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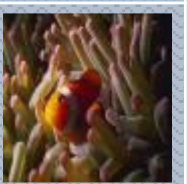

GOVERNMENT OF SAINT LUCIA

MINISTRY OF AGRICULTURE, LANDS, FISHERIES AND FORESTRY

DEPARTMENT OF FORESTRY

FINAL REPORT

RIVERBANK ASSESSMENT CONSULTANCY FOR SAINT LUCIA

Publication Reference: SFA 2003/SLU/0709/PE/LC

ANNEX I

FINAL RIVERBANK ASSESSMENT REPORT

Prepared by

AGRICO LTD.
AGRICULTURAL CONSULTANCY & TECHNICAL SERVICES LTD.

October 2008

GOVERNMENT OF SAINT LUCIA

MINISTRY OF AGRICULTURE, LANDS, FISHERIES AND FORESTRY

EU National Authorising Office

Riverbank Assessment Consultancy
For Saint Lucia

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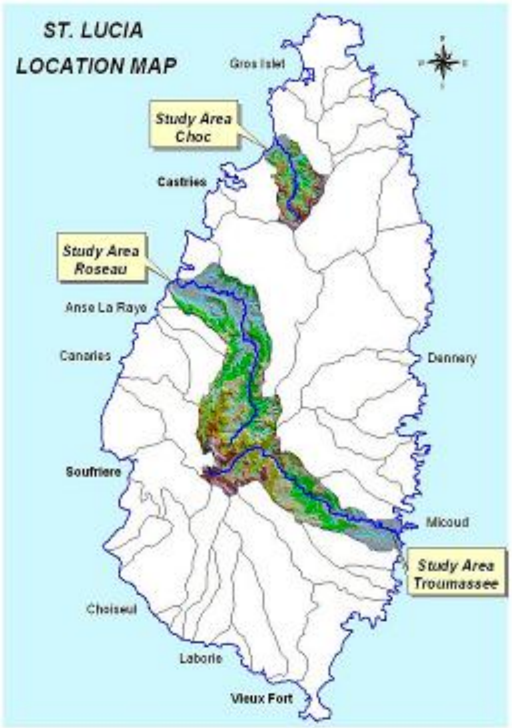

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RIVERBANK ASSESSMENT REPORT

Prepared

by

August, 2008

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EXECUTIVE SUMMARY

Agricultural Consultancy and Technical Services Limited (AGRICO Ltd.) was contracted by the Government of Saint Lucia (GOSL) through the Department of Forestry, under the EU Special Framework of Assistance (SFA) 2003 programme, Economic and Agricultural Diversification and Poverty Reduction through Integrated Natural Resources Management, to develop a rapid assessment methodology for the physical assessment of the current status/ condition of targeted rivers[1] and to make recommendations and formulate an action plan that will be required for an extensive "RIVERBANK REHABILITATION AND PROTECTION" programme. The assessment is to adopt an economic, social and ecological approach towards the conservation and protection of the rivers, riverbanks, water resources and associated natural landscapes.

The assignment was undertaken over the period April to August 2008 and the tasks encompassed the following, with the outcome of the first two components being the focus of this Riverbank Assessment Report:

- **Design/ adaptation and testing of a methodology for rapid riverbank assessment (RRA) based on internationally accepted standards and methods, and the conduct of Bank Condition Assessment to evaluate the nature and** extent of watercourse and riverbank degradation**;**

- **Production of a Riverbank Assessment Report, outlining the results of assessments based on desk study and results from more comprehensive field assessments for a minimum of three (3) key/critical watercourses.**

- **Development of a Riverbank Assessment and Rehabilitation Plan and Proposed Implementation Plan, based on the outputs of the Riverbank Assessment Report.**

After consultations and confirmation of the strategic objectives with the Adhoc multi-disciplinary Technical Committee (TC), a method and approach for the assessment exercise was developed, field tested and adjusted accordingly.

The Rapid Riverbank Assessment (RRA) methodology entailed a five phase process, including:
Phase 1 – River System Profiling
Phase 2 – Database Development and Application
Phase 3 – Stakeholder Participation/Consultation
Phase 4 – Bank Condition Assessment (BCA)
Phase 5 – Data Analysis

The Methodology involved the use of a combination of tools and techniques for desk research and field-based activities, which included much data and information gathering through and from primary and secondary data sources, including

[1] With focus on the general conditions of the riverbanks, inclusive of an established riparian buffer, and the open channel or watercourse.

stakeholder consultations, and direct field observations[2], to facilitate the analysis and evaluation of the rivers.

Phase 1 – River System Profiling, involves data gathering from largely secondary data sources to create an initial profile of the river system based on broad core parameters to provide a basis for prioritization for more in-depth assessment and/or to provide a broad indication of pre-disposition to river degradation. This stage comprises two tiers:

(i) Scoping – Preliminary or initial profiling is used to appraise the river system based on three (3) base criteria: 1) physical classification of type of river (inactive/active/permanent); 2) broad national socio-economic significance and 3) geographical spread in terms of coverage of the socio-economic activities impacting river systems on the island;

(ii) Screening or second level profiling incorporates the use of GIS tools and techniques for the creation of a preliminary digital database derived from secondary sources of information including key attributes of the river systems and three main assessment parameters/aspects derived from secondary data – 1) slope, 2) dominant soil type/stability and 3) land use.

Phase 2 – Database Development and Application, involves the use of GIS technology to compile and relate data and information collected from both primary and secondary data sources into a digital database for assessing status and future monitoring

Phase 3 – Stakeholder Consultations, uses a participatory approach to obtain stakeholder input to identify, confirm and assess the potential factors contributing to existing river conditions.

Phase 4 – Bank Condition Assessment (BCA), involves the use of field observations for the consideration of a limited number of core aspects of bio-physical, socio-economic and environmental parameters, which sought to encapsulate the relative susceptibility levels of the selected rivers to channel and /or riverbank degradation on a qualitative basis.

Phase 5 – Data Analysis, utilizes a combination of techniques for scoring and ranking probabilities for risk, impact and threat of occurrence of erosion of field observations to derive and overall score or **Susceptibility Index (*Si*)**.

The core parameters assessed and documented under the RRA methodology, include:

- Biophysical Aspects:
    - Geologic aspects including dominant soil type and stability;
    - Hydraulic aspects including channel dimensions and estimated bed gradient;
    - Adjacent land use and associated management practices; described by riparian vegetation condition including type, density, and proximity with respect to the banks/ channel;
- Socio-Economic Aspects:

[2] With consideration of intrinsic and exogenous aspects, including human influences.

- Settlements in the vicinity
- Built infrastructure – the nature and condition of any physical structure, entity or object (*permanent, transient or temporary/ movable or immovable*) existing in the river's channel and immediate environment[3].

➢ Environmental Aspects:
- Physical condition with respect to bank/riverbed erosion - types and extent (*where visibly evident*) and associated processes and patterns identified;
- Pollution - physical conditions that reflect/ indicate improper, injudicious or inadequate disposal and/ or discharges of wastes[4], directly or indirectly, into the river's immediate environment;

For the purposes of the assignment, given its short time frame, the consulting team's initial focus was the preliminary profiling of the river systems on the basis of the methodology developed, aimed at selecting three pilot rivers for further testing of the other phases of the methodology. The various phases of the methodology were then tested using the 3 pilot rivers namely, Choc, Roseau and Troumassee, and the outputs presented under Section 5.0, Results and Findings.

The outputs included, a comprehensive *GIS database* comprising special descriptive profile information of each river system which is created in ARC GIS to support the information, mapping and analytical requirements of the Rapid Riverbank Assessment (RRA) Methodology. The database is also to provide a base for future visual monitoring of the status of riverbanks/river systems. Outputs of the stakeholder consultation process were also summarized in matrices to support data analysis and interpretation.

In pursuit of the scope of works ultimately, it was necessary that the form of indication or measure developed for the assessment be logical, objective and appropriately aligned with conventional scientific methods. Consequently, the **Susceptibility Index**, ***Si***, was identified as the qualitative measure which could provide such indication or measure. The analysis phase therefore involved the determination of the conjoined effect/ impact and the manifestation through the dynamic interaction of selected bio-physical, socio-economic and environmental parameters assessed during the field survey in Phase 3 – Bank Condition Assessment, as an indicator of the level of susceptibility of the river channel to degradation (that is, the **Susceptibility Index**, ***Si***).

The adopted method and approach proved to be relatively simple to implement[5], yet effective in accomplishing the set objectives, of efficiency in cost and time. The robustness of the conceptual nature of the methodology, throughout its development and its eventual outputs, was tested and strengthened through the creative and cost-

[3] Which may have a detrimental impact on the river's stability.
[4] Refer to any solid or liquid waste, commercial and agricultural/ industrial
[5] Field data was collected by a small corps of junior and mid-level technicians with minimum supervision.

effective '*implanting*' of a stakeholder consultation/ engagement component and the effective use of existing GIS expertise and tools at the more critical phases, such as criteria development and selection, river profiling and prioritization (*to select pilot rivers*), data collation, database development, spatial and pictorial presentations and ultimately river assessment and monitoring.

The methodology identified overall high levels of susceptibility and pre-disposition related primarily to environmental and bio-physical parameters, and overall a moderate level of susceptibility to degradation of the three assessed rivers in relation to the likely impacts of socio-economic related activities. The outputs and analyses revealed that the main activities are related to: mainstream agricultural and industrial production systems (removal of riparian vegetation, location of infrastructure within buffer/ river, waste discharges, poor infrastructure design); municipal/ commercial and domestic/settlement-related activities (disposals and discharges); other fringe-based livelihood systems and socio-cultural practices (e.g. sand/ gravel mining, vehicle washing, bathing).

Further, the assessment revealed that of the three rivers, only Choc displayed the most complex mix of diverse activities. Troumassee was primarily agricultural-based with very low settlement density, while Roseau was similarly agricultural, but with more low-density satellite settlements, with a few low-intensity industrial sites.

Of the 13 monitoring sites within the two lower zones, the coastal zone sites of each river turned out to be relatively the more threatened, and particularly exposed to on-going environmental pollution and degradation. These processes are chiefly associated with the existing pre-dispositions and susceptibilities facilitated by the poorly maintained physical conditions of the rivers, relative soil stability/ erodibility, poor land use and management practices (*especially intensive agriculture, poor land drainage*), high nutrient load discharges, accelerated/ active soil and bank erosion and severe sedimentation.

Based on the above findings, it is necessary to determine what measure(s) of control and /or remediation may be effected to address or mitigate the threat and/or the impact(s). Such measures may relate to specific actions, processes and procedures which could remove the threat/risk or reduce the chance of the threat being realised. The remedial measures may however, relate to a combination of direct physical interventions (**harder measures**) and "**softer**" measures, which impact on policy design, data and information management, governance and regulatory/enforcement issues.

Measures for riverbank/ river systems rehabilitation and protection will be further developed in the companion document to follow "Riverbank Assessment and Rehabilitation Plan" (RARP), which will seek to develop recommendations based on the outputs of this assessment report including the recommendations of stakeholders emanating from the consultative process.

However, prior to considering the implementation of remedial and control measures in a river, it is necessary to ensure that priorities established as a first step, are followed by further comprehensive study and examination of the factors and issues[6], undertaken in a holistic and integrated manner, to eventually determine and formulate the appropriate and most cost-effective solutions.

In the final analysis, the data and information generated and the analyses and interpretation demonstrate the utility of the RRA methodology, in assessing the condition of the selected pilot rivers, with the capability to effectively “flag” factors, processes and eventual likely impacts/ effects on the integrity in a fairly rapid and cost-effective manner, as determined by the susceptibility index (***Si***).

It is important to emphasize that the ***Si*** should be treated as an indication of a set of physical conditions or relative levels of exposure associated with a category/ categories of factors or aspects, which pre-disposes the assessed locations and zones of the river to degradation or further degradation, if timely and appropriate mitigation measures and interventions are not taken. The ***Si*** is a composite and dynamic indicator. Its valuation and/or ranking can change with time and in accordance with the changing conditions of the river, subject to the level of impact/ likely impact that category/categories of factors may have on the river or some segment thereof.

The **Susceptibility Index**, ***Si***, can therefore serve as a tool to assist/ aid planners and river management technicians in “flagging” trends in the monitored locations (reaches/ segments/ zones) of the river with respect to changes in the value of Si with time as an indication of level of threat or susceptibility of the river system to degradation. Such trends, however, indicate the need for more in-depth examination of the contributing factors and processes, to determine the extent of the threat and the corresponding appropriate, site-specific remedial measures and interventions. The investigation will also determine whether the main causative and influential factors are localized, catchment-related or drainage basin-wide, including the consideration for more detailed studies/ assessments and some of the “*softer*” aspects, such as institutional and local capacities, appropriate incentive measures and regulatory framework, relevant enforcement mechanisms and adequate human and material resources.

This in turn, will facilitate the prioritization of actions/ interventions, based on the relative values and significance accorded to the respective river systems, as included in the monitoring regime. The corollary to this is that overall the methodology and the Index also help to identify the rivers/ streams or the segments/ zones that systematically may be manifesting relatively low levels of susceptibility, thus providing indications of what may be identified over time as possible ‘*benchmarks’* of a stable river systems, to work towards for other more ‘threatened’ rivers.

The RRA methodology focuses on the use of a limited core of variables/parameters deemed capable of providing a strong indication of susceptibility to degradation or threat of susceptibility to degradation if prevailing conditions continue or worsen. The number of core variables is therefore deliberately limited in order to remove as much variability in the likely interactions among variables/parameters and to reduce as far

[6] This implies further study/ examination at the “river” level, as a discrete and dynamic physiographic unit, and at the wider drainage basin or relevant catchment levels, which should take into consideration issues, policies, strategies, etc. at the local/ drainage basin, regional/ district and national levels.

as possible complexity in the application of the RRA methodology. The downside to this however, is that river systems are dynamic systems, and there is the likelihood that the parameters used to indicate susceptibility may change over time.

Further, the RRA methodology may not necessarily be applicable for every possible combination of variables/parameters and would need to be tested for each set or combination of variables/parameters to determine its effectiveness and utility under these conditions.

One basic assumption of the RRA methodology is that conditions approximate normal conditions with respect to impacting factors such as weather and management. This suggests that under extreme conditions the RRA may not be resilient enough to produce a predictable response, as would be the case for any natural system faced with abnormal conditions.

The main use of the GIS in the current RRA is in the development of a comprehensive digital database of pertinent information required to undertake a rapid assessment of riverbanks and the quality of water systems based on the key factors discussed earlier. The GIS is thus a data management tool – capture, storage, retrieval, mapping and data manipulation, and brings together data from a number of sources into a single system. For the future application of the RRA, the use of GIS as an analytical tool is circumscribed by the *availability of existing detailed data about each water system*.

Given the paucity of data on many parameters and the variable data formats for those available data, the variables to be utilized in the RRA are currently limited. Expanded research and data collection on natural resources will therefore be required to support an expanded application of the RRA.

With respect to water quality monitoring, it is useful to note that currently there is no major research work or sustained routine monitoring of river water quality or stream discharge measurements or systematic river maintenance programme. Moreover, there is no developed national database for monitoring environmental quality of freshwater resources, apart from agency-specific initiatives. Working collaboratively with landowners, resource users/ producers and their relevant representative agencies, other resource managers and service providers, and other relevant stakeholders would therefore assist in identifying appropriate, cost-effective and meaningful solutions for future monitoring of water quality.

With the establishment of a well managed monitoring regime and data collection/management systems, the RRA Methodology will provide the platform for development of a simulation model for monitoring the condition of river systems. This however, will require continuous updating based on emerging circumstances including changes in bio-physical, socio-economic and environmental conditions, as well as technological advances.

1.0 Introduction

1.1 General

Agricultural Consultancy and Technical Services Limited (AGRICO Ltd.) was contracted by the Government of Saint Lucia (GOSL) through the Department of Forestry, under the EU Special Framework of Assistance (SFA) 2003 programme, Economic and Agricultural Diversification and Poverty Reduction through Integrated Natural Resources Management, to develop a rapid assessment methodology for the assessment of the current status of targeted rivers and their riverbanks, to make recommendation and formulate an action plan that will be required for an extensive "RIVERBANK REHABILITATION AND PROTECTION" programme using an economic, social and ecological approach towards the conservation and protection of the rivers, riverbanks, water resources and natural landscapes.

The assignment is the first phase of a proposed two phase approach to address this major environmental problem of national import having as its aim, the development of a rapid assessment methodology for the assessment of the current status of targeted rivers and to eventually formulate a strategic framework geared towards a sustained "RIVERBANK REHABILITATION AND PROTECTION" programme for the conservation and protection of the rivers, riverbanks, water resources and associated natural landscapes.

The assignment was undertaken between the period April to August 2008 and involved two phases, with the outcome of the following tasks in Phase I being the focus of this Riverbank Assessment Report.

- Conduct stakeholder analysis and consultations, to promote a participatory approach and community involvement for ensuring mainstreaming and upscaling of recommended actions.

- Formulate a Checklist of criteria for assessing/evaluating watercourses, based on available data and information.

- Utilising this Checklist, conduct a Scoping Exercise through desk research using available base data and information from stakeholder consultations, for the preliminary evaluation of the twenty seven (27) watersheds. The scoping exercise will also serve to identify a representative sample of a minimum of three (3) key/critical watercourses for more comprehensive assessment through a field reconnaissance exercise.

- Develop/adapt an internationally acceptable methodology as a model/template for rapid riverbank assessment (RRA).

- Conduct rapid field assessments to test the methodology and undertake Bank Condition Assessment of the selected minimum of three (3) key/critical watercourses on the island to elaborate on the nature and extent of problems within each representative sample.

- Prepare Riverbank Assessment Report on the assessments of the extent of watercourse and riverbank degradation and the relative exposure for further degradation (susceptibility index).

- Develop GIS database for the representative rivercourses, with the defined river bank boundaries forming the core spatial unit of the dataset and populated with the relevant descriptive information required for the assessment.

This Riverbank Assessment is intended to inform the next phase of the assignment which involves the development of a **Riverbank Assessment, and Rehabilitation and Protection Programme** as a vital complement to ongoing initiatives in integrated land management, water resource management, biodiversity protection, and agriculture diversification including agro-tourism initiatives, in accordance with the country's development objectives of economic diversification and sustainable development.

1.2 Scope of Work

The scope of the work for this component of the assignment, encompassed:

- Review of past technical reports and photographs to identify and assess the potential factors contributing to river bank erosion;
- Organise and conduct a consultation programme so that stakeholders have an opportunity to put forward issues relating to the erosion of the river bank;
- Elaboration of Rapid Riverbank Assessment (RRA) Methodology;
- Profiling of rivers to select a sample of rivers to be assessed using the RRA methodology;
- Conduct field assessments within sample river courses to undertake Bank Condition Assessment with the RRA to document existing bank conditions for both sides of the river;
- Identify and assess the potential factors contributing to physical degradation of the riverbank and channel;
- Rank factors, after they have been identified and assessed in regards to their risk and relative contribution to degradation;
- Identify riverbank sites along the targeted riverine segments/zones of the selected sample of rivers in respect of their need for rehabilitation, as well as relatively stable sites in need of continued protection;
- Identify appropriate management actions including typical works to stabilise the priority sites and manage key processes identified;
- Prepare a report of findings.

1.3 Report Structure

The report is structured as follows:

- Section 2 of the report provides a background to the study and includes a summary of river systems based on the desk study;
- Section 3 describe the main components of the Rapid Riverbank Assessment (RRA) methodology;
- Section 4 describes the application of the RRA methodology including the initial profiling, field assessments and the framework for the future monitoring program based on bank condition assessments undertaken, as well as the consultation process;
- Section 5 discusses the key findings of the study focusing on the condition assessment at site inspected as well as the main processes contributing to degradation, and providing a qualitative provisional ranking of the sites; and
- Section 6 provides analysis of the key finding which will be used to propose possible recommendations that may be considered in developing the rehabilitation programme, including typical remedial works to stabilise the priority sites and zones and manage key processes identified in section 4.
- Section 7 presents conclusions and considerations for implementation measures for rehabilitation and remedial works towards the development of a Riverbank Rehabilitation and Protection Plan.

2.0 Background

2.1 General

The island of **Saint Lucia** is located within the chain of islands in the Eastern Caribbean at 14° north and 61° west latitude. It is the second largest of the Windward Islands, with a total land area of 616 sq. km (*238 sq. miles*) and a population of approximately168, 000. The island measures 43.4 km (27miles) long and 23.5km (14 miles) wide. Like many of its neighboring islands Saint Lucia is of volcanic origin, evident by the island's rugged interior. The rugged and higher mountains are predominantly in the south-central portion of the island. Its tallest peak, Mount Gimie extends 959 meters above sea level.

The island experiences a tropical maritime climate, influenced by the North East Trade Winds. The climate is characterized by average daily temperatures of 26°C, and a relative humidity of about 75% with little seasonal or diurnal variation. Long-term mean annual rainfall pattern shows both topographic and seasonal variations, with the range from 1153 mm in the lower coastal regions to approximately 3,800 mm in the mountainous interior, indicative of the predominantly orographic influence of the latter. Rainfall is distributed into a drier season from January-May and a wetter season from June-December, with the risk of hurricanes and severe tropical storms with high winds and very heavy rains from late June through November.

Water is primarily available through surface flow, and the forests in St. Lucia play a primary function in the preservation of the island's water supply. There is no natural surface storage (e.g. lakes) and very limited groundwater supply. The island's terrain (steep with incised valleys), coupled with heavy rainfall and relatively short river runs heighten the need for effective land and water resources management and in particular middle and upper watershed protection and the management of the river systems of the country.

Like most Small Island Developing States (SIDS) the island is highly dependent on its finite natural resource endowment for the viability and sustainability of all forms of economic and social activity. Rivers and watercourses are critical to the sustainability of the island's ecological systems/ assets, including the estuarine, coastal and near shore marine habitats, while they support key sectors of the St Lucia economy, namely services, agriculture and tourism. Increasingly, there has been mounting pressure on the natural environment, particularly on the land and aquatic systems and by extension the primary water resource base, which poses a major challenge to the country's thrust towards sustainable development.

Land along the riverbanks is frequently utilized in an unplanned manner for unsustainable livelihood purposes, such as agriculture, and in other instances for construction and other industrial developments. Rivers are also used to provide social services, including recreational and sanitation services (washing, bathing and household water supply). These typically[7] result in accelerated land degradation, manifested in the increased sedimentation of the waterways or channels (sediment loading), causing water pollution, progressive dwindling of the islands freshwater resources (which is essentially surface water), the loss of productivity in cultivated areas, and increased incidents of land slippage in areas of unplanned development. The corollary, is the negative impact of high sediment levels on the natural environment; aquatic life, mangroves and corals, and near-shore fisheries; and increased health and related livelihood risks. The ravages of "Tropical Storm Debbie" in September 1994, and the persistent and pervasive problems of soil loss and land degradation have underscored the need for effective and systematic natural resources management, watershed management and in particular riverbank protection and the management of the island's major rivers.

In response to the degrading state of lands and the coastal environment due to improper planning and management practices, which eventually lead to high turbidity levels and flooding which result from slightly moderate to heavy rainfall, there is need for immediate re-dress of this situation, to control and prevent further degradation of the rivers and the associated negative environmental, social and economic consequences. Moreover, this would further serve a variety of purposes, such as the evacuation of floods and the lowering of flood levels,

To this end, a rapid assessment method of assessing riparian conditions of the riverbanks and channels of the premier watercourses on the island is needed to underpin strategies for improved management through a proposed extensive "RIVERBANK REHABILITATION AND PROTECTION" programme.

[7] Rapid expansion of the banana industry in the 1970's and 1980's and the associated unsustainable agricultural practices, leading to soil erosion and encroachment of R/Bks and forested areas, have in particular been recognized as a major cause of land degradation – WEMP Report (Watershed and Environmental Management Programme, 1995 -97)

2.2 Overview of the River Systems Environment in Saint Lucia

The river system[8] environment involves a very complex and interactive network of natural and man-made process interfaces, which provide social, environmental/ ecological and economic goods and services. In simple physical terms, a river is a naturally defined channel with water flowing over the land from a source to its main outfall or mouth. The area of land from which a river receives water is normally referred to as its drainage basin or water catchment. The drainage basin is often described in terms of surface area, altitudinal range and the length of the main channel, among other biological and physiographic parameters.

Probably, one of the primary factors which elevate the value of rivers in St. Lucia to national significance is the fact that they are the main sources of freshwater, in support of life[9], social, economic and environmental services. Such a primordial function is manifested through innumerable complex interactive natural processes, relationships and interconnections with other natural cycles and "systems", such as coastal and marine systems and the water or hydrologic "cycle".

In practice rivers are often used as disposal sites and discharge outlets for domestic and industrial wastes, which eventually impacts negatively on the rivers' capacity to effectively sustain its primary natural and other functions. In this respect, the sustainable use and management of the country's river systems and their associated environments remain necessary obligations.

2.2.1 Broad descriptions and classification of rivers

In Saint Lucia, rivers play an important role in sustaining the natural, socio-cultural, economic and environmental systems that contribute towards the overall development of the individual, households, communities and the society as a whole. Hence, from historic times major human settlements around the island have developed primarily in the vicinity of main river systems or some other natural body which provides a water supply.

In this context, rivers can be generally classified according to their flows, such as:
Perennial flows ~ refer to rivers/ streams with continuous flows throughout the year;
Seasonal flows ~ refer to rivers/ streams with seasonal flows, usually during the "rainy season", while the channels run dry during the drier months;
Ephemeral flows ~ refer to rivers/ streams with flows of short duration, which occur during rainfall events and last for only a few hours after the event.

With reference to its general relief and other bio-physical conditions, which vary for every system, a river is conditioned by the characteristics of the watershed that provides both water and nutrients. Likewise, it is equally important to consider the body of water that receives its drainage/ discharges. In this regard, rivers can be

[8] System herein refers to a series or a network of coordinated natural processes which normally produce responses that are predictable, generally consistent and replicable.

[9] Water which is also essential to the survival of flora and fauna, providing food/ nutrients , water and shelter, thus supporting the viability of their habitats.

differentiated on the basis of the various morphometric parameters that relate them to the watershed's relief features and drainage area. These influence greatly, for example, the number and order of tributaries and eventually the hydrological response of the river.

In relation to elevation, typically, a river system can be zoned into four broad zones, each depicting unique characteristics, physically and ecologically.

Head waters or 'conservation' zone ~ which refers to and relates to the area where the main sources of water are located;

Mid or 'catchment' zone ~ which is located below the head waters zone and relates to the area/ zone where the primary water supply abstraction points are normally found[10];

Lower zone or zone of intensive and multiple use ~ normally the area or zone of intensive and multiple uses for social and economic developments;

Coastal zone ~ generally refers to the lower flood plain area leading to the estuarine segment and mouth of the river, including its interface with the nearshore marine environment.

Ultimately, the aim of any on-going rehabilitation and management programme is to ensure a sustainable healthy river status which involves:

- Stable riverbed and banks, with a natural conditioning environment which promotes optimum in-stream habitat diversity; and
- The riparian zone of the main river and its tributaries are continuously well managed and conserved, with appropriate considerations made for endemic species as far as practicable.

2.2.2 Physical Factors

Watersheds

St. Lucia has 37 main watersheds[11] corresponding to 37 main drainage basins each of which are at various states of utilization or degradation; ten of these are small multiple small drainage basin complexes[12]. Refer to Figure 1 below. They all radiate from the central mountain ranges[13] of the interior towards the coast. Of those watersheds drained by single main channels, ten are classed as major basins greater than 1500ha; the major watersheds account for 48% of the island's total area while the minor basins account for just under 23%. Of these, seven major river basins, namely, Marquis, Roseau, Vieux Fort, Cannelles, Troumassee, Fond d'Or and Cul de Sac rivers, supply most of the water used for domestic, agricultural and industrial purposes. The effects of agriculture have impacted all the major watersheds with some catchments totally deforested.

[10] To optimize production levels without overly compromising quality;

[11] Migeot, J and Hawden, P. 1986. Saint Lucia Water resources: preliminary Assessment. Vols. 1&2. Ministry of Agriculture, Castries, Saint Lucia.

[12] Christopher Anthony Cox 2003 Integrated Watershed Management Planning for Saint Lucia. A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements of the degree of Doctorate of Philosophy. McGill University, Quebec Canada

[13] From which the sources of the main rivers originate.

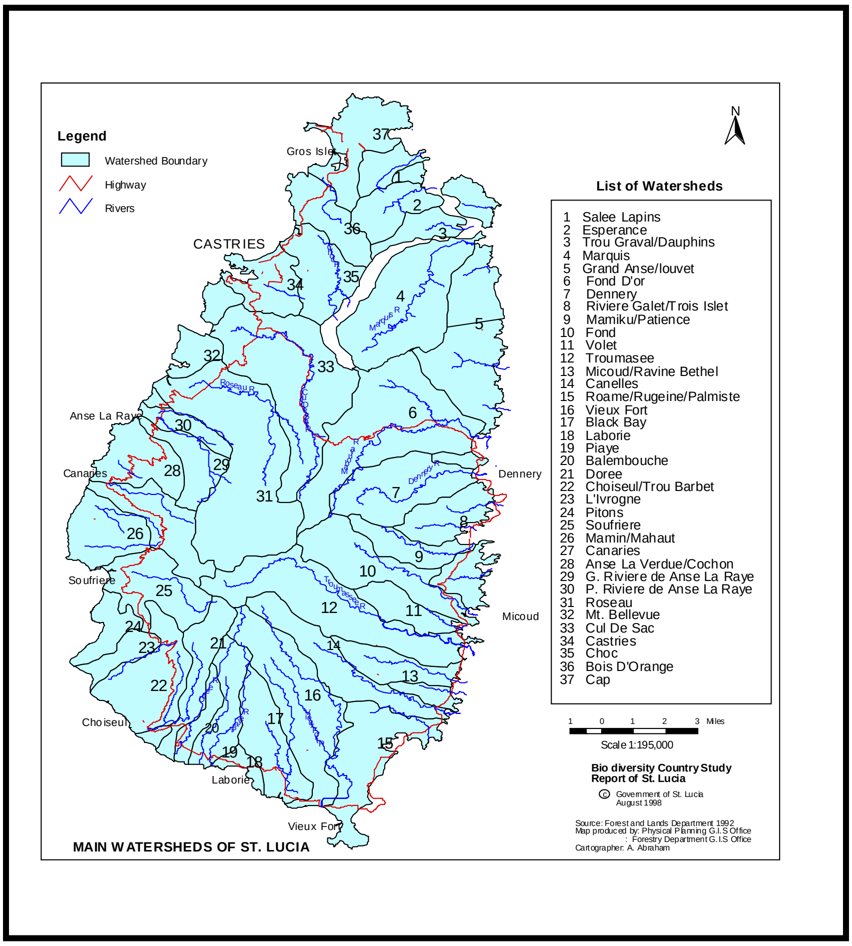

Figure 1: Location of Watersheds and Rivers in Saint Lucia
Source: Biodiversity Country Study Report of Saint Lucia

The largest watersheds are Roseau, Cul de Sac and Fond D'or with areas of 4,962; 3,150; and 4,142 hectares respectively. The Troumassee River is the longest having a length of 8.76 miles followed by Roseau which has a length of 8.63 miles.

Groundwater storage is potentially restricted due to impermeable volcanic substrata. Despite the paucity of data on ground water supply reserves have been estimated to be inadequate for major use but may be able to support exploitation on a small scale. More recent exploration by the private sector (hotel developers) has identified significant good quality groundwater sources on the east coast of the island, and to a lesser extent in the far northern and north-eastern parts of the island.

Relief and Drainage

About 55 per cent of the island falls within the $10^0 – 30^0$ slope range; approximately 20 per cent of the island is within the 0^0 to 5^0 slope. Thirteen per cent of the island is more than 30^0, while the remaining 12 per cent is made up of miscellaneous surface types comprising several slope categories, including bare rock, beach sand, and urban areas[14]. As a result of the rugged topography and the absence of intermediate collection points such as lakes and ponds[15], the majority of this rainfall flows to the sea with very little opportunity for ground water storage.

Rainfall and Water Availability

Figure 2, depicts a typical pattern of rainfall distribution for a sampled rainy and dry season.

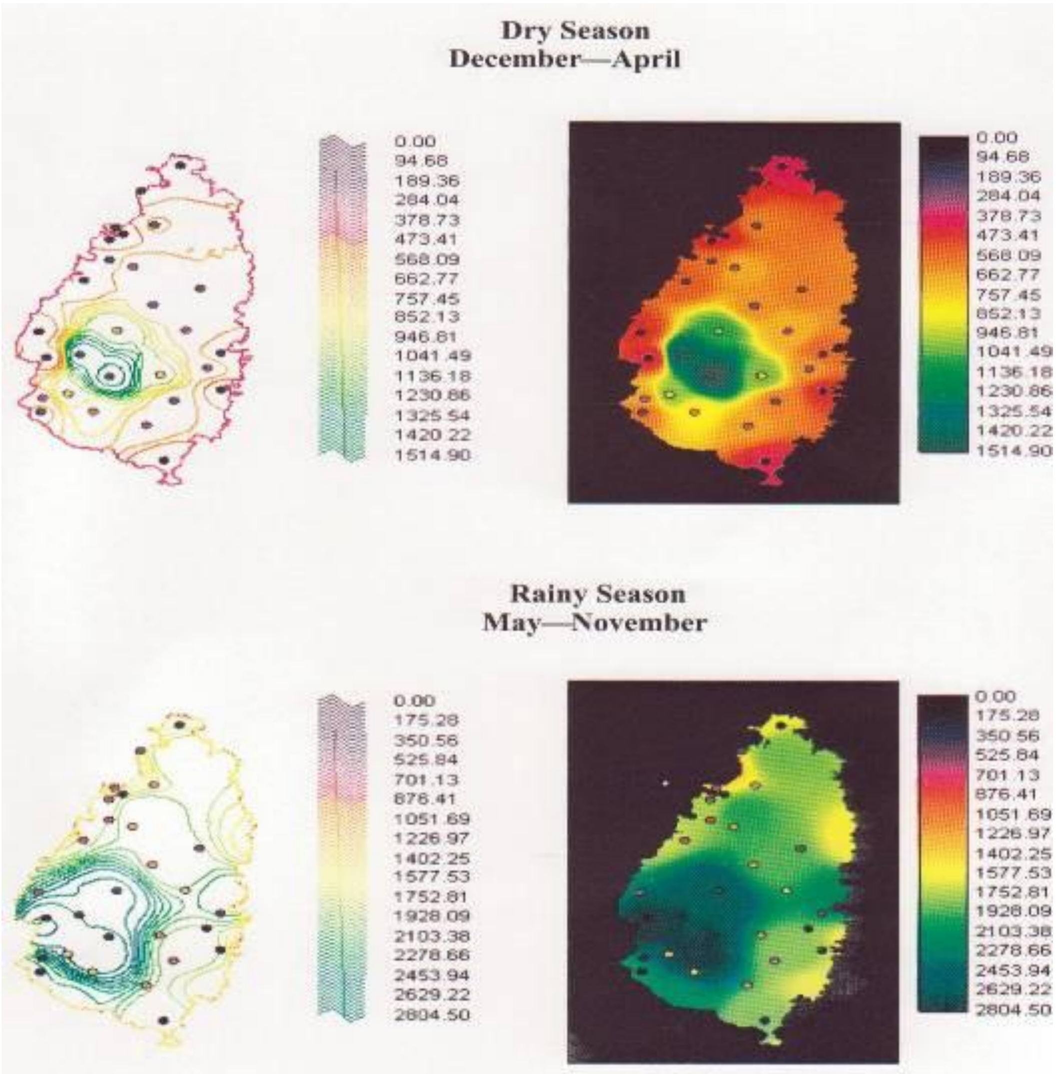

Figure 2- Example of Rainfall Distribution for a Sampled Rainy and Dry Season

Source: Ministry of Agriculture, WRMU, Saint Lucia

[14] Polius and Pretel 1981
[15] With the exception of the John Compton / Roseau Dam.

This seasonal variation in rainfall strongly corresponds with the marked seasonal variation in base flow in the island's river systems.

Figure 3 shows the distribution pattern of mean annual water deficit (*difference between potential evaporation and precipitation*) where large portions of the island's interior contain annual water surpluses up to 13 mm day-1 while coastal regions experienced annual deficits up to 5 mm day-1.

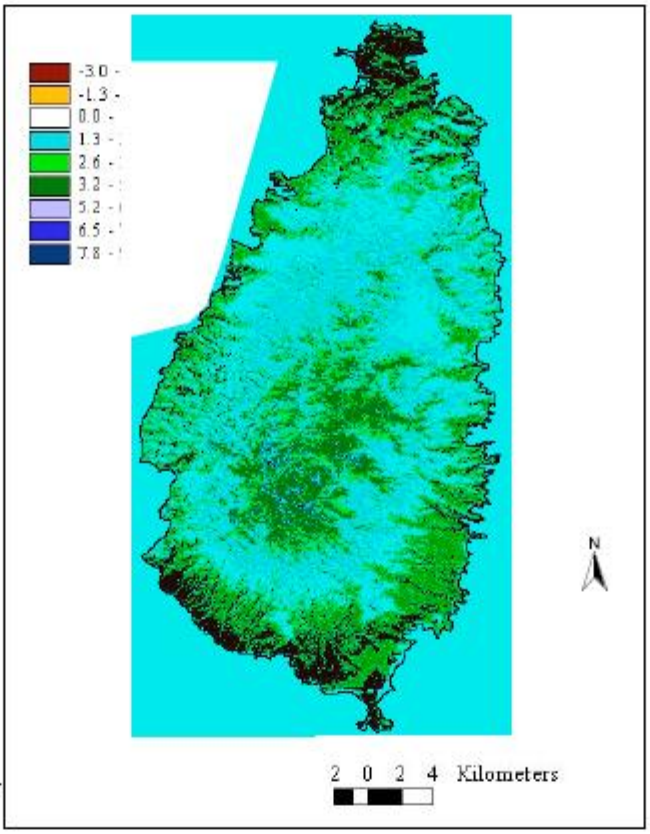

Figure 3: Mean Annual Water Deficit (mm day^{-1})
(Source: Isaac, 2001)

Isaac (2001) also premised that the observed shift in the energy balance towards greater evapotranspiration, due largely to the removal of natural vegetation, is likely to result in increased water deficits, evidenced in more prolonged drought conditions. The resultant drier microclimate occurring even in the upper watershed reaches will thus affect the ability of the watershed to maintain stable base flows.

Appendix 1 provides more details on climatic issues and the current status of related water resource management issues in St. Lucia.

During the dry season, water supply is particularly dependent on base flows of the river systems and any run-off that results from rainfall. The base flows in the watersheds are dependent mainly on (i) catchment size; (ii) soil types and their depth and water holding capacities; (iii) land use and vegetation cover, in terms of influencing soil surface evaporation, evapo-transpiration, detention storage and other rainfall-runoff characteristics and (iv) abstractions from the river system by human intervention.

Declining base flows in the island's river systems have however been attributed to two main factors, long term climatic variation and changes in land use (Cox, 2003). The seasonal variation in flow can be explained by the corresponding rainfall regime, though more research is needed to determine whether there has been a declining trend in rainfall. During the dry season flows in the lower reaches of the rivers draining the watersheds of St. Lucia can become exceedingly low, ranging from 100 l/s to 200 l/s for the larger watersheds in the central part of the island to zero in the smaller watersheds/ drainage basins. The inter-annual variations in low flows can be large in percentage terms being a function of the preceding wet season rainfall volumes and the intermittent rainfalls which occur during the dry season (GOSL 1997). In the case of land use, removal of the natural vegetation through deforestation has caused changes in the hydrologic response of river systems, with increased runoff following rainfall events as relatively less moisture is retained to recharge base flow.

Geology and Soils

Stark *et al* (1966) produced a comprehensive study of Saint Lucia soils, which identified an extensive range of soil types (52 series).

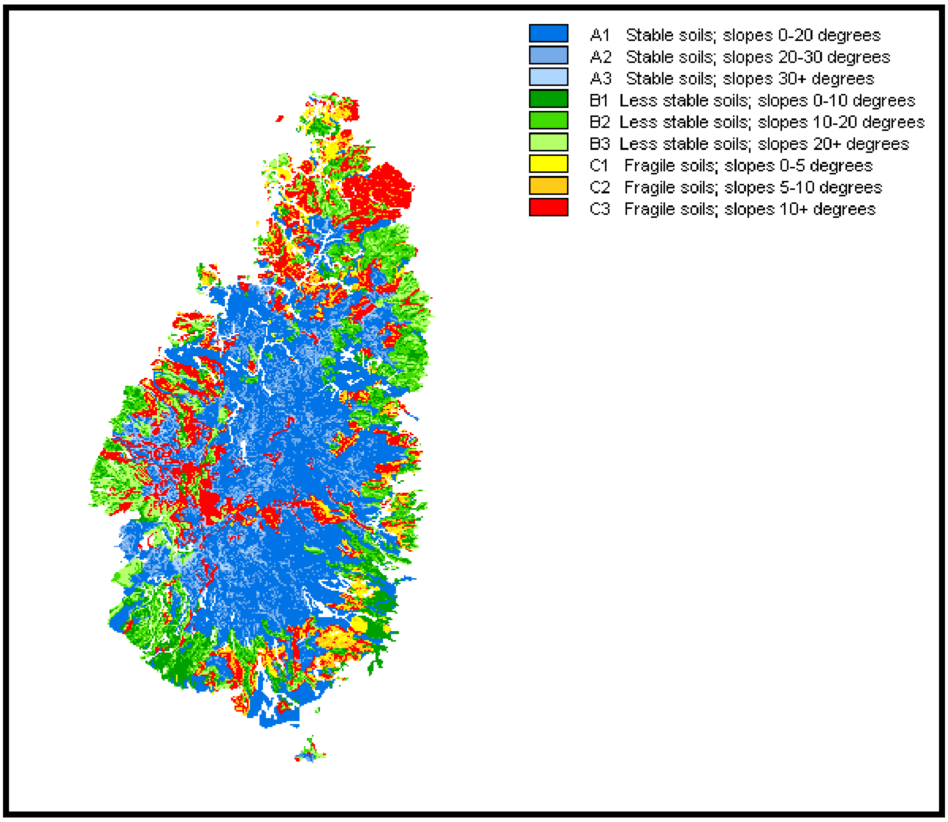

Figure 4: Saint Lucia Land Capability[16]

[16] (After Ahmad 1989)

Saint Lucia's soils are youthful, derived from a relatively narrow range of parent materials, including andecites, basalts and dacites.[17] Soils derived from andecites are the most extensively occurring and cover almost half of the island. These soils are characterised by low to medium acidity and problems of drainage and erosion. They are largely found in relatively steep areas with annual rainfalls greater than 1250mm. Alluvial deposits are well drained and fertile and occur on slopes of less than 5^0. (see Fig.4 above)

2.2.3 Land Use and Management Issues

According to the last major land use assessment carried out in 1992, rain-fed agriculture was the dominant land use, accounting for just over 55% of the total land area[18]. Forest (all broad classes) accounted for just over 35%. The bulk of agricultural production (dominated by bananas) took place within the flat alluvial plains of the major river valleys (such as the Roseau, Cul de Sac and Mabouya watersheds), extending to the mid-watershed reaches within the steep interior of the island. The areas along the coastal corridor tend to less suited to rain-fed cultivation on account of soil and water availability limitations. Other land uses accounted for a relatively minor proportion of the total land area (9.5%). The more heavily urbanized areas are clustered along the coastline and some areas in the interior where the settlement patterns tend to follow major roadways.

However, significant changes have occurred over time in land use patterns, due primarily to the decline in the agricultural sector in general and the banana sub-sector in particular, on the one hand. On the other hand, greater focus and emphasis on the tourism and services sector has led to increasing urbanization (the rural – urban drift), resulting in less lands being cultivated on a permanent basis. In fact, outputs from the 2006/7 Census of Agriculture clearly indicated that "…the apparent abandonment of banana plots has contributed to the decrease in land used for permanent/ medium term crops…" on holdings within the last decade, declining from 67.1% to 56.3%, while temporary crops increased from 4.9% to 10.8%. See Figure 5 which shows the changes in land use structure between 1996 and 2007[19]. A comparison of the area under arable land and land under permanent/medium term crops (Figure 6) also illustrates changes in land use.

