CONSERVATION AND SUSTAINABLE USE OF THE MESOAMERICAN BARRIER REEF SYSTEMS PROJECT (MBRS)

COMISION CENTROAMERICANA DE AMBIENTE Y DESARROLLO

SAM / MBRS

DESIGN OF THE REGIONAL DATA COMMUNICATIONS NETWORK FOR THE MBRS PROJECT

April 2003

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LIST OF ACRONYMS AND ABBREVIATIONS

ADSL	Asymmetric Digital Subscriber Line
CBAC	Context Based Access Control
CCAD	Comisión Centroamericana de Ambiente y Desarrollo
CONANP	Comisión Nacional de Áreas Naturales Protegidas, Mexico
CZM	Coastal Zone Management Authority and Institute, Belize
DoS	Denial of Service
FTP	File transfer protocol
GEF	Global Environment Facility
GIS	Geographical Information Systems
HTTP	Hypertext Transfer Protocol
IABIN	Inter-American Biodiversity Information Network
IDS	Intrusion Detection System
ISP	Internet Service Provider
IW:LEARN	International Waters: Learning Exchange and Resource Network
Kbps	Kilobits per second
LAN	Local Area Network
Mbps	Megabits per second
MBRS	Mesoamerican Barrier Reef System
MPA	Marine Protected Area
NGO	Non-governmental Organization
PCU	Project Coordinating Unit
RDS	Red de Desarrollo Sostenible
REIS	Regional Environmental Information System
RPI	Research Planning, Inc.
SIAM	Sistema de Información Ambiental Mesoamericano
SICA	Sistema de la Integración Centroamericana
SIMEBIO	Sistema Mesoamericano de Información sobre Biodiversidad
TWG	Technical Working Group
UPS	Uninterruptible Power Supply
UQROO	Universidad de Quintana Roo
UVG	Universidad del Valle de Guatemala
VPN	Virtual Private Network
WAN	Wide Area Network

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PREFACE

The Project for the Conservation and Sustainable Use of the Mesoamerican Barrier Reef Systems will be generating and managing important information pertaining to scientific, conservation management, social, legal and policy-related areas. To manage this information, it has identified the need for a Regional Environmental Information System (REIS), which will reside on a regional data communications network. The Project embarked on the task of designing this information system and supporting data communications network in May 2002, in parallel with the design of scientific monitoring programs for the reef and related ecosystems and the Marine Protected Areas within the Project's geographical area of interest. To assist with these design tasks, the Project hired two consulting firms, ESG International of Canada to design the network and Research Planning Inc of the USA to design the REIS.

This document describes the process of designing the regional data communications network and presents the results of this design process. The current document was prepared by the Information Systems Specialist of the Project and is based largely on the consultancy report entitled "The Design and Implementation of the Data Communications Network for the Mesoamerican Barrier Reef System", which was presented to the Project by ESG International. The final design choices presented herein however are the responsibility of the Project itself and are the result of many additional consultations and much research.

Special recognition is hereby given to the contributions made by the consulting firms of ESG International of Canada and Research Planning Inc. of the United States, who contributed their time and ideas over the course of many discussions and email exchanges and who participated significantly in realizing the results presented herein. The contributions of the Project's Technical Working Group for Environmental Information Systems, the Project's National Coordinators of the Project, and the participants in the Information Systems Expert Meeting held in May 2002 are also hereby recognized. These groups helped formulate ideas in the early stages of network design and also participated in identifying and selecting node agencies. The node agencies themselves contributed to the design process by presenting proposals, freely providing information regarding their infrastructure and resources, and helping to collect information regarding telecommunications service in their respective countries.

1. INTRODUCTION

The Mesoamerican Barrier Reef System (MBRS), extending from the southern half of the Yucatan Peninsula to the Bay Islands of Honduras, includes the second longest barrier reef in the world. It is unique in the Western hemisphere due to its length, composition of reef types, and diverse assemblage of corals and related species. The MBRS contributes to the stabilization and protection of coastal landscapes, maintenance of coastal water quality, and serves as breeding and feeding grounds for marine mammals, reptiles, fish and invertebrates, many of which are of commercial importance. The MBRS is also of immense socio-economic significance providing employment and a source of income to an estimated one million people living in adjacent coastal areas.

Despite its significance in both ecological and socio-economic terms, the MBRS is increasingly at risk from a number of anthropogenic threats and natural disturbances. The challenge to manage the MBRS is further complicated by the transboundary nature of the System and the lack of an effective mechanism to facilitate the regional cooperation needed to achieve a comprehensive management approach.

Recognizing the importance of the MBRS to the economy of the region and to the natural and cultural heritage of its people, and conscious of the increasing threats to its overall health, the leaders of the four countries bordering the MBRS convened in Tulum, Mexico in June 1997 to pledge their commitment to protecting this outstanding resource. The Tulum Declaration called on the four littoral states of the MBRS and its partners in the region to join in developing an Action Plan for its Conservation and Sustainable Use. The Central American Commission on Environment and Development (CCAD), comprised of the Ministers of Environment of the seven Central American countries and Mexico (as an observer), approached the Global Environment Facility (GEF) through the World Bank to request support for the design and implementation of an Action Plan for management of the MBRS, which resulted in the formulation of the Project for the Conservation and Sustainable Use of the Mesoamerican Barrier Reef System.

This Project was officially launched on June 20, 2001. The MBRS Project is the first phase of a 15-year conceptualized program, and was designed based on the regional components of the Action Plan and included an exhaustive process of broad stakeholder consultation and participation throughout the MBRS region. The MBRS Project is funded by the Global Environment Facility (GEF) and the Governments of Belize, Guatemala, Honduras, and Mexico. The project is implemented by the World Bank and is executed by the four countries through the Central American Commission on Environment and Development (CCAD) of the System for Central American Integration (SICA). The MBRS project is being executed by the Project Coordinating Unit (PCU) on behalf of CCAD, with headquarters in Belize City, Belize.

The goal of the Mesoamerican Barrier Reef System Project is to enhance protection of the unique and vulnerable marine ecosystems comprising the MBRS, and to assist the countries of Mexico, Belize, Guatemala and Honduras to strengthen and coordinate regional policies, regulations, and institutional arrangements for the conservation and sustainable use of this global public good. The regional objectives of the MBRS Program, agreed to by the four participating countries, are to: (a) strengthen Marine Protected Areas (MPAs); (b) develop and implement a standardized data management system of ecosystem monitoring and facilitate the dissemination of its outputs throughout the region; (c) promote measures which will serve to reduce non-sustainable patterns of economic exploitation of MBRS, focusing initially on the fisheries and tourism sectors; (d) increase local and national capacity for environmental management through education, information sharing and training; and (e) facilitate the strengthening and coordinating of national policies, regulations, and institutional arrangements for marine ecosystem conservation and sustainable use. These regional objectives are reflected in four (4) Project components. The second project component specifically addresses the need for a regional environmental monitoring and information system to manage data and disseminate information related to the conservation and sustainable use of the MBRS. The design and implementation of a regional data communications network falls within the scope of the second Project component.

2. THE SYNOPTIC MONITORING PROGRAM AND THE REGIONAL ENVIRONMENTAL INFORMATION SYSTEM

Information is a vital tool for the realization of changes in policy and in public attitudes related to natural resource use. Policy formulation is guided by sound scientific information, whereas public education relies on the broad dissemination of information targeted towards different interest groups. Within the design of the MBRS Project, therefore, the collection, analysis and dissemination of scientific and socio-economic information to decision makers and stakeholders are critical strategic activities being carried out to achieve Project goals.

The Project will be generating and managing important information pertaining to scientific, conservation management, social, legal and policy-related areas. Its aim is to make this information accessible to the region and to the world via the World Wide Web with the ambition that improved knowledge of the Mesoamerican Barrier Reef and related ecosystems will lead to improved regional policies relating to the management of this resource and to stronger political commitment to its conservation at all levels of society. Component 2 of the Project specifically addresses the objective of increased knowledge and dissemination of information relating to coastal and marine ecosystem health in the MBRS. This is linked to Component 4 of the Project aims to increase public awareness of the importance of the conservation of the MBRS at regional and international levels.

A principal objective of Project Component 2 is to develop a reliable base of data for the MBRS eco-region and an information system that can be used to support more informed management decisions. The establishment of a regional environmental information system (REIS) will provide an essential tool to organize and manage data in support of improved decision-making. In the Program's initial phase, the objective of the REIS component will be to provide the basic framework to guide the collection, processing, distribution and utilization of data, both bio-physical and socio-economic.

To feed into the REIS, Component 2 also supports the establishment of a regional and issue-specific monitoring program that will generate information on the region's oceanographic current regime and on the status and processes of MBRS reefs and other critical ecosystems. Data will be collected on reproduction, larval dispersal, and recruitment of corals, fish, and other important reef components to further our understanding of ecological linkages between reefs and other marine environments, and processes which influence reef integrity.

Specifically, the Project is carrying out the following information-related activities:

- Design and implementation of a Synoptic Monitoring Program
- Establishment of a bi-lingual (English and Spanish) Project website
- Establishment of a web-based Regional Environmental Information System
- Provision of computing and networking equipment and infrastructure to four national network nodes, which will comprise a regional data communications network.

3. THE NETWORK DESIGN PROCESS

The establishment of the Regional Environmental Information System implies two principal tasks: (1) the design and implementation of an electronic information system, which will manage, and make accessible to the project's clients, the information relevant to the management of the MBRS and related ecosystems and to the human communities that depend on it for their livelihood; and (2) the design and installation of a computer network on which this information system will run. This document describes the first part of the second task i.e. the process of network design and presents the results of this design exercise. The Project determined that consultants would be employed to assist the Project Team in the execution of these tasks. In February 2002, therefore, the availability of a consultancy entitled The Design and Installation of a Regional Data Communications Network was advertised internationally via the Project website and the United Nations Development Business website. The full Terms of Reference as advertised can be found in Appendix A hereto. A Canadian firm, ESG International, was contracted in early May 2002 to execute this consultancy.

