Analysis of the morphological and environmental changes at the confluence of the Daule and Babahoyo rivers in front of the city of Guayaquil.

Análisis de los cambios morfológicos y ambientales en la confluencia de Los Ríos Daule y Babahoyo frente a la ciudad de Guayaquil

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Abstract: The purpose of this research is to provide a proposal for environmental impacts based on bibliographic information in order to identify the problems that could cause the accumulation of sediments and contamination in El Palmar islet, which is located at the confluence of the Daule and Babahoyo rivers. This work is expected to determine the factors that could generate possible flooding, minimize the risks for safe navigation and investigate the contamination that could be found in the sediments. The components that have been of greatest concern in recent years due to anthropological actions such as: the construction of the Daule-Peripa dam, natural phenomena such as El Niño, sea level rise, water discharges into the rivers, are factors that accelerate erosion, affecting the dynamic equilibrium and flow conditions that occur at the confluence of rivers, causing a new condition of hydraulic equilibrium.

Keywords: environmental pollution, sediments, hydraulic equilibrium, safe navigation.

Resumen: Esta investigación tiene como objeto dar una propuesta a las afectaciones ambientales en base a información bibliográfica con la finalidad de identificar los problemas que podrían ocasionar la acumulación de sedimentos y la contaminación que se presenta el islote El Palmar, el mismo que se encuentra en la confluencia de los ríos Daule y Babahoyo. Con este trabajo se espera determinar los factores que podrían generar posibles inundaciones, minimizar los riegos para la navegación segura e investigar la contaminación que se podrían encontrar en los sedimentos. Las componentes que han sido de mayor preocupación en los últimos años provenientes de las acciones antropológicas como: construcción de la represa Daule-Peripa, fenómenos naturales como el niño, aumento del nivel de mar, descargas de aguas en los ríos; son factores que aceleran la erosión, afectando el equilibrio dinámico y condiciones de flujo que se presenta en la confluencia de los ríos, originando una nueva condición de equilibrio hidráulico.

Palabras clave: contaminación ambiental, sedimentos, equilibrio hidráulico, navegación segura.

Introduction

The purpose of this research work is to generate an environmental proposal and analyze the morphological changes of El Palmar Islet, in relation to the studies that have been carried out at the confluence of the Daule and Babahoyo rivers in front of the city of Guayaquil, based on bathymetric data and existing environmental parameters in the study area.

The study area is located at the confluence of the Daule and Babahoyo rivers where the islet known as El Palmar can be seen according to the following geographic description (Figure 1):

Projection Coordinates: UTM
Datum: WGS 84
Zone : 17 South

Point	Length (m)	Latitude (m)
1	625173.00 m E	9761594.00 m S
2	625681.00 m E	9761679.00 m S
3	626366.00 m E	9760347.00 m S
4	625240.00 m E	9760226.00 m S

Figure 1. Islote el Palmar Study Area

Figure 1.
Islote el Palmar Study Area

The relationship between flows and the angle of convergence controls the confluence between 2 rivers. If this relationship is modified, the angle of convergence increases and can generate sedimentation in the river with the lower flow, forming sandbanks. (Best 1988).

The results of the Morphological Analysis of the sector will allow visualizing the changes in the bottom of the Guayas River, it is important to identify the origin of the accumulation of sediments and erosion, because when sediments accumulate, there are navigation problems and risk of flooding or erosion in the basin, and also, when there are sediment banks with vegetation, birds fly over them and in the case of the Guayas River, due to the formation of the Palmar islet, birds make aerial navigation difficult. (Dumont et al. 2007).

The main system, the Guayas River is formed by two rivers that join 5 km before the city of Guayaquil, which has a length of 93 km from La Puntilla in the province of Guayas to Punta Arenas on Puna Island (estuary) to flow into the Pacific Ocean in the Gulf of Guayaquil. (Tapia 2012)

According to the Commission of Studies for the Development of the Guayas River Basin (CEDEGE), there is an average annual rate of laminar erosion of 0.5 mm, equivalent to approximately 15 million cubic meters of sediment. In the 1997-1998 period, this erosion rate increased to 1.75 mm, equivalent to approximately 50 million cubic meters of sediment. This erosion process is mainly attributed to forest clearing, land use changes, landslides, and other activities throughout the watershed. (CAMAE 2013).