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[17] Stark et al *ibid*
[18] Biodiversity Country study Report
[19] Extracted from ***St. Lucia Census of Agriculture, Portrait of the Main Findings, 2007***

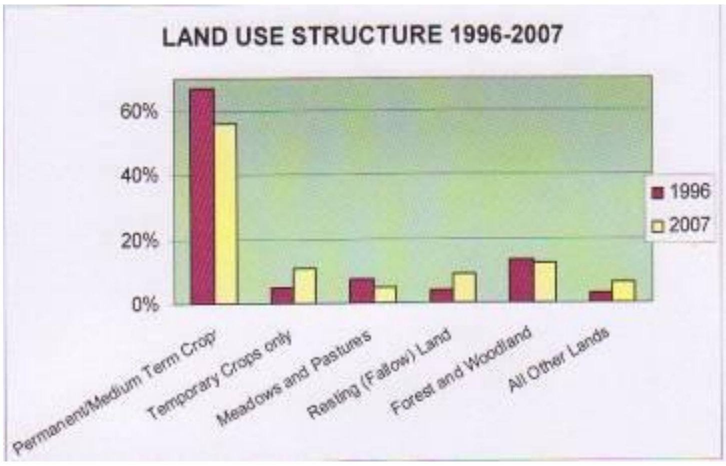


Figure 5: Land Use Structure – 1996-2007

Source: St. Lucia Census of Agriculture, Portrait of the Main Findings, 2007

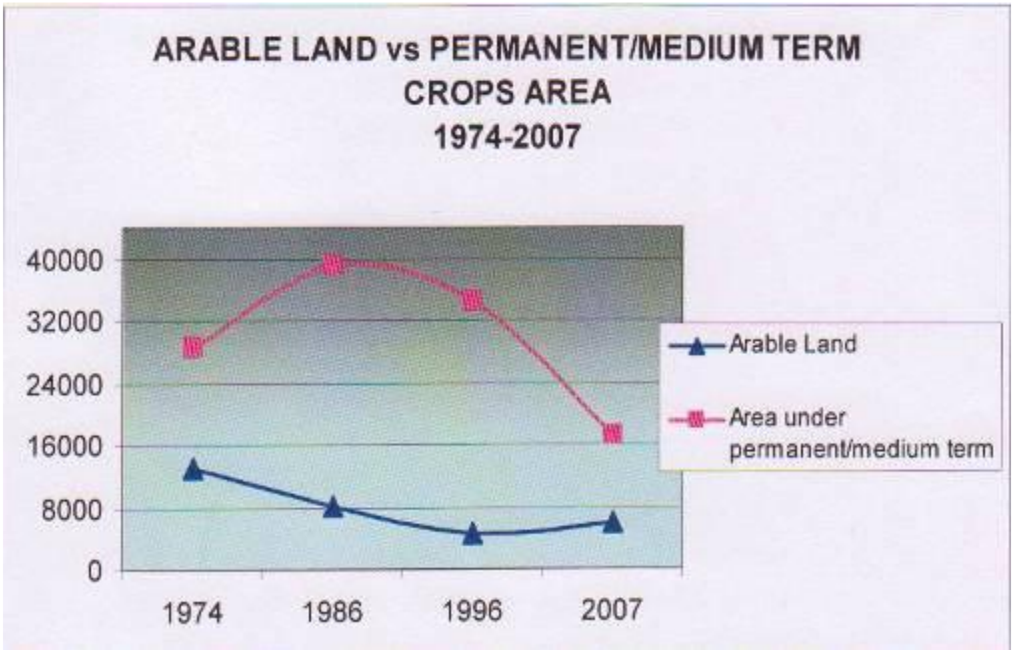


Figure 6: Comparison of Cropping Area

Source: St. Lucia Census of Agriculture, Portrait of the Main Findings, 2007

Unsustainable agricultural practices however, have seriously impacted the natural environment. Farming on hillsides has contributed to excessive erosion and loss of topsoil, with sedimentation of the eroded material within the lower reaches of river channel and/or discharge and deposition of sediment in the near-shore marine environment. Sedimentation within river channels reduces hydraulic capacities and increases flood risk, as well as increasing turbidity of off-shore waters resulting in blanketing and eventual damage to marine ecosystems. Further, the tourism product can be compromised since water-related recreational activities in the coastal zone are also impacted.

2.2.4 Water supply and management issues[20]

With respect to the water supply, rainfall is the primary source of fresh water, which is abstracted from the various river systems around the island. Annual rainfall averages about 1600mm in the north and south of the island to about 3500 mm in the higher altitudes. There are two distinct seasons – a rainy season, from June to December and a dry season, from January to May, with February, March and April being the driest months. Approximately 60% of the annual rainfall occurring between August to November. This uneven distribution can be problematic in the drier periods of February to April in the absence of adequate collection and storage facilities.

The island is sub-divided into 37 watersheds, with perennial streams emanating from 10 of these watersheds, with head waters of these streams in the zones of highest rainfall. Eleven watersheds have head waters in the drier zone of the country. Twenty-two catchments are used for harnessing most of the water for domestic and industrial consumption. In some cases springs are the source of supply, as in the case of the Soufriere area. This available water increases in quantity during the periods of rainfall especially in the rainy season.

Information on river flow is poor. Run off is generally rapid on steep slopes and recession of base flow is largely related to low water retention capacity of some of the volcanic soils of the island. The natural forested areas[21] make a significant contribution to the interception of this rainfall allowing infiltration/ deep percolation into the sub surface thereby contributing to the sustainability of base flows beyond the rainy periods.

Despite the paucity of long-term quantitative data, there has been a steady decline in dry-season baseflows in most rivers over time. This may be related to the gradual reduction in contiguous natural forest cover within the upper reaches of the major drainage basins over the past few decades. The net effect of the replacement of natural forest cover by intensive agriculture is the reduction of deep percolation potential and soil moisture retention, with an increased in surface runoff

Data on ground water supply is sparse. Bore holes have been dug in the north of the island. Some of these have indicated a production of at least 7 liters per second and a static water level of 2-3 meters below ground level. However, more recent exploration by the private sector (*hotel developers*) has identified significant good quality

[20] See Appendix 1
[21] The rainforest areas are dominantly the central regions of the island with cultivated areas surrounding these areas and extending outwards to the coastal regions.

groundwater sources on the east coast of the island, and to a lesser extent in the far northern and north-eastern parts of the island.

With the continuous decline of the island's previous main revenue earner – the banana sub-sector, the Government has increasingly promoted its tourism thrust with the construction of a number of new hotels and associated infrastructure, to boost the services sector[22]. The increasing numbers of visitor arrivals will place greater demands on the island's finite freshwater resources, to meet the increasing demands, as well as to meet domestic demands, including the demand for agricultural production, as agro-tourism linkages continue to strengthen.

It has been recognized that an appropriate localized approach needs to be developed to assist in the overall thrust of improving the management of the water resources which must of need include the river systems environment.

Water Quality Assessment

The water quality characteristics of streams are determined by the inflows to the stream, the amount of turbulence, interactions between water and the channel rocks and soils, and the interactions of the air-water interface. The stream channel serves as the meeting place of water from surface runoff, interflow, groundwater, and the municipal and industrial discharges. Thorough mixing of materials within the stream is typical. The carrying capacity of a stream for suspended materials increases with the increased velocity and turbulence.

In many cases, pollutants (*solid and liquid from point and non-point sources*) transported in surface runoff are a major contribution to water pollution. Wash-off materials of most concern include sediment, mineral salts, nutrients, pesticides/ agro-chemicals, biodegradable organics, industrial wastes/ effluents and microbial pollution. Pollutant accumulation is site specific and depends on land use, season and climate.

Overall, river water quality depends on the amount of suspended sediment and the chemical and biological composition of the water. The quality requirements of the river's water depend on the intended use (social, economic and environmental) ~ e.g. domestic supplies, irrigation, recreation, etc. A determination has to be made as to what quality standards are deemed acceptable for the specific river.

[22] Which now accounts for well over 80% of economic activity in the country.

From a pollution standpoint, pollutants can originate from point and non-point sources. Example:

Point sources	**Non-Point sources**
Waste disposal sites	via run-off from cultivated lands
Manufacturing & processing plants	discharges from settlements
Livestock farms	from widespread construction activity
Quarries.	

Sediment is by far the most significant pollutant, since it not only depletes the land of the soil necessary for crop growth, but also carries away nutrients, agro-chemicals, organic material and beneficial micro-organisms, in turn, impacting on land fertility and productivity.

It is therefore critical to determine the major sources of the sediment and the associated causative factors (within the immediate river environment and /or the wider catchment or basin area). Working with landowners, resource users and other relevant stakeholders would assist and also help to identify appropriate solutions.

The value and contribution of water quality towards a river's general integrity cannot be overstated, hence it must be considered as an integral component of any Riverbank Assessment.

2.2.5 Socio-Economic Issues

The growth of the economy of St. Lucia in recent years has been modest. The adjustment to the restructuring of the banana industry has been painful. Not only has the cost been large in terms of shrunken output as banana production fell, but alternative agriculture has not kicked in to compensate. The country lacks the mechanisms for trade adjustment and the enormity of the task of assisting marginal banana farmers to withdraw from bananas and to embrace alternative crops all of which have different technical and infrastructural requirements has stretched the institutional resources of the country. Moreover, because of the fiscal impact of adjustment, the Government has lacked resources generated from internal sources to support the necessary adjustment.

The general economic slowdown and the economy's overall performance over the past ten years are responsible, in part, for current levels and patterns of poverty in rural communities. Contraction in all key sectors has increased unemployment and has reduced income in poor households.

The banana industry was once the main source of income for a significant number of households in the rural communities and whether individuals had been employed as farmers or as laborers, their place in the formal economy was assured. However, now that the industry has declined they have been displaced and their income source eroded. Large numbers are therefore now unemployed and have become poorer in the process. For them as well as for their families and communities this loss has resulted in less availability and circulation of cash, in many hardships and in greater poverty. At the same time, from the field discussions and from a review of the 2005/2006 Country Poverty Assessment, it appears that not many of this group has benefited from attempts to diversify the agriculture sector. Some admitted to being involved in some or other aspect of agriculture, their ability to generate income is often times hampered by the absence of markets for their produce.

The resultant effect(s) of the above is a myriad of complex socio-economic ills, such as increasing marginalization, unsustainable livelihoods, drug use/ addiction, violent crime, poor health and sanitation and the rural-urban drift, among others (ref. figure 8). These issues in more than one way impact on the management of limited natural resources, river systems included.

2.2.6 Ecological/ Environmental Issues

The natural environment is characterised by small and fragile ecosystems, and by the high level of inter-connectivity among these and their natural functions. Less than 10% of the total land area occurs on slopes less than five (5) degrees. More importantly, activities occurring in one area can very rapidly have negative environmental impacts on surrounding ecosystems and in particular, changes taking place in upper watershed areas very rapidly impact on lower watershed and coastal areas.

Saint Lucia is highly vulnerable to a number of hazard events with the potential for substantial loss of life and property damage. These hazard events include natural hazards such as hurricanes, floods, earthquakes, volcanic eruptions, and man-made hazards including fires, marine accidents involving oils and hazardous material spills. Historically, hurricanes and flooding have been the most likely hazard to affect Saint Lucia. Tropical Storm Debbie in 1994 resulted in losses over EC$230 million. The Tropical Wave of October 1996 also incurred an estimated EC$12 million in damages to properties and infrastructure. There is also now, growing concern about the vulnerability of Saint Lucia to the non-traditional threat of climate change and sea level rises, land degradation and drought, and biodiversity loss. Studies on climate change to date are predicting an increase in the occurrence of extreme phenomena such as droughts, storms and floods. This situation requires strategic planning and preparation for such an eventuality.

The adverse impacts of poor land and river systems management, the most apparent being erosion, flooding and coastal degradation, are evidenced by the severe social, environmental and economic costs incurred from hazard events such as storms, hurricanes and floods. The impacts of poor land and river systems management arising from conflicts with regard to recommended treatment (see figure 7), has serious implications for Saint Lucia as the towns, villages and City which are located in the coastal areas have major infrastructure and property, in particular that used for the tourism industry.

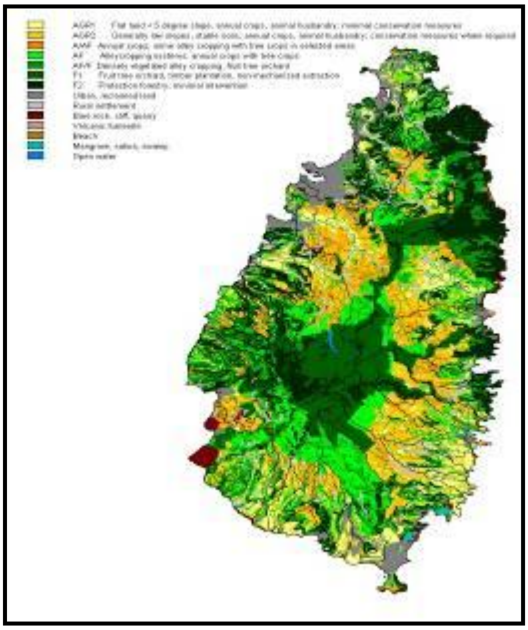


Figure 7: Recommended Land Management Regimes
Source: Revised Land Capability (UWI Treatment-Oriented Approach)[23]

Moreover, within the island's coastal zone (near shore marine areas) and forests, several protected areas have been established for ensuring the integrity of the coastline. It is necessary that all steps be taken to minimize the impact of land-based sources of pollution, which potentially can decimate St. Lucia's increasing attraction as a holiday destination and the associated livelihoods that are directly and indirectly linked to the hospitality sector, as well as threaten food supply and security (see Figure 8).

[23] Cox, 2003, based on Polius, 1989 and Ahmad, 1989

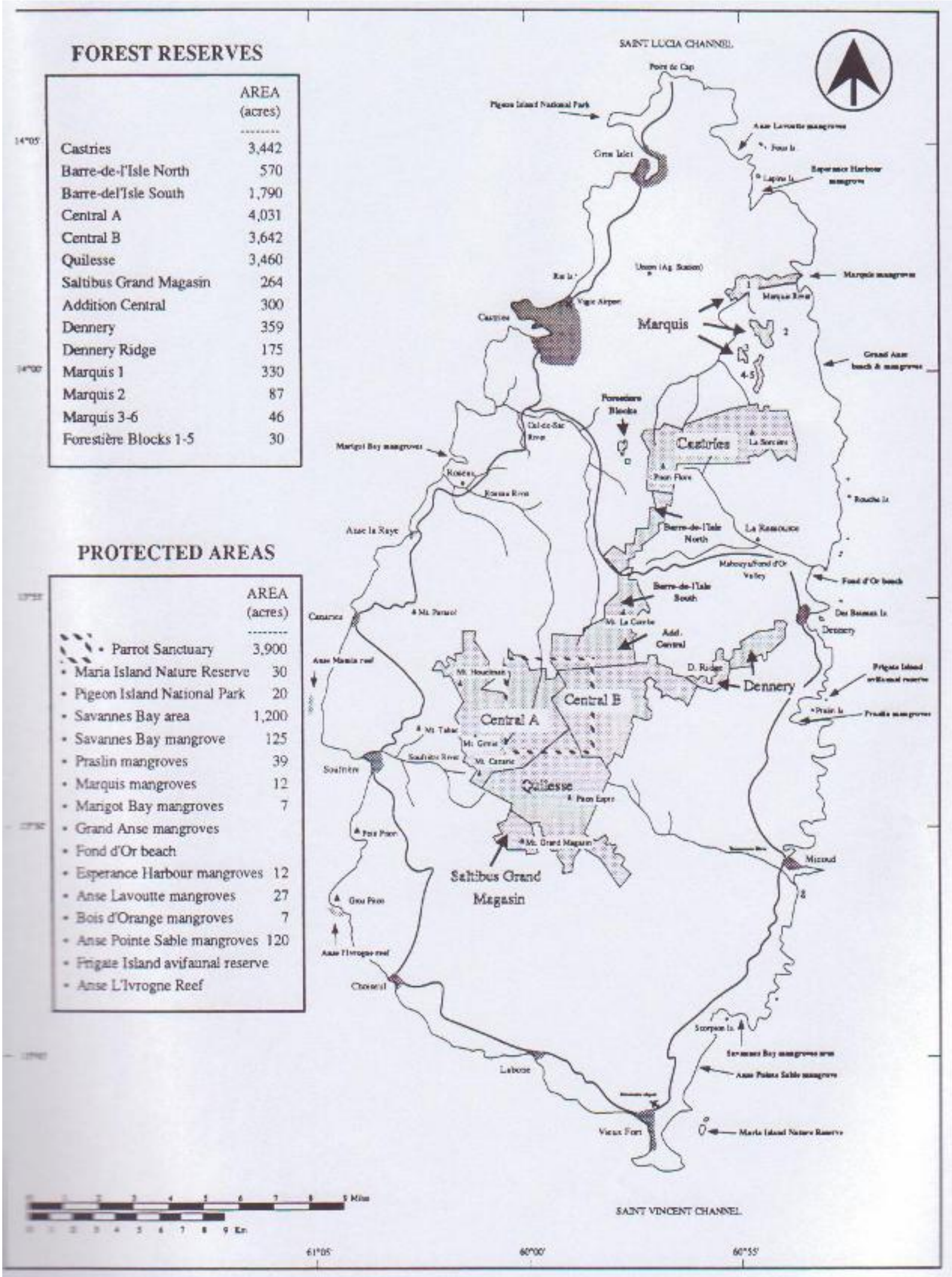


Figure 8: Map of Forest Reserves & Location of Protected Areas

2.2.7 Institutional and Legislative/ Regulatory Issues

The management of river systems and the associated impacting land areas comes under the ambit of watershed and water resources management. Ideally, the benchmark[24] that defines optimal land use should be based on *functional land capability*, or the capacity of the land to support particular management regimes sustainably with minimal adverse environmental impact.

However, in the absence of statutory land management, and in particular land zoning, prescriptions that define spatial allocations for optimal land use within a watershed, land development patterns are now driven more by land market forces rather than policy and strategic planning instruments. Planning for land development has traditionally been very sectoral-driven with little attention paid to holistic management based on maintenance of supply capacity for the various ecosystem services (rivers/water, soil productivity, biodiversity, buffer to natural hazards, etc.). The result has been exploitation of land resources beyond the carrying capacity, with little or no mitigation of the impacts on the water resources and by extension river systems, and subsequent loss in potential to maintain ecosystem services.

The current institutional framework for watershed management and by the extension river systems management continues to be characterized by a number of governmental agencies and a few non-governmental agencies involved in the execution of several programmes and projects in a largely uncoordinated manner. Further, there are significant weaknesses in institutional capacities and structures; there is a dispersion of efforts and a lack of co-ordination among governmental agencies. There is a weak and poorly organised civil society and organisations, and there is no established system of collaboration between government agencies and NGOs[25]. In many sectors, there is a need for a more coherent and coordinated approach that maximises the use of available resources.

At the local level, social capital is somewhat weak and many communities are poorly organised. Poverty reduction and social development agencies have noted the frequent lack of community- level institutional mechanisms for collective action. Development committees are emerging in several locations, but many lack capacity and need strengthening.

[24] Government of Saint Lucia 2003 National Land Policy Green Paper
[25] Presently there is no structured plan of action in approaching civil society (rural or urban) in the management of watershed assets. Interventions are often Adhoc, reactive and demand-driven (near crisis point).

3.0 RAPID RIVERBANK ASSESSMENT METHODOLOGY

The proposed Rapid Riverbank Assessment (RRA) Methodology emphasizes the stability of the river as a bio-physical unit[26], with its varying and relative degrees of susceptibilities and eventual exposure to the various bio-physical, socio-economic and environmental factors. In this context, the Consultants utilized and adapted contemporary and tested conventional methodological approaches[27] to develop the method and approach used for the RRA.

The method involves systematic and comprehensive desk study, including a literature review (see Appendix 1 for the list of documents reviewed), the use of GIS tools and techniques for data and information gathering from secondary data sources, to identify aspects and impacts of the various factors impacting river system with regard to river bank stability/erosion; these factors are further combined with including stakeholder consultations, and primary data gathered from direct field observations[28],to derive a comprehensive assessment to facilitate the analysis and evaluation of the rivers.

The three main categories of aspects/ factors used to assess impacts in the assessment of the river system are:

- Biophysical Aspects
    - Geologic including dominant soil type and stability;
    - Hydraulic including channel dimensions and estimated bed gradient;
    - Adjacent land use and associated management practices; described by riparian vegetation condition including type, density, and proximity with respect to the banks/ channel;
- Socio-Economic Aspects:
    - Settlements in the vicinity
    - Built infrastructure – the nature and condition of any physical structure, entity or object (*permanent, transient or temporary/ movable or immovable*) existing in the river's channel and immediate environment[29].

- Environmental Aspects:
    - Physical condition with respect to bank/riverbed erosion - types and extent (*where visibly evident*) and other transient conditions likely to impact the stability and capacity to sustain its functionality;

[26] The river herein refers to the channel and the banks within a 50 metre riparian /"buffer" zone. The selection of this distance is to: a) accommodate some reasonable level of observation and analysis of the issues and aspects (from a physical planning perspective) that can impact directly on the functionality of the river, and b) to facilitate a fair level of spatial representation and analysis, particularly with the use of GIS as a useful and convenient tool.
However, it is noted that in practice, the Development Control Authority (DCA), for physical development purposes considers 15m (~50 feet) as a minimum distance for a river buffer. The Forestry Department considers a min. of 20m for main channels and 10m for tributaries ~ for purposes of resource conservation.

[27] Such as the Global International Water Assessment (GIWA), Project Management tools (project planning & analysis, in particular risk analysis).

[28] With consideration of intrinsic and exogenous aspects, including human influences.

[29] Which may have a detrimental impact on the river's stability.

- o Pollution - physical conditions that reflect/ indicate improper, injudicious or inadequate disposal and/ or discharges of wastes[30], directly or indirectly, into the river's immediate environment;

The bio-physical parameters are meant to indicate/ flag relative level of susceptibility of the channel to degradation; the socio-economic and environmental aspects flag potential sources or factors which could further impact negatively on the stability of the channel, thus affecting its relative susceptibility status.

The Rapid Riverbank Assessment (RRA) methodology entails a five-phase process, including:
Phase 1 – River System Profiling (RSP)
Phase 2 – Database Development and Application
Phase 3 – Bank Condition Assessment (BCA)
Phase 4 – Stakeholder Consultation
Phase 5 - Data Analysis

Phase 1 – River System Profiling, involves data gathering from largely secondary data sources to create an initial profile of the river system based on broad core parameters to provide a basis for prioritization for more in-depth assessment and/or to provide a broad indication of pre-disposition to river degradation. This phase comprises two stages:

(i) Stage 1 or Preliminary/initial level profiling which involves the use of three (3) base criteria: 1) physical classification of type of river (inactive/active/permanent); 2) broad national socio-economic significance and 3) geographical location in terms of coverage of the socio-economic activities impacting the river system;

(ii) Stage 2 profiling using components of the Phase 2 process to create a baseline digital database for the river system, comprising the basic components of the river system and three main parameters/aspects derived from secondary data – 1) slope, 2) dominant soil type/stability and 3) land use.

Phase 2 – Data Base Development and Application, involves the use of GIS technology to compile and relate data and information collected from both primary and secondary data sources into a digital database for status and future monitoring

Phase 3 - Bank Condition Assessment, involves the use of field observations for the consideration of a limited number of core aspects of bio-physical, socio-economic and environmental parameters, to encapsulate the relative susceptibility levels of the river system to channel and /or riverbank degradation on a qualitative basis.

Phase 4 – Stakeholder Consultation, involves the use of participatory approaches to obtain stakeholder input to identify, confirm and assess the potential factors contributing to existing river conditions.

[30] Refer to any solid or liquid waste, commercial and agricultural/ industrial

Phase 5 – Data Analysis, utilizes a combination of techniques for scoring and ranking probabilities for risk, impact and threat of occurrence of erosion of field observations to derive and overall score or **Susceptibility Index (SI)**.

It is important to note that all the phases are inter-related and where necessary activities in phases are combined so that the relevant outputs all feed into each other and are informed by one another. Thus, phases have been prescribed, mainly to describe and make clear the various tasks required in a step-wise manner for a well-coordinated decision support system for river systems assessment, including data capture, storage, retrieval, analysis and monitoring.

3.1 River Systems Profiling

The components of several internationally accepted methodologies were reviewed, and where relevant combined and integrated to develop a method and the criteria to undertake a Profiling comprising Scoping and Screening of River Systems that was country-appropriate. The purpose of this method of categorisation is to allow for a profile description of an individual river system using different criteria which would serve as indicators of riverbank stability and/ or relative importance, from a national perspective. In this regard, characteristics and parameters which reflect the bio-physical, social and economic sensitivities relative to the river system's capacity to effectively sustain its primary functions, delivering goods and services with minimum compromise of its integrity.

The bio-physical parameters are meant to indicate/ flag relative level of susceptibility of the channel to degradation; socio-economic and environmental aspects flag potential sources or factors which could further impact negatively on the stability of the channel, thus affecting its relative susceptibility status.

The process for river systems profiling is two-tiered and involves;
i) Scoping - Preliminary/initial profiling; and
2) Screening – Second level profiling to derive a bio-physical profile of the river system that would facilitate the assessment and integration of other parameters at the field level leading to further analysis of the susceptibility of the river system.

3.1.1 First Stage Preliminary Profiling - Scoping

The first level of profiling comprises a preliminary desk-based assessment of the major river systems[31] of the island. This is supplemented with input from stakeholder consultations thereby requiring some overlap with the Phase 4 process.

This preliminary profiling or scoping is used largely to appraise river systems based on three (3) core characteristics. This first level classification is then used to identify or pre-select "Priority" Rivers which would need to be subjected to further empirical

[31] Profiling methodology utilises a modified version of the Global International Waters Assessment (GIWA) methodology for selection.

assessments to determine the status of the river system; and in turn assist in the determination of special management measures/interventions required for rehabilitating, protecting or preserving the river system.

The three (3) selection criteria used for this exercise are broad based and include:

- Bio-physical condition – with respect to a physical classification of the type of river based on flow, which is used as an indicator of whether river is an active/permanent river or inactive/seasonal;
- Broad national significance (socio-economic and environmental) ~ which relates to the function of the river in major existing social and economic infrastructure, including settlements and related livelihood systems and important ecological services provided; Factors/issues to be considered include:
  - *Extent to which the resources within the river basin currently or have the potential to support the livelihood of local communities (agriculture, tourism, forestry derivatives);*
  - *Extent to which the resources within the river basin currently or have the potential to support the national development (agriculture, tourism, forestry derivatives);*
  - *Extent to which the site is a government priority;*
  - *Extent to which the site is of regional and/or global significance and priority;*
- Geographical spread ~ with a view to ensuring that the broad range of socio-economic activity impacting river systems across the island is considered for early redress. Factors/issues to be considered include:
  - *Estimated size of the basin area*
  - *Estimated affected population*

A summary matrix, to serve as a template for compiling the output of the preliminary appraisal is provided in Table 1.

Table 1. Preliminary Appraisal of River Systems for Pre-Selection.[32]

River Course	Bio-Physical Condition	National Significance	Geographic Spread	Priority Ranking
Name of River System/ Watershed	√	Very low/ Low/ Moderate/ High/ Very High	VW, W, N or VN	1 – n (where n= total number of river systems)

Legend:

[32] Note that of the 37 watersheds/ drainage basins of St. Lucia, this study took into consideration the relatively more permanent systems, with the exclusion of the more seasonal and ephemeral streams.

Biophysical Condition – Check marked for river systems with perennial flows and deemed to be active/permanent; Unchecked for streams with seasonal and ephemeral flows and deemed to be inactive
National Significance – Five levels of significance (very low, low, moderate, high or very high) based on a partially subjective determination using a combination of document review and stakeholder consultation
Geographic Spread – Determined at four levels: very wide (VW), wide (W), narrow (N) or very narrow (VN); based on a combination of actual geographic location and estimation of nature and extent of impacting issues discerned from stakeholder consultation

Determination of Priority Ranking

Each criterion for a river system is scored by allocating the relevant score from the scoring table below. The three scores are then multiplied to arrive at a total score which will range from 1 to 40, 1 representing the least critical (or lowest significance) and 40 representing the most critical (or highest level of significance) as a relative indication of the need for more in-depth assessment of the condition of the river system.

Table 2. Scoring Table for Preliminary Assessment- Scoping of River Systems

River Course	Bio-Physical Condition	National Significance	Geographic Spread	Total Score
Name of River System/ Watershed	1 2	Very low - 1 Low - 2 Moderate -3 High - 4 Very High - 5	VW – 4 W – 3 N – 2 VN - 1	1 – 40

The river systems are then ranked based on the total score, the highest score indicating the most critical to the low score indicating the least critical. In the likely event that more than one river system produce similar scores, these river systems are ranked comparatively through a process of stakeholder consultation to provide a judgment/considered opinion with respect to a relative ranking, which would generally be based on the stakeholder interests which are currently driving the need for prioritisation. Lower scoring river systems are then ranked accordingly.

3.1.2 Stage Two Profiling - Screening

Stage two profiling incorporates the use of GIS tools and techniques which are further described in the Phase 2 process, to produce a more empirical, baseline profile of the river systems, as a prerequisite for the more detailed study.

This involves the preparation of a preliminary database, developed from secondary sources (analogue maps, existing digital information, aerial photography and documents), as the baseline for the decision support system of the RRA. The database provides for the mapping of the buffer zones of rivers and the description of key attributes within the buffer areas. Several specific data sets can be produced based on various attributes.

The summary matrix in Appendix 2 provides a range of attributes or parameters defined in terms of factors/aspects which contribute to riverbank erosion which can be used to assess and rank these factors/aspects. Three core parameters are however used to create the baseline profile for building the preliminary database for screening the river system namely:

(i) Dominant soil/ soil stability; (ii) Slope and (iii) Land Use

It is anticipated that the other parameters will be included over time as data becomes more readily available and in the appropriate formats.

The methodology used to create this preliminary database is further elaborated within the Stages 1 to 4 of the Phase 3 methodology, described in Section 3.2 of the report.

This preliminary profile is then used to assist in the identification of specific stretches/reaches of the river within each zone/segment. Each zone/segment represents similar geomorphic traits within the river as observed in the initial profiling and are confirmed in more detail at the field level assessment. The right and left banks of the river are described as if looking downstream.

The characteristics of the database and the methodology for the development of the database are further outlined in section 3.2 of this report, *Digital Database Development and Application.* This section also includes guidelines for use. The application aspects of the GIS tools are further outlined in Section 7.0 on conclusions and recommendations.

In an effort to simplify the method of this zoning/segmentation, without compromising its scientific quality and objectivity, a **River zoning system** was considered and used, as a **practical and functional** classification based on:

a) Elevation;
b) Visual observations of general land use intensity and management patterns associated with the river system and its associated drainage area.

This simplifies the methodology, without compromising objectivity; while it facilitates and simplifies the rapid appraisal procedures and the analytical/ evaluation process.

A matrix combining the outputs of the preliminary profiling – Scoping and Stage 2 profiling – Screening exercise is presented in Section 5, Table 11 - River Assessment Findings.The outputs are further used to facilitate analysis and selection of critical river systems for further in-depth study.

Of particular note is that the matrix lists a range of attributes defined in terms of factors/aspects which contribute to riverbank erosion that can be used for assessing and ranking these factors/aspects. As indicated earlier, it is anticipated that the matrix will be refined to include appropriate parameters over time as data becomes more readily available and in the appropriate formats.

3.2 Phase 2 – Digital Database Development and Application

3.2.1 Overview

A comprehensive *GIS database* comprising special descriptive profile information of each river system is created in ARC GIS to support the information, mapping and analytical requirements including future monitoring, of the Rapid River Bank Assessment Methodology (RBAM). The database comprises *four (4) main GIS datasets* created from a combination of secondary (analogue maps, existing digital information, aerial photography and documents) and primary sources (field sources and consultation).

These are summarised as follows and further detailed in **Table 3, later in this section:**

1. A database of *the Rivers and Buffers* along with their attributes (description) relevant to the analysis.
2. A database of the *Segments of the Rivers and Buffers* along with their attributes (description) relevant to the analysis.
3. A database of *River Based Control Stations* and their attributes (description) falling within each river.
4. A database of *Hyperlinked Pictures* of river bank conditions at or around the based control points but within the main river to facilitate future visual monitoring.

The use of ARC GIS, ARC VIEW and related ESRI products was dictated by the existence of this software within the Forestry Department and other key agencies in St. Lucia. As such the Forestry Department has some local capacity and proficiency in the use of the software along with hands-on experience in a number of GIS application areas.

3.2.2 Database Development Process and Application

<u>Stage 1 – Selection of Rivers</u>

Individual rivers are selected as line files from the hydrology layer of the 1:25,000 topographic sheet (1990) and saved as separate layers within the database.

<u>Stage 2 - Buffering Rivers to Create the First Unit of Spatial Assessment</u>

Using the buffering function in ARC GIS, a 50 m buffer is created on either side of each river within each of the layers:

The 50 m buffer exceeds the nationally applied 20 m/60 ft (Policy decision by Cabinet Conclusion) but was used to get a large enough physical area around the river to enable reasonable analysis of land use, soil type and other factors pertinent to the analysis.

Stage 3a – Creating River Bank Specific Datasets from Existing Digital data

The buffer is then used as a *clip coverage/layer* to derive the River Bank or study area-specific descriptive information required for the analysis from the national GIS database. These layers are as follows:-

- Soil type
- Slope (categories:- >5%, 5%-10%,>10%) – from a slope map developed by the Physical Planning Unit (PPU) using the SPANS GIS Contouring function. The source data was the 1:25,000 Digital Elevation Model of St. Lucia (DEM) developed from the DEM points from the 1:25,000 (1990) map sheet. The data structure of the slope map produced by the PPU SPANS system was a quad tree – an efficient data structure for quick analysis but with a blocky visual appearance. This was converted to a vector (sharper appearance) in ARC GIS and a new vector based slope map was produced.
- Contour heights in ft. , converted to meters by using a calculated field in the descriptive or attribute table.
- Life zones / vegetation
- Land use (Forestry Management Plan 1992).

Stage 3b - Creating a Current Land use layer for the River Buffer from Aerial Photographs

The 2004 digital aerial images for the river are first ortho-rectified and then geo-referenced in the GIS so that the images fall in their correct geographic location with respect to the geo-referenced topographic map of St. Lucia. Once referenced the aerial images are clipped with the *Buffer Clipped Coverage for each river* to facilitate the interpretation of land use within the buffer area only.

The 1992 Forestry Management Plan land use data definitions (categories) are used for consistency to enable comparative analysis and to ensure the correctness of life zones and interpretation of other land use classes.

Stage 4. Segmenting River Bank Areas into 4 Zones (Upper, mid, lower and coastal)- Second Unit of Spatial Assessment

Four (4) segments are created for each buffered river based on the captioned height thresholds. This is done to create a framework for location-specific assessments of the selected rivers and their banks and to set the framework of control stations or points to measure, assess and monitor key parameters of the RRA.

The segments are derived from an overlay of the river buffer and contour map. Selection is done through visual assessment of the respective contour heights (where they cross the river). Areas outside the selection are deleted and the files saved. This is done for each zone within each river. At the end of the process 3 new segment files, for each river are produced.

Stage 5a – Selection of Control Stations within each Segment

A number of Control Stations are selected at specific points within the coastal and lower segment of each river. The points selected are to be geographically referenced using GPS in conjunction with topographic and manmade feature descriptions for validation and accuracy in locating.

A pre-designed Data Collection Sheet used in the Phase 4 process (see Appendix 3**)** is utilised to capture information about the river channel at the control points. These include, *inter alia*, the following channel characteristics:-

- Channel bed width, Channel width and depth;
- Description of site location –vegetation cover, land use, observed siltation;
- General weather conditions and time of day;
- Lat/Long coordinates (GPS reading).

Other parameters related to *biophysical characteristics*, *socio economic* factors and *environmental issues* are derived from a number of input layers developed from clipping the various buffer maps with the individual segment boundaries.

- Soil stability determined by dominant soil group
- Channel gradient – slope of the river bed as an indicator of the velocity of flow
- Land use management practices and their facilitation and impacts on degradation in the river buffer
- Socio-economic parameters (e.g. impact of settlement on water quality) and the existence of infrastructure in buffer area to assess the facilitation of damage in the buffer

For each of these, the *probability of risk* and *impact level* are determined and scored, using the process in Phase 5 – Data Analysis. The probabilities of risk and impact scores when combined produce a composite score which reflects a threat of impact (highest score implying greatest impact).

The main purpose of this application with the use of these parameters is to assess the level of susceptibility of the river channel to degradation.

The above parameters and their Probability of Risk, Impact level and threat of Impact are added to the attribute table of the Control Point file**.**

Stage 6 – Creating a Pictorial Database within Control Stations of Each River to Facilitate Future Monitoring of Critical Areas

As many digital photographs are taken at the Control Points, particularly within the lower and coastal areas. The pictures are then hyperlinked to the point file (lat/long coordinates) in the main database. In order to facilitate several digital pictures per site, a number of approximate points around the Ground Control Points are chosen to hyperlink each picture.

The purpose of this database is to provide a base for future visual monitoring of the status of river banks.

Table 3. Digital Database Summary

Database Type and Description	Source and Existing Scale of capture of Data	Year of Capture	Comments
DATABASE OF SELECTED RIVERS			
a. **Select Rivers** from Hydrology layer of the topographic map of St. Lucia	1:25,000 topographic map	1990	
b. **Create Riparian Buffers** (existing in accordance with local policy)	Cabinet Conclusion defined buffer - minimum of 20m but for convenience a 50 m buffer was used	Current	
c. **Clip of <u>Existing Relevant GIS Layers</u> from PPU Database** using river buffer as boundary	From Riparian Buffer File	Current	This serves as the First Spatial Unit of Assessment.
• Slope	DEM, 1:25,000 topographic map sheet	1988?	DEM points From PPU database – may have to create slope map from these
• Soils	1;25,000 map, Ahmad, UWI	1966?	Clip from PPU database
• Life zones	OAS Development Atlas, 1:50000	1985	Clip from PPU database
• Topographic	Topographic map, 1:25,000	1988?	Clip from PPU database
• Watershed Boundaries	Forestry, FMP 1:25,000	1990?	Clip from FMP
Creation of New <u>Landuse Layer</u> digital aerial photos within River Buffer boundary. Landuse classes are in accordance with the Forestry Management Plan	Forestry, FMP 1:25,000 Survey and Mapping Aerial photos,	1992 2004	PPU aerial were geo-referenced and ortho-rectified
DATABASE OF SEGMENTS OF SELECTED RIVERS			
• Clip of soils	1;25,000 Soils	1966	

Database Type and Description	Source and Existing Scale of capture of Data	Year of Capture	Comments
• Clip of slope Map • Clip of Current Landuse	Map, Ahmad, UWI PPU slope map smoothed to vector Digital aerial photos	Current 2004	
DATABASE OF CONTROL STATIONS			
6. **Database of <u>Control Stations</u> in Rivers**			
• Use GPS locational information to create points and expanded fields in point file to capture descriptive information for degradation, Impact level and Impact Threats	Primary field data	current	
DATABASE OF DIGITAL PICTURES FOR MONITORING			
• Create hyperlinks with photos of views around control stations or problem areas along the river (for future monitoring)	Primary field data	current	

Note that all the layers of information are inter-related and can be combined where necessary. The above divisions have been prescribed to describe and make clear the GIS tasks required to develop the Digital\GIS Database for decision support – data capture, retrieval, analysis and monitoring.

3.3 Phase 3 – Stakeholder Consultation

This component of the assessment aims to ensure a consultative approach that embraces the range of stakeholders from "ridge to reef" and promotes partnerships for river systems management.

The first stage of this phase involves undertaking a stakeholder analysis for identification of key stakeholders, and determining the most appropriate modes of engagement of these stakeholders. The stakeholder identification and analysis exercise is to provide early and essential information on the individuals, groups, and institutions that will be affected by and should participate and benefit from river systems management activities and related watershed interventions.

Preliminary information is gathered regarding the policy, institutional and governance framework for the management of river systems and watersheds, through primarily the literature review and desk research exercise to commence the process of stakeholder identification and set the basis for further stakeholder analysis.

The following criteria used to identify and generate stakeholder lists, and to undertake the stakeholder classification and analysis in order to facilitate the consultative process are described in Table 4, Stakeholder Listing and Analysis.

The next stage involves consultation with stakeholders. Consultations with key stakeholders are used for information gathering to update information from desk review with regard to the current status of premier watercourses and identification of key/critical river courses for the conduct of rapid field assessments; also to compile lessons learned and best practices for further evaluation and future improvements in design of RRA and remedial measures.
The process involves:

(i) Confirmation of the review of past technical reports and photographs to identify and assess the potential factors contributing to river bank erosion;

(ii) provide input into the process in terms of:
- – Identifying specific areas along river system undergoing bank erosion;
- – Identifying specific processes and factors along the river system that contribute to bank erosion and existing river conditions;
- – Identifying other general areas with respect to river bank erosion that the study should address; and
- – Identifying previous relevant studies that could assist in the investigation.

Table 4.Stakeholder Listing and Analysis

Stakeholder	Characteristics (influence/ importance)	Interests and Expectations	Implications of outputs on stakeholder	Opportunities and Threats	Risks and Assumptions
Primary Stakeholders:					
Resource Managers/ Regulators: Public Sector:					
e.g. Key Government Ministries					
Regional/International Agencies					
Private Sector/ NGOs					
Resource Users					
Statutory Bodies					
Secondary Stakeholders:					
Resource Managers/ Public Service					
Other Government Departments					
Regional/International					
Private Sector/NGO					
Resource Users					
Private Sector					

Recommended modes for engagement of stakeholders for consultation include workshops/ working sessions (e.g. training workshop/session in use of RRA), focused group discussions, and one-on-one interviews as deemed appropriate. The primary mode of engagement though is through the use of a Technical Working Group (TWG) the composition of which should include a range of stakeholders from ridge to reef, for example:

- Ministry of Agriculture, Forestry and Fisheries (Representatives from Department s of Forestry, Engineering, Fisheries, Extension and WRMA);
- Ministry of Economic Affairs - (Representatives from the Departments of Planning and Crown Lands;
- Ministry of Environment;
- Ministry of Social Transformation;
- Ministry of Communications, Works and Transport;
- Water and Sewerage Corporation (WASCO)
- Representative from tourism sector/hotel sub-sector
- CEHI
- IWCAM
- A representative from the major Farmer Organisations/National Fair Trade Organisation;
- A representative from CBOs;
- National Emergency Management Organisation (NEMO);
- WASCO

The outputs of the stakeholder consultation process are summarised in three main tables as follows and further elaborated in Appendix 4 comprising:

(i) Summary Table 1 – Potential Causes of Erosion Identified by Stakeholders
(ii) Summary Table 2 - Specific Matters of Concern regarding Riverbank Degradation
(iii) Summary Table 3 – Stakeholder Recommendations for Riverbank Protection and Rehabilitation

The information in the Summary Tables 1 and 2 is used to inform and guide the Screening process in Phase 2 and the process in Phase 4 - River Bank Condition Assessment, as well as assist with the Phase 5 exercise - Data Analysis and Interpretation. The information in the Summary Table 3 is used to inform the formulation of Riverbank Rehabilitation Plans. The process of stakeholder consultation at the local level is essential for the further elaboration of site-specific plans.

3.4 Phase 4 - River Bank Condition Assessment

The aim of the River Bank Condition Assessment phase of the RRA is to assess and document existing bank conditions for both sides of the river, as well as assess the changing profile of the river system, based on periodic monitoring surveys.

