

NATURAL RESOURCES SYSTEMS PROGRAMME

FINAL TECHNICAL REPORT¹

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Project title

Impact and amelioration of sediment and agro-chemical pollution in Caribbean coastal waters.

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Organisation

University of York and MRAG Ltd

NRSP Production System

LWI

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Annex A1

Annex A1. Mees, C., N. Esteban and S. Seddon-Brown, 2003. Management of agro-chemicals for improved public and environmental health - A strategy for improved agro-chemical use and management for the Wider Caribbean: DFID NRSP Project R7668. Policy and Management Strategy Document, MRAG Ltd.

Appendix 1. Policy Brief 1: Management of agro-chemicals for improved public and environmental health (2003)

Appendix 2. Policy and Management Brief 2: The fate of agro-chemicals in the land-water interface in St Lucia and Jamaica: Environmental monitoring (2003)

Appendix 3. Policy and Management Brief 3: The quantification and toxicity of agro-chemical imports into St Lucia and Jamaica (2003)

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Appendix 5. Policy and Management Brief 5: Harmonisation of agro-chemical management in the Caribbean (2003)

Appendix 6. Policy and Management Brief 6: Management options for the use of agro-chemicals (2003)

Annex A2

Annex A2. Roberts, C.M., Barker, N.L.H., Clarke, A.J., Gell, F.R.G., Hawkins, J.P., Nugues, M.M., Schelten, C.K. 2003. Impact and amelioration of sediment pollution on coral reefs of St. Lucia, West Indies. University of York, York.

Appendix 1. Policy and management brief 1: Impacts and mitigation of sediment pollution on coral reefs

Appendix 2. Policy and management brief 2: Value of the Soufriere reef fishery

Appendix 3. Policy and management brief 3: Value of coral reefs for tourism and costs of reef degradation

Appendix 4. Policy and management brief 4: Funding coral reef management

Appendix 5. Policy and management brief 5: Impacts of tourism on coral reefs and options for management

Annex B1

Annex B1.1. Report 1: Esteban, N., P. Espeut, B. Hay, C. Mees and S. Seddon-Brown, 2003. Importation, administration and harmonisation of agrochemical management in St Lucia, Jamaica and the wider Caribbean. DFID NRSP Project R7668. C-CAM and MRAG Ltd.

Annex B1.2. Report 2: Simpson, L., 2003. Review of soil management and farming practices, including the use of agro-chemicals in the Caribbean, with particular reference to St Lucia and Jamaica. DFID NRSP Project R7668. CARDI (Jamaica).

Annex B1.3. Report 3: Dasgupta, T. and C. Perue, 2003. Toxicity review for agro-chemicals in St Lucia and Jamaica. DFID NRSP Project R7668. Chemistry Department, UWI, Mona.

Annex B1.4. Report 4: Boodram, N., 2002. The fate of agro-chemicals in the land-water interface, with reference to St Lucia and the wider Caribbean. DFID NRSP Project R7668. CEHI.

Annex B1.5. Report 5: Edwards, P., 2001. The fate of agro-chemicals in the land-water interface, with reference to Jamaica and the wider Caribbean. DFID NRSP Project R7668. Centre for Marine Studies, UWI, Mona.

Annex B1.6. Report 6: Lewis, A. and N. Esteban, 2002. Environmental survey of agro-chemicals in the land water interface of St Lucia. DFID NRSP Project R7668. CEHI and MRAG Ltd.

Annex B1.7. Report 7: Pearce, J., and N. Esteban, 2002. Database review and user requirements analysis prepared for the Coordinating Group of Pesticide Control Boards of the Caribbean. DFID NRSP Project R7668. MRAG Ltd.

Annex B1.8. Report 8: Esteban, N., C. Mees, and S. Seddon-Brown, 2003. Environmental monitoring options. DFID NRSP Project R7668. MRAG Ltd.

Annex B1.9. Report 9: Seddon-Brown, S., C. Mees and N. Esteban, 2003. Management options for the use of agro-chemicals in the environment. DFID NRSP Project R7668. MRAG Ltd.

Annex B1.10. Communication partners involved in various project activities or in receipt of promotional material

Annex B2

Report B2.1: Schelten, C.K. and C.M. Roberts. 2002. The effects of human-induced pollution on the replenishment of coral reefs. DFID NRSP Project R7668. University of York, UK.

Report B2.2: Schelten, C.K., Roberts, C.M., Nugues, M.M., Hawkins, J.P. 2002.

- The interacting effects of sedimentation, fishing and hurricanes on coral reefs: a long-term study in St. Lucia, West Indies. DFID NRSP Project R7668. University of York, UK.
- Report B2.3: Schelten, C.K., Roberts, C.M., Wabnitz, C.C.C., Nugues, M.M. and Hawkins, J.P. 2002. The effects of human-induced sedimentation on juvenile coral assemblages. DFID NRSP Project R7668. University of York, UK.
- Report B2.4: Schelten, C.K., Roberts, C.M., Hawkins, J.P., and Nugues, M.M. 2003. The effects of sedimentation on coral larval settlement. DFID NRSP Project R7668. University of York, UK.
- Report B2.5: Schelten, C.K., Roberts, C.M., Hawkins, J.P., and Nugues, M.M. 2003. Impacts of sedimentation on juvenile coral settlement, mortality and growth. DFID NRSP Project R7668. University of York, UK.
- Report B2.6: P. Hubert. 2001. A study of the Soufriere Fisheries. DFID NRSP Project R7668. University of York, UK.
- Report B2.7: Preliminary report on the economic effects of marine reserves on the reef fishery of Soufrière, Saint Lucia, West Indies. DFID NRSP Project R7668. University of York, UK.
- Report B2.8: Gell, F.R., C.M. Roberts, P. Hubert, J.P. Hawkins, R. Goodridge, H.A. Oxenford, W. Joseph and S.N. George. 2003. The rate and trajectory of recovery of fisheries adjacent to marine reserves. DFID NRSP Project R7668. University of York, UK.
- Report B2.9: Gell, F.R., C.M. Roberts, J.P. Hawkins, R. Goodridge and H.A. Oxenford. 2003. The effects of marine reserves on reef fish populations and catch composition. DFID NRSP Project R7668. University of York, UK.
- Report B2.10: Gell, F.R. and C.M. Roberts. 2003. Availability and uptake of alternative sources of income for fishers in Soufriere, St Lucia. DFID NRSP Project R7668. University of York, UK.
- Report B2.11: Barker, N.L.H. and C.M. Roberts. 2003. Scuba diver behaviour and the management of diving impacts on coral reefs. DFID NRSP Project R7668. University of York, UK.
- Report B2.12: Barker, N.L.H. and C.M. Roberts. 2003. Snorkeler behaviour on coral reefs. DFID NRSP Project R7668. University of York, UK.
- Report B2.13: Barker, N.L.H. and C.M. Roberts. 2003. Economic benefits of coral reef tourism and maximising the potential for tourists to fund management of marine protected areas. DFID NRSP Project R7668. University of York, UK.
- Report B2.14: Barker, N.L.H. and C.M. Roberts. 2003. Relationships between tourist perceptions and measured attributes of coral reefs. DFID NRSP Project R7668. University of York, UK.
- Report B2.15: Barker, N.L.H. and C.M. Roberts. 2003. Management and development of coral reef tourism in St. Lucia. DFID NRSP Project R7668. University of York, UK.

Annex C

- Annex C1.1: Roberts, C.M, J.A. Bohnsack, F.R. Gell, J.P. Hawkins and R. Goodridge. 2001. Effects of marine reserves on adjacent fisheries. *Science*, 294: 1920-1923.
- Annex C1.2: Roberts, C.M, J.A. Bohnsack, F.R. Gell, J.P. Hawkins and R. Goodridge. 2002. Marine reserves and fisheries management. *Science* 295: 1233-1235.

Annex D. Final Project Inventory

Abbreviations and Acronyms

CARDI	Caribbean Agricultural Research and Development Institute
CARICOM	Caribbean Community and Common Market
CAR/RCU	Caribbean Regional Co-ordinating Unit (UNEP)
C-CAM	Caribbean Coastal Area Management (Jamaica)
CEHI	Caribbean Environmental Health Institute (St Lucia)
CGPC	Coordinating Group of Pesticide Control Boards in the Caribbean
CPUE	Catch-per-unit-effort
CSL	Central Science Laboratory, UK
DFID	Department for International Development (UK)
EU	European Union
FAO	Food and Agriculture Organization
GAP	Good Agricultural Practice
ICENS	International Centre for Environmental and Nuclear Sciences (Jamaica)
IICA	Inter-American Institute for Cooperation on Agriculture
ILO	International Labour Organization
IPM	Integrated Pest Management
LBS	Protocol on Land Based Sources of Pollution
LWI	Land Water Interface
MRAG	Marine Resources Assessment Group Ltd (UK)
MRL	Maximum Residue Limit
NPA	National Plan of Action
NRSP	Natural Resources Systems Programme (of DFID)
OECS	Organisation of Eastern Caribbean States
PCA	Pesticides Control Authority, Jamaica
PCB	Pesticides Control Board
POPs	Persistent Organic Pollutants
SMMA	Soufriere Marine Management Area
UNEP	United Nations Environment Programme
UPCS	Uptake Promotion / Communications Strategy
UWI	University of the West Indies
WCR	Wider Caribbean Region
WHO	World Health Organization

1. Executive Summary

Sediment and agro-chemical pollutants represent two of the most serious threats to the integrity of tropical coastal ecosystems in the Caribbean. Although developing countries use 10-25% of the world's pesticides, they suffer up to 50% of the reported cases of acute poisoning and 73-99% of the reported fatalities among pesticide applicators². Farmers in developing countries are especially at risk because of inadequate training or inability to read instructions for application of hazardous pesticides. In the Caribbean it is the poor and socio-economically disadvantaged who are at greatest risk. Coral reef ecosystems are sensitive to sediment pollution, which can stress corals and cause their mortality, potentially impacting on fish catches, tourism amenity value and other ecosystem services provided by reefs. The Protocol on Land Based Sources of Pollution (LBS Protocol) to the Cartagena Convention (1983) addresses these problems, and outlines the obligations of Caribbean states to set up national plans to address the issue of ameliorating all types of pollution from land-based sources including sediment and agro-chemical pollution.

This project has undertaken research to evaluate and document the impacts of land based sources of pollution on the coastal waters of St. Lucia and Jamaica. We have developed products (a management strategy, policy and management briefs, and technical reports) that contribute towards the goal of integrated natural resource management and prevention of threats from pollution on Caribbean coastal ecosystems and people dependant upon them for their livelihoods. Local adoption of these products is required to deliver that goal, and will be the focus of a subsequent uptake promotion project. This Final Technical Report (FTR) conforms to a prescribed format, and describes all project activities and the products generated against Output indicators specified in the project logical framework³. To assist the reader, Figure 1 provides an overview of project activities and products (all project documentation, i.e. the Annexes to this FTR) for the agrochemical research, indicating how the different components of the project fit together, and how they relate to the 'agro-chemical life-cycle' of events. A strategy, or action plan, for improved agro-chemical use and management (Annex A1) is a major product of this research. The strategy was developed with policy makers (see below) and has been informed by the outcome of all prior project activities (Annexes B1.1 – B1.9). Figure 1 illustrates the critical control points within the 'agro-chemical life-cycle' at which these products contribute towards the mitigation and monitoring of agro-chemical pollution.

We explored the existing arrangements for the import and administration of agro-chemicals and the quantities of chemicals imported. Existing agricultural land management, and agro-chemical use practices were reviewed, including an evaluation of who uses agro-chemicals. Potential sources of sediment pollution were identified. We recorded agro-chemical loadings and their probable pathways and assessed their fate in the environment for the two countries⁴. Workshops were held in year two for the agro-chemical work and in years two and three for the sediment and fisheries work to gather data and solicit opinions of stakeholders. Field research was also conducted and quantitative data analysed for both sediment and agro-chemical pollutants in St Lucia, and from this a sustainable mechanism for continuous data collection and monitoring programmes was developed. We evaluated the toxicity of agro-chemicals to human health and the environment, and the impacts of pollution on the livelihoods of small-scale farmers and fishers, including an estimate of some of their economic impacts. A synthesis of all these studies informed specific ways of reducing these impacts to the benefit of both farmers and fishers, and identified the points in the life cycle of events at which interventions of different kinds were appropriate.

Information on pollution threats and their economic implications, details relating to best-management practices for control of agro chemical pollution, and monitoring of pollution derived

² Source: PCA (2003) Summary Annual Report April 2002 - March 2003. Paper presented to CGPC in St Vincent & Grenadines. June 2003.

³ See Section 5, Table 1 which relates project documentation (Products) to logframe Outputs and Activities.