Morphological Analysis. - From the bathymetric information collected by INOCAR since 1975 and analyzed by Castro. A., 2009, we can highlight the growth of a sandy shallows called "El Palmar islet", which over the years has been increasing in area and height and which in 2016 was technically determined as an island by stabilizing its shores and raising the ground level by the deposit of dredged material, according to the dredging works carried out by the Navy Dredging Service (SERDRA) for the National Water Secretariat (SENAGUA). (Villa et al. 2016).

The sedimentation process causes the river to have a lower water catchment causing flooding when long duration rains occur and together with the time of high tide increases the problem. (Gómez De La Torre, Villa 2018)

The dredging and hydraulic filling works carried out in our country have been developed with social interest. Internationally, experiences of large-scale hydraulic filling works of economic interest have been reviewed, (Gómez De La Torre, Villa 2018)

Fluvial Morphology is the study of the various forms that characterize rivers. Fluviomorphology involves the study of the changes that a river undergoes, both in its course (longitudinal profile) and in its cross section (bed and banks). However, it should be pointed out that fluviomorphology is not only interested in the study of the current forms of a river, but fundamentally in the explanation and manner in which the river has reached its present form. (Rocha 2013).

This is the area through which fresh water flows into the sea, usually of two types:

Estuary is the area of the river that is funnel-shaped and in contact with the waves, tides, and marine currents that at high tide collide with the river currents and the water level rises, but when the low tide arrives these waters leave quickly, which causes the river to cleanse and the riverbed to deepen (Rocha 2013).

According to Rocha, the delta is a geographical feature, produced by the accumulation of sediments brought by the river, unlike the estuaries, the marine currents do not have much effect in this area and make the water flow through different channels, the typical shape is triangular.

Fluvial erosion occurs due to the energy of the water current flowing over a riverbed, this current releases fragments that are dragged and tear off new fragments to carry them downstream. (Rocha 2013)

Scour is a type of water erosion that refers to the loss of material from the bed and banks of a channel, due to the transport capacity associated with a hydrological event. The reduction of this level with respect to a reference level is called scour depth. The scour depth reached depends on the type and size of the particles that make up the bed and the magnitude and duration of the hydrologic event. (Pacheco Cervantes 2016).

The morphology of the Guayas River must be constantly monitored, to know in what conditions it is and to be able to define the actions to be taken in relation to the intrinsic conditions of the sector.

1. Improve inter-institutional coordination to address future cases of this type, creating a response mechanism with specific roles according to the competence and experience of the people assigned to the event. The efforts currently being made by the Ministry of Environment to develop a protocol for strandings and rescue of marine megafauna are recognized.

2. Form a specialized marine wildlife rescue team, properly trained and equipped with basic equipment for the rescue of small and large animals, including whales, sea lions, sharks, manta rays and turtles. Only people with experience in handling large animals should be in close proximity to live specimens.

3. Evaluate the need to intervene according to the conditions of the moment under the premise of acting if the life of the animal or the local population is in danger.

4. Provide accurate and real-time information to the media and the general public to reduce media pressure and make decisions with serenity.

Materials and methods

Through the analysis of existing documents of the dredging works, hydraulic filling and water sampling evaluation studies in the vicinity of El Palmar Islet, a flow chart (Figure 2) has been determined for this work, to identify the methodology to be followed to present an environmental proposal where future impacts can be considered in the application of dredging for El Palmar Islet.

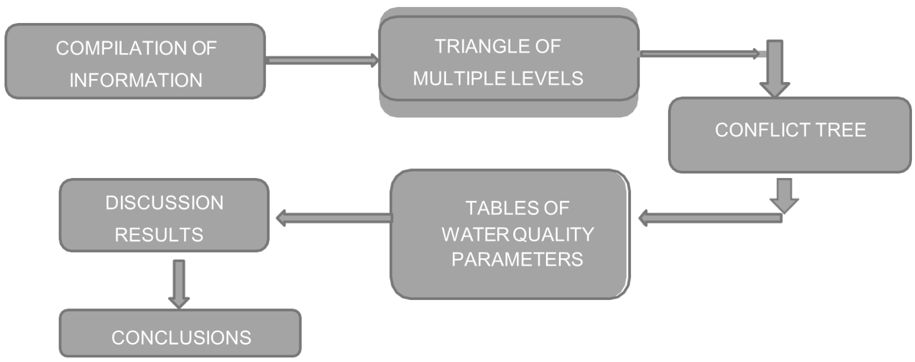

Figure 2

Methodology applied to the environmental problems of El Palmar Islet.

