*Conference Topic: Integrated Water Resources and Coastal Areas Management*

# National Water Information Systems: A Tool to Support Integrated Water Resources Management in the Caribbean

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National Water Information Systems (NWISs) are powerful tools to contribute to the strengthening of Integrated Water Resources Management (IWRM) in the Caribbean and to address the problems of compartmentalized data, lack of central storage, and limited access to data for decision-making in water management. This paper reviews the development process of the NWIS in two Caribbean countries, Jamaica and Grenada; outlines their main outcomes to date along with the challenges encountered and lessons learnt; and provides an overview of their potential for the wider Caribbean region. NWISs serve as the official repository for hydrologic, climate, land, watershed, infrastructure and water-related data. They are extremely powerful quantitative and qualitative tools which allow not only the archiving of data, but also display information in a very comprehensive and visual manner to give a snapshot of the water resources at any time and geographical scale. The Grenada NWIS has significantly expanded on the capabilities of the earlier Jamaican version through (i) the introduction of a user-friendly system administration interface that readily facilitates the inclusion of new parameters into the database and (ii) links to Google Earth imagery. Since their implementation, the systems have brought together data previously scattered across different agencies, providing timely information to decision-makers and planners freely and remotely through internet access. On a regional scale, the Grenada NWIS offers a starting point for the modernization and standardization of data management led by the Caribbean Institute for Meteorology and Hydrology (CIMH). As part of its role in maintaining a central archive of meteorological and hydrological data for its member countries, CIMH is building on the Grenada NWIS to establish a new standard for the region in data management, an important step in the modernization of water information management in the wider Caribbean region.

**Keywords:** National Water Information System, monitoring, hydrological data management, data availability, drought

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## Introduction

Water resources management in the Caribbean region is facing a number of challenges, notably increased water demand resulting from rapid growth in urbanisation and tourism; increased competition for land and water resources; increased climate variability and frequency of natural disasters; and reduced water quality due to pollution from industrial, agricultural and municipal wastes. The cross-disciplinary and multiple-use character of water resources calls for an integrated approach across multiple scales and sectors to tackle these issues, and has prompted the adoption of Integrated Water Resources Management (IWRM) as a leading paradigm globally. The Global Water Partnership (GWP) defines IWRM as "a process that promotes the coordinated management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP, 2000).

Access to data for decision-making is one main enabling factor, but also a key challenge, of IWRM. Beyond data collection itself, data dissemination and the sharing of existing information between data collectors and decision-makers remain difficult to coordinate. Water management in most Caribbean countries has traditionally been characterised by a sectoral approach to data collection, analysis, storage, and dissemination; the shared responsibilities and multiplicity of agencies involved in the water sector are main obstacles to achieving centralized and standardized data management. IWRM relies on the collaboration of multiple stakeholders with different needs and priorities, and at various scales of management, from the national level down to the watershed or community. One important building block of IWRM is therefore the creation of a system that facilitates the exchange of information among the stakeholders, and the access to this information for decision-makers.

In response to these concerns, various Caribbean countries have turned to the creation of a National Water Information System (NWIS) as a valuable tool to address these challenges. Water Information Systems bring together data previously scattered across different agencies into one database, and can provide timely, centralized information to decision-makers and planners. They can be powerful tools to not only archive water-related data, but also to provide timely and user-friendly access to comprehensive water resources information.

This paper reviews the development process of the NWIS in two Caribbean countries, Jamaica and Grenada, outlining their main features and outcomes to date, along with the challenges encountered and lessons learnt. The paper concludes with a discussion on the future potential of Water Information Systems throughout the wider Caribbean region.