The objective of the Consultancy was to support the Project in the design of a regional network that would serve the Project's needs for data management, information dissemination, and public education. A key information system that would be developed and managed by the Project is the Regional Environmental Information System (REIS), which was envisioned as a database with GIS functionality that will manage the environmental monitoring and other information collected through Project activities.

It was further envisioned that each MBRS country would have at least one network node. Users at the network nodes in each country would have access to the REIS through the Project website. This website would also provide users, and the general public, access to a variety of information systems and information products. The Project conducted various other consultancies and program design activities concurrently, several of which had information to offer in terms of system requirements. Most significantly, the design and implementation of the Regional Environmental Information System and the design of the environmental monitoring methodology have been closely interlinked with the design of the regional data communications network. This necessitated close liaison among Project components and among all contracted Consultants, in particular the Consultant hired for the design and implementation of the REIS, namely Research Planning Inc. (RPI), to ensure that the design of the network can support the Project's information management needs.

The design of the data communications network involved the following tasks:

a. Requirements analysis. An Expert Meeting to discuss the Regional Environmental Information System and the Regional Data Communications Network took place from 16 to 18 May, 2002. The 15 regional and international experts who participated provided the Project and Consultants with specific recommendations for hardware, software and network technologies, long-term sustainability, as well as information regarding resources and levels of telecommunications services available in the four countries of the MBRS. This meeting was the first step in the design of the regional network and the REIS. Subsequently, representatives of ESG International and Research Planning Inc. (hired for the design of the REIS) visited Belize to conduct information-gathering interviews with the Project Team, the local telecommunications provider, each other, and other key actors to determine the Project's information management and networking needs.

b. Node agency selection. To implement the regional network, the Project needed to choose agencies in each MBRS country to host network nodes. Candidates were invited to submit proposals describing how they meet the criteria set by the Project. The Information Systems Specialist worked with the National Barrier Reef Committees to select the agency in each country that best satisfied the criteria. The section below entitled Node Agencies gives greater detail of the site selection process.

c. Physical site verifications of proposed node agencies. In September 2002, the Information Systems Specialist and a representative of ESG International, visited the facilities of the candidate agencies to conduct physical site verifications. Where possible the National Coordinator or his representative accompanied them on this visit to the site where equipment will be located. Meetings were also held with Internet Service Providers in each country to assess available service and prices. The most important results of these visits were 1) obtaining first-hand information about the facilities in node agencies, for use in network design; 2) ascertaining quality and prices regarding the telecommunications services available in each city visited; and 3) most importantly, strengthening relations between the Project and these agencies, on whom the long-term success of the regional network depends. The nodes selected through this process are: Coastal Zone Management Authority and Institute (Belize), Universidad del Valle de Guatemala (Guatemala), La Red de Desarrollo Sostenible (Honduras) and Universidad de Quintana Roo (Mexico).

d. Research on the data communications and telecommunications infrastructure in Belize, Guatemala, Honduras and Mexico to identify what technologies and connectivity are available. This research was done by electronic correspondence as well as personal interviews conducted during the site visits to each country.

e. Preparation of a Network Design Specification. This entailed the synthesis of the information obtained during the Expert Meeting, interviews, site visits; the evaluation of various network topologies; and significant research on current hardware and software technologies. In the end, this process resulted in design recommendations, a comparison of various network configuration options accompanied by network diagrams, an analysis of the advantages and disadvantages of each design configuration; and detailed Statements of Requirements for equipment procurement.

f. Preparation of a comprehensive set of Statements of Requirements for all the equipment to be procured in order to implement the network. Hardware requirements included all the computer hardware for nodes, peripherals for input and output, networking components, and electrical requirements, along with operating system and networking software requirements for the hardware. Operating system and other software requirements were determined in consideration of the requirements of the REIS to ensure compatibility.

g. Procurement of the equipment through a transparent bidding process based on the detailed Statements of Requirements prepared. The Statements of Requirements were explicit and specific, to ensure the successful and efficient procurement of the appropriate goods and services. The procurement process was conducted by the PCU following World Bank guidelines.

4. NODE AGENCIES

The regional data communications network was conceived as having at least one national node in each of the four countries participating in the MBRS Project. The design of the network therefore required that node agencies be found in each MBRS country who would comply with certain criteria and who would be willing to commit themselves to contributing certain in-kind resources.

The compliance criteria outlined by the MBRS indicated, among other things, that these agencies must have access to the Internet and basic telecommunications services, a reliable and stable supply of electricity and a room with a controlled environment where the necessary network equipment could be safely housed. The possibility of taking advantage of the existing network infrastructures that were present in each node was also of interest to the Project. In addition to providing information regarding their computing facilities and infrastructure, each agency was asked to make a recommendation as to the type of infrastructure upgrade they would most need to facilitate their participation in the Project.

4.1. Node Selection Process

Candidate agencies were nominated by the Project's Technical Working Group (TWG) for Environmental Information Systems and the National Barrier Reef Committees, through the National Coordinators. This TWG also drafted the selection criteria to be used in choosing the most appropriate agencies and outlined the role of the node agencies in the establishment and maintenance of the network.

In July 2002, the candidate agencies from each MBRS country were invited to submit proposals detailing their suitability and willingness to serve as node agencies. From amongst these candidates, the National Coordinators, in coordination with the Information Systems Specialist of the MBRS Project, selected those that best fulfilled the established criteria.

A matrix was designed based on the agreed site selection criteria for the purpose of evaluating the proposals in a fair and transparent manner. On this matrix, a weight was assigned to each criterion based on its importance. Each proposal was evaluated by the National Coordinator of the respective country and by the Information Systems Specialist using this matrix. The candidates with the highest score for each country were chosen as the node agency.

Physical site verifications were conducted to each of the selected agencies to verify their suitability to serve as node agencies and to obtain first-hand information about the facilities in node agencies.

4.2. Role of the Node Agencies

The node agencies would be expected to provide the following support to the regional network over the lifetime of the network.

4.2.1 The node agency would provide a secure and environmentally appropriate location for any equipment required for the establishment of the network. The agency should moreover provide Internet connectivity for the operation of the network. Administration of the equipment would also be the responsibility of the agency, which would include physical and operational maintenance on the agency's premises.

4.2.2 Keep the information clearinghouse updated with current information pertaining to the node country in Project-related topics The scope of this responsibility will vary from node to node depending on the amount of data which the agency manages and to which it has access. It may potentially include the collection of existing data for that country and the maintenance of country-specific website content within the Project website.

4.2.3 Support the thematic node agencies (e.g. those that do the biophysical monitoring for the Project) by providing physical access or connectivity to the regional network.

4.2.4 Data Sharing. Each node agency would be requested to share some of the information it manages with the Project either for internal Project use or for public dissemination. This would be governed by data sharing agreements to be signed between the Project and the node agencies.

4.3 Node Agencies Selected

The four agencies chosen to become Project nodes are Universidad de Quintana Roo (Chetumal, Mexico), the Universidad del Valle de Guatemala (Guatemala City, Guatemala), Red de Desarrollo Sostenible (Tegucigalpa, Honduras) and the Coastal Zone Management Authority (Belize City, Belize). The following is a summarized version of the responses obtained from each node:

Universidad de Quintana Roo (UQROO) has a complete network infrastructure in place to allow them to participate as an MBRS node. UQROO has volunteered use of a server, a GIS lab and student technicians for the implementation of the program. The server farm at UQROO is Sun-based running the Solaris operating system. They also had a Windows 2000 Server that could be used for the project. UQROO recommended an increase in bandwidth or connectivity to the Internet to facilitate their participation in the project.

Universidad del Valle de Guatemala (UVG) has a complete network infrastructure in place to allow the institution to participate as a node agency. UVG has volunteered use of a server, a GIS lab, and student technicians for implementation of the Project. UVG runs both Windows 2000 and Linux servers on Dell and clone hardware. UVG recommended the purchase of a robust GIS workstation to facilitate their participation in the project.

Red de Desarrollo Sostenible (RDS) has a complete network infrastructure in place to allow them to participate as a node agency. RDS runs Linux on Dell servers. Although they have the network infrastructure and bandwidth in place, they lack a GIS component. To facilitate their participation in the project, RDS recommended the purchase of a GIS workstation.

Coastal Zone Management Authority (CZM) is located in the Coastal Resources Multi-complex Building, where the MBRS headquarters is also based. CZM manages a GIS for coastal and marine resources of Belize and has significant in-house GIS capability. CZM presently do not have an operational office network although they do share a networked printer and have the infrastructure (cabling and hub) to put a server in place. They have dial-up connectivity to email and Internet services. CZM suggested the purchase of a server and/or access to a proxy server for email to facilitate their participation in the project. CZM also stated that they would need to hire a technician, as their present staffing would not permit having an individual devoted to project duties.

The networking infrastructures at UVG, UQROO, and RDS clearly provide an opportunity for the Project to utilize components presently in place in order to facilitate the design and development of the network.

5. CENTRAL DESIGN ISSUES

5.1. Centralized vs. Distributed Network Design

The network design team looked at several factors to determine whether a centralized or a distributed network solution would best suit the requirements of the Project. The factors were: number of concurrent users, redundancy and scalability.

The main factor determining whether one design would be recommended over another is the number of concurrent users. In general, the greater the number of users, the more likely a distributed design would be recommended. A fully distributed network design would provide local connections to servers, which would provide for quicker access for users, reduced load on the main server, and require less bandwidth to function efficiently.

At the time of network design a precise estimation of the number of concurrent users that the proposed network can expect was not available, since the scientific monitoring programs and the database that would reside on the network were being designed concurrently. Design decisions, therefore, were based on generous estimates of the foreseeable numbers of users.

Another factor is the issue of redundancy. With a distributed system design, redundancy is accomplished at each location thereby ensuring optimal up-state capability and the integrity of the network. A centralized design, on the other hand, would achieve redundancy by providing a duplicate server installation at the main installation site or a co-hosting facility at a remote location. Redundancy at the main installation site is a calculated proposition. Although redundancy is necessary to guarantee the up-time of the network, central site redundancy would not provide adequate protection in the event of a disaster. Co-location, on the other hand, although providing a greater level of security for the integrity of the network in the event of a disaster, has associated costs and implications for network management.