The assessment involves:

(i) Field Reconnaissance - conduct of a systematic and thoroughly planned field survey program to identify and assess identified aspects and impacts with respect to river bank stability/erosion utilising:

a) Ground location of Control Points – The baseline for monitoring bank erosion is taken as the initial established profiles of points along main tributaries or waterways that exist within the Zone; ideally these points are selected during the Screening Process in Phase 2; a chosen site should be at least a reasonable distance downstream or upstream of a confluence (where tributary meets main channel), where flows appear to be relatively 'stable/normal'. To delineate the main causes of bank erosion a number of the cross-sections are selected in areas where impacting activities are excluded. These cross-sections are to be representative of typical stable high banks and typical eroding low banks with varying levels or types of activity (land use) and varying levels of vegetation stability, so as to provide comparable levels of activities and riparian vegetation.

b) Field survey using pre-designed format/sheet to document visual observations on conditions assessed, including:

- Channel dimensions
- Biophysical observations including
    - Dominant soil material
    - Average channel grade/slope
    - Land use/management practices within buffer area; including bank and riparian vegetation condition in terms of type, density (thickness), and location with respect to the bank;
- Socio-Economic Observations
    - Settlements in vicinity
    - Built-in infrastructure within Channel/Buffer – nature and condition

- Environmental Observations
    - Pollution sources
    - Physical condition of bank and channel – with respect to erosion type and extent (if evident)

General explanatory notes and notes related to the measurement and recording of field observations are provided in the field survey form.

Stage 1 - Field Reconnaissance

Ground truthing, in respect of confirmation of the location of control points and of changes to data generated during the Screening Process in Phase 1 and 2, in terms of processes and activities impacting the selected river systems, is undertaken during the field reconnaissance stage.

1A - Location of Control Station Points

Control Points selected if initially geographically referenced during Phase 2 are located using GPS in conjunction with the topographic map and documented along with manmade feature descriptions for validation and accuracy in locating, for mapping of these locations. Alternatively, control points, if identified at the field level, are to be geographically referenced using GPS in conjunction with topographic and manmade feature descriptions for validation and accuracy in locating.

It is important to use a topographic map out in the field to collect field data related to ground control points as GPS readings can sometimes produce inaccurate locational information due to issues relating to the absence of stationary GPSs which provide accurate references for the roving GPS used by researchers in the field.

1B – Field Survey – Bank Condition

The methodology employed in the field survey of bank condition is elaborated in the Field Survey Form in Appendix 3. The methodology designed for the survey is devised to provide a means of continual monitoring by non-technical parties while still providing a qualitative assessment on the processes.

A comprehensive assessment of the physical landscape, including soil surface assessment, land use and vegetation assessment, regular activities within the riparian zone, observation of bank degradation, is undertaken and documented for mapping of the Control Point locations. This is applied within the demarcated sections/reaches and the riparian buffers of the river system.

Measurements and observations are limited to the lower two of four zonal areas used to zone the river's channel (see Field Assessment table) below), i.e. ~ coastal and lower reaches. Measurements and observations are made in at least two sampling locations within each of the selected two zones. Preferably, each selected location should be about 50 metres long; one of the two sampling locations should be a fairly straight stretch, while the other should include a bend, if possible.

Table 5.Example Listing of Locations of Field Assessment Inspection Sites

Inspection Site No:	*River*	*Zone*	*Stretch/Reach*
1	X	1	1
2	X	1	2
3	X	2	1
4	X	2	2
5	Y	1	1
6	Y	1	2
7	Y	2	1
8	Y	2	2
9	Z	1	1
10	Z	1	2
11	Z	2	1
12	Z	2	2

Zone 1 – Coastal; Zone 2 - Lower

All bank recordings are performed at or near low surge (flow) to allow safe access to the river and allow a full visualisation of the channel's condition.

The guidelines for data collection and recording are fully articulated in the Field Survey Form (Appendix 3).

Bank condition is also recorded using photographs. As many digital photographs are taken at the Control Points, particularly within the lower and coastal reaches to be hyperlinked to the point file (lat/long coordinates) in the main database. The purpose of this is to provide a base for future visual monitoring of the status of river banks.

Equipment and Tools:

Basic field tools & equipment needed include:

- GPS unit - to be used to accurately record the locations
- Other conventional field measuring equipment – all weather measuring tape; clinometer; stop watch;
- Digital camera;
- Appropriate protective gear– cloak, shoes & water boots; cutlass;
- Stationery - pen; pencil; waterproof sketch folder;
- *Optional*: surveying equipment;

3.4.1 Bank & Channel Degradation Monitoring

The methodology, instruments, and tools for assessing key parameters which indicate the status of riverbank condition are to be continually used to generate the necessary information during field visits to the respective reaches/sections of the river systems for monitoring. The sites and timing of the monitoring surveys are chosen with a view to identify the potential causes of erosion. It is also necessary to ascertain the effects of the various activities on erosion from the natural variability.

The application of the assessment methodology involves establishing a routine at least once every six (6) months (or preferably at least twice/ season) for bank erosion monitoring as well as channel monitoring of the selected rivers in an attempt to:

- identify specific areas along the river undergoing bank/ channel erosion;
- identify the potential causes/ contributing factors of erosion/ degradation;
- Identifying specific processes/ practices along the river that contribute to bank erosion/ degradation;
- Identifying general areas and/ or specific issues within the zone that may require immediate attention or further examination within the study areas;
- Prioritise riverbank sites along the lower and estuarine segments of the river, according to their need for rehabilitation, as well as relatively stable sites in need of continued protection;

While the data generated from this phase will have to be fed into the next phase before a determination can be made on the erosion status of the river system, there are some key performance indicators (KPIs) which can be used to supplement the RRA at this stage for a rapid overview of the condition of the river. The approach for using the KPI is provided in Table 6.

Table 6.Key performance indicators (KPI) and methodology to be used

KPI Target	Methodology	Performance
Bank Erosion	• Photographs • Mapping • Aerial Photography	No increase in bank erosion
Riparian Erosion	• Mapping • Aerial Photography • Monitor Vegetation (e.g. success of new plantings)	No reduction of vegetation or inhibition of re-vegetation

The outputs derived from these assessments will over time assist to:

(ii) Design a long-term river monitoring programme that details monitoring sites, frequency and methods; and develop over time a comprehensive database which would inform the decision process.

(ii) Identify appropriate and effective management actions.

3.5 Phase 5 – Data Analysis

The basis of the RRA is the emphasis on the stability of the river as a bio-physical unit with its varying and relative degrees of susceptibility and eventual exposure to the various bio-physical, socio-economic and environmental factors. Hence the conjoined effect/ impact and its manifestation, through the dynamic interaction of these factors, on an on-going basis can be analysed/ assessed (qualitatively and quantitatively) by considering:

a) the probability of the risk factor to cause or facilitate an impact, which contributes eventually to the river's degradation (P)
b) the likely level of impact (l) and
c) the assessed threat or likelihood of the impact occurring (T) an its frequency.

The principle of the methodology is therefore based on a determination of the status of the river (the study area) by **a Qualitative Measurement of:**
1. Pre-disposition to degradation: ~ Risk assessment of biophysical factors
2. Potential Threat to Degradation (*Susceptibility*):~ Probability of Risk (*Pre-disposition*) + Assessed Level of Impact (*should it occur*), due to Socio-Economic & Environmental Factors + likelihood of impact.

This Phase uses of a combination of techniques for scoring and ranking, Probability of Risk, Impact level and threat of Impact of the occurrence of erosion from the various factors assessed in field observations. Scores for The probability of risk, impact and threat are combined to form a composite score or **Susceptibility Index (SI)**, which reflects the level of susceptibility of the river channel to degradation (highest score implying greatest susceptibility).

The application of the methodology is thus focused on the determination of three main factors; Probability Factor, Impact Factor and Threat Factor, and the final computation of the **Susceptibility Index (SI)**, with the considerations for their determination are outlined below.

These steps have also been outlined in a Flow Chart in Appendix 5 as a means of integrating the concept of action learning.

STEP 1

1. Data Compilation

Raw data is first compiled into basic spreadsheet formats with each field representing an aspect/factor assessed through field observations.

2. Qualitative ranking of the likely impact if the probable risk is realised.
This ranking is based on an assessment of the river system's capability to continue to provide/deliver its "normal" services[33] (*social, economic and environmental*) based on the status of each aspect/factor. It refers to an assessment of the "***likely loss of function***" (e.g. recreation, water supply, ecological services, etc.).
    a) The "loss of function" is also assessed based on the "*likely duration of the event*" and/ or "*the severity of the impact of the event*". Duration refers to the period after which "normal services" are likely to be recovered.
    b) The severity or extent of the impact takes into consideration specific zonal areas/ segments of the river or the entire river system, based on the nature of the triggering mechanism.
    c) The considerations and qualifications are summarized in the table below.

Table 7.Ranking of Relative Impact on the River System

Qualification of Impact	Low	Medium	High
	Score:1	Score :2	Score:3
Loss of Function	Reduction in service provision (or some services)	Serious reduction or total loss of services temporarily	Complete loss of services
Duration of Impact	Recovery of services within 6 months	Recovery of services between 6 months-1 yr	Recovery of services beyond a year
Extent of Impact (severity)	Periodic or limited	Moderate impact	Severe impact

[33] Services refer to, e.g. recreation, water supply, ecological services, etc.)

d) This assessment is a "holistic" qualification which is effected for each factor per category of factors *(bio-physical, land use/management practices, socio-economic and environmental).* Based on the assessment options provided in the "Data collections and field Observation" Form, each option is scored accordingly (See Table 7, which outlines the allocated matrix of scores).

STEP 2

Considerations in the determination of the "Probability" Factor ranking and scoring matrix. (This refers to the probability of the assessed risk factor causing or contributing to an impact).

a) The assigned options for selection are ranked for each factor/ category, based on the assessed probability of an impact occurring with respect to the said risk factor.
b) These are scored as low, medium or high, with a score of 1, 2 or 3 respectively. See "Table 19", in Section 5 which further elaborates the scoring matrix for each category of factors.

STEP 3

Considerations in the determination of the "Threat" factor scores.

(See "Table 20", in Section 5 which further elaborates the scoring matrix for each category of factors)

a) The threat factor scores for each "assessed option" per risk factor is determined based on the following formula, and the scores assigned to each variable in assessing the possible threat level.

Threat= [1+ (*probable speed of impact*) + (*probable duration of impact*) + (*probable lag time for impact*)]

b) A desk-based analysis was undertaken to calculate the score for each factor, as per outlined in "Table 22", in Section 5 which further elaborates the scoring matrix for each category of factors)

Example: For a Stable Soil.
Probable speed of impact= slow (assign "0")
Probable duration of impact= long (assign "2")
Probable lag time= long (assign "0")

Enter values in formula:

Threat = $(1 + 0 + 2 + 0) = 3$

c) Similar procedures and analyses were effected for all the various factors and their respective assessment options.

STEP 4

1) Steps 1-3 lay the basis to assign the relevant scores for the Probability factor (P), Impact factor (I), and Threat factor (T) for each assessed condition or selection per each evaluated risk factor, based on the available secondary data (*such as dominant soils, slope and land use classifications*), which is further verified at field level.
2) Similarly, scores are assigned to the field-based assessments for the remaining factors/ category (*socio-economic and environmental*), provided in the data collection form.
3) The data for each control point/selected reach can then be tabulated using pre-generated "master" excel spreadsheets (referred to as "Look-up Tables"), in which the maximum values of P (*Pmax*), T (*Tmax*) and I (*Imax*) have been determined. The parameter, "C" = (*Pmax+ Tmax+ Imax*), has also been determined in the look-up tables for each category of risk factors.
4) Once the various assessed values for P, T, and I and other physical dimensional data (width, depth, slope, etc.) have been entered in the "look-up tables", the following susceptibility weightings and average cross-sectional area/ reach are automatically determined, given the formulas set therein.
5) Relative ***Inter-Category weighting for each factor***, which indicates the relative weighting of the risk factors within the broad category of factors (*bio-physical, Socio-economic, or Environmental*). Once determined, the output can be ranked as *high, medium or low*. The weighting is determined as per the following formula:
    a. Factor weighting= $\frac{Wf}{\sum(Wnf)} \times 100\% = \frac{(Pf \times Tf \times If)}{\sum(Wnf)} \times 100\%$
    b. Where P_f, T_f, and I_f refer to the assessed values for the relevant risk factor;
    c. $\sum W_{nf}$, refers to the sum of the respective weightings (P, T, I) for each factor, within the category.
    d. An example is noted in the "look-up tables"

6) The susceptibility index, ***Si***, is calculated as per:

    Si = $\left[\sum_{1}^{n}\left(\mathbf{Pcf} + Tcf + Icf\right) \div \left(\mathbf{Pmax} + \mathbf{Tmax} + \mathbf{Imax}\right)\right] \times 100\%$

    a. Where P_{cf}, T_{cf}, I_{cf} refer to the assessed values of the factors/ category; and P_{max}, T_{max}, I_{max}, refer to the maximum attainable values for each assessed factor/ category.

STEP 5
Ranking of the "Si"

a) Once the "Si" is determined, it is now simple to allocate the category of factors under the adopted ranking (*high, medium or low*), as per the template below *(see file-tables*) for each assessed location (*river reach*).

River Zone Reach	Bio-Physical				Socio-Economic			Environmental			Comment
	Dom soil	Bed grade	Land use	Si	Settle-	Infrastruc	Si	pollution	Physical conditions	Si	
	H	L	M	H	L	M	M	H	H	H	

High (H)	Medium (M)	Low (L)
51-100%	11-50%	1-10%

b) For spatial representations, colour coding for "*high*", "*medium*", and "*low*" can be adopted in depicting the associated ranking. In some instances, very high scores may be/ are obtained. This certainly is a strong indication that the relevant segment or zonal areas of the river need further and more in-depth examination and more direct interventions, subject to the related issues, which must be fully studied/ analysed.

The scoring output is then used to determine location specific management recommendations with respect to the contributing factors/processes and the location in the river.

Another supporting tool worth considering as a rapid approach to appreciate the relative level of exposure is to estimate the potential financial loss/implications should the threat of the impact be truly realized). This is referred to as the Annualized Loss Exposure (ALE)[34] and is represented as:

ALE = number of times the impact (event) occurs/may occur for the year (f) X the estimated cost (or loss) for each occurrence of the impact (C).

[34] It must be noted that the ALE is only an indicator and certainly has limitations, since it does not capture all direct and indirect costs/losses (in particular social and environmental and longer term losses in general). The consideration is primarily the remedial costs in returning the river channel to its near normal physical state of functionality.

4.0 APPLICATION OF RAPID RIVERBANK ASSESSMENT METHODOLOGY

It is important to note that whereas the methodology outlined in Section 3 indicates a phased approach, for practical purposes and if and where resources of time and personnel permit, the sequence of phases can be maintained in an iterative manner. However, in circumstances where time and other resources are limiting and of the essence, it is possible to execute some of the desk-based and field activities of different phases simultaneously or in parallel, remaining cognizant of the inter-dependence among certain activities in some phases.

Given the time constraints in particular, and the limited availability personnel for the field exercise, it was necessary to adopt the latter approach and to execute several desk-based studies and field-based activities in parallel. Once the first level river profiling activity was concluded and the selection of prioritized rivers and the general methodology confirmed with the Adhoc Technical Committee (ATC), the final design of the field data collection format was undertaken.

Whereas the preferred approach would be to have developed the relevant supporting GIS- generated spatial data and information[35], such as the dominant soils, land use and slope maps for the pre-selected reaches, it was not feasible, given the time constraint. In this regard, the use of 1:25,000 and 1:10,000 topographic maps facilitated the pre-selection of river reaches to be assessed and subsequently monitored. The field assessments and the supporting GIS- generated spatial data and information were undertaken in parallel, while the data and other related collated information generated from the field exercise are fed into the developing GIS databases, subsequently utilized to develop spatial and pictorial outputs, to facilitate analysis and interpretation.

4.1 River Systems Profiling

For the purposes of the assignment, in light of the short time frame, the consulting team undertook the preliminary profiling of the river systems on the basis of the methodology developed, aimed at selecting three pilot rivers for further testing of the other phases of the methodology.

The various background documentation on river systems and watershed management at the national level, as well as specific project documents related to the main riverbank management initiatives, were assembled and reviewed.

Preliminary information was also gathered regarding the institutional and policy framework for the management of river systems and watersheds, and this provided a basis to commence the process of stakeholder identification and analysis.

[35] Based on the existing and accessible data.

4.1.1 Preliminary Profiling - Scoping

Having noted the foregoing time limitations, and in the quest to eventually determine a selection of three key pilot rivers for detailed study, the consultants first undertook a preliminary desk-based assessment of the 27 major river systems[36] of the island. A comprehensive application of the profiling template was not entirely feasible and the team produced a first stage scoping matrix.

This preliminary assessment/Scoping and its rationale was subjected to a process of stakeholder consultation in order to agree on and confirm the base criteria of selection of the three sample/pilot rivers within the context of strategic objectives of the assignment.

Against this background, the river systems were appraised and scored using the scoring system provided in the methodology for the three base criteria. The outcome of the Preliminary Assessment/Scoping was then summarized according to the template summary matrix provided as part of the methodology. The River systems were then denoted for significance by ranking towards a final selection of the Pilot/Sample Rivers.

The river courses selected in the final analysis for more in depth assessment and in order to test the methodology were as follows:

i. **Troumassee River**: the largest river in St. Lucia located in the Eastern part of the island with a relatively pristine profile as a significant part of the river falls within forested and protected forested areas. Its mid and upper reaches are not significantly impacted upon by settlement and other such uses;

ii. **The Roseau River**: located in the western part of the island; it is an active system with diverse impact scenarios – forested, intensive agriculture, damming, industrial uses etc. ;

iii. **The Choc River** : located in the north of the island; also with diverse impact scenarios (forested, intensive agriculture, damming, industrial uses, urban settlement, up market real estate in some locations, tourist developments within the coastal sphere of influence and critical facilities e.g. Dame Pearlette Louisy School etc.). The water system thus has significant economic impacts.

[36] Note that of the 37 watersheds/ drainage basins of St. Lucia, this study takes into consideration the relatively more permanent systems, with the exclusion of the more seasonal and ephemeral streams.

4.1.2 Stage Two Profiling - Screening

Given the time limitations of the assignment, and delays in data collection largely associated with a protracted process of conversion of aerial photography to derive current land use information[37], the stage 2 Screening exercise of Phase 1, which is actually combined with Stages 1 to 3 of Phase 2, had to be undertaken within the overall Phase 2 process.

Consequently, only some elements of the empirical baseline profile developed with the use of GIS tools and techniques were available in time to serve as a pre-requisite for informing the Phase 4 process – Bank Condition Assessment.

Hence the production of the initial baseline profile involved the preparation of a preliminary database, developed from secondary sources (analogue maps, existing digital information, and documents), and the mapping of the buffer zones of rivers. The proposed **River zoning system** was used, for classification based on:
a) Elevation;
b) Empirical observations of general land use intensity and management patterns associated with the river system and its associated drainage area.

This preliminary profile was then used to assist in the identification of specific stretches/reaches of the river within each zone/segment in accordance with the Methodology, in preparation for further field reconnaissance.

The description of key attributes within the buffer areas, required for the development of specific data sets on various attributes for mapping were however, incorporated into the Phase 2 process. As indicated in the Methodology, only three core attributes/parameters were used to create the baseline profile for building the preliminary database for screening the river system namely:
(i) Dominant soil/ soil stability; (ii) Slope and (iii) Land Use

The outputs of the various elements are provided in Section 5, of this report, Findings and Results. Of note, is that in the interests of time, the proposed matrix for combining the outputs of the preliminary profiling – Scoping and Stage 2 profiling – Screening exercise described in the Methodology was dispensed with at this testing stage and was substituted with the preparation of the comprehensive matrix emanating from the Phase 4 process, to include descriptions of attributes from field observations to facilitate timely data analysis and interpretation.

[37] In light of the need to produce a rapid assessment methodology to assess the status of river banks, it is arguable whether the use of aerial photography to derive current land use information, though critical to the exercise, can be considered to be part of a rapid process. This is due to the fact that the existing 2004 aerial photographic data set is neither geo-referenced nor ortho-rectified – two factors important for the immediate use of geographic data to interpret land use for use in analysis.

4.2 Digital Database Development and Application

1. Overview

A comprehensive ***GIS database* of the three (3) selected or pilot rivers** was developed in ARC GIS to support the information, mapping and analytical requirements including future monitoring, of the Rapid River Bank Assessment (RRA) Methodology. The database comprises *four (4) main GIS datasets* created from a combination of secondary (analogue maps, existing digital information, aerial photography and documents) and primary sources (field sources and consultation).These are summarised as follows and detailed in Table II:-

1. A database of *the Selected Rivers and Buffers* along with their attributes (description) relevant to the analysis
2. A database of the *Segments of Selected Rivers and Buffers* along with their attributes (description) relevant to the analysis
3. A database of *River Based Control Stations* and their attributes (description) falling within the river segments
4. A database of *Hyperlinked Pictures* of river bank conditions at or around the based control points within the respective segments to facilitate future visual monitoring

As indicated in the methodology, the use of ARC GIS, ARC VIEW and related ESRI products was dictated by the existence of this software within the Forestry Department and other key agencies in St. Lucia. As such the Forestry Department has some local capacity and proficiency in the use of the software along with hands-on experience in a number of GIS application areas.

2. Database Development Process and Application

Stage 1 – Selection of Rivers

The three (3) pilot rivers, namely Troumassee, Roseau and Choc Rivers, were selected as line files from the hydrology layer of the 1:25,000 topographic sheets (1990) and saved as three (3) separate layers.

Stage 2 - Buffering Rivers to Create the First Unit of Spatial Assessment

Using the buffering function in ARC GIS, a 50 m buffer was created on either side of each river within each of the 3 layers: _

- Troumassee
- Roseau
- Choc

The 50 m buffer is over the nationally applied 20 m/60 ft (Policy decision by Cabinet Conclusion) but was used to get a large enough physical area around the river to enable reasonable analysis of land use, soil type and other factors pertinent to the analysis.

Stage 3a – Creating River Bank Specific Datasets from Existing Digital data

The buffer was then used as a *clip coverage/layer* to derive the River Bank or study area-specific descriptive information required for the analysis from the national GIS database. These layers are as follows:-

- Soil type
- Slope (categories:- >5%, 5%-10%,>10%). A slope map was developed by the Physical Planning Unit (PPU) using the SPANS GIS Contouring function. The source data was the 1:25,000 Digital Elevation Model of St. Lucia (DEM) developed from the DEM points from the 1:25,000 (1990) map sheet. The data structure of the slope map produced by the PPU SPANS system was a quadtree – an efficient data structure for quick analysis but with a blocky visual appearance. This was converted to a vector (sharper appearance) in ARC GIS and a new vector based slope map was produced.
- Contour heights in ft. This was converted to meters by using a calculated field in the descriptive or attribute table.
- Life zones / vegetation
- Land use (Forestry Management Plan 1992).

Stage 3b - Creating a Current Land use layer for the River Buffer from Aerial Photos.

The digital aerial image was first orthorectified and then geo-referenced in the GIS so that the images fell in their correct geographic location with respect to the geo-referenced topographic map of St. Lucia. Once referenced the aerial images were clipped with the *Buffer Clipped Coverage for each river* to facilitate the interpretation of land use within the buffer area only.

The 1992 Forestry Management Plan land use data definitions (categories) were used for consistency to enable comparative analysis and to ensure the correctness of life zones and interpretation of other land use classes.

Stage 4. Segmenting River Bank Areas into 4 Zones (Upper, mid, lower and….)- Second Unit of Spatial Assessment

Four (4) segments were created for each buffered river based on the captioned height thresholds. This was done to create location-specific assessments of the selected rivers and their banks and to set the framework of control stations or points to measure, assess and monitor key parameters of the RRA.

The segments were derived from an overlay of the river buffer and contour map. They were selected through visual assessment of the respective contour heights (where they cross the river). Areas outside the selection were deleted and the files saved. This was done for each zone within each river. At the end of the process 12 new segment files, three (3) for each river were produced.

Stage 5a - Control Stations were Selected within each Segment

A number of Control Stations were selected at specific points within the coastal and lower segment of each river. The points selected were geographically referenced using GPS in conjunction with topographic and manmade feature descriptions for validation and locational accuracy.

The points are as follows:

	Location in Segment	**Description of Location\land Features**	**Lat**	**Long**
Troumassee River				
	Lower Moreau	Road Crossing	0514880	1539388
	Lower Mahaut	Near Mahaut Bridge Bend	0512902	1530577
	Coastal	Near Troumassee Bridge	0518728	1527926
	Coastal	Beauchamp Area Bend	0517273	1528465
Roseau River				
	Coastal	Roseau Bridge	0505983	1543230
	Coastal		0508149	1542660
	Lower	Vanard Bridge	0509158	1542040
	Lower	Near health centre – Upper Vanard	0508949	1540883
Choc River				
	Coastal	Near Caribbean metals Bridge	00511858	1551585
	Coastal	Near union Power Station	0512288	1550748
	Lower	Morne Dudon\Balata Bridge	0512501	1549759
	Lower	Girard/Cacoa Bridge	0512085	1548024

Stage 5b – Populating the Control Station Points with Risk Analysis Information

Data from the pre-designed Data Collection Sheet was used to capture information about the river channel at the control points. These included the following channel characteristics:-

- Channel bed width, Channel width and depth
- Description of site location –vegetation cover, land use, observed siltation
- General weather conditions and time of day
- Lat/Long coordinates (GPS reading)

Other parameters related to *biophysical characteristics*, *socio economic* factors and *environmental issues* were derived from a number of input layers developed from clipping the various buffer maps with the individual segment boundaries.

- Soil erodibility determined by dominant soil group
- Channel gradient – slope of the river bed to determine the velocity of flow
- Land use management practices and their facilitation and impacts on degradation in the river buffer

- Socio-economic parameters (impact of settlement on water quality) and the existence of infrastructure in buffer area to assess the facilitation of damage in the buffer

For each of these, the *probability of risk* and *impact level* were determined and scored. The probability of risk and impact scores were then combined to form a composite score which reflects a threat of impact (highest score implying greatest impact).

The main purpose of this application and the use of these parameters is to assess the level of susceptibility of the river channel to degradation.

The above parameters and their Probability of Risk, Impact level and Threat of Impact were added to the attribute table of the Control Point file.

Stage 6 – Creating a Pictorial Database within Control Stations of Each River Segment to Facilitate Future Monitoring of Critical Areas

A number of digital photographs were taken at the Control Points within the segments (lower and coastal). The pictures will be hyperlinked to the point file (lat/long coordinates) Because there are several digital pictures per site a number of approximate points around the Ground Control Points were chosen to hyperlink each picture.

The purpose of the database is to provide a base for future visual monitoring of the status of river banks.

The above divisions have been prescribed to describe and make clear the GIS tasks required to develop the Digital\GIS Database for decision support – data capture, storage, retrieval, analysis and monitoring (see Table 8). Note that all the layers of information are inter-related and can be combined where necessary.

Table 8.Summary of Development of Digital Database for Pilot Rivers

Database Type and Description	Source and Existing Scale of capture of Data	Year of Capture	Comments
DATABASE OF SELECTED RIVERS			
d. **Select Rivers** from Hydrology layer of the topographic map of St. Lucia	1:25,000 topographic map	1990	
e. **Create Riparian Buffers** (existing in accordance with local policy)	Cabinet Conclusion defined buffer - minimum of 20m but for convenience a	Current	

Database Type and Description	Source and Existing Scale of capture of Data	Year of Capture	Comments
	50 m buffer was used		
f. **Clip of Existing Relevant GIS Layers from PPU Database** using river buffer as boundary	From Riparian Buffer File	Current	This serves as the First Spatial Unit of Assessment.
• Slope	DEM, 1:25,000 topographic map sheet	1988?	DEM points From PPU database – may have to create slope map from these
• Soils	1;25,000 map, Ahmad, UWI	1966?	Clip from PPU database
• Life zones	OAS Development Atlas, 1:50000	1985	Clip from PPU database
• Topographic	Topographic map, 1:25,000	1988?	Clip from PPU database
• Watershed Boundaries	Forestry, FMP 1:25,000	1990?	Clip from FMP
Creation of New Landuse Layer digital aerial photos within River Buffer boundary. Landuse classes are in accordance with the Forestry Management Plan	Forestry, FMP 1:25,000 Survey and Mapping Aerial photos,	1992 2004	PPU aerial were georeferenced and ortho rectified
DATABASE OF SEGMENTS OF SELECTED RIVERS			
• Clip of soils • Clip of slope Map • Clip of Current Landuse	1;25,000 Soils Map, Ahmad, UWI PPU slope map smoothed to vector Digital aerial photos	1966 Current 2004	
DATABASE OF CONTROL STATIONS			
6. **Database of Control Stations in Rivers**			
• Use GPS locational information to create points and expanded fields in point file to	Primary field data	current	

Database Type and Description	Source and Existing Scale of capture of Data	Year of Capture	Comments
capture descriptive information for degradation, Impact level and Impact Threats			
DATABASE OF DIGITAL PICTURES FOR MONITORING			
• Create hyperlinks with photos of views around control stations or problem areas along the river (for future monitoring)	Primary field data	current	

Building Intelligence in Data sets for future applications

The RRA methodology uses a set of indicators and their strengths expressed as a score in relation to risk and impact. This intelligence needs to be built into the future datasets for other locations. This can be done using a set of 'Look Up tables' in the GIS for the following variables.

Bio-Physical and Socio-Economic variables

- Land use classes (15 types) and their assigned suitability classes of risk, impact and overall score (developed as an output in Section 4)
- Dominant soil types (49 types) and their assigned stability classes of risk, impact and overall score (developed as an output in Section 4)
- Gradient (3 levels) and their assigned classes of risk, impact and overall score (developed as an output in Section 4).

These variables are to be contained in an Excel spreadsheet to be joined to each new river buffer clip layer by a common identifier – dominant soil class for the Soils map; Landuse class name for the Landuse Map etc.

In so doing the impact, risk and overall scores will be automatically assigned to each layer.

4.3 Stakeholder Consultation

The stakeholder analysis process focused largely on identifying stakeholder function, as time in this regard (given the short time frame of the assignment) had to be limited in order to progress the subsequent activities, particular with respect to early stakeholder consultation. Table 9, provides a summary of stakeholder functions with respect to river systems management in Saint Lucia.

Table 9.Stakeholder Functions for Riverbank Rehabilitation and Management in Saint Lucia

Function	Policy Formulation	Regulation	Resource Management	Resource User	Resource Monitoring and Evaluation	Mitigation and Risk Reduction	Financing	Public Awareness
Public Sector								
Ministry of Agriculture, Lands, Forestry and Fisheries*[38]	x	x	x		x	x	x	x
Ministry of Economic Affairs – SDES, CZMU, National Development, Crown lands Dept.	x	x	x		x	x	x	x
Ministry of Finance	[x]	[x]					[x]	
Ministry of Communications, Works, Transport and Public Utilities – Meteorological Services Department				x	x			
Ministry of Tourism and Civil Aviation				x		x		x
Ministry of Education and Culture								x
Ministry of Social Transformation			x		x	x		x
Ministry of Physical Development, Housing, Urban Renewal and Local Government – Housing Department	[x]			x		x		
Ministry of Health		[x]			x	x		x
Statutory Bodies								
Water and Sewerage Corporation	x	x		x	x	x	x	x
Solid Waste Management Authority	[x]	[x]			x		x	x
Saint Lucia National Trust			x	x	x	x		x
SLBS	[x]	[x]						
Banana Production Management Unit		x	x		x	x		x
National Conservation Association		x	x		x	x		
NEMO	x				x	x		x
Private Sector								
Farmers Organisation- Fairtrade, TQFC, SLBC				x		x		x
Fishers Organisation				x				
Saint Lucia Chamber of Commerce - Business Sector				x				

[38] Departments of Agriculture/Extension, Forestry, Fisheries, Engineering, WRMA, IWCAM

Function	**Policy Formulation**	**Regulation**	**Resource Management**	**Resource User**	**Resource Monitoring and Evaluation**	**Mitigation and Risk Reduction**	**Financing**	**Public Awareness**
Representatives of Manufacturer Sector				x				
Saint Lucia Hotel and Tourism Association (SLHTA)/Private Tour/Site owners				x		x	x	x
Caribbean Agri-business Association and affiliates – Local Chapters				x				x
Community Organisations								
Community Based Organisations (CBOs)			x	x	x	x		x
Watershed/Water Catchment Groups			x	x	x	x		x
SMMA/SRDF	x	x	x		x	x		x
Regional Agencies								
Organisation of Eastern Caribbean States (OECS)	x				x	x	x	x
Caribbean Environmental Health Institute (CEHI)	[x]		x		x	x	x	x
Caribbean Conservation Association (CCA)	[x]				x	x		x
Inter-American Institute for Cooperation on Agriculture (IICA)	[x]							x
Windward Islands Banana Development and Exporting Company (WIBDECO)			[x]			x		x
Caribbean Agricultural Research and Development Institute (CARDI)						x		

Table 10 captures the main stakeholders, who were in one way or the other consulted and engaged throughout the implementation of the assignment.

Table 10.Stakeholder Consultation and Engagement Process

Stakeholder Group	Format of Engagement	Comments
Department of Forestry - Technical Advisory Team; - Technical Coordinating Team	Organized meetings: project initiation; progress meetings; routine queries/ clarifications	
Multi-disciplinary/ multi-sectoral Adhoc Technical Committee (ATC)	Meeting of 9 July 2008	See listing in Appendix 6; also follow-up one-and-one discussions/ communications
Water Resources Management Unit (WRMU)	Several meetings with officers	Water resources data collection & river monitoring
IWCAM Coordinator	Water resources data collection & river monitoring	On-going Demo project at Fond D'or watershed
Technical Assessment Team	Discussions & engagements for field orientation & assessments	Multi-level/ disciplinary technical teams

In the interest of time and efficiency, the several consultative and engagement exercises were conducted utilizing organized technical working groups, direct one-and-one encounters with technical and supervisory personnel, and other indirect communication means (*e.g. e-mail messaging, telephone*). However, much of the information related to the community-based and general civil society resource user groups was collated from secondary sources, such as previous documented interventions, which were reviewed as part of the general literature review activity, and the reports and feedback of knowledgeable public officers/ personnel, such as the Senior Community Development Officers, Senior Forestry personnel and others from the WRMU, IWCAM Project and the EU-Technical Coordinating and Advisory Team.

The main mechanism for obtaining stakeholder input during the assignment was however, through a meeting of the multi-disciplinary Adhoc Technical Committee (ATC), which was held on July 09, 2008. Other input was obtained from interactions with technical officers through the process of training/orientation and field testing of the methodology. Feedback was also obtained from key stakeholders, through focus group discussions and one-on-one interviews, in particular with Department of Forestry staff, as well as select members of the TWG on the various assignment deliverables.

The outcome of the stakeholder consultation process is documented in Section 5 of the Report, Results and Findings. The information gathered during the process was summarized according to the following three summary tables, which were previously presented in Appendix 4 of this Report.

* Summary Table 1 potential causes of erosion identified by stakeholders.
* Summary Table 2 specific matters of concern regarding riverbank degradation
* Summary Table 3 stakeholder recommendation for riverbank protection and rehabilitation.

The summary tables generated from the stakeholder consultation process involved an estimation of the potential causes of erosion and specific matters of concern regarding riverbank degradation. These tables were further expanded to include other causes and concerns identified during the field assessment. The expanded tables were then used to report on findings in terms of the frequency of occurrence with respect to the number sites sampled.

This aspect of the methodology provides a mechanism for identifying incidence of erosion and contributing factors and processes across the river systems on the island which can then be used to determine the more specific management interventions required within a Riverbank Assessment Rehabilitation Plan.

4.4 Bank Condition Assessment

The application of Phase 4 of RRA methodology focused on the assessment and documentation of baseline data on current bank conditions for each river, to facilitate future assessments of existing bank conditions and the changing profile of the river system, based on periodic monitoring surveys.

The process involved a combination of training, field reconnaissance and field survey comprising the following Steps:

1. Training/Orientation Workshop on RRA Methodology
2. Ground Reconnaissance to confirm the *Segments of Selected Rivers and Buffers* along with the *attributes* (description) relevant to the analysis
3. Ground Reconnaissance to establish/(confirm) *River Based Control Stations* and their attributes (description) falling within the river segments
4. Field surveys to identify and document attributes of river segments
5. *Cataloguing* of river bank conditions through photographs taken at or around the based control points within the respective segments to facilitate future visual monitoring

Step 1 - Training/Orientation

A training workshop/session was conducted by the Consultant on Monday 21st July, 2008. The session provided an orientation to the methodology to field personnel, and included the pre-testing of the methodology and the field data form, at a sample site in Roseau. Persons involved in the orientation exercise and field testing of the methodology included a combination of technical and non-technical field personnel from the Department of Forestry and the Water Resources Management Agency (WRMA) of the Ministry of Agriculture, Lands, Forestry and Fisheries. The short assignment time frame did not permit the requisite invitations to be extended to the community persons to allow for a timely response.

The training/orientation activity also facilitated the participatory approach for stakeholder input on the various aspects of the methodology and its implementation. This input obtained during the activity was used to assist in the further refinement of the methodology. The activity also set the stage for continual monitoring by non-technical parties, for providing a qualitative assessment on the processes involved in riverbank erosion and management.

Step 2 – Field Reconnaissance

1A – Ground Location of Control Points

There was a slight variation in the process of ground-truthing, with respect to confirmation of the location of control points generated during the Screening Process in Phases 1 and 2. As indicated earlier, the preliminary GIS profile derived from the activities in Phases 1 and 2, could not be made available within the time frame slated for this phase of the assignment to come on stream. Instead, the Consultant along with the field personnel, who all had significant technical background, utilized the base 1:25,0000 topographic map to undertake the process of identification of specific stretches/reaches of the river within each zone/segment of the rivers. As far as possible the team in undertaking the election sought to ensure that each zone/segment represented similar geomorphic traits within the river. as observed in the initial profiling and are confirmed in more detail at the field level assessment.

A minimum of two sites were selected for the establishment of control station points within each of the lower two reaches of the three sample River channels to permanently established marked cross-sections for monitoring of erosion. Site selection was as per the guidelines in the RRA methodology, with sites representative of typical stable high banks and typical eroding low banks with varying levels or types of activity (land use) and varying levels of vegetation stability. In addition, in the process of selection the assessor sought as far as possible to ensure that one of the two sampling locations was a fairly straight stretch, while the other included a bend.

Each site was then geographically referenced using GPS in conjunction with the topographic map and manmade feature descriptions for validation and accuracy in locating.

1B Field Survey

The focus of the field survey, keeping with the objectives of the assignment, was to generate baseline data for the establishment of a baseline database required to support ongoing river systems monitoring.

The Bank Condition Assessment survey involved the assessment and documentation of the parameters outlined in the pre-designed Field Survey Form as per Appendix 3. The methodology was employed at each of the selected control point locations along the river to undertake a comprehensive assessment of the physical landscape, including soil surface assessment, land use and vegetation assessment, regular activities within the riparian zone, observation of bank degradation. Measurements and observations were recorded at the sampling locations within the demarcated sections/reaches and the riparian buffers of the river system.

As far as possible, bank recordings were performed at or near low flow levels to allow safe access to the river and allow a full visualisation of the channel’s condition.

The data collected was recorded as per the guidelines articulated in the Field Survey Form.

Several digital photographs were taken at the Control Point locations, particularly within the lower and coastal reaches as part of the process of recording bank condition.

Water Quality Assessment

Due to the constraints of time and resources, the study was not able to examine the aspects of water quality.

4.5 Data Analysis and Interpretation

Ranking of aspects/impacts, after they have been identified and assessed in regards to their relative contribution to bank erosion;

In implementing an testing this Phase of the RRA methodology, the combination of techniques were applied for scoring and ranking aspects/impacts, which had been identified and assessed through field observations in regards to their relative contribution to bank erosion.

Scores for Probability of Risk, Impact Level and Threat of Impact were derived by the using the various considerations provided in the methodology to determine the three main factors, Probability Factor, Impact Factor and Threat Factor.

The formulas provided in the methodology were used to compute a combined or composite score - the **Susceptibility Index (SI)**. The **Si** reflects the level of susceptibility of the river channel to degradation (highest score implying greatest susceptibility).

The outputs in the above regard are provided in Section 5, Results and Findings.

The final scoring output was then used to determine location specific management recommendations with respect to the contributing factors/processes and the location in the river for the three river systems sampled. It is important to note that the recommendations in this regard are location specific and there is need for caution in extrapolation to other sites. It is anticipated that information on the diverse factors/processes within the various reaches of all the river systems on the island will be compiled and further analysed to determine applicability of recommendations for specific situations.

5.0 PRELIMINARY RIVER ASSESSMENTS FINDINGS

On the basis of the general phased-approach outlined in Section 3, along with the adjustments made and noted in Section 4, the following section presents the main findings.

5.1 Phase 1 – River System Preliminary Profiling

First Stage Profiling – Scoping

This involved a desk-based scoping and general screening of the major twenty-seven (27) river systems identified by the Forestry Department, which primarily included the perennial river courses in St. Lucia, taking into consideration a limited number of selected criteria. Ultimately, the intention was to narrow the initial list down to three key rivers, which would serve as pilots for developing a national river management and rehabilitation programme.

As indicated in Section 4, the table outlined in Appendix 2 serves as a template for such an exercise. The parameters and factors included in the template however are merely to indicate the range of parameters that may be used as scoping/screening criteria, since the selected parameters used for scoping and screening should depend on the intent and purpose/objectives to be achieved.

As the use of too many parameters would only serve to complicate this initial process, the number of parameters was kept to a minimum in order to minimize the variability within and the complexity of the processes, in order to ensure the provision of and maintain the validity of a methodology for a rapid assessment.

The selected criteria and the respective outputs of the screening exercise are noted in the following Table 11.

Table 11.Preliminary Screening of River Systems for Final Selection

Criteria / River Course	Bio-Physical Condition[39]	National Significance (socio-economic)	Geographic Location
Marquis	√	Moderate	North-east
Fond D'or[40]	√	High	east
Dennery	√	moderate	east
Troumassee	√	Very High	√ - east
Canelles	√	High	South-east
Vieux Fort	√	high	south
Soufriere	√	High	west
Canaries	√	High	west

[39] Based on flow classification ~ perennial (√) or seasonal.
[40] Demo site for the IWCAM programme.

Grande Riviere du Anse la Raye	√	High	west
Roseau	√	Very High	√ - west
Cul-de-sac	√	Moderate	west
Choc	√	High	√ - north-west

Stage 2 River System Preliminary Profiling - Screening

Having confirmed the selection of the pilot rivers, stage 2 profiling activities incorporated the use of GIS tools and techniques to develop a preliminary database from existing secondary data sources, such as analogue maps, aerial photography and other existing digital information (e.g ~ *dominant soils, slope, vegetation and land use*). This was effected based on the zoning of the river course, using elevation as a primary topographic feature; the demarcation of the buffer area and the preliminary selection of at least two river reaches/ zone, each 50 metres long.

This step assisted in establishing the framework for the further development of the respective databases for each river, once the field-based data collection and assessment activities have been fully processed. The following figures and maps present the key outputs from this phase.