## Case Studies from the Caribbean

### *1) The Jamaica System*

*Background and Development Process*

The recent modernisation of National Water Information Systems, and consequent advancements in information management tools to support decision-making in the Caribbean region, were greatly stimulated by the Food and Agriculture Organisation (FAO) of the UN. In 2005, the

FAO, in collaboration with a consultant, developed a NWIS for the Water Resources Unit in St. Lucia. Following this in 2006, the then Director of Resource Monitoring of the Water Resources Authority of Jamaica (WRA) provided services under a FAO technical cooperation project in St. Lucia. During this visit he was exposed to the web-enabled database that was developed for the Government of St. Lucia. The NWIS functions were demonstrated through a web-conference and log-me-in remote access session between the consultant who developed the system and the WRA. In January 2007, the WRA officially invited the consultant to develop the system for Jamaica. The NWIS was developed between February 25 and March 22, 2007. On a preliminary visit the consultant assessed the infrastructure and obtained shape files and sample data. During the NWIS development period a national workshop was held to expose other stakeholders (particularly government agencies) to the proposed system and to solicit their input for its development and management. The NWIS, known as the Water Resources Authority Management Information System (WRAMIS) in Jamaica, was launched in 2007 and made available to the public.

*Institutional Setting*

The WRA is the premiere organization for water resources management in the country. It is part of an inter-agency system of permits, checks and counterbalances to ensure proper utilization of the resource, equitable distribution, efficient delivery, environmental stewardship and fair customer practices. The other agencies include the National Irrigation Commission, the Irrigation Unit of the Rural Agricultural Development Authority, the National Water Commission, the Office of Utilities and Regulation and the National Environment and Planning Agency.

The WRA is responsible for the management, protection and controlled allocation and use of Jamaica's water resources. Its mission is "to ensure the sustainability of Jamaica's water resources through continual assessment and proper management, promotion of conservation and protection, and optimal development of these resources; to ensure rational and equitable allocation of the nation's water resources; and to reduce conflicts among water users" (Water Resources Act, 1996). The major activities of the WRA include hydrologic data collection, compilation and analysis; water resources investigation, assessment and planning; water resources allocation; and environmental monitoring and impact assessment. The WRAMIS was established to fulfill the mandate under Section 4.3a of the Water Resources Act, to "obtain, compile, store and disseminate data concerning the water resources of Jamaica" (Fletcher-Paul *et al*., 2007).

*Primary Data Collection*

The WRA of Jamaica routinely monitors river flows at 127 gauging stations, and groundwater at 278 wells throughout the island. It has a database of quality checked data, stored in computerized format dating back to the 1950s. It also monitors 9 rainfall intensity gauges for flood assessment and warnings. The Meteorological Service of Jamaica has overall rainfall monitoring responsibilities. Table 1 below summarizes the number and type of recording stations.

**Table 1. Number and type of water recording stations in Jamaica**

| Type | Stream flow | Rain gauge | Groundwater |
|---|---|---|---|
| Recording | 20 | 0 | 0 |
| DCP loggers | 33 | 20 | 0 |
| With telemetry | 1 | 4 | 0 |
| Manually read | 73 | 327 | 278 |
| TOTAL | 127 | 351 | 278 |

*Operation*

Data is only input into the WRAMIS by the System Administrator. The WRAMIS is not automatically linked with the in-house databases; therefore the data have to be extracted from the in-house databases and resaved as .txt files with the station/well identifier, followed by the date and then the discharge/abstraction/water quality value. While the format of the input file is quite simple and easy to prepare, it still takes considerable time to prepare new input files for the current gauging stations and wells. The input files for streamflow and water levels are prepared by WRA staff members whereas water quality files were prepared by external workers. Due to the absence of a regular water quality monitoring network only historical data were entered. Abstraction data files were only prepared once for input into the WRAMIS and no further update is anticipated as the in-house database does not allow for an easy transfer and manpower is limited.

*Capabilities and features*

The database is based on the MySQL setting that not only stores data but also holds layers/layer attributes which provides an environment for instant access. The design follows a Client-Server model comprising two primary components. On the server side three specific software products were installed:

- A relational database management system - MySQL
- Apache Web Server (versions 1.3.28 or higher), or Microsoft IIS and a
- PHP engine (Version 9)

which are all open-source software packages. This was seen as an advantage as other software packages (such as Microsoft's SQL server) required payment of licensing fees or purchase of upgrades.