Scalability is the final factor to be taken into consideration with respect to recommending a centralized or a distributed solution. To accommodate additional users and nodes, growth, in a centralized design, would require the purchase of additional bandwidth. Since annual bandwidth costs are at a premium, growth could very possibly be limited by the operating budget available. A distributed network could accommodate many more users because the load is distributed across a number of servers in the network. In a distributed network, the need to increase bandwidth may not arise as early as it would in the case of a centralized network.

A distributed network design would not only allow for any contingency with respect to concurrent use, it would address the limitations with respect to redundancy and scalability posed by a centralized solution.

5.2. Proprietary vs. Open Source Software

The debate between proprietary and open source software is ongoing in the Information Technology industry. The choice between one or the other often is based on cost. Windows and other proprietary software programs are costly to purchase, license and maintain, whereas the cost of obtaining open source operating systems and software programs is negligible. The tradeoff is that the proprietary systems generally offer greater functionality and they tend to be easier to configure and maintain. Various products were investigated and compared, including the proprietary database packages Microsoft SQL Server, Oracle 9i Enterprise, Sybase ASE and IBM's DB2 Universal Database as well as two open source database products MySQL and PostgreSQL.

The Project decided to opt for open source software wherever feasible (i.e. wherever quality and functionality are not sacrificed) to minimize the annual operating costs, especially annual licensing fees, for the Project and for the node agencies. The criteria considered in making this choice were the following:

- <u>Cost and long-term sustainability</u>. This involves the initial costs, the annual licensing fees, and any training costs which may apply. The technologies chosen should be appropriate to the available budget and the in-country capacity of each node. An investigation of the costs showed that the more popular commercial database products had initial costs ranging from USD$4000 to $40,000 and 5 year operational costs ranging from USD$20,000 to US $75,000 (with 25 client licenses.) The open source software had nominal initial costs less than US $200 and no annual license fees. In consideration of the fact that the Project will provide only the capital costs of system installation and initial implementation and that all maintenance costs and annual fees will be borne by the node agencies in each country, it was considered prudent to opt for open source software wherever possible provided that this software provided the functionality required to implement the REIS.

- Functionality. It was considered essential that the database application products chosen would support the essential SQL features as well as adequate administration tools. The proprietary products generally offer greater functionality than the open source products; however, the PostgreSQL product was found to offer all the essential SQL functions, which would be needed for this application.

- Ease of installation, configuration and maintenance. The proprietary products generally have friendlier user interfaces and administration tools although Oracle is very complex to manage.

- Performance. This refers to the efficiency in processing database requests. According to a PC Magazine comparison done in March 2002, all the databases mentioned above (except for PostgreSQL which was not included in the study) have either very good or excellent performance. Other reports investigated indicate however that PostgreSQL also demonstrated very good performance.

In consideration of the above, it was decided that PostgreSQL offered the best combination of acceptable functionality and long-term affordability. The latter was the key factor in making the decision as the annual costs of the proprietary database packages were considered prohibitively high and would therefore jeopardize the sustainability of the network in the long term. In the case of the GIS software, ESRI's ArcView was chosen but it was determined that only a single license for this would be needed for a single installation which would be located in the office of the PCU. An Internet Map Server (such as ArcIMS) was not considered essential at this time but should it become necessary in the future, the choice would then be made between the proprietary products and the open source products in a similar exercise.

5.3. Windows vs. Unix-based Operating System

The two operating system platforms that are generally used for running low- to medium-sized web server applications are Microsoft Windows 2000 Advanced Server and UNIX, of which there are a number of popular variants including Sun Solaris, Linux (Debian, Redhat, Mandrake and SUSE) and Mac OS X. While it is beyond the scope of this document to outline all the differences between these platforms, and their respective advantages and disadvantages, a brief discussion is given here of how the choice was made between the two.

The criteria considered in this design process for the choice between operating system platforms were the following:

- Compatibility with the hardware, especially the CPU of the server. The hardware recommended for the MBRS servers is not compatible with the Mac OS X and Sun Solaris Unix variants. From the list of operating systems mentioned above, this left the choice between Windows 2000 Advanced Server and Linux variants.

- Compatibility with application software. In the case of the MBRS design process, special consideration had to be given to the database server software, which would be chosen to implement the REIS database application with GIS functionality. Microsoft makes its own database server product, Microsoft SQL Server, which is a highly functional (and relatively expensive) product. Being proprietary Microsoft software, it must run on a Microsoft operating system. Oracle makes a suite of highly functional and very expensive database management products, which run on both Unix and Windows platforms. The Sybase and DB2 products mentioned above also run on both platforms.

  Additionally, there are open source solutions that are either free, or cost a nominal fee, and run on both platforms. (Please refer to the section herein entitled Proprietary vs. Open Source Software for a discussion of the advantages and disadvantages of these classes of software.) The GIS platform chosen for use with the REIS is ESRI's ArcView and possibly other packages made by ESRI. Arcview runs on Windows operating systems only, although the ESRI Internet map server ArcIMS runs on a variety of platforms including Windows and Unix/Linux platforms.

- Costs. This includes the cost of the hardware on which the operating system runs, the cost of the operating system software itself, and the cost of annual server licensing, and the potential cost of staff training in system administration. At the time of investigation, Windows 2000 Advanced Server had an initial cost of US $4000 and an annual client license cost of $2000/yr whereas the Linux variants, being open source, had initial costs ranging from free to US $200 with no annual costs.

- Staff familiarity with the operating system. The experience of the Project's Information Systems Specialist and of node agency staff in the administration of each operating system was considered. Of the node agencies chosen, UVG, UQROO, and RDS were all running primarily UNIX systems and had significant in-house expertise in Unix administration. The Information Systems Specialist of the MBRS Project, moreover, had significant system administration experience with Unix systems.

- Security. This involves the robustness of the inherent security system of the software, the security level of the default installation, and the effort and expertise required to increase system security from the default installation. The reputation of the Unix operating system, which extends to its many variants, is that the default installation boasts a much more robust security system than its Windows competitors. Additionally, the security of UNIX systems can easily be further enhanced to a very high level. Microsoft Windows has an inferior reputation in security even where firewall protection systems are used. Microsoft has developed an intricate 'Security Model', but this has not been sufficient to counter the frequent malicious attacks and security breaches, which specifically target Microsoft systems.

- Ease of installation, configuration and maintenance. System administration and maintenance of a web-server, regardless of platform, require considerable technical expertise. The ease of administration in a particular circumstance depends greatly on the individual expertise of the administrator(s). It is generally considered, however, that the Windows platform is easier to install and maintain whereas the Unix/Linux variants are more difficult to configure and require more routine maintenance.

- Virus protection. This criterion considers how prone the particular operating system platform is to malicious attacks. To date, the majority of viruses have targeted Microsoft software, especially the Microsoft Outlook e-mail application software. For the most part, Unix systems have escaped this bombardment by hackers and therefore have been comparatively virus-free. Nevertheless, it is highly recommended to provide virus protection software on all operating systems, including Unix.

Ultimately, the Project determined that in consideration of the above criteria, the Redhat Linux operating system offered the best solution for the MBRS regional network, given the amount of in-house expertise of the Project and the nodes agencies, security considerations, and costs. Although ArcView does not run on this platform, it is not considered necessary to run this application package on the server itself but rather it will be run on a separate GIS workstation which would be Windows based. Regarding the database application, only if a Microsoft SQL Server were chosen, would the Windows platform be considered a distinct advantage. Since the PostgreSQL open source package was chosen, Windows offered no advantage in terms of compatibility.

The choice of operating system platform was necessarily made in parallel with the choice of database and GIS software platforms, since some of the application software choices were exclusive on one or the other operating system platforms. In making these choices, significant research was done on the advantages and disadvantages of each platform, and several discussions held amongst the Information Systems Specialist, the networking consultants and the database consultants. The final decision was made by the Project primarily based on robustness, security, and Unix's proven record in web-related applications. Long-term cost was also a significant deciding factor.

5.4. The Co-location Option

Given that the REIS is being designed as a web-based database, its implementation will require that the Project manage and house its own web-server or opt for a web-hosting service from an Internet Service Provider (ISP). At the start of its operation, the Project contracted a local ISP to host its website on a server that was shared with other ISP clients. This option was considered suitable for hosting a small number of pages for a website that would receive relatively low traffic. This option is not considered adequate for hosting a web-based database that is expected to have significantly increased usage. In designing the REIS and the regional network therefore, the Project has had to consider options that would provide higher performance and reliability. Various options exist for hosting web-servers, including (1) having the ISP host the website on one of its own servers, which could be shared with other ISP customers or dedicated to a single customer; (2) housing and hosting one's own website on one's own server; and (3) co-location.

Co-location is commonly defined as "the renting of data facility space for the purpose of housing server / telecommunications equipment and accessing bandwidth connections to the Internet or a private data network." In this scenario, telecommunication service providers and ISPs rent rackspace, power and a link to the Internet for their customers' servers within their network operations center, or similar facility, in order to achieve the best interconnection and highest possible bandwidth. Being designed and managed primarily for the secure and reliable housing of expensive telecommunications and computing equipment, Network Operations Centers offer an ideal environment for equipment, including air conditioning, power generator and uninterruptible power supply backup, physical security, hurricane shutters, full-time monitoring and minimal human traffic. The cost of establishing such an environment would be prohibitive for smaller organizations whose primary activity is not computing or telecommunications.

Added to these environmental advantages is the availability of high bandwidth to ensure web-server performance in high traffic situations.

Although the option exists for housing the web-server in the office of the MBRS' Project Coordinating Unit in the Coastal Resources Multi-complex Building in Belize City, this office is small, busy, highly vulnerable to hurricanes due to its coastal location, and sometimes experiences power outages. Essentially, the office is managed for human use and not equipment management thus making it less than ideal for housing the REIS web-server. Given the potential in Belize City for natural disasters from hurricanes and other tropical storms, co-location of the network at the ISPs' facility in Belmopan, an inland city which is less vulnerable to hurricanes, offered an attractive option which would guarantee improved protection from hurricanes, power problems, human interference or theft, as well as very high bandwidth. In this case, the ISP has offered a 100Mbps direct link to the Internet.