For the present investigation, scientific technical information has been compiled from documents of El Palmar islet focused on geomorphological and fluvial analysis, water quality monitoring studies, as well as historical information of studies related to the dredging carried out.

In order to determine the actors at the different local, national and international levels, as well as the analysis of the issues of interest to each of them, the Multilevel Triangle methodology was used, as shown in (Figure 3).

Figure 3.

Multilevel triangle applied to the environmental problems of El Palmar Islet.

CONFLICT TREE

Through this methodology, the tree of the conflict will allow us to place the conflict in perspective and determine the causes and their effects as visualized (Figure 4).

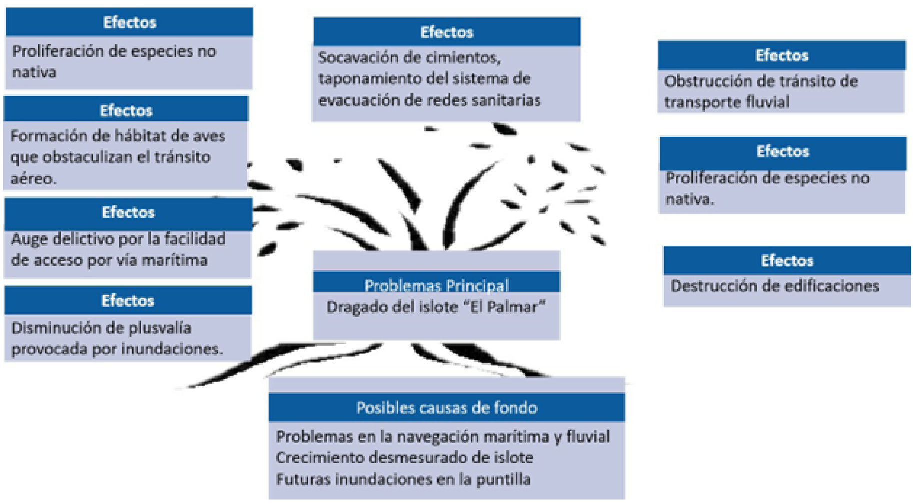

Figure 4

Conflict tree for the environmental problems of El Palmar Islet.

According to this methodology, it has been possible to identify that El Palmar has vegetation, which becomes a nesting, permanence and nutrition site for birds. It is estimated that there are different types of birds such as coconut herons, snail sparrowhawks, variable sparrowhawks, among others as shown (Figure 5); which initially presented problems to navigation in the air, but at present it is already under control. The problem in maritime and river navigation cannot be identified because there are currently no defined navigation routes for maritime traffic in the El Palmar Islet sector.

Figure 5.
Birds that inhabit El Palmar Islet

The presence of the islet becomes an obstacle to water flow, which could be taken advantage of if a tourist corridor were placed in the study area.

According to Villa, De La Torre and Pacheco, there is a sedimentation trend in the study area, so there is a possibility that the sandbar formed on the east branch of the Daule River could join the islet of El Palmar with La Puntilla. The closure of the east branch of the Daule River could hinder the normal flow of the Daule River channel, increasing the flow of the west branch, which could cause an erosion impact in the study area that would affect the city of Guayaquil and La Puntilla. (Villa et al. 2016).

Table 1.
Water quality parameters

PARÁMETROS PARA LA EVALUACIÓN DE LA CALIDAD DEL AGUA	ESTUDIOS DE IMPACTO AMBIENTAL		ACUERDO MINISTERIAL 097A			TULSMA
	CONSULTO-RA VERA Y ASOCIADOS CONSULTIN GROUP (2014)	SAMBITO C. LTDA. (2012)	Límite Máximo Permisible para la Protección de Vida Acuática en estuarios.	Criterios de descargas a cuerpos de agua dulce.	Criterios de descargas a cuerpos de agua marina en zonas de rompientes.	Anexo 1 Criterios de calidad de aguas para la preservación de flora y fauna en estuarios.
DBO5	14 -25 mg O2/l	3-8 mg/l	N	N	200 mg/l	100 mg/l
Acites y grasas		0.5 mg/l	0.3 mg/l	30 mg/l	30 mg/l	0.3 mg/l
Aluminio		0.4 - 1 mg/l	1.5 mg/l	5 mg/l	5 mg/l	1.5 mg/l
Cadmio	0.0004 mg/l	0.003 mg/l	0.005 mg/l	0.02 mg/l	N	0.005 mg/l
Coliformes Fecales	100 - 1850 NMP	600 - 1800 NMP	N	2000 NMP	2000 NMP	200 NMP
Sólidos Suspendidos Totales		3 - 27 mg/l	N	130 mg/l	250 mg/l	N
Sólidos Totales	7100 mg/l	N	N	1600 mg/l	N	N
Coliformes Totales	5000 m/l	3600 mg/l	N	N	N	N
Mercurio	0.00263 mg/l	0.0001 mg/l	0.0001 mg/l	0.005 mg/l	0.01 mg/l	0.0001 mg/l