⁴ Sediment studies were confined to St Lucia only.

through the various components of the study were promoted in both the study countries. Policy and Management Briefs were prepared to distil the important features described in the more detailed project technical documents. Experiences from St Lucia and Jamaica within these technical reports were synthesised into two papers on impacts and amelioration of pollution, and a strategy for implementing recommendations for amelioration of agro-chemical pollution was developed:

- Management of agro-chemicals for improved public and environmental health: A strategy for improved agro-chemical use and management for the Wider Caribbean (Annex A1).
- Impact and amelioration of sediment pollution on coral reefs of St. Lucia, West Indies (Annex A2).

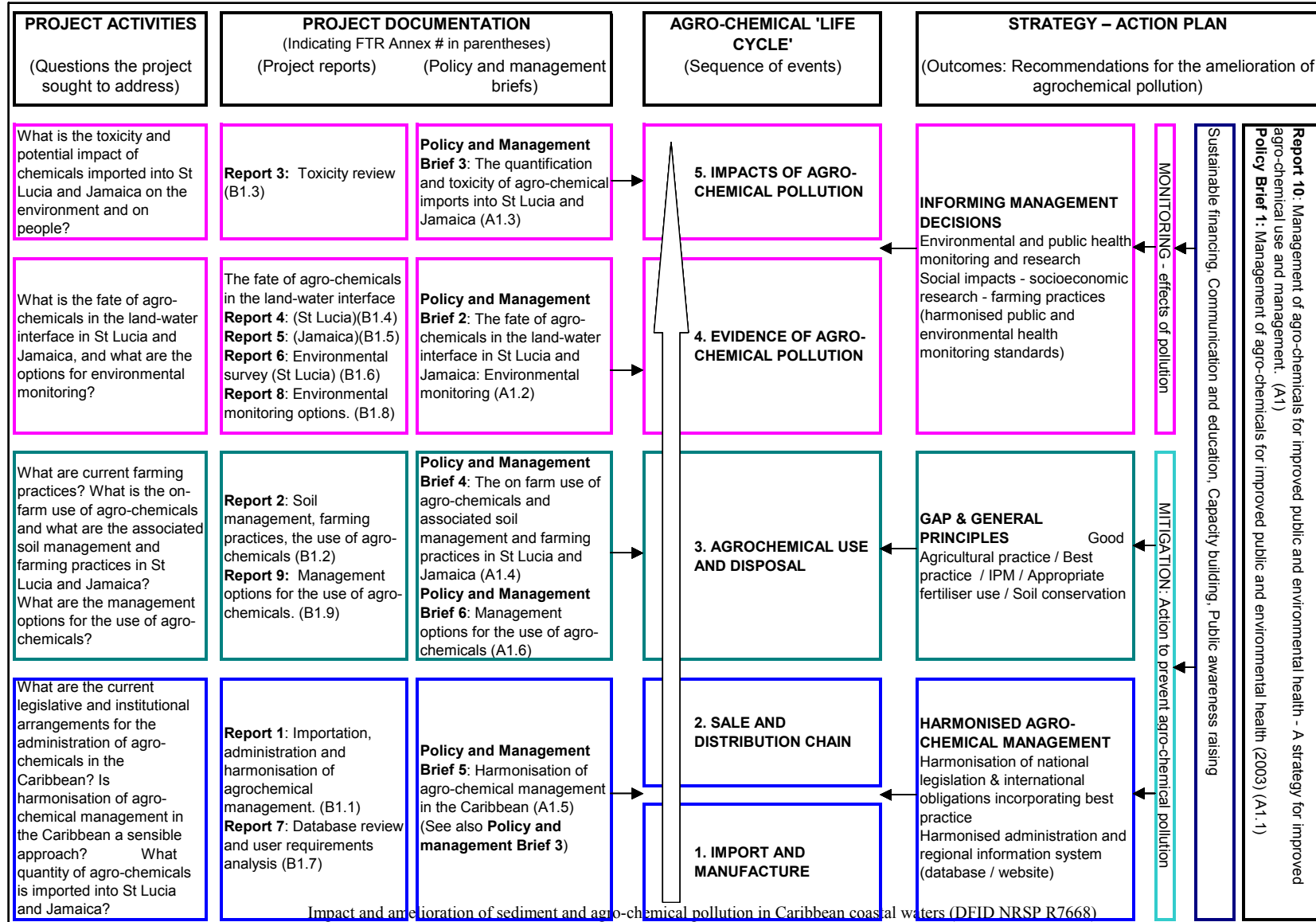
These documents represent key products arising from this project and they will be disseminated across Wider Caribbean countries and others as appropriate. The key prioritised recommendations (and implementation methods) for improved agro-chemical management in the Wider Caribbean reflected in Annex A1 were developed through the Coordinating Group of Pesticide Control Boards of the Caribbean (CGPC). This group brings together key policy makers and institutions supplying services or agro-chemicals to farmers and has representatives from many of the CARICOM countries. This consultation was conducted throughout the duration of the project and through a final workshop in year three to disseminate project findings and discuss recommendations.

The recommendations and strategy were endorsed by the CGPC and will be promoted to national governments through CARICOM for future adoption and implementation. The final measurable indicator for the successful implementation of these recommendations is that it also envisaged that these recommendations and strategy will be integrated into national plans to satisfy the requirements of the LBS Protocol to the Cartagena Convention (although this was not completed during this project). The sedimentation impact report will be disseminated through the various policy makers and stakeholder groups in St. Lucia.

Through the help of the Extension Services, relevant Ministries in St Lucia and Jamaica and also other Caribbean countries, these recommendations will help to deliver new knowledge to poor small-scale farmers, fishers and other relevant stakeholders. Through the implementation of the strategies developed in this project, these target groups, who are largely dependent on the natural resource base, will have improved livelihoods and health through better use and management of agro-chemicals, which will in turn improve crop production in the regions' farms.

With respect to implementation of the strategies developed, we understand that NRSP will commission an uptake promotion project. Promotional activities for different recommendations arising from this project are indicated in the relevant sections of the FTR, as required in the reporting format. Immediate dissemination of the Strategy (Annex A1) and Policy and Management Briefs (Annex A1 Appendices 1-6) is recommended to their intended target audience, policy makers and managers (members of this audience helped draft and define these documents). Subsequent amendments to these documents may occur for different target audiences identified in any follow on uptake promotion project. The form of any uptake promotion project will be defined by NRSP. However, uptake promotion of the strategy for improved agro-chemical use and management could, for example, explore how the strategy may be developed into or incorporated into relevant national plans of action. In developing such plans a participatory consultative process should be followed to take account of the views of all relevant persons and institutions from the users and those affected by pollution through to implementing bodies. This will be essential to achieve effective agro-chemical management and thus pollution control.

Figure 1: Framework indicating how project activities and products contribute to the goal of improved integrated agro-chemical use and management for the prevention of pollution (Outline sequence of events leading to potential agrochemical pollution, questions the project sought to address and associated project documentation, synthesised to develop a strategy for the amelioration of agrochemical pollution, and critical control points for interventions).



2. Background

The environment of the Wider Caribbean region is especially vulnerable to agro-chemical and sediment pollution because of the small size of its islands, frequently high rainfall, and steep slopes on which farming takes place. These factors mean that pollutant sources within watersheds are closely linked to the coastal and marine environment, and pollutants therefore may be found in high concentrations in coastal waters. Improper use of agro-chemicals and poor land-use practices have also been shown to have harmful effects on human health as well as on the environment. Good management and proper use can bring social and economic benefits.

In 1991, a comprehensive report on the state of the environment in St. Lucia identified erosion as a key economic problem and recommended research was needed to determine its severity and identify solutions (Towle and Towle 1991). Since then there have been only limited efforts to address the problem, although devastating flooding and landslides in 1995 increased public awareness of the issue (Sladek Nowlis et al. 1997). The Soufriere Marine Management Area (SMMA) was set up in 1995 to improve management of marine resources along the West coast of St. Lucia. Previous research by the University of York, in collaboration with the Department of Fisheries and SMMA, has revealed that pollution is a growing problem on the coral reefs and that improved management to reduce pollution is badly needed. These institutions are looking for more detailed information on the severity of the problem and mechanisms to reduce it. Independently, a project by the Department of Agriculture identified soil loss as a serious concern for agricultural sustainability (Cox and Madramootoo 1998). Erosion and soil loss carries chemicals from hillside farms into nearby coastal waters and greatly impacts coastal systems. There is a need to establish long-term monitoring programmes and targeted research activities which are the focus of this study.

There is also an urgent need to address the amelioration of agricultural non-point sources of pollution in the Wider Caribbean Region as this has been formalised through the LBS Protocol to the Cartagena Convention (1983). The Protocol constitutes a legal commitment to the Contracting Parties, which means that each signatory country will have to formulate national plans, policies and legal mechanisms for the prevention and amelioration of land-based pollution. This project focused on the development of a method to assess the type and extent of land-based pollution in selected Caribbean countries, addressing at the same time means of control and management of land-based input and distribution in keeping with these legal commitments.

This project's research directly linked the interests of the above-mentioned organisations and facilitated an integrated approach to management. The project goal was to develop and promote improved resource-use strategies in coastal zone production systems. The study focussed on producing recommendations and a strategy for improved use and management of agro-chemicals and the reduction of sedimentation in coastal zone production systems. The recommendations and strategy for improved resource-use were presented and promoted through two synthesis reports which will be taken forward and implemented by the national governments through the CGPC and CARICOM and government departments and NGOs. It is envisaged that the Pesticide Control Boards will also bring the information to the local farmers through the Extension Services of the various Ministries of Agriculture and through training.

There is paucity of previous research on the impact of agro-chemicals and sedimentation on the ecosystems of tropical coastlines and this has been confirmed through the literature reviews conducted during this study. There was a lack of data to be found on pesticide use in the Caribbean, apart from summary documents provided by UNEP-Caribbean Environment Program (1999) and some previous research conducted by the University of the West Indies (UWI), the Caribbean Agricultural Research and Development Institute (CARDI), Caribbean Coastal Area Management Foundation (C-CAM), the Caribbean Environmental Health Institute (CEHI) and some studies commissioned by the Ministries of Agriculture and Fisheries and the Pesticide Control Boards. This project therefore built on this previous research (and worked in close partnership with these organisations), quantified some of the knowledge gaps, provided critically needed baseline information and suggested the need for further targeted research and more long-term monitoring programmes. This enabled best management practices for agro-chemical use, and erosion

prevention to be identified and it is hoped that the strategies developed will be successfully applied in both St Lucia and Jamaica and potentially applied throughout the Wider Caribbean.

3. Project Purpose

The aims of this project included:

- To assess the role that poor agricultural practice plays in increasing sedimentation and agro-chemical pollution to coastal areas in St. Lucia;
- To assess the use of agro-chemicals in two representative Caribbean countries, St. Lucia and Jamaica;
- To assess the environmental and economic impacts of sediment pollution on coral reef ecosystems in St. Lucia;
- To promote monitoring and best management practices for sediment and agro-chemical pollution in order to reduce pollution of coastal waters.

The activities proposed to achieve these aims were to:

- Document pollution levels and effects in the land water interface (from the watershed to the marine environment), including for sediment pollution evaluation of the costs of pollution of reefs;
- Describe and develop monitoring systems for these pollutants;
- Advise on, and promote uptake of 'best-management practices' to reduce soil loss and sedimentation and use of agro-chemicals.

These activities contribute to more sustainable management through adoption of best management practices to ameliorate pollution. In support of arguments for adoption of project recommendations for sedimentation, the likely costs of not implementing them are highlighted for St. Lucia. Adoption of project recommendations will help improve long-term environmental and public health, and the sustainability of farming, fishing and tourism-based livelihoods.

4. Outputs

4.1. Introduction

Six Outputs were defined to deliver the project Purpose. Outputs 3-6 relate to the agro-chemical components of the study and Outputs 1,2, and 5-6 relate to sediment pollution. The agro-chemical components of the study were managed by MRAG Ltd and activities were executed with project partners in Jamaica and St Lucia. Formal project partners included, in Jamaica: Centre for Marine Science, UWI Mona; Caribbean Coastal Area Management Foundation; Caribbean Agricultural Research and Development Institute; Department of Chemistry, UWI Mona; Department of Life Science, UWI Mona; and in St Lucia, Caribbean Environmental Health Institute; Ministry of Agriculture, Forestry and Fisheries; Pesticides Control Board. The project also worked closely with the Pesticides Control Authority in Jamaica, and the regional Coordinating Group of Pesticides Control Boards for the Caribbean (CGPC). The University of York in collaboration with the Soufriere Marine Management Area (SMMA) and the Department of Fisheries, conducted the sediment components of the study in St. Lucia.