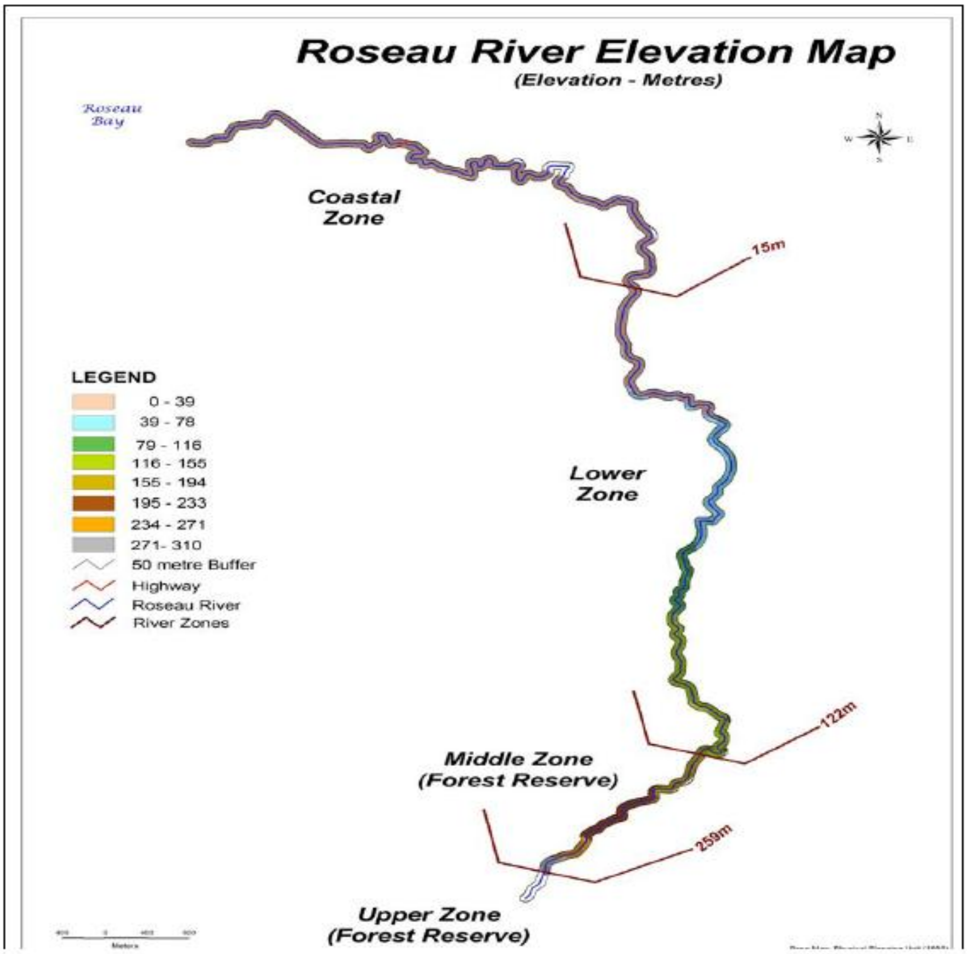


Figure 9: River Zoning, based on Elevation ~ Roseau River

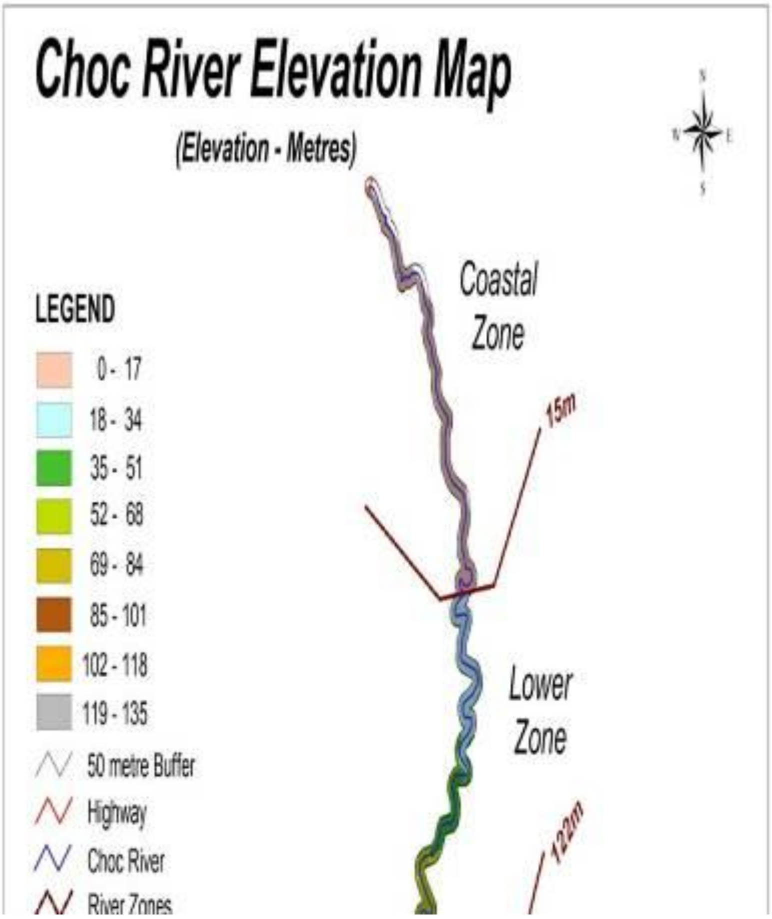


Figure 10: River Zoning, based on Elevation ~ Choc River

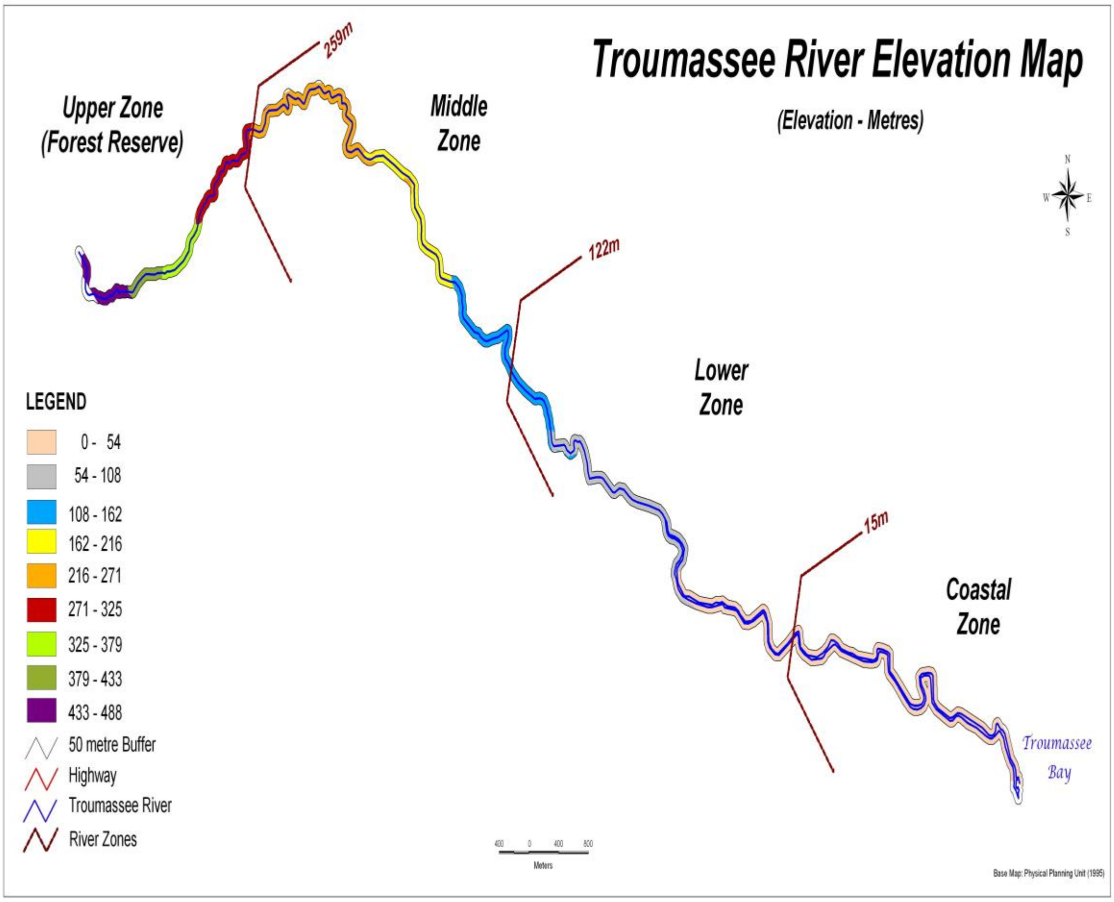


Figure 11: River Zoning, based on Elevation ~ Troumassee River

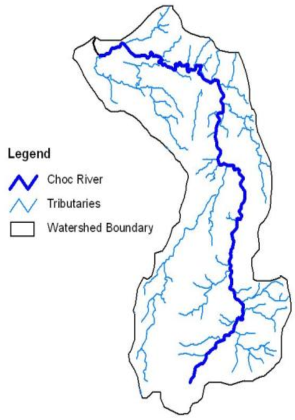
		
Roseau River	**Choc River**	**Troumassee River**

Figure 12: River Zoning, based on Tributaries

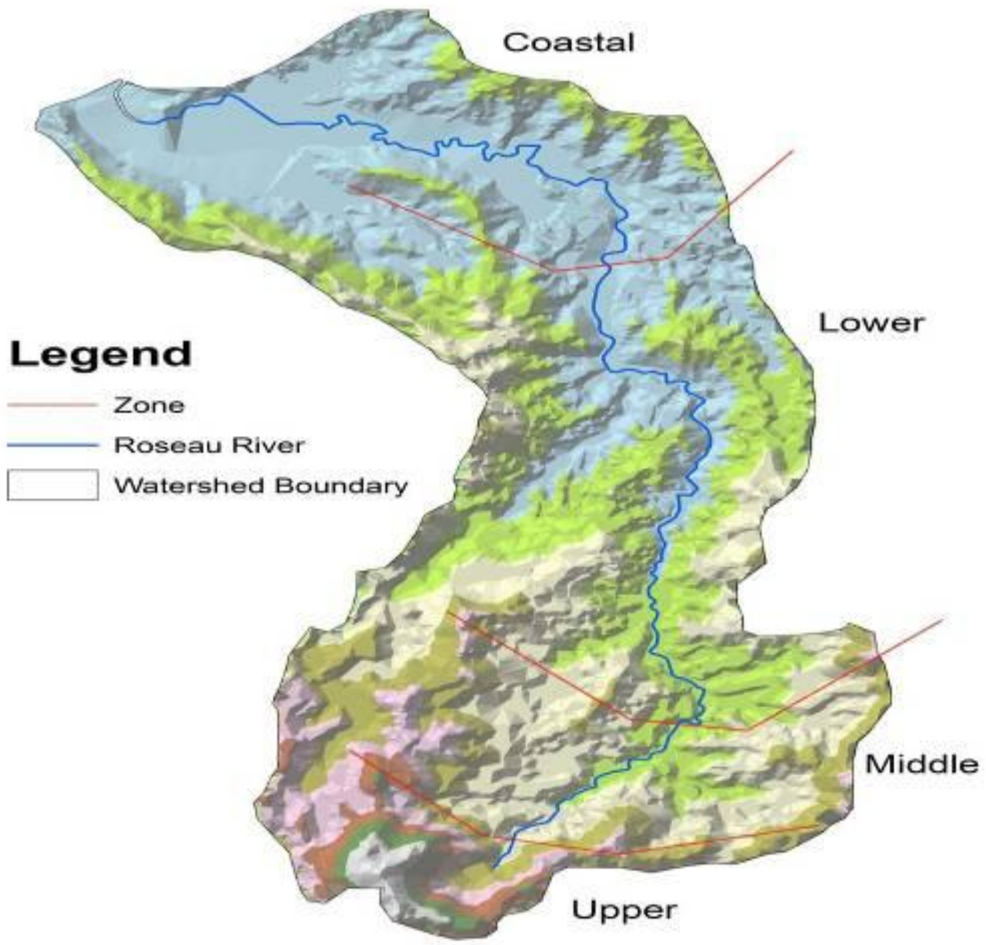


Figure 13: Roseau River System[41]

[41] Note: watershed boundary is not to scale.

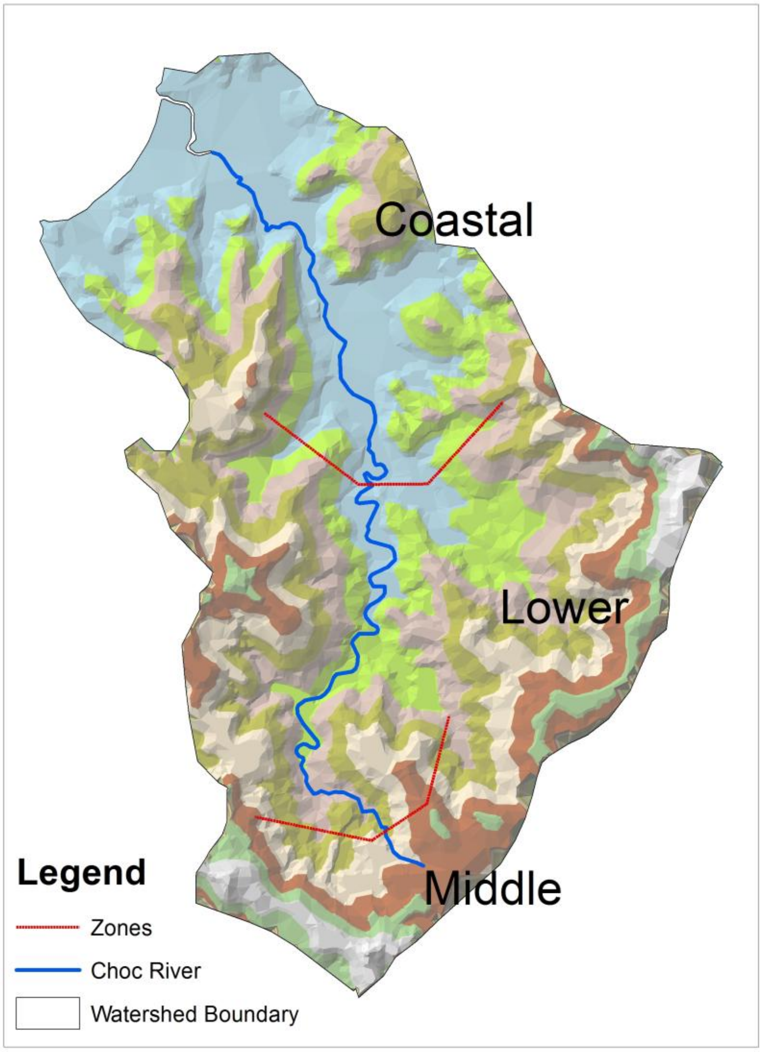


Figure 14: Choc River System[42]

[42] Note: watershed boundary is not to scale.

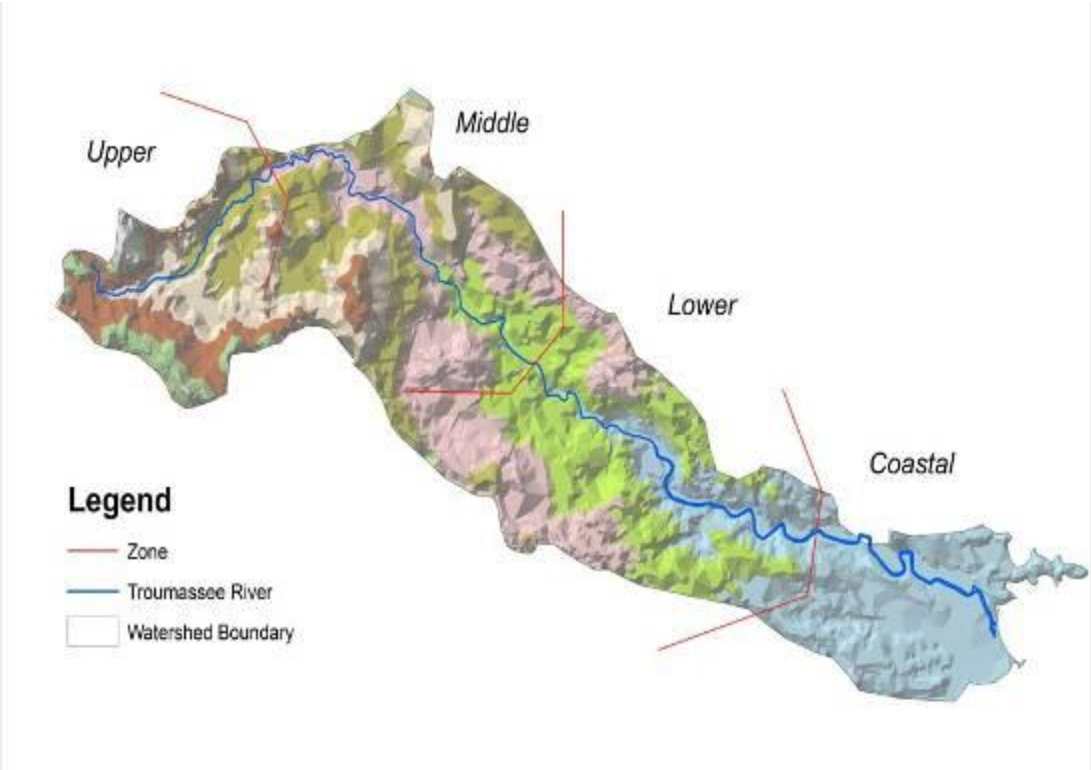


Figure 15: Troumassee River System

Other outputs for the various selected reaches/ river included slope maps, dominant soils maps, land use maps (1992 & 2004), clips of which are included further on in this section.

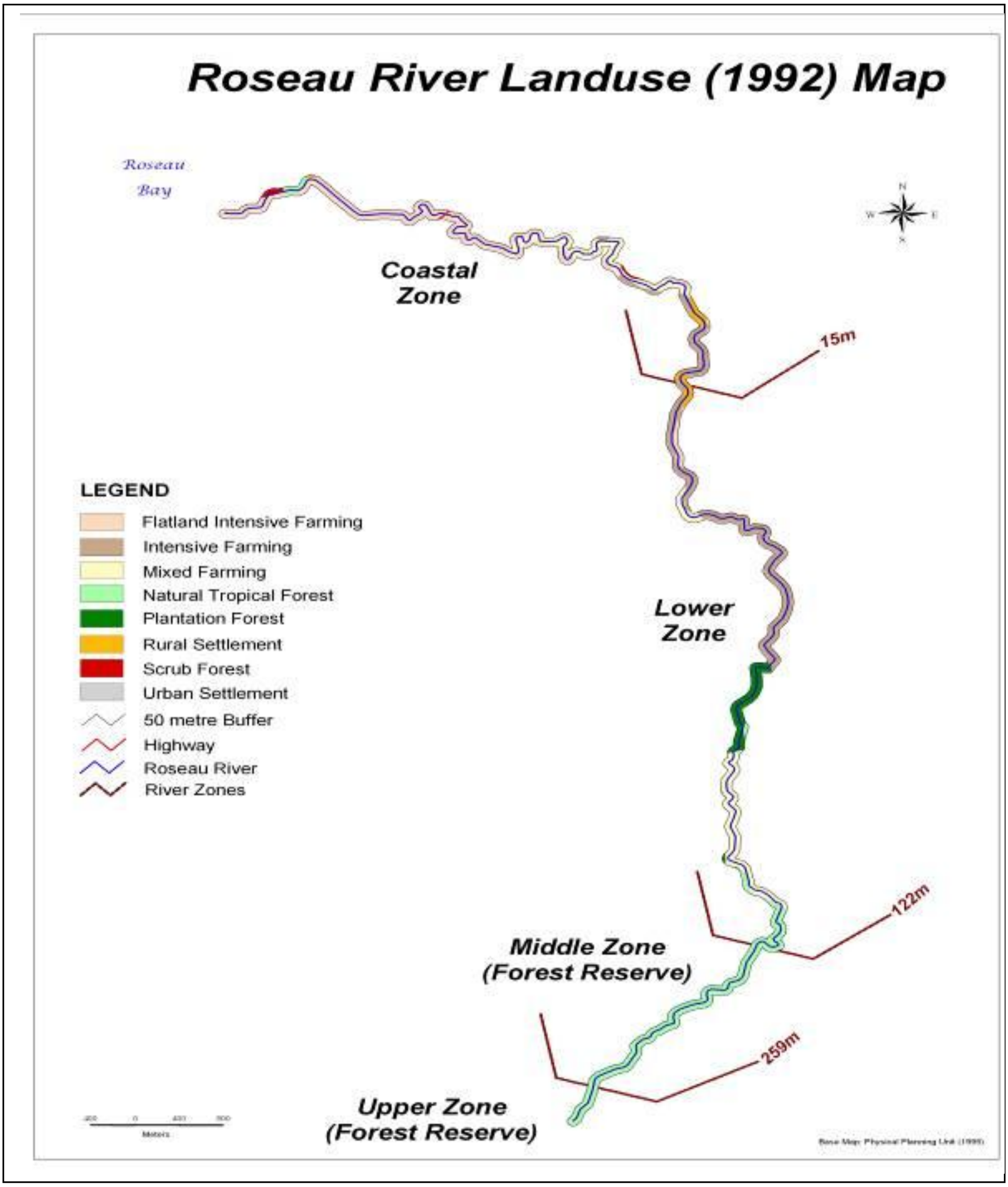
5.2 Phase 2 –Database Development an Application

This phase involved the effective capture and transformation of the data outputs from the field assessments into spatial and pictorial formats that permit and facilitate analysis and interpretation. It is primarily a build-up on the actions initiated in phase 1. Moreover, this phase sets the platform for additional future data capture, to develop a monitoring regime over time, which should assist to enhance the predictive capabilities of the methodology.

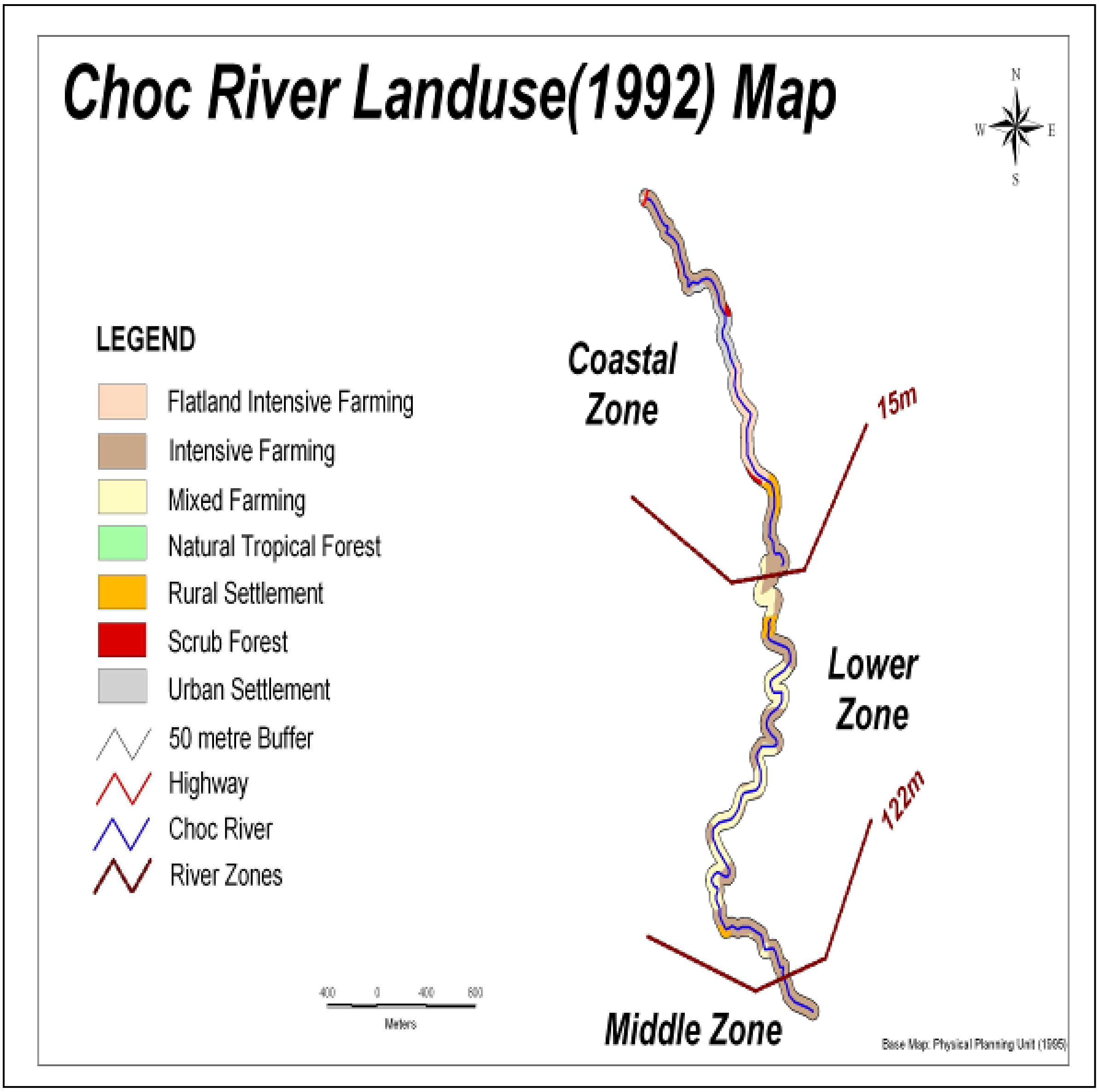
Some of the initial outputs from this phase have already been presented in the earlier section on Phase 1. A major output of this phase, is the Flow Chart of the main steps followed in the use of GIS tools which is presented in Appendix 8.

The remaining outputs of this phase of the RRA are presented as findings from each step within the phase. The analyses of these findings are further elaborated in Section 6 of the report– "Analysis and Recommendations".