The table of water quality parameters (Table 1) is the result of the evaluations made to the technical monitoring reports under the water quality criteria of the companies Sambito (2012) and Vera Group. (Vera 2014)The results show that the wastewater in the vicinity of El Palmar islet has residues from domestic and industrial wastewater discharges. The results of total solids are 7000 mg/liter and fecal coliforms are at 1800 mg/liter, in addition to oils and fats in the order of 0.5 mg/liter, nitrogen and phosphorus compounds were found, which can be evidenced by the presence of wastewater.

Results

According to researchers Santana, Dumont and King 2007, the shape of the drainage network in the southern sector of the Guayas basin goes from Quevedo in the north to the confluence of the Daule and Babahoyo rivers in the south. The idea that the distribution of drainage in the Guayas basin is variable and may have an effect on the distribution of the respective flows of the Daule and Babahoyo rivers is based on two elements, one geological and the other historical.(Dumont et al. 2007).

The geological element corresponds to the continuation of the Guayas Basin towards the Gulf of Guayaquil to the south, which was an active tectonic structure during the Quaternary. This activity continued in the most recent Holocene epoch and is present in the opening of the El Morro channel since the last interglacial, as this channel is in the continuation of the Guayaquil-Babahoyo subsidence axis of the Guayas Basin.

The main problem of the islet is that it increases in size and has vegetation that allows birds to settle on it, which is why the studies that have been carried out in the study area have managed to minimize and control the incidence of birds in aerial navigation.

Considering the difficulty of finding a place to deposit the dredged sediments, it is proposed to carry out a hydraulic filling, considering a maximum filling level of 5.60 MLWS (Mean Low Water Springs); that is, referring to the lowest level of the syzygy low water level, which is above the BM level (point on the ground of natural or artificial origin whose elevation is known) located in the Rotonda.

Morphological evolution of El Palmar Islet

In 2001-2002 surveys, the islet appeared to be subtriangular in shape, with a sharp point to the southwest that gave the islet the appearance of being a continuation of the Puntilla. While the islet occupies the channel of the Daule River, the southeastern edge of the islet underlines the continuation of the western bank of the Babahoyo River. The general shape of the islet suggests a transverse bar at the level of the mouth of the Daule River into the Babahoyo River, maintaining two communications located at the ends of the islet.

The main channel with the strongest current is located between Cerro Santa Ana and the southern tip of the islet. The islet developed over an earlier bar, observed in the 1982 photo, and appearing in earlier photos from 1966, suggesting an episodic occurrence of the bar. In the 1982 photo, this bar was located slightly east of the central part of the channel, with an elongated shape in the N-S direction, parallel to the course of the Daule River. It corresponds to a longitudinal bar, and is of a type characteristic of estuaries and rivers, (Dumont et al. 2007). The evolution of the islet as determined by bathymetric surveys carried out by Oceanographic and Antartic Institute (INOCAR) in 1982, 1985, 1997, 1999, 2000 and 2001 shows a progressive change from the longitudinal bar to the current shape. The northern end of the islet did not change much, probably having its definitive position since 1985, but a progressive extension towards the south is noted, at the same time that the width of the northern part widens, reaching the current triangular shape.