On the client side the following products were required:

- Internet Explorer (IE) V 5.0or higher
- Java Script Engine, V 1.2
- VML (Vector-Mark-up language) vector image rendering engine

The latter two are generally preinstalled with Internet Explorer. There was therefore no need to expend additional funds for these software packages.

The general concept of the database follows a child-parent relationship, e.g. a rainfall station belongs to a particular watershed, or a stream gauging station belongs to the river in the specific watershed. The first step in the database design is therefore the creation of the appropriate layers, containing the objects to which the data will be attached. Figure 1 shows the various layers that are available on the WRAMIS.

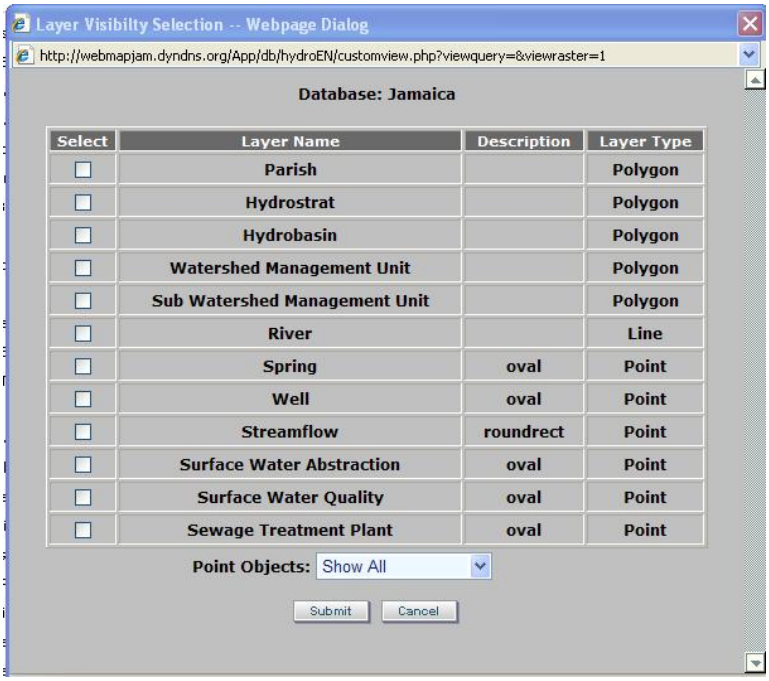


**Figure 1. Layers in WRAMIS**

The main part of the database is a cartographic interface and comprises layers of the type 'polygon' and 'line'. Layers of type 'point' have data attached, e.g. well points have water quality data and abstraction data attached, stream gauging station points have discharge data attached and so on. The hydrologic network comprises some 250 stations (current and abandoned) where water level data are collected either continuously via a recording device or twice daily via an observer and then converted in the office to a discharge. Groundwater and surface water abstraction data is submitted by the licensee on a regular basis. The data for the various layers are stored in in-house databases (either Access, Excel or Hydata).

The WRAMIS allows for free access to data for everyone with internet access via the http://www.wra.gov.jm website. The user can switch between the various layers, create overlays, choose point shape files with and without data, zoom and pan. Any data can be accessed as a report, table or chart and information can be downloaded as a .txt file. Other government agencies could theoretically add their layers to the WRAMIS, and it was hoped that particularly the Meteorological Service would be interested in joining as rainfall information is critical for any assessment. At this point in time however, only the WRA adds data to the WRAMIS.

*Outcomes and Benefits*

The WRA has always provided data to any interested person. While in the past interested parties had to call in and technical officers extracted the data from the in-house databases these persons are now directed to the website. The fact that interested parties can now access data without calling the office results in time savings at the agency.

*Challenges*

One of the challenges the agency is facing is that the software is now outdated, as newer versions have been developed, in Grenada for example. Updated versions now allow for a linkage with Google Earth; zooming is also easier as the point features now remain in the same scale, unlike in the presently used version where point features crowd out other information (Figure 2). An upgrade was suggested by the consultant at a very high cost; however, given the economic situation Jamaica finds itself in, resulting budget cuts in government agencies do not allow incurring this expense. Sources of external funding are being sought.

