4 Hydrology and Wastewater

Table of Contents

Hydrology and Water Exchange

The hydrology of Graeme Hall swamp is unique to the island. Its position contiguous to the ocean provides the opportunity for strong ocean influences to the swamp. At the same time, these ocean influences are tempered by a continual source of fresh water from runoff and, more importantly, from underground springs and streams.

The major hydrologic considerations during development and operation within the swamp are:

- protecting and maintaining the source and quality of surface and subterranean freshwater flows from the uplands, and from deliberate mechanical discharges of emergency raw effluent from the South Coast Sewage Treatment Facility
- maintaining the interchange of surface water flows from the uplands
- maintaining contributions of saline water to the swamp from the ground water and the sea
- if economically possible, developing reliable method to optimise water exchange between the swamp and the sea
- eliminating or reducing discharge of coloured (tannin) water to the beaches
- providing sufficient discharge capacity from the swamp to avoid unplanned and undesirable flooding

Graeme Hall Swamp is the recipient of significant fresh water resources flowing from springs and underground streams and as runoff from associated lands. This fresh water moderates the influence of saline water entering the swamp via ground water seepage and tidal actions through the canal when it is open to the sea. This fresh water provides a clear gradation of water and biological characteristics from the ocean to the uplands. The fresh water outflow is a major contributor to the well being of the sedge communities in the swamp. Many other plants, such as water lilies, are extremely sensitive to saline conditions, and owe their survival to the constant supply of fresh water.

Some springs have recently been rehabilitated, but these springs need additional protection from pollution and contamination by saline swamp water from the lake. Some underground streams have been adversely affected by the construction of the Sewage Treatment Plant, which resulted in the significant de-watering efforts that

were required during plant construction. The plant location may have changed the flow patterns of these streams. These springs and underground streams must be adequately protected and maintained so that they continue to serve as a quality source of fresh water for the swamp.

Flows within the swamp, particularly along the cut channels, are important to maintain water quality and prevent stagnation. Water quality sampling indicated generally good dissolved oxygen concentrations in the swamp. The extensive de-watering associated with plant construction resulted in substantial sediment deposition in many of the cut channels. These channels must be cleaned and their natural flows restored to alleviate potential stagnation problems.

Overland Flow and Groundwater

The upland drainage basin for Graeme Hall Swamp is approximately 4.68 square kilometers (Cattaneo et al. 1988). The drainage basin extends "in a narrow band from the southern extremity of the swamp to the height of the Christ Church Dome, lying at about 100 meters a.s.l. near the border of Christ Church with the parishes of St. George and St. Michael." Lands immediately adjacent to the swamp that provide direct runoff include:

- agricultural fields maintained by the Ministry of Agriculture
- urban neighborhoods with roads to the Northwest, East, South and Southwest
- spoil lands used as pastures to the South
- upland grass areas to the East

Drainage within the swamp flows from the higher agricultural uplands and the freshwater springs, from the cut channels in the East Unit into the lake or the main drainage channel, and from the lake to the main drainage channel to the sea. These general runoff and flow pathways were observed during a site reconnaissance in December 1996 under generally high water conditions. Sheet flow was observed from the north end of the red mangrove, east of the lake to the lake. During the wet season, the central causeway appears to act as a restriction to flow nearer to the highway.

Flow within the main drainage channel along the central causeway is determined by the operation of the sluice gate. When the gate is opened, flow may either be out to the ocean or into the swamp

depending upon offshore ride levels. In addition to upland runoff, groundwater to GHS through springs feed pools near the east side of the causeway.

The commercial and residential developments surrounding Graeme Hall Swamp have developed structures that drain the developed structures that in turn drain the developed uplands. The waters flowing into the swamp from these drains provides substantial potential for uncontrolled pollution of the swamp's waters.

The South Coast Sewage Treatment Project measured water levels at various locations within the swamp between March and September 1996, while the dewatering associated with plant construction was ongoing. Water level elevations of 0.67-87 meters a.s.l. within the swamp during the period sampled reflect approximately three million gallons of water per day being pumped into the swamp.