The remainder of this section on Outputs summarises the results and findings that the project has achieved against each Output as specified in the project logical framework⁵. The project was an enabling project, and whilst some of the research has been conducted directly with poor farmers and fishers, the outcomes of the research are targeted at policy and management. Benefits to the

⁵ The key findings and results presented in the Reports and Briefs (detailed elsewhere in this section) crosscut the log-frame activities and Outputs, but are nevertheless presented here by output as is required for the FTR. Annex A1 presents a summary of the findings and provides a more coherent 'story' than reflected in the description of Outputs.

poor will be delivered via appropriate intermediary bodies following uptake and adoption of the findings of this research. The research products generated by the project are a contribution to scientific understanding, the provision and collation of technical information useful to managers, recommendations for the amelioration of sediment and agro-chemical pollution, and a strategy for implementing project recommendations and best practice for improved agro-chemical use and management.

All project Outputs were achieved. Unexpected, or particularly noteworthy outcomes are highlighted below against each output.

Amelioration of agro-chemical pollution

In respect of the agro-chemical component of this study (Outputs 3-6), the research products are presented in nine project reports (Annexes B1.1-B1.9), a Policy and Management Strategy Document (Annex A1), and six Policy and Management Briefs (Annex A1. Appendices 1-6). The project reports (Annexes B1.1-B1.9) are detailed technical findings appropriate for scientists and managers. Figure 1 provides a framework for all these project components and illustrates how they fit together within a life cycle of events relating to agro-chemicals. This Section places these products within the context of the Outputs described in the project logframe, and Section 5 describes the research activities undertaken to derive these documents. Annex A1 is a Policy and Management Strategy Document, and presents the main product of this study, a strategy for implementing project recommendations and best practice for improved agro-chemical use and management, aimed at key policy and decision makers and managers of agro-chemicals throughout the Wider Caribbean. Also aimed at this target group are the Policy Brief (Annex A1. Appendix 1), which is short, high level, highlights the need for action and a strategy to achieve it), and the Policy and Management Briefs (Annex1. Appendices 2-6) which outline the key project findings, and the recommended action required.

Early in the life of the project a critical control points analysis and uptake promotion / communications strategy (UPCS) was developed. The process for developing the critical control points analysis and UPCS was also documented. The analysis and communications strategy were discussed with the NRSP Communications Specialist. It was clear that within available resources, the project should prioritise its communications and focus on the key target group, policy makers and managers, and that intermediaries should undertake the necessary actions related to other stakeholder groups. Hence the project has developed the Policy and Management Strategy Document and Policy and Management Briefs detailed in Annex A1 and Appendices 1-6 to that Annex. The original critical control points analysis and communications strategy documents have previously been lodged with NRSP and are not now included with the FTR. They are superseded by the strategy for implementing project recommendations (Annex A.1), which indicates what action should be taken by whom, and how to communicate the information.

The products and findings of the agro-chemical component of the research have been promoted via a number of mechanisms described elsewhere in this document (see Outputs below, particularly Output 6, Section 8, and Annex B1.10).

The Policy and Management Strategy Document (Annex A.1) indicates in some detail what needs to be done to take the research findings forward. Details are presented under each Output in Sections 4.2 and 4.4 (see particularly Output 6).

Amelioration of Sediment pollution

Research products from the sediment pollution component of this study (Outputs 1,2, 5-6), are presented in 15 project reports (Annexes B2.1-B2.15), a Policy and Management Strategy Document (Annex A2), and five Policy and Management Briefs (Annex A2. Appendices 1-5). The project reports (Annexes B2.1-B2.5) give the detailed technical findings and are appropriate for scientists and managers. Section 5 describes the research activities undertaken to derive these documents. Annex A2 is a synthesis report on the impacts of sediment pollution and is aimed at policy and decision makers and coral reef and fishery managers throughout the Wider Caribbean. Policy briefs are also aimed at these audiences. This element of the research was co-funded by the UK Natural Environment Research Council. In 2003, NERC chose this companion study as one of its 8 top performing projects of the year.

While there are many differences in approach to tackling agro-chemical and sediment pollution problems, research outputs also highlight areas of synergy. In particular, reforming farming practices in ways that limit chronic erosion and reduce the risk of severe erosion events during periods of high rainfall will help greatly reduce sediment pollution on reefs. We address these areas of synergy in Annex B1.2.

4.2. Outputs related to the amelioration of agro-chemical pollution

Output 3

Estimates of agro-chemical loadings and fate of loadings in St Lucia.

- *Quantify imports of agro-chemicals into participating countries, and describe their use locally.*
- *Review agro-chemical toxicity and recommended management in other countries (e.g. USA, EU)*
- *Carry out baseline survey for agro-chemicals in coastal zone in St. Lucia.*

Project reports 1-6 (Annex B1.1-B1.6) and Policy and Management Briefs 2-4 (Annex A1. Appendix 2-4) present the results, key findings and recommendations for this output and its activities. Quantification of imports of agro-chemicals into participating countries is described in Annex B1.1, and their local use in Annexes B1.2, 4 and 5. The toxicity of imported agro-chemicals is reviewed in Annex B1.3, and Annex B1.9 describes international best practice and recommended management options for the use of agro-chemicals in other countries. Annex B1.6 relates to the baseline snapshot survey of water, sediment and indicator organisms that was conducted to establish the potential fate of agro-chemicals in the environment in St Lucia.

The key findings include the following:

- There has been a long-term increase in the quantities of imports and manufacture of agro-chemicals in St Lucia and Jamaica, and the Wider Caribbean.
- Agro-chemicals are known to accumulate in the environment and to have detrimental effects on the environment and human health.
- There is a lack of monitoring and research into the fate of agro-chemicals in St Lucia and Jamaica and this is thought to be the situation in the Wider Caribbean.
- Improper use of agro-chemicals can harm human health and the environment
- There is an urgent need to:
 - Raise public awareness of the potential dangers of agro-chemicals
 - Conduct further research into the chronic and acute effects of agro-chemical use on people, including occupational exposure, environmental pollution and food contamination.
 - Conduct further research on the toxic effects of agro-chemicals in the environment

This output was achieved although the baseline snapshot survey conducted in St Lucia produced an unexpected result. Pesticide levels in all tissue, water and sediment samples were found to be below minimum detectable limits apart from one crab tissue sample (Refer to Report 6, Annex B1.6). This could have been due to the fact that sampling was conducted after a dry period on the island, which would have reduced the risk of water contamination from runoff. Unfortunately, there were insufficient funds to repeat the survey at other times of the year. Furthermore, there had been a recent steady decline in the banana industry and there were improved pest and pesticide management practices, therefore resulting in less pesticides being used by farmers. This suggests the need for a more comprehensive agro-chemical monitoring programme in St Lucia, paying close attention to application rates/frequency and weather patterns. A monitoring programme has been designed by CEHI following the results of this snapshot survey for the purpose of seeking additional funding.

The products of this Output are the policy and management briefs and scientific/management reports referenced above. Furthermore, a flow chart model for evaluating priority pesticides was developed by the UWI Chemistry Department for the toxicity review conducted and presented in Report 3 (see Annex B1.3). This is a useful tool that could be used for similar projects when prioritizing what chemicals to test for toxicity. Promotion of all research products is described under Output 6 (see also Section 8, and Annex B1.10). As indicated above, CEHI have already acted upon the need for improved monitoring by developing a funding proposal. Whilst funding is a constraint, at the least it is planned to undertake a repeat survey in St Lucia during 2003 (Boodram, pers. comm.).

To continue to take these research findings forward and continue to monitor agro-chemical imports into St Lucia and Jamaica, it is essential that the agro-chemical import figures are consistently reported either as active ingredients or as formulations and that they are recorded electronically for ease of comparison in future years (see Annex B1.1). Funding of the proposal for a monitoring programme is required. In addition, it is suggested that public awareness programmes need to be established in St Lucia and Jamaica to ensure that the potential dangers of agro-chemicals and their impacts on human and environmental health are widely communicated (Annex A1 provides more details).

Output 4

Review and evaluation of existing agricultural land management in participating countries.

- *Review administrative procedures of agro-chemical imports / production*
- *Review soil management and the use of agro-chemicals in agriculture*
- *Identify critical control points for management and dissemination of information*

Reports 1, 2, 7 and 9 (Annexes B1.1, B1.2, B1.7 and B1.9) and Policy and Management Briefs 5 and 6 (Annex A1. Appendix 5-6) describe the results, findings and recommendations for this output and its activities. Administrative procedures are described in Annex B1.1. Two existing databases for administration of agro-chemicals were also reviewed during the project, and a user requirements analysis was conducted (Annex B1.7). Soil management, and the use of agro-chemicals in agriculture are described in Annex B1.2. That report also describes soil conservation techniques, relevant to the amelioration of sediment pollution. The Critical control points for management and dissemination of information were produced through consultation with project partners and the CGPC members and have been discussed in Section 4.1.

The key findings include the following:

- Good Agricultural Practices (GAP) and Integrated Pest Management (IPM) must be promoted to improve agro-chemical use and promote alternative solutions.
- Training, communication and education of farmers is vital.
- Soil testing should be conducted on farms to ensure appropriate use of fertilisers.
- Soil conservation and water management practices are essential to reduce run-off and agro-chemical application and pollution.
- Limited human and financial resources are the major constraint to the implementation of national and regional obligations and best practice codes of conduct for agro-chemical management
- Adequate legislation is needed to control the use and application of agro-chemicals and this is best achieved via the implementation of harmonised legislation throughout the Wider Caribbean.
- Within national systems, jurisdiction for all user groups needs to be defined and duplication of effort reduced to rationalise the use of limited resources.
- Harmonisation of administrative arrangements for agro-chemicals throughout the Wider Caribbean is seen as a means of making better use of limited resources in the region to address this complex task.
- Model harmonised legislation, if adopted, will bring considerable benefits (cost-savings,

shared resources, etc.):

- To address international obligations that are currently not fully met throughout the Wider Caribbean
- To establish the framework for best practice management of agro-chemicals
- A regional database for recording registration and management of pesticides is a valuable tool to support the process of harmonisation and enable information sharing.

All components of this Output were achieved. Research products are the policy and management briefs and scientific/management reports referenced above. Promotion of all research products is described under Output 6 (see also Section 8, and Annex B1.10). Annex A1 describes mechanisms to take these research findings forward. Specifically in respect of recommendations relating to a regional database, MRAG have been requested by the CGPC to develop a project proposal to seek further funding for such a database (locally owned and managed) for recording registration and management of pesticides and this will be written after project completion.

4.3. Outputs related to the amelioration of sediment pollution

Output 1

Improved understanding of the effects of sedimentation on (a) coral reefs, (b) on the efficacy of current management measures (marine reserves and zoning plan), and (c) on reef recovery from natural disturbances (storms).

- *Sedimentation rates monitored and related to rainfall and underwater visibility*
- *Effects of sediment on benthic communities estimated*
- *Sedimentation effects on coral recruitment and juvenile mortality and growth rates estimated*

Annexes B2.1-B2.5 and Policy and Management Brief 1 and the synthesis report (Annex A2.1) describe the results, findings and recommendations for this output and its activities. Monitoring of sedimentation rates and links to rainfall are described in Annex B2.2. We review existing studies on the effects of sedimentation on coral reefs in Annex B2.1, and describe research findings on its effects on St. Lucia's reefs in Annexes B2.2 and B2.3. The effects of sediment on coral recruitment in St. Lucia are described in Annex B2.4 and its effects on juvenile coral mortality and growth are documented in Annex B2.5.

The key findings include the following:

- Sedimentation rates were correlated with rainfall, indicating terrestrial origin for much of the inputs. This confirms findings of an earlier study which showed an increasing terrestrial sediment fraction in marine deposits with closer proximity to river mouths. Underwater visibility was also linked to rainfall but less closely; visibility also affected by wave action resuspending deposits. Localised spikes of intense sediment input were also related to coastal construction activities.
- Between 1995 and 2001, reefs lost an average of 47% of their coral cover in shallow water and 48% in deeper water due to a combination of storms and sediment pollution. While Hurricane Lenny in 1999 did a great deal of damage, about 3% of coral losses in shallow water and 19% in deep water could be attributed to sediment pollution. In the worst affected places, losses have been much greater than these average figures suggest.
- Impacts of human and natural stresses on reefs may be cumulative and synergistic, thereby exacerbating the effects of individual stresses. The combination of human (fishing pressure, sediment, tourism) and natural (storms, diseases) stresses have led to serious problems for St. Lucian reefs. At present, only fishing pressure is being adequately managed. Reversing reef decline will require management measures targeting all the key sources of stress caused by people.
- In two key reef building coral species, rates of partial mortality were significantly higher close to sources of sediment around river mouths than in low sediment sites. Rates of loss

of coral cover were closely correlated with rates of partial mortality. Sediment stress to adult corals has been killing them.

- Sediment pollution did not appear to depress levels of coral settlement to artificial settlement plates but did alter species composition of new recruits and settlement behaviour. Monitoring of juvenile corals on the reef gave more cause for concern. Sediment reduced growth rates of juvenile corals and increased rates of partial and total mortality of juveniles.
- Marine reserves in the Soufriere Marine Management Area did not prevent reef degradation from sediment pollution. To avoid the potentially severe economic losses associated with sedimentation (see below), additional management measures specifically targeting sediment sources need to be undertaken.

