CHAPTER 3. NATURAL CONDITION OF THE ORINOCO RIVER DELTA

3.1 River Characteristics

(1) Morphology of the Delta

The Orinoco Delta is the alluvial swamp having an area of 22,000 km^2 bordered by the northwestern edge of the Guayana Shield. It is formed by the deposition of the sediment from the Orinoco River and the longshore current laden fine sediment from the Amazon. The tropical climate contributes to the active vegetation growth on the emergent land. Sea level is quite possibly the principal factor affecting the development of the Orinoco Delta as well.

The Orinoco Delta is influenced by 6 major factors; (1) Water and sediment discharge from the Orinoco River, (2) Longshore currents that transport fine sediments to the Delta from the Amazon region, (3) Wave, tide and current regime of the continental shelf, (4) Tropical climate of the region, (5) Sea level rise, (6) Tectonic setting of the Delta and its proximity to the South American-Caribbean plate boundary.

The lower Orinoco Delta shows two distinct channel patterns. Distributaries of the southeastern Delta between Rio Grande Channel and Araguao Channel form anastomosing patterns and discharge into numerous small bays along the Atlantic Coast. In contrast, distributaries located northwest of Araguao Channel typically converge near the coast reflecting past episodes of mudcape progradation and northwestward deflection of channel courses. Arcuate beach ridges and sandy accretionary shorelines are common along parts of the northeastern and eastern Delta coast especially between Boca de Mariusa and Boca de Araguao.

(2) Geometrical Characteristics

1) Rio Grande Channel

The Rio Grande Channel, the largest branch in the Delta, is managed and maintained as navigation canal by INC. Total length of the channel is 339 km from the mile 0 in Boca Grande to Palua and can be divided into 2 sections. The outer channel is defined from mile 0 to 78 km point. The inner channel is defined as river section from 78 km point to 339 km. The averaged depth of the inner channel is 11 m in dry season.

2) Macareo Channel

The Macareo Channel starts from Ya-Ya Section of the Rio Grande Channel and flows northeastward until the Sea, receiving the Tucupita Channel. Total length of the channel is 194 km. The Macareo

Channel is an irregularly meandering channel with regular point bars. The averaged depth is 8 m in dry season. The average and the narrowest channel width are 630 m and 300 m, respectively.

3) Manamo Channel

The Manamo Channel starts at 20 km downstream of Ya-Ya and flows northward into Atlantic Ocean through Manamo Gate at Volcan, receiving the major tributaries draining Monagas State. The total length is 203 km . At 188 km of Manamo Channel, there is Manamo Gate constructed by CVG in 1960s for the purpose of flood control and agricultural land development. The Manamo Channel is an irregularly meandering channel like Macareo Channel. The averaged depth is 7 m in dry season. The average and the narrowest channel width are 580 m and 160 m, respectively.

(3) Discharge, Water level and Velocity

1) Rio Grande Channel

The annual average discharge at the head of the Orinoco Delta is estimated to be 35,000 m^3/s. The monthly discharge in August (rainy season) and March (dry season) at the head of the Orinoco Delta are 68,000 m^3/s and 7,200 m^3/s, respectively. Accordingly the water level at Palua varies 12 m in a year. The tidal amplitude at the river mouth exceeds 1.7 m. The average velocities in rainy and dry season are 1.0 m/s and 0.2 m/s, respectively.

2) Macareo Channel

The annual average discharge is 3,600 m^3/s at the downstream of the bifurcation of the Manamo Channel. It is 10 % of the Orinoco River discharge. The monthly discharge in August (rainy season) and March (dry season) are 7,000 m^3/s and 1,000 m^3/s, respectively. Accordingly the water level varies from 7.1 m in August to less than 1 m in March. The annual maximum and minimum velocities at 140 km from the river mouth are 0.9 m/s and 0.2 m/s as a cross sectional average value, respectively.

3) Manamo Channel

The discharge through the Manamo Gate at present controlled as 130 m^3/s and 200 m^3/s in dry season and rainy season, respectively. At present the waterlevel of Manamo Channel varies in a range between 0.7 m and 1.2m, while before the closure there was about 7 m seasonal variation. The annual maximum and minimum velocity at 70 km from the river mouth are 0.5 m/s and 0 m/s as a cross sectional average value, respectively, as a result of tidal flow.

(4) Sediment Transport

The total sediment load of the Orinoco River is reported approximately as 150 million ton per year. The amount of bed material load is reported to be 34 – 54 million ton per year (approx. 15 million m^3 per year).

In rainy season, almost all bed material can move as total bed material load because the shear velocity exceeds the critical shear velocities of bed materials. The sediment deposition takes place at the end of rainy season in all river sections (not only in the dredged sections). The downstream of Manamo Gate has few bed material load except for the tidal reaches. The total suspended sediment load does not contribute to the bed elevation change because the discharge itself is small.

The variation of the bed material along the inner channel of Rio Grande Channel is insignificant and generally the diameter ranges from 0.1 mm to 1 mm of fine sand. The average of Mean Diameter, d_{50}, is 0.4 mm, while finer sand or silt may exist on the river bed. The bed material of Rio Grande can be treated as uniform material represented by d50 .

Compared with Rio Grande Channel, the bed materials of Manamo and Macareo Channels are composed of finer sand and silt as a result of low flow velocity due to the water level control by Manamo Gate.

(5) Course Changes due to Meandering and Sand Bar

According to the results of satellite image analysis, the annual river course change is insignificant in the Orinoco Delta. The difference in the river course between 1987 and 1998 is also minor in the whole delta. The only difference in river course is detected in the mid-channel reaches in San Felix and Barrancas sections.