Tidal Exchange and Sluice Gate

Water level within the swamp is normally controlled by the sluice gate in the main drainage channel. This sluice gate, installed in 1930, is currently operated by the Ministry of Public Works.

The sluice gate allows swamp water to discharge to the ocean when it is opened during low tide. During periods of sufficiently high tide (primarily meteorological events combined with high astronomical tides), ocean waters can pass into the system through the drainage channel. During these periods, ocean water mixes and interchanges with swamp water at a point where the channel crosses Highway 7. Existing elevation data for the swamp is not accurate enough to estimate the frequency of ocean water exchange if the sluice gate is open during these high tide events. It is estimated that this mixing could occur about five to six days per month (Gerald Proverbs, personal communication).

The sluice gate has historically been operated frequently to manage water levels within the system. This frequent operation has provided flushing of upland runoff as well as some inflow of clean saline ocean waters during periods of high tide. This operational practice has become less and less frequent in recent years due to deterioration of the gate structure. This infrequent operating schedule has resulted in complaints from neighbouring hotel owners on the coloured quality of water released from the swamp. In addition, movement of sand along the beach rapidly blocks the canal between the sluice gate and the sea and this sand buildup requires frequent and extensive excavation to provide proper overflow.

The major single issue related to the hydrology of the swamp is the interaction of the swamp with the sea and re-engineering of the existing sluice gate. This sluice gate has been operated as both a water control structure and a mechanism for water interchange with the sea since it was constructed early in this century. However, it must be noted that this is primarily a drainage structure, and as of 2005-2006, has been rendered useless due to major erosion of Worthing Beach.

As of August 2006, due to the inoperative sluice gate, the Ministry of Public Works controls water levels in Graeme Hall Swamp using a backhoe to add or remove sand fill in the sluice gate channel.

The existing discharge channel structure and sluice gate has two major constraints to providing adequate drainage and interchange with the sea. The channel structure and sluice gate is currently located on the beach well up from the normal high tide level. As long as there is a beach this location, combined with normal beach dynamics, means that a channel must be regularly excavated through the sand to provide for discharge flow to the sea.

Regardless of beach condition however, chronic shortages or unavailability of equipment often means that swamp water levels are not maintained in an acceptable manner.

The sluice gate mechanism is old, difficult to operate, and requires manual operation that is usually not available at the optimum times or during emergency situations for its operation. The gate provides the mechanism to control water levels in the swamp. To perform this function adequately, the gate should be upgraded and configured with a remotely controlled, electric control mechanism so that it can be easily and quickly operated when needed.

A simpler and more cost-effective solution, if the discharge channel structure is moved to the high water level, would be to remove the sluice gate mechanism entirely. Water levels in the swamp could be controlled by a series of flashcard risers (weirs) installed in the discharge channel that can be easily adjusted as required. These flashcard risers would be installed to control water at a fixed elevation. Any excess water would be spilled continuously over the top, alleviating any need to operate a sluice gate. Fluctuations of swamp water levels for management purposes could be accomplished by raising or lowering the level of the flashcard risers. A major advantage of this mechanism is that water will be spilled continuously from the discharge channel and this continuous and

relatively low volume discharge will probably eliminate the existing concerns regarding discoloured water at the beach. The other major constraint is that the system eliminates the need for a sophisticated and expensive control structure on the existing sluice gate.

One major problem with the flashcard riser system is that when the South Coast Sewage Treatment Facility undergoes an emergency raw sewage discharge event, as it did in 2005, the Barbados Water Authority, under pressure from hotels and beach tourism interests, re-direct the raw sewage into Graeme Hall Swamp, instead of the designed emergency outfall system to the bisecting canal and on to the sea. The flashcard riser system would further contain the effluent, and would add to the accumulation of toxic discharges that have historically been dumped in the Swamp.

The other major potential constraint to a system of flashcard risers is that their presence in the discharge channel during periods of high tide may constrain the interchange of freshwater and seawater. This would affect swamp salinity discouraging the exchange of biological organisms. However, scheduling the lowering or the removal of the flashcard risers during a period of high tide events can eliminate this constraint, and sea and swamp waters and aquatic organisms can move between the sea and the swamp.