In this case, co-location offers the Project an attractively robust, reliable and affordable high bandwidth solution.

6. ADDITIONAL DESIGN CONSIDERATIONS

6.1. Shared Resources

Files and data will be shared through automated replication features of the operating system and related components. Designated areas of the server will provide storage of project files to ensure replication and security.

6.2. Scalability

The servers are equipped with significant storage capacity (although it is difficult at this time to gauge a specific requirement for storage). Additional storage capacity can be provided through replacement with larger drives or with added external storage capacity. Nodes or additional agencies may be added at any time. High capacity switches are provided for adding additional workstations. Servers can be added into the system.

6.3. Reliability

Each server has two network ports, two power supplies, as well as a RAID 1 log file system and a RAID 5 data file system for built-in fault-tolerance. A high capacity UPS will provide filtered and backup power to the server. Data will be automatically replicated to all servers for fast and timely access. Tape storage backup is also built in for data recovery in the case of catastrophic server failure. Each server has monitoring tools in place for drive space utilization, component temperatures, drive reliability and other critical components. Pro-active system maintenance alerts can be generated before failure occurs. The primary server will contain a network management package for the collection and distribution of network reliability statistics. Components are identical in all servers for ease of management, spare parts inventory, and replacement. Redundancy is accomplished by a distributed network design and/or co-location.

6.4. Maintainability

Servers are Linux based and technical expertise in managing this platform is readily available in the region. Care will be taken to ensure that all equipment and software will be purchased from internationally recognized vendors and can be supported by expertise within the region.

6.5. Modularity

Components are common at all server nodes. Configurations are similar between all units and can be used as templates for adding agency nodes. As a result, each node can work independently when communication facilities are unavailable but will re-establish connectivity when communications are restored.

6.6. Security

User security is maintained at several levels. Primary user management is maintained on the server and is replicated between all servers. Each user can be assigned specific privileges with respect to, for example, VPN access, file areas, web area, server management etc. Similar security is carried over for ensuring protection with database access. The proposed Cisco 1721 router has firewall and intrusion detection capability. The VPN keeps data updates localized to the network. The network management program will communicate with the firewalls in the router to detect intrusions.

6.7. Web Server Software

Apache, an open-source product with 66% market dominance on the World Wide Web, will be used as the web server software within a Linux operating system environment. If required, each server can share web-serving responsibilities.

6.8. Affordability and Long Term Sustainability

Three options for a network design have been outlined in Section 7 of this report. With respect to the long-term sustainability, each node will be supplied with high-quality networking components that are warranted. Open source software will be used wherever feasible (i.e. wherever quality and functionality are not sacrificed) to minimize the annual operating costs, especially annual licensing fees, for the Project and for the node agencies. Furthermore, the Project will opt for hardware and software platforms that have a sound international reputation and large installed base to ensure that expertise and support are readily available. Consideration was also given to the existing expertise and installed base at the node agencies and at the Project's own PCU when selecting application and operating system software.

6.9. Back-end and Front-end Application and Systems Software

The choice of database and GIS application software was made in parallel with the network design through consultations between the Project, the networking consultant and the database consultant to ensure compatibility between the network and the REIS. This coordination will continue through the installation and implementation of the network and the REIS to ensure the network will perform the required services.

6.10. Interoperability with SIAM and IABIN

Two regional networks are now in place: the Mesoamerican Environmental Information System (SIAM, formerly SIMEBIO) and the Inter-American Biodiversity Information Network (IABIN). SIAM is a proposed network of institutions and trained personnel who work together to share and disseminate information relevant to biodiversity conservation and the environment in Mesoamerica. The IABIN is a hemisphere-wide information system established to facilitate the exchange and dissemination of environmental information in the Americas. To ensure compatibility between REIS and IABIN, the Information Systems Specialist of the MBRS Project has met with SIAM and IABIN representatives during the network design process. Additionally, a detailed questionnaire was filled out for the IABIN project on the data and metadata the MBRS Project will be maintaining. These exchanges ensure compatibility between the REIS, SIAM, and IABIN systems. As the IABIN and SIAM databases have not been developed to the point where interoperability issues can be addressed, the MBRS has supplied information to the interested parties as well as an assurance of conformity with international standards. The MBRS will provide further information on interoperability at the appropriate time.

7. DESIGN OF THE REGIONAL DATA COMMUNICATIONS NETWORK

The regional data communications network will be a Wide Area Network (WAN), within which node servers would each be permanently connected to a central server via a Virtual Private Network (VPN) established over the Internet to facilitate data sharing, collaboration and file replication. Remote users and specially designated organizations such as CONANP, IABIN and SIAM would have access to the REIS database from the central server via the Internet, while government agencies, research institutions, NGO's and the public would connect to the Project website via the Internet.

Within the context of the design issues discussed in sections above, a total of 10 options were considered offering different operating system platforms, varying levels of distribution, some offering co-location at the ISP in Belmopan, some offering the use of existing equipment at the nodes. The project decided to opt for co-location at the ISP's facility in Belmopan and for a Linux operating system platform. Eliminating the five options, which were based on the Windows operating system platform, as well as those which did not include co-location, three options remain and these are discussed below.

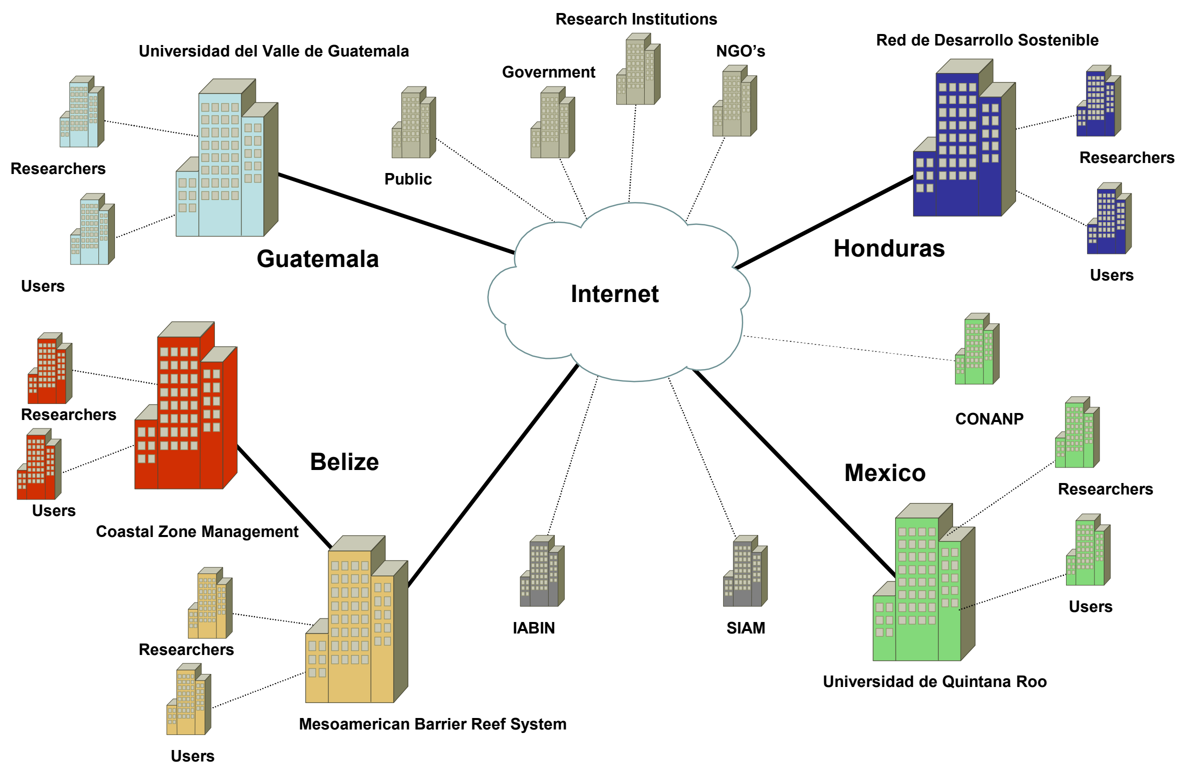

Figure 1. Conceptual design of the proposed regional data communications network

7.1. Option 1: Fully distributed network.

Option 1 provides for a fully distributed network with redundant servers located in each of the four countries. The representative nodes making up the network are the MBRS (central node), CZM (Belize), UVG (Guatemala), UQROO (Mexico), and RDS (Honduras). As each node is designed to offer high capacity and powerful processing capability in a Local Area Network (LAN) setting, local researchers and users would connect to the node server in each country. Forming a wide area network (WAN), the node servers, in turn, would be permanently connected to a central server via a Virtual Private Network (VPN) established over the Internet to facilitate data sharing, collaboration and file replication. This design is intended to provide a high degree of data redundancy in case a disaster should occur at any node. A server is also located at a co-location facility hosted in Belmopan by a local ISP as there is a higher than acceptable risk of hurricane or other disaster at MBRS headquarters in Belize City. The ISP server would become the central server in the design due to the extremely high bandwidth availability. The node servers would be located at MBRS, UVG, UQROO and RDS. As they are located in the same building, CZM would share a node server which is to be located at MBRS headquarters. Except for the ISP (where a UPS is provided with co-location fees), the network equipment (Figure 2) provided for each node would be identical. The equipment list for this option is as follows:

- 5 Cisco 1721-VPN/K9 routers with firewall and hardware VPN capability, or equivalent
- 5 Cisco WIC-1ENET second Ethernet ports for 1721, or equivalent
- 6 Cisco WS-C2950-24 24 port switches, or equivalent
- 5 Web / Database Servers
- 5 Uninterruptible Power Supplies
- 4 110 LTO tape backup units
- 1 GIS Workstation at the MBRS PCU

Connection to the Internet for the various nodes would be as follows:
- MBRS - a proposed ADSL connection.
- UVG - existing 2Mbps fiber connection
- UQROO – existing 256Kbps fiber connection
- RDS - existing 512Kbps fiber connection
- CZM - would connect to the information via the MBRS server. It is anticipated that this will be done via switch-to-switch connectivity using CAT 5 Ethernet cabling.