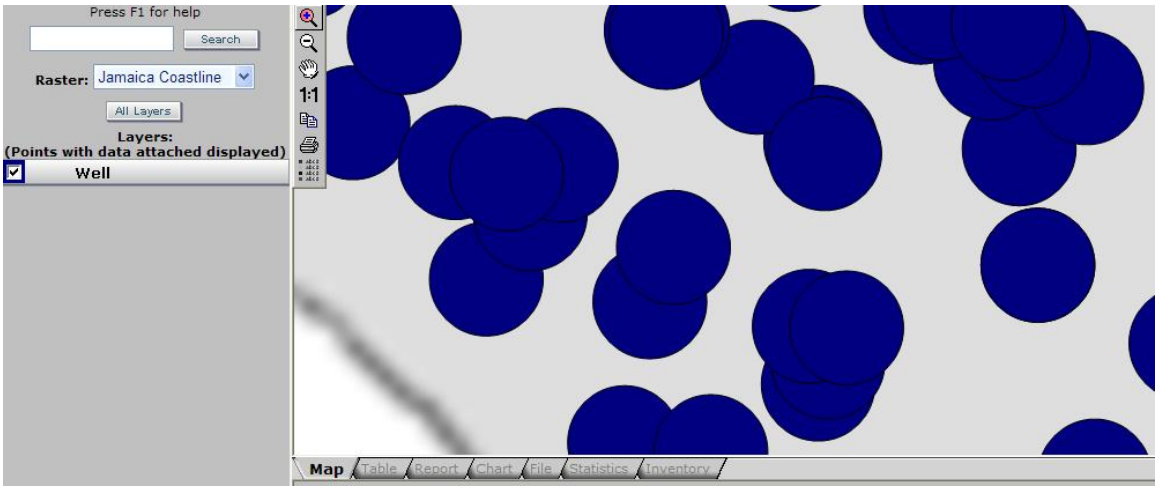


**Figure 2. Zoom into Wells**

The other main challenge with the WRAMIS is that the database is designed for data access and visualization only, such that the analysis of data has to be done in independent application software programs. A link between the WRAMIS and these in-house databases would further increase efficiencies in the operations.

### *2) The Grenada System*

*Background and Development Process*

The systems developed in St. Lucia and Jamaica were some of the earlier versions of NWIS in the Caribbean. Although the system developed by the FAO in St-Lucia was a technical success, it lacked in-country political support. The situation in Jamaica differed as the country recognised the advantages and power of what the FAO had achieved in St-Lucia and followed by

independently financing the development of its own NWIS based on the same model. Following the completion of the FAO-driven *Feasibility Study for Expansion of Small-Scale Irrigation, Grenada*, the paucity of hydrological data to do complete analysis for long term planning was highlighted as a major issue for Grenada, thus triggering the development of a NWIS for the country. The challenge for Grenada and the need for a NWIS were well stated in the FAO Technical Cooperation Programme project document entitled *Assistance to establish a National Agricultural Water Information System for St Lucia* (2007):

> "Currently water management data [in Grenada] are collected by a multiplicity of agencies and the data are stored in various formats without a standard mode of dissemination. This arrangement encourages a compartmentalized and isolated approach to the management of the water resource."

In 2008 the institutional setting in Grenada was such that the country was ripe for a major overhaul and modernisation of its information management according to IWRM principles. Grenada had completed the drafting of a National Water Policy, that seeks to address many of the issues relating to IWRM and water management in general; a Water Sector Review, that identifies the major issues relating to water in Grenada; a National Implementation Plan; and a Legislative Review and draft legislation relating to the National Water Policy. In fact, the government of Grenada boldly declared that "government position is that water resources management cannot be viewed in isolation from the wider national context such as land use, land use change, watershed management and economic and social development" and that "...by 2009, a National Water Information System will have been established and implemented" (National Water Policy, Basis for Action, 2007).