All components of this Output were achieved. Promotion of research products is described under Output 6.

Output 2

Economic estimates of the value of coral reefs to the St. Lucian economy, in terms of fishing, snorkelling and scuba diving tourism. Estimates of the economic costs of sedimentation on fisheries and tourism and of the benefits of reducing sediment and nutrient pollution.

- *The impacts of marine reserves on fish landings estimated*
- *Amenity value of reefs estimated*
- *Opportunities and constraints on coastal fishers to participate in the tourism industry evaluated*
- *Economic costs of reef degradation to coastal communities estimated.*

Annexes B2.6-B2.14 and Policy and Management Briefs 1-4 (Annex A2, Appendices 1-4) describe the results, findings and recommendations for this output and its activities. The impacts of marine reserves on fish landings are documented in Annexes B2.6, 2.8 and 2.9 and C1.1 and C1.2. We estimate the value of the reef fishery in Annex B2.7, and the value of reefs for tourism in Annexes B2.14 and B2.15. Reef attributes valued by tourists are documented in Annex 2.13. In order to develop scenarios for sustainable tourism growth documented in Annex B2.15, we also had to conduct extensive work on the impacts of tourism on reefs. This research is described in Annexes B2.11 and B2.12. Opportunities and constraints on coastal fishers' participation in the tourism industry are described in Annex B2.10. Costs of reef degradation to coastal communities are explored in Annexes B2.7, B2.14 and B2.15, and in Policy and Management Briefs 2,3 and 5.

The key findings include the following:

- From 1995-2002, biomass of exploited species quadrupled in marine reserves and tripled in adjacent fishing grounds. These effects have been translated into greater catches in the fishery. Trap catches increased 46-90% between 1995 and 2001.
- For 1995/6 estimates for the total value of the fishery varied from a lower bound estimate of EC\$141,320 to an upper bound estimate of EC\$269,576. For 2000/1 estimated values lay between EC\$233,004 and EC\$356,471.
- Fishery profits increased by between 28 and 159% from 1995-2001 depending on method of estimation used.
- Some fishers have given up fishing to work with tourists, and many of those that still fish have family members in the tourist industry. For those who wish to work with tourists, constraints include lack of equipment, education and training, and access to loans.
- In 2000, visitors spent an estimated EC\$19.7million on diving and snorkeling tours, nearly half of which (EC\$9.45million) was attributable to tours taken within the SMMA. 44% of visitors said they went to St. Lucia because of the existence of the SMMA. These sums include only money spent on tours and marine park fees and exclude broader spending on

accommodation, transport, food and souvenirs. Taking this broader spending into account, each visitor spent on average US\$2,276 on his or her trip to St. Lucia. The abundance and size of fish present and underwater visibility were important to the quality of the reef experience for tourists. Tourists disliked seeing dead corals and garbage on the reef. Through its impacts on visibility and on coral cover, sedimentation reduces the appeal of coral reef sites for diving and snorkelling, jeopardising revenue from reefs.

- Reef degradation has already reduced number of dive sites in use in the Soufriere area of St. Lucia by 20%. If left unchecked, sediment pollution could have major impacts on the quality of the environment, quality of life and employment opportunities for St. Lucians and on the economy. The cost of sediment pollution in foregone income could range from US\$160,000 to US\$280,000 per diving site lost per year. That cost is conservative because it does not include other foregone income to businesses reaped from providing transport, accommodation or other goods and services associated with visitors staying in St. Lucia.

All components of this Output were achieved. Promotion of research products is described under Output 6.

4.4. Outputs related to the amelioration of sediment and agro-chemical pollution.

Output 5

Options for pollution monitoring for participating countries.

- *Determine options for monitoring for agro-chemical imports.*
- *Determine alternative options for environmental monitoring to detect changes in concentration of agro-chemicals and sediment loads in coastal zone.*

Monitoring of agro-chemical pollution

Reports 1, 6 and 8 (Annexes B1.1, B1.6 and B1.8) and Policy and Management Brief 2 (Annex A1. Appendix 2) cover the results, findings and recommendations for this output. Annex B1.1 describes the administration of agro-chemical imports whilst monitoring is described in Annex B1.6 and B1.8

The key findings include the following:

- Harmonised Administrative procedures provide the best option for common monitoring procedures for imports – see Output 4.
- There is a need to establish long-term monitoring programmes and targeted research activities including bioaccumulation. Report 8 outlines the options (Annex B1.8).

All components of this Output were achieved. Research products are the policy and management briefs and scientific/management reports referenced above. Promotion of all research products is described under Output 6 (see also Section 8, and Annex B1.10). Annex A1 describes mechanisms to take these research findings forward. CEHI are currently planning to continue monitoring according to the proposal presented in Report 6 (Annex B1.6) and described under Output 3.

Monitoring of sediment pollution

A sediment monitoring infrastructure was implemented in St. Lucia based on best practice developed previously in the country by the Caribbean Natural Resources Institute (CANARI) and elsewhere. Sediment monitoring is ongoing by staff of the SMMA and has been adopted as one of the management area's core activities. It is complemented by annual monitoring of reef condition according to the protocol developed by Reef Check. More detailed monitoring of reef condition using methodologies and sites employed in this project will require additional funding to be raised by the SMMA. Consideration could be given to expanding the scope of the monitoring to provide

important additional information on the sources of sediment. In addition to monitoring present on-reef sedimentation rates, an expanded study could look at sediment composition (terrestrial versus marine origins), organic matter in sediment and levels of suspended particulate matter. Fluorescent tracers could be added to suspected sources of sediment on land to partition sediment loads from particular sources. In addition, studies of hydrology, marine circulation and water movement could link terrestrial sources to site of deposition.

All components of this Output were achieved. Findings from sediment monitoring underpin Output 1 and many aspects of research under Output 2.

Output 6

Identification of management options to ameliorate sediment and agro-chemical pollution in participating countries and dissemination and promotion through appropriate networks in the wider Caribbean.

- *Identify critical control points for both sediment and agro-chemical pollution control and identify any common/separate target institutions/stakeholders to each type of pollution.*
- *Define appropriate products and mechanisms for dissemination to a range of target institutions and stakeholders.*
- *Identify management options to improve the use of agro-chemicals and to reduce agro-chemicals / sediment in the marine environment.*
- *Maintain regular communication with target institutions and relevant stakeholders.*
- *Participatory consultation with target institutions and relevant stakeholders to produce guidelines for sediment and agro-chemical pollution control and dissemination through appropriate networks.*

Amelioration of agro-chemical pollution

All 6 Policy and Management Briefs (Annex A1. Appendix 1-6), Reports 1 to 9 (Annex B1.1-B1.9) and the Policy and Management Strategy Document (Annex A1) cover the results, findings and recommendations for this output. Identification of critical control points and the definition of products and dissemination mechanisms were part of the process in defining the communications strategy discussed under Section 4.1, including regular communication with target institutions. Annex B1.9 describes the management options to improve the use of agro-chemicals and reduce agro-chemicals to the marine environment. Guidelines, or project recommendations for agro-chemical management were developed through participation with key target institutions. The Policy and Management Strategy Document, Annex A1 presents the main product of this study, a strategy for implementing project recommendations and best practice for improved agro-chemical use and management, aimed at key policy and decision makers and managers of agro-chemicals throughout the Wider Caribbean.

The key findings include the following:

- Recommendations and management options were identified in all project reports (Annex B1.1-B1.9) and summarised in the policy and management briefs. They were synthesised and reviewed by the CGPC (Annex A1. Appendices 1-6).
- 10 Key recommendations were endorsed by CGPC, and a strategy to implement them was developed. Details are presented in full in Annex A1 and are not re-iterated here.

Output 6 is the key Output of this project and has been achieved. Under the activities described for this Output, all the work previously undertaken was drawn together and synthesised. Recommendations and an implementation strategy for them were developed and communicated. The process by which the strategy presented in Annex A1 was developed is now described, rather than under Section 5, as it is relevant at this point, and links closely to communication and promotion of the products of research. Firstly the research findings were synthesised to tell a coherent story looking first at what are the international and national obligations for agro-chemical management, how are they currently administered, how do they relate to agro-chemical use, and

what is the fate of agro-chemicals in the environment (see also Figure 1). The following questions were addressed:

1. What are the current legislative and institutional arrangements for the administration of agro-chemicals in the Caribbean? Is harmonisation of agro-chemical management in the Caribbean a sensible approach?
2. What are the management options for the use of agro-chemicals?
3. What quantity of agro-chemicals is imported into St Lucia and Jamaica, and what is the toxicity and potential impact of those chemicals on the environment and on people?
4. What are current farming practices? What is the on-farm use of agro-chemicals and what are the associated soil management and farming practices in St Lucia and Jamaica?
5. What is the fate of agro-chemicals in the land-water interface in St Lucia and Jamaica, and what are the options for environmental monitoring?

Material from all 9 reports was synthesised and the outcomes were the first-draft Policy and Management Briefs. Recommendations taken from the 9 reports and reflected in the briefs were then synthesised and summarised against a number of themes. These themes correspond to the questions the project sought to address but recommendations relating to the fate of agrochemicals were separated into environmental and human impacts, and the monitoring and research related to them. Additionally, a number of recommendations emerged that crosscut the themes. The themes by which recommendations were grouped are:

1. Legislation and international obligations;
2. Administration / harmonisation;
3. Agro-chemical use / Good agricultural practices;
4. Environmental Fate - Monitoring and Research;
5. Public Health and Social Impacts - Monitoring and Research.

The crosscutting issues were:

- Institutional arrangements / capacity;
- Financing mechanisms; and
- Communications, training and education.

During a round table meeting held on 13 June 2003 with all project partners, recommendations and the text of the briefs were verified. The amended recommendations and briefs were used as the basis for a workshop held with members of the Coordinating Group of Pesticide Control Boards for the Caribbean (CGPC) on 18 June 2003. The CGPC is the primary target institution for the outcomes of this project. The Group, comprised of key managers and policy makers representing Pesticide Control Boards in the Caribbean meets annually, and this project has presented its findings to the Group each year since 2000, culminating in the workshop held in 2003 (see Section 8.10.2). There has been close and effective collaboration with this Group. The workshop consisted of a working group session and two plenary sessions to:

- Prioritise the recommendations and derive and formally agree the top 10 key recommendations;
- Develop mechanisms for implementation of the recommendations; and,
- Develop and agree the final "strategy"⁶.

The strategy for improved agro-chemical use and management (Annex A1), and policy and management briefs (Annex A1 Appendices 1-6) represent the principal products of this research for policy makers and managers. Reports 1-9 (Annex B1.1-B1.9) provide additional technical

⁶ Note that following the Workshop during July 2003, the strategy document was circulated amongst all attendees at the 8th CGPC meeting (and workshop) and all project partners. Comments were included in the revised text of the final document presented here as Annex A1.

material for managers and scientists. The process for developing these products was inclusive, an important factor in their promotion. In addition to the CGPC, in both St. Lucia and Jamaica collaborating institutions included target institutions, which facilitated their close involvement and ownership of the results. Annex B1.10 lists the participants at each of these meetings and workshops.

Within project promotion of project findings

Throughout this project, the Pesticide Control Boards and other target institutions have been in close liaison with the project partners and much of the on-going material produced during the life of the project has been widely disseminated through the relevant stakeholders and organisations in St Lucia, Jamaica and other Caribbean countries. A Flyer (Flyer 1, see 8.7) was produced during the project and sent out to a wider distribution list (see Annex B1.10) to inform stakeholders of the status of the project and its findings thus far.

At the end of year 3, Seminars were held in Jamaica and St Lucia (June 2003) with stakeholders relevant to the agro-chemical industry. The Policy and Management Briefs and outcomes of all research, including that from the final Workshop held at the CGPC were presented. Discussions and presentations included key findings from the project including advice on education, training and awareness needs, and appropriate legislative and policy measures to improve management of agricultural non-point sources of pollution. The seminars were attended by relevant stakeholders including farmers, university researchers, Pesticides Control Boards, agricultural boards, chemical manufacturers and vendors, and government representatives from the Ministries of agriculture, fisheries, forestry, health and other parts of the governments involved in agro-chemical management (See Annex B.1.10).

At the conclusion of the project (i.e. following review) a glossy version of the Policy and Management Strategy Document (Annex A1) will be prepared. Together with the Policy and Management Briefs (Annex A1 Appendices 1-6) these documents will be disseminated via the CGPC to national governments throughout the Wider Caribbean, as well as to a wider distribution list (Annex B1.10), which includes other stakeholders beyond this project. Additionally, hard copies of all the project reports and briefs will be provided to all project partners and CGPC members.

