ASSESSMENT REPORT

Coastal Inundation Forecasting Demonstration Project (CIFDP)

by

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(Fiji flooding, Nadi, 2012)

Acknowledgements: The authors would like to acknowledge the large number of experts from the CIFDP Project Steering Group for sharing their experience and wisdom, the WMO Secretariat, the NMHS of Fiji and the NMHS of the Dominican Republic and associated national agencies and other scientists. Past and present. In particular the authors would like to acknowledge the strong support in the early stages of this review by Mr Val Swail, founding co-chair of the CIFDP.
RC and CB 31/10/18.

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1 EXECUTIVE SUMMARY

As tweeted by @UNGeneva on ***22 October 2018,*** *the number of people at risk of floods is projected to rise from 1.2 billion to around 1.6 billion in 2050. This is nearly 20% of the world population.*

---- and coastal inundation, the topic of this assessment, is a large component requiring enhanced coastal inundation warning systems. *RC and CB.*

The Coastal Inundation Forecasting Demonstration Project (CIFDP) was established in 2009 to facilitate the development of efficient warning systems, to alert coastal communities of imminent coastal flooding for their safety and to support sustainable infrastructure development.

Its aims were to:

- Identify and support end-user needs;
- Encourage full engagement of all the stakeholders;
- Transfer technology (soft, hard and intellectual) to the adopting countries;
- Facilitate the development and implementation of warning services; and
- Support coastal risk assessment, vulnerability and risk mapping;

We have undertaken a structured assessment of the CIFDP and its four sub-projects in accordance with the ToRs provided by the WMO Secretariat and endorsed by CHy and JCOMM. Neither of us has been involved in any way with the project since its inception and we therefore can be considered as independent reviewers.

We have also undertaken site visits to the two sub-projects that are still in development (Caribbean and Fiji) to examine the processes, strengths and weaknesses of the whole program. This also allowed us an opportunity to comment on, and provide advice, to assist these sub-projects.

In undertaking the assessment, we followed the requirements of the OECD DAC Principles for Evaluation of Development Assistance. A carefully prepared and comprehensive Questionnaire was prepared; and key members of the project's steering group and past and present experts were interviewed. We also sought the wisdom of WMO Secretariat staff who had been involved one way or another in establishing, or now coordinating the development of CIFDP.

Currently, the number of national agencies globally that run storm surge, wave and hydrological models, and coupled coastal forecasting systems is limited and almost non-existent in developing countries. Hence, the CIFDP is designed to work with responsible national agencies to support them in utilizing forecast products operationally and linking them to coastal flood management programmes and related activities. This requires both substantive and substantial training in the use of these products, under different hydro-meteorological and risk situations.

We also considered the criteria for successful future projects, including future governance options and resource requirements for carrying out further development efforts and on-going operations in a sustainable manner. In undertaking the review, we particularly sought out case studies of events for each sub-project. These are included in this report for the Caribbean and Fiji.

The key to successfully developing a comprehensive coastal inundation forecasting and warning system is the cooperation of different scientific disciplines and user communities. An integrated approach to river flow, storm surge, wave and flood forecasting is the strategy for building improved operational forecasts and warnings capability for coastal inundation. We found most of these attributes in the sub-projects, depending of course on the hazards affecting the country or location. Integration of hydrology was either limited or yet to be implemented.

As well as presenting in this report a large number of findings, we rated them according to the urgency and relevance of each before determining necessary recommendations. We were able to analyse many as not being “show stoppers” for development or future projects.

However, the linkages between hydrological models and/or data and the other ocean and weather models was lacking. We have recommended this for a high priority in the future. We also found a large training deficit in all disciplines and models and also in the emergency response agencies who need to understand the output for intelligent decision making.

Finally, during the assessment we continually considered the right governance for the future. This is presented in the section “Recommendations and the Way Forward”. We were convinced that the “demonstration” label can be removed, since most of the sub-projects have already demonstrated that coastal inundation forecasting is an efficient and effective service for saving lives and infrastructure, and future planning. Conclusions on Fiji and the Caribbean were limited due to the level of development and the Caribbean in particular has not received its software or training (expected in December 2018) at the time of writing this report.

We also provided three scenarios for governance within the current WMO structure or any renewed commission structure. We believe the latter should NOT hamper the future expansion of coastal inundation forecasting in developing countries. With any of the governance scenarios there is a real opportunity to attract additional donor funding with a stable, important and “non-demonstration” service for vulnerable communities.

It was quite obvious to us that there is a growing demand of developing countries that need Coastal Inundation Warning capability but on the other hand it is not obvious how the needed funding can be obtained to meet this urgent and growing need. It is very satisfying to see the success obtained from the sub projects that are now operationally providing state of the art coastal inundation warning services, and that these sub projects serve as excellent systems that may be applied to the many countries that need them.

During the assessment process we also considered the need to include another hazard that has a major impact on coastal inundation: tsunami. We questioned many developers and users on the appropriateness of including this hazard in a Coastal Inundation Forecasting (CIF) System. Opinions were mixed, but our assessment is that it should be considered in early planning because the critical "last mile" of distribution to the public is similar (if not better, often with sirens), even if the phenomenon is different, and the lead time shorter.

As part of this review we have interviewed and provided questionnaires to a large number of participants and observers of the CIFDP during its lifetime. This has included donors, emergency agencies, developers, forecasters and leaders of NMHS. The questionnaires and interviews were designed and undertaken after an initial examination of the existing background reports, which were well documented and exceedingly beneficial.