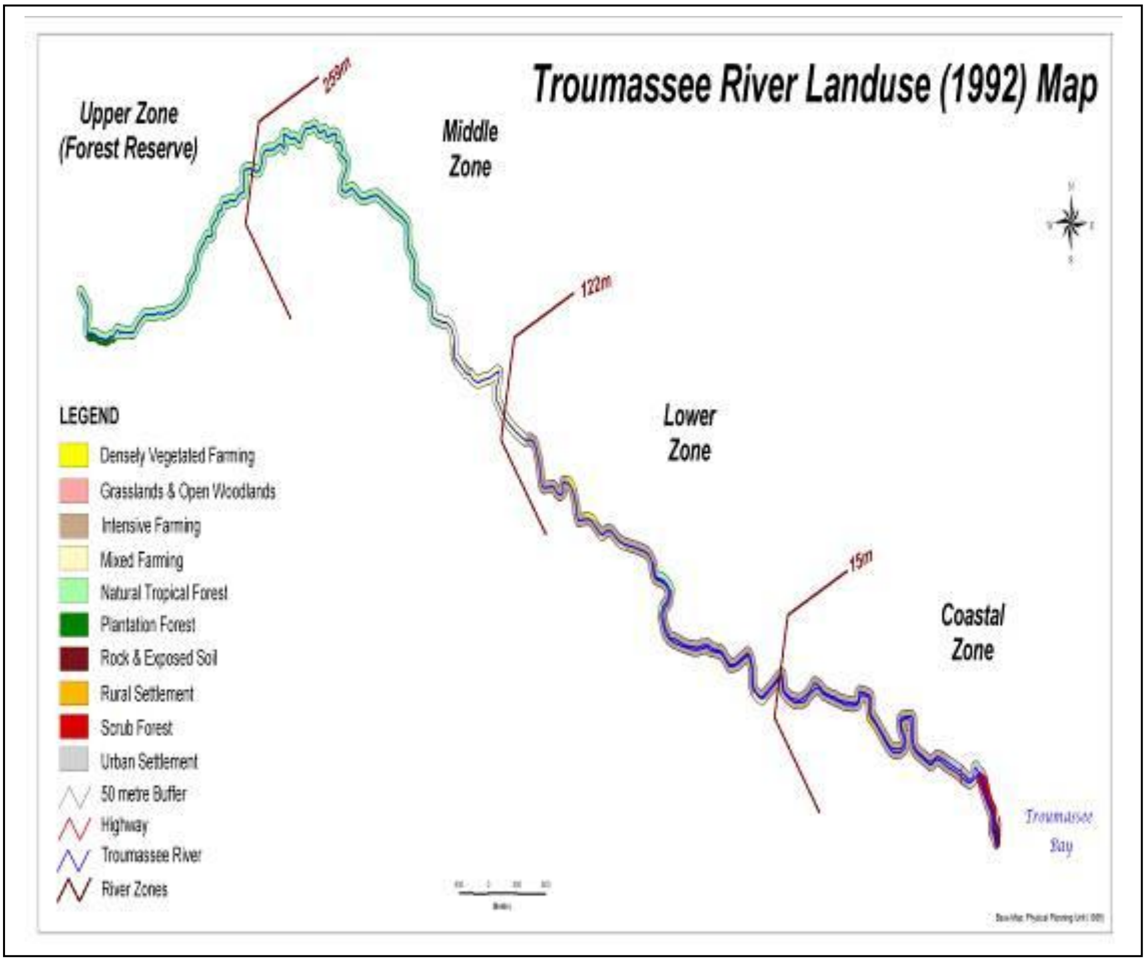
5.2.1 Outputs from Stages 3 to 6



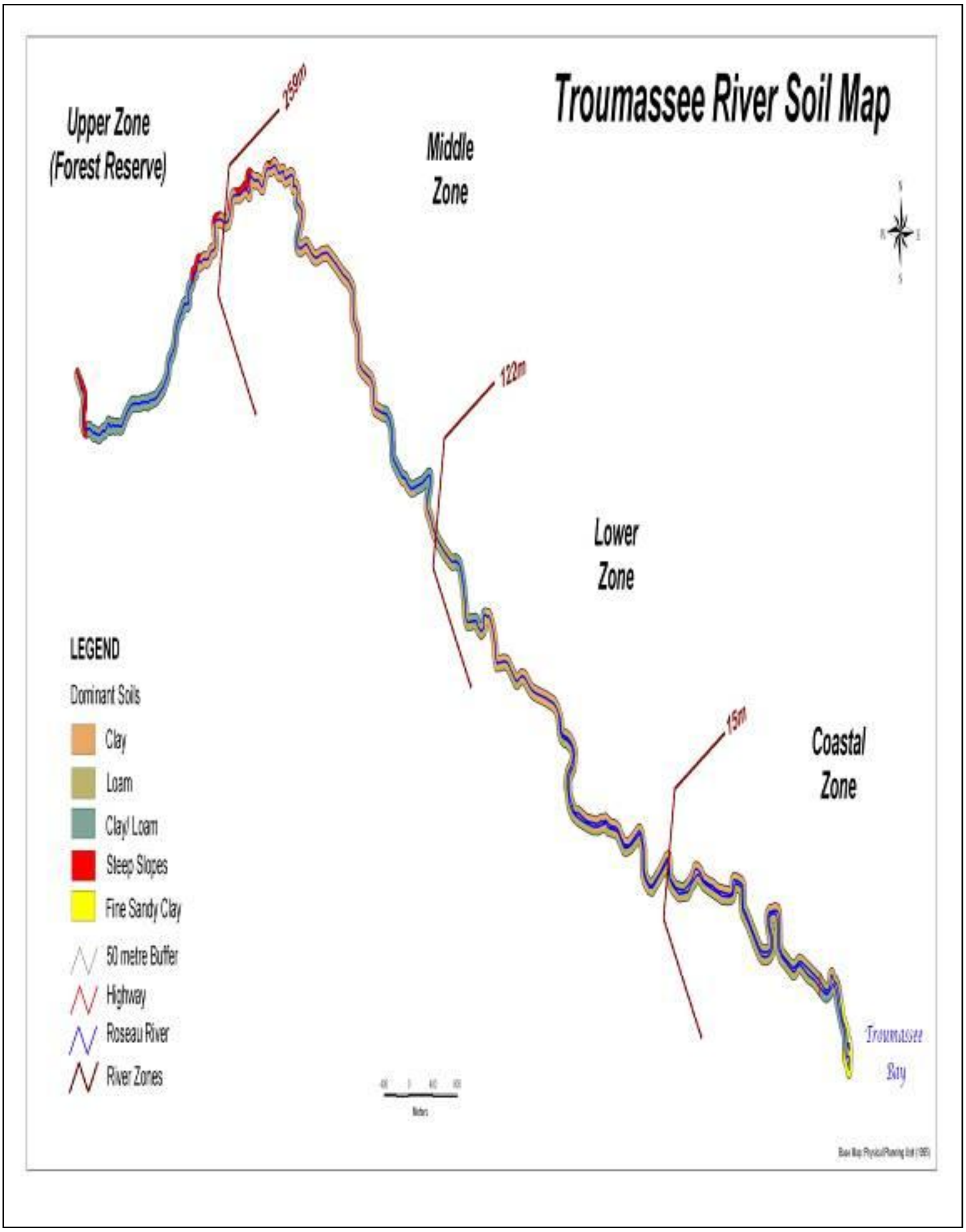
Map 1-Roseau River Landuse Map



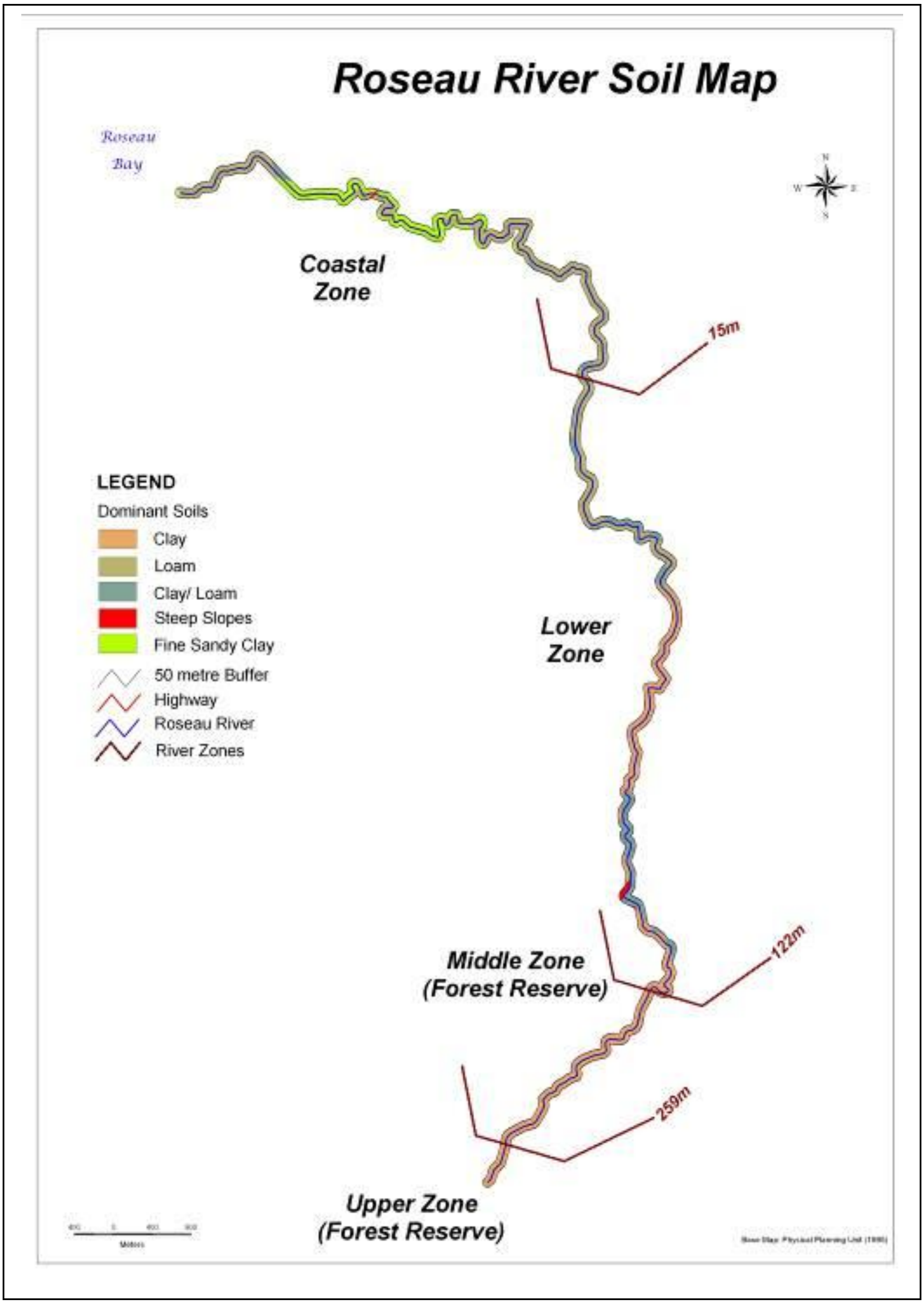
Map 2-Choc River Landuse Map



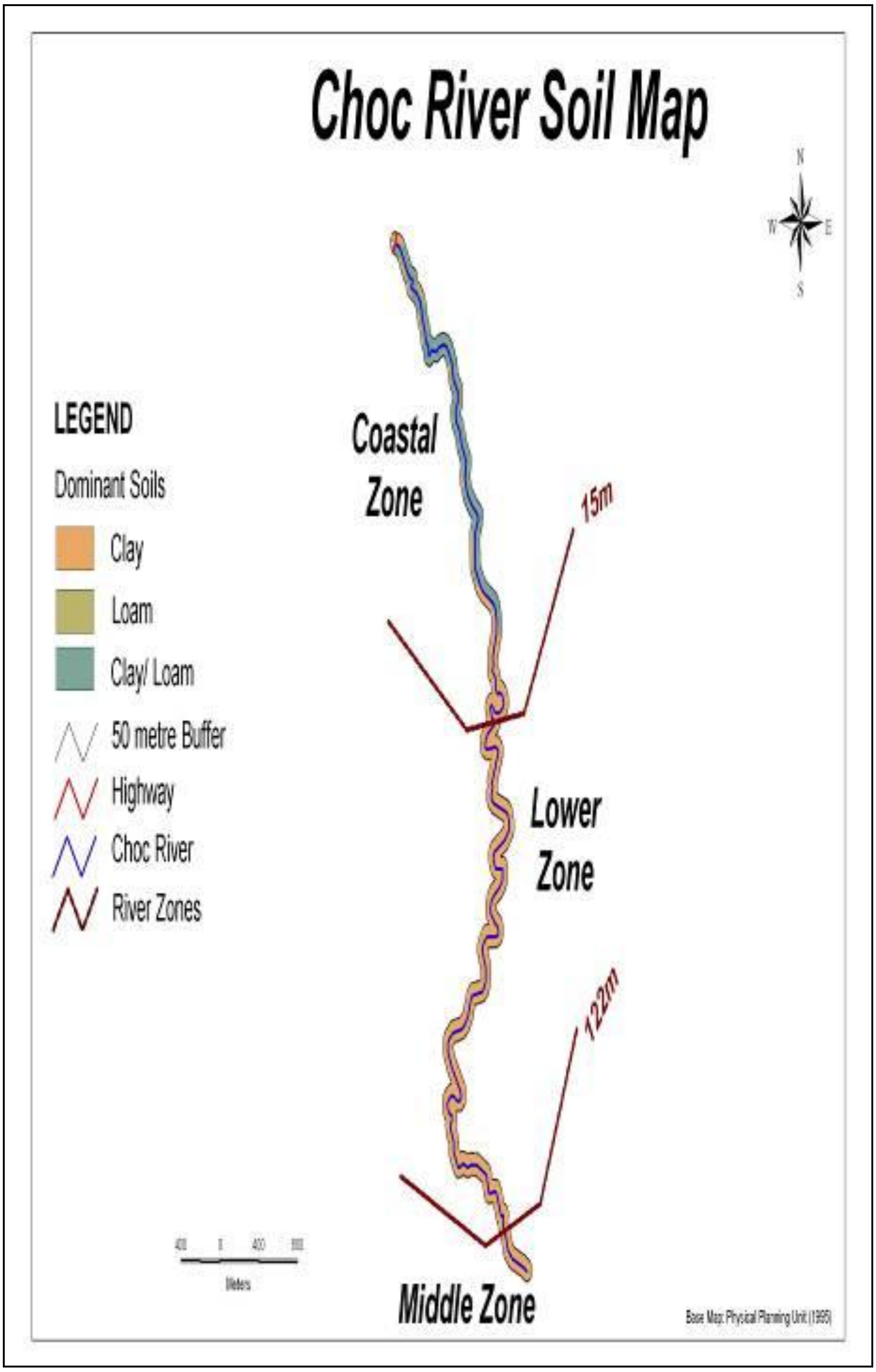
Map 3-Troumassee Landuse Map



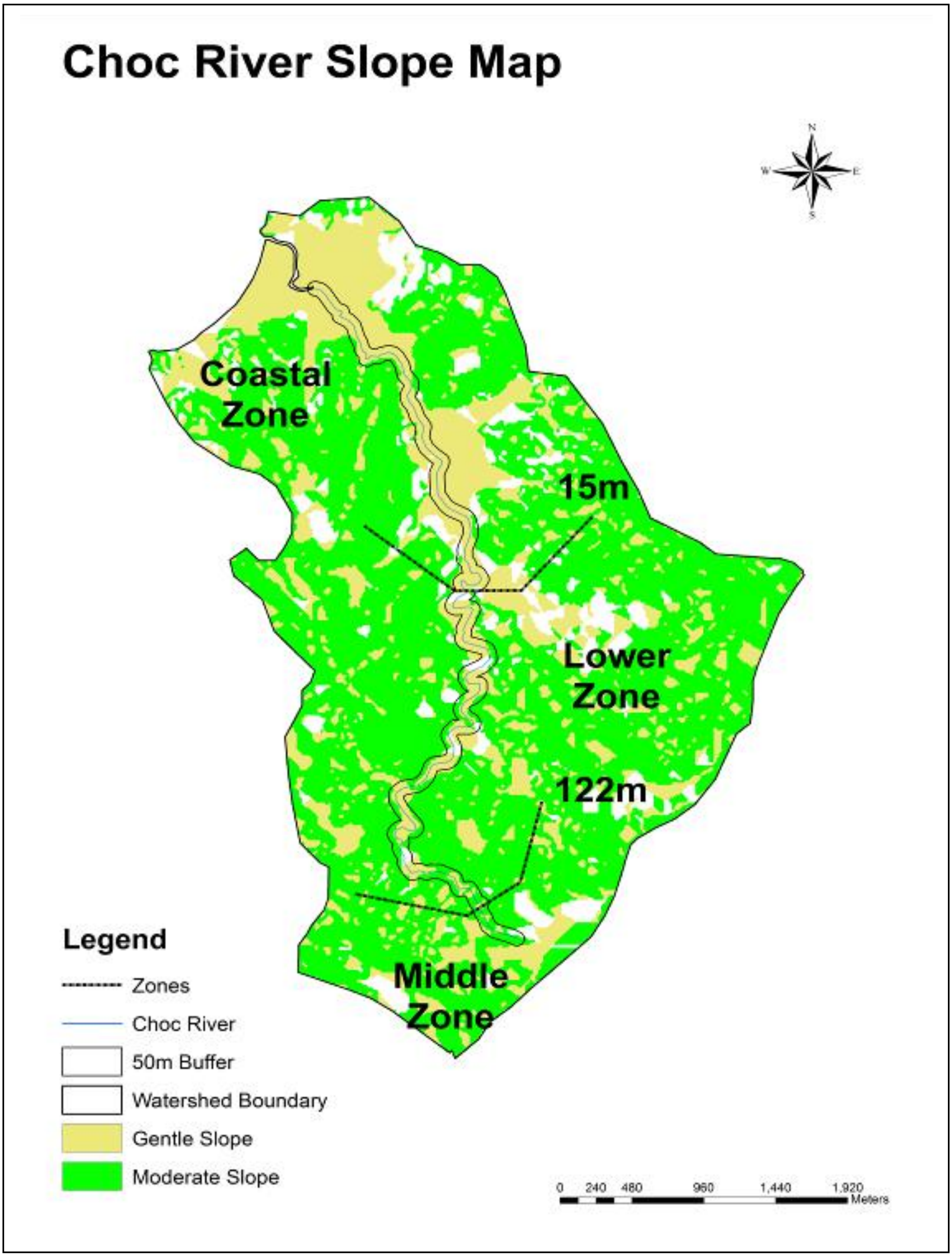
Map 4-Troumassee River Soil Map



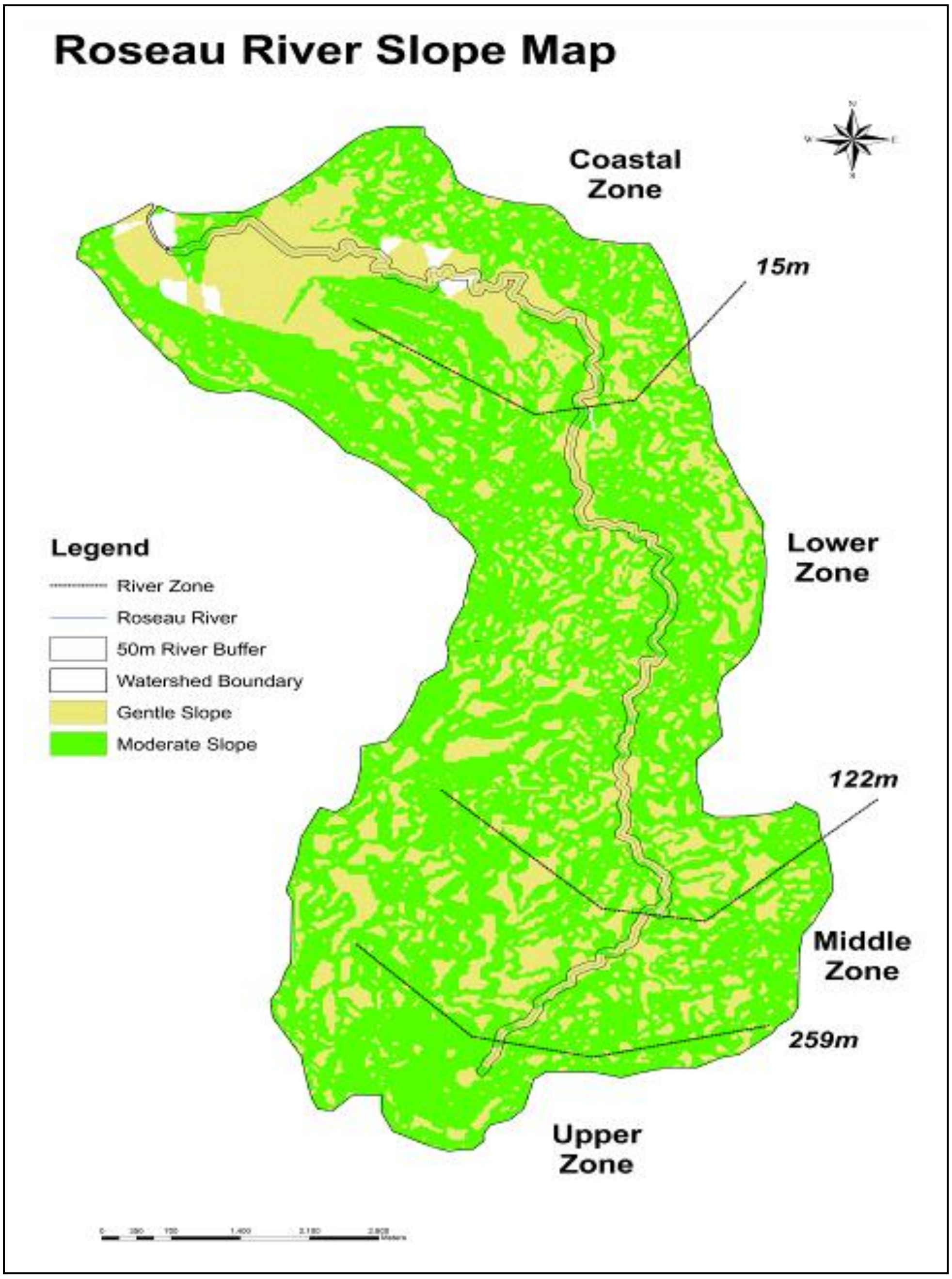
Map 5-Roseau Soil Map



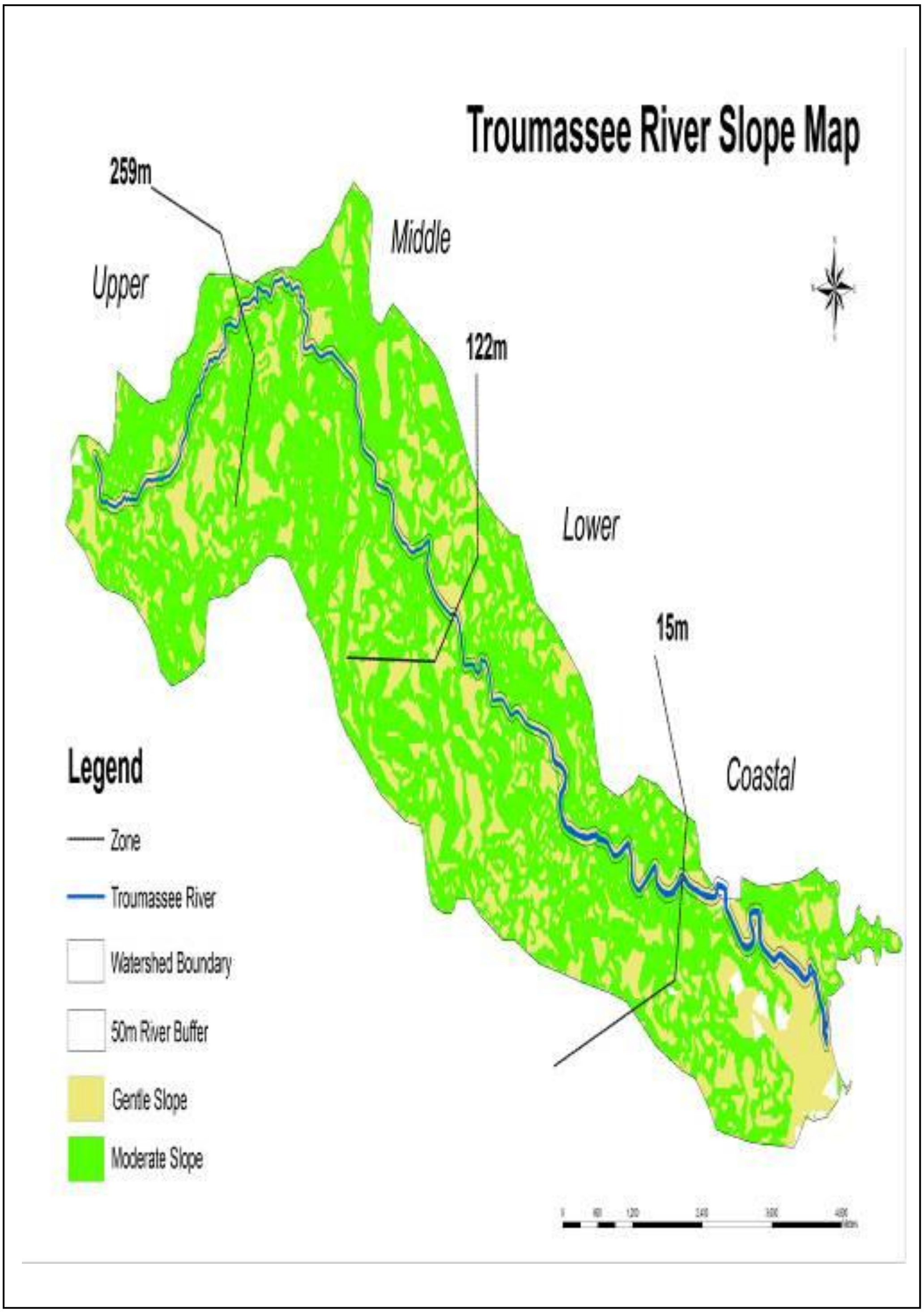
Map 6-Choc River Soil Map



Map 7- Choc River Slope Map



Map 8-Roseau River Slope Map



Map 9- Troumassee River Slope Map

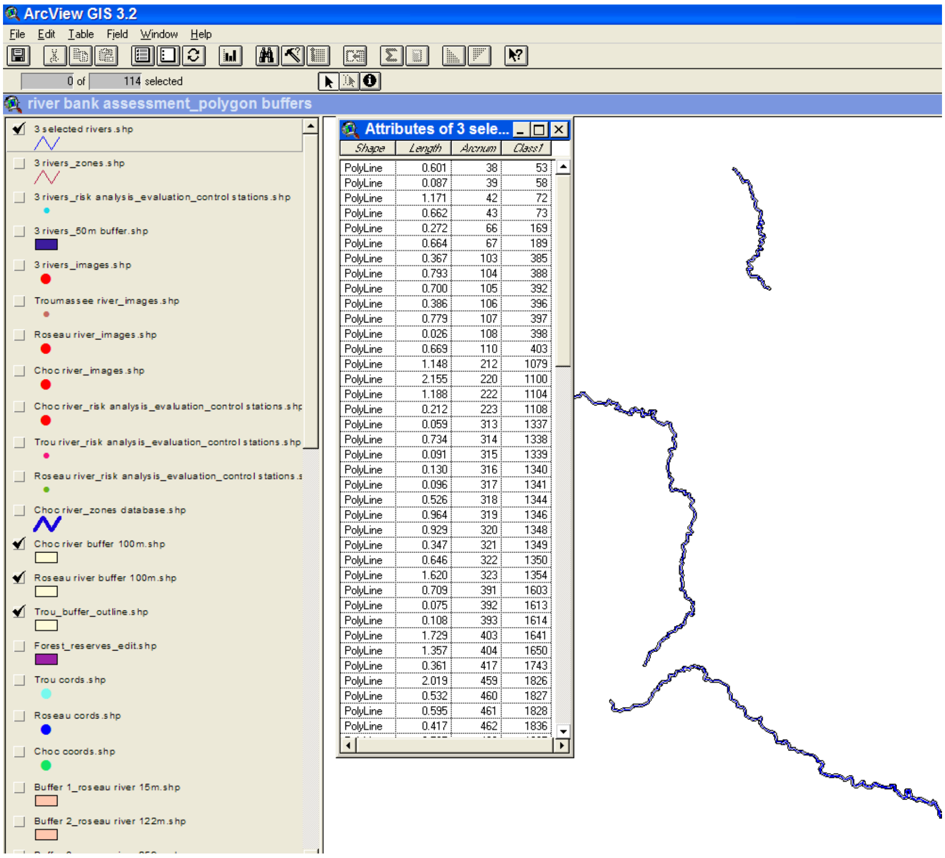


Figure 16: Rivers with Buffers and Database

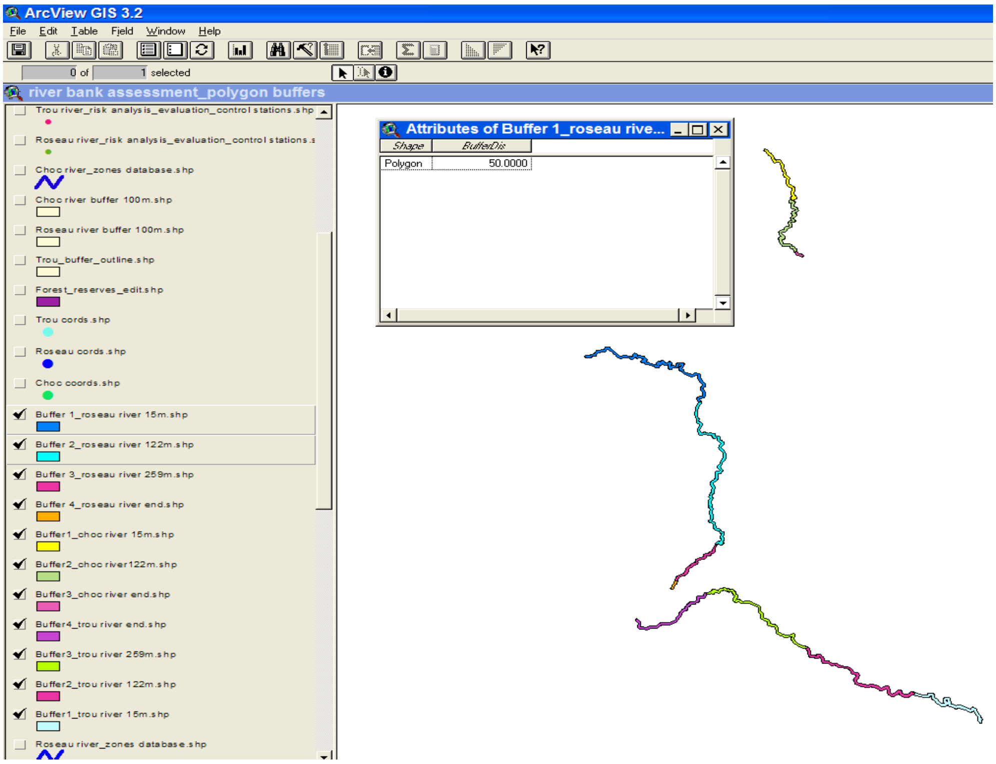


Figure 17: Polygon of Zones and Database

MAIN RIVER DATABASE FOR RISK ANALYSIS & EVALUATION USING CONTROL STATIONS

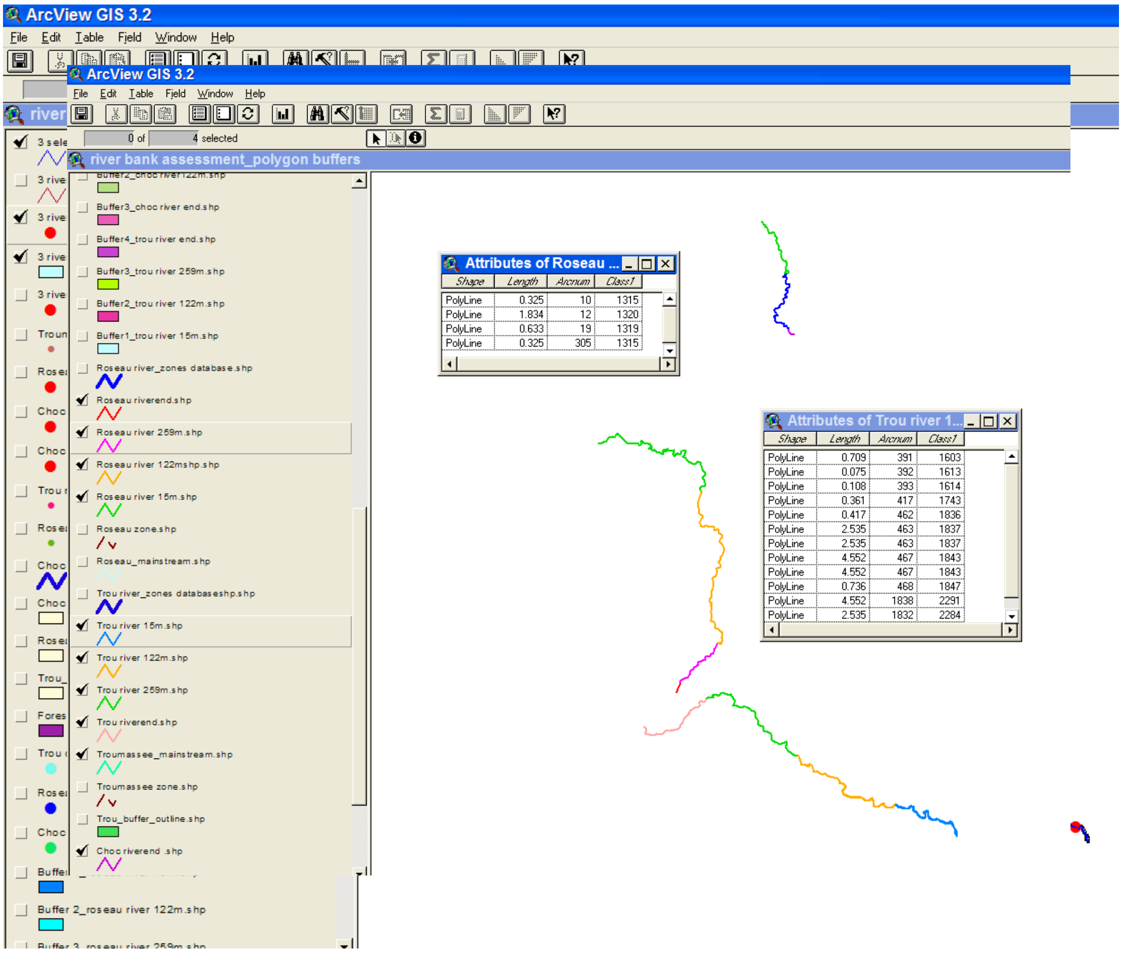


Figure 18: River Segments in Zones and Database

Figure 19: Topography of Troumassee River and Alignment with Forest Reserve

Figure 20: Topography of Choc River

Figure 21: Topography of Choc River

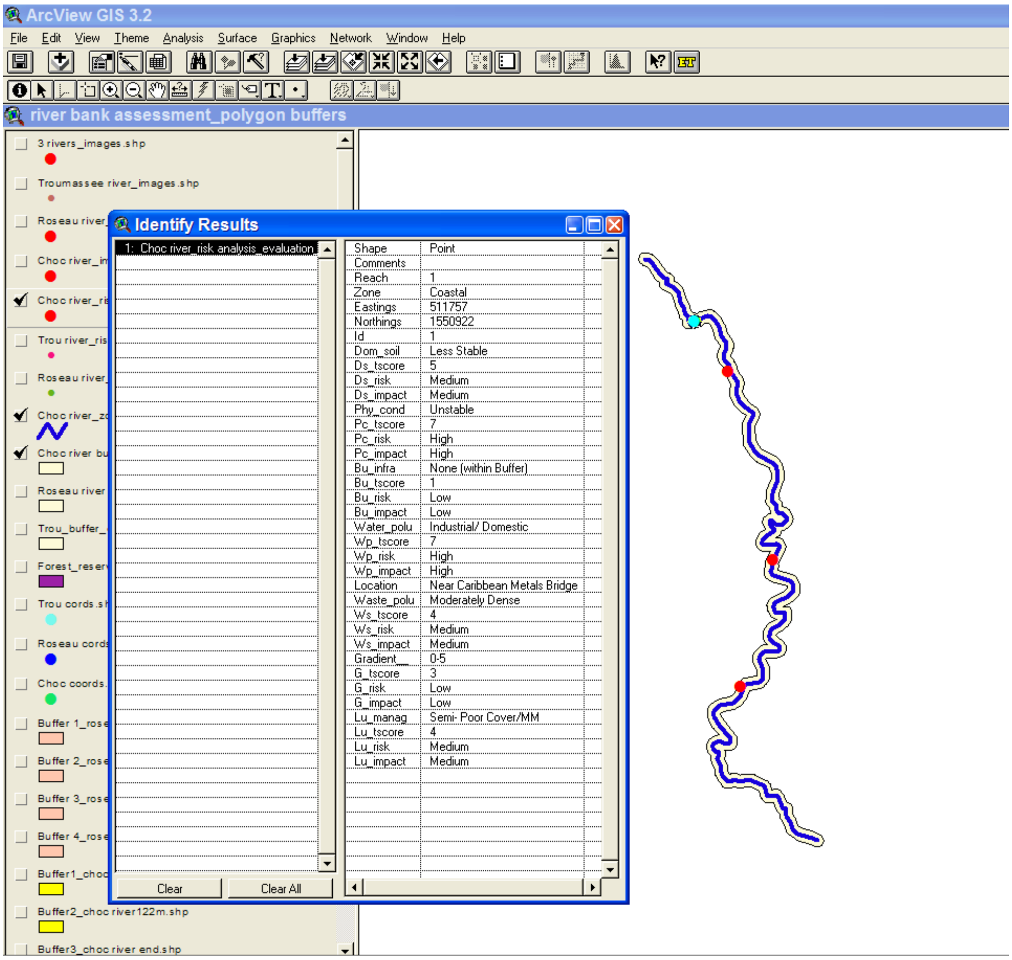


Figure 22: Attributes of Control Points

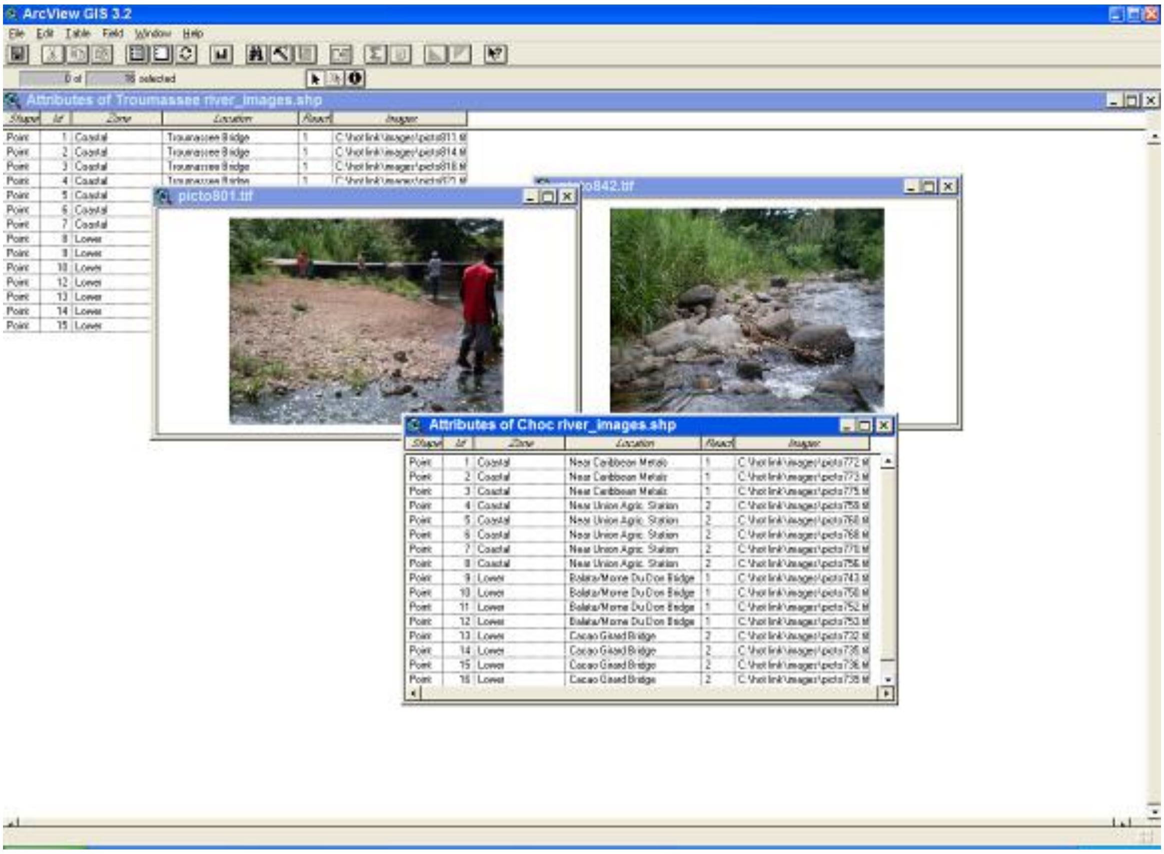


Figure 23: Pictorial Database of Control Points (1)

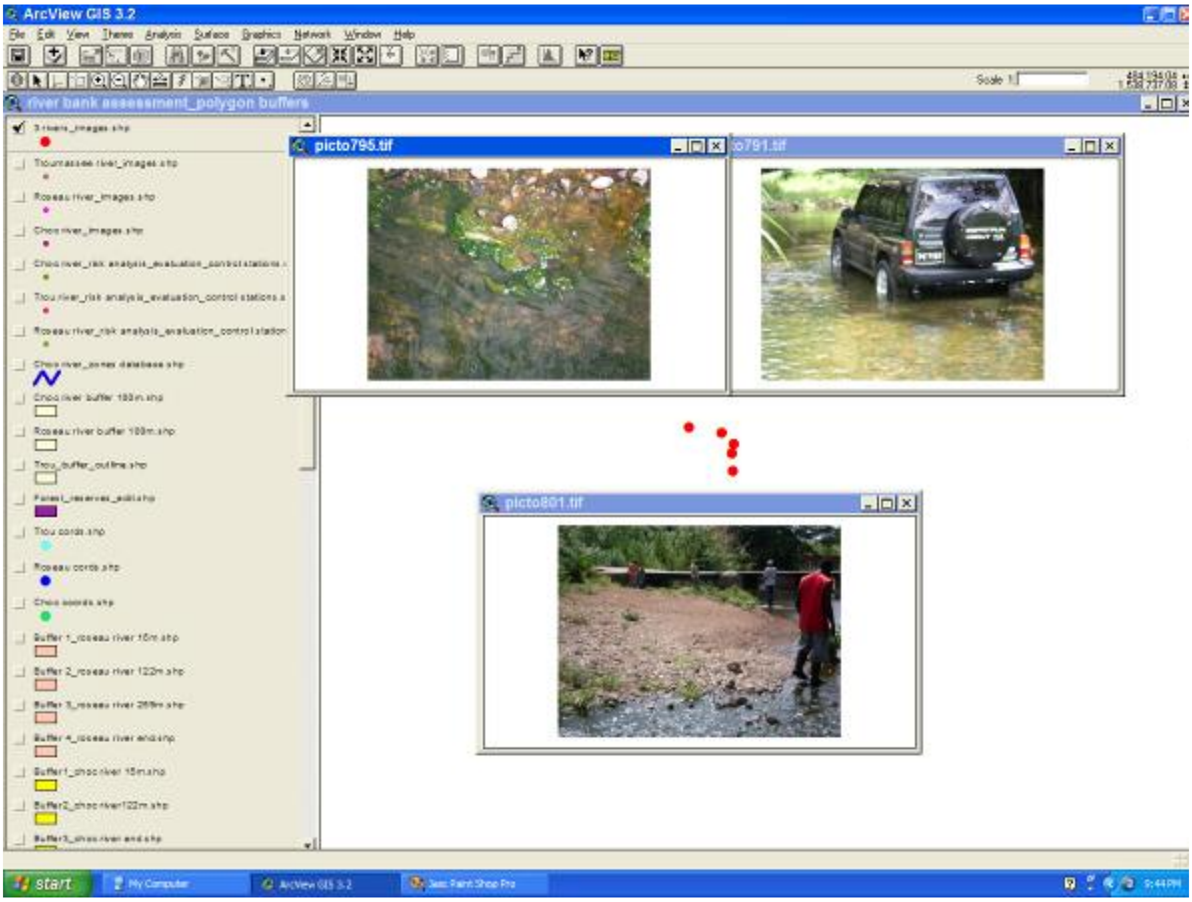


Figure 24: Pictorial Database of Control Points (2)

5.2.2 Data Catalogue

DIRECTORY

1	**SHAPEFILES**
2	**HOT LINK**

(A) SUB DIRECTORY- SHAPEFILES

1	**3 RIVERS_LANDUSE 2004**	2004 Landuse for each river
2	**3 RIVERS_MAIN DATABASE**	Main Databases showing Risk Analysis and Evaluation
3	**RIVER SEGMENTS_BUFFER POLYGON**	River Segments and Buffers based on Zones: Zones are 15m, 122m, 259m
4	**CHOC**	(a) Choc Main River (b) Choc River 50metre Buffer (c) Choc River Risk Analysis & Evaluation (d) Choc River Zones
5	**ROSEAU**	(a) Roseau Main River (b) Roseau River 50metre Buffer (c) Roseau River Risk Analysis & Evaluation (d) Roseau River Zones
6	**TROUMASSEE**	(a) Troumassee Main River (b) Troumassee River 50metre Buffer (c) Troumassee River Risk Analysis & Evaluation (d) Troumassee River Zones

FILESNAMES – SHAPEFILES:

1. 3 RIVERS: LANDUSE 2004

1	2004_Choc_landuse.shp	Landuse for 2004
2	2004_Roseau_landuse.shp	Landuse for 2004
3	2004_Troumassee_landuse.shp	Landuse for 2004

2. 3 RIVERS MAIN DATABASE: CHOC/ ROSEAU/ TROUMASSEE

1	3 rivers_50m buffer.shp	All 3 rivers with 50m buffer
2	3 rivers_risk analysis_evaluation_control stations.shp	All 3 rivers showing risk analysis and evaluation using control stations
3	3 rivers_zones.shp	All rivers showing zones

		Eg. 15m - coastal 122m – lower 259m – middle >259m - upper
4	3 selected rivers.shp	All 3 rivers for study

3. RIVER SEGMENTS/ BUFFER POLYGONS

CHOC
Buffer/ Polygons

1	coastal choc river polygon_15m.shp	Buffer polygon for coastal zone
2	lower choc river polygon_122m.shp	Buffer polygon for lower zone
3	middle choc river polygon_259m.shp	Buffer polygon for middle zone

River Segments

1	coastal choc river segment_15m.shp	River segment for coastal zone
2	lower choc river segment_122m.shp	River segment for lower zone
3	middle choc river segment_259m.shp	River segment for middle zone

ROSEAU
Buffer/ Polygons

1	coastal roseau river polygon_15m.shp	Buffer polygon for coastal zone
2	lower roseau river polygon_122m.shp	Buffer polygon for lower zone
3	middle roseau river polygon_259m.shp	Buffer polygon for middle zone
4	upper roseau river polygon.shp	Buffer polygon for upper zone

ROSEAU
River Segments

1	coastal roseau river segment_15m.shp	River segment for coastal zone
2	lower roseau river segment_122m.shp	River segment for lower zone
3	middle roseau river segment_259m.shp	River segment for middle zone
4	upper roseau river segment.shp	River segment for upper zone

TROUMASSEE
Buffer/ Polygons

1	coastal troumassee river polygon_15m.shp	Buffer polygon for coastal zone
2	lower troumassee river polygon_122m.shp	Buffer polygon for lower zone
3	middle troumassee river polygon_259m.shp	Buffer polygon for middle zone
4	upper troumassee river polygon.shp	Buffer polygon for upper zone

TROUMASSEE
River Segments

1	coastal troumassee river segment_15m.shp	River segment for coastal zone
2	lower troumassee river segment_122m.shp	River segment for lower zone
3	middle troumassee river segment_259m.shp	River segment for middle zone
4	upper troumassee river segment.shp	River segment for upper zone

4. CHOC

1	choc river_50m buffer.shp	Choc river with 50m buffer
2	choc river_risk analysis_evaluation_control stations.shp	Choc river showing risk analysis and evaluation using control stations
3	choc river_zones.shp	Choc river showing zones Eg. 15m - coastal 122m – lower 259m – middle >259m - upper
4	choc river.shp	Choc main river

5. ROSEAU

1	roseau river_50m buffer.shp	Roseau river with 50m buffer
2	roseau river_risk analysis_evaluation_control stations.shp	Roseau river showing risk analysis and evaluation using control stations
3	roseau river_zones.shp	Roseau river showing zones Eg. 15m - coastal 122m – lower 259m – middle >259m - upper
4	roseau river.shp	Roseau main river

6. TROUMASSEE

1	troumassee river_50m buffer.shp	Troumassee river with 50m buffer
2	torumassee river_risk analysis_evaluation_control stations.shp	Troumassee river showing risk analysis and evaluation using control stations
3	troumassee river_zones.shp	Troumassee river showing zones Eg. 15m - coastal 122m – lower 259m – middle >259m - upper
4	troumassee river.shp	Troumassee main river

(B) SUB DIRECTORY- HOT LINK

IMAGES

1	**CHOC**	Choc River Images (tiff files)
2	**ROSEAU**	Roseau River Images (tiff files)
3	**TROUMASSEE**	Troumassee River Images (tiff files)

SHAPEFILES

1	**CHOC**	Choc river_image.shp
2	**ROSEAU**	Roseau river_images.shp
3	**TROUMASSEE**	Troumassee river_images.shp

DATA DESCRIPTIONS FOR RISK EVALUATION

COLUMN NAME	DESCRIPTION	COLUMN NAME	DESCRIPTION
EASTINGS	*Geog. location*	WS_IMPACT	*Waste Pollution Impact*
NORTHINGS	*Geog. location*	BUILT_INFRA	*Built infrastructure*
DOM_SOL	*Dominant group*	BI_TSCORE	*Built infrastructure total score*
DS_TSCORE	*Dominant Soil Total score*	BI_RISK	*Built infrastructure risk*
DS_RISK	*Dominant Soil Risk*	BI_IMPACT	*Built infrastructure impact*
GRADIENT%	*Gradient*	WATER POLUTION	*Water pollution*
G_TSCORE	*Gradient Total score*	WP_TSCORE	*Water pollution Total Score*
G_RISK	*Gradient Risk*	WP_RISK	*Water pollution risk*
G_IMPACT	*Gradient Impact*	WP_IMPACT	*Water pollution impact*
LU_MANAGEMENT	*Landuse classes*	PHYSICAL CONDITION	*Physical condition*
LU_TSCORE	*Landuse Total score*	PC_TSCORE	*Physical condition Total score*
LU_RISK	*Landuse Risk*	PC_RISK	*Physical condition risk*
LU_IMPACT	*Landuse Impact*	PC_IMPACT	*Physical condition impact*
WASTE POLLUTON	*Waste pollution*	DESCRIPTION	*Location description*
WS_TSCORE	*Waste pollution score*	ZONE	*Location (height) within river*
WS_RISK	*Waste Pollution risk*	REACH	

5.2.3 Building Intelligence in Data Sets for Future Applications

The current application was conducted using the RRBA assessment method which uses a set of indicators and their strengths expressed as a score in relation to risk and impact. This intelligence needs to be built into the future datasets for other locations. This was done using a set of 'Look Up tables' in the GIS for the following variables.

Bio-Physical and Socio-Economic variables

- Landuse classes (15 types) and their assigned suitability classes of risk, impact and overall score (Appendix 9);
- Dominant soil types (49 types) and their assigned stability classes of risk, impact and overall score (Appendix 10);
- Gradient (3 levels) and their assigned classes of risk, impact and overall score (Appendix 11).

These will be contained in an Excel spreadsheet and will be joined to each new river buffer clip layer by a common identifier – dominant soil class for the Soils map; Landuse class name for the Landuse Map etc.

In so doing the impact, risk and overall scores will be automatically assigned to each layer.

5.3 Phase 3 – Stakeholder Consultations

In light of the main objective of selecting three key pilot rivers for detailed study, having duly considered the parameters for scoping and screening in the context of the profiling phase, and given the constraints of time and the limited availability of technical personnel at the Forestry Dept. at that time, it was deemed necessary to immediately engage the ATC, to discuss and confirm the proposed method and approach.

On 9 July 2008 a meeting of the ATC was convened at the Forestry Department, in compliance with the endorsed and adopted approach at the Project Inception Meeting. Appendix 6 includes the draft agenda and the list of participants in reference to it. The main objectives and conclusions/ outputs of this engagement are outlined in the box below.

Main Objectives

1) Re-affirmation of Client's objectives and expectations;
2) Clarification and endorsement of general method and approach;
3) Key stakeholders' participation (*some users and resource managers*) in the preliminary profiling exercise and the selection of the pilot rivers.

Main Conclusions

1. The ATC endorsed the general method and approach, including the use/selection of a few core parameters or category of a few risk factors for assessment, such as bio-physical factors, including land use and the associated management practices, socio-economic factors and environmental factors.
2. Endorsed the final selection of the pilot rivers – Roseau, Troumassee and Choc;
3. Consider the concern of water quality and water pollution monitoring by reviewing the utility of initiatives by the Water Resources Management Unit (WRMU), IWCAM Demo Project at Fond D'or, CEHI, WASCO, Ministry of Health, Hotel Sector, Dept. of Fisheries and that of any other relevant group/ agency. This is with the view of somehow incorporating the community in water quality and water pollution monitoring.
4. Within the general scope of this assignment it was not possible to model the proposed methodology; Indeed, it was necessary first to field test the methodology and subsequently develop over time the necessary monitoring regime and associated databases that may serve as baseline inputs in the future development of a model, which could serve as a useful time and cost-efficient tool in the management of the island's rivers.

Selected Rivers

The outputs of the inter-related activities in Phase 1 (Scoping/Screening) and Phase 3 (Stakeholder Consultation), have been summarized in the following table.

Table 12. Combined output of Scoping/Screening and Stakeholder Consultation on River Selection Process

River / location	Area (sq. km)	Main Aspects Highlighted		Comments
Choc West coast	12.7	Complex river system; relatively small drainage basin; diverse land uses and a wide variety of socio-economic activities; mixture of urban, peri-urban & rural livelihood systems	Agriculture, irrigation, light industry, construction, quarrying, settlements throughout, eco/tourism, commerce/ retail outlets, institutions, recreation, waste disposal facility,	Few designated conservation areas, mainly in lower & coastal areas; no major forest reserve;
Roseau West coast	49.1	Largest river basin in St. Lucia; main source of water supply for northern communities; primarily agricultural-based (*banana & non-*	Agriculture, water supply, including significant storage infrastructure (*John Compton Dam*), (*irrigation - IMU dam*), light industry/ manufacturing, construction, quarrying, satellite settlements/ communities,	Significant designated forest reserve, conservation/ protected areas, mainly for water supply & biodiversity management (Parrot

		banana), with other diverse, less extensive socio-economic activities; primarily rural-based livelihood systems;	eco/tourism, commerce/ retail outlets, institutions, recreation,	sanctuary) mainly in mid-upper water catchment zones ;
Troumassee East coast	31.7	Second largest river basin in St. Lucia; source of water supply for some east-bound communities; primarily agricultural-based (*mainly banana in lower & coastal zones*), with other socio-economic activities; primarily rural-based livelihood systems; low density	Agriculture, water supply, quarrying, low density satellite settlements/communities, eco/tourism,	Significant designated forest reserve, conservation/ protected areas, mainly for water supply & biodiversity management, eco/ nature tourism mainly in mid - upper water catchment zones ;

		satellite communities;		

In the final analysis, the river courses selected as pilots, for more in depth assessment, were:

- **Choc** – River system noted for its complexity with respect to diverse social, economic and environmental significance at the national level- located in the north-west of the island; from the hinterland down to the coastal area, the river traverses several settlement centres, commercial, agricultural and a multiplicity of industrial areas (*of diverse activities, such as irrigation, quarrying, construction, manufacturing*), areas with major social institutions (*and associated physical infrastructure ~such as, roads/ highways*) and touristic developments (*including eco-tourism*).
- **Roseau** – River deemed to be of high national socio-economic significance: – particularly in agriculture and water supply, located in the western part of the island; this river is the primary source of the island's largest water supply infrastructure, which services nearly 50% of island's population and 80% of the national tourism plant (*and the related services*) located in the northwestern and northern corridors of St. Lucia; moreover, it houses within its upper zone the main sanctuary for the island's national bird, the St. Lucian Parrot, Amazona versicolor and supplies agricultural water to the cultivated lower and coastal zones.
- **Troumassee**[43] – River deemed to be of high national economic and environmental significance, located in the Eastern part of the island is also noted for its provision of water supply for domestic consumption and to the predominantly agricultural areas; it plays host to some of the most significant eco/ nature tourism developments and experiences on the island, including its role in sustaining the habitats of a variety of significant biodiversity.

[43] Pre-feasibility studies for the development of the south-eastern and southern water supply systems have targeted the Troumassee R. as the main system with the potential for development and exploration.

5.4 Phase 4 – Bank Condition Assessment

This phase involving the field-based data collection for River bank and Channel Assessment was central to the testing of the utility of the designed methodology, and important for facilitating any future modifications as deemed necessary.

This phase involved the design of the data collection form, the training and orientation of data collectors/ field officers (*who assisted in this assignment and could become part of a team to continue with future work on this exercise*) on the application of the developed methodology and the data collection procedures and guidelines, the field assessments of the selected reaches/ reference locations of the pilot rivers. The latter consisted of the field verification of collated secondary data (*primarily bio-physical data*), assessment of the prevailing physical conditions based on the provided options, procedures and guidelines provided in the form (Appendix 3) as outlined in sections 3 and 4 and the recording of photographic images of the observed conditions, as detailed below.

The outputs from this phase along with those from the stakeholder consultation process were all taken into consideration in the analysis of the data and information generated thus far, as well as that which was developed in phase 2 (Database Development and GIS Applications).

Listing of Locations of Field Assessment Inspection Sites

Inspection Site No:	***River***	***Zone***	***Reach***
1	Choc	coastal	1
2	Choc	coastal	2
3	Choc	lower	1
4	Choc	lower	2
5	Roseau	coastal	1
6	Roseau	coastal	2
7	Roseau	lower	1
8	Roseau	lower	2
9	Roseau	lower	2A
10	Troumassee	coastal	1
11	Troumassee	coastal	2
12	Troumassee	lower	1
13	Troumassee	lower	2

Tables 13 & 14 provide a summary of the raw data generated at the field level and extracted from the data collection forms.

Table 13. Summary of Field Observations for Three Pilot/Sample Rivers

ID	River	REACH	ZONE	Dominant Soil (stability)	GRADIENT (%)	Land Use/Management	SETTLEMENTS	Built Infrastructure	Pollution	Physical Conditions
1	T	1	Lower	Less Stable	0-5	Semi- Poor Cover/MM	Low Density	None (Within Buffer)	Industrial	Stable
2	T	2	Lower	Stable	0-5	Semi- Poor Cover/MM	Low Density	None (Within Buffer)	Industrial	Stable
3	T	1	Coastal	Unstable	0-5	Little/ No cover/PM	Low Density	None (Within Buffer)	Industrial/ Domestic	Unstable
4	T	2	Coastal	Less Stable	0-5	Little/ No cover/PM	Low Density	None (Within Buffer)	Industrial/ Domestic	Unstable
5	R	1	Coastal	Less Stable	0-5	Semi- Poor Cover/MM	Low Density	In Channel	Industrial/ Domestic	Unstable
6	R	2	Coastal	Unstable	0-5	Semi- Poor Cover/MM	Low Density	None (Within buffer)	Industrial/ Domestic	Unstable
7	R	1	Lower	Less Stable	0-5	Little/ No Cover/PM	Low Density	None (Within buffer)	Industrial	Stable
8	R	2	Lower	Less Stable	0-5	Semi- Poor Cover/MM	Low Density	In Channel	Industrial/ Domestic	Moderately Stable
9	R	2A	Lower	Less Stable	0-5	Semi- Poor Cover/MM	Low Density	None (Within buffer)	Industrial	Moderately Stable
10	C	1	Coastal	Less Stable	0-5	Semi- Poor Cover/MM	Moderately Dense	None (within Buffer)	Industrial/ Domestic	Unstable
11	C	2	Coastal	Less Stable	0-5	Semi- Poor Cover/MM	Low Density	In Channel	Industrial/ Domestic	Moderately Stable
12	C	1	Lower	Less Stable	0-5	Semi- Poor Cover/MM	Moderately Dense	None (within Buffer)	Industrial/ Domestic	Moderately Stable
13	C	2	Lower	Less Stable	0-5	Semi- Poor Cover/MM	Low Density	None (within Buffer)	Industrial/ Domestic	Moderately Stable

Table 14. Location and Description of Pilot Sites

ID	River	REACH	ZONE	LOCATION	EASTINGS	NORTHINGS
1	Troumassee	1	Lower	u/s Road Crossing	514371	1529002
2	Troumassee	2	Lower	u/s Mahaut Bridge- Bend	512723	1529962
3	Troumassee	1	Coastal	u/s Troumassee Bridge	518811	1527192
4	Troumassee	2	Coastal	Beauchamp Area - Bend	517407	1527847
5	Roseau	1	Coastal	u/s Roseau Bridge	505865	1542576
6	Roseau	2	Coastal	u/s Irrigation Management Unit's/Dam	508176	1542197
7	Roseau	1	Lower	u/s Vanard Bridge	509033	1541382
8	Roseau	2	Lower	Upper Vanard- Near Health Centre	508946	1540752
9	Roseau	2A	Lower	u/s Millet - Durandeau	508984	1539462
10	Choc	1	Coastal	u/s Near Caribbean Metals Bridge	511757	1550922
11	Choc	2	Coastal	Near Union Agric Pump Station	512019	1550530
12	Choc	1	Lower	u/s Morne Du Don/ Balata Bridge	512367	1549056
13	Choc	2	Lower	u/s Cacao/ Girard Bridge	512113	1548056

The following compilation, Table 15 provides a summary of the key findings and observations made during the field-based exercises. The summary incorporates the field-based assessments[44] along with other site-related observations made by the assessing officers[45], including the raw photographic images/ footage.

Also, Appendix 12 – Photo Cache of Pilot Rivers and Other Rivers depicts other observations made during the initial reconnaissance surveys of changes to physical conditions within coastal and lower zones of the three pilot rivers and some of the main rivers around the island.

[44] Field assessments were effected during the period 28 – 31 July 2008, which was preceded by a half day field orientation exercise on 23 July 2008. See Appendix 1 for a listing of the participating officers.

[45] All the officers involved have had several years of practical and technical field-based experience.

Table 15. Summary of Findings from Field Assessments of Selected Pilot River Reaches/ Reference Locations.