Experience from past tidal events indicate that there is not enough tidal “head” for extension of sea water much beyond the location of the Highway 7 bridge.

Sewage Treatment Plant

The Sewage Treatment Facility, located on the Northeast margin of Graeme Hall Swamp, is accessed off Harmony Hall Road through a predominantly residential area to Highway 7. The facility occupies land under Government ownership and abuts the Ministry of Agriculture land to the North. Although partially hidden by a small ridge to the North, it is still visible from the Ministry of Agriculture buildings and passing traffic on the link road between the ABC Highway and Highway 7.

Manhole construction, which is now completed, began in July 1997 along Highway 7 near the sluice gate. A raised marl workpad is almost completed along the East and South margins of the swamp to the manhole near the sluice gate. This workpad will be used as a platform from which to bury the effluent sewerage pipe from the plant along the margins of the swamp to the manhole near the sluice

gate and thence to Needham Point for deep ocean disposal. This main effluent line will be the only sewerage line within the swamp, since an emergency overflow disposal pipe will not be necessary for safe plant operation (Matt McTaggart, personal communication).

The Sewage Treatment Plant has affected Graeme Hall Swamp primarily by:

- physical location of the plant within the swamp boundaries
- location of a large construction workpad and storage area on the Southeast corner of the western, government-owned lands
- construction of a marl workpad/road from the plant to the manhole near the sluice gate along the East and South margins of the swamp
- extensive de-watering during plant construction

The plant site proper takes about 1.02 acres from the swamp, although it is located on higher elevations on the Northwest margin of the swamp. An additional two acres was required for access road and future expansion. The plant site is not located in any known critical habitats, and its subsequent operation is not expected to adversely affect the overall viability of the swamp fauna or flora. Its location does, however, obviously interfere with existing groundwater flows and underground streams given the magnitude of de-watering that was required during plant construction. The plant does present a visual physical intrusion into the swamp, and subsequent development and management plans must accommodate or mitigate for this intrusion by protective landscaping and careful planning of activities.

The construction of the marl workpad along the East and South margins of the swamp has been a major physical intrusion into the swamp, and has adversely affected swamp fauna and flora. While the affects of workpad construction was relatively short-term, retention of all or part of this workpad has significant planning implications for swamp management and development. Although the workpad provides efficient and relatively low impact access to the effluent pipe in the event of emergency repairs, it can also provide a major access point into the swamp. This access can be successfully developed to provide foot access to the swamp, however, the access must be carefully controlled and managed consistent with the long term plans for the swamp.

The extensive de-watering program conducted during plant construction had significant effects on both the swamp and the St. Lawrence Bay. The water volumes increased water levels and changed the water quality parameters of the swamp throughout its duration. The large water volumes also contained relatively high concentrations of sediments, and the resultant sedimentation of the cut channels in the eastern portions of the 100-year Graeme Hall floodplain.

The volumes of water discharged from the swamp to the sea also had a significant effect on the seagrass beds in St. Lawrence Bay. The potential effects of this de-watering on the seagrass beds of St. Lawrence Bay was investigated between March and May 1997. The study measured the shoot density, areal biomass, leaf productivity, leaf growth rate and leaf area of *Thalassia* (turtle grass). This species is a relatively long-lived and slow growing seagrass that is a climax species in seagrass bed development. Its presence indicates a seagrass bed that has been able to retain viability for extended periods of time.

All of the *Thalassia* parameters measured decreased between during the study, with areal biomass decreasing by 80 percent during the study. These results indicate a strong negative effect of increased flushing of swamp water on *Thalassia* beds in St. Lawrence Bay, and suggest that management measures to improve water quality in Graeme Hall Swamp will have a positive effect on seagrass beds in the bay.