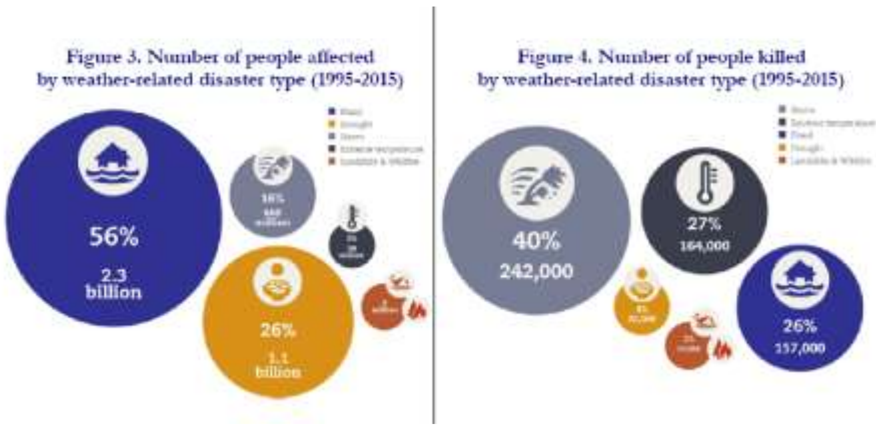
2 BACKGROUND

Coastal inundation occurs throughout the world's vulnerable coastlines, and the combination of storm surge (typically from tropical cyclones, also known as hurricanes and typhoons), with hydrological flooding at various tidal states, can regularly lead to major loss of life. Many Members have systems that provide services for one or other of these hazards, but often not in combination. The Coastal Inundation Forecasting Demonstration Project (CIFDP) is designed to provide such a combined warning service. It should be remembered that many countries with vulnerable coastal communities also have tsunami warning systems that are trialled and tested regularly due to the major loss of life that has occurred, in particular after the tragic 2004 Indian Ocean tsunami. The UNESCO Intergovernmental Oceanographic Commission worked with WMO in the immediate period after this tragedy, and the IOC has taken responsibility to coordinate the continued development and sustainability of the tsunami warning systems. The IOC (with support from WMO) has been playing a major role in these tsunami warning systems over the last 14 years and we believe this work provides opportunities for leverage for the CIFDP.

As published in the World Bank Report 2005, at least 2.6 million people are estimated to have drowned due to coastal inundation, particularly caused by storm surges, over the last 200 years. Indeed, coastal inundations are an increasing threat to the lives and livelihoods of people living in low-lying, highly-populated coastal areas. However, the situation for most countries that have vulnerable coastlines is the increased level of development for fishing, tourism, building development along coastal areas, and sustainability of their populations. This has led to an even greater level of concern for coastal flooding and inundation. Coupled with this are the changes that are occurring in catchment areas through land use and resulting modifications to runoff that can exacerbate ocean related flooding from storm surge, extreme waves etc. More recent figures can be obtained from a number of studies from the United Nations International Strategy for

Disaster Reduction (UNISDR) and the Centre for Research on Epidemiology of Disasters (CRED)[1]. These statistics, plus many others highlight the terrible cost on populations, especially those in coastal areas, pointing to the need for coastal inundation warning systems. CIFDP Co-Chair Mr Val Swail (JCOMM Technical Report No.64, 2014 update) and the Project Steering Group (PSG) at their first meeting in June 2009 in Geneva, recognised the importance of this work in establishing the CIFDP. Nine years later, the project has seen many milestones and successes, along with numerous challenges, most of which have been overcome.

As part of this assessment it has been clear that it is a credit to the PSG, WMO Secretariat, Members and expert volunteers of the WMO Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM), the Commission for Hydrology (CHy) and the relevant NMHS that this Demonstration Project has achieved so much and no doubt contributed significantly to saving lives from these natural hazards. The number of people affected and killed by weather related disaster type are shown in this schematic from CRED and UNISDR (2015).



3 OVERVIEW

As a result of the high humanitarian costs globally from natural coastal hazards, the WMO, initially through JCOMM (Joint Commission for Oceanography and Marine Meteorology), commenced a Coastal Inundation Forecasting Demonstration Project (CIFDP) in 2009. Recognising the importance of coastal riverine flooding and to strengthen this approach, the Commission for Hydrology (CHy) recently joined as a co-sponsor of the project.

The CIFDP was designed as a multi-hazard early warning system (MHEWS) that promotes an integrated approach in the enhancement and delivery of early warnings, no matter what the causes for coastal inundations. This is in line with the concept of impact-based forecasting and the UN Sendai Framework for Disaster Risk Reduction (DRR). The CIFDP also directly relates to four of the five WMO Strategic Priorities (Disaster Risk Reduction, Service Delivery, Global Framework for

[1] "Human costs of weather related disasters" UNISDR (2015)

Climate Services, and Capacity-building). The two sponsoring Commissions are supported by the WMO Secretariat for the Marine Meteorology and Ocean Affairs Division, and the Hydrological Forecasting and Water Resources Division. Regarding project management and coordination, the MMOA Division currently takes the lead.

At present the CIFDP is still in its 'Demonstration' mode but with two of the four sub-projects, Bangladesh completed and Indonesia nearing completion. The successful implementation of these two sub-projects effectively shows that integrated coastal inundation forecasting and warnings can be improved and effectively coordinated by the National Meteorological and Hydrological Services (NMHSs).

There is a growing interest in the enhancement and delivery of coastal and inundation early warnings by Members not currently included in the demonstration sub-projects. The ongoing sustainability of the CIFDP and the 'demonstration' aspect, and its governance, needs to evolve to meet the growing need by countries. We have provided options on the way forward to be considered by WMO and its partners.

4 REVIEW OF DOCUMENTS AND PROCESSES

We found the CIFDP to be a particularly well documented project. The JCOMM web site (www.jcomm.info/CIFDP) carries key documents and references to WMO technical reports. As it is a joint commission of WMO with the UNESCO Intergovernmental Oceanographic Commission (IOC), a sharing of support resources has been valuable. In this respect the web site is well hosted by the UNESCO/IOC project Office for the International Oceanographic Data and Information Exchange (IODE), Oostende, Belgium. WMO (MMOA Division) is responsible uploading all the CIFDP documents and keeping the material up to date, for all stakeholders to access. A review of the documents was able to be undertaken from its inception in 2009 up until mid 2018. The project material is well up to date and underpins the responses to the questionnaires and interviews that we conducted; in that committee meetings of the four sub-projects and their status reports were able to be accessed and compared for context and verification.

Additional documents were obtained from some interviewees that provided more background and the site visits also allowed access to more local information.

As a result of the excellent extent of available documentation and the generous sharing by interviewees and responders to the questionnaire of their experience and "inside" views of the whole beginning-to-end development of the CIFDP in each country, we were able to undertake an efficient assessment. Indeed, we were able to seek information ahead of the site visits that made them more valuable in seeking specific aspects of those particular sub-projects.