Studies of sediment cores should be referenced to

The 9 cores obtained according to Dumont, Santana, King 2007, are distributed in the different parts of the islet. All of them are superficial, with a maximum length of 110 cm, i.e. they give sections of the upper or middle part of the tidal zone. A typical core in the upper part of the islet is constituted from the top to the base by 0-20 cm of silt including very thin (less than 1 mm) sheets of fine sand, 20-70 cm of flat and thin sheets of medium to fine sand. These laminae frequently appear in triple associations, made of two fine sand laminae intercalated with a fine silt lamina. It is a typical sedimentation of tidal flats (Weimer et al., 1982). (Dumont et al. 2007). In the lower part (70-110 cm) there is laminated sedimentation of fine sand and silt, passing downward to a sedimentation of more powerful silt layers, including isolated lenses of fine sand with oblique wavey bedding and lenticular bedding, characteristic of tidal flats (Reading and Colinson, 1996; Weimer et al., 1982). Cores 3, 4 and 5 (Figure. 6) are located on the eastern edge of the islet. The sedimentary structures observed in Cores 4 and 5 are of fine ripple mark type, indicative of low energy current. Core 3 shows upward transition to laminar sedimentation indicating a shallow depth located in the high intertidal zone. Cores 7, 9 and 4 show lenticular facies with oblique layering indicating opposite paleocurrent directions. The orientation of the cores allows us to determine current directions alternately from east or west, which is evidence of the tidal effect. In core 9 collected near the southern tip of the islet, the highest energy tidal facies were observed.

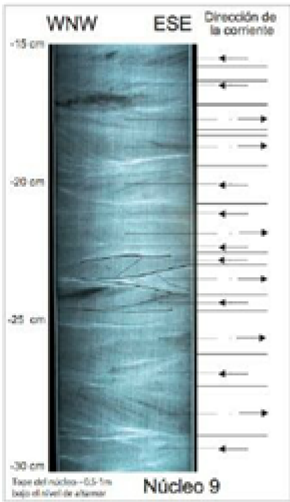

Figure 6

Sedimentological section of the upper part of core 9 observed with X-radioscopy, showing sediment layers with oblique stratification indicating alternating currents from WSW and ESE sectors according to the initial orientation of the core. Source: F. Dumont, E. Santana, B. Soledispa 2007.

Sedimentological analysis of the cores of the islet gives evidence of the tidal effect. This effect is not surprising, as the islet is located in the tidal effect zone, which reaches as far as Samborondon on the Babahoyo River and La Toma on the Daule River. However, this tidal flat sedimentation appears further north than is known, which can be interpreted as a northward migration of the estuarine zone. The loss of flow of the Daule River combined with the rising sea level trend, which may be more important in tectonic estuaries than on the other coasts may explain the formation of the Islet. What is observed now is a set of short and long term elements, which indicate a trend towards a loss of flow of the Daule River in favor of the Babahoyo River. It is difficult to say which is the most effective at present. Anthropic effects, including the Daule-Peripa dam, were not considered in this study. The construction of a dam generally results in a reduction of the river flow and a narrowing of the river channel, which goes in the same direction. (Andrews 1982)The construction of a dam generally results in a reduction of the flow of the river, and a narrowing of its channel, which goes in the same direction to favor the formation of an islet at the confluence with the Babahoyo River. At the end of the 19th century, Teodoro Wolf considered the Daule and Babahoyo rivers to be of almost equal importance, rejecting any opinion as to whether one is a tributary of the other. To see the confluence today it would be difficult to give the same opinion. (J. F. Dumont, E. Santana, B. Soledispa 2007).

From these records we can conclude that they are mostly silt sediments in a greater proportion with intercalated sand deposits, which may show that they are not only fluvial sediments but other types of sediments.

Geomorphological analysis of the origin of El Palmar Islet.

El Palmar islet corresponds to a tidal plain developed on top of a transverse bar, formed by the weakness of the flow of the Daule River with respect to the Babahoyo River. This situation can be considered temporary. However, the long-term evolution of the drainage network of the Guayas Basin indicates a progressive loss of flow of the Daule River with respect to the Babahoyo River. The trends of this long-term evolution suggest that the islet is likely to remain. This trend also coincides with the global phenomenon of sea level rise - with a tendency to move the estuarine zone to the north - and the tectonic tendency of the zone to subsidence.

The regional context of the occurrence of El Palmar Islet was analyzed here. However, there is a lack of qualitative morphology data (drainage analysis, connections), quantitative data (precise elevations, slopes and river-dependent changes, flow estimates by morphological measurements), and dating of the most important abandoned courses to pinpoint the stages and what caused these changes.