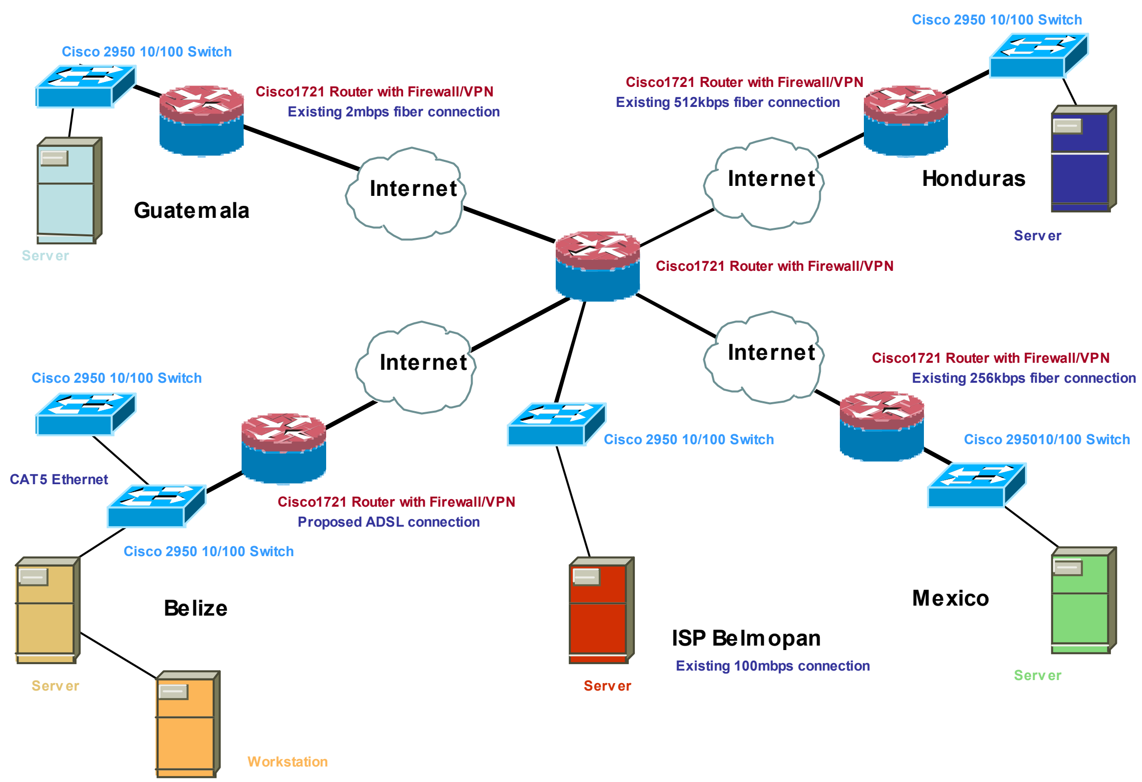

Figure 2. Network equipment and layout for Option 1.

7.1.1 Advantages

- Full redundancy and safeguards for network integrity
- Identical hardware and software placed at each node for ease of management
- Users in each country connect to the country node for quicker access.
- Estimated up-time of 99.5%

7.1.2 Disadvantages

- Computing capacity significantly exceeds the estimated usage in the first 2 years of the system lifetime
- Each server requires its own database server license, thus multiplying the database software costs by a factor of five (5)
- Does not address specific infrastructure needs expressed by the node agencies.

7.2. Option 2: Fully distributed network utilizing existing node agency infrastructure

Option 2 provides for a fully distributed network with redundant servers located in each of the four countries. This option, however, proposes to utilize infrastructure components, which currently exist at each node. Servers, routers and switches presently installed at UVG and UQROO would be configured for use within the network; routers and switches would be utilized at RDS. The existing fiber optic link at UQROO would be increased from 256K to 384K in response to their expressed need. New servers would be implemented at RDS and MBRS. As in Option 1, a server is also located at a co-location facility hosted by the ISP in Belmopan as there is a higher than acceptable risk of hurricane or other disaster at MBRS headquarters in Belize. The ISP server would become the central server in the design due to the extremely high bandwidth availability. Additionally, the MBRS would be provided with a GIS workstation. CZM would connect to the Internet via the MBRS router and would share their information server. It is anticipated that this will be done via switch-to-switch connectivity using CAT 5 Ethernet cabling.

The network equipment (Figure 3) provided for the RDS, MBRS and ISP nodes would be identical. The equipment list for this option is as follows:

- 2 Cisco 1721-VPN/K9 routers with firewall/hardware VPN capability, or equivalent
- 2 Cisco WIC-1ENET second Ethernet ports for 1721, or equivalent
- 3 Cisco WS-C2950-24 24 port switches, or equivalent
- 3 Web / Database Servers
- 3 Uninterruptible Power Supplies
- 2 110 LTO tape backup
- 1 GIS Workstation
- Additional 128Kbps fiber optic connection for UQROO (to increase an existing 256K to 384K)

Connection to the Internet for the various nodes would be as follows:

- MBRS - a proposed ADSL connection.
- UVG existing 2Mbps fiber connection
- UQROO – existing 256Kbps fiber connection plus additional 128K connectivity (384Kbps)
- RDS - existing 512Kbps fiber connection

7.2.1 Advantages

- Less costly as it takes advantage of existing installed capacity in each of the 4 nodes
- Addresses specific computing needs as stated by the node agencies
- Full redundancy and safeguards for network integrity
- Users in each country connect to the country node for quicker access.
- Estimated up-time of 99.5%

7.2.2 Disadvantages

- More difficult to install, maintain and manage due to heterogeneous servers and networking components
- Capacity exceeds the estimated usage in the first two (2) years of the system lifetime
- Each server requires its own database server license thus multiplying the database software costs by a factor of five (5)
- The Project can only afford to support the additional connectivity at UQROO for one (1) year
- Loss of control over those servers and network components not purchased by the Project

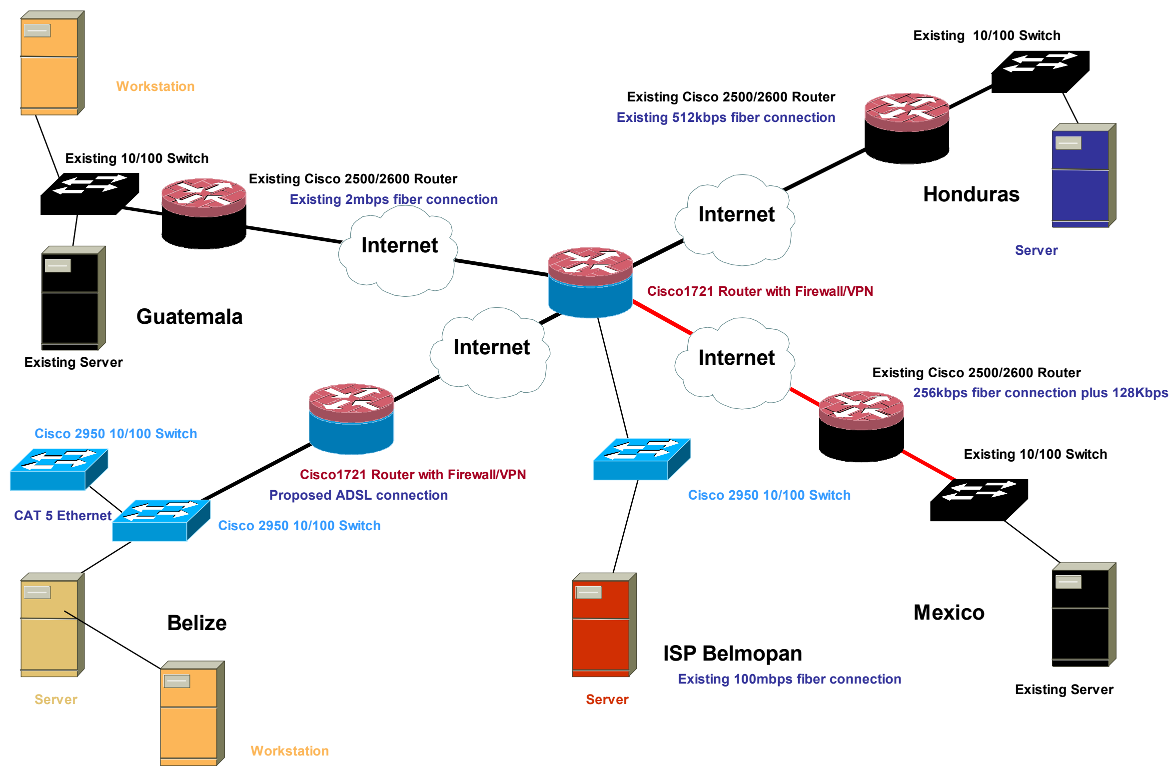

Figure 3. Network equipment and layout for Option 2

7.3. Option 3. Partially distributed network

Option 3 provides for a partially distributed network with two redundant servers located in Belize. New servers would be installed at the MBRS and the ISP. As in Option 1, a server would be located at a co-location facility hosted by the ISP in Belmopan as there is a higher than acceptable risk of hurricane or other disaster at MBRS headquarters in Belize. The ISP server would become the central server in the design due to the extremely high bandwidth availability. A redundant node server would be located at MBRS PCU office in Belize City. The existing fiber optic link at UQROO would be increased from 256K to 384K in response to their expressed need. Additionally, the MBRS, UVG and RDS would be provided with GIS workstations. CZM would connect to the Internet via the MBRS router and would share the MBRS server. It is anticipated that this will be done via switch-to-switch connectivity using CAT 5 Ethernet cabling. The network equipment (Figure 4) provided for the MBRS and the ISP would be identical. The equipment list for this option is as follows:

- 2 Cisco 1721-VPN/K9 routers with firewall/hardware VPN capability, or equivalent
- 2 Cisco WIC-1ENET second Ethernet ports for 1721, or equivalent
- 3 Cisco WS-C2950-24 24 port switches, or equivalent
- 2 Web / Database Servers
- 4 Uninterruptible Power Supplies
- 1 110 LTO tape backup unit
- 3 GIS Workstations
- Additional 128Kbps fiber optic connection for UQROO (to increase an existing 256K to 384K)