5 APPROACH TO THIS ASSESSMENT

In July 2018, the WMO requested Mr Curtis B Barrett, Hydrometeorological Advisor USAID OFDA and Dr Ray Canterford, Meteorological Hazards Specialist (former Division Head, Hazards, for the

Australian Bureau of Meteorology) to conduct a review of the CIFDP. The review is to culminate in this report with findings and recommendations and be submitted to the WMO by 31 October 2018. This report summarises extensive investigations into past reports of various project committees, publications, presentations and outcomes of the program for each sub-project. The most valuable has been direct interviews with the designers, developers, users, the WMO Secretariat and NMHS personnel. Over 40 staff were involved in providing information for this assessment. Additionally, a comprehensive questionnaire was sent (via WMO channels) to most participants in the project (past and present). We were grateful for the > 90% response rate to the questionnaire and the willingness of interviewees to be frank about strengths and weaknesses of the program, as well as suggestions for improvement. We also undertook second interviews with some participants to clarify ideas and issues.

The performance of the CIFDP has been assessed (Appendix A) using the methodology developed by OECD DAC principles for the Evaluation of Development Assistance (OECD, 1991) based on the following criteria:

- relevance to underline the adequacy between the needs of the target groups and CIFDP results;
- effectiveness to compare achievements to objectives;
- efficiency to measure if funding was best suited;
- impact to determine the benefits produced all along CIFDP life; and
- sustainability to evaluate how the benefits of the program will continue.

As background to our assessment, the concept structure from Phase 0 (preparation) to Phase 4 (operation) with the associated Objectives, Scope and Expected Outcomes, are reproduced from in Appendix B - Implementation Plan, the 2018 update in jcomm.info/CIFDP.

The assessment criteria listed above, from the OECD DAC principles, were used to develop the questionnaire (see Appendix C) for the interviews. The interviews, discussions with key WMO Secretariat staff, additional discussions with designers and developers, as well as the comprehensive questionnaire responses, have made this assessment particularly gratifying, as well as providing a strong background for the findings and recommendations. The questionnaire was carefully designed to cover the completed or near complete sub-projects separately from those still in development. Furthermore, we were able to visit the sub-projects that are still in a development phase, CIFDP-Caribbean and CIFDP-Fiji, for “on the ground” assessments of processes, forecaster views and other agencies views (such as national emergency services) contributing to public alerts and warnings.

The interviews commenced in August 2018 and were completed in October 2018. They were held in parallel with the questionnaire process. Where possible they were done face to face during site visits, by video conferencing utilising WMO facilities and lastly by telephone. Where time zones allowed, both reviewers took part.

A table of key interviewees and questionnaire recipients is included at Appendix D. Some field work was delayed due to serious hurricane activity in the Atlantic and some interviews/questionnaires were delayed due to key personnel being caught up on operations and recovery aspects. Additionally, the tragic tsunami and earthquake that killed thousands in Palu, Indonesia on 28 September 2018, caused some interviewees to be diverted for assessing that event. Nonetheless, they did follow up with us at a later date. One of the PSG members had agreed to follow up the progress of the Indonesian sub-project and report to us, but he had to cancel because of this event.

Mr Barrett travelled to the Dominican Republic on 17-18 September 2018, and Dr Canterford to Fiji on 13-14 September 2018. Both site visits provided essential first-hand assessments of the state of these sub-projects and what was needed for the future.

Considering the above OECD DAC principles, the assessment involved surveying the participants through the questionnaire, interviews and site visits in the following four categories:

1. Project development and implementation;
2. CIFDP operation and, maintenance;
3. Current and future resourcing models (if appropriate to stakeholder); and
4. Existing governance and proposed governance improvements.

Focussing on these four categories, assessments were made of the various organisations and partners involved in implementation of the program. CIFDP program documentation was also reviewed by the team such as Implementation plans, strategy documents, Steering committee reports, training sessions, PSG reports, Project briefs, Workshop reports and the CIFDP Implementation plan.

The surveys and interviews were essentially conducted with key personnel involved in CIFDP, either in country, or internationally, such as the co-chairs of the PSG, nearly all its members and past members, including sub-project lead officers. Key personnel involved in the operational program in the WMO Secretariat were also interviewed, but not required to complete a questionnaire.

6 ASSESSMENTS OF EACH CIFDP SUB-PROJECT

6.1 Bangladesh

Sub-Project Background – why Bangladesh

The CIFDP Bangladesh sub-project is the most advanced, having completed operational implementation, Stage 4, in December 2017. It was funded by USAID and a Final Report can be found on the JCOMM web site (jcomm.info/CIFDP).

This CIFDP sub-project covers the whole coast of Bangladesh which is subject to major storm surge, river discharge and tidal impacts in particular. The first meeting of the Project Steering Group in 2009 selected Bangladesh for this reason. As they highlighted "*the long continental shelf, shallow bathymetry, complex coastal morphology with many kinks and islands, and long tidal range between the east and west coasts of Bangladesh are well-known features for generating the highest storm surge, and the longest duration. About 5% of the global tropical cyclones form over the Bay of Bengal. On average, 5 to 6 storms are formed in this region every year*."

As we are aware from media reports, the terrible storm surges and casualties are shocking and can account for 80% of the global casualties. Indeed, UNDP has identified Bangladesh to be the most vulnerable country in the world to tropical cyclones and the resulting storm surges. Furthermore, as recognised by the PSG in their selection, "*three large rivers systems, Ganges, Brahmaputra and Meghna, covering a combined total catchment area of about 1.7 million sq. km. extending over Bhutan, China, India and Nepal, flow through this country. The combination of the discharge of these major river systems and storm surge heights which can exceed 10 m above mean sea level can create catastrophic coastal inundation."*

Sub-Project Description

The Definitive National Agreement (DNA) was signed in 2013 and the system design for Bangladesh is covered in detail in JCOMM Technical Report 75 (2013). The storm surge model of the Japan Meteorological Agency (JMA) Meteorological Research Institute (MRI) was upgraded to incorporate wave and hydrological input into forecasting total water level estimates. Hydrological and hydrodynamic input from stream discharge is parametrized for input to the forecasting system at this stage. Similarly, cyclone information is from the Regional Specialised Meteorological Centre (RSMC), the Joint Typhoon Warning Center (JTWC) and the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES). The integrating system is Delft Flood Early Warning System (FEWS). Bathymetry data, a major component of the warning system, is available from various sources with the best being that of the Bangladesh Navy. Digital Elevation Model data are also critical and those of the Survey of Bangladesh (SOB) are used for this purpose.