In the case of El Palmar Islet, it seems that the drainage upstream of the Islet is characterized by a high instability due to tectonic reasons in the first place, but combined with climatic variations during the Holocene. A better understanding of these parameters will be a necessity to appreciate the potential changes, and to maintain a sustainable development. (J. F. Dumont, E. Santana, B. Soledispa 2007)

Analysis of pollutant loads in the Guayas Estuary

The confluence of the two rivers, Daule and Babahoyo, with their two different riverbeds, the Babahoyo river being stronger, has changed the sedimentation of small particles transported by the two rivers.

It is known by the entire community of Guayaquil that in the 70's - 80's, all organic and inorganic sediment discharges poured into the rivers mentioned above, and by tidal effects in geomorphological conditions and states in constant movement, the particles of suspended solids could go to the sector of the current island contributing to the sedimentation of the islet.

The current sediment deposition zone in the island area has been aided by the convergence of ebb and flow in the tidal flat zone.

The waters that are circulating and recirculating in the Guayas estuary are mostly composed of fluvial sediments that are silty clay sediments that are being dragged by the currents of the Daule and Babahoyo rivers and that discharge into the Guayas estuary;

Unfortunately at the time of the 70's - 80's the Guayas river or estuary received discharges of domestic and industrial wastewater from the large population of Guayaquil, Daule, Babahoyo and confluent sectors that discharged directly or indirectly, domestic wastewater that are direct contributions of large amounts of biodegradable organic matter that meets a natural biological process and by great dilution of the estuary Guayas has been able to assimilate its pollution load, However, the sediments that are produced by the natural biological activity in the estuary itself is what has caused the accumulation of sediments helped by the influence of the tide and that have led to the formation of sedimentation islands such is the case of El Palmar Island.

Here is a small calculation showing the amount of solids for the case of domestic waste load produced per person. We consider 60gr /day /person of organic matter, considering 365 days a year and an average population of 4 million users and a contribution of 25 years as a minimum we would have a load of sludge 60x4000000x365x25 equal to 2, 2 million tons of sludge and if we consider an aqueous content of 30% we have about 3 million tons of sludge occupying an area.

If we read many, writings, reports and listen to newscasts in the last months of 2019, very little consideration is given to the aspect of the environmental danger that would represent the sediments that have formed in the Islote El Palmar, which could be dredged technically and properly, since the organic sediments could cause environmental problems, the same that if they are not deposited properly and treated for reuse.

While it is true that sediments occupy a large volume of water according to Archimedes' principle, this volume of sediments would cause an increase in water levels in the basin and in some cases could result in flooding, the evacuation of sediments should be considered, and the corresponding analyses should be carried out to determine the nature of these sediments, most of which could be organic sludge produced by the digestion of wastewater discharged into Estero Guayas. Considering the premise that the sludge or sediments are products of wastewater discharges and that the large Guayas estuary is a deposit of organic and inorganic sediments that due to tidal effects are aerated and deposited in the geomorphological zone of the Palmar Island area that is constantly growing due to continuous water inputs and the effects of currents.

The determination that they are sewage sludge is due to the fact that they are discharged directly or indirectly into the rivers that discharge into the Guayas estuary, and according to the studies there are contamination values in samples from the Palmar islet. The most important contaminants are arsenic, nitrogen compounds, among others, see studies by the Ministry of the Environment of Ecuador MAE 2004, (Vera 2014).

For this reason explained in the previous paragraph, it is necessary to treat this sludge, which could be dredged to treatment sites for subsequent dehydration and disinfection and could be used for organic fertilizer on the Ecuadorian coast.

As Ecuadorian citizens and currently aware of the environmental problems, a precautionary measure of prevention of the negative impacts that we could have, if the decontamination measures are not taken, could cause a case of severe tropical diseases or in extreme conditions of an environmental pandemic due to dredging without ecological prevention.

Conclusions

Initially, the formation of El Palmar islet brought about an ecological change because many birds chose its habitat, which resulted in the birds interfering with airplanes as they collided with them because they were near the takeoff and landing axis of the Guayaquil airport; currently this problem has been overcome and controlled through the implementation of projects that have considerably reduced this affectation.

If the data from current studies present the scenario of contaminated sediments in relation to water quality, dredging activities for hydraulic filling purposes should be considered. It is suggested that they be carried out by applying sectorial non-contamination techniques, that is, confining the area to be dredged by using hermetic board-stakes walls to prevent contamination of the surrounding area to be dredged; the dredged material should be treated at the dump site by means of dehydration ditches and solar exposure or by means of a properly executed sanitary landfill.

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