<u>Choc River</u> Zone 1: Coastal			
Reach 1 (near Caribbean Metals) **Average Bed Width (m)** **Average Channel Width(top)(m)** **Average Depth (m)** **Channel Bed Grad. (%)** 		12.5 16.75 4.3 1.1 %	**<u>Riverbanks</u>** Scattered and poorly managed tree crops on banks; stockpiles of metal scraps/derelict vehicles & metal scraps on southern bank. Much debris and solid waste on southern bank, which is more prone to flooding. **<u>Channel.</u>** Low velocity flow; highly turbid river water, silty, with some debris deposits. **<u>Other</u>** Quarry operations upstream & other commercial outlets nearby, partly within buffer; few households within south bank buffer area, others nearby; **<u>General Susceptibility Assessment:</u>** *Bio-Physical*:- **High**; actively eroding soils on riverbanks; fairly flat bed gradient facilitates deposition of sediments; poor/ inadequate land use/ management practices lend to a high threat level; *Socio-Economic*- **Medium/Moderate,** primarily due to industrial & to a lesser extent domestic wastes discharges/ disposal. *Environmental*:- **very High**, jointly contributed by polluting activities, e.g poor wastes disposal,

			siltation, runoff from adjacent lands with diverse and intense uses and poorly managed physical state of the river.
 **Reach 2 (Union Agricultural Pump Station)** **Average Bed Width (m)** **Average Channel Width(top)(m)** **Average Depth (m)** **Channel Bed Grad. (%)** 		6.7 16.8 3.85 1.5 %	**<u>Riverbanks</u>** Actively unstable banks; *South Bank*:- Forest species planted; good cover provided, but some scouring exist; *North Bank*:- location of farm fence & pumping facility- p/house and intake infrastructure. **<u>Channel</u>** Irrigation water facility and intake structure. Very turbid flows; silt deposits & sediment bars observed; **<u>Other</u>** Union Agricultural Station located on North bank and forest plantation on South bank. Settlements, commercial/ retail outlets & institutions within the drainage area. **<u>General Assessment:</u>** Bio-Physical: **high**; actively eroding soils on riverbanks, especially on north bank, which contributes to (visually) very high sediment load and turbidity; also industrial activity & to a lesser extent domestic wastes discharges/ disposal; fairly flat bed gradient facilitates deposition of sediments; poor/ inadequate land use/ management practices lend to a high threat level; *Socio-Economic-* **Medium/Moderate,** primarily due to industrme built infrastructure within

 **<u>Recommendations Zone 1 (continued)</u>** *b) need for a routine river zonal maintenance & management programme.* c) *a detailed baseline study of current land use and management practices, to inform the need for more stringent monitoring & where necessary enforcement of existing regulatory requirements or the development of appropriate regulatory framework.* d) *with the generation of new information, new and relevant public awareness and education tools and media should be developed/ designed to solicit and facilitate the more active role of identified influential key stakeholders to contribute towards the effective management of core issues of concern.*			the assessed location facilitates sedimentation and physical degradation/ bank erosion. *Environmental*:- **High**, jointly contributed by polluting activities, e.g agricultural activities, poor/ unregulated wastes disposal, siltation/ sedimentation, runoff/ discharges from adjacent lands with diverse and intense uses and poorly managed physical state of the river. **<u>Zonal Assessment:</u>** High levels of exposure to degradation, primarily due to Bio-Physical pre-dispositions and contributing socio-economic & environmental factors. **<u>Recommendations (Zone 1</u>**):- a) given the increasing urbanization and the touristic developments within the coastal areas: R*esearch on the current situation/ fate of municipal, agricultural & other industrial wastes generated within this zone is necessary, to inform and guide the design of future management interventions.*

Choc River **Zone 2-Lower** **Reach No.1 (upstream Morne Du Don/Balata Bridge)** **Average Bed Width (m)** **Average Channel Width (top)** **Average Depth (m)** **Channel Gradient. (%)**  	5.2 7.8 2.7 1.2 %	**Riverbanks** Banks are moderately stable, clayey soil material; some tree crops and 'opportunistic' species provide moderate cover and protection to banks; some signs of cattle grazing; households nearby on both banks, but low density; secondary forest vegetation provide some stability; some scouring on south bank; north bank more prone to flooding. **Channel** Pronounced sedimentation; gravelly and stony bed material; Very turbid flows; silt deposits & sediment bars observed. **General Assessment;** *Bio-Physical*:- **High**; actively eroding soils on riverbanks, despite moderate stability; fairly flat bed gradient facilitates deposition of sediments, especially the coarser material; inadequate land management practices contribute to a degrading condition; *Socio-Economic-* **Medium/Moderate,** primarily due to a low level of industrial activity & to a lesser extent domestic wastes discharges. No built infrastructure within buffer area or channel; *Environmental*:- **High**, jointly contributed by polluting activities, primarily 'heavy' sediment loads, high turbidity, runoff from adjacent lands and poorly managed physical state of the river.

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>Reach No.2 (upstream Girard-Cacoa bridge):
Average Bed Width (m)
Average C/Width (m)
Average Depth (m)
Channel Gradient. (%)

</td><td>6.55
12.2
3.3
1.4 %</td><td><u>Riverbanks</u>
Banks moderately stabilised with secondary forests species; Settlements on both banks, but low density & outside 50m assessed buffer; low intensity agricultural cultivations; no signs of grazing; North bank more prone to flooding; generally steeper banks.
<u>Channel</u>
Moderate levels of sedimentation; some stones and boulders in channel; some debris present; scouring and undercutting of bank side slopes.
<u>General Assessments:</u>
Bio-Physical:- High; actively eroding, moderately stable clayey soils on riverbanks; inadequate land management practices in a more rugged and steep environment contribute to a high susceptibility level;
Socio-Economic- Medium/Moderate, primarily due to a low level of industrial activity & domestic wastes discharges. No built infrastructure within assessed location;
Environmental:- High, jointly contributed by polluting activities,</td></tr>
</table>

 		primarily sediment loads, moderate level of turbidity, runoff from adjacent lands and inadequately managed physical state of the river, with debris serving as medium diverting flows which cause further erosion. Note: the *boulders and stones play an important role in improving water quality and tempering the velocity of flows in the river.* **<u>Zonal Assessments</u>** High susceptibility levels – Environmental and Bio-Physical factors; related to in particular soil and bank stability and Land Management practices. **Recommendations:** *a) need for a routine river zonal maintenance & management programme.* c) *a detailed baseline study of current land use and management practices, to inform the need for more stringent monitoring & where necessary enforcement of existing regulatory requirements or the development of appropriate regulatory framework.*

Roseau River

Zone 1: Coastal

Reach No.1 (u/s Roseau Bridge)

Average Bed Width(m)	14.7
Average Channel Width (top)(m)	20.8
Average Depth (m)	4.4
Channel Bed Gradient. (%)	1.4

Riverbanks

Banks' side slopes covered with very dense "Roseau Cane" grass, providing effective surface cover and effective bind of soil particles with fibrous root matting; banana cultivation on south bank; vegetable cultivation on north bank;

Channel

Highly turbid river flows; pronounced silt bars at bridge; no significant debris observed.

General Assessment:

Bio-Physical – ***High***; moderate soil stability; mainly a fine sandy clay loam, which is easily dislodged and eroded with some exposure or physical disturbance, which contributes to very high sediment load and turbidity; fairly flat bed gradient facilitates deposition of sediment loads from upstream; inadequate land use/ management practices, with some cultivations well within buffer; bank side slopes fairly

well protected by pseudo-perennial grasses.

Socio-Economic- **Medium/Moderate,** primarily due to agricultural activity, which dominates the surrounding environment and lends to physical degradation/ bank erosion due to poor land management measures.

no significant built infrastructure

		within the assessed location; *Environmental*:- **High**, jointly contributed by polluting activities, e.g – poorly managed agricultural activities, poor/ unregulated wastes disposal, soil/ bank erosion, siltation/ sedimentation, runoff/ discharges from adjacent lands and to a lesser extent other diverse uses, such as construction activities and the lack of management of the physical state of the river.
Reach No.2 (upstream IMU Dam) **Average Bed Width (m)** **Average Channel Width (top)(m)** **Average Depth (m)** Channel gradient – not measured  	 10.2 23.1 1.8	**Riverbanks** banana cultivations on both banks within buffer; Banks' side slopes covered with very dense "Roseau Cane" grass; access across river channel; south bank more prone to flooding; North Bank with steeper side slopes; irrigation infrastructure in the vicinity installed within channel and across banks. **Channel** Pronounced algal blooms, stony and gravelly bed material; vehicle access across channel. **General Assessment:** Bio-Physical: **high**; silty clay loam soils of moderate stability; despite some bank side slope protection, erosion continues in an active mode on riverbanks and in channel from upstream; high sediment and nutrient content, an indicator of the impact of agricultural activity and the extent of discharges from cultivated fields, resulting in deteriorating river water quality, manifested by the pronounced algal blooms ~ an indication of progressing eutrophication; fairly flat bed gradient facilitates deposition of sediments; poor/ inadequate land use/ management practices lend to a high susceptibility level to degradation; *Socio-Economic*- **Medium/Moderate,** primarily due to low non-agricultural industrial activity and no significant built infrastructure within the assessed location; sedimentation and physical degradation may be affected by on-

Recommendations *a) need for a routine river zonal maintenance & management programme.* b) *a detailed baseline study of current land use and management practices, to inform the need for more stringent monitoring & where necessary enforcement of existing regulatory requirements or the development of appropriate regulatory framework*. c) *with the generation of new information, new and relevant public awareness and education tools and media should be developed/ designed to solicit and facilitate the more active role of identified influential key stakeholders to contribute towards the effective management of core issues of concern.* d) R*esearch on the current situation/ fate of agricultural & other wastes generated within this zone is necessary, to inform and guide the design of future management interventions.*		going drainage basin-wide detrimental discharges from surrounding satellite settlements, including poorly managed household and subsistence-based hillside agricultural activity. *Environmental*:- **High**, jointly contributed by polluting activities, e.g agricultural activities, poor/ unregulated wastes disposal, siltation/ sedimentation, runoff/ discharges from adjacent upstream drainage areas, lack of routine management of physical state of the river. ; **General Zonal Assessments:** High susceptibility levels to Bio-Physical and Environmental factors - primarily to moderate condition of soil erodibility properties, inadequate land management practices, including wastes discharges (agricultural in particular), contributing to high nutrients loads, which eventually lead to deteriorating water quality; vehicular access encourages/ facilitates other detrimental activities which can impact on river stability.

<table>
<tr><td colspan="3"><u>Roseau River</u></td></tr>
<tr><td colspan="3"><u>Zone 2:Lower</u></td></tr>
<tr><td>Reach No.1(Vanard Bridge)
Bed Width (m)
Channel Width (top)(m)
Depth (m)
Bed Slope (%) – not measured, but


</td><td>
17.65
18.9
1.6
<5</td><td><u>Riverbanks</u>
Banana cultivations on both banks, within buffer; No signs of livestock rearing/grazing; ‘patchy’ vegetal cover on bank side slopes; main drain discharging into channel.
<u>Channel</u>
Pronounced sedimentation (observed ‘bars’ and ‘islands’); stony bed material; Pronounced algal blooms; stony and gravelly bed material;
<u>General Assessment:</u>
Bio-Physical: high; silty and sandy clay material of moderate stability; limited bank side slope protection exposes banks to active erosion; high sediment load and nutrient content, an indicator of the impact of agricultural activity and the extent of discharges from cultivated fields nearby, resulting in deteriorating river water quality, manifested by the pronounced algal blooms ~ an indication of progressing eutrophication; fairly flat bed gradient facilitates deposition of sediments and gravelly material; poor/ inadequate land use/ management practices in surrounding lands upstream lend to a high susceptibility level to degradation;
from adjacent lands and to a lesser extent other diverse uses
Socio-Economic-
Medium/Moderate, primarily due to agricultural activity, which dominates the surrounding environment and lends to physical degradation/ bank erosion due to poor land management measures;</td></tr>
</table>

		no significant built infrastructure within the assessed location; *Environmental*:- **High**; jointly contributed by polluting activities, e.g. – poorly managed agricultural activities, poor/ unregulated wastes disposal, soil/ bank erosion, siltation/ sedimentation, runoff/ discharges, such as construction activities and the lack of management of the physical state of the river.
Reach No.2 (Upper Vanard, segment near Health Centre) **Average Bed Width (m)** **Average Channel Width (m)** **Average Depth (m)** **Average Bed Gradient. (%)**  	 ~12 ~19 ~2 <5%	**<u>Riverbanks</u>** Scouring on south bank; Boulder "*rip-rap*" in place, as part of earlier bank stabilization works, but poorly constructed & maintained; banana cultivation and some scattered tree crops on both banks; side slopes moderately covered with Roseau cane grass; no built infrastructure; **<u>Channel</u>** Northern side of channel heavily silted, with gravelly sediment 'bars'. Evidence of significant previous channel bed erosion overtime (*layered profile*); stony and gravelly bed material; existing vehicular access across channel; **<u>General Assessments</u>** Bio-Physical: **high**; silty clay soil, with gravelly and stony material; despite moderate bank side slope protection, bank erosion seems to be in active mode; high sediment and nutrient content, though appears to be much reduced given reduced level of 'blooms', an indicator of the impact of nearby agricultural activity and the extent of wastes discharges from cultivated fields, resulting in deteriorating river water quality, ~ an indication of progressing eutrophication; fairly flat bed

		gradient and river morphology facilitate deposition of sediments; this site seems to have been repaired after severe storm damage previously; poor/ inadequate land use/ management practices lend to a high susceptibility level; **General Assessments** (cont'd) *Socio-Economic-* **Medium/Moderate,** primarily due to agricultural activity, which dominates the surrounding environment and lends to physical degradation/ bank erosion due to poor land management measures; no significant built infrastructure within the assessed location; vehicular access can facilitate further degradation; *Environmental*:- **High**; jointly contributed by polluting activities, e.g – poorly managed agricultural activities, poor/ unregulated wastes disposal, soil/ bank erosion, siltation/ sedimentation, other runoff/ discharges, such as construction activities and the lack of management of the physical state of the river.
Reach 2A (Millet) **Average Bed Width (m)** **Average Channel Width (m)** **Average Depth (m)** **Average Channel Bed Gradient. (%)**	 16.2 19.8 2.1 1.3	**Riverbanks** Tree crops cultivation (e.g. - coconuts, mangoes); south bank more prone to flooding; higher and steeper side slopes on north bank. No signs of livestock grazing/rearing; **Channel** Stony bed material; pronounced sediment bars and algal blooms; evidence of easy vehicular access ~ *vehicle washing*; some debris in the channel; **General Assessment:** Bio-Physical: **high**; heavy textured clayey soils of moderate

  		stability; despite some bank side slope protection erosion mode remains active on riverbanks and in channel; high sediment and nutrient content, an indicator of the impact of agricultural activity and the extent of discharges from cultivated fields, resulting in deteriorating river water quality, manifested by the pronounced algal blooms ~ an indication of progressing eutrophication; fairly flat bed gradient facilitates deposition of gravelly sediments and stony material; poor/ inadequate land use/ management practices lend to a high susceptibility level; *Socio-Economic-* **Medium/Moderate,** primarily due to agricultural activity, which dominates the surrounding environment and lends to physical degradation/ bank erosion, due to lack of effective land management measures; no significant built infrastructure within the assessed location; *Environmental*:- **High**, jointly contributed by polluting activities, e.g. – *poorly managed agricultural activities*, poor/ unregulated wastes disposal, soil/ bank erosion, siltation/ sedimentation, runoff/ discharges from adjacent lands and to a lesser extent other diverse uses, such as vehicle washing and the lack of management of the physical state of the river. **<u>General Zonal Assessments</u>** High levels of exposure recognised, contributed mainly by bio-physical pre-dispositions and on-going practices/ activities which contribute to worsening pollution levels and environmental conditions. **<u>Recommendations</u>**

		*Similar to zone 1.*
River: Troumassee **Zone: 1 - Coastal** **Reach 1, upstream Troumassee Bridge** **Average Bed Width (m)** **Average Channel Width (top)(m)** **Average Depth (m)** Channel gradient (%) 	 19.7 25.8 2.6 4	**Riverbanks** South bank – active scouring; intensive banana cultivation; North bank – more prone to flooding; scattered mix of tree crops and forest spp., bamboo clusters; livestock grazing; near vertical/ steep & unstable side slopes in some places; **Channel**: Pronounced sedimentation bars & algal blooms; evidence of active river sand/ gravel mining; access to channel & vehicle washing; **General Assessments**: *bio-physical* – **High;** loamy soils **;** moderate soil erodibility level; river bed appears unstable, affected by multiple, unregulated uses; very poor land use & management practices; *Socio-Economic-* **Medium/Moderate;** primarily due to agricultural activity, which dominates the surrounding environment and other diverse & direct in-channel interventions, which lend to physical degradation/ bank erosion; also due to lack of regulated and effective land management measures/ practices; no settlements in the immediate vicinity/ buffer area; no significant built infrastructure within the assessed location; *Environmental*:- **High**, jointly contributed by polluting

		activities, e.g – *poorly managed agricultural activities*; poor/ unregulated wastes disposal; soil/ bank erosion, siltation/ sedimentation, runoff/ discharges from adjacent lands and other diverse, unregulated and direct detrimental uses, such as vehicle washing, sand mining; and, the lack of management of the physical state of the river.
		

		
River: Troumassee **Zone: 1 - Coastal** **Reach 2, Beauchamp** **Average Bed Width (m)** **Average Channel Width (top)(m)** **Average Depth (m)** Channel gradient (%) 	 15.9 20.5 2.15 3	**<u>Riverbanks</u>** Intensive agricultural cultivations on both banks, with some mahogany, Melina, 'khus khus' grass; signs of cattle grazing; motoring access to channel; South bank – scouring; north bank – very little side slope protective cover; **<u>Channel</u>**: Stony riverbed; evidence of vehicle washing, garbage disposal & sand mining; Pronounced sediment & stony 'bars'; presence of algal blooms; **<u>General Assessments:</u>** *bio-physical* – **High;** loamy alluvial soils **;** moderate soil erodibility level; river bed appears unstable, affected by multiple, unregulated uses; poor land use & management practices; *Socio-Economic-* **Medium/Moderate;** primarily due to agricultural activity, which dominates the surrounding environment and other diverse & direct in-channel interventions, which lend to physical

 		degradation/ bank erosion; also due to lack of regulated and effective land management measures/ practices; no settlements in the immediate vicinity/ buffer area; no significant built infrastructure within the assessed location; *Environmental*:- **High**, jointly contributed by polluting activities, e.g. – *poorly managed agricultural activities*; poor/ unregulated wastes disposal; soil/ bank erosion, siltation/ sedimentation, runoff/ discharges from adjacent lands and other diverse, unregulated and direct detrimental uses, such as vehicle washing, and the general lack of management of the physical state of the river.  **<u>General Zonal Recommendations</u>** *a) need for a routine river zonal maintenance & management programme.* b) *a detailed baseline study of current land use and management practices, to inform the need for more stringent monitoring & where necessary enforcement of existing regulatory requirements or the development of appropriate regulatory framework.* c) *with the generation of new information, new and relevant public awareness and education tools and media should be developed/ designed to solicit and facilitate the more active role of*

		identified influential and other key stakeholders to contribute towards the effective management of core issues of concern. d) *Research on the current situation/ fate of agricultural & other wastes generated within this zone is necessary, to inform and guide the design of future management interventions.*
River: Troumassee **Zone: 2 – Lower** **Reach 1, Moreau** **Average Bed Width (m)** **Average Channel Width (top)(m)** **Average Depth (m)** Channel gradient (%)  	 19.5 27.55 1.4 1	**Riverbanks** Mixed tree crops cultivated on banks, but not in a structured manner (e.g. -*coconut, mango, breadfruit*), bamboo clusters; North bank – very stony constitution; limited protective vegetative cover; **Channel**: Pronounced sediment and stony 'bars'; algal blooms; very stony riverbed; many boulders; litter, mainly polythene bags; flow diversion and meandering due to stone & sediment bars; **Other**: Quarry ~ about 200m above river stretch on south bank; evidence of landslides & bank slips in the vicinity; no intensive cultivations or animal grazing; **General Assessments:** *bio-physical* – **High;** loamy alluvial soils **;** moderate soil erodibility level; river bed appears unstable, affected by multiple, unregulated uses; poor land use & management practices; *Socio-Economic-* **Medium/Moderate;** primarily due to agricultural activity, which dominates the surrounding environment and other diverse & direct in-channel interventions, which lend to physical degradation/ bank erosion; also

		due to lack of regulated and effective land management measures/ practices; no settlements in the immediate vicinity/ buffer area; no significant built infrastructure within the assessed location; *Environmental*:- **High**, jointly contributed by polluting activities, e.g. – *poorly managed agricultural activities*; poor/ unregulated wastes disposal; soil/ bank erosion, siltation/ sedimentation, runoff/ discharges from adjacent lands and other diverse, unregulated and direct detrimental uses, such as vehicle washing, and the general lack of management of the physical
River: Troumassee **Zone: 2 – Lower** **Reach 2, upstream Mahaut Bridge** **Average Bed Width (m)** **Average Channel Width (top)(m)** **Average Depth (m)** Channel gradient (%)  **<u>General Zonal Recommendations</u>** *a) need for a routine river zonal monitoring programme, to inform any necessary mitigation interventions.*	 12 15.7 1.15 4	**<u>Riverbanks</u>** North bank:- Flood prone stretch; sparse distribution of forest trees bamboo clusters; South bank: – banana cultivation; no signs of livestock rearing/ grazing; no major infrastructure; **<u>Channel</u>**: Very stony, with huge boulders; agricultural wastes/ litter; some debris ~ e.g. tree trunks; generally free and steady flows; **<u>General Assessment:</u>** *bio-physical* – **High;** clayey soils**,** moderate soil erodibility level; stony channel, with huge boulders, which help to improve water quality and manage faster flows**;** river bed appears relatively stable, compared to lower river segments ~ *not severely affected by multiple uses*; land use & management practices can be improved; *Socio-Economic-* **Medium/Moderate;** primarily due to agricultural activity, which dominates the surrounding environment, which lend to some

		physical degradation/ bank erosion ~ litter; also due to lack of more effective land management measures/ practices; no settlements in the immediate vicinity/ buffer area; no significant built infrastructure within the assessed location; *Environmental*:- **High**; contributed by polluting, *poorly managed agricultural activities*; poor/ unregulated wastes disposal; soil/ bank erosion appears to be normal, with remnants of severe degradation caused by previous storm events; in channel siltation/ sedimentation not significant; **<u>General Zonal Assessment</u>**: susceptibility levels range from medium to high, with bio-physical and environmental factors posing the highest threat; primary concern being soil erodibility and land use/ management practices ~ e.g. *bed erosion & bank instability*; 

5.5 Phase 5 – Data Analysis and Interpretation

The first output of this phase, with respect to the development of the methodology, i.e. the Flow Chart outlining the steps used in the RRA methodology which ultimately lead to the determination of the **Susceptibility Index**, ***Si,*** for each broad category of factors is provided in Appendix 5.

The outputs of this phase of the RRA are presented based on each step within the phase. The analyses of the findings are further elaborated in Section 6 of the report– "Analysis and Recommendations".

Step 1 - Riverbank and Channel Risk Assessment

Table 16. Scoring Matrix for "Impact" Factor**, to Score Collated Data and Field Assessed Selections.**

Factor	Low (1)	Medium (2)	High (3)
Bio-physical			
Dominant Soil Material			
• stable Soil	1		
• less stable		2	
• unstable/ fragile			3
Ave. channel grade			
• <5%	1		
• >5% -10%		2	
• >10%			3
Land Use/ Management Practices**			
- Perm. Cover/ Good Mngt	1		
- Semi-perm cover/ mod. Mngt		2	
- Little/no cover/ poor mngt.			

3

Socio-Economic
Settlements:
- low density;
- mod. density; 1
- high density; 2

3

Built infras.
- none/within buffer;
- in channel; 1
- both channel & buffer;

2

3

Environmental
Pollution sources:
- none/ domestic;
- industrial; 1
- both;

2

Physical Conditions of channel: 3
- stable;
- mod. Stable;
- unstable;

1

2

3

Qualification of Impact	**Low**	**Medium**	**High**
Loss of Function	Reduction in service provision (or some services)	Serious Reduction or Total Loss of Services temporarily	Complete Loss of Services
Duration of Impact	Recovery of services within 6 months	Recovery of services between 6 months to 1 year	Recovery of services beyond 1 year
Extent of Impact	Periodic or limited	Moderate Impact	Severe Impact

Note: Services or function refer to social, economic and environmental services (e.g. *recreation*, *water supply*, *support of ecosystems/habitats (ecological services)*, etc.)

** ~ Also see Table 17 below, which categorises/ groups land use classes as per 1992 classification system.

Table 17. Grouping of 1992 Land Use Classes

Permanent Cover/ Good Management	**Semi-permanent cover/ moderate Management**	**Little/no cover/ poor management.**	**Not applicable**
1. Densely vegetated farming; 2. Grasslands & open woodlands; 3. Mangrove; 4. Natural tropical forest; 5. Plantation forest;	1. Flatland intensive farming; 2. Intensive farming (25% forest); 3. Mixed farming (forest/ intensive farming); 4. Rural settlement; 5. Scrub forest;	1. Eroded agricultural land; 2. Rock & exposed soil; 3. Urban settlement;	water

Table 18. Allocation of Scores to Established 1992 Land Use Classes

Description	Allocation of Scores - 1992 Land Use Classification		
	High	Medium	Low
Water	n/a	n/a	n/a
Densely Vegetated Farming			1.00
Eroded Agricultural Land	3.00		
Flatland Intensive Farming		2.00	
Grasslands and Open Woodlands			1.00
Intensive Farming (25%Forest)		2.00	
Mangrove			1.00
Mixed Farming (Forest/Intensive Farming)		2.00	
Natural Tropical Forest			1.00
Plantation Forest			1.00
Rock and Exposed Soil	3.00		
Rural Settlement		2.00	
Scrub Forest		2.00	
Urban Settlement	3.00		

Table 19. Scoring Matrix for "Probability/Risk" Factor

Factor	Low (1)	Medium (2)	High (3)
Bio-physical			
Dominant Soil Material			
• stable Soil	1		
• less stable		2	
• unstable/ fragile			3
Ave. channel grade			
• <5%	1		
• >5% -10%		2	
• >10%			3
Land Use/ Management Practices**			
- Perm. Cover/ Good Mngt	1		
- Semi-perm cover/ mod. Mngt		2	
- Little/no cover/ poor mngt.			

			3
Socio-Economic			
Settlements:			
- low density;			
- mod. density;	1		
- high density;		2	
			3
Built infras.			
- none/within buffer;			
- in channel;	1		
- both channel & buffer;			
		2	
			3
Environmental			
Pollution sources:			
- none/ domestic;			
- industrial;	1		
- both;			
		2	
Physical Conditions of channel:			3
- stable;			
- mod. Stable;			
- unstable;			
	1		
		2	
			3

(Use to score collated data and field assessed selections).

<u>Considerations in the determination of the "Threat" Factor scores (likelihood of impact</u>)

The "threat" factor is calculated by the following formula:

Threat = {1 + (probable speed of impact) + (probable duration of impact) + (probable lag time for impact)}.

Where each of the noted variables are classified accordingly:

Speed	duration	Lag time
0 – slow;	0 – short;	0 – long;
1 – medium;	1 – medium;	1 – medium;
2 – fast;	2 - long	2 – short/ no time

A desk-based analysis was undertaken to pre-determine/ calculate the possible score per each possible assessed option per assessed risk factor. For example, for a selection of "stable soil" under the dominant soil factor, the calculation was as follows:

		consideration
probable speed of impact score = 0	= "slow"	Under "normal conditions"**, soil particle dislodgement is slow.
probable duration of impact score = 2	= "long"	Takes relatively longer to erode
probable lag time for impact score = 0	= "long"	Takes relatively longer for dislodgement & significant erosion to occur

** In comparison to extreme climatic or weather conditions.

Calculated threat = {1 + 0 + 2 + 0} = **3 (***see table 18, with scoring method below***).**

Similar procedures and analyses were undertaken to determine the scores in the following table.

Table 20. Matrix of Calculated Scores for "Threat**" Factor**

Factor	Low (1)	Medium (2)	High (3)
Bio-physical			
Dominant Soil Material			
• stable Soil	3		
• less stable		5	
• unstable/ fragile			7
Ave. channel grade			
• <5%	3		
• >5% -10%		5	
• >10%			7
Land Use/ Management Practices**			
- Perm. Cover/ Good Mngt	1		
- Semi-perm cover/ mod. Mngt		4	
- Little/no cover/ poor mngt.			

7

Socio-Economic
Settlements:
- low density;
- mod. density; 1
- high density; 4

7

Built infras.
- none/within buffer;
- in channel; 1
- both channel & buffer;

4

7

Environmental
Pollution sources:
- none/ domestic;
- industrial; 1
- both;

5

Physical Conditions of channel: 7
- stable;
- mod. Stable;
- unstable;

1

4

7

See also Table 22, which outlines the rationale for the calculations for the respective variables and the threat score.

Table 21. Template - Ranking of Susceptibility Index, Si, per Category of Factors.

River Zone reach	Bio-physical				Socio-economic			Environmental			comments
	Dom. soil	Bed grade	Land use	Si	Settlement	infras	Si	Pollution	Physical Condition	Si	
1.	H	L	H	H	L	L	M	H*	H	H*	*Very High ranking

H – *Refers to High*; H* - *very high ranking*; M – *Medium*; L – *Low.*

Table 22. Determination of Threat Scores

Threat Formula = [1+(***probable speed or frequency of impact/event***) + (***probable duration of impact***) + (***probable lag time of impact***)]

Variables	***Speed***	***duration***	***Lag time***
	0 – slow; *1 – medium;* *2 – fast;*	*0 – short;* *1 – medium;* *2 - long*	*0 – long;* *1 – medium;* *2 – short/ no time*

Category: **Bio-physical** Factor:- *Dominant soil(s)*	Variables + scores assigned	Considerations + Interpretation of scores	Threat score	Comment
Stable	Speed/Freq= *slow* (0)	More resistant to detachment	(1+0+2+0)	Analysis & interpretations are limited to the *"system"* under consideration, i.e. – *"river channel + riverbanks, with 50 m buffer"* (each side)
	Duration=*long* (2)	Once detached, impacts are likely long term	**(3)**	
	Lag time=*long* (0)	Higher resistance, active erosion process takes longer to develop.		
Less stable	Speed/Freq=*med.* (1)	Less resistant to detachment	(1+1+2+1)	
	Duration=*long* (2)	Once detached, impacts are likely long term	**(5)**	
	Lag time=*med.* (1)	Less resistance, active erosion process develops sooner		
Unstable/Fragile	Speed/Freq=*fast* (2)	Least resistant to detachment	(1+2+2+2)	
	Duration=*long* (2)	Once detached, impacts are likely long term	**(7)**	
	Lag time=*short* (2)	Least resistant, active erosion process develops quickly		

Category: Bio-physical
Factor: *Channel Gradient.*

<5%	Speed/Freq= *slow* (0)	Slower & less erosive flows	(1+0+2+0) **(3)**
	Duration= *long* (2)	Once affected, erosion impacts tend to be long term	
	Lag time= *long* (0)	active erosion process takes longer to develop.	
5-10%	Speed/Freq= *med.* (1)	Faster & more erosive flows	(1+1+2+1) **(5)**
	Duration= *long* (2)	Once affected, erosion impacts tend to be long term	
	Lag time= *med.* (1)	active erosion process develops sooner	
>10%	Speed/Freq= *fast* (2)	Rapid with high erosive flows	(1+2+2+2) **(7)**
	Duration= *long* (2)	Once affected, erosion impacts tend to be long term	
	Lag time= *short* (2)	active erosion process develops quickly	

Factor: *Land use/management*

Permanent. Cover/Good management	Speed/Freq=*slow* (0)	Offers good protection; Retards potential impact;	(1+0+0+0) **(1)**
	Duration= *short* (0)	Effective control; shorter duration of likely effects;	
	Lag time= *long* (0)	Effective control helps delay effects;	
Semi- permanent/ mod. Management	Speed/Freq=*med.* (1)	reduced protection; but Retards potential impact	(1+1+1+1) **(4)**

	Duration=*med*. (1)	Less effective control; longer duration of likely effects;	
	Lag time=*med*. (1)	Shorter "set in" time for impacts;	
Little/No Cover/Poor management	Speed/Freq=fast (2)	Quick & easy set in of impacts	(1+2+2+2)
	Duration=long (2)	Much longer duration of likely effects;	**(7)**
	Lag time=short (2)	Much shorter "set in" time for impacts	
Category: Socio-economic Factor- *Settlements*			
None/Low density	Speed/Freq=slow (0)	Much reduced rate	(1+0+0+0)
	Duration=short (0)	Short duration likely	**(1)**
	Lag time=long (0)	longer "set in" time	
Moderately dense	Speed/Freq=med. (1)	Likely higher rate	(1+1+1+1)
	Duration=med. (1)	Longer duration likely	**(4)**
	Lag time=med. (1)	shorter "set in" time	
High Density	Speed/Freq=fast (2)	Likely much higher rate	(1+2+2+2)
	Duration=long (2)	Much longer duration likely	**(7)**
	Lag time=short (2)	Much shorter "set in" time	
Factor: *Built Infrastructure*			
None/within buffer only	Speed/Freq=slow (0)	Likely reduced rate	(1+0+0+0)
	Duration=short (0)	Short duration likely	**(1)**
	Lag time=long (0)	longer "set in" time	
In-channel	Speed/Freq=med. (1)	Likely higher rate	(1+1+1+1)
	Duration=med. (1)	Longer duration likely	**(4)**

	Lag time=med. (1)	shorter “set in” time		
Both channel + buffer	Speed/Freq=fast (2)	Likely much higher rate	(1+2+2+2)	
	Duration=long (2)	Much longer duration likely	**(7)**	
	Lag time=short (2)	Much shorter “set in” time		
Category: Environmental				
Factor: *Pollution*				
None/ Domestic only	Speed/Freq=slow (0)	Likely reduced rate	(1+0+0+0)	
	Duration=short (0)	Short duration likely	**(1)**	
	Lag time=long (0)	longer “set in” time		
Industrial only	Speed/Freq=med. (1)	Likely higher rate	(1+1+1+1)	* based on field assessment, relative to extent and/or intensity;
	Duration=med. (1)	Longer duration likely	(1+1+1+2)	
	Lag time=med./short (1 or 2)*	shorter “set in” time	**(4 or 5)***	
Both industrial + Domestic	Speed/Freq=fast (2)	Likely much higher rate	(1+2+2+1)	* based on field assessment, relative to extent and/or intensity;
	Duration=long (2)	Much longer duration likely	(1+2+2+2)	
			(6 or 7)*	
	Lag time=med./short (1 or 2)*	Much shorter “set in” time		
Factor: *Physical Conditions*				
Stable	Speed/Freq=slow (0)	Likely reduced rate	(1+0+0+0)	
	Duration=short (0)	Short duration likely		
	Lag time=long (0)	longer “set in” time	**(1)**	
Moderately stable	Speed/Freq=med. (1)	Likely higher rate	(1+1+1+1)	
	Duration=med. (1)	Longer duration likely	**(4)**	
	Lag time=med. (1)	shorter “set in” time		
Unstable	Speed/Freq=fast (2)	Likely much higher rate	(1+2+2+2)	
	Duration=long (2)	Much longer duration likely	**(7)**	
	Lag time= short (2)	Much shorter “set in” time		

Table 23. Ranking of Relative Impact on the River System

Qualification of Impact	**Low**	**Medium**	**High**
	Score:1	Score :2	Score:3
Loss of Function	Reduction in service provision (or some services)	Serious reduction or total loss of services temporarily	Complete loss of services
Duration of Impact	Recovery of services within 6 months	Recovery of services between 6 months-1 yr	Recovery of services beyond a year
Extent of Impact (severity)	Periodic or limited	Moderate impact	Severe impact

Summary of findings

Table 24, summarises the outputs of the various steps used and outlined above, '*flagging*' the river zones that are relatively more susceptible or are threatened if prevailing conditions continue or worsen.

Table 24. Summary of Susceptibility Assessment

SUMMARY OF SUSCEPTIBILITY ASSESSMENT
(Probability Of Impact & Level Of Threat)

RIVER		**BIO-PHYSICAL**			
TROUM	***Dom. Soil stability***	***Bed Grad***	***Land Use/ Mngt.Practices***	*Suscep.*	*INDEX*
CZ/ R1	H	L	H		**H**
CZ/ R2	M	L	H		**H**
LZ/ R1	M	L	M		**H**
LZ/ R2	L	L	M		**M**
ROSEAU					
CZ/R1	M	L	M		**H**
CZ/ R2	H	L	M		**H**
LZ/ R1	M	L	H		**H**
LZ/ R2	M	L	M		**H**
LZ/ R2A	M	L	M		**H**
CHOC					
CZ/ R1	M	L	M		**H**
CZ/ R2	M	L	M		**H**
LZ/ R1	M	L	M		**H**
LZ/ R2	M	L	M		**H**

KEY

CZ/ R1 ~ coastal zone, reach 1	SE ~ soil erodiblilty/ stability
CZ/ R2 ~ coastal zone, reach 2	BG ~bed gradient
LZ/ R! ~ lower zone, reach 1	LU/MP ~ land use/ management practices
LZ/ R2 ~ lower zone, reach 2	S/ INDEX ~ susceptibility index

H ~ HIGH **M ~ MEDIUM** **L - low**
H** ~ **VERY HIGH**

Summary of Susceptibility Assessment (cont'd)

SUMMARY OF SUSCEPTIBILITY ASSESSMENT		(Probability Of Impact & Level Of Threat)						
		SOCIO-ECONOMIC			**ENVIRONMENTAL**			COMMENTS
(Troum.) Settlements		***Infrastructure***	*Suscep. Index*	***Pollution***	***Phys. Conditions***	*Suscep. Index*		
CZ/ R1	L	L	**M**	H**	H	**H****		**XX**
CZ/ R2	L	L	**M**	H	H	**H****		**XX**
LZ/ R1	L	L	**M**	M	L	**M**		
LZ/R2	L	L	**M**	M	L	**M**		
Roseau								
CZ/R1	L	L	**M**	H	H	**H****		**XX**
CZ/R2	L	M	**M**	H	H	**H****		**XX**
LZ/R1	L	L	**M**	M	M	**H**		**X**
LZ/R2	L	L	**M**	H	M	**H**		**X**
LZ/R2A	L	M	**M**	M	M	**H**		**X**
Choc								
CZ/ R1	M	L	**M**	H	H	**H****		**XX**
CZ/R2	L	M	**M**	H	M	**H**		**X**
LZ/R1	M	L	**M**	H	M	**H**		**X**
LZ/R2	L	L	**M**	H	M	**H**		**X**

L ~ LOW

XX ~ AREA OF HIGH PRIORITY
X ~ PRIORITY AREA

The overall outputs are considered under two broad headings, viz, i) the broad and main findings; ii) the zonal assessments/ pilot river are elaborated in Section 6.

The contributing factors, likely causes and other specific considerations regarding those findings will be elaborated on further in the following section – Analysis and Interpretation.

The table of findings outlined earlier in this section however, point to some recommended actions that should be taken in addressing some of the findings in the more critical zones. Researching and packaging of the right information (*bio-physical, socio-economic, environmental, institutional, regulatory, etc*.) at the drainage basin and relevant regional/ national levels are central to any future interventions that may be contemplated, if sustainability is to be a hallmark of this process.

6.0 Analysis and Recommendations

This section provides an analysis of the main findings with respect to the development of the methodology and its subsequent application on a pilot basis to help determine and flag, albeit in a qualitative and physical context, the pre-disposition and relative susceptibility of the pilot rivers to degradation as displayed with respect to the various assessed bio-physical, socio-economic and environmental factors. In the context of integrated river systems management, such a determination is a useful and cost-effective means of facilitating the early indication or "*front-end*" flagging of the zones or segments of the main rivers within a monitoring regime which would require some further and more urgent attention.

Generally, the level of analysis and interpretation of the findings, outlined further below, are conditioned by the inherent limitations of the sources of data, the quality and relative accuracy of the data and information generated, as well as the associated generalizations and assumptions made in the development of the methodology.

6.1 - The Rapid River Assessment Methodology (RRA)

In pursuit of the scope of works ultimately, it was necessary that the form of indication or measure developed for the assessment be logical, objective and appropriately aligned with conventional scientific methods. Consequently, the **Susceptibility Index**, ***Si***, was identified as the qualitative measure which could provide such indication or measure.

In this context, the ***Si*** should be treated as an indication of a set of physical conditions or relative levels of exposure associated with a category/ categories of factors or aspects, which pre-disposes the assessed locations and zones of the river to degradation or further degradation, if timely and appropriate mitigation measures and interventions are not taken. The ***Si*** is a composite and dynamic indicator. Its valuation and/or ranking can change with time and in accordance with the changing conditions of the river, subject to the level of impact/ likely impact that category/categories of factors may have on the river or some segment thereof.

The **Susceptibility Index**, ***Si***, can therefore serve as a tool to assist/ aid planners and river management technicians in "flagging" trends in the monitored locations (reaches/ segments/ zones) of the river with respect to changes in the value of Si with time as an indication of level of threat or susceptibility of the river system to degradation. Such trends, however, indicate the need for more in-depth examination of the contributing factors and processes, to determine the extent of the threat and the corresponding appropriate, site-specific remedial measures and interventions. This in turn, facilitates prioritization of actions/ interventions, based on the relative values and significance accorded to the respective river systems, as included in the monitoring regime. The corollary to this is that overall the methodology and the Index also help to identify the rivers/ streams or the segments/ zones that systematically may be manifesting relatively low levels of susceptibility, thus providing indications of what may be identified over time as possible '*benchmarks'* of a stable river systems, to work towards for other more 'threatened' rivers.

It is important to emphasize that establishing priorities is a first step, which needs to be followed by further comprehensive study and examination of the factors and issues[46], undertaken in a holistic and integrated manner, to eventually determine and formulate the appropriate and most cost-effective solutions.

Moreover, the robustness of the conceptual nature of the methodology, throughout its development and its eventual outputs, was tested and strengthened through the creative and cost-effective '*implanting*' of a stakeholder consultation/ engagement component and the effective use of existing GIS expertise and tools at the more critical phases, such as criteria development and selection, river profiling and prioritization (*to select pilot rivers*), data collation, database development, spatial and pictorial presentations and ultimately river assessment and monitoring. The details and the utility of these 'value-added' components have been articulated in previous sections.

<u>GIS Application in the RRA</u>

The main use of the GIS in the current RRA is in the development of a comprehensive digital database of pertinent information required to undertake a rapid assessment of riverbanks and the quality of water systems based on the key factors discussed earlier.

The GIS is thus a data management tool – capture, storage, retrieval, mapping and data manipulation, and brings together data from a number of sources into a single system. In this case data was derived from:-

i. Aerial photography in the development of current landuse
ii. GPS locations for control stations
iii. Data collected manually by measurement and observation at control points.
iv. Existing digital datasets at a national scale e.g. dominant soil classes

For the future application of the RRA, the use of GIS as an analytical tool is circumscribed by the *availability of existing detailed data about each water system*.

The base or input datasets necessary for future analysis can be derived as follows:-

<u>Within the Existing RRA Database</u>

i. National Soils dataset with the dominant group
ii. National Rivers dataset which can be easily buffered using the same buffer sizes (50m)
iii. National Contour information which can be derived from a referenced topographic digital map to clip river segments
iv. National Slope (gradient) layer can be adjusted to yield the slope categories for other river bank locations

<u>RRA can be expanded</u> to include:-

---

[46] This implies further study/ examination at the "river" level, as a discrete and dynamic physiographic unit, and at the wider drainage basin or relevant catchment levels, which should take into consideration issues, policies, strategies, etc. at the local/ drainage basin, regional/ district and national levels.

- Land use for the rest of St. Lucia with classifications consistent with the Forestry Management Plan (1992). These are available for some watersheds – Cul-de-Sac and Soufriere (AGRER 2008), Choiseul, Laborie, Micoud and Vieux-Fort (NAP 2008). These can be obtained and stored for future analysis.

Outside these locations up-to-date land use maps would have to be developed through ortho-rectification and geo-referencing of the 2004 digital aerial photos. The identical land use classes (FMP 1992) would have to be used to ensure consistency and to facilitate comparative analysis.

Collection of Field Data:-

Primary field data within the coastal and lower segments of future rivers along with picture evidence would have to be collected from the field and the subjective code assigned to each control point to determine risk, impact and overall score. Sections 4 and 5 provides the guide to understanding and assigning scores.