The developers considered a large range of integration and operational requirements before settling on the best system, which included simplified modelling in some cases (such as the flood modelling) in order to keep computer-run time reasonable for three hourly forecasts. The complete design was an end-to-end impact-based early warning system which utilises cooperation between agencies in the country and internationally. The Final Report on the system (Final Meeting of the CIFDP-Bangladesh, 28-30 November 2017) is excellent and covers the six years of development, mainly funded by USAID, and the major contributions of a large number of national and international volunteers in all areas of science, community engagement, policy, project planning etc.

In the project overview, we must recognise the prescient comments of Mr Val Swail (Co-Chair of the CIFDP), who emphasized that "*the goal of the project was not to change any procedures for disaster management in the country, but to improve and assist the decision-making for the procedures already in place, by responding to the needs of Bangladesh, and the local stakeholders*." (our emphasis).

This has been borne out since the operation of the system with fewer lives being lost (26 in 2016 and 2 in 2017) compared to thousands in 1998 and 2007 events. Clearly future events could still overwhelm the country, but the evidence so far is extremely positive that the CIFDP-B has been a success.

Through our wide-ranging Questionnaire, we posed specific questions on the Bangladesh and Indonesia sub-projects due to their state of completion. These responses and special interviews with users, developers and managers from the PSG and the WMO Secretariat amongst others showed there is still more work required (especially the improved integration of hydrology). This also includes improved bathymetry and DEM resolution and installation of additional tide gauges, with possible remediation of the existing ones.

Of course, maintenance of the system, regular component upgrades and training are all necessary to avoid the coastal forecasting system degrading. We will include those findings and recommendation (albeit small for Bangladesh) in that section of our report.

6.2 Indonesia

Sub-Project Background – Why Indonesia

In terms of coastal flooding, Indonesia is unique in its vulnerability of coastal communities. It also has almost 100,000 km of coastline as an archipelagic country and is subject to catastrophic flooding caused by a number of hazards, either individually or in parallel: including high tides, heavy rainfall, river flooding, sea surface height anomalies and ocean waves. Indeed, subtle pressure and wind variations can even cause a 0.5m surge over low lying land. Not to mention disastrous tsunami, as we have seen even this year (28 September 2018). Another unique aspect for the coastal flooding in Indonesia is the large subsidence in surrounding areas, coupled with ever increasing coastal land development. There are also (smaller) effects from Tropical Cyclones in the South China Sea.

The CIFDP Project Steering Group assessed these major risks and possibilities of coastal forecasting improvements as another candidate for a CIFDP sub-project. The capability and readiness of the Indonesian Meteorological Climatological and Geophysical Agency (BMKG) to lead the project and for institutional collaborations were among several other factors.

Sub-Project Description

A National Stakeholders Workshop in December 2013 brought together the major collaborators, including BMKG, the National Agency for Water Resources (PUSAIR), the National Agency for Geospatial Information (BIG), Agency for the Assessment and Application of Technology (BPPT), Ministry of Marine Affairs and Fisheries (KKP), State Ministry of National Development Planning (BAPPENAS), and the Indonesian Institute of Science (LIPI). We mention this full list here because this is an example of the type of collaboration needed in establishing a successful Coastal Inundation Forecasting system in a country.

Further still, the Definitive National Agreement (signed four years later in 2017) for the CIFDP-I included 5 Ministries/ Institutions, namely BMKG Maritime Meteorology Centre, Research Centre and Development of Water Resources of the Ministry of Pupera, Directorate of Coastal and Small Island Utilization of KKP, BIG Geodetic Control and Geodynamics Control Centre, and Directorate of Preparedness of BNPB.

Systems integrated under Delft FEWS include Delft 3D (hydrodynamic) for storm surge, and several other national and international models, including Australian Bureau of Meteorology operational forecasts of sea surface anomaly, global tidal models etc. It is important to note however that BMKG has a strong forecasting capability and well-trained staff and procedures. This allows further advancement of the system as well as sustainability. Complementing this is the fact that the major funding was supplied by BMKG itself.

The Indonesian system has now reached Phase 3 with pre-operational testing to be conducted by BMKG, PUSAIR and Deltares. The completion workshop is planned for January 2019 and the system performance appears, from our responses and interviews, to be ready for operational implementation. Another finding was that the capability and capacity of BMKG has improved dramatically with CIFDP.

As mentioned in the previous section, our CIFDP Questionnaire posed specific questions on Bangladesh and Indonesia sub-projects due to their state of completion. Indonesia also appears to require still more work (again especially improved integration of hydrology to the system model). Investment in IT infrastructure and experts is always needed.

Of course, as with Bangladesh, maintenance of the system, regular component upgrades and training are all necessary to avoid the coastal forecasting system degrading.

6.3 Site Assessment Caribbean

Sub-Project background—Why Caribbean

Tropical cyclones continually pose a threat to Hispaniola (an island comprised of 2 countries: Dominican Republic - Spanish speaking, and Haiti - French speaking) each year during the hurricane season of June 1 to November 30th. Historically, tropical cyclones and hurricanes have generated high storm surges, flooding, and large waves in both Haiti and the Dominican Republic. In fact, since 1851 over 150 tropical cyclones have come within a radius of 200 miles centred on the island. The growing tourism industry on the island in the Dominican Republic produces a growing vulnerability of a large population to a potential catastrophic humanitarian disaster. In addition, the Dominican Republic and Haiti do not currently have storm surge and coastal inundation planning and preparedness products available to aid in emergency management. This is also true for other Caribbean Members. It is this reason that Hispaniola was chosen as a sub project of the CIFDP. The WMO Regional Specialized Meteorological Centre for Tropical Cyclone (RSMC-TC), and the US/NOAA National Hurricane Center (NHC), provides the leading technical contribution in collaboration with the PSG and other partners. Funding of this project was provided by the USAID Office of Foreign Disaster Assistance.