The upper and middle reach of the Rio Grande Channel is flanked by fine and cohesive bank materials and their lateral movement is insignificant. The lower reach is also stable since the tide effect is dominant.

The upper reach of the Macareo Channel is meandering and flanked by levee system composed of fine and cohesive materials. At 100 km, the meandering progressed well, which resulted in cutoff of the channel at least after 1953. The new channel does not have natural levee, which means the channel itself is in progress of meandering in this reach. The lower reach is stable since the tide effect is dominant.

Sedimentation has proceeded in the upstream reach of Manamo Gate mainly due to the blockage of the bed load by the Gate. The upstream reach, the bifurcation point, is might be separated due to

sedimentation in the future. The downstream reach of the Gate is strongly dominated by tidal flow rather than fluvial flow.

(6) Salinity Concentration

Salinity intrusion is not recognized in the Rio Grande channel, since the tidal amplitude is comparatively small and the river flow is so large (Fundacion La Salle).

According to the previous studies (CVG in 1960s and CVG in 1990s), the salinity intrusion in the Macareo channel was recognized at 90 km from the river mouth. It was before the closure by the Manamo gate. As evidence to supplement the previous studies, the JICA measurement in 1998-1999, salinity concentration in the Macareo channel is only within 20 km from the river mouth.

There was no significant difference in salinity intrusion between high tide and low tide in both Manamo and Macareo channels.

(7) Navigational River Characteristics

In this section, in order to evaluate the navigational potential of the 3 channels of Rio Grande, Macareo and Manamo, channel length, depth, width, sinuosity and channel stability were considered.

Based on the channel characteristics illustrated above and also summarized in Table S.3.1, it is concluded that the Rio Grande Channel has the highest potential for navigation regarding the depth, width, sinuosity and channel stability.

Table S.3.1 Navigation Potential of 3 Channels

Item	Rio Grande Channel	Macareo Channel	Manamo Channel
Length	339 km including Boca Grande	194 km	203 km
Length of the section its depth is smaller than 34 feet	128 km (50 km in river sections and 78 km in Boca Grande)	47 km	114 km
Average Depth below LWL	11 m	8 m	7 m
Channel Width (Min / Ave.)	420 m / 2100 m	340 m / 630 m	160 m / 580 m
Channel Pattern	Mostly Straight & Braided / Some sections Meandering	Irregularly Meandering	Irregularly Meandering

Channel Stability	Comparatively Stable	Still in Progress (Cutoff and Bank Erosion)	Used be in Progress, but the downstream reach by the Gate became Stable
Others			Presence of Manamo Gate at 188km
Navigation Potential	○	×	×

3.2 Coastal Characteristics

The Defense Mapping Agency of the United States has about 50 representative areas/stations in the North Atlantic Ocean where surface weather observations are available. Stations No. 44, 45 and 48 provide information offshore in the Atlantic coast of Venezuela that are most relevant to the study area. It can be noticed that prevailing wind directions in front of the Venezuelan Atlantic coast are E, NE and SE respectively, and prevailing wind speed varies between 9 to 14 knots.

Wave data in front of the study area are synthesized from the data available at stations 44, 45 and 48. The significant wave height is of about 1.6-1.7 m with a period of about 6-7 sec.

Tides along the coastal lines of the Orinoco Delta are semidiurnal with a maximum tidal range of about 1.8~2 m near Boca Pedernales Entrance and 1.5~1.7 m near Rio Orinoco Entrance.

The South Equatorial Current flows in a northwesterly direction off the coasts of Suriname, Guyana and Venezuela at average rate of about 1.25 knots. The effect of currents is less marked landward of the -100m depth contour especially within 30 miles of the coast where tidal influence may predominate.

Hurricanes do not represent a hazardous factor to the study area.

Orinoco delta around the Boca Grande area is a typical example of an active delta with a river-dominant type delta especially around the mouth of Rio Grande. Unlikely, it is believed that the delta is rather stable west of longitude 61°. In general, the river-sediment discharge has minor effect on shaping depth contours for depths equal or greater than MLWS-38m. Further, funnel shape of the river outlets west of longitude 60° 30', is an evidence of the influence of tides and tidal currents, especially during the low-level periods of the river. This infers that this area of the delta is a tide-dominant.

In the coastal area around the mouth of Macareo river, depth contours are parallel and more uniform than those at Boca Grande. The seabed has rather mild slope up to depth MLWS-5m and then has steeper slope between depths MLWS-5 and MLWS-30m.

The average annual dredging volume in Boca Grande reach was about 7,000,000 m^3 for the period between 1964 to 1974. This means that an average depth, over the whole reach of Boca Grande (74 km by 120 m), of about 0.8 m needed to dredged annually. However, according to the Nouel and TAMS (1991), the total dredged volume was about 10,420,000 m^3, which means an average depth of about 1.2m needed to be dredged. Moreover, results of depth surveys of the outer channel at Boca Grande performed at April 1997 (pre-dredging) and September 1997 (post-dredging) shows that dredging amount was about 13,320,000 m^3. It can be seen that the average dredging depth is increasing in recent years. This is due to the recent decrease in efficiency of dredging activities.

On the other hand, it is believed that the sedimentation rate at the mouth of Macareo will be less than at Boca Grande for the following reasons.

1. The area is well protected from open sea, i.e. less exposed to wave energy.
2. The Macareo river discharge is much less than that of Rio Grande.
3. Depth contours in front of Macareo are steeper than those at Rio Grande area.