Connection to the Internet for the various nodes would be as follows:
- MBRS - a proposed ADSL connection.
- UVG - existing 2Mbps fiber connection
- UQROO – existing 256Kbps fiber connection plus additional 128K connectivity(384Kbps)
- RDS - existing 512Kbps fiber connection

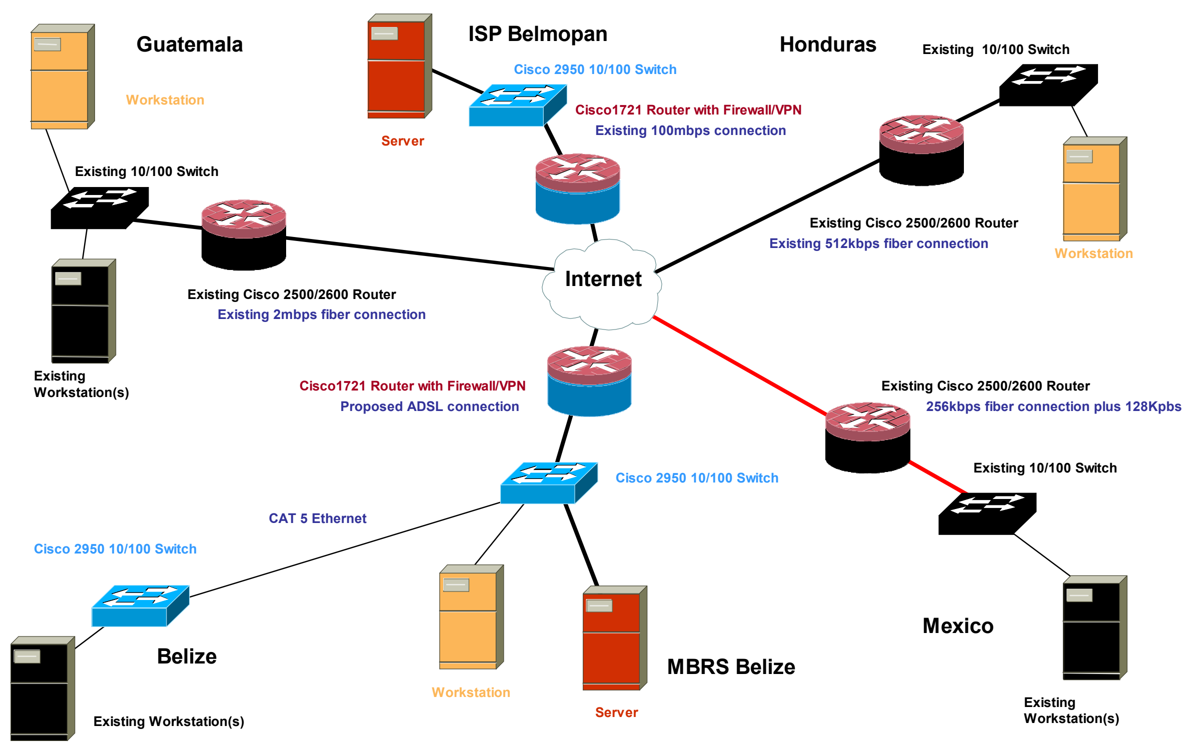

Figure 4. Network equipment: and layout for Option 3.

7.3.1 Advantages

- In-country redundancy
- Easy to implement, configure and maintain
- Level of investment is congruous with estimated 2 year requirements
- Redundant site provides safeguards for network integrity
- Identical hardware and software placed at two locations for ease of management
- Addresses specific computing needs as stated by the node agencies
- Guaranteed up-time of 99.5%
- Allows for measured growth in the future based on usage statistics collected during the first 2 years of operations

7.3.2 Disadvantages

- Less redundancy and distribution than other options
- The Project can only afford to support the additional connectivity at UQROO for one (1) year
- Potentially slower access to database by users if traffic should become high since all regional and international access is to the central node in Belize
- Each server requires its own database server license, thus multiplying the database software costs by 2.

7.4. Option Chosen: Initial Configuration and Upgrade Path

The Project opted for Option 3 as the initial configuration because it offered the most appropriate fit for the current usage requirements; moreover, it offers an acceptable level of distribution and redundancy as well as very high bandwidth connectivity at the central server. Once the network is operational, system usage, traffic, and performance statistics will be collected. Based on the performance, additional components can be added to the system over the Project lifetime. Should system usage and user needs require it, the network can grow in a modular and distributed manner by adding servers, at the node agencies. This upgrade path could follow either the configuration proposed in Option 2 or Option 3 above, depending on the statistical evaluations of system performance and observed needs. This choice allows for moderate initial investment with the possibility of measured needs-based growth.

7.5. Protocols

The proposed network is based upon the universal network transport standard called TCP/IP. The public Internet is based upon this standard. In the OSI seven layer model of network communications, IP is layer 3 and TCP is layer 4. TCP/IP is a connection-oriented protocol for ensuring the timely, reliable and guaranteed delivery of byte streams.

The network design is based upon providing maximum network security while extending privileged access to project information. The server is meant to be connected to a public communications medium such as the Internet through a dedicated firewall. The firewall also provides intrusion detection capabilities (IDS). Each node is designed to be a self-sufficient and highly protected data repository based upon a concept of layered security. The nodes replicate and share information. To ensure data security and privacy, the firewalls provide a private, encrypted, full meshed Virtual Private Network (VPN). This allows data between servers to be replicated without fear of data interception, manipulation, or discovery outside of the nodes.

The firewall also allows client based VPN's to be connected. This means that authorized personnel can connect to the nodes through the public Internet, but yet maintain security and privacy of data manipulation.

The network switch and router work in conjunction with each other. For example, specific ports on the switch can be dedicated to the server and related accessories. Other ports on the switch can be used for workstations and connectivity to other LAN's and workstations on the hosting node's network. The router is used to segregate the two sections of the switch to ensure privacy and controlled access to all information elements.

7.5.1. Intrusion Detection

The Cisco IOS Firewall IDS feature identifies 59 of the most common attacks using "signatures" to detect patterns of misuse in network traffic. The intrusion-detection signatures included in the Cisco IOS Firewall were chosen from a broad cross-section of intrusion-detection signatures. The signatures represent severe breaches of security and the most common network attacks and information gathering scans.

The Cisco IOS Firewall IDS acts as an in-line intrusion detection sensor, watching packets and sessions as they flow through the router, scanning each to match any of the IDS signatures. When it detects suspicious activity, it responds before network security can be compromised and logs the event through Cisco IOS syslog. The network administrator can configure the IDS system to choose the appropriate response to various threats. When packets in a session match a signature, the IDS system can be configured to take these actions:

- Send an alarm to a syslog server or a Cisco Secure IDS Director (centralized management interface)
- Drop the packet
- Reset the TCP connection

7.5.2. Firewall i.e. Context Based Access Control (CBAC)

CBAC intelligently filters TCP and UDP packets based on session information. Without CBAC, traffic filtering is limited to access list implementations that examine packets at the network layer, or at most, the transport layer. However, CBAC examines not only network layer and transport layer information but also examines the application-layer protocol information (such as FTP connection information) to learn about the state of the session. This allows support of protocols that involve multiple channels created as a result of negotiations in the control channel.

CBAC inspects traffic that travels through the firewall to discover and manage state information for TCP and UDP sessions. This state information is used to create temporary openings in the firewall's access lists to allow return traffic and additional data connections for permissible sessions.

Inspecting packets at the application layer, and maintaining TCP and UDP session information, provides CBAC with the ability to detect and prevent certain types of network attacks such as SYN-flooding. A SYN-flood attack occurs when a network attacker floods a server with a barrage of requests for connection and does not complete the connection. The resulting volume of half-open connections can overwhelm the server, causing it to deny service to valid requests. Network attacks that deny access to a network device are called denial-of-service (DoS) attacks.

7.5.3. Alerts and Audit Trails

CBAC also generates real-time alerts and audit trails. Enhanced audit trail features use SYSLOG to track all network transactions; recording time stamps, source host, destination host, ports used, and the total number of transmitted bytes, for advanced, session-based reporting. Real-time alerts send SYSLOG error messages to central management consoles upon detecting suspicious activity. Using CBAC inspection rules, you can configure alerts and audit trail information on a per-application protocol basis. For example, if audit trail information for HTTP traffic is required, it can be specified in the CBAC rule covering HTTP inspection.

8. WAY FORWARD

Having designed the network, the Project proceeded to procure the equipment and services required for its installation. The procurement of equipment should be completed in April 2003. Procurement of telecommunications services should be completed during May 2003. After this, the installation of the hardware can proceed, shortly followed by the implementation of the REIS. At the time that the network is installed, a Maintenance Plan and a Security Plan will be drafted and whatever training in network or server management that is needed will be provided to the system administrators assigned to those tasks.

In addition to system implementation, the administrative and operational framework for the operation of the network and of the REIS must be set in place. This will involve, *inter alia*, the agreement of Memoranda of Understanding and Data Sharing Agreements with node agencies, data collection and data entry agencies, and other partners who may be involved in the operation of the network.

The completion of the installation tasks should coincide closely with the implementation of the Synoptic Monitoring Program. At the time of implementation, system monitoring software will start to collect system usage and performance statistics. This type of information collected over the course of the network's lifetime, will serve to guide future expansion of the network and to address performance bottlenecks as they arise.

Ultimately, the success of the network will depend on its usefulness to users, its efficiency in providing information related to the reef and related ecosystems, and the cooperation of all node agencies, support agencies and partners involved in creating, analyzing and managing the information housed on the network.

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APPENDIX A:

TERMS OF REFERENCE
FOR THE
DESIGN AND IMPLEMENTATION
OF THE
REGIONAL DATA COMMUNICATIONS NETWORK

Conservation and Sustainable Use of Mesoamerican Barrier Reef System Project (MBRS)

Vacancy: **Design and Installation of a Regional Data Communications Network**

Location of Consultancy: **Belize**
Funding Organism: **GEF/World Bank**
Executing Agency: **SICA/CCAD-PCU**

Length of Consultancy:

Background

The Mesoamerican Barrier Reef System (MBRS), extending from Isla Contoy on the north of the Yucatan Peninsula to the Bay Islands of Honduras, includes the second longest barrier reef in the world. It is unique in the Western Hemisphere due to its length, composition of reef types, and diverse assemblage of corals and related species. The MBRS contributes to the stabilization and protection of coastal landscapes, maintenance of coastal water quality, and serves as breeding and feeding grounds for marine mammals, reptiles, fish and invertebrates, many of which are of commercial importance. The MBRS is also of immense socio-economic significance providing employment and a source of income to an estimated one million people living in adjacent coastal areas.