Sub-Project Description:

The CIFDP Sub Project had its stakeholders meeting in November 2011 in the Dominican Republic, and the National Agreement was signed August 2012, between the national meteorological agency and hydrological agency, Oficina Nacional de Meterologia (ONAMET) and Instituto Nacional de Recursos Hidráulicos (INDHRI), based on the National Law No. 147-02 establishing the Sistema Nacional para la Prevención, Mitigación y Respuesta ante Desastre (SN-PMR), or the "National System for Risk Prevention, Mitigation and Response", the CIFDP-DR National Coordination. A Stakeholders Workshop, encompassing both a user requirements component and a technical component, was organized and held during the third week of November, 2016, hosted at the ONAMET. The National Coordination Team NCT was established with membership of the experts, forecasters, and disaster managers from ONAMET, INDHRI and Comision Nacional de Emergencia (CNE). In December, 2018, the system will be delivered and forecasters trained. The final wrap up meeting, tentatively in 2nd quarter 2019, will bring together all the national stakeholders (including disaster management agencies) to ensure end users are educated.

The Florida International University, a contractor of NHC, just completed making runs of various category hurricanes and different paths that could approach or make landfall in Hispaniola. All possible scenarios are about 10,000 track runs. These were run using a supercomputer. A wave model was run superimposed on the storm surge model output to account for wave action and raises the water level reached.

These SLOSH runs that created Maximum Envelope of Water (MEOW) and Max of MEOWS (MOMS) used a Digital Terrain Model provided by a German Satellite on a 12-meter grid resolution. This remarkable fine resolution was needed since only very coarse resolution grid data were otherwise available and unacceptable for use in the storm surge model runs. The Bathymetry data were single beam data used for Tsunami models. The high tide elevation to the closest tide gauge was used as the initial sea level elevation to which the surge and wave model add.

This approach is quite different from the other Sub projects in that it does not require NMHS Dominican Republic and Haiti to run SLOSH on a large cluster computer. All that is needed is a regular PC. Unfortunately, at the present time, this project does not have any link to a hydrologic model and thus riverine surge coupling has not been achieved. There is no question that linking the surge system to hydrologic models is needed in the future.

Description of visit:

The Assessment team selected the CIFDP - Caribbean (CIFDP-C) as one of the 2 sub projects to visit. The other subproject visited was Fiji by Dr Ray Canterford. This project was selected because of the high vulnerability to a Coastal Surge catastrophe and because both NMHS's (Dominican Republic and Haiti) were also using the Flash Flood Guidance system which was also being assessed by another WMO GFFG Assessment team. Curt Barrett (USAID/OFDA) visited Dominican Republic September 17-18. This visit was coordinated by the Dominican Republic National Meteorological Service (ONAMET) and meetings and interviews were attended with the National Hydrologic Service (INDRHI), the National Tourism Agency (Tourist Planning Section), the Center of Emergency Operation Center (COE) and directly with weather forecasters of ONAMET.

Although the Caribbean CIFDP has not been delivered yet, all the personnel interviewed were well aware of the system that would be delivered. There was great anticipation to get the system operational. The Tourist group was very pleased to see this system coming to the island as the MEOWS and MOMS would be useful tools for planning and disaster preparedness (see example Punta Cana MEOW below, Figure 1).

Outcomes from visit

The main outcome from the visit was the lack of hydrologic models and information. It was clear there is an urgent need for hydrologic data for federal agencies and the public. Because of the impact of inundation on development, tourist architects are keen to obtain better resolution maps for representing infrastructure. They are limited in 1:50,000 resolution and apparently there is no lidar data available.

It was also clear that there is no ongoing coordination between the ONAMET and INDRHI for the CIDFP project. In our discussions, the hydrologic modelling of the Ozama river which travels through Santo Domingo, would be an excellent start of coupling a hydrologic model with the storm surge system. An MOU between INDRHI and ONAMET would be a good step to get the process moving for linking hydrology and meteorology.

As an important lesson on the need for ongoing funding, the CIDFP-C was stopped from 2012-15 because of a lack of funding. Thankfully USAID OFDA, with technical cooperation of NOAA, funded the project. This funding was predicated under the condition other countries can have access to the data, and these countries would the follow the template established by ONAMET.

The bathymetric data surrounding the Dominican Republic is an issue, with little data being available. For DEM, Jamie Rhome of NHC has obtained German Satellite high resolution DEM data, which are of sufficient resolution to not degrade model accuracy.

A CIFDP training workshop scheduled for December 2018 has invited approximately 10 people from different institutions (including both Dominican Republic and Haiti). This will be the first time the training is conducted across 3 languages (French, Spanish and English), and the first time participants from Haiti are invited, as well, hydrological specialists. Day 2 and 3 will be training for meteorologists and hydrologists and Day 4 for is designated for Decision makers. One concern is that this CIFDP is a powerful tool when operational but no one will understand the products. The Public being able to understand the information is also a concern.

The HURREVAC[2] program would be desirable if the Federal Emergency Management Agency (FEMA) would agree to allow the Dominican Republic access to the software.

Mr Jamie Rhome (NOAA NHC) has developed this CIFDP project to gain benefits from the Disaster Risk Reduction Planning Sector as well as Operational Application with the only computer requirement of a routine PC. This makes the system potentially a very sustainable one with possible broader applicability to other Caribbean countries.

Emergency Services (COE) in Dominican Republic works very closely with ONAMET to utilize warnings and execute decisions to minimize losses. This interaction and relationship were demonstrated in the delivery of flash flood warnings to community's disaster response centres.

It is likely this good relationship will lead to improved coastal flood alerts and warnings once CIFDP-C becomes operational.

Lack of funding plagues the planning for the final meeting in 2019, which will see all the stakeholders present. WMO is responsible for the funding of the final meeting but needs to access extra-budgetary resources to do so. At present, no extra budgetary resources exist to hold it, and WMO is faced with risk of not fulfilling its commitment to USAID, to complete the CIFDP-C.

[2] HURREVAC is a storm tracking and decision support tool to assist the local emergency manager in determining the most prudent evacuation time and the potential for significant storm effects such as wind and storm surge (see: hurrevac.com).