The defining difference for the Grenada NWIS was that its development and implementation were nurtured through a multi-stakeholder collaboration (including several agencies of the government of Grenada, FAO, and other regional entities) under the aegis of the Caribbean Water Initiative (CARIWIN), a project co-directed by the Caribbean Institute for Meteorology and Hydrology (CIMH) and McGill University, and funded by the Canadian International Development Agency (CIDA). CARIWIN's objectives include *inter alia* 1) making national water sector data systems compatible with IWRM principles and 2) strengthening CIMH national outreach program which provides water specialists and decision-makers with tools for developing IWRM policies.

CARIWIN facilitated the development of the Grenada NWIS over a seven-month period. Two workshops were prepared and delivered at the national scale in Grenada, and one at the regional scale. The first national workshop, the Grenada National Water Information System Workshop, was held at St George's University in Grenada on June 23 and 24, 2008. The workshop was an opportunity for data collectors, data users and stakeholders to meet and engage in the early phases of development of the Grenada NWIS. An information gathering exercise was conducted with the participants to permit the system programmer to begin structuring the database and the next steps in the development process were identified. Focus groups were formed to support the Ministry of Agriculture in moving forward with the NWIS. These groups, brought together by email communication, were comprised of key persons from various institutions of the national, regional and international collaborators, extending beyond those in attendance at the workshop.

These groups successfully collaborated within the time-frame, resulting in a world-class NWIS for Grenada which is state-of-the-art and the new standard for the Caribbean.

The second national workshop was an implementation phase event with national capacities strengthened in data management, database administration, GIS features, and web-based technologies. The Government of Grenada officially launched the NWIS on January 26, 2009. The Grenada National Water Information System Installation, Deployment and Training Mission was held at the Grenada Ministry of Agriculture, St-Georges, Grenada, from January 21-28, 2009. The system installation and verification was completed over a three-day period. This was followed by the NWIS Training Session from January 26-28, 2009. The training session was attended by administrators, data managers, technicians and end-users of the information from the three main government agencies involved (Ministry of Agriculture, Point Salines International Airport Meteorological Office, National Water and Sewerage Authority), as well as participants from the Caribbean Youth Environmental Network and St. George's University.

The Grenada NWIS was previewed at a regional-scale event during CARIWIN's 2nd Senior Administrators Workshop held at CIMH in Barbados, January 19-20, 2009. A total of 39 delegates participated in the workshop including representatives from regional organisations such as the Caribbean Disaster Emergency Management Agency (CDEMA), Food and Agriculture Organisation of the United Nations – Subregional Office for the Caribbean, and the Caribbean Environmental Health Institute. It was an opportunity to showcase the attributes of the system and to display the potential for data management and information product generation for the Caribbean. The event had a catalytic effect on the movement to modernise data management in the region. Senior Managers from other countries in attendance, notably Barbados and Guyana, pressed for the migration to a similar system in their countries. However, the ground-breaking strides were made by CIMH as it assumed leadership in promoting the system as the new standard for the region; for modernising its services by archiving in a compatible mode; and by seeking external sources of funding to develop similar systems in the remainder of the CARICOM countries.

*Primary data collection*

Grenada has a well defined hydrometric network, with data collected from over 40 rainfall, agrometeorological and meteorological stations. There are a number of stream flow data collection points, including one automatic water level recorder. Data for all of the dams, water treatment plants, and wells including their daily production figures, along with data on water bodies and streamflow are also available. These data are input into the Grenada NWIS, and documents, reports, pictures and other relevant information can also be attached to the features in the system.

*Operation*

The Grenada Ministry of Agriculture has committed a significant budgetary contribution toward the new National Water Information System by hiring a System Administrator and taking responsibility for all related recurring costs. The cost of operation includes web hosting, registration of domain name, and data collection from stations on the island. Major stakeholders like the National Water and Sewerage Authority collaborate by providing staff to collect data

daily, and the Maurice Bishop International Airport Met Office provides data collection and data quality management functions. Other stakeholders providing invaluable input and contributions include St. George's University, the Ministry of Works, and the Ministry of Health. Unlike the system in Jamaica, the Grenada NWIS succeeded in breaking sectoral barriers and is a functional example of IWRM at work.