All of the final project documents, and earlier working documents (including trip reports, the mid-term project flyer, and other internal documents) are posted on the project web-site (see section 8). A final project Flyer⁷ (Flyer 2) will also inform all relevant stakeholders (see distribution list in Annex B1.10) that the project has reached a conclusion, and summarise key project findings and recommendations as well as give the project website where the products may be located.

Policy action and other changes undertaken by stakeholders that have ensued from this promotion work have been mentioned under each Output. In particular, however, it is worth highlighting the following. During the closed session of the 8th CGPC meeting on 20 June 2003, the CGPC members endorsed the project recommendations and strategy to implement them, and further recommended that:

- The 'strategy' and its recommendations are promoted to national governments, by the CGPC, for adoption and future implementation;
- A policy statement, relating to the strategy and its recommendations is presented to the CARICOM for potential support.

It is also worth highlighting the fact that Mr Julius Polius, who collaborated on this project as Director of Agricultural Services, MAFFE St Lucia, has subsequently been promoted to the position of Permanent Secretary. He nevertheless confirmed his commitment to this project by Chairing the St Lucia Seminar in June 2003, and at that Seminar re-iterated his commitment to implement recommendations arising from the research. The Registrar of the Pesticide Control Authority chaired the Jamaica seminar. Both local partners, and collectively the CGPC expressed their satisfaction with the outcomes of the project.

⁷ Note that all the new project documents will be converted to pdf format and put on the project website early in August 2003. Flyer # 2 will not be sent out until this has occurred.

Further promotion of project products, has occurred through presentations at Workshops and Seminars attended by project partners (see 8.4). Plans also exist to include material included in project reports in university curricula (Warner, Pers. Comm.).

Post project uptake promotion of project findings

As described, the research findings included recommendations, and the development, by CGPC, of a strategy to implement them in order to take the research findings forward. That strategy indicated the level of action required (national or regional), the implementing body and specific action needed to achieve implementation, and who and how (what form) to communicate the outcomes of that action to. It will take several years of further effort, by committed governments, to implement the recommendations and strategy presented in Annex A1, assisted through the dissemination and promotion of these project outputs via the CGPC and continuing work of project collaborators.

To take the research findings forward there is a need for national and regional action to implement the recommendations:

National: Develop a prioritised plan of action based on the recommendations, including costed proposals for implementation over time. Seek national and where appropriate, external funding to implement the plan of action. The development of national plans of action should be participatory and seek to engage all relevant stakeholders from the users of agrochemicals, the general population who may be affected by any pollution, through to all the various implementing agencies whose actions will need to be integrated. This will be essential to achieve effective agro-chemical management and thus pollution control.

Regional: CGPC need to develop a prioritised plan of action based on commissioned reports/projects to implement recommendations including costed proposals for implementation over time. Regional projects identified requiring further work (detailed in Annex A1) relate to the following areas:

- i. Database (MRAG have already agreed to seek funding to take this forward, see Output 4)
- ii. Public health monitoring
- iii. Maximum Residue Limits
- iv. Environmental monitoring
- v. Development of a research strategy
- vi. Cost recovery mechanisms
- vii. Train trainers – legislation
- viii. Train trainers – change management
- ix. Institutional arrangements

There is potential for NRSP to further contribute to the uptake promotion of the projects products and to take forward the findings to achieve implementation. This may occur via facilitation of the development of national plans of action. Such a project would not develop those plans, which would be the responsibility of national governments, but could work together with relevant institutions to identify the structure of such a plan and how to draft it. This could be achieved through facilitated workshops at a regional level through the CGPC or another body. Alternatively, or additionally, potential exists to take up and execute one (or more) of the above regional projects. The Secretariat of the CGPC has already written to determine whether the project team 'may wish to assist in sourcing funding to carry out some of these useful recommendations' (Ambrose, pers. comm.).

Amelioration of sediment pollution

Annexes B2.1-2.15, and policy and management briefs Annex A2, Appendices 1-5, cover the results, findings and recommendations for this output. We identified critical control points for sediment pollution in association with project partners mid-way through the project and the analysis has been lodged with NRSP and is not included here. Throughout the project, we communicated regularly with collaborating institutions, and they represent the main organizations responsible for promoting project findings to policy makers. The integration of sediment pollution findings into policy is less well advanced than that for agro-chemicals because of the nature of the research necessary to draw conclusions on the impacts of pollution. Less was known about the effects of sediment on coral reefs at the outset of the project than on the toxicity and management of agro-chemicals. Therefore, while the former aspect of the project moved quickly into the policy arena, the case for sediment impacts had first to be made through field study. That field study necessarily took up two and a half of the three years of the project, although project findings were communicated throughout the study as they emerged.

The key policy level findings communicated in the project were:

- The Soufriere Marine Management Area, with marine reserve zones at its core, has been highly successful in driving the recovery of reef fish stocks and the associated fishery. It has greatly increased the tourism amenity value of the reefs and has significantly improved the profitability of the reef fishery.
- Increases in fish stocks have been made against a background of severe decline in the reef habitat. While a series of storms and coral disease outbreaks contributed significantly to the decline, sediment pollution has also been responsible for serious degradation, and is likely to impair recovery. Sediment pollution is degrading the economic values of reef resources and, unless addressed robustly, will limit opportunities for economic growth in the country, and for the poorest members of St. Lucian society to benefit from development of reef associated businesses.
- The main sources of sediment to St. Lucia's reefs include soil erosion and runoff from agriculture, land clearing for development, especially on the coast, dredging, coastal defence works, and clearing of vegetation from roads and gardens. At present there is little monitoring or management of most of these sources. Inputs are growing as the island becomes more developed.
- Policy actions to address soil loss from farming include continuing support for development of soil and slope vulnerability maps in St. Lucia to identify places that should not be farmed. Legislation enacted to prevent farming on unsuitably steep slopes and vulnerable soils. Development of riverine vegetated buffer zones, including agro-forestry. Improved soil conservation measures used on farms and small-holdings with provision of incentives for their use.

Project findings were given widespread publicity in St. Lucia through two workshops with stakeholders, print, radio and television media. In particular, the project's demonstration of the success of management efforts to recover the reef fishery attracted a great deal of interest and media attention both in St. Lucia and internationally. The findings were published in the journal *Science*, and were featured in an Editorial in the *New York Times* calling for similar efforts to be made in the United States. They were again described in a recent front page article of the *New York Times* (29th July 2003) as a necessary response to the ongoing global fisheries crisis. In addition, findings from the research were featured in the following places, among many others: Associated Press (worldwide), CNN.com (USA), National Geographic News (USA), Financial Times (UK), Liberation (France), MSNBC (worldwide), Science News (USA), World Fishing (worldwide), Nature News (UK), Discover magazine (USA).

The high level of international attention for St. Lucia generated by the study has become a source of national pride and has led to other benefits. For example, findings from the project were

important in the designation of the Soufriere Marine Management Area as a Global Coral Reef Monitoring Network management demonstration site in 2001. This designation was made in view of the quality of design of the SMMA, the quality of implementation of management, and the success of management efforts as demonstrated by our research.

5. Research Activities

Amelioration of agro-chemical pollution

Research activities were structured around a number of questions, or themes, that the project sought to address (described in Section 4.4. Output 6, above), rather than specifically against log-frame Outputs and Activities. The themes cross cut log-frame activities, and as a consequence any one project report may relate to more than one project activity. Five Policy and Management Briefs were developed against these themes (Annex A1. Appendices 2-6). The Policy Brief (Annex A1. Appendix 1) and Policy and Management Strategy Document (Annex A1) address the requirements under Output 6 to communicate the research findings in an appropriate format. Table 1 indicates what project reports and Policy Documents relate to each Output and research activity.

Table 1: Project documentation related to log-frame Outputs and Activities; agro-chemicals

Output	Activity	Reports (Annex B1)	Policy documents
3. Estimates of agro-chemical loadings and fate of loadings in St. Lucia.	3.1 Quantify imports of agro-chemicals into participating countries, and describe their use locally.	Annex B1. 1; Annex B1. 2	Policy and Management Brief 3
	3.2 Review agro-chemical toxicity and recommended management in other countries (e.g. USA, EU)	Annex B1. 3; Annex B1. 9	Policy and Management Brief 3
	3.3 Carry out baseline survey for agro-chemicals in coastal zone in St. Lucia.	Annex B1. 6 (Also Annex B1. 4; Annex B1. 5)	Policy and Management Brief 2
4. Review and evaluation of existing agricultural land management in participating countries.	4.1 Review administrative procedures of agro-chemical imports / production	Annex B1. 1; Annex B1. 7	Policy and Management Brief 5
	4.2 Review soil management and the use of agro-chemicals in agriculture	Annex B1. 2:	Policy and Management Brief 4
	4.3 Identify critical control points for management and dissemination of information	Annex B1. 9:	Policy and Management Brief 6
5. Options for pollution monitoring for participating countries.	5.1 Determine options for monitoring for agro-chemical imports.	Annex B1. 1	Policy and Management Brief 5
	5.2 Determine alternative options for environmental monitoring to detect changes in concentration of agro-chemicals and sediment loads in coastal zone.	Annex B1. 8	Policy and Management Brief 2
6. Identification of management options to ameliorate sediment and agro-chemical pollution in participating countries and dissemination and promotion through	6.1 Identify critical control points for both sediment and agro-chemical pollution control and identify any common/separate target institutions/stakeholders to each type of pollution.	Annex B1. 1-9, plus Annex A1 and Appendices 1-6.	Policy and Management Strategy Document Policy Brief 1
	6.2 Define appropriate products and mechanisms for dissemination to a range of target institutions and stakeholders.		Policy and Management Briefs 2-6
	6.3 Identify management options to improve		

Output	Activity	Reports (Annex B1)	Policy documents
appropriate networks in the wider Caribbean.	<p>the use of agro-chemicals and to reduce agro-chemicals / sediment in the marine environment.</p> <p>6.4 Maintain regular communication with target institutions and relevant stakeholders.</p>		

To achieve the Outputs of the project, the research activities conducted against each of the 5 themes, and the lead project partner undertaking that activity, were as follows (see also Figure 1):

Administrative arrangements / Harmonisation of agro-chemical management in the Caribbean

This aspect of the project related to an institutional appraisal of agro-chemical and administrative arrangements and a comparative review of relevant legislation for Jamaica (CCAM) and St Lucia (MRAG/MAFF). A technical review of the two pesticides databases in use in the region was undertaken and a user requirements analysis to identify the need and demand for a shared database system amongst pesticide control boards in the region (MRAG). The move towards harmonisation of administrative procedures promoted through the CGPC was examined (MRAG).

Management options for the use of agro-chemicals

In respect of the use of agro-chemicals, this aspect of the project examined international obligations, existing best practice Codes of Conduct and principles (GAP, IPM, etc). The institutional capacity to implement international obligations and Codes of Conduct was examined. The responsibilities of different implementing agencies for agro-chemical management, and their jurisdiction over different farmer groups, were examined. The findings were analysed to indicate management gaps and gaps in jurisdiction, and to detail recommendations on management options (MRAG).

Quantification of imports and toxicity of agro-chemicals

This aspect of the study was based on a compilation of imports of agro-chemicals into Jamaica and St Lucia (MRAG). These data informed a toxicity review (UWI) for these chemicals. This toxicity review was based on a literature review, and additionally on work currently underway by the Pesticides Research Group at UWI.

On farm use of agro-chemicals and associated soil management and farming practices

This aspect of the study was based on a literature review (CARDI Jamaica) and farmer surveys (MAFF, St Lucia; RADA, Jamaica). These surveys were supplemented by information collected during workshops (MRAG/CARDI) with MAFF and RADA in St Lucia and Jamaica respectively.

The fate of agro-chemicals

This aspect of the study was based on literature reviews conducted in St Lucia (CEHI) and Jamaica (UWI), a project survey of the fate of agro-chemicals in St Lucia (CEHI) and a review of environmental monitoring options (MRAG). The snapshot survey was conducted by CEHI with MRAG, and sampled material was analysed at the CEHI and Central Science Laboratory (CSL, UK) laboratories.

The activities described above address Outputs 3-5 and Activity 6.3 of Output 6. Activities relating to Output 6, communication of project findings and the development of a 'manual', in this case a Policy and Management Strategy Document (Annex A1), drew on findings from activities carried out under all of the above themes. The process for achieving this has previously been described in Section 4.4 (Output 6).

Modifications to log-frame activities occurred at two points in the life of the project. Immediately after the project started the original MRAG project team were assigned long term overseas contracts and the whole team thus changed. The new team considered that there were problems with the original proposal and suggested changes that were agreed with the NRSP Programme Manager. It was felt that the original Outputs needed to remain similar to the original, but activities changed. This partly explains the thematic approach adopted by the new team to address the cross cutting issues that existed between Outputs. As these changes were agreed very early on, the project has thus been operating against the same log-frame since the start.