The goal of the Mesoamerican Barrier Reef System Project is to enhance protection of the unique and vulnerable marine ecosystems comprising the MBRS, and to assist the countries of Mexico, Belize, Guatemala and Honduras to strengthen and coordinate national policies, regulations, and institutional arrangements for the conservation and sustainable use of this global public resource. The Project is part of a long-term Program to safeguard the integrity and continued productivity of the MBRS. The MBRS initiative is being actively promoted by a variety of donors and partners in the region and within the context of the Mesoamerican Biological Corridor Program.

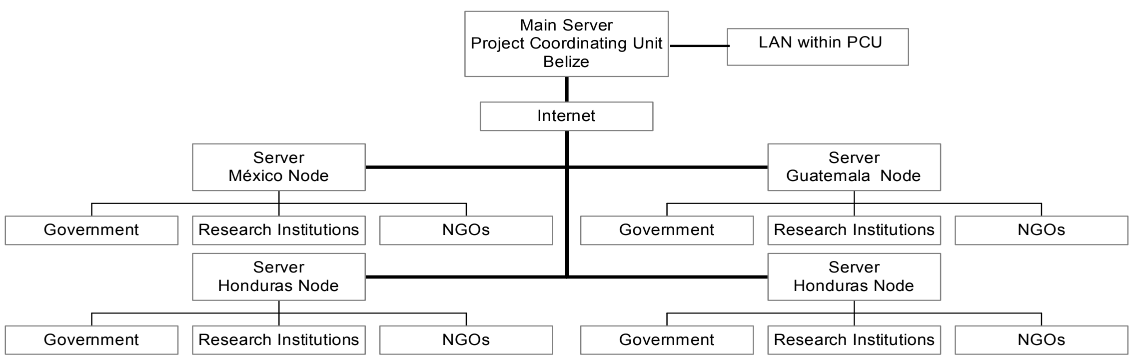
The objectives of the MBRS Program, agreed to by the four participating countries, are to: (a) strengthen Marine Protected Areas (MPAs); (b) develop and implement a Regional Environmental Monitoring and Information System that will provide a synoptic view of the health of the MBRS and facilitate dissemination of these findings throughout the region; (c) promote measures which will serve to reduce non-sustainable patterns of economic exploitation of the MBRS, focusing initially on the fisheries and tourism sectors; (d) increase local and national capacity for environmental management through education, information sharing and training; and (e) facilitate the strengthening and coordinating of national policies, regulations, and institutional arrangements for marine ecosystem conservation and sustainable use.

The second objective, Regional Environmental Monitoring and Information System, is in turn subdivided into two sub-components: i) the Creation and Implementation of a Distributed Regional Environmental Information System (REIS) and ii) the Establishment of a Synoptic Monitoring Program (SMP). This Consultancy falls within the REIS sub-component. Specifically, this component will support the design and implementation of a bilingual information center whose architecture will allow broad access to policy decision makers, technicians and the general public and which should become an essential tool for organizing and managing data to support improved decision making. While the establishment of this information system will be a major product of the initial 5-year phase of the Project, it nevertheless should be visualized as a "living" system that will grow in complexity and value as new data are developed and made accessible.

Scope of Consultancy
The Consultant or Consultancy team will design and implement a data communications network with nodes in Belize, Guatemala, Honduras, and Mexico. The network will comprise a central node located in the office of the Project Coordinating Unit (PCU) and at least one node in each of the four participating countries. The nodes in each country would be servers with one or more workstations from within the node agency or from other agencies in the country. The Project will be purchasing new equipment for at least one node agency in each country; however, the Project may also choose to connect other agencies that already have the necessary equipment. The network design must therefore be flexible enough to allow the connection of a variety of workstations.

The facilities at the node agencies and at the workstations should allow Project users to input data and retrieve information in the form of reports, maps, etc. to information systems, between and among the nodes. It is important to note that, subsequent to installation of the new equipment, the agencies connected to the regional network will be responsible for all maintenance costs. The Project will therefore choose agencies that have the necessary resources to undertake this responsibility. Nevertheless, the Consultant must give careful consideration to the long-term costs when designing the system to ensure that it is within the capacity of these agencies.

The intended layout of the network is portrayed in the diagram below.



The Consultant is expected to establish the technical specifications for the connectivity (bandwidth), hardware and software required for the servers, workstations and all networking components for the Regional Data Communications Network. The Project will procure the hardware, software and services specified and the Consultant will subsequently install the network. Moreover, the Consultant must develop and install the hardware and/or software for the enforcement of a Security Policy that will protect the network and its constituent servers from illegal intrusions and hackers, which may originate from the Internet. The network security must allow for various levels of user access such that some information on the network would be restricted and others would be public. The Consultancy will end upon successful installation of the network including the four country nodes.

The network being designed under this Consultancy should be interoperable with the Sistema de Información Mesomericano para la Biodiversidad (SIMEBIO) and the Inter-American Biodiversity Information Network (IABIN) both of which are presently under development. IABIN and SIMEBIO are networks being implemented to facilitate the interchange and dissemination of biodiversity information, where the scope of SIMEBIO is Mesoamerica (Central

America and Mexico) and the scope of IABIN includes all the Americas. SIMEBIO is a subsystem of IABIN.

Objectives of the Consultancy
The Project will be generating and managing important information pertaining to scientific, conservation management, social, legal and policy-related areas. Its aim is to make this information accessible to the region and to the world via the World Wide Web with the ambition that improved knowledge of the Mesoamerican Barrier Reef and related ecosystems will lead to improved regional policies relating to the management of this resource and to stronger political commitment to its conservation at all levels of society.

The objective of the Consultancy, therefore, is to design a regional network that will serve the Project's needs for data management, information dissemination, and public education. A key information system that will be developed and managed by the Project is the Regional Environmental Information System (REIS). The REIS is envisioned as a database with GIS functionality that will manage the environmental monitoring and other information collected through Project activities. It will be a distributed database with nodes in each of the four participating countries. Users at the network nodes in each country will access the REIS through the Project website. This website will also provide users, and the general public, access to a variety of information systems and information products. A brief outlay of the types of information to be housed on the Project website and in the REIS are included in Annex 1.

The network should provide reliable and robust connectivity with built-in redundancy and security that will guarantee 99% uptime. It should facilitate remote administration of all nodes from the central node.

Specific Tasks
The Consultancy will comprise two phases: the Design Phase (Tasks 1, 2 and 3) and the Installation Phase (Tasks 4 to 9). The principal tasks of the Consultancy are the following:

Design Phase

Task 1. Prepare a Consultancy Action Plan in coordination with the Project's Information Systems Specialist (ISS) and submit to the ISS for approval. The Action Plan must include a time schedule showing start and end dates, working days and calendar days, resources required for each phase, a critical path analysis, potential limitations, and products resulting from each action. Moreover, responsibilities of each actor should be clearly defined.

Task 2. Network Design
Based on the projected information management needs, design a data communications network on which the Project website and the REIS will reside.

At minimum, this task should comprise the following tasks:

a. Conduct interviews with the Technical Team, the National Barrier Reef Committees, the Technical Working Groups and other key actors to determine the Project's information management needs and networking needs.

b. Research the data communications and telecommunications infrastructure in Belize, Guatemala, Honduras and Mexico to identify what technologies and connectivity are available. This research may be done by written or electronic correspondence.

c. Review the Node Agency Description Reports provided by the ISS in order to comprehend the infrastructure available in each of the identified node agencies.

d. Prepare a Network Design Specification, which clearly specifies the connectivity (bandwidth), hardware, software and protocols to be used and which individually addresses the following issues:

- Shared resources – how will the network enable the sharing of resources and data, what resources will be shared
- Scalability and suggested growth paths for the system in terms of additional workstations, nodes, processing and storage capacity, as well as additional components
- Network reliability and built-in redundancy
- Maintainability – since systems will be maintained by each node agency, much of the maintenance requirement should be within the scope of the abilities of the agency's personnel and the host countries' expertise.
- Modularity and independence of function for each node
- Security and user access – different levels of security for different types of info.
- Web hosting options
- Affordability and long-term sustainability in regards to infrastructure needs, operational costs, software licenses, etc. The technologies chosen should be appropriate to the available budget and in-country capacity of each node. (The Project will provide only the capital costs of system installation and initial implementation. All maintenance costs and annual fees will be borne by the node agencies in each country.)
- All backend (server-side) and front-end (client-side) application and system software required for the network to perform the required services to the Project website and its constituent databases, libraries and web pages. This will need to be done in consultation with the Consultant hired to design and implement the REIS.
- Interoperability with SIMEBIO and IABIN.

If it is appropriate, the Consultant should prepare a comparison of various network configuration options, with a full analysis of the advantages and disadvantages of each.

e. Prepare a network diagram to accompany the Network Design Specification, showing all network components including hosts/workstations, peripherals, routers/hubs, web-server(s), other servers, and physical transmission media.

f. Design a Security Policy that will protect the network and its constituent servers from illegal intrusions and hackers which may originate from the Internet.

Task 3. Prepare a comprehensive set of technical specifications of all connectivity (bandwidth), hardware, software and services required to implement the regional network. Hardware requirements should include all the computer hardware for nodes, peripherals for input and output, networking components, and electrical requirements. Software requirements should include networking, operating systems, web server software, application backend and server-side software, etc. Operating system and other software requirements must be determined in consideration of the requirements of the REIS to ensure compatibility.

Although the Consultant is being asked to prepare the Statement of Requirements, the Project itself will conduct the procurement process and will assume full responsibility for the actual procurement. Installation will begin as soon as the procurement is complete. The Statement of Requirements must be explicit and specific, to ensure the successful and efficient procurement of the appropriate goods and services.