*Capabilities and features*

The Grenada NWIS has now become an official repository for all hydrologic, climate, land, watershed, infrastructure and water-related data in the country. The Grenada NWIS was conceived in a different manner to the other systems in the region, in that it built on the previous platforms, but with the recognition that the software and technology had improved remarkably since. This meant that even though the system is similarly built on a Client-Server model, the consultants included new features and improved the system to make it more user-friendly. Table 2 outlines the different types of data provided by the Grenada NWIS.

The system features are as follows:

- the system is installed on a server and accessible via the internet at http://cariwin.gd
- the interface is very user-friendly
- no client installation is necessary as each agency/user enters the NWIS through the website with username and password
- all objects in the database are geo-referenced so that choosing a specific site or moving the cursor over the map will reveal all of the information available for each location (Figure 3)
- the database inventory allows users to see all objects in the database
- the system is linked to Google Earth imagery
- procedures for data collection and data entry which are presently in place at agencies need not be modified as the system accepts various formats of primary data
- logs from website hits reflect what data is most requested
- it is possible to restrict data access or charge access fees

**Table 2. Types of data generated by the Grenada NWIS**

| **Type of Data** | **Description** |
|---|---|
| Tabular data | Monthly, yearly, minima, maxima and averages |
| Report data | Tabular, print-ready, Microsoft Word format |
| Chart data | Line or bar charts – the charts may be zoomed, copied and printed; values may be accessed by moving the mouse over the point of interest on the chart |
| File data | ASCII, Excel or comma delimited data for a selected period |
| Maps | Soils, agroclimatic zones, watershed, rivers, roads, meteorological stations, topographic, water intake, water bodies, administrative boundaries, water storage & production facilities |

One main advantage of the Grenada NWIS is its user-friendly open-source software, which can be freely downloaded from the Internet, thus eliminating licensing issues and user fees. Regrouping information from all agencies under one system provides for access to real-time data and information.