Sewage Treatment Plant Operations

One direct source of detrimental pollution to the Graeme Hall swamp as well as the entire watershed is the emergency dumping of raw sewage. The South Coast Sewerage Project has in the past dumped raw sewage into the mangrove wetlands in an emergency. This and similar events is in direct violation of treaties and international lending requirements to which Barbados has signed. In the case of the South Coast Sewage Treatment Plant, as a result of a system failure in July 2005, Barbados Water Authority management authorized a major dump of an estimated 3 to 6 million gallons of raw sewage into the Graeme Hall Swamp Environmental Heritage Site. The volume of raw effluent was enough to significantly contaminate all water bodies within the 35-acre Graeme Hall Nature Sanctuary, as well as the Sanctuary's main spring.

The deliberate operation to deviate from standard emergency sewage dump procedures bypassed the Sewage Treatment Plant's designed emergency outfall that runs from the treatment plant to the Swamp bisecting canal. The bisecting canal drains the eastern and western portions of the Swamp, and discharges to the sea at Worthing Beach. The

Emergency Discharge Structure was designed and built as part of the South Coast Sewerage Project (South Coast Sewage Treatment Plant), and was financed in large part by the Inter-American Development Bank (IADB).

The South Coast Sewage Treatment Plant emergency outfall had been specifically designed to enable emergency discharges to the sea, rather than the Heritage Site, since the effects of sewage dumping in the Heritage Site are considered to be long-term and cumulatively detrimental to the environment, as there is little natural flushing or cleansing action within the Heritage Site ecosystem.

The design decision to provide an Emergency Discharge Structure to the sea was based on the knowledge that the reef and associated areas are more likely to recover from an emergency discharge event. In fact, studies financed by the Inter-American Development Bank (IADB) and the Government of Barbados, and conducted by consultants and the University of the West Indies, were the basis for the subsequent design of the sewage treatment plant, the Needham Point Outfall, and the Emergency Discharge Structure in Worthing.

IADB financing of the South Coast Sewage Treatment Plant was, and is, contingent on appropriate operation of the sewage treatment system in accordance with local and multi-lateral agreements such as the United Nations Convention on Biological Diversity (Barbados signed this Convention in 1993), and in accordance with measurable environmental standards such as the numeric limits contained in "*The Pollution Prevention and Abatement Handbook, Part III.*"

If continued raw effluent dumps are directed into the Graeme Hall Swamp, contrary to designed intent, Barbados will face scrutiny by the IADB, whose financed operations must comply with in-country environmental laws, regulations, standards and environmental assessment procedures. Where Barbados' environmental regulations, standards or environmental assessment procedures differ significantly from the generally accepted international equivalent, the more stringent option generally applies, unless otherwise approved by the IADB. The following points apply:

- The IADB has acknowledged the Heritage Site as a critical conservation area, as defined by IADB policy guidelines.

- The Bank will not support operations and activities that will significantly convert or degrade critical cultural sites and/or critical conservation areas. The current operational decision to re-direct emergency raw sewage into the Heritage Site directly endangers and is in conflict with the current RAMSAR Convention on Wetlands Application.

- IADB loan documents specify Terms of Reference (TOR) for the environmental assessment or due diligence associated with South Coast Sewage Treatment Plant design, construction and operations. The TOR refers to applicable International Treaty requirements to which a borrower is subject, a requirement for the IADB to analyze any potential violation of such Treaties, and the requirements of the IADB and the borrower to initiate analysis and mitigation such violations.

- The IADB specifies that it is available to finance mitigation solutions for environmental violations and will support borrowing member countries in meeting their obligations under ratified international environmental treaties and agreements.

The Graeme Hall National Park Master Plan should incorporate re-engineering and management of emergency raw sewage discharges within a new, comprehensive drainage system for the Graeme Hall Watershed. While it is true that the Barbados Water Authority is working on an emergency effluent management system to store larger temporary volumes of effluent in existing mains through a series of isolation valves, the fact remains that if volumes exceed the capacity of this optimization programme, the Graeme Hall Swamp may be subject to inappropriately directed discharges.

Solutions may include, but are not restricted to:

- Optimizing emergency storage capacity of the existing influent line on the South Coast (this work is underway.)
- construction of a temporary emergency effluent holding pond, large enough to hold one to three days of raw effluent and allow authorities to make repairs
- construction of an alternate offshore outfall at Worthing Beach
- expansion of primary wastewater treatment to include tertiary treatment, and use resulting water for organic agriculture