Installation, Testing and Training Phase

Task 4. Prepare a Consultancy Action Plan in coordination with the ISS and submit to the ISS for approval. The Action Plan must include a time schedule showing start and end dates, working days and calendar days, resources required for each phase, a critical path analysis, potential limitations, and products resulting from each action. Moreover, responsibilities of each actor should be clearly defined.

Task 5. Perform site inspections of all locations where nodes will reside to ensure that they meet the manufacturers' specifications for the equipment to be installed.

Task 6. Install and configure the network to make it immediately ready to house the Project website and REIS. The networks servers should be configured to support a web-based distributed database and to provide system redundancy, synchronization between mirrored components, user-friendly content management of web pages, etc. The Consultant will be responsible for all hardware and software installations, liaising with in-country technical teams, if necessary.

Task 7. Develop and install the hardware and/or software for the enforcement of a Security Policy to protect the system from illegal intrusions.

Task 8. Conduct User and System Administration Training as required for system use and maintenance for the node agencies and for the ISS. This should entail, at least, the following tasks:

a. Prepare well-structured hands-on training courses in English and Spanish with training manuals for later reference.
b. Deliver on-site training courses for all node agencies and for the PCU in both Spanish and English as appropriate to the audience.

Task 9. Provide full documentation of installed systems and required maintenance procedures. This should include, at least, a description of the configuration of all hardware and software, maintenance schedules, a network diagram, scalability options, etc. with sufficient detail to ensure that the installation exercise can be replicated if necessary in the future. The system maintenance plans should include a discussion of the following issues: access, security and permissions, arrangements and schedules for corrective and preventive maintenance, division of responsibilities between nodes and PCU, recommendations regarding maintenance contracts, scalability and growth path of the system, expertise and skills required, disaster recovery plans, synchronization schedules for mirrored functions, etc.

Reporting and Coordination of Tasks

The Consultant will report directly to the Information Systems Specialist. In the case that the Consultancy is awarded to a team of consultants, then this team should designate a single person in charge of coordinating the entire team and of liaising with the ISS.

1. At the start of each phase of the Consultancy, the Consultant will prepare a Consultancy Action Plan in coordination with the ISS. This plan is to be approved by the ISS before work begins.
2. The Consultant will submit progress reports at those times designated by the Consultancy Action Plan.
3. At the completion of each phase of the Consultancy, the Consultant will submit a Consultancy Report describing the status, achievements, limitations and forward recommendations proceeding from the Consultancy Phase.
4. The Consultant will remain in close coordination with the ISS and with the Project to ensure that the execution of the Consultancy is on time and within budget, and that it is in keeping with the Project's requirements.
5. During the course of the Consultancy, the Consultant must contact the ISS, at least once per week, to discuss the progress of the work.
6. During the course of this Consultancy, wherever it is deemed necessary for coordinating system installation or for obtaining networking requirements, the Consultant will liaise with the ISS and with the Technical Team to establish information processing requirements.
7. The Project will be hosting a series of Expert Meetings for various Project components. Where it is feasible, the Consultant may be asked to attend these meetings and to interact with the participants to clarify the information needs of the Project.
8. There will also be an Expert Meeting specifically dealing with the Project's information systems. The draft products of the Consultancy will be reviewed here. It is intended that this Information Technology Expert Meeting will be held within the time frame of this Consultancy, in which case, the Consultant would be expected to participate fully in order to clarify the details of these products.
9. If the Expert Meeting is held within the timeframe of this Consultancy, the Consultant would be required to modify or expand upon the draft products to reflect the inputs from the Expert Meeting.

Methodology

As part of the Application for this Consultancy, the Applicant will be required to submit a detailed Proposal elaborating how they will meet the objectives stated in this Terms of Reference and how they will conduct the tasks comprising the Consultancy. This proposal must be as specific as possible regarding methodologies, technologies, time and human resources to be employed in the execution of the Consultancy.

The Consultant will work under the direct supervision of and in close coordination with the Information Systems Specialist. The first step in each component of the Consultancy will be for the Consultant to draft a Consultancy Action Plan for approval by the ISS. The preliminary steps in the Consultancy involve an analysis of requirements as well as of existing systems. The detailed requirements of the second phase cannot be known until the completion of these analyses. It will be necessary therefore to await the completion of a prior phase of the Consultancy before elaborating the Consultancy Action Plan for the following phase. The Consultant must therefore plan for flexibility when estimating the work entailed for the subsequent phases. Wherever it is feasible, the Consultant may, in the interest of time, choose to embark on a subsequent phase before completion of the previous phase(s), provided that running them in parallel does not jeopardize the completeness or quality of any of the products. Any elaborations made during the course of the Consultancy, however, must not affect its duration or completion date.

The Consultant is expected to employ standard methodologies that are well established in the IT industry when conducting the analyses, design, and implementation of systems. Moreover, hardware and software recommended must be from reputable and recognized manufacturers. All products are subject to the approval of the ISS before final submission to the Project.

It is essential that the Consultancy result in systems that are functional and serve the Project's information management needs within the next six months. With this in mind, wherever possible, Consultancy actions should be run concurrently and a critical path analysis should be done at the outset to minimize any halt in Consultancy activity.

The Project will be conducting other Consultancies, which have information to offer in terms of system requirements. The Consultancy entitled Design and Implementation of the Regional Environmental Information System is closely interlinked with the Design and Installation of the Regional Data Communications Network. The Consultant is expected to liaise with the Project and with other contracted Consultants, particularly the Consultant hired for the Design and Implementation of the Regional Environmental Information System, to ensure that the design of the network can support the Project's information management needs.

The Consultant will be expected to liaise with those involved with the design of SIMEBIO and IABIN to ensure interoperability with those networks. The Project will supply the necessary contact information.

Deliverables

The deliverables required from the Consultant are listed below per task.

Tasks 1 and 4. Consultancy Action Plans for each phase of the Consultancy.

Task 2. Network Design

a. Physical layout of network in diagrams, specifying what types of equipment, what connectivity and what network protocols are to be used at all layers of the network.
b. Technical description of network design and discussion of protocols to be used at all network layers.
c. System maintenance plan
d. Security Policy, documented and installed.
e. Specification of how linkages to SIMEBIO and IABIN will be achieved.

Task 3. Hardware and Software Procurement

a. Full specification of all computer, networking and power hardware required for the Project website and REIS, in the format of a Statement of Requirements.
b. Full specification of all operating system, networking, web-related software packages required for the regional network and for facilitating the functions of the Project website and REIS, in the format of a Statement of Requirements.
c. Full specification of connectivity (bandwidth) requirements.

Task 5. Site Certifications for all approved sites.

Task 6. Full documentation of system installation and configuration.

Task 7. User and System Administration Training. All the following must be provided in both English and Spanish.

a. Training manuals
b. Training presentations
c. User Manual
d. System Administration Manual
e. Any other materials used in the training

Task 8. A firewall and intrusion detection system.

Task 9. In addition to the documents mentioned above for Tasks 1 to 7, the Consultant must leave all copies of technical manuals for software and hardware with the Project.

Qualifications
The Consultant/Consultancy Firm should be in possession of the following qualifications:

i. Bachelor's Degree or higher in Computer Science, Information Systems, or other relevant qualifications;
ii. At least five years experience in designing web-based distributed networks;
iii. At least ten years experience in the design and implementation of wide-area networks;
iv. Must be fully bilingual in English and Spanish (fluency in reading, writing and speaking).

In addition, specific expertise working in the region (Mexico, Central America and/or the Caribbean) and working on multi-agency networks are significant advantages.

Length of Consultancy
The Consultancy should be completed within 65 person days. It is expected to start in March 2002 and must be completed by the end of July 2002.

Location of Consultancy
The location of the Consultancy is in Belize; however, the Consultant must be prepared to travel to all the MBRS countries (Belize, Mexico, Guatemala & Honduras) and to other areas of interest to the Project. The Consultant is expected to provide its own office facilities in Belize.

Submission of Application
Submit Application with Proposal, C.V., the names and contact details of 3 referees, and other required documents not later than March 12, 2002 to:

Ms. Marydelene Vasquez
Information Systems Specialist
Mesoamerican Barrier Reef System Project
PO Box 93
Coastal Resources Multicomplex Building
Princess Margaret Drive,
Belize City, Belize
Tel: 501-2-33895 or 00 (501) 2-34561/Fax: 501-2-34513
E-mail: queenconch@mbrs.org.bz or mbrs@btl.net

Annex 1. Brief Description of the Project Website and the Regional Environmental Information System

The Project website is one of the Project's primary tools for information dissemination and information management. It is envisioned as an information clearinghouse with a broad scope that will comprise, *inter alia*, the following types of information in its various sub-components:

- Regional Environmental Information System (REIS)
- General information about the MBRS Project
- A bibliography of publications related to the MBRS
- Technical reports
- A directory of the principal actors (people, projects and organizations) in the management and conservation of the MBRS
- Links to Web sites of related projects and agencies
- Marine and Coastal protected areas in the MBRS Project area
- National, regional and international legislation
- National, regional and international environmental policies and policy instruments
- A searchable database of metadata describing the information (spatial and non-spatial) available for the region
- Environmentally-friendly tour operations

The REIS would be a database that manages the information proceeding from the Project itself. Examples of information that would populate the REIS include, *inter alia,* attribute and geographic data relating to the following areas of Project activity:

- Synoptic Monitoring Program
- Marine and Coastal protected areas in the MBRS region
- Sustainable Use – Tourism and Fisheries research
- Socio-economic monitoring
- National, regional, and international legislation
- Regional environmental policies and policy instruments

It is expected that a GIS would be directly linked to the REIS, and would function as a fully incorporated module within the REIS.

The Project website will be accessible to the general public. The REIS be accessible through the Project website but to authorized users only. Information stored within the REIS may from time to time be made available to the public through the Project website in the form of prepared reports, maps, or graphics. Examples of such information products potentially include brief descriptions of marine protected areas, legislation and policies relating to management and use of the MBRS, and prepared reports and maps showing results of monitoring activities and Project activity sites. The Project website would therefore be a dissemination medium for information products generated by the REIS.