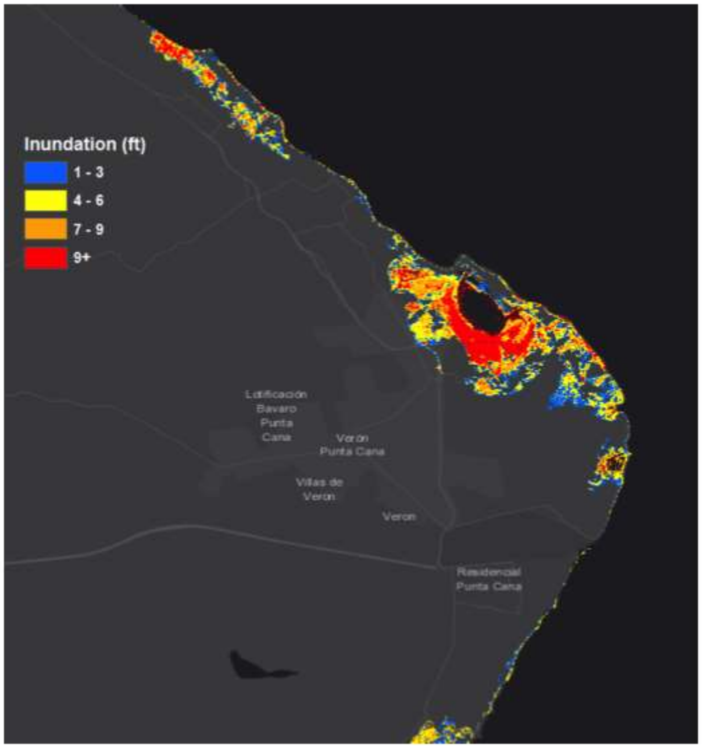


Figure 1:

Punta Cana- Category 5 MEOW

- The goal of this project was to develop and implement a system that strengthens with time, builds confidence and gains capacity and will be independent of NHC but NOAA NWS NHC can back up if needed!
- The idea of this approach was to turn multi-million dollar CIFDP projects into "$300,000" more affordable and sustainable projects.

6.4 Site Assessment Fiji

Sub-Project Background – why Fiji

Fiji is subject to all coastal flooding and inundation threats identified under the CIFDP. However, these hazards affect coastlines, cities and villages in different ways. Fiji and its islands are particularly vulnerable to all the coastal flooding phenomena: tsunami, storm surge, swell, extreme waves, tides, sea level rise (from climate change) and hydrologic flooding. As a demonstration project, the CIFDP has concentrated on two major areas of the main island Viti Levu: the Coral Coast on the southern edge of the island and NW coast around Nadi. Additionally, it has a serious flash flooding issue in many areas and this includes Nadi and surrounds.

Sub-Project Description

Following the standard procedures set down by the Project Steering Group, the Definitive National Agreement was signed in 2013 by all emergency service agencies at the highest level of government. The National Capacity Assessment, User Requirements Plan and the System Design Document were completed and published in 2014.

Essentially there are currently two components to the CIFDP in Fiji:

(i) the south coast subject to inundation from distant swell waves; and
(ii) the NW coast predominantly subject to storm surge (including from tropical cyclones) and hydrological flooding.

The Fiji CIFDP has now reached Phase 3 of the four-phase project. However, the training required in Phase 2 has been lacking. It was clear from the site visit that this was an essential missing component for all Fiji's systems, except perhaps the JMA Storm Surge model.

The expertise of the meteorologists and hydrologists has enabled the preliminary testing and evaluation without the formal training required for a full implementation. But the training (including for emergency decision makers) must be delivered prior to Phase 4.

Progress on the first component of flooding and inundation on the south coast has been significant.

This type of flooding is caused by low pressure systems, frontal systems or remote swell approaching Fiji from the south. Coupled with high tides this can lead to serious and disruptive inundation for those communities. Work by the Pacific Community (previously the South Pacific Community) on modelling these extreme waves has been instrumental in a small number of major events that allowed early and comprehensive warnings for the south coast (eg 24 August 2017 and 27 May 2018). Additionally, although the current Swell Model is calibrated to Maui Bay (the Coral Coast), there are three other locations to be integrated into the forecast system.

Description of visit

We selected Fiji as one of two sub-projects to visit for first-hand experience. The other site visit was by Mr Curt Barrett to the CIFDP-Caribbean, in particular the Dominican Republic of Hispaniola It was clear from Dr Canterford's site visit to Fiji that a recent major inundation event in May this year (2018) was captured and well forecast by the SPC coastal inundation model. Figure 5 below shows the media release based on the expertise within FMS supported by the model. It also shows the level of detail and warning that was able to be provided to the public. Indeed, the site visit was very encouraging in that the quality and innovation of the forecasters was of a high level with strong local input and understanding of the models, even if manual intervention was needed (such as tide heights).

It was clear during the visit that more ground truthing with wave rider buoys and sea level gauges is required to verify forecasts; and in addition there is a need for new model developments. Nonetheless there is overall better coastal inundation forecasts now due to CIFDP and the SPC Wave Swell model. For wave swell forecasts, alerts are broadcast 48 hours ahead of time and then warnings with a 24-hour lead time.

In terms of impacts, on the coral coast there is a major transport road plus tourist hotels. Inundation is huge problem. Forecasters are always being asked what the inundation will be and now they have some valuable data from the SPC model. Otherwise they were doing it blind. However, they need better independent verification to determine if the results are satisfactory.

Figure 2: Car stuck in Kings Highway due to over wash (24 May 2018 event) – in line with FMS media release (see Figure 5 below). (Ref: Herve Damlamian and Jens Kruger SPC.)