6.2 Major Impacting Factors in Pilot River Assessments

In examining the main findings and to determine any pre-dispositions and relationships between and among the various factors, which would assist in the interpretation of these findings, it is useful to clarify the context in which the various factors are treated and conceptualized, and the processes with which they are normally associated. This facilitates the interpretative aspects and provides the rationale for future actions geared towards the effective management of the island's river systems. The key the contributing factors with respect to riverbank erosion are therefore outlined in this regard.

Soil types

The soil type determines the inherent nature of the soil with respect to soil stability and erodibility. These terms imply and are associated with the relative ease/ difficulty and likelihood of soil loss through detachment and displacement in a natural manner, caused by the interaction of the natural properties of the soil itself and natural factors and events (e.g. *climatic factors/ events*).

Sedimentation

This refers to the deposition of silts, sands, gravel, stones, which can create conditions for instability of the river. The accumulated material is usually referred to as an "alluvial fan" or sediment "bar", which with time may become relatively stable and productive if not exposed to severe '*stressors'* and extreme disturbances. Such accumulations may even support the growth of "*opportunistic*" vegetation, which can further contribute to the channel's instability, by diverting flows or serving as trapping points for debris, which generally facilitate flow diversions, resulting in further bank scouring and destabilization.

Land Use and Management Practices

These refer to the relative degree of physical protection of the soil provided by the type, extent and management of vegetative cover within the referenced locations/ selected sites. Notwithstanding, it is recognize that such activities outside of the limited study area and within the river's wider drainage/ catchment areas do impact significantly in diverse manner on the condition of the river (*settlements, agriculture, other industrial and municipal uses, etcetera*).

Environmental Aspects and Pollution

Pollution is not simply an event, but a multifaceted on-going process, driven by a multiplicity of conditioning and interacting natural and man-made environmental aspects/ factors and events. Accelerated soil erosion, for example, and the generation of sediments, is one of the more direct pathways to transport pollutants (e.g. *agro-chemicals*) into waterways, streams and the marine environment, subsequently and eventually resulting in the pollution/ contamination of these environments.

Many pollutants bio-accumulate in debris, suspended solids and living plankton, literally serving as reservoirs for environmental contaminants, which ultimately have detrimental impacts on freshwater sources, ecosystems/ biodiversity, associated livelihoods and other socio-economic activity.

Socio-Economic Aspects/ Factors

These are diverse and difficult to manage, given the limited control and influence over how these aspects interact and impact on the river and the wider environment. Generally, they relate to settlement and demographic aspects, physical and production-related infrastructure, services, land tenure, livelihood systems, among others.

Other Enablers

These refer in the main to the policy, institutional and regulatory instruments/ framework that ought to support, help manage and facilitate an enabling environment to mitigate detrimental impacts and promote the effective use and sustainable management of the island's rivers.

6.3 Summary Assessment of Pilot Rivers

The analysis of the pilot rivers was based on measurements and observations which were limited to the lower two of the four zonal areas ~ *coastal and lower*. The general outputs of this sub-section are thus considered under two broad headings, viz, i) the general findings; ii) the zonal assessments/ pilot river.

The summary table (Table 21) presented in section 5, captures the main outputs of the methodology, which when associated with the spatial and pictorial outputs create a reasonably comprehensive 'snapshot' of the current status of the assessed river reach/ zonal segment of the river. More detailed analyses for each river are outlined later in this section, with consideration of the inter-relations of the outputs among the factors and categories of factors.

6.3.1 General Findings of River Assessment

Based on the summary table, the following broad observations can be made:

a. With few exceptions, all three rivers display a moderate to high level of pre-disposition and susceptibility to degradation within their coastal and lower zones with respect to the assessed bio-physical factors, driven in particular by the soil stability and land use and management practices, which primarily ranged from moderate to high. In the coastal zones, the majority of the soils are stable alluvial clays, clay loams and sandy clay loams, while the lower zones presented a mix of stable, less stable and fragile soils (alluvial clays, silty clays and poorly drained clays respectively). The dominant land use within study areas was agriculture, primarily banana cultivation within the buffer zones, with instances of poorly managed scattered tree crops and some secondary forest, mainly in the lower zones of the Choc and Troumassee rivers.
b. The river bed gradient, as a hydraulic factor, for all river reaches assessed was ranked in the less than 5% slope group, seemingly did not provide any significant indication of how this factor could play its influential role and impact on the status of the river. This consideration could be a future research exercise by disaggregating this slope group into two sub-groups and also possibly including the middle zone in the assessment.
c. The existing physical conditions of the river channel, along with the resulting effects of the lack of a routine river maintenance programme and unregulated practices, along with the cumulative flows from the wider zonal environments, render these zones exposed and severely threatened to on-going pollution (*in particular the coastal zone*), manifested by the extensive algal blooms and high turbidity levels; (*their conditions being affected by worsening pollution and continuous physical degradation, if timely mitigation measures are not effected*). Such effects would/ do have implications for the integrity of near shore, estuarine and marine ecosystems.
d. Given the minimal level of major infrastructure and the generally dispersed nature of settlements, with low densities, within two of the three drainage basins, only a moderate level of susceptibility to degradation was recorded for the three rivers, which is a logical and consistent output. Notwithstanding, the eventual compounding effects of the dominant agricultural activities and other diverse and poorly regulated industrial and municipal activities make these factors important for consideration. Moreover, over time they do have implications for the environmental 'health'/ status of the river systems and water quality. Further, the cumulative effects of the many different types of activities, albeit dispersed, cannot be discounted and left unchecked (e.g. ~ *illegal dumping of wastes, littering, spillages and discharges of sewage*) especially those that are associated with settlements in general, and in particular where services and supporting infrastructure/ facilities may be lacking.
e. Waste discharges from the more densely settled Choc River environment indicated a notable moderate *Si* levels in both the lower and coastal zones, which is consistent with the principles of the methodology.
f. It is clearly highlighted that the coastal zones of all three rivers are the most threatened, recording extremely high *Si* indices, particularly being the most accessible and exploited. In addition, this zone is the lowest, in terms of elevation, and functions as a transitory '*sink' or 'reservoir'*, prior to the final '*pour out'* in the near shore/ marine environment. The dominance of the environmental aspects, in this regard, are driven and strongly influenced primarily by the contributing effects and impacts of soil/ bank erosion, sedimentation and the associated polluting activities and land uses

in the of immediate vicinity (*in particular agriculture*). Bio-physical factors also do have an influencing effect, the soil factor in particular, and especially when the river has been affected severely by previous events (*such as TS-Debbie in September 1994 and the storm events of October and November 1996*) without significant remedial and stabilization measures taken.

g. The general lack of a dedicated and routine river maintenance programme undoubtedly facilitates and accentuates the on-going associated processes of degradation.
h. There is an apparent trend, based on the recorded scores, (*which should be confirmed by applying the methodology in the middle and upper zones*) that the general conditions of the rivers improve with elevation, thus rendering such zones relatively less susceptible and threatened to degradation. The much reduced *Si* levels/ scores and related moderate impacts of socio-economic and other likely detrimental environmental factors are considerations that are worth noting.

6.3.2 Considerations of the Assessed Zones of the Pilot Rivers

In addition to the above general observations, a closer examination of the results from the summary table reveals the likely factors and category of factors that seemingly ‘drive and influence’ the final determination of the *Si* score/ rank for each river. The table below outlines the outputs and allows a cross-referencing of the factors/ categories and the *Si* rankings.

Table 25 . Analysis of *Si* rankings for Pilot Rivers

<table>
<tr><td colspan="4">Factor & Category Rankings
(Locations in descending order: coastal – lower zone; cz1&2; lz1 & 2)</td><td>**Comments**
Note:
The apparently more influential and ‘stressor’ factors highlighted and/ or in italics.</td></tr>
<tr><td colspan="4">**River**: TROUMASSEE
Bio-physical</td><td rowspan="6">Land use and management practices stand out as the driving ‘stressor’ in every location, while the soil factor remains an influential aspect, especially in CZ2 & LZ2; where the factors are equally ranked, it is fair to assume that the impacts are as a result of the cumulative and inter-acting effects of the said factors.</td></tr>
<tr><td>soil</td><td>grad</td><td>LU/Mgt</td><td>Si</td></tr>
<tr><td>*H*</td><td>L</td><td>*H*</td><td>H</td></tr>
<tr><td>M</td><td>L</td><td>***H***</td><td>***H***</td></tr>
<tr><td>*M*</td><td>L</td><td>*M*</td><td>H</td></tr>
<tr><td>L</td><td>L</td><td>***M***</td><td>***M***</td></tr>
<tr><td colspan="4">ROSEAU</td><td rowspan="7">Both Land use and management practices and Soils stand out as the driving ‘stressors’ in different locations; the bed gradient does not seem to determine the Si ranking level in a significant manner; this does not imply that this factor is not significant; all locations recorded a low ranking and therefore difficult to conclude on this consideration. Sub-groupings of this slope group (<5%) could be examined further in the future.</td></tr>
<tr><td>soil</td><td>grad</td><td>LU/Mgt</td><td>Si</td></tr>
<tr><td>*M*</td><td>L</td><td>M</td><td>H</td></tr>
<tr><td>***H***</td><td>L</td><td>M</td><td>***H***</td></tr>
<tr><td>M</td><td>L</td><td>***H***</td><td>***H***</td></tr>
<tr><td>L</td><td>L</td><td>***M***</td><td>***M***</td></tr>
<tr><td>*M*</td><td>L</td><td>*M*</td><td>H</td></tr>
<tr><td colspan="4">CHOC</td><td rowspan="7">Both Land use and management practices and Soils stand out as the main driving ‘stressors’ in the different locations.</td></tr>
<tr><td>soil</td><td>grad</td><td>LU/Mgt</td><td>Si</td></tr>
<tr><td>*M*</td><td>L</td><td>*M*</td><td>H</td></tr>
<tr><td>*M*</td><td>L</td><td>*M*</td><td>H</td></tr>
<tr><td>*M*</td><td>L</td><td>*M*</td><td>H</td></tr>
<tr><td>*M*</td><td>L</td><td>*M*</td><td>H</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">SOCIO-ECONOMIC</td><td rowspan="2">There appears to be a moderate cumulative effect due to the less intense nature of socio-economic activities, with the exception of agricultural activities, mainly banana cultivation.</td></tr>
<tr><td colspan="4">*TROUMASSEE*
Settmts Infra Si
L L M
L L M
L L M
L L M</td></tr>
<tr><td colspan="4">*ROSEAU*
Settmts Infra Si
L *L* M
L *M* M
L *L* M
L *L* M
L *M* M</td><td>Similar to Troumassee, but a larger drainage basin, with low density satellite communities and few high-impact industrial activity
There appears to be a moderate cumulative effect due to the less intense nature of socio-economic activities, with the exception of agricultural activities, dominated by banana cultivation.</td></tr>
</table>

CHOC Settmts Infra Si *M* L M L *M* M *M* L M *L* *L* ***M***	A smaller, more compact and complex drainage basin (shorter river length, fewer tributaries), with more dense settlements and industrial activities/ infrastructure. The overall ranking is a manifestation of effects on the longer term, given the generally low-impact (relative to highly industrialized areas), but continuous impacts. Agriculture is of low intensity and not as extensive, in comparison to Roseau and Troumassee.
ENVIRONMENTAL	***{for all three rivers}***
TROUMASSEE Poll p/con. Si H H H** H H H** *M* L M *M* L M *ROSEAU* H H H** H H H** *M* *M* H *H* M H M M H *CHOC* H H H** *H* M H *H* M H *H* M H	Relatively, the pattern of the ranking is generally similar for each river, with the exception of the LZ in Troumassee, which displayed a gradually improving environmental condition, with reduced cultivation intensity, improved channel physical condition and no nearby settlements. With a slightly steeper bed gradient and stoniness, any normal sediment load is easily transported and deposited downstream, in the coastal zone. The coastal zones of all three rivers are severely stressed as a result of the various factors, impacting and contributing to the degrading processes at varying degrees, based on the intensity and/or extent of the relevant activity, such as agriculture and associated discharges, erosion and sedimentation, poor physical condition, industrial & municipal waste discharges.
Category Ranking	
Troumassee Bio-phy S/Econ Envir *H* *M* *H*** *H* *M* *H*** *H* *M* *H* M M H	Practically and in every instance, the environmental & bio-physical factors are clearly the more dominant and influential categories. However, the moderate level ranking of socio-economic factors may be due to the apparent very low settlement density and very limited major economic infrastructure in the assessed zones, whose eventual impacts are more longer term in manifestation.
Roseau Bio-phy S/Econ Envir H M H**	The environmental & bio-physical factors are clearly the more dominant and influential categories, especially in the coastal zone, due

H M H** H M H H M H H M H	to in addition to the cumulative effects of upstream activities. Apart from agriculture as the dominant economic activity, other industrial activities are few; settlement density is indeed low, given the satellite nature and distant locations of communities from the immediate river environment.
Choc Bio-phy S/Econ Envir H M H** H M H H M H H M H	The environmental & bio-physical factors are clearly the more dominant and influential. However, the moderate level ranking of the socio-economic category may be due to the non-point nature of the impacts of the higher level settlement density, but whose eventual impacts are longer term in manifestation; The more concentrated nature of major industrial infrastructure in the coastal zone probably has contributed to the very high pollution levels and the poor physical conditions noted. The lack of routine maintenance undoubtedly accentuates the degrading environmental conditions.
Key H** ~ very high *Si* score.	

6.3.3 Identification of Associated Contributions of Factor-Related Processes

The various **factor-related processes** which in some way or the other contribute to the degradation of the river have been collated from the table of findings in Section 5 and summarized in the Table 26 below, indicating the relative contribution of these processes in determining the quality and integrity of the river. The percentage of occurrence at the various sites sampled highlights the relative importance of the likely impact and role played by such factor(s). It must be noted that these are mere observed qualitative relationships, and not actual measurable parameters.

Moreover, it is recognized that the sampled locations are limited in size and cannot in any definitive manner be sufficiently representative of the entire segment or zone. Thus, the indications are useful for monitoring purposes, with the potential of flagging issues that contribute to the various degrading/ detrimental processes.

Table 26. Potential Associated or Contributory Causes of Degradation[47] Identified

Potential Causes/ *indications*	% Occurrence in 13 sampled locations	Main Interest &Impacting Groups
Bio-Physical		
Geo-morphology – riverbank steepness; unstable banks & slopes ~ *slumping/ scouring/ under-cutting; soil erosion; sedimentation;*	33	Resource managers; Property owners; Resource users;
Geology - Soil stability & erodibility ~ *erosion; sedimentation*	**50***	Resource managers; Property owners; Resource users
Hydraulic – average flow velocity; physical dimensions (C/Sectional area; bed gradient) ~ *bed erosion/ sedimentation*		Resource managers; Property owners; Resource users;
Climatic factors – rainfall/ hydrology; impact of previous (storm) events ~ *overland flows/ flooding; bed & bank erosion; sedimentation; ecological damage;*	**58***	Land/ property owners; Resource Users; Resource managers;
land use & management practices ~ *conflicting uses & improper management practices ~ inadequate*	33	Environmental Group Land/ property owners Resource Users

[47] It must be emphasized that the factors noted are highlighted within the context of the deliberate and limitedly defined river system (*channel with defined 50 m buffer*), for the purposes of the analysis. It is recognized that other natural and anthropogenic factors within and outside of the immediate river environment do also contribute and impact (directly & indirectly) on the status/ condition of the river, as a physiographic unit.

drainage, intensive use– in agriculture; ecological damage		
Livestock grazing on riverbanks ~ bank erosion; sedimentation;	42	Land/ property owners; Resource Users; Resource managers;
Removal of protective vegetative cover/ riparian vegetation (deforestation, etc.)~ erosion & sedimentation;	**58***	Land/ property owners; Resource Users; Resource managers;
Socio-Economic		
Socio-economic activity in river & near/ within buffer/ Non- adherence to riparian buffers ~ *improper, unregulated developments/ uses/ sedimentation*	**100****	Environmental Group Land/ property owners; Resource Users
~ River stone and sand mining/quarrying ~ ~ erosion &sedimentation; poor, unregulated waste disposal	42	Environmental Group; Land/ property owners; Resource Users & managers;
Settlements (density) - *Poor waste discharge/disposal ~ especially in unplanned/ unregulated developments*	17	Land/ property owners; Resource Users; resource managers;
Physical structures/ infrastructure – *unplanned/ improper designs/ developments; poor maintenance;*	25	Land/ property owners; Resource Users; resource managers; investors/ developers/ designers/ contractors
Environmental		
Pollution – domestic/ municipal, agricultural, industrial ~ wastes *disposals/ discharges; sedimentation ~ eutrophication; ecological damage, poor water quality;*	**100****	Environmental Group; waste generators; Resource Users/ managers; service providers;
Pollution (other) – e.g ~ Vehicle access/washing ~ waste discharges ~ *ecological damage, poor water quality;*	42	Environmental Group Resource Users/ managers/regulators

Physical conditions – transitory debris/ blockages *~ sedimentation, erosion;* *water pollution;* *“opportunistic” vegetation* *~ blockages & flooding;*	**85****	Environmental Group Resource Users/ managers/regulators; Property owners; disaster management agencies;

**high frequency of occurrence;
* moderate frequency of occurrence;

From the table it is observed that the more dominant and influential factors relate to:

- The bio-physical properties and transient physical conditions of the river;
- The pollution sources associated with agricultural/ industrial, municipal and domestic waste management; and, to a lesser extent,
- Other socio-economic activities within and in the vicinity of the assessed river environment.

Factors such as the removal/ loss of protective riparian vegetation (*due to some inappropriate economic activity*), climatic factors/ events and their impacts (*mainly due to previous events*) and the river bed slope (*hydraulic factor*) do contribute in a cumulative manner and influence the various processes that lend to degradation, such as riverbank and bed erosion, waste discharges and sedimentation.

In other words, while it is not possible to discount the natural/ bio-physical factors, which obviously play a key role, it appears that in several instances the anthropogenic factors (the *‘human element’*) with their resultant ‘*alterations, conflicts and disturbances’* can and seem to influence immensely the general physical condition and integrity of the river.

For example, the lack of routine river maintenance/ management, the abundant and injudicious use/ disposal of agro-chemicals (*fertilizers, in particular*), the poor land use and management practices (*developing conflicts*) seem to have a more determinant and significant impact on the integrity and functional aspects of the assessed rivers.

6.4 Stakeholder Considerations on Land and River Management Practices

Stakeholder observations and perspectives obtained through the assessment process were also used in the analysis and interpretation of the various factor-related processes as outlined below.

- *Land Use*

Major land uses along the riverbanks assessed comprise a range of agricultural uses (*intensive, such as banana cultivation; and low intensity* ~ e.g. *secondary forest, scattered friut tree, mixed tree crops and dense pseudo-perennial vegetation of grasses and shrubs)*. Only the Choc River possessed some reasonably dense secondary forest and fruit tree blaze patches within its zones. Both Roseau and Troumassee (*to a lesser extent in its lower zone*) were extensively cultivated with banana trees, which have shallow root systems and provide less than adequate cover against moderate to severe rainfall events.

These observations were much in line with the concerns expressed by the majority of stakeholders consulted. It was noted that in several instances, however, farmers/ land owners pursue inappropriate land use, including the removal of riparian vegetation on riverbanks, as a deliberate tactic to discourage/ minimise praedial larceny and would be prowlers on their properties. Some choose to minimise their losses by cultivating the riverbanks and avoiding certain plant species (e.g. fruit trees ~ mangoes, citrus) believed to attract would be predators or rodents as in the case of *vertiver* grass ("*khus khus*"), despite their known effective use in soil conservation measures.

Moreover, in situations where lands are leased/ rented or family-owned, there is limited/ no incentive to undertake any meaningful/ effective conservation measures.

Further, livestock grazing remains a major contributor to the poor land use and management practices that give rise to riverbank degradation. Livestock have significant access along the river and were observed within the river and the buffer area grazing during the study period. Cattle impact on riverbanks by direct de-stabilisation, through pugging of soils and through the suppression of vegetation, which would normally provide both bank reinforcement and direct protection. Photos of livestock on riverbanks are depicted in the Photo Cache in Appendix 11.

Other forms of animal husbandry likely to be found within river buffers include piggeries, and to a much lesser, small ruminants (sheep).However, the waste from chicken farms (generally not located within or near major streams) but eventually reaches streams and main watercourses.

Among the 3 rivers, only the Choc river buffer environment is well known to have some piggery establishments, and noted for several public complaints[48] regarding foul odors and the inappropriate discharge of effluents directly, without treatment, into the nearest watercourse (*which eventually enters the main Choc watercourse*).

- Soil Types – Stability/Erodibility

Most of the dominant soil types observed along the riverbanks ranged from stable to fragile soils (with low - high erodibility indices respectively). The stable soils are generally freely drained, medium textured alluvial clays[49], sandy clay loams and loamy soils, while the less stable and fragile soils were imperfectly / poorly drained silty clays/ clays and/ or heavy textured colluvial soils[50].

Within the deliberations of the ATC consultation, it was observed and endorsed that the use of the dominant soil types and their relative stability to erosion[51] as a bio-physical factor for consideration in the methodology was deemed acceptable.

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[48] There is evidence from the Ministry of Health/ Public health Dept. indicating such situations which have sought resolution at the Courts.
[49] Which are generally found within the coastal zones
[50] Which are generally found within the upper reaches of the lower zones
[51] Refers to a soil classification system for the Soils of St. Lucia, developed by Professor Ahmad/ University of the West Indies, St. Augustine Campus

- Previous storm events and flood flows

Various sources concur, including reviews of existing reports[52], personal knowledge and verbal reports by participants/ stakeholders[53] that, generally, the status of all major river systems in St. Lucia was severely affected by the passage and impacts of Tropical Storm Debbie (TSD) in 1994 and to a lesser extent the significant rainstorm events of October and November 1996 (WEMP Report 1997). Despite the significant amount of rehabilitation works (mainly civil works) post TSD, geared to restore some stability and to reduce more extensive damage, many of the major river systems, including the selected pilot rivers, remained, to the present, in general, a poor physical condition.

- Catchment Runoff & Water Quality

It was observed at the ATC consultation that at least two of the selected rivers did have significant water abstraction infrastructure, mainly for agriculture/ irrigation; and by coincidence, two of the referenced sites assessed were located near such intakes, CZR2/ Choc (Union Pumping Station) and CZR2/ Roseau (IMU irrigation system). It was acknowledged that the impacts of catchment activities and runoff within these areas would have implications for the quality of the abstracted waters, as well as the quality of downstream flows, based on the inadequate land drainage controls/ measures and poor management practices within the catchments.

- River Sedimentation

Accelerated soil erosion, riverbank slumpings/ scouring/ slippages and physical watercourse blockages are some of the more common and direct causes of river sedimentation, which can also be facilitated by the hydraulic features of the channel (channel capacity, bed slope, cross sectional area and shape). Also, river flow migration[54] and diversions often occur in rivers, subject to the river's sediment load and sediment transport capacities, which are intrinsic characteristics of the said river. Flow diversions can lead also to further scouring of riverbanks. The erosion of soil and the subsequent deposition and accretion of sediment often result in various physical formations in the channel, such as sediment point bar/bench complexes, channel meanderings and meander cut-offs, and even abandoned channel segments, which permit the growth of "opportunistic" vegetation. Such formations are continuously changing, subject to the dynamic interaction of the various bio-physical, socio-economic and environmental factors within the river and its wider drainage area.

Moreover, high levels of sedimentation, particularly in agricultural areas where extensive and intensive use of agro-chemicals is common, tend to be associated with river and water pollution[55]. Sediments/ suspended solids serve as one of the main transmission media for pollutants, within which over time bio-accumulation occurs, which eventually affects the

[52] Example – the Watershed and Environmental Management Report (WEMP), 1997.

[53] There was consensus that sufficient work was not done to sustain the benefits of the general public awareness that was evoked by events like TSD, including the institutionalization of a river management program.

[54] Is an on-going process that results in lateral movement of flows and the channel across the floodplain, facilitated by the hydraulic features of the channel, which results in erosion of the outside of the meander bends and deposition of sediment on the inside. The transient physical condition of the channel also influences this process.

[55] A river can be said to being polluted when the condition and quality of its water has deteriorated to such an extent that it is no longer suitable for its intended function and use.

food chain linkages, with consequences for flora and fauna and livelihood systems. The primary sources of pollutants of water are:

- Industrial (manufacturing, construction, mining)(e.g. heavy metals, organics);
- Agricultural (e.g. pesticides, fertilizers, soil erosion);
- Municipal (commercial, domestic, urban/ peri-urban) (e.g. wastewater, pesticides, road runoff);
- Landfills / waste dumps.

The officers of the WRMU/ WRU confirmed that currently no data collection on sediments and sediment transport is being pursued. Moreover, hydrological and water quality data collection in general has always being problematic, lacking reliability and continuity, and currently the same is at an all time low due to resource constraints, human and otherwise. However, the network of meteorological data collection equipment is functional and being maintained. It is anticipated shortly that a follow-up agency, the Water Resource Management Agency[56] (WRMA) will be made operational.

The outputs of the assessments confirmed the gravity of the existing issue of sedimentation and its concomitant impacts within/ and on the piloted rivers.

- Socio-economic Aspects

The assessments indicated overall a moderate level of susceptibility to degradation of the assessed rivers in relation to the likely impacts of socio-economic related activities. The outputs and analyses revealed that the main activities are related to: mainstream agricultural and industrial production systems (removal of riparian vegetation, location of infrastructure within buffer/ river, waste discharges, poor infrastructure design); municipal/ commercial and domestic/settlement-related activities (disposals and discharges); other fringe-based livelihood systems and socio-cultural practices (e.g sand/ gravel mining, vehicle washing, bathing).

Further, the assessment revealed that of the three rivers, only Choc displayed the most complex mix of diverse activities. Troumassee was primarily agricultural-based with very low settlement density, while Roseau was similarly agricultural, but with more low-density satellite settlements, with a few low-intensity industrial sites.

Stakeholders at the ATC consultation and discussions with the IWCAM/St. Lucia Coordinator expressed some concerns about untreated waste discharges associated with livestock enterprises and community households. The Choc River is probably the only of the three rivers which to some moderate extent is exposed to such activities and issues.

Quarrying is also an intensive activity which was noted in discussion, and tends to generate much sediment load. All three rivers are exposed to the impacts of this industrial activity, but to varying degrees. In the immediate vicinity of the CZR1/ Choc River is located a well established industrial complex, which includes a quarry. The related impacts (high turbidity & sedimentation) were observed and adequately assessed and documented.

- Environmental Aspects

[56] See Appendix ?? for more details on the status of water resource information management in St. Lucia.

Activities with environmental impacts were found to be a major and dominant contributor to riverbank degradation, particularly in respect of sedimentation and pollution of water quality, particularly in the coastal zones, and thus revealed high *Si* scores and rankings. Debris accumulation and sedimentation also contributed to the process of flow diversion and the erosion of riverbanks. The issues of poor waste disposal and discharge, including runoff from poorly drained agricultural fields and municipal areas, were observed as significant within the zones assessed. Waste comprised largely solid waste from industrial, agricultural and/or domestic activities; discharges of effluent comprise mainly agricultural and industrial chemicals/pollutants – *both point and non-point sources*.

Other matters of concern identified through the stakeholder engagements and assessment process are outlined below in Table 27.

Table 27. Specific Matters of Concern

Matters of Concern	Comments
Rate of erosion has accelerated in the last ten years	Increase in removal of vegetative cover for various developments along riverbanks – agriculture, including livestock rearing; settlement, infrastructure, etc.; decline in agriculture appears to be having positive impact though with re-vegetation occurring on abandoned holdings;
Experience intense erosion in rainy season	Largely due to impacts of floods; debris flows/ land slips and sedimentation.
Soil structure/ properties facilitates bank erosion/ degradation	High soil erodibility; stony banks; poor/ no protective cover pre-dispose banks to accelerated erosion.
Silt from erosion affecting water quality	Suspended solids/ Sedimentation contributing to turbid flows and accumulation of pollutants.
Zone 1 (coastal) in particular, and the lower reaches are most threatened and affected by erosion	Higher incidence of sedimentation and pollution in these locations; river maintenance/ management programme is absolutely necessary.
Point and non-point source pollution	Poor waste disposal practices - industrial and domestic waste; reducing impact of agricultural runoff due to decline in agricultural/banana production; these issues need further study/ research.
Increasing demand for water in all sectors	Rapid development expansion impacting ecosystem services and the integrity of rivers island wide; resource use conflict management needs examination.
Lack of valuation of watershed services	An expected output of the IWCAM Demo project.

6.5 Considerations **on Identified Erosion Processes**

The following are some other likely contributing causes to erosion along the various river reaches of the three selected rivers. The quantitative analysis and extent to which these suggested causes impact such processes should be the subject of a more comprehensive and detailed drainage area-wide/ watershed examination or study.

Pre -Disposition Factors:

- ***Bio-Physical Aspects***

Natural Processes and River Characteristics:

- previous major climatic events[57], e.g storm / flood impacts[58];
- catchment geo-morphology and physiographic features ~ geology, topography, vegetation, etc;
- catchment geo-hydrological features (catchment runoff, including runoff – duration relationships);
- River hydraulic features;
- Soil type (geology); and,
- River morphometric[59] features

Aggravating factors ("*stressors*"):

- ***Socio-Economic Aspects***

- Livelihood systems, with associated land uses and management practices, e.g *livestock grazing and intensive crop cultivation along/ on the riverbanks*;
- Other socio-cultural & economic uses – e.g. unplanned settlements, river stone and sand mining, quarrying, vehicle washing, etc.;
- Infrastructure associated with the provision of goods & services – e.g. *irrigation, manufacturing/ industrial activities, municipal activities*;

- ***Environmental Aspects***
  - Poor land drainage and river management;
  - Removal of riparian vegetation & effective cover;
  - Poor waste management, discharge and disposal (*domestic, industrial/agriculture, municipal*);
  - Sedimentation and other associated causes, e.g. physical blockages/debris accumulation;

Of the 13 monitoring sites within the two zones, the coastal zone sites of each river turned out to be relatively the more threatened, and particularly exposed to on-going environmental pollution and degradation. These processes are chiefly associated with the existing pre-dispositions and susceptibilities facilitated by the poorly maintained physical conditions of the rivers, relative soil stability/ erodibility, poor land use and management practices (*especially intensive agriculture, poor land drainage*), high nutrient load discharges, accelerated/ active soil and bank erosion and severe sedimentation.

[57] It should be noted that there was no weather event worth noting which impacted the execution of the field based activities which were implemented during the latter part of July 2008.
[58] Example TSD of 1994 & major rainfall events in October/ November 1996.
[59] Relates to morphological aspects of the river, such as average (longitudinal) slope, water course length, number and order of tributaries.

Ultimately, these factors and processes lead to contamination and a deterioration of the water quality, manifested by indicators, such as high turbidity levels, extensive algal blooms and sediment bars. The developed pictorial database serves as hard evidence and a useful reference in the development of a monitoring regime over time.

6.6 Proposed Treatment and Actions for Degrading Segments of Pilot Rivers

The RRA methodology determined relatively high levels of susceptibility indices (***Si***) for the assessed rivers. These were influenced primarily by the bio-physical and environmental parameters, while moderate levels for the socio-economic parameters were found.

In the final analysis, the data and information generated and the analyses and interpretation demonstrate the utility of the methodology, in assessing the condition of the selected pilot rivers, with the capability to effectively "flag" factors, processes and eventual likely impacts/ effects on the integrity in a fairly rapid and cost-effective manner.

Given the aforementioned, the following considerations worth noting in terms of treatment measures, based on the field-based assessments of the 3 rivers are presented in Table 28.

Table 28.Some Considerations for Treatment Measures based on Pilot River Assessments

Main observations associated with the Field Assessments & some Proposed Measures for Remediation				
Rivers	**Roseau**	**Troumassee**	**Choc**	**Comment**
Main issues (lower & coastal zones)	Soil and Riverbank instability; Riverbank erosion; sedimentation; Riverbed erosion & instability; poor land use and management within buffer; water quality; lack of routine maintenance; Other: vehicle washing;	Soil and Riverbank instability; active Riverbank erosion; high level of sedimentation; Riverbed instability; very poor land use and management within buffer; water quality; lack of routine maintenance; others: mining, v/washing;	Soil and Riverbank instability; Active Riverbank erosion; high sedimentation & indications of pollution; Riverbed erosion & instability; poor land use and management within buffer (*diverse uses*); water quality; lack of routine maintenance;	Generally the observed issues are similar, but vary in intensity and extent, with the exception of Choc R., which undoubtedly visibly depicted high levels of turbidity & indications of pollution and active environmental degradation.
Probable impacts ("do nothing" scenario)	Continued riverbank degradation; worsening flood prone conditions; Increasing sedimentation & worsening water quality/ pollution levels; threat of loss of biodiversity, productive lands and private property (*primarily Choc R.*); loss of some socio-economic & ecological benefits through loss of use, such as recreation, irrigation, loss of flora & fauna,			Generally, coastal areas, including estuarine & near shore marine environment continue to be

<table>
<tr><td></td><td>possibly irreversible damage to land & near shore seascapes, habitats, ecosystems & some forms of livelihoods.</td><td>under threat, especially through increasing sedimentation.</td></tr>
<tr><td>Some Possible urgent stabilization measures/ remedial treatments</td><td colspan="2">Riverbank stabilization, using vegetative material, preferably indigenous or native spp., economic crops (tree crops or forest spp); grass spp. on bank side slopes, forming “wattles” or grass strips; vegetation in combination with physical structures (“bio-engineering” structures), such as gabion baskets, used with geotextile materials, rock/ boulder “rip-rap”, to rapidly protect the more actively eroding banks; monitor & enforce & identify improved discharge methods.</td></tr>
<tr><td colspan="3">The rationalization/ improvement of drainage systems is critical ~ i.e. improved routing and control of surface runoff, such as the construction of “collector” and diversion drains near or in the vicinity of the buffer, with a reduced number of outfalls into the river’s channel. Livestock rearing/ grazing must be managed. An effective, consistent and routine maintenance plan must be institutionalized (before, during & after rainy season). “Softer” measures must be factored, to optimize and sustain likely benefits, e.g – incentives, cultural preferences/ traditions, stakeholder education, enforcement, community sensitization/ mobilization & active involvement..

Considerations must be given to stakeholders’ cultural preferences and socio-economic realities in finalizing treatment designs, e.g – selection of plant/ crop spp. ~ e.g - some farmers resist tree crops on riverbanks for fear they may encourage praedial larceny; or “vertiver” grass, for fear of an infestation of rodents.</td></tr>
</table>

It is worth noting that *“hard measures”,* such as structures should be utilized as a last resort, due to:

- the high cost involved;
- the need for highly skilled technicians to design and supervise the construction of such structures; and,
- the general physical disturbance that occurs during such activities.

However, they are generally used to manage high velocity flows, reducing velocities to near non-erosive levels, taking into consideration the existing site conditions.

Where deemed relevant and beneficial, multi-purpose structures, such as small sediment retention dams/ structures, can be constructed to both manage water/ irrigation supplies during the drier months, while managing sediment loss and flood risk during the rainy season.

It is recommended that structural treatments be combined, wherever possible, with vegetative treatments and improved drainage systems. Indeed, structures should be durable, of appropriate design and with the capacity to handle the design discharge. Moreover, they should not create conditions that are detrimental downstream the channel or to legitimate downstream resource users/ beneficiaries, including flora and fauna.

Water Quality and Pollution Issues

River water quality depends generally on the amount of suspended sediment and the chemical and biological composition of the water. The quality requirements of the river's water depend on the intended use (*social, economic and environmental*) ~ for example, domestic supplies, irrigation, recreation, etc. A determination has to be made as to what quality standards are deemed acceptable for the specific river. In this regard, technical support can be solicited from the CEHI.

It is necessary to appreciate that sediment is by far the most significant pollutant, since it not only depletes the land of the soil necessary for crop growth, but also carries away nutrients, agro-chemicals, organic material and beneficial micro-organisms ~ all of which impact eventually on land fertility and productivity and biodiversity management.

It is therefore critical to determine the major sources/ generators of the sediment and the associated causative factors (*within the immediate river environment and /or the wider catchment or basin area*). Working collaboratively with landowners, resource users/ producers and their relevant representative agencies, other resource managers and service providers, and other relevant stakeholders would assist and help to identify appropriate, cost-effective and meaningful solutions.

It is useful to note that currently there is no major research work or sustained routine monitoring of river water quality or stream discharge measurements or systematic river maintenance programme. Moreover, there is no developed national database for monitoring environmental quality of freshwater resources, apart from the following agency-specific initiatives;

- WRU/WRMU ~ sporadic river flow measurements for a limited number of streams at best, and on demand; and mainly during the 'dry season';
- WASCO ~ weekly domestic water supply quality monitoring (mainly distribution systems, after treatment);
- CEHI ~ samplings, when commissioned by a public or private entity or project-related;
- Ministry of Health ~ only demand-driven requests;
- Others, such as hoteliers, Fair Trade Banana Farers' Groups ~ only demand-driven requests, primarily by market-driven requirements/ 'standards'.

Recommendations for Water Quality Monitoring

Based on the issue at hand, it may be necessary to establish joint/ collaborative actions with other agencies to effectively address some relevant issues/ concern(s)[60]. This can be promoted through i<u>nter-agency collaboration for e.g. among the Solid Waste Management Authority, Banana Fair Trade Groups, WRMA[61], etc.)</u>

[60] Example, the management of solid waste in the lower and coastal zones of the Choc River.
[61] Water Resource Management Agency ~ to formally replace the transient WRMU/ WRU.

Such engagements may involve discussions of the issue(s), which can lead to specific actions, such as the implementation of surveys, public awareness/ education initiatives, implementation of specific measures (*physical or otherwise*) and/ or the coordination of a monitoring/ data collection programme. These arrangements may even be formalized through special protocol/ memoranda of understanding or agreement.

6.7 Advantages and Limitations for Application of RRA Methodology

One of the advantages of the RRA methodology is the focus on the use of a limited core of variables/parameters deemed capable of providing a strong indication of susceptibility to degradation or threat of susceptibility to degradation if prevailing conditions continue or worsen. The number of core variables is deliberately limited in order to remove as much variability in the likely interactions among variables/parameters and to reduce as far as possible complexity in the application of the RRA methodology.

This may also be seen as a limitation of the RRA, as river systems are dynamic systems, and there is the likelihood that the parameters used to indicate susceptibility may change over time.

Further, the RRA methodology may not necessarily be applicable for every possible combination of variables/parameters and would need to be tested for each set or combination of variables/parameters to determine its effectiveness and utility under these conditions.

Even within the same set or combination of variables/parameters, there may be variations in the effectiveness or utility of the RRA methodology from one period of the year to the next. Hence the methodology would need to be tested with data collected over more than one season, with a minimum frequency of twice a year.

One basic assumption of the RRA methodology is that conditions approximate normal conditions with respect to impacting factors such as weather and management. This suggests that under extreme conditions the RRA may not be resilient enough to produce a predictable response, as would be the case for any natural system faced with abnormal conditions. However, the RRA is capable of flagging/identifying a general pre-disposition and susceptibility to degradation in order to assist with determining broad recommendations for addressing degradation. Moreover, more in-depth assessment of the parameters or additional parameters will be required to make a determination with respect to site-specific remedial actions/measures.

It is important to note therefore, that the RRA methodology is more indicative in its output, rather than predictive. In fact, the methodology seeks to "flag" the existence or the likelihood (threat) of occurrence of some form of impact, if the necessary mitigation measures are not effected on time. Once the observation has been confirmed and prioritized, it will require further investigation to determine whether the main causative and influential factors are localized, catchment-related or drainage basin-wide, including the consideration more detailed studies/ assessments and some of the "*softer*" aspects, such as institutional and local capacities, appropriate incentive measures and regulatory framework, relevant enforcement mechanisms and adequate human and material resources.

Given the outputs of the investigation one should then be in a better situation to assess and identify the probable root causes and probable solutions to the assessed problems. Hence the recommendation for a pilot project which involves, inter alia, a feasibility study of the likely treatment measures for the suggested lower and coastal zones of the rivers and deemed in need of urgent attention[62] (*Troumassee and Choc Rivers, being the ones identified with the higher susceptibility indices*), which should facilitate the appropriate and cost-effective design of proposed solutions. Lessons learned from this intervention should help mainstream and upscale the approach for other prioritized rivers.

The overall methodology entailed desk reviews, the data collation process and the developed field assessments and observations methods, along with the application of the GIS tools and associated methodology and the stakeholder consultation/engagement mechanisms. Overall, the data and information generated and the analyses and interpretation demonstrate the utility of the methodology outlined in terms of assessing the condition of the selected pilot rivers, with the capability to effectively "flag" factors, processes and eventual likely impacts/ effects on the integrity in a fairly rapid and cost-effective manner.

However, the efficiency in implanting the methods and approach will be greatly enhanced if the useful required bio-physical data is readily available and accessible. The existing format of the available data is also of importance. The easy access and use of appropriate GIS tools can certainly facilitate and enhance the database development and analytical processes.

Even so, a rapid assessment requires readily available data in usable formats. Given the paucity of data on many parameters and the variable data formats for those available data, the variables to be utilized in the RRA are currently limited. Expanded research and data collection on natural resources will be required to support an expanded application of the RRA.

It is also necessary that a dedicated team be identified and charged with the mandate to oversee and coordinate this assignment, in particular if a medium to long-term monitoring regime is to be established.

Other Limitations in application of GIS

i. In light of the need to produce a rapid assessment methodology to assess the status of river banks, it is arguable whether the use of aerial photography to derive current landuse information, though critical to the exercise, can be considered to be part of a rapid process. This is due to the fact that the existing 2004 aerial photographic data set is neither geo-referenced nor ortho-rectified – two factors important for the immediate use of geographic data to interpret landuse for use in analysis

ii. It is important to use a topographic map out in the field to collect field data related to ground control points as GPS readings can sometimes produce inaccurate locational information due to issues relating to the absence of stationery GPSs which provide accurate references for the roving GPS used by researchers in the field.

iii. The GIS information used in the assessment is bounded by the accuracy and currency of existing GIS base information from secondary sources.

[62] All three rivers, with a few exceptions, recorded high indices, but comparatively Troumassee and Choc displayed higher Si values.

Recommendations and Suggested Applications for GIS

The main use of the GIS in the current RRA is in the development of a comprehensive digital database of pertinent information required to undertake a rapid assessment of riverbanks and the quality of water systems based on the key factors discussed earlier.
.
The GIS is thus a data management tool – capture, storage, retrieval, mapping and data manipulation, and brings together data from a number of sources into a single system. In this case data was derived from:-

v. Aerial photography in the development of current landuse
vi. GPS locations for control stations
vii. Data collected manually by measurement and observation at control points.
viii. Existing digital datasets at a national scale e.g. dominant soil classes

For the future application of the RRA, the use of GIS as an analytical tool is circumscribed by the *availability of existing detailed data about each water system*.

The base or input datasets necessary for future analysis can be derived as follows:-

Within the Existing RRA Database

v. National Soils dataset with the dominant group
vi. National Rivers dataset which can be easily buffered using the same buffer sizes (50m)
vii. National Contour information which can be derived from a referenced topographic digital map to clip river segments
viii. National Slope (gradient) layer can be adjusted to yield the slope categories for other river bank locations

RRA can be expanded to include:-

- Land use for the rest of St. Lucia with classifications consistent with the Forestry Management Plan (1992). These are available for some watersheds – Cul-de-Sac and Soufriere (AGRER 2008), Choiseul, Laborie, Micoud and Vieux-Fort (NAP 2008). These can be obtained and stored for future analysis.

Outside these locations up-to-date land use maps would have to be developed through ortho-rectification and geo-referencing of the 2004 digital aerial photos. The identical land use classes (FMP 1992) would have to be used to ensure consistency and to facilitate comparative analysis.

Applications

i. Selection of critical rivers using biophysical and socio-economic scores: The Look Up tables can be joined to assign classes to each soils, land use and slope layer of every new river. The scores will signal the possible worse case scenarios and thereby flag priority rivers for further investigation via socio-economic and environmental field assessments.

ii. All RRA datasets (along with pictorial data) for each river can be used for bench marking. These benchmarks will be used to monitor the impact of improvement and rehabilitation programmes.

iii. A new pictorial database can be developed for each year using the same ground control points to monitor change and to create time series data.

iv. When a large number of rivers have complete datasets, a profile of a typical 'poor', 'average' and 'good' riverbank can be built.

v. The GIS can also assist in quantifying rehabilitation work through physical measurement of affected areas and estimates of cost

vi. The GIS can also be used to as a tool to plan the river bank rehabilitation programme.

vii. The segmentation of each river can be used to direct and allocate manageable units for data collection in the future.

7.0 Conclusions

The RRA methodology determined relatively high levels of susceptibility indices (***Si***) for the assessed rivers. These were influenced primarily by the bio-physical and environmental parameters, while moderate levels for the socio-economic parameters were found.

Although the contribution of these various factor-related processes could not be individually quantified, the study did confirm that erosion is occurring and there is a need to address those processes that can be readily managed. Further, management of these processes has the potential to significantly reduce the extent and rate of erosion.

In the final analysis, the data and information generated and the analyses and interpretation demonstrate the utility of the methodology, in assessing the condition of the selected pilot rivers, with the capability to effectively "flag" factors, processes and eventual likely impacts/ effects on the integrity in a fairly rapid and cost-effective manner, as determined by the **Susceptibility Index**, ***Si***. The logical next step is to determine what measure(s) of control and /or remediation may be effected to address or mitigate the threat and/or the impact(s). Such measures may relate to specific actions, processes and procedures which could remove the threat/risk or reduce the chance of the threat being realised.

The remedial measures may relate to direct physical interventions (**harder measures**) or in combination with "**softer**" measures, which impact on policy design, data and information management, governance and regulatory/enforcement issues.

General measures for riverbank/ river system rehabilitation and protection will be further developed in the companion document to follow "Riverbank Assessment and Rehabilitation Plan" (RARP), which will seek to develop recommendations based on the outputs of this assessment report including the recommendations of stakeholders emanating from the consultative process.

It must be noted that the RRA is capable of flagging/identifying a general pre-disposition and susceptibility to degradation in order to assist with determining broad recommendations for addressing degradation. Moreover, more in-depth assessment of the parameters or additional parameters will be required to make a determination with respect to site-specific remedial actions/measures.

Hence, prior to considering the implementation of remedial and control measures in a river, it is necessary to ensure that priorities are established as a first step, and are followed by further comprehensive study and examination of the factors and issues[63], undertaken in a holistic and integrated manner, to eventually determine and formulate the appropriate and most cost-effective solutions, involving the following:

• Collection and analysis of relevant additional data/information (*technical, social, economic, environmental, institutional, regulatory,* etc.) which should further and better inform the decision process;

[63] This implies further study/ examination at the "river" level, as a discrete and dynamic physiographic unit, and at the wider drainage basin or relevant catchment levels, which should take into consideration issues, policies, strategies, etc. at the local/ drainage basin, regional/ district and national levels.

• Determination of the relative level of importance in effecting measures, based on the examination of potential impact and exposure related to the risk factor and threat concerned. That is, rivers or segments/reaches of river(s) which exhibit a probability of high risk of failure and high impact should be placed in a **“high priority basket”** for further review/ study and prioritization (on the basis of available resources and national significance).

Other categorizations or “baskets” (***high risk/low impact and high impact/low risk***) should also be considered and be reviewed individually, noting any specific or unique particularities which are deserving of attention, given their critical nature (i.e. ~ social, economic, environmental, cultural), and based on concerns of national or local value/significance).

It is important to emphasize that the **Susceptibility Index, *Si*,** should be treated as an indication of a set of physical conditions or relative levels of exposure associated with a category/ categories of factors or aspects, which pre-disposes the assessed locations and zones of the river to degradation or further degradation, if timely and appropriate mitigation measures and interventions are not taken. The ***Si*** is a composite and dynamic indicator. Its valuation and/or ranking can change with time and in accordance with the changing conditions of the river, subject to the level of impact/ likely impact that category/categories of factors may have on the river or some segment thereof.

In this context, the **Susceptibility Index**, ***Si***, can therefore serve as a tool to assist/ aid planners and river management technicians in “flagging” trends in the monitored locations (reaches/ segments/ zones) of the river with respect to changes in the value of Si with time as an indication of level of threat or susceptibility of the river system to degradation. Such trends, however, indicate the need for more in-depth examination of the contributing factors and processes, to determine the extent of the threat and the corresponding appropriate, site-specific remedial measures and interventions.

APPENDICES

Appendix 1- List of Documents Reviewed

Literature Review for R/bank Assessment & Stabilization

1. Risk Assessment of Agrochemicals in Eastern Caribbean, Workshop proceedings, 27 Oct. - ! Nov. 1985, CARDI/UNESCO-MAB.;

2. River Ecology, Vol. 2, Whitton, B.A., 1975;

3. A Reference Guide on the Use of Indicators for Integrated Coastal Management, Dossier No. 1, UNESCO, 2003;

4. Watershed and Environmental Management Project, Phase 2, Final Report - Vols 4 &3, Huntings Technical Services/ Mott McDonald Ltd., Nov. 1997;

5. Coastal Zone Management in St. Lucia – Issues Paper, Ministry of Agriculture, Forestry & Fisheries, 2002;

6. Land Drainage – Planning & Design, Smedema, L.K., Rycroft, D.W., 1983;

7. Engineering Field Manual, USDA – Soil Conservation Service, 1984;

8. Geology and the Environment – vol. 1, UNEP/UNESCO Series, Kozlovsky, E.A., Sytchev, K.I., 1988;

9. Proposed Strategy – to Encourage and Facilitate Improved Water Resource Management in Latin America and the Caribbean, Lord,B., Israel, M., 1996;

10. The St. Georges Declaration of Principles for Environmental Sustainability in the OECS, OECS, 2001;

11. National Biodiversity and Action Plan of St. Lucia, GOSL/ UNEP, 2000;

12. Saint Lucia National Climate Change Policy and Adaptation Plan, GOSL, 2004;

13. Forest Management and Conservation Project No. 868 12151 – Sociological Survey, Roche, Nov. 1992;

14. Education for Rural Development – Towards new policy responses, FAO/ UNESCO, 2003;

15. The Assessment of Poverty in St. Lucia, Vol. 1 –Main Report, Kairi Consultants Ltd., Aug. 2006.

Appendix 2. Summary Matrix of Attributes/Parameters for Profiling River Systems

	RIVER SYSTEMS /IMPACT																					
PROFILING CRITERIA (ASPECTS)																						
Bio Physical Aspects																						
Hydrology: Drainage Area Length (km) Width range (m) Avg. Long. Gradient (m/km) No. of tributaries Stream Discharge																						
Geomorphology – Topo/ relief features Slope Classes																						
Adjacent Land Use Vegetation Percentage of Cover Type of Cover																						
(Climatic Regimes) – Hydromet Condition: Rainfall																						
Edaphic Condition Parent material Soil classes Dominant soil type																						
Status of riparian buffers																						
River Training/Manipulations																						
Socio-Economic Aspects																						
Livelihoods																						
Land Tenure																						
Infrastructure																						

	RIVER SYSTEMS /IMPACT																					
PROFILING CRITERIA (ASPECTS)																						
Population																						
Settlements (No. and Location)																						
Water Supply Systems																						
Environmental Aspects																						
Ecological Value - Conservation Areas																						
Water Production/Abstraction Levels																						
Water quality: Pollution Sources																						
Physical Channel Degradation																						
Vulnerability (landslides/flood/drought)																						
Management/ Governance																						
Legislation/Regulations																						
Institutional/Organisation																						
Stakeholder Involvement																						
Community Participation																						

Appendix 3-Pre-Designed Field Survey Form

DEPARTMENT OF FORESTRY & LANDS
Data Collection & Field Observations

Project: Riverbank Assessment and Rehabilitation

Watershed/ River: ---------------------------------------

Data Collected by:	**Checked By**:	**Date**: **Time**: **Start**: **End**:	**Sheet 1 of** 3
Location-Observation Site:	**Zone**: Coastal/ Lower/ Middle/ Upper *(Select one- see topo map)* **Observation point/ stretch**: length:……………..m;		

CHANNEL DIMENSIONS AT SAMPLED LOCATION POINTS
(**Note**: *at least 2 measurements to determine averages*)

Dimension	**u/stream pt. (m)**	**d/stream pt. (m)**	**Average (m)**
Channel Bed width			
Channel. Width (top)			
Depth			
Estimated Bed Gradient (%):			

Coordinates (GPS instr.): Latitude:……………….. Longitude:……………………….

General Description of Observation site: *(note key features, infrastructure, land use, settlement etc.)*
____
____
____
____
____

General Weather: *(Tick off as appropriate)*

Clear/Sunny ___ partly cloudy ___ overcast ___

Windy ___ Light rain ___ Heavy rain ___

BIO-PHYSICAL OBSERVATIONS

Aspect/ Factor	Impacts/ Issue	Observed Intensity/status
Dominant Soil Material (*Geologic*)	(Erodibility)	1. Stable soil 2. Less/ mod. Stable soil 3. Unstable soil
Average Channel Grade (*Hydraulic*)	(Flow Velocity)	1. < 5% 2. >5% - 10% 3. >10%
Land Use/Management Practices (*mngt*) (*see attached notes*)	(facilitation of degradation)	1. perm. Cover/ GM 2. Semi-perm cover/MM 3. little/no cover/PM

SOCIO-ECONOMIC OBSERVATIONS

Aspect/ Factor	Impacts/ Issue	Observed Intensity/status
Settlement in vicinity	(wastes discharges/disposal)	0 - **None** 1- low density 2 – moderately dense 3 –high density
Built Infrastructure Within Channel/Buffer	(facilitation of damage)	0 - **None** 1 – within buffer 2 – in channel 3 – Both channel & Buffer

ENVIRONMENTAL OBSERVATIONS

Aspect/ Factor	Impacts/ Issue	Observed Intensity/status
Pollution Sources (*Pollution*)	(Chemical/ biological/physical water quality)	**0 - None** 1- Domestic only 2 – Industrial only 3 – Both
Physical Condition Of channel (stretch)	(Channel Stability) (*see notes below*)	1 - stable 2 – Moderately stable 3 – Unstable

GENERAL EXPLANATORY NOTES:

1. The purpose of this exercise is to establish some preliminary and general indication of the relative levels of susceptibility and vulnerability to degradation of a river channel and/or stretches of the same, based on a limited number of parameters/ aspects related to biophysical characteristics/ properties, socio-economic and environmental issues.

2. For the definition of specific designs and remedial works further planning and more in-depth and extensive field assessments must be undertaken, including the consideration of institutional/governance and regulatory issues.

3. The bio-physical parameters are meant to indicate/ flag relative level of susceptibility of the channel to degradation; socio-economic and environmental aspects flagged potential sources or factors which could further impact negatively on the stability of the channel, thus affecting its relative vulnerability status.

4. Ultimately, the aim of this initiative is to test this approach, in the first instance, and subsequently make the necessary adjustments/ improvements towards the establishment of a river monitoring regime, based on a list of prioritized river systems, which should inform the decision process related to sustainable watershed management and national development in general.

NOTES RELATED TO FIELD OBSERVATIONS

1. General methodology & approach: measurements and observations are limited to the lower three of four zonal areas used to zone the river's channel (*see table below*) ~ ***coastal, lower and middle***. Measurements and observations are to be made in at least two sampling locations within each of the selected three zones. Preferably, each selected location should be about 50 metres long; one of the two sampling locations should be a fairly straight stretch, while the other should include a bend, if possible.

2. **Some considerations in selecting a sampling location**:

- Consider the location of main tributaries or waterways that may exist within the zone; a chosen site should be at least a reasonable distance downstream or upstream of that confluence (where tributary meets main channel), where flows appear to be relatively 'stable/normal';
- Consider the location of major nearby social & economic infrastructure (major settlements centres, tourism infras., factories/ manuf. Infras., bridges, highways, agric. Fields, quarries, irrigation facilities, water supply infras., etc.);
- Consider the location of known significant ecosystems/ habitats (*marine & terrestrial*), established sanctuaries, protected areas, etc.;
- Discussions with local people usually helps;
- Where possible discuss with and notify property owners/ land users or neighbouring households before commencement of exercise;

IMPORTANT: please sketch on reverse side of form – i) a cross section and ii) a longitudinal profile of sampled location, and iii) any other observations made worth noting, even if the issue may be temporary; TAKE A PHOTO, if necessary & possible!!

3. **River zoning**: this is an arbituary classification based on ~ *a) elevation b) empirical observations of general land use intensity and management patterns associated with the river system.* This simplifies the methodology, without compromising objectivity; and it facilitates the analytical process.

Zone	Elevation	General land use Intensity & Mngt	Comments
Coastal	Up to 15 m	Generally Intense	Mixed uses: – agric./fisheries; industrial; Tourism; settlements & social infras.
lower	15 – 125 m	Generally Intense	Mixed uses: – agric.; industrial; settlements & social infras.
Middle	125 – 250 m	Moderately Intense	Settlements; agriculture; water abstraction & water catchment areas;
Upper	>250 m	Less intense; protection/ conservation	Water catchment areas; forest reserves/ private forests;

4. **Basic Field tools & equipment needed**: GPS unit; clinometer; digital camera; all weather measuring tape; watch; appropriate protective clothing, cloak, shoes & water boots; pen; pencil; waterproof sketch folder; cutlass; *Optional*: surveying equipment;

5. Key for symbols:

m – metre (~3.28 ft); GM – good management; MM – moderately managed; PM - poor management;

permanent cover/ GM ~ refers to buffer, with or without flood berm, and river banks with permanent vegetative cover. or some structural protective cover, such as grasses, well managed tree crops/ forest spp. Or properly designed & constructed bio-engineering bank protection structures; no livestock rearing within buffer, on r/banks and/or within channel OR well maintained drainage outfalls;

semi-permanent cover/MM ~ refers to buffer, with or without flood berm, and river banks with semi-permanent vegetative cover (*or with permanent vegetative cover, but of much lower density*) or some limited structural protective cover:- such as annual crops which provide limited bank protection, some tree crops/ forest spp., but not well managed Or some bio-engineering bank protection structures with limited effect; some livestock rearing within buffer, on r/banks and/or within channel, but not intense OR some/ partial maintenance of drainage outfalls;

little/ no cover/PM ~ refers to buffer, with or without flood berm, and river banks with little or no permanent vegetative cover for bank protection or no structural protective cover:- with indications of intense land use (e.g. – *clean cultivations*), livestock rearing within buffer, on r/banks and within channel OR poorly maintained drainage outfalls;

6. ***Channel stability***:- refers primarily to the existence and observation of physical conditions within the channel and/or the stipulated buffer zone which may render the river more vulnerable to physical degradation ~ e.g. - r/bank slippages, scourings, banks' side slope under cuttings; sediment bars within the channel (*with or without 'opportunistic' vegetation*); debris accumulation due to blockages/ fallen trees/ under-capacity structures (e.g. – *bridges, culverts*, etc.); ***Note***: significant signs or threats of degradation should be outlined and sketched; photos taken also, if possible.

Stable ~ no significant signs or threats of degradation;

Moderately/ less stable ~ some significant signs or threats of degradation, but not critical;

Unstable ~ several significant/ critical signs or threats of degradation, which may require immediate remedial action.

Appendix 4-Summary of Stakeholder Consultations Processes

Stakeholder Consultation Input Formats

Phase 3 - Table 3.1 Potential Causes of Erosion

Potential Causes	No. of Submissions/Comments	Interests Groups
Lack of sound soil management practices – in agriculture		Environmental Group Land owners Resource Users
Cattle grazing on riverbanks		
Flooding		
Private land owners not adhering to riparian buffers		
River stone mining		
Inadequate protected forests		

Phase 3 - Table 3.2 Specific Matters of Concern

Matters of Concern	No. of Submissions/Comments	Interests Groups
Rate of erosion has accelerated in the last five years		Environmental Group Land owners Resource Users
Experience intense erosion in rainy season		
Soil structure is affecting bank erosion		
Silt from erosion affecting water quality		
Xxxx worst places affected by erosion		
Point and non-point source pollution		
Increasing demand for water in all sectors		
Lack of valuation of watershed services		

Phase 3 - Table 3.3 Recommendations for Remedial Action

Recommendations	No. of Submissions/Comments	Interests Groups
Public Education		
Controlled Grazing of cattle		
Need for more rehabilitation work		
Adoption of Compensation for environmental services (CES) approach		
Legislation and Policy		
GAPs		

Appendix 5 –Flow Chart of Susceptibility Index

FLOW CHART

Determination of Probability Factor, Impact Factor and Threat Factor

Step 1
Qualitative ranking of the likely impact if the probable risk is realised, based on an assessment of the river system's capability to continue to provide/deliver its "normal" services1 (social, economic and environmental). It refers to an assessment of the "likely loss of function"; (e.g. recreation, water supply, ecological services, etc.).

The "loss of function" is also assessed based on the "likely duration of the event" and/ or "the severity of the impact of the event". Duration refers to the period after which "normal services" are likely to be recovered. The severity or extent of the impact takes into consideration specific zonal areas/ segments of the river or the entire river system, based on the nature of the triggering mechanism.

This assessment is a "holistic" qualification which is effected for each factor per category of factors (bio-physical, land use/management practices, socio-economic and environmental).

Step 2.

Considerations in the determination of the "Probability" Factor ranking and scoring matrix. (This refers to the probability of the assessed risk factor causing or contributing to an impact).

The assigned options for selection are ranked for each factor/ category, based on the assessed probability of an impact occurring with respect to the said risk factor. These are scored as low, medium or high, with a score of 1, 2 or 3 respectively.

Step 3

Considerations in the determination of the "Threat" factor scores.

The threat factor scores for each "assessed option" per risk factor is determined based on the following formula, and the scores assigned to each variable in assessing the possible threat level. **Threat= [1+ (probable speed of impact) + (probable duration of impact) + (probable lag time for impact)]**

A desk-based analysis was undertaken to calculate the score for each factor and similar procedures and analyses were effected for all the various factors and their respective assessment options

Step 4

Steps 1-3 lay the basis to assign the relevant scores for the Probability factor (P), Impact factor (I), and Threat factor (T) for each assessed condition or selection per each evaluated risk factor, based on the available secondary data (such as dominant soils, slope and land

a) Similarly, scores are assigned to the field-based assessments for the remaining factors/ category (socio-economic and environmental), provided in the data collection form.

b) The data for each control point/selected reach can then be tabulated in excel spreadsheets (referred to as "Look-up Tables"), in which the maximum values of P (Pmax), T (Tmax) and I (Imax) have been determined. The parameter, "C" = (Pmax+ Tmax+ Imax), has also been determined in the look-up tables for each category of risk factors.

c) Once the various assessed values for P, T, and I and other physical dimensional data (width, depth, slope, etc.) have been entered in the "look-up tables", the following susceptibility weightings and average cross-sectional area/ reach are automatically determined, given the formulations set therein.

\

d) Once the Relative Inter-Category weighting for each factor, which indicates the relative weighting of the risk factors within the broad category of factors (bio- physical, Socio-economic, or Environmental) is determined, the output can be ranked as high, medium or low. The weighting is determined as per the following formula:

a. Factor weighting= $\frac{Wf}{\sum(Wnf)} \times 100\% = \frac{(Pf \times Tf \times If)}{\sum(Wnf)} \times 1$ 100%

b. Where **Pf, Tf, and If** refer to the assessed values for the relevant risk factor;

c. $\sum$**Wnf,** refers to the sum of the respective weightings (P, T, I) for each factor, within the category.

e) The susceptibility index, Si, is calculated as per:

Si =

$$[\sum_{1}^{n}\left(\mathbf{Pcf} + Tcf + Icf\right) \div \left(\mathbf{Pmax} + \mathbf{Tmax} + \mathbf{Imax}\right)$$

x 100%

Where Pcf, Tcf, Icf refer to the assessed values of the factors/ category; and Pmax, Tmax, Imax, refer to the maximum attainable values for each assessed factor/ category.

Step 5: Ranking of the"SI"

a) Once the "Si" is determined, it is now simple to allocate the category of factors under the adopted ranking (high, medium or low).

b) For spatial representations, colour coding for “high”, “medium”, and “low” can be adopted in depicting the associated ranking. In some instances, very high scores may be/ are obtained. This certainly is a strong indication that the relevant segment or zonal areas of the river need further and more in-depth examination and more direct interventions, subject to the related issues, which must be fully studied/ analysed.

Appendix 6-Adhoc Technical Committee and Draft Adgenda

A-List of Participants and Agenda (WORKING SESSION – July 9, 2008)

1	Name of Participants	Department/Company Represented	Contact Number.	Email
2	Aquila Luncheon	St.Lucia Tourist Board	458-7106	aluncheon@stlucia.org
3	Dawn French	NEMO Secretariat	452-3802	slunemo@gmail.com
4	Martha Blanchard	Ministry of Social Transformation	468-5728/719-8618	Blanchard_martha@yahoo.com
5	Donatian Gustave	MALFF - DoF	468-5647	Choulu79@gmail.com
6	Julian King	Ministry of Physical Development	468-5015	kingjul@hotmail.com
7	Christopher Lamont	Co-operative Department	468-5573	Chris.fire@live.com
8	Rufus Leandre	MALFF- Extension	468-4128/29	aoe@slumaffe.org
9	Faustinus Monero	MALFF - WRMA	450-2281	faustinusm@hotmail.com
10	Alfred Prospere	MALFF- DoF	487-7251	Starbathc2006@yahoo.com
11	Deborah Bushell	SFA 2003,TA Team	456-0146	Sfa.inrm.specialist@gmail.com
12	Jacinta Francis	Ministry of Tourism	468-4619/451-6849	ajacintafrancis@gmail.com
13	Marian Francis-Henry	Physical Planning	468-4437	physicalplanningstlucia@gov.lc
14	Michael Andrew	MALFF- DoF	468-5634	gaspardtalk@yahoo.com
15	Elizabeth Charles-Soomer	AGRICO/RRA Consultant	452-5055	Soomer-ec@yahoo.com
16	Cecil Henry	IWCAM	453-3148	hudgehenry@hotmail.com
17	Martin Satney	AGRICO/RRA Consultant	258-5089	martsaatline@gmail.com
18	Luvette Louisy	AGRICO/RRA Consultant	451-3088	louisyt@candw.lc

B.List of Data Collectors/Field Officers Forming Assessment Team

NAME	DEPARTMENT
Donatian Gustave	Forestry Department
Alfred Prospere	Forestry Department
Odetta James	Forestry Department
Patrick Charles	Forestry Department
Karl Augustin	Forestry Department
David Lewis	Forestry Department
Fitz John	Engineering Department
Junior Mathurin	Water Resources Unit

Riverbank Assessment Consultancy

For Saint Lucia

Working Session with Technical Working Group
Wednesday, July 9, 2008, Forestry Department, Union

Background

There is need for immediate re-dress of the situation of severe land degradation and turbidity in water resources that continues to accompany heavy rainfall, as a result of the socio-economic practices of communities that lie in close proximity to riverbanks. This is essential to control and prevent further erosion of the riverbanks and the consequent negative environmental, social and economic consequences resulting thereof. To this end, a rapid assessment method of measuring riparian conditions of the riverbanks of the premier watercourses on the island is needed to underpin strategies for improved management through a proposed extensive "RIVERBANK REHABILITATION AND PROTECTION" programme.

This consultancy for Riverbank assessment is intended to inform a riverbank rehabilitation and protection programme. It is expected that this assignment would be the first phase of a proposed two phase approach to address this major environmental problem of national import having as its aim, the development of a rapid assessment methodology for the assessment of the current status of targeted riverbanks to make recommendation and formulate an action plan that will required for an extensive "RIVERBANK REHABILITATION AND PROTECTION" programme using an economic, social and ecological approach towards the conservation and protection of the rivers, riverbanks, water resources and natural landscapes.

Objectives:

- To present the main elements of the rapid riverbank assessment methodology
- To discuss and refine key components of a methodology applicable to Saint Lucia for conducting rapid riverbank assessment and evaluation based on internationally accepted standard;

- To employ the methodology for profiling river systems to select at least three river systems to pilot the RRA methodology at field level to assess the bio-physical and geographical nature of degraded riverbanks;
- To use information from the exercise to establish a framework to categorize and prioritize the issues and remedial measures needed to address the deterioration of riverbanks.

Agenda:

1. **Welcome and Introductions**
2. **Review and confirm criteria for methodology for Profiling River Systems and apply criteria for the scoping and selection of** Pilot **river systems**
3. **Review of main elements and key thematic issues of RRA**
4. **Develop action plan for conduct of field assessments**
5. **Discussion of Table of Contents of Riverbank Assessment Report**
6. **AOB**
7. **Next steps**

Appendix 7- Summary Table - Status of River Systems based on Profiling Criteria

	RIVER SYSTEMS /IMPACT																					
PROFILING CRITERIA (ASPECTS)																						
Bio Physical Aspects																						
Hydrology: Drainage Area Length (km) Width range (m) Avg. Long. Gradient (m/km) No. of tributaries Stream Discharge																						
Geomorphology – Topo/ relief features Slope Classes																						
Adjacent Land Use Vegetation Percentage of Cover Type of Cover																						
(Climatic Regimes) – Hydromet Condition: Rainfall																						
Edaphic Condition Parent material Soil classes Dominant soil type																						
Status of riparian buffers																						
River Training/Manipulations																						
Socio-Economic Aspects																						
Livelihoods																						
Land Tenure																						
Infrastructure																						
Population																						
Settlements (No. and Location)																						
Water Supply Systems																						
Environmental Aspects																						
Ecological Value - Conservation Areas																						
Water Production/Abstraction Levels																						
Water quality: Pollution Sources																						
Physical Channel Degradation																						
Vulnerability (landslides/flood/drought)																						
Management/ Governance																						

Legislation/Regulations																						
Institutional/Organisation																						
Stakeholder Involvement																						
Community Participation																						

Appendix 8- GIS FLOW CHART

FLOW CHART

RIVER BANK RAPID ASSESSMENT – DIGITAL DATABASE DEVELOPMENT

1. Overview

A comprehensive GIS database of the three (3) selected or pilot rivers was developed in ARC GIS to support the information, mapping and analytical requirements including future monitoring, of the Rapid River Bank Assessment Methodology (RBAM). The database comprises four (4) main GIS datasets created from a combination of secondary (analogue maps, existing digital information, aerial photography and documents) and primary sources (field sources and consultation).

These are summarised as follows:

1. A database of the Selected Rivers and Buffers along with their attributes (description) relevant to the analysis.
2. A database of the Segments of Selected Rivers and Buffers along with their attributes (description) relevant to the analysis
3. A database of River Based Control Stations and their attributes (description) falling within the river segments
4. A database of Hyperlinked Pictures of river bank conditions at or around the based control points within the respective segments to facilitate future visual monitoring

The use of ARC GIS, ARC VIEW and related ESRI products was dictated by the existence of this software within the Forestry Department and other key agencies in St. Lucia. As such the Forestry Department has some local capacity and proficiency in the use of the software along with hands-on experience in a number of GIS application areas

2. Database Development Process and Application

Stage 1- Selection of Rivers Three (3) rivers were selected to test the methodology.

Troumassee River: the largest river in St. Lucia with a relatively pristine profile as a significant part of the river falls within forested and protected forested areas. Its mid and upper reaches are not significantly impacted upon by settlement and other such uses

The Roseau River: an active system with diverse impact scenarios – forested, intensive agriculture, damming, industrial uses etc.

The Choc River : also with diverse impact scenarios (forested, intensive agriculture, damming, industrial uses, urban settlement, up market real estate in some locations, tourist developments within the coastal sphere of influence and critical facilities e.g. Dame Pearlette Louisy School etc.). The water system thus has significant economic impacts.

The three (3) rivers were selected as line files from the hydrology layer of the 1:25,000 topographic sheet (1990) and saved as three (3) separate layers

Stage 2- Buffering Rivers to Create the First Unit of Spatial Assessment

Using the buffering function in ARC GIS, a 50 m buffer was created on either side of each river within each of the 3 layers: _

- Troumassee
- Roseau
- Choc

The 50 m buffer is over the nationally applied 20 m/60 ft (Policy decision by Cabinet Conclusion) but was used to get a large enough physical area around the river to enable reasonable analysis of landuse, soil type and other factors pertinent to the analysis.

Stage 3a – Creating River Bank Specific Datasets from Existing Digital data

The buffer was then used as a clip coverage/layer to derive the River Bank or study area-specific descriptive information required for the analysis from the national GIS database. These layers are as follows:-

- Soil type

- Slope (categories: - >5%, 5%-10 %,> 10%). A slope map was developed by the Physical Planning Unit (PPU) using the SPANS GIS Contouring function. The source data was the 1:25,000 Digital Elevation Model of St. Lucia (DEM) developed from the DEM points from the 1:25,000 (1990) map sheet. The data structure of the slope map produced by the PPU SPANS system was a quadtree – an efficient data structure for quick analysis but with a blocky visual appearance. This was converted to a vector (sharper appearance) in ARC GIS and a new vector based slope map was produced.

- Contour heights in ft. This was converted to meters by using a calculated field in the descriptive or attribute table.

- Life zones / vegetation

- Landuse (Forestry Management Plan 1992).

Stage 3b - Creating a Current Landuse layer for the River Buffer from Aerial Photos.

The digital aerial image was first orthorectified and then geo-referenced in the GIS so that the images fell in their correct geographic location with respect to the geo-referenced topographic map of St. Lucia. Once referenced the aerial images were clipped with the Buffer Clipped Coverage for each river to facilitate the interpretation of landuse within the buffer area only.

The 1992 Forestry Management Plan landuse data definitions (categories) were used for consistency to enable comparative analysis and to ensure the correctness of life zones and interpretation of other landuse classes.

Stage 4. Segmenting River Bank Areas into 4 Zones (Upper, mid, lower and….) - Second Unit of Spatial Assessment

Four (4) segments were created for each buffered river based on the captioned height thresholds. This was done to create location-specific assessments of the selected rivers and their banks and to set the framework of control stations or points to measure, assess and monitor key parameters of the RRBA

The segments were derived from an overlay of the river buffer and contour map. They were selected through visual assessment of the respective contour heights (where they cross the river). Areas outside the selection were deleted and the files saved. This was done for each zone within each river. At the end of the process 12 new segment files, three (3) for each river were produced.

Stage 5a - Control Stations were Selected within each Segment

The segments were derived from an overlay of the river buffer and contour map. They were selected through visual assessment of the respective contour heights (where they cross the river). Areas outside the selection were deleted and the files saved. This was done for each zone within each river. At the end of the process 12 new segment files, three (3) for each river were produced.

Stage 5b – Populating the Control Station Points with Risk Analysis Information

A standard Data Collection Sheet (Appendix 3) was developed to capture information about the river channel at the control points. These included the following channel characteristics:-

- Channel bed width, Channel width and depth
- Description of site location –vegetation cover, landuse, observed siltation
- General weather conditions and time of day
- Lat/Long coordinates (GPS reading)

Other parameters related to biophysical characteristics, socio economic factors and environmental issues were derived from a number of input layers developed from clipping the various buffer maps with the individual segment boundaries.

- Soil erodability determined by dominant soil group
- Channel gradient – slope of the river bed to determine the velocity of flow
- Landuse management practices and their facilitation and impacts on degradation in the river buffer
- Socio-economic parameters (impact of settlement on water quality) and the existence of infrastructure in buffer area to assess the facilitation of damage in the buffer

For each of these, the probability of risk and impact level were determined and scored. The probability of risk and impact scores were then combined to form a composite score which reflects a threat of impact (highest score implying greatest impact).

The main purpose of this application and the use of these parameters is to assess the level of susceptibility and vulnerability of the river channel to degradation.

The above parameters and their Probability of Risk, Impact level and threat of Impact were added to the attribute table of the Control Point file.

Stage 6 – Creating a Pictorial Database within Control Stations of Each River Segment to Facilitate Future Monitoring of Critical Areas

The purpose of this database is to provide a base for future visual monitoring of the status of river banks.

A number of digital photographs were taken at the Control Points within the segments (lower and coastal). The pictures will be hyperlinked to the point file (lat/long coordinates) Because there are several digital pictures per site a number of approximate points around the Ground Control Points were chosen to hyperlink each picture.

3. Limitations

i. In light of the need to produce a rapid assessment methodology to assess the status of river banks, it is arguable whether the use of aerial photography to derive current landuse information, though critical to the exercise, can be considered to be part of a rapid process. This is due to the fact that the existing 2004 aerial photographic data set is neither geo-referenced nor orthorectified – two factors important for the immediate use of geographic data to interpret landuse for use in analysis

ii. It is important to use a topographic map out in the field to collect field data related to ground control points as GPS readings can sometimes produce inaccurate locational information due to issues relating to the absence of stationery GPSs which provide accurate references for the roving GPS used by researchers in the field.

iii. The GIS information used in the assessment is bounded by the accuracy and currency of existing GIS base information from secondary sources.

4. Recommendations and Suggested Applications

The main use of the GIS in the current RRBA is in the development of a comprehensive digital database of pertinent information required to undertake a rapid assessment of riverbanks and the quality of water systems based on the key factors.

The GIS is thus a data management tool – capture, storage, retrieval, mapping and data manipulation, and brings together data from a number of sources into a single system

Sources of Data

i. Aerial photography in the development of current landuse
ii. GPS locations for control stations
iii. Data collected manually by measurement and observation at control points.
iv. Existing digital datasets at a national scale e.g. dominant soil classes

The base or input datasets necessary for future analysis can be derived as follows

For the future application of the RRBA, the use of GIS as an analytical tool is circumscribed by the availability of existing detailed data about each water

Within the Existing RRBA Database

i. National Soils dataset with the dominant group
ii. National Rivers dataset which can be easily buffered using the same buffer sizes (50m)
iii. National Contour information which can be derived from a referenced topographic digital map to clip river segments
iv. National Slope (gradient) layer can be adjusted to yield the slope categories for other river bank locations

The RRBA can be expanded to include:-

- Landuse for the rest of St. Lucia with classifications consistent with the Forestry Management Plan (1992). These are available for some watersheds – Cul-de-Sac and Soufriere (AGRER 2008), Choiseul, Laborie, Micoud and Vieux-Fort (NAP 2008). These can be obtained and stored for future analysis.

Outside these locations up-to-date landuse maps would have to be developed through orthro-rectification and geo-referencing of the 2004 digital aerial photos. The identical landuse classes (FMP 1992) would have to be used to ensure consistency and to facilitate comparative analysis.

Collection of Field Data

Data within the coastal and lower segments of future rivers along with picture evidence would have to be collected from the field and the subjective code assigned to each control point to determine risk, impact and overall score.

Building Intelligence in Data sets for future applications

This application was conducted using the RRBA assessment method which uses a set of indicators and their strengths expressed as a score in relation to risk and impact. This intelligence needs to be built into the future datasets for other locations and can be done using a set of 'Look Up tables' in the GIS.

Bio-Physical and Socio-Economic variables

- Landuse classes (15 types) and their assigned suitability classes of risk, impact and overall score (APPENDIX 9)
- Dominant soil types (49 types) and their assigned stability classes of risk, impact and overall score (APPENDIX 10)
- Gradient (3 levels) and their assigned classes of risk impact and overall score (APPENDIX 11).

These variables will be contained in an Excel spreadsheet and will be joined to each new river buffer clip layer by a common identifier – dominant soil class for the Soils map; Landuse class name for the Landuse Map etc. Hence; the impact, risk and overall scores will be automatically assigned to each layer.

Applications

1. In selecting critical rivers using biophysical and socio-economic scores, the Look Up Tables can be joined to assign classes to each soil, landuse and slope layer of every new river. The scores will signal the possible worse case scenarios and thereby flag Priority Rivers for further investigation via socio-economic and environmental field assessments.

2. All RRBA datasets (along with pictorial data) for each river can be used for bench marking. These benchmarks will be used to monitor the impact of improvement and rehabilitation programmes.

3. A new pictorial database can then be developed for each year using the same ground control points to monitor change and to create time series data.

4. When a large number of rivers have complete datasets, a profile of a typical 'poor', 'average' and 'good' riverbank can then be built.

5. The GIS can also assist in quantifying rehabilitation work through physical measurement of affected areas and estimates of cost.

6. The GIS can also be used as a tool to plan the river bank rehabilitation programme.

5. Data Catalogue

This is sub headed into a directory. This directory can be further broken down into two groups namely: **SHAPEFILES AND HOT LINK**.

SHAPEFILES:
The sub directory SHAPEFILES consists of 6 categories which are further elaborated

(1) 3 RIVERS_LANDUSE 2004: 2004 Landuse for each river

(2) 3 RIVERS_MAIN DATABASE: Main Databases showing Risk Analysis and Evaluation

(3) RIVER SEGMENTS_BUFFER POLYGON: River Segments and Buffers based on Zones: Zones are 15m,

(4) CHOC:
(a) Choc Main River
(b) Choc River 50metre Buffer
(c) Choc River Risk Analysis & Evaluation
(d) Choc River Zones

(5) ROSEAU

- **(a) Roseau Main River**
- **(b) Roseau River 50metre Buffer**
- **(c) Roseau River Risk Analysis & Evaluation**
- **(d) Roseau River Zones**

(6) TROUMASSEE

- **(a) Troumassee Main River**
- **(b) Troumassee River 50metre Buffer**
- **(c) Troumassee River Risk Analysis & Evaluation**
- **(d) Troumassee River Zones**

HOT LINKS

Provides images of the three different rivers: Troumassee, Roseau and Choc rivers.

Appendix 9- Landuse classes and their Assigned Suitability Class of Risk, Impact and overall score

Landuse Classes	Land Grouping	Impact Score	Probability Risk Score	Threat Score	Total Score
Flatland Intensive Farming*	B	2	2	4	8
Eroded Agricultural Land**	C	3	3	7	13
Intensive Farming (25% Forest)*	B	2	2	4	8
Densely Vegetated Farming	A	1	1	1	3
Mixed Farming*	B	2	2	4	8
Open Grasslands & Woodlands	A	1	1	1	3
Forest Reserve	A	1	1	1	3
Natural Tropical Forest*	A	1	1	1	3
Mangrove*	A	1	1	1	3
Plantation Forest*	A	1	1	1	3
Scrub Forest	C	3	3	7	13
Pasture (Wetland)	B	2	2	4	8
Rock and Exposed Soil	C	3	3	7	13
Pond	NA	-	-	-	-
Sand Deposit	NA	-	-	-	-
Water	NA	-	-	-	-
Urban Settlement	C	3	3	7	13
Rural Settlement	B	2	2	4	8
Millennium Highway	NA	-	-	-	-
Old Garbage Dump	NA	-	-	-	-

Includes 1992 and 2001 classes combined

Based on categories in Table 17(section 5) Grouping of 1992 Land Use classes as per adopted field based scoring of land use management practices.

A - Permanent Cover/Good Management

B -Semi-Permanent Cover/ Moderate Management

C -Little/ No Cover/Poor Management

Appendix 10-Dominant soils and their Assigned Suitability Class of Risk, Impact and overall score

Soil Type	Dominant Soils Group/Family		Stability Class	Impact Score	Probability/ Risk Score	Threat Score	Total Score
Annus Clay	Vertisol	C	Unstable/Fragile	3	3	7	13
Anse Clay	Vertisol	C	Unstable/Fragile	3	3	7	13
Assor Clay	Ultisol	B	Less Stable	2	2	5	9
Balembouche Gritty Clay Loam	Mollisol	A	Stable	1	1	3	5
Balembouche Gritty Clay Loam (shallow)	Mollisol	B	Less Stable	2	2	5	9
Bare Rock	-	-	-	-	-	-	-
Beach Sands	-	-	-	-	-	-	-
Becune Loam	Mollisol	A	Stable	1	1	3	5
Belfond Clay Loam	Alfisol	A	Stable	1	1	3	5
Bocage Stony Clay	Mollisol	A	Stable	1	1	3	5
Calfourc Silty Loam	Andisol	A	Stable	1	1	3	5
Cannelles Clay	Inceptisol	A	Stable	1	1	3	5
Casteau Gravelly Boulder	Inceptisol	B	Less Stable	2	2	5	9
Cliff	-	-	-	-	-	-	-
Cochon Silty Clay Loam	Inceptisol	A	Stable	1	1	3	5
Deglos Silty Clay	Vertisol	A	Stable	1	1	3	5
Delomel Clay	Vertisol	C	Unstable/Fragile	3	3	7	13
Dennery Clay	Inceptisol	B	Less Stable	2	2	5	9
Dry Pond	-	-	-	-	-	-	-
Dugard Clay	Vertisol	C	Unstable/Fragile	3	3	7	13
Esperance Clay	Inceptisol	A	Stable	1	1	3	5
Excessively Steep Slopes	-	-	-	-	-	-	-
Falaise Stony Loam	Mollisol	B	Less Stable	2	2	5	9
Franciou Stony Clay	Inceptisol	B	Less Stable	2	2	5	9
Garrand Clay Loam	Inceptisol	A	Stable	1	1	3	5
Gommier Stony Clay Loam	Mollisol	B	Less Stable	2	2	5	9

Soil Type	Dominant Soils Group/Family		Stability Class	Impact Score	Probability/ Risk Score	Threat Score	Total Score
Hardy Clay	Vertisol	C	Unstable/Fragile	3	3	7	13
Haut Clay Loam	Inceptisol	A	Stable	1	1	3	5
Ivrogne Stony Clay	Inceptisol	B	Less Stable	2	2	5	9
Jalousie Clay	Inceptisol	A	Stable	1	1	3	5
Jambette Stony Silty Clay Loam	Inceptisol	A	Stable	1	1	3	5
Jean Baptiste Silty Clay Loam	Inceptisol	A	Stable	1	1	3	5
Latille Clay Loam	Inceptisol	A	Stable	1	1	3	5
Mabouya Silty Clay	Inceptisol	B	Less Stable	2	2	5	9
Made Land	-	-	-	-	-	-	-
Mahaut Silty Clay Loam	Inceptisol	A	Stable	1	1	3	5
Mangrove Swamp	-	-	-	-	-	-	-
Marquis Clay	Inceptisol	A	Stable	1	1	3	5
Michel Gritty Clay	Alfisol	A	Stable	1	1	3	5
Micoud Gritty Clay	Mollisol	B	Less Stable	2	2	5	9
Moreau Clay	Ultisol	B	Less Stable	2	2	5	9
Panache Silty Clay Loam	Inceptisol	A	Stable	1	1	3	5
Parasol Clay	Inceptisol	A	Stable	1	1	3	5
Piaye Silty Clay	Entisol	A	Stable	1	1	3	5
Quarry	-	-	-	-	-	-	-
Quilesse Silty Clay	Inceptisol	C	Unstable/Fragile	3	3	7	13
Rabot Clay	Alfisol	A	Stable	1	1	3	5
Raveneau Clay	Vertisol	A	Stable	1	1	3	5
Regnier Stony Clay	Inceptisol	A	Stable	1	1	3	5
Richfond Fine Sandy Clay Loam	Inceptisol	A	Stable	1	1	3	5
Rozette Gritty Clay	Alfisol	A	Stable	1	1	3	5
Salina	-	-	-				
Soucis Silty Clay Loam	Inceptisol	A	Stable	1	1	3	5
Sulphur Springs	-	-	-	-	-	-	-
Swamp	-	-	-	-	-	-	-

Soil Type	Dominant Soils Group/Family		Stability Class	Impact Score	Probability/ Risk Score	Threat Score	Total Score
Troumassee Loam	Inceptisol	A	Stable	1	1	3	5
Urban Area	-	-	-	-	-	-	-
Vanard Peat	Histosol	C	Unstable/Fragile	3	3	7	13
Venus Loam	Andisol	A	Stable	1	1	3	5
Warwick Clay	Inceptisol	A	Stable	1	1	3	5
Zenon Gravelly Bouldery	Mollisol	B	Less Stable	2	2	5	9

Appendix 11- gradient and their Assigned Suitability Class of Risk, Impact and overall score

Gradient Class	Impact Score	Probability Risk Score	Threat Score	Total Score
<5%	1	1	3	5
>5%-10%	2	2	5	9
>10%	3	3	7	13

Appendix 12- Photo Cache

Photo Cache

PHOTO CACHE
Conditions at some of the sample sites.