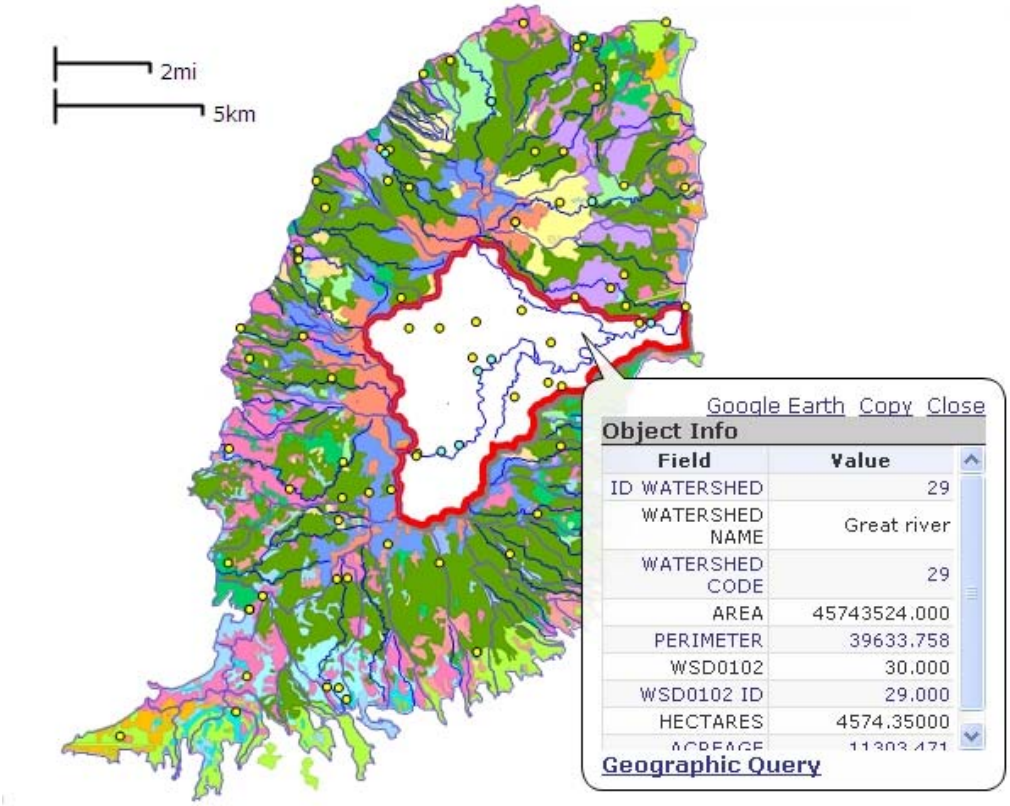


**Figure 3. Snapshot of the Grenada NWIS, highlighting the Great River watershed and associated information**

*Outcomes and benefits*

The NWIS has strengthened the management of services to the population, as agencies in Grenada are now more prepared to effectively manage the resource. In particular, governance has been strengthened in Grenada as water managers, now armed with the NWIS, are better able to assess the resource; share information with other national agencies and stakeholders; clearly report pertinent information; and positively influence policy. For example, the NWIS has been used to generate information which is used by water managers in media briefings, National Sustainable Development Council meetings, and presentations made to Permanent Secretaries of all Ministries and to the Senior Management Board of the Public Service. The NWIS has also become a source of income for the Government of Grenada as the maps that it generates are sold to private enterprises.

*Challenges and suggestions for improvement*

One main challenge since the inception of the Grenada NWIS has been to ensure that data and reports are provided in a timely manner from the relevant organizations. Time and capacity building efforts have also been required to learn the software components in order to make improvements to the site (Html, JavaScript, Ajax, PHP, SQL statements). Lack of feedback from users and data analysis have also been key challenges. Following from the experience with the Grenada NWIS thus far, a number of issues need to be considered for future application:

- Expansion of the NWIS to include wider functions such as forecasting, early warning, and water quality
- Type, placement and maintenance of instrumentation for data collection
- Staff and incentives for data collection
- Data entry and prevention of error in transcribing each time data is transferred
- Data analysis, interpretation and dissemination
- Understanding of who uses the data and for what purpose

The review of the NWIS in Grenada and other countries has shown that the system works when the users see its value and when there is government commitment to support it. Based on the Grenada experience, suggestions for improvement include:

- Establishing guidelines to ensure data accuracy
- Streamlining institutional arrangements
- Computerizing data entry in the field to reduce changes and errors
- Developing simple tools linked with IWRM
- Promoting additional applications e.g. crop production, IWRM planning

## Water Information Systems on a Regional Scale

The Jamaica and Grenada case studies provide a promising outlook on the potential of Water Information Systems as a valuable tool to support Integrated Water Resources Management. Looking beyond these national applications, this last section of the paper outlines the potential of such systems on a regional scale in the Caribbean, under ongoing initiatives led by the CIMH.

### *Role of CIMH in Centralized Data Management*

CIMH's mission is to improve the meteorological and hydrological services and to assist in promoting the awareness of the benefits of these services for the economic well-being of the sixteen member states of the Caribbean Meteorological Organisation (CMO), which include the three national partners of CARIWIN. Apart from its training and research programmes, for which it is regionally and globally recognized, two of CIMH's other roles are to 1) collect, analyse, and publish meteorological and hydrological data and 2) maintain a service for the upkeep, repair, and calibration of meteorological instruments. Both of these roles make CIMH an important stakeholder in the establishment and maintenance of NWIS in the region. The development of NWISs like that of Grenada makes it much easier for CIMH to fulfill the former. Furthermore, CIMH is currently modernizing the manner in which it collects data from its member countries by developing the instantaneous duplication of the NWIS to a server housed at

