24**
		Range	**6.15-7.92**	**0.16-11.57**	**0.16-11.58**	**0.88-6.31**

Table 4: Sand Reef North Path – pH, TDS and Salinity

The average NaCl/TDS percentage calculated from Table 4 is found to be 56%, not significantly different from those found from Tables 2 and 3.

Sample No.	Description	Distance/m	pH	TDS (ppt)	TDS (g/L)	Salinity (ppt)
1	From East Drainage Canal to ditch 25 m	0	7.10	5.95	5.96	3.40
2		20	7.56	8.17	8.17	4.61
3		40	8.10	OL	OL	OL
4		60	7.77	15.12	15.30	8.58
5		80	7.93	OL	OL	OL
6		100	7.80	OL	OL	OL
7		120	8.23	OL	OL	OL
8		140	8.04	OL	OL	OL
9		160	7.85	OL	OL	OL
10		180	6.30	6.30	6.30	3.51
11		200	7.80	14.42	14.41	8.01
12		220	8.33	0.81	0.81	0.45
13		240	8.83	1.15	1.15	0.60
14		260	7.56	3.16	3.16	1.76
15		280	8.17	2.81	2.80	1.58
16		300	8.15	6.80	6.72	3.78
		Average	**7.85**	**6.47**	**6.48**	**3.63**
		Standard Dev.	**0.56**	**5.01**	**5.04**	**2.82**
		Range	**6.30-8.83**	**0.81-15.12**	**0.81-15.30**	**0.45-8.58**

Table 5: Sand Reef Middle Path – pH, TDS and Salinity

It is noted that the meter gave OL readings for six samples, indicating that these samples have higher salinity and TDS than 20 g/L, which is the maximum that the meter can measure. Here, the average NaCl/TDS percentage calculated from Table 5 is found to be 56%, not significantly different from those found from Tables 2, 3 and 4.

Sample No.	Description	Distance/m	pH	TDS (ppt)	TDS (g/L)	Salinity (ppt)
1	From East Drainage Canal to ditch 25 m	0	8.00	7.60	7.60	4.10
2		20	8.07	8.21	8.21	4.55
3		40	9.14	8.51	8.51	4.71
4		60	7.06	0.21	0.21	0.12
5		80	5.08	4.59	4.59	2.56
6		100	5.60	8.82	8.87	4.80
7		120	5.30	4.03	4.04	2.40
8		140	7.23	1.23	1.24	0.70
9		160	5.63	1.98	1.98	1.08
10		180	6.02	5.90	5.90	3.32
11		200	6.03	0.14	0.14	0.70
12		220	5.19	0.97	0.97	0.53
13		240	6.01	7.78	7.76	4.28
14		260	5.36	0.16	0.16	0.90
15		280	7.60	0.11	0.11	0.59
16a		300	7.30	7.20	7.21	3.75
16b		300	6.45	9.00	9.00	4.95
		Average	**6.53**	**4.50**	**4.50**	**2.59**
		Standard Dev.	**1.20**	**3.57**	**3.57**	**1.81**
		Range	**5.08-9.14**	**0.11-9.00**	**0.11-9.00**	**0.12-4.95**

Table 6: Sand Reef South Path – pH, TDS and Salinity

The average NaCl/TDS percentage calculated from Table 5 is found to be 58%, again, not significantly different from those found from Tables 2, 3, 4 and 5.

A summary of the averages found for the five locations calculated from Tables 2, 3, 4, 5 and 6 is presented in Table 7.

Table	Location	Avg NaCl/TDS %	Avg pH	Avg TDS (ppt)	Avg TDS (g/L)	Salinity (ppt)
1	Rose Hall Beach	53	7.76	7.50	7.70	4.05
2	Wellington Park Beach	55	8.91	3.65	3.65	2.02
3	North Path	56	6.79	5.54	5.54	3.10
4	Middle Path	56	7.85	6.47	6.48	3.63
5	South Path	58	6.53	4.50	4.50	2.59

Table 7: Summary of the pH, TDS and Salinity Averages for the Five Locations

V. DISCUSSION

The high average salinity and TDS of the soil samples from the sand reef relative to those obtained from the two beaches (Table 7) is a good indication that the sea level once reached that portion of land where the sand reef is located in the past, but it no longer does, even at high spring tide.

By processes of sedimentation dynamics, a sand reef developed in that area. Then as sea levels along the Guyana coast fell in the historic or prehistoric past, the sea receded and the deposited sand remained above sea level to become the high sand reefs as we know them today. The high sand reefs are therefore the remains of ancient beaches as believed to be by Case *et al*.

The almost similar average NaCl/TDS percentages shared by the sand reef and the two beaches (Table 5.6) is another good indicator that the sand reef was once a beach and hence of marine origin.

Over the years since the formation of the sand reef, leaching by rainfall and fresh ground-water would have occurred, resulting in a reduction in the salinity and TDS of its soil as observed in the measurements obtained in this research. The average NaCl/TDS for sea water is 66%, while the sand reef and beach samples yielded averages ranging from 53% to 58%, again indicating that leaching of sodium chloride would have occurred in the sand reef.

The presence of sea shells observed so far inland in the sand reef is another indication of the marine origin of the reefs. However, no direct measurement of seashell content was done in this investigation.

The results and findings of this research indicate that the sand reef at Rose Hall-Port Mourant is of marine origin and was formed by processes of coastal sediment dynamics. After the sea retreat in the past, the sand reef remained, running parallel to the shoreline, and eventually became overgrown with vegetation, especially coconut trees, which have a good tolerance for salinity.

Today, this and other sand reefs along the Guyana coast form an important natural resource exploited for its building material, but should be exploited wisely.

VI. CONCLUSION AND FURTHER RESEARCH

The actual seashell content of the sand reef was not obtained. This has to be done by digging deeply into the reef or by using deep core borings which were not available to the researcher.

Deep core borings will also be able to ascertain salinity, TDS and pH values for deeper layers and soil profiles beneath the sand reef, instead of the surface layer only as was done by the researcher.

Radiometric dating processes, when available, can be used to actually date the layers and profiles within the sand reefs so as to ascertain their ages so as to determine when the original sand beds were deposited.

Electrical conductivity of sand reef soils can also be measured and compared with that of other coastal soils to determine their electrical properties.

Similar investigations can also be done at the other sand reefs located along the Guyana coast, including the well-known ones at Annandale in Demerara, Albion in Berbice and the Supenaam to Lima Sands reefs in Essequibo. Other lesser-known ones can also be investigated.

Data available within the article: Data generated or analyzed during this study are provided in full within the manuscript.

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