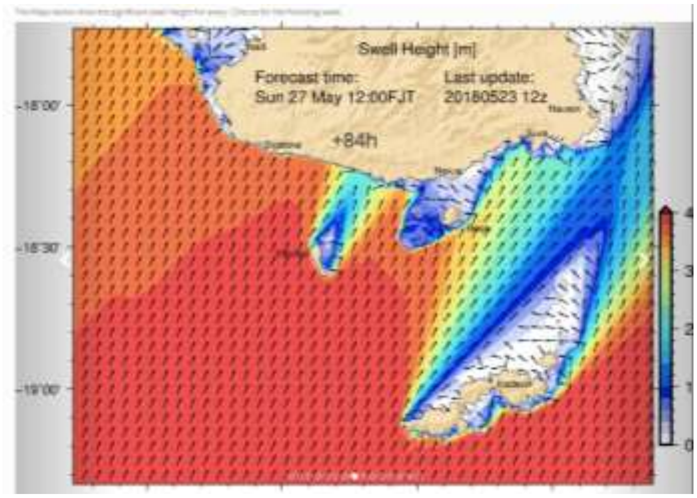


Figure 3

Predicted wave field off Maui Bay, Coral Coast 27 May 2018.

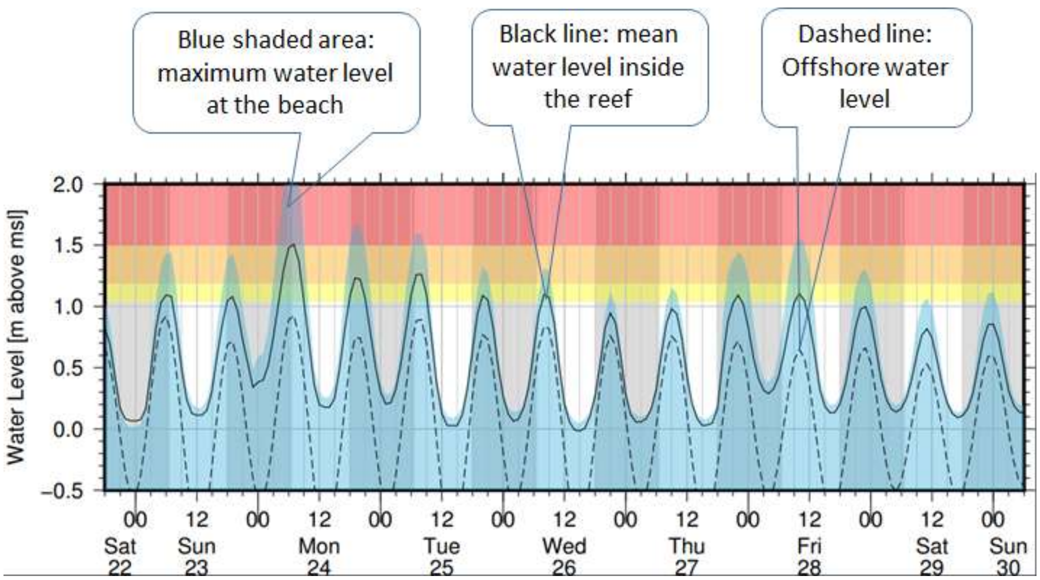
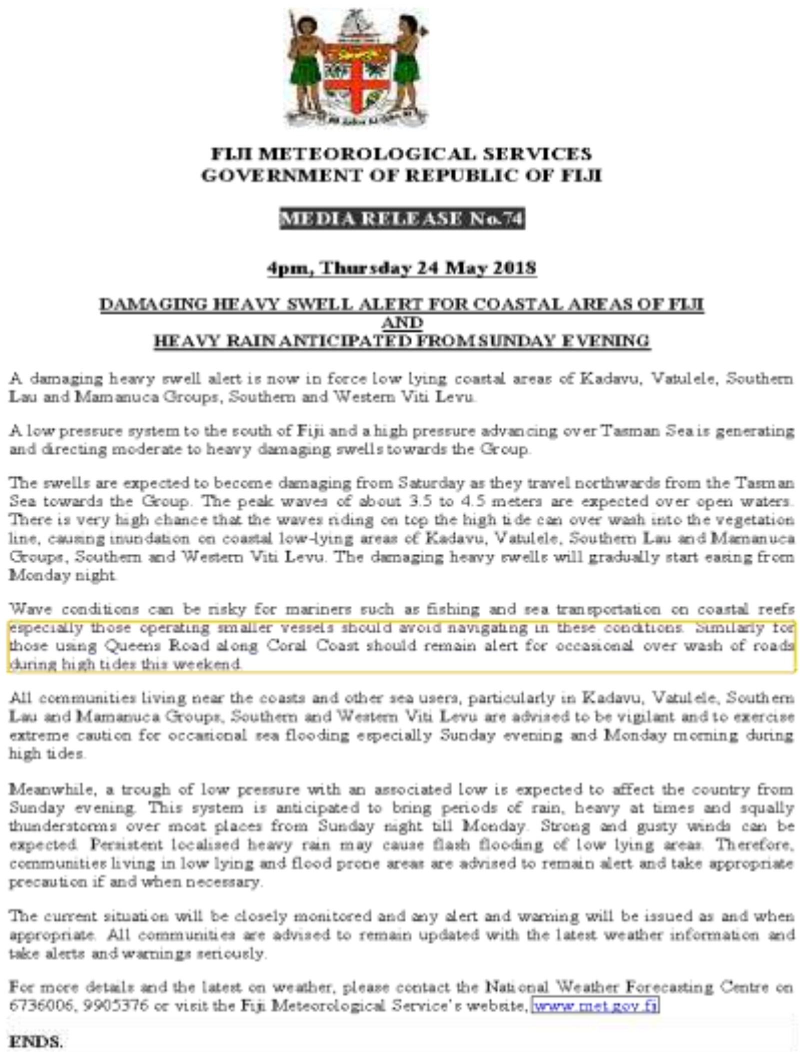


Figure 4

Forecast for Maui Bay 22-30 August 2017



FIJI METEOROLOGICAL SERVICES
GOVERNMENT OF REPUBLIC OF FIJI

MEDIA RELEASE No.74

4pm, Thursday 24 May 2018

DAMAGING HEAVY SWELL ALERT FOR COASTAL AREAS OF FIJI
AND
HEAVY RAIN ANTICIPATED FROM SUNDAY EVENING

A damaging heavy swell alert is now in force low lying coastal areas of Kadavu, Vatulele, Southern Lau and Mamanuca Groups, Southern and Western Viti Levu.

A low pressure system to the south of Fiji and a high pressure advancing over Tasman Sea is generating and directing moderate to heavy damaging swells towards the Group.