Following the project Mid Term Review, minor changes to the log-frame were made to address the requirement for improved communications and uptake promotion of project products. This change also reflected the changes occurring within NRSP at that time, and was not therefore a requirement at the start of the project. These changes are reflected in Output 6.

Planned inputs to the project were all achieved, as described in Sections 4.2 and 4.4. Particular achievements have also been highlighted in Sections 4.2 and 4.4. In particular it is worth highlighting the fact that the project recommendations and strategy for implementing them were endorsed by high-level policy makers, namely the CGPC, and a commitment was made to implement them.

Amelioration of sediment pollution

Research activities were structured around log-frame Outputs and Activities. Five Policy and Management Briefs were developed against these themes (Annex A2. Appendices 1-5). Table 2 indicates what project reports and Policy Documents relate to each Output and research activity.

Table 2: Project documentation related to log-frame Outputs and Activities; sedimentation

Output	Activity	Reports (Annex B1)	Policy documents
1. Improved understanding of the effects of sedimentation on (a) coral reefs, (b) on the efficacy of current management measures (marine reserves and zoning plan), and (c) on reef recovery from natural disturbances (storms).	1.1 Sedimentation rates monitored and related to rainfall and underwater visibility.	Annex B2.2 Annex B2.3	Annex A2 Policy and Management Brief 1
	1.2 Effects of sediment on benthic communities estimated.	Annex B2.1, Annex B2.2	Annex A2 Policy and Management Brief 1
	1.3 Sedimentation effects on coral recruitment and juvenile mortality and growth rates estimated.	Annex B2.3 Annex B2.5 Annex B2.6	Annex A2 Policy and Management Brief 1
2. Economic estimates of (a) the value of reefs to the St. Lucian economy, and (b) the costs of sediment pollution.	2.1 The impacts of reserves on fish landings will be estimated.	Annex C1, C2 Annex B2.6 Annex B2.7 Annex B2.8 Annex B2.9	Annex A2 Policy and Management Brief 2
	2.2 Amenity value of reefs estimated.	Annex B2.7 Annex B2.11 Annex B2.12 Annex B2.13 Annex B2.14 Annex B2.15	Annex A2 Policy and Management Briefs 3, 4 and 5
	2.3 Opportunities and constraints on coastal fishers to participate in tourism industry evaluated.	Annex B2.10	
	2.4 Economic costs of reef degradation to coastal communities estimated.	Annex B2.7 Annex B2.14 Annex B2.15	Annex A2 Policy and Management Briefs 3 and 5
5. Options for pollution monitoring for participating countries.	5.2 Determine alternative options for environmental monitoring to detect changes in concentration of agro-chemicals and sediment loads in coastal zone.	Annex B2.2 Annex B2.3	Annex A2 Policy and Management Brief 1
6. Identification of management options to ameliorate sediment and agro-chemical pollution in participating	6.1 Identify critical control points for both sediment and agro-chemical pollution control and identify any common/separate target institutions/stakeholders to each type of pollution.	Annexes B2.1-2.15 Annexes C1, C2.	Policy and Management Strategy Document A2
	6.2 Define appropriate products and mechanisms for dissemination to a range of		Annex A2 Policy and Management

Output	Activity	Reports (Annex B1)	Policy documents
countries and dissemination and promotion through appropriate networks in the wider Caribbean.	target institutions and stakeholders. 6.3 Identify management options to improve the use of agro-chemicals and to reduce agro-chemicals / sediment in the marine environment. 6.4 Maintain regular communication with target institutions and relevant stakeholders.		Briefs 1-5.

To achieve the Outputs of the project, the research activities conducted were as follows:

Sedimentation rates monitored and related to rainfall and underwater visibility

Sedimentation rates were monitored at 14 locations and 2 depths in St. Lucia using PVC sediment traps. Sediment inputs were measured at biweekly intervals over field seasons encompassing the period 1997-2001. Sediment inputs continue to be monitored in this network by staff of the SMMA. Rainfall measurements were taken by collaborators in St. Lucia and underwater visibility was monitored at a range of sites in the SMMA on a daily basis during two field seasons in 2000 and 2001.

Effects of sediment on benthic communities estimated

This part of the study involved in situ monitoring of bottom-living corals and associated organisms. Sites encompassing the entire SMMA and an area to the north in St. Lucia were sampled annually from 1995-2002 using 1m² quadrats placed randomly at two depths, 5 and 15m. The composition of the benthos and changes in it were related to sediment inputs, storms and protection in marine reserves.

Sedimentation effects on coral recruitment and juvenile mortality and growth rates estimated

Coral recruitment was monitored on in situ recruit collectors installed on the reef at 15m and sampled at six monthly intervals for a period of one year. Growth and mortality of juvenile corals was tracked in a series of 20 x 30cm fixed quadrats placed on the reef between 12 and 18m deep at 14 locations. Quadrats were photographed and corals measured at six monthly intervals over a 12 month period. Recruitment, mortality and growth were related to sediment inputs and protection in marine reserves.

The impacts of reserves on fish landings will be estimated.

Catches and catch per unit effort in the Soufriere reef fishery were measured over a five month period from 2000-2001, and compared with identical measures made in 1995/6 at the outset of reserve management in the SMMA. Compliance with reserves was estimated in 2000-2001 during daily surveys.

Amenity value of reefs estimated

Over the same period as catch sampling in 2000-2001, we applied questionnaires to Soufriere fishers to assess the costs of fishing. In combination with catch data, this enabled us to estimate fishery revenues and profitability in relation to reef area. We also applied questionnaires to a large sample of scuba diving and snorkelling visitors to St. Lucia to estimate reef-related revenues from tourism, and to identify the attributes of reefs most important to a high quality tourist experience. In particular we sought. We also explored tourist willingness to pay for reef management, and assessed the relationships between willingness to pay, tourist attributes, the quality of their reef experience and the nature of management activities.

Opportunities and constraints on coastal fishers to participate in tourism industry evaluated

During interviews with fishers, we applied a semi-structured questionnaire to assess income to the fisher or family members from tourism-related activities. Where there was an income from tourism,

we assessed its nature and extent. All fishers were asked about what opportunities they had to benefit from tourism, and what the constraints were on their involvement in tourism.

Economic the costs of reef degradation to coastal communities estimated

We used our estimates of the amenity value of reefs in relation to reef area to examine the potential costs of reef degradation from sediment pollution. We looked at present and possible future costs under different scenarios of management and tourist expansion.

6. Environmental assessment

6.1. What significant environmental impacts resulted from the research activities (both positive and negative)?

None

6.2. What will be the potentially significant environmental impacts (both positive and negative) of widespread dissemination and application of research findings?

Uptake of the approaches and strategies developed in this study will help improve long-term environmental and public health, and the sustainability of farming, fishing and tourism-based livelihoods. Improved use and management of agro-chemicals, and reduction of soil erosion, will have positive environmental impacts (potentially including reduced impacts to coral and other organisms and increased water quality in the coastal zone) due to less chemicals being used, pests being eliminated through integrated pest management programmes and through improved spraying regimes and good agricultural practices. Adoption of the recommendations and strategy for implementation both nationally and regionally (via the ten implementation projects indicated in Section 4.4 Output 6), will result in improved agro-chemical use, management, administration, monitoring and increased public awareness on the health hazards associated with their use (see Annex B1.9 and Annex A1).

6.3. Has there been evidence during the project's life of what is described in Section 6.2 and how were these impacts detected and monitored?

It is too early to detect any environmental benefits arising from promotion of project findings.

6.4. What follow up action, if any, is recommended?

Follow up action in respect of the agro-chemical survey carried out as part of this project is indicated above in Section 4.2, Output 3. Beyond that survey there is an urgent need to implement long term targeted environmental monitoring for agro-chemicals and for sediment pollution. Environmental monitoring is vital to inform policy of the extent of agro-chemical and sediment pollution, and of any impacts of measures taken to combat them. This is a recommendation arising from this project and monitoring is a key feature of the strategy for improved agro-chemical use and management presented in Annex A1, and of reduction of sediment input to the sea (Annex A2). Implementation of the recommendations is necessary to achieve this.

7. Contribution of Outputs

NRSP's purpose is 'To deliver new knowledge that enables poor people who are largely dependant on the NR base to improve their livelihoods', and the production system Output to which this project contributes is 'Improved resource use strategies in coastal zone production systems developed and promoted'.

This was an enabling project. New knowledge and recommendations for ameliorating agro-chemical pollution have been delivered to policy makers. Improved livelihoods of the poor will result from adoption of these recommendations, as their implementation will have significant impacts on public health and the environment.

Fishers and farmers are among the poorest people in the Caribbean. Their livelihoods are critically dependent on fertile soils and healthy marine ecosystems. At present, fish stocks are severely overexploited in the target countries, and fishers are suffering additional losses from reef

degradation by pollution. Improved land use and more effective and selective use of agro-chemicals will reduce costs for farmers and thus improve their income. Careful application of agro-chemicals will reduce pollution at source, and reduce public health risks to farmers, as well as reducing pollution downstream in the watershed and coastal zone and so reduce public health risks to men women and children in coastal communities. Pollution amelioration may improve fish yields as well as possibly help secure new opportunities for fishers and farmers offered by the growing tourist industry.

There were two Purpose level OVIs:

- Adoption of project recommendations by informed policymakers and integration into national plans and land management of target countries and the wider Caribbean;
- Awareness among local communities and decision makers of the impacts of sediment and agro-chemical pollution.

In respect of amelioration of agro-chemical pollution, project recommendations have been adopted by the CGPC, and evidence of this will be published in the proceedings of the 8th meeting of the CGPC held in St Vincent and the Grenadines. CGPC members are high-level policy makers from countries throughout the Caribbean, and are in a position to influence national action. The CGPC members include representatives from Jamaica and St Lucia, the target countries directly involved in the research. As noted previously (see Section 4.4) the Permanent Secretary in the St Lucia MAFFE and the Registrar of the Jamaica PCA have both indicated that they will seek to implement project recommendations. By working through the CGPC the project has also reached policy makers in the Wider Caribbean who have endorsed the project recommendations and strategy to implement them, and further recommended that:

- The 'strategy' and its recommendations are promoted to national governments, by the CGPC, for adoption and future implementation;
- A policy statement, relating to the strategy and its recommendations is presented to the CARICOM for potential support.

In respect of the impacts of sediment pollution, our efforts concentrated on researching the effects of pollution, rather than policy development, since less was known about the impacts of sediment at the outset of the study than about agro-chemicals. The project has revealed the value of coral reef ecosystems to the economy in St. Lucia and to the livelihoods of poor fishing communities. It has documented the serious impacts that sediment pollution is having on reef integrity and amenity value for fishing and tourism. Project findings have been communicated to stakeholders and decision makers in St. Lucia through collaborating bodies and government agencies and recommendations made as to how to ameliorate pollution and its impacts.

Integration of the recommendations into national plans and land management of target countries will take time and has not occurred during the life of the project. The project has, however, worked with CGPC members to develop a strategy for implementing the recommendations, including the development of nation plans of action.

The project has raised awareness among decision makers of the impacts of agro-chemical and sediment pollution, both via the CGPC and through the continuous interaction and participation of a wide range of target institutions throughout the project, and through their involvement in end of project seminars held in St Lucia and Jamaica (Annex B1.10). Awareness amongst local communities has been augmented through two radio interviews related to project activities in St Lucia. However, this aspect of awareness raising is a key recommendation arising from the project and will not fully occur until the project recommendations are nationally implemented.

A participatory approach to development of the mechanisms for implementing project recommendations was adopted. Through this mechanism policy makers have been directly involved in the thinking behind the strategy developed. Project partners have also been influenced through their involvement in the project. In particular, the project has been highly multi-disciplinary and has brought together people from different areas that would not normally work with each other. This has raised awareness of the complexity of the issues surrounding agro-chemical management amongst the members of the project team. Team members highlighted this aspect during concluding sessions of the final national Seminars. In Jamaica it has also brought together

scientists from the University of West Indies with administrators from the Pesticides Control Authority (PCA) with learning in both directions. Team members are also involved in a number of other activities and sit on various boards and committees, and experience gained through the project has been taken to these committees. For example, both Jamaica and St Lucia are currently developing national plans of action to implement the land-based sources of pollution protocol of the Cartagena Convention. However, the current group meeting to discuss this does not include representation of the PCA, and a project team member who is part of that group has highlighted this as a deficiency.

Further action required to promote project research products has already been presented in Section 4.4. As an enabling project, the promotional pathway to reach poor women, men and children is through policy interventions and appropriate intermediary implementing agencies. This project has worked directly with both the policy agents and relevant intermediary bodies, and research products are being sent to them (Annex B1.10). The Policy and Management Strategy Document developed with the CGPC has identified the pathways for specific interventions arising from the recommendations. The implementing agency, the course of action, and who and how to communicate the outcomes of that action have been defined (See Box 1 Annex A1). Follow up actions regarding these pathways relate to actions to implement the recommendations and strategy, described in Section 4.4 Output 6.

8. Publications and other communication materials

8.1 Books and book chapters

None

8.2 Journal articles

None

8.2.1 Peer reviewed and published

Roberts, C.M, J.A. Bohnsack, F.R. Gell, J.P. Hawkins and R. Goodridge. 2001. Effects of marine reserves on adjacent fisheries. *Science*, 294: 1920-1923.

Roberts, C.M, J.A. Bohnsack, F.R. Gell, J.P. Hawkins and R. Goodridge. 2002. Marine reserves and fisheries management. *Science* 295: 1233-1235.

8.2.2 Pending publication (in press)

8.2.3 Drafted

Barker, N.L.H. and C.M. Roberts (2003) Scuba diver behaviour and the management of diving impacts on coral reefs. *Biological Conservation*

Barker, N.L.H. and C.M. Roberts (2003) Snorkeler behaviour and impacts on coral reefs. *Coastal Management*.

Barker, N.L.H. and C.M. Roberts (2003) Relationships between tourist perceptions and measured attributes of coral reefs. *Aquatic Conservation: Marine and Freshwater Ecosystems*.

Barker, N.L.H and C.M. Roberts (2003) Economic benefits of coral reef tourism and maximising the potential for tourists to fund management of marine protected areas. *Coastal Management*.

Barker, N.L.H. and C.M. Roberts (2003) Management and development of coral reef tourism in St. Lucia. *Coastal Management*.

Gell, F.R., C.M. Roberts, P. Hubert, J.P. Hawkins, R. Goodridge, H.A. Oxenford, W. Joseph and S.N. George (2003) The rate and trajectory of recovery of fisheries adjacent to marine reserves. *Conservation Biology*.

Gell, F.R., C.M. Roberts, J.P. Hawkins, R. Goodridge and H.A. Oxenford (2003) The effects of marine reserves on reef fish populations and catch composition. *Fish and Fisheries*.

Schelten, C.K., Roberts, C.M., Nugues, M.M., Hawkins, J.P. (2002) The interacting effects of sedimentation, fishing and hurricanes on coral reefs: a long-term study in St. Lucia, West Indies. *Conservation Biology*.

Schelten, C.K., Roberts, C.M., Wabnitz, C.C.C., Nugues, M.M. and Hawkins, J.P. (2002) The effects of human-induced sedimentation on juvenile coral assemblages. *Coral Reefs*.

Schelten, C.K., Roberts, C.M., Hawkins, J.P., and Nugues, M.M. (2003) The effects of sedimentation on coral larval settlement. *Coral Reefs*.

Schelten, C.K., Roberts, C.M., Hawkins, J.P., and Nugues, M.M. (2003) Impacts of sedimentation on juvenile coral settlement, mortality and growth. *Journal of Experimental Marine Biology and Ecology*.

8.3 Institutional Report Series

8.4 Symposium, conference, workshop papers and posters

Lauckner, Bruce. (2003) Effect on the Environment Of Agricultural Practices For Hillside Agricultural Production In Jamaica. 9TH Annual Research Symposium -Institute of Marine Affairs, 12-13 November 2002, Chaguaramas, Trinidad. CARDI, Jamaica.

Simpson, L. (2003) Paper to be presented at 17th Annual National Conference on Science and Technology in Jamaica. CARDI, Jamaica. (Forthcoming)

8.5 Newsletter articles

Research and monitoring: An interview with Dr Callum Roberts. *SMMA Connection* 4(1) March 2001.

Gell, F.R. 2001. The Soufrière Marine Management Area, St Lucia: a pioneer in networking marine reserves. *Reef Encounter*, Newsletter of the International Society for Reef Studies.

Schelten, C.K. 2000. Why is it so important to monitor the sedimentation rate in our ocean. *SMMA Connection* 3(2).

8.6 Academic theses

Barker, N.L.H. (2003) Ecological and socio-economic impacts of dive and snorkel tourism in St. Lucia, West Indies. PhD Thesis, University of York.

Schelten, C.K. (2002) The impacts of multiple stresses on the replenishment of coral communities. PhD Thesis, University of York.

8.7 Extension leaflets, brochures, policy briefs and posters

Annex A1. Policy Brief 1: Management of agro-chemicals for improved public and environmental health (2003)

Annex A1. Policy and Management Brief 2: The fate of agro-chemicals in the land-water interface in St Lucia and Jamaica: Environmental monitoring (2003)

Annex A1. Policy and Management Brief 3: The quantification and toxicity of agro-chemical imports into St Lucia and Jamaica (2003)

Annex A1. Policy and Management Brief 4: The on farm use of agro-chemicals and associated soil management and farming practices in St Lucia and Jamaica (2003)

Annex A1. Policy and Management Brief 5: Harmonisation of agro-chemical management in the Caribbean (2003)

Annex A1. Policy and Management Brief 6: Management options for the use of agro-chemicals (2003)

Flyers 1: Agro-Chemical pollution in the Caribbean. Flyer # 1. January 2003

Flyer 2: Agro-Chemical pollution in the Caribbean. Flyer # 2. August 2003

Annex A2. Policy and management brief 1: Impacts and mitigation of sediment pollution on coral reefs (2003)

Annex A2. Policy and management brief 2: Value of the Soufriere reef fishery (2003)

Annex A2. Policy and management brief 3: Value of coral reefs for tourism and costs of reef degradation (2003)

Annex A2. Policy and management brief 4: Funding coral reef management (2003)

Annex A2. Policy and management brief 5: Impacts of tourism on coral reefs and options for management (2003)

8.8 Manuals and guidelines

Report 10: Mees, C., N. Esteban and S. Seddon-Brown, 2003. Management of agro-chemicals for improved public and environmental health - A strategy for improved agro-chemical use and management for the Wider Caribbean: DFID NRSP Project R7668. Policy and Management Strategy Document. MRAG Ltd.

8.9 Media presentations (videos, web sited papers, TV, radio, interviews etc)

Interviews on St Lucia Radio following Farmer Survey workshop and the end of project seminar in St Lucia, and reporting on the increases in fish stocks and improvement of reef fishery.

Video: Soufriere Marine Management Area stakeholder comments. Caribfilms, Soufriere. Regularly aired on St. Lucian TV.

Examples of international radio programmes featuring work done in St. Lucia include Quirks and Quarks (Canadian Broadcasting Corporation), All Things Considered (National Public Radio, USA; audience 15 million), and Earth and Sky Radio (USA); BBC Radio 4; Australian Broadcasting Corporation News, Maritime Radio (Canadian Broadcasting Corporation) and World Service. We also did 15 network radio interviews with local radio stations in the USA.

8.10 Project reports and data records

8.10.1 Citation for the project Final Technical Report (FTR)

Roberts, C, C. Mees, and S Seddon-Brown (2003) Impact and Amelioration of Sediment and Agro-chemical pollution in Caribbean Coastal Waters. Final Technical Report. DFID NRSP Project R7668. University of York, York and MRAG Ltd London.

8.10.2 Project technical reports including project internal workshop papers and proceedings

Technical Reports

Report 1: Esteban, N., P. Espeut, B. Hay, C. Mees and S. Seddon-Brown, 2003 Importation, administration and harmonisation of agrochemical management in St Lucia, Jamaica and the wider Caribbean. DFID NRSP Project R7668. C-CAM and MRAG Ltd.

Report 2: Simpson, L., 2003. Review of soil management and farming practices, including the use of agro-chemicals in the Caribbean, with particular reference to St Lucia and Jamaica. DFID NRSP Project R7668. CARDI (Jamaica).

- Report 3: Dasgupta, T. and C. Perue, 2003. Toxicity review for agro-chemicals in St Lucia and Jamaica. DFID NRSP Project R7668. Chemistry Department, UWI, Mona.
- Report 6: Lewis, A. and N. Esteban, 2002. Environmental survey of agro-chemicals in the land water interface of St Lucia. DFID NRSP Project R7668. CEHI and MRAG Ltd.
- Report 7: Pearce, J., and N. Esteban, 2002. Database review and user requirements analysis prepared for the Coordinating Group of Pesticide Control Boards of the Caribbean. DFID NRSP Project R7668. MRAG Ltd.
- Report 8: Esteban, N., C. Mees, and S. Seddon-Brown, 2003. Environmental monitoring options. DFID NRSP Project R7668. MRAG Ltd.
- Report 9: Seddon-Brown, S., C. Mees and N. Esteban, 2003. Management options for the use of agro-chemicals in the environment. DFID NRSP Project R7668. MRAG Ltd.
- Report 10: Schelten, C.K. and C.M. Roberts. 2002. The effects of human-induced pollution on the replenishment of coral reefs. DFID NRSP Project R7668. University of York, UK.
- Report 11: Schelten, C.K., Roberts, C.M., Nugues, M.M., Hawkins, J.P. 2002. The interacting effects of sedimentation, fishing and hurricanes on coral reefs: a long-term study in St. Lucia, West Indies. DFID NRSP Project R7668. University of York, UK.
- Report 12: Schelten, C.K., Roberts, C.M., Wabnitz, C.C.C., Nugues, M.M. and Hawkins, J.P. 2002. The effects of human-induced sedimentation on juvenile coral assemblages. DFID NRSP Project R7668. University of York, UK.
- Report 13: Schelten, C.K., Roberts, C.M., Hawkins, J.P., and Nugues, M.M. 2003. The effects of sedimentation on coral larval settlement. DFID NRSP Project R7668. University of York, UK.
- Report 14: Schelten, C.K., Roberts, C.M., Hawkins, J.P., and Nugues, M.M. 2003. Impacts of sedimentation on juvenile coral settlement, mortality and growth. DFID NRSP Project R7668. University of York, UK
- Report 15: P. Hubert. 2001. A study of the Soufriere Fisheries. DFID NRSP Project R7668. University of York, UK.
- Report 16: Preliminary report on the economic effects of marine reserves on the reef fishery of Soufrière, Saint Lucia, West Indies. DFID NRSP Project R7668. University of York, UK.
- Report 17: Gell, F.R., C.M. Roberts, P. Hubert, J.P. Hawkins, R. Goodridge, H.A. Oxenford, W. Joseph and S.N. George. 2003. The rate and trajectory of recovery of fisheries adjacent to marine reserves. DFID NRSP Project R7668. University of York, UK.
- Report 18: Gell, F.R., C.M. Roberts, J.P. Hawkins, R. Goodridge and H.A. Oxenford. 2003. The effects of marine reserves on reef fish populations and catch composition. DFID NRSP Project R7668. University of York, UK.
- Report 19: Gell, F.R. and C.M. Roberts. 2003. Availability and uptake of alternative sources of income for fishers in Soufriere, St Lucia. DFID NRSP Project R7668. University of York, UK.
- Report 20: Barker, N.L.H. and C.M. Roberts. 2003. Scuba diver behaviour and the management of diving impacts on coral reefs. DFID NRSP Project R7668. University of York, UK.
- Report 21: Barker, N.L.H. and C.M. Roberts. 2003. Snorkeler behaviour on coral reefs. DFID NRSP Project R7668. University of York, UK.
- Report 22: Barker, N.L.H. and C.M. Roberts. 2003. Relationships between tourist perceptions and measured attributes of coral reefs. DFID NRSP Project R7668. University of York, UK.

Report 23: Barker, N.L.H and C.M. Roberts. 2003. Economic benefits of coral reef tourism and maximising the potential for tourists to fund management of marine protected areas. DFID NRSP Project R7668. University of York, UK.

Report 24: Barker, N.L.H and C.M. Roberts. 2003. Management and development of coral reef tourism in St. Lucia. DFID NRSP Project R7668. University of York, UK.

Workshop Proceedings

Edwards, P., Kenward, N., Mees, C., Simpson, L. and Martin R. (2001) Workshop Proceedings for the DFID NRSP Project R7668 Workshop held on the 11 June 2001 in Kingston, Jamaica. DFID NRSP Project R7668. MRAG Ltd.

Kenward, N., Mees, C.C., Philigence, A. and Simpson, L. (2001) Workshop Proceedings for the DFID NRSP Project R7668 Workshop held on the 26 June 2001 in Still Plantation, Soufriere, St Lucia. DFID NRSP Project R7668. MRAG Ltd.

Esteban, N., C. Mees, A. Philigence, and L. Simpson. (2001) Impact and Amelioration of Sediment and Agro-Chemical Pollution on Caribbean Coastal Waters. Workshop Proceedings. DFID NRSP Research Project R7668. June 2001. London: MRAG Ltd. www.mragltd.com (select land water interface; selected project examples and Workshop report).

Mees, C., S. Seddon-Brown and N. Esteban. (2003) Workshop proceedings for the DFID NRSP Project R7668 Workshop held during the 8th Annual Meeting of the Coordinating Group of Pesticide Control Boards of the Caribbean, St Vincent and the Grenadines, 18-20 June 2003. DFID NRSP Project R7668. MRAG Ltd.

Working /Internal documents

Barker, N. and C.M. Roberts (2002) Preliminary results from scuba diver impact study, Saint Lucia, West Indies, 2000-2001. Environment Department, University of York.

Barker N. and C.M. Roberts (2002) Preliminary results from snorkeller impact study, St. Lucia, Environment Department, University of York,

Barker N. and C.M. Roberts (2003) Results from reef-tourist perception study, St. Lucia, West Indies 2000-2001. Environment Department, University of York.

Barker N. and C.M. Roberts (2003) Value of coral reef tourism and options for funding reef management. Environment Department, University of York.

Espeut, P and B Hay (2002) Administrative procedures for agro-chemical management in Jamaica. DFID NRSP Research Project R7668. Caribbean Coastal Area Management Foundation, Clarendon, Jamaica.

Gell, F.R., Clark, A. and C.M. Roberts (2002) Preliminary report on the economic effects of marine reserves on the reef fishery of Soufrière, Saint Lucia, West Indies. Environment Department, University of York, UK

Gell, F.R., Roberts, C.M., Goodridge, R. and Hawkins, J.P. (2001) Preliminary report on the change in status of the Soufriere reef fishery 1995/6 to 2000/1. Environment Department, University of York.

Kenward, N and Mees, C. (2000) Report of a project inception visit to Barbados, St Lucia and Jamaica. Research Project DFID NRSP R7668. November 2000. London: MRAG Ltd. www.mragltd.com (select land water interface; selected project examples).

Kenward, N. (2001) Sampling programme for agro-chemical in St Lucian coastal waters. November 2001. London, MRAG Ltd.

Kenward, N and C Mees (2001-3) Uptake Promotion / Communications Strategy Agrochemical elements (R7668)

Kenward, N and C Mees (2001-3) Critical control points analysis and mechanisms for communication (CCPAMC).

Kenward (2003) Steps taken to draft uptake promotion/communication strategy (UPCS) and critical control points analysis and mechanisms for communication (CCPAMC)

Philigence, A. (2001) Agro-chemical application (pesticides and fertilisers) in St Lucia. Report for research project DFID NRSP R7668. November 2001.

Roberts, C.M. (2001-3) Critical control points analysis and mechanisms for communication, University of York.

Simpson, L. (2001) Outline of existing knowledge of farming practices and soil conservation techniques in Jamaica. Report for Research project DFID NRSP R7668. December 2001.

Trip Reports

Esteban, N. (2001) Report of a project visit to Jamaica and St Lucia. Impact and Amelioration of Sediment And Agro-Chemical Pollution On Caribbean Coastal Waters. Report for research project DFID NRSP R7668. December 2001. London: MRAG Ltd. www.mragltd.com (select land water interface; selected project examples and Trip Report 3).

Kenward, N. and Mees, C. (2000) Report of a project visit to Barbados, St Lucia and Jamaica. Impact and Amelioration of Sediment And Agro-Chemical Pollution On Caribbean Coastal Waters. Report for research project DFID NRSP R7668. November 2000. London: MRAG Ltd. www.mragltd.com (select land water interface; selected project examples and Trip Report 1).

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8.10.3 Literature reviews

Report 4: Boodram, N., 2002. The fate of agro-chemicals in the land-water interface, with reference to St Lucia and the wider Caribbean. DFID NRSP Project R7668. CEHI.

Report 5: Edwards, P., 2001. The fate of agro-chemicals in the land-water interface, with reference to Jamaica and the wider Caribbean. DFID NRSP Project R7668. Centre for Marine Studies, UWI, Mona.

Schelten, C.K. and C.M. Roberts. 2002. The effects of human-induced pollution on the replenishment of coral reefs. DFID NRSP Project R7668. University of York.

8.10.4 Scoping studies

8.10.5 Datasets, software applications

Farmer survey database (in Access). CARDI, 2002⁸.

8.10.6 Project web site and/or other project related web addresses

MRAG Ltd. website (<http://www.mragltd.com>) contains all the reports as downloadable Adobe Acrobat pdf files. Select the land water interface option in the left hand margin and then select the specific project examples (see files under R7668).

⁸ Note that this database was for internal project use for analysis of the farmer surveys carried out as part of the agro-chemical component of the project in Jamaica and St Lucia. It does not represent a product of the project for wider dissemination. Nevertheless it form as a useful resource, and CARDI have already interrogated it to provide materials in support of presentations made at workshops outside this project.

9. References cited in the report, sections 1-7

References, where applicable, have been included in footnotes to the text. Detailed reference lists occur in the project technical reports.

Cox, C. and C. Madramootoo. 1998. Application of geographic information systems in watershed management planning in St. Lucia. *Computers and Electronics in Agriculture* 20:229-250.

Sladek Nowlis, J., C.M. Roberts, A. Smith and E. Siirila. 1997. Human enhanced impacts of a tropical storm on nearshore coral reefs. *Ambio* 26: 515-521.

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10. Project logframe

R7668: Ameliorating pollution in Caribbean coastal waters

Revised log-frame: 28th June 2002

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Goal			
Improved resource-use strategies in coastal zone production systems developed and promoted.	<p>By 2002, new approaches to integrated natural resource management and prevention of pollution which explicitly benefit the poor validated in two targeted areas.</p> <p>By 2004, these new approaches incorporated into strategies for the management of coastal resources and adopted by target institutions in two targeted countries.</p>	<p>Reviews by Programme Manager.</p> <p>Reports of research team and collaborating /target institutions.</p> <p>Appropriate dissemination products.</p> <p>Local, national and international statistical data.</p> <p>Data collected and collated by the Programme Manager.</p>	<p>Target beneficiaries adopt and use strategies.</p> <p>Enabling environment exists.</p> <p>Budgets and programmes of target institutions are sufficient and well managed.</p>
Purpose			
Technical understanding, and methods for management of coastal zone habitats improved.	<p>Adoption of project recommendations by informed policymakers and integration into National Plans and land management of target countries and the wider Caribbean.</p> <p>Awareness among local communities and decision-makers of the impacts of sediment and agro-chemical pollution.</p>	<p>Country Policy Plans.</p> <p>Interview surveys of local people.</p> <p>Resource and pollution monitoring.</p>	<p>National GOs and NGOs committed to improved management solutions, and will participate in institutional restructuring, changes to legislature etc.</p>
Outputs			
<p>1. Improved understanding of the effects of sedimentation on (a) coral reefs, (b) on the efficacy of current management measures (marine reserves and zoning plan), and (c) on reef recovery from natural disturbances (storms).</p> <p>2. Economic estimates of (a) the value of reefs to the St. Lucian economy, and (b) the costs of sediment pollution.</p>	<p>Measures quantified by the end of research.</p> <p>Final surveys completed by the middle of the third year of research.</p> <p>Workshops held in years 2 and 3 to disseminate findings and solicit user views.</p> <p>Completed by the end of the third year of research.</p> <p>Questionnaire survey of scuba divers completed and analysed by the end of the second year of research.</p>	<p>Research programme report; scientific papers; leaflet and posters for in-country circulation.</p> <p>Research programme report; scientific paper; printed education materials – leaflets and poster; final year workshop.</p>	<p>Weather conditions favourable for adequate data collection in the field.</p> <p>Reserves continue to be managed as no-fishing zones.</p> <p>Weather conditions favourable for adequate field data collection.</p>

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
<p>3. Estimates of agro-chemical loadings and fate of loadings in St. Lucia.</p> <p>4. Review and evaluation of existing agricultural land management in participating countries.</p> <p>5. Options for pollution monitoring for participating countries.</p> <p>6. Identification of management options to ameliorate sediment and agro-chemical pollution in participating countries and dissemination and promotion through appropriate networks in the wider Caribbean.</p>	<p>Quantitative estimates of pollution loadings and probable pathways.</p> <p>Identification of shortfalls in BMPs addressed in National Plans.</p> <p>Monitoring options evaluated and described</p> <p>Data on appropriate best management practices collected in year 2 workshop.</p> <p>Manual completed by the end of year 3 of the research.</p> <p>Appropriate dissemination products and promotion methods completed and delivered by end of year 3.</p>	<p>Research programme report.</p> <p>Research programme report.</p> <p>Research programme report</p> <p>Manual defining recommended methodology</p> <p>Second year workshop</p>	<p>Access to in-country chemical import and distribution data.</p> <p>Favourable weather conditions for data collection.</p> <p>Relevant government departments / farmers co-operate.</p> <p>Access to literature on alternative management practices elsewhere.</p>
Activities	Project Milestones and budget		Important assumptions
1.1 Sedimentation rates monitored and related to rainfall and underwater visibility.	Data analysed annually, and final sampling conducted by end of second year.		Rainfall and underwater visibility data continue to be collected by collaborators
1.2 Effects of sediment on benthic communities estimated.	Data analysed annually, and final sampling conducted by end of second year.		Sediment effects on reefs successfully separated from other factors causing degradation. Experimental design and previous research facilitates this.
1.3 Sedimentation effects on coral recruitment and juvenile mortality and growth rates estimated.	Data analysed annually, and final sampling conducted by end of second year.		Permission obtained to establish experiments on the reefs (Permission has always been granted in the past).
2.1 The impacts of reserves on fish landings will be estimated.	Data collected during second year of study. Analysed early in third year.		Cooperation of fishers obtained.
2.2 Amenity value of reefs estimated.	Questionnaire survey complete by end of second year; data analysed by early in third year.		Cooperation of scuba diving companies, scuba divers, hotels and tourism companies obtained.

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
2.3 Opportunities and constraints on coastal fishers to participate in tourism industry evaluated.	Second year workshop to explore and quantify stakeholder interests and involvement in tourism.		Cooperation of fishers obtained.
2.4 Economic the costs of reef degradation to coastal communities estimated.	Modelling initiated at the end of the second year; complete by end of third year.		Biological, fishery and tourism studies completed successfully.
<p>3.1 Quantify imports of agro-chemicals into participating countries, and describe their use locally.</p> <p>3.2 Review agro-chemical toxicity and recommended management in other countries (e.g. USA, EU)</p> <p>3.3 Carry out baseline survey for agro-chemicals in coastal zone in St. Lucia.</p>	<p>Project report at end of first year.</p> <p>Establishment of baseline database.</p> <p>Project report at end of second year.</p> <p>Snapshot survey of water, sediment and indicator organisms to establish the potential fate of agro-chemicals completed by the end of second year.</p>		<p>Relevant government department make information available.</p> <p>Data available adequate to estimate imports and application rates.</p> <p>Favourable weather conditions during field work phases.</p>
<p>4.1 Review administrative procedures of agro-chemical imports / production</p> <p>4.2 Review soil management and the use of agro-chemicals in agriculture</p> <p>4.3 Identify critical control points for management and dissemination of information</p>	<p>Review completed by end of first year</p> <p>Review completed by end of first year. Workshop with farmers and government completed in second year.</p> <p>Project report by end of second year.</p>		<p>Co-operation for the collection of import and local distribution data.</p> <p>Farmers co-operate with the collection of information.</p> <p>Adequate data available from baseline sampling and government offices.</p>
<p>5.1 Determine options for monitoring for agro-chemical imports.</p> <p>5.2 Determine alternative options for environmental monitoring to detect changes in concentration of agro-chemicals and sediment loads in coastal zone.</p>	<p>Options for monitoring imports of agrochemicals defined for target countries by end of project</p> <p>Alternative monitoring options based on cost defined for target countries by end of project.</p>		<p>Relevant government departments co-operate</p> <p>Government implements methodology</p>
<p>6.1 Identify critical control points for both sediment and agro-chemical pollution control and identify any common/separate target institutions/stakeholders to each type of pollution.</p> <p>6.2 Define appropriate products and mechanisms for dissemination to a range of target institutions and stakeholders.</p>	<p>Framework developed and agreed by partners by October 2002.</p> <p>Type, format and uptake strategy defined by October 2002.</p>		Cooperation of farmers obtained.
6.3 Identify management options to improve the use of agro-chemicals and to reduce agro-chemicals / sediment in the marine environment.	Management options (including advise on education, training and awareness needs, and appropriate legislative and policy measures to improve management of agricultural non-point sources of pollution) presented at Workshop to relevant stakeholders including farmers and government bodies during final year.		

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
6.4 Maintain regular communication with target institutions and relevant stakeholders.	Measurable interaction with relevant institutions.		
6.5 Participatory consultation with target institutions and relevant stakeholders to produce guidelines for sediment and agro-chemical pollution control and dissemination through appropriate networks.	Workshops to define guidelines for agro-chemical control and management. Appropriate products (determined in A6.2) for different stakeholders written and disseminated at end of project.		

11. Keywords

Caribbean, pollution management, sediment, agro-chemicals, pesticides, environmental health, public health, baseline monitoring, St. Lucia, Jamaica, coastal waters, coral reefs, fisheries, tourism.

12 Annexes