CIMH, in order to facilitate accessibility to national databases at all times. CIMH is striving to improve and expand the information products it provides to its member states at the regional scale as it modernizes its databases and analytical tools in step with the NWIS movement. From raw climatic data CIMH produces a precipitation outlook for the Caribbean and monthly weather summaries among other products, which can be viewed on CIMH's web page (http://www.cimh.edu.bb). The NWIS makes the transformation from data to summarized information much easier. It also takes this process further by providing graphical summaries, and through its GIS and Google interfaces, one can see from which part of the country information has originated. It also provides wider water-related data other than the climatic data, including data on streamflow and reservoirs. With the NWIS, both types of data are available on one system. It is expected that the Grenada NWIS and the replicas developed in other Caribbean countries will feed into other regional initiatives, including the Caribbean Drought and Precipitation Monitoring Network (CDPMN) and the Caribbean Agrometeorological Initiative (CAMI), which require ready and easy access to data and information. This comprehensive water data provision system can feed directly into the CDPMN by providing not only rainfall data, whose extremes trigger droughts and floods, but also information on streamflow, reservoirs, and groundwater, which are impacted by these extremes in rainfall and are also indicators of their severity. Having one centralized information base for water makes it easier for the CDPMN to monitor holistically the occurrences of drought in particular.

CAMI is a European Union-funded project under the African, Caribbean and Pacific Group of States (ACP) Science and Technology Programme with the objective to provide meaningful information to the farming and wider agricultural communities. The relationship between climate and agriculture is well known. It is also known that rainfall, and by extension water availability, are the most limiting and variable factors influencing agricultural productivity in the Caribbean. Accordingly, NWISs have a potential role in facilitating access to information related to water loss and irrigation needs, two of the focal areas of CAMI. The system's comprehensive climatic data base also facilitates the other climate-related activities of CAMI, such as pest and disease predictability and crop weather modeling. The relevance of NWISs to CAMI was expressed when a Grenada representative was invited to make a presentation of the Grenada NWIS at a stakeholder meeting in Barbados.

With its data archiving role, CIMH also acts as a data provider to numerous research and development and private sector entities. Nations with developed NWISs will now be in a position to provide their own data with much ease. CIMH is in the process of expanding the development and use of NWIS in the region. However, until more nations in the region develop such NWISs, CIMH will continue to be the major provider of climatic data.

### *Expansion of the NWIS in the Caribbean*

Based on the positive feedback the NWIS has received, several national governments and regional organizations have expressed a willingness to adopt and fund the expansion of the NWIS. The Caribbean Disaster Management (CADM) Phase II, funded by Japan International Cooperation Agency (JICA) through an agreement with the Caribbean Disaster Emergency Management Agency (CDEMA), is currently developing an NWIS system for Guyana. The system will reflect the collected experiences gained from prior installations of the NWIS in

Grenada, Jamaica and St. Lucia. The new system features upgrades which should be applied to previous installations in these countries in order to maintain uniformity in the region.

The NWIS is an extremely powerful quantitative and qualitative tool which allows not only the archiving of data, but also displays information in a very comprehensive and visual manner to give a snapshot of the water resources at any time, and any scale, from the national to watershed to parish to community levels. It allows for a review of information by all stakeholders including water users at the community level. The NWIS is a tool that can provide timely information to decision-makers and planners and, if used to its potential, can drastically improve their ability to address water resources and land use challenges. The experience of the NWIS in Grenada as implemented by CARIWIN has resulted in a viable application of IWRM principles which has improved the flow of data to information to policy to action. In turn, other countries in the Caribbean are taking steps to develop similar systems with the support of CIMH, and CIMH is taking steps to back-up these systems at their facilities. The expansion of the NWIS in numerous countries in the Caribbean region, which is expected in the next few years, will result in greater capabilities to manage the resource nationally and far greater capabilities for the CIMH to generate information products (such as weather forecasting and drought monitoring) at the regional scale to support decision-making, planning and disaster mitigation.

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