The swells are expected to become damaging from Saturday as they travel northwards from the Tasman Sea towards the Group. The peak waves of about 3.5 to 4.5 meters are expected over open waters. There is very high chance that the waves riding on top the high tide can over wash into the vegetation line, causing inundation on coastal low-lying areas of Kadavu, Vatulele, Southern Lau and Mamanuca Groups, Southern and Western Viti Levu. The damaging heavy swells will gradually start easing from Monday night.

Wave conditions can be risky for mariners such as fishing and sea transportation on coastal reefs especially those operating smaller vessels should avoid navigating in these conditions. Similarly for those using Queens Road along Coral Coast should remain alert for occasional over wash of roads during high tides this weekend.

All communities living near the coasts and other sea users, particularly in Kadavu, Vatulele, Southern Lau and Mamanuca Groups, Southern and Western Viti Levu are advised to be vigilant and to exercise extreme caution for occasional sea flooding especially Sunday evening and Monday morning during high tides.

Meanwhile, a trough of low pressure with an associated low is expected to affect the country from Sunday evening. This system is anticipated to bring periods of rain, heavy at times and squally thunderstorms over most places from Sunday night till Monday. Strong and gusty winds can be expected. Persistent localised heavy rain may cause flash flooding of low lying areas. Therefore, communities living in low lying and flood prone areas are advised to remain alert and take appropriate precaution if and when necessary.

The current situation will be closely monitored and any alert and warning will be issued as and when appropriate. All communities are advised to remain updated with the latest weather information and take alerts and warnings seriously.

For more details and the latest on weather, please contact the National Weather Forecasting Centre on 6736006, 9905376 or visit the Fiji Meteorological Service's website, www.met.gov.fj

ENDS.

Figure 5

Forecast and media alert for wave swell and coastal flooding from distant swell - five days lead time and community awareness though FMS Director press conference. Utilises CIFDP swell wave system.

The second component of the CIFDP Fiji is the NW coast, predominantly subject to storm surge and hydrological flooding. This is an equally important part of this Fiji CIFDP sub-project. Flooding of Nadi and surrounds is a major disruption to an important city, and can occur within 2 to 4 hours of a major rainfall event over the catchment. The site visit was particularly valuable to see the issue "on the ground" and allowed an extensive mission into the upper reaches of the catchment to view the complexity and sharp relief of the catchment.

Outcomes from visit

Whilst visiting the FMS and the upper reaches of the Nadi River catchments it was an opportunity to also view the operations of the forecasting office and the capability of the hydrological office within FMS (co-located after the 2012 major floods). It was pleasing to see the high level of expertise from the meteorologists (many trained in Australia), hydrologists, technical experts and

IT staff. Additionally, the leadership of the FMS is very encouraging of CIFDP for the future and for other countries in the region.

The sub-project is currently developing a Nadi floodplain inundation warning system (termed the Coastal Inundation Alert Support System – CIASS) supported by NIWA, New Zealand (G. Smart 2017-18). Also, the Japan Meteorological Agency (JMA) is providing a Storm Surge Model that will be in trial mode in 2018-19, with plans for operational implementation the following year. This runs on a Desktop PC with Australia maintaining the Tropical Cyclone forecasting module and wave boundary files.

A Phase 3 Review Meeting on 19-21 November 2018 will consider these models and their implementation in more detail. Planning is well advanced, and there is a good level of sophistication and knowledge that will be seen in this meeting making it ready for Phase 4 of the sub-project. It is encouraging to see this level of progress, interest and expertise being accorded the CIFDP-F.

The Nadi hydrological flooding is a particularly serious issue. Figure 6 shows the 2012 event. NIWA has assisted addressing this problem with the installation of 60 telemetered rain and river gauges, with an addition 4 by SUTRON (USA). Figure 7 shows the distribution along with Automatic Weather Stations. During the catchment visit undertaken by Ray Canterford, evidence was clear of the relative sparser spatial density in the Nadi catchments. Additionally, one or two key stations should be supported with nearby gauges for some redundancy given the criticality of early warnings using the current "manual" system. It also worth noting that dredging of the Nadi River at its mouth has been substantial in recent years and will continue. Additional efforts and investments are needed to include hydrological modelling as part of the multi-hazard early warning system.

Figure 6. Major Fiji flooding event January-February 2012 showing impact around Nadi and districts. Heavy rains caused unprecedented flooding and landslides, which led to a state of emergency being declared. Subsequently the hydrology unit was incorporated into FMS.

Given the limited available technology at FMS, the proposed CIASS is being designed with a straightforward decision tree logic to guide forecasters. This will create a coastal alert protocol with possible "look up" from pre-computed maps. This is necessary due to the very short lead times - essentially flash flooding. Figure 7 shows some of the important water level stations observed during the site visit. Nadi flooding forecasts usually start with a heavy rain warning - 100mm in 24 hours. Hydrologists then issue general flood alert. They then examine river height thresholds and commence issuing flood warnings, if appropriate. Several lives have been lost in flooding and it has had a major impact on the economy.

FMS are also aiming to become a level 3 regional Specialised Forecasting Centre but they are currently at Level 1. One of the drivers is the need to run the FFGS models, and this also requires more forecasters and IT support. This would help FMS issue Nadi flood warnings and also for other locations for Fiji and eventually the region where there are many vulnerable towns and villages. Forecasters and leadership believe that warning lead times are not enough. This was confirmed by an emergency services officer. Hence, there is a desire for hydrological models to eventually be used to base warnings upon for Nadi, and for their use elsewhere in the Fiji Islands.

Tsunami warnings are now **not** undertaken from FMS- they are done from the Mineral Resources Department (MRD) of the Ministry of Lands and Mineral Resources based on the Pacific Tsunami Warning Center (PTWC) in Hawaii advice. That department, MRD, has just installed the first batch of sirens and sends warnings via SMS. This is an area that should be explored in the future for cooperation in message dissemination for flash flooding (possibly utilizing cooperative sirens). This would strengthen CIFDP-F.

There are three radars on the main island but they would be of increased value if quantitatively used for flood forecasting. However, as such products are not yet available, the forecasters do find the JAXA satellite of good value for precipitable water, for example coming towards coast and over catchments, for some additional lead time.

In summary, it was determined that CIFDP is very necessary for Fiji. Coastal flooding can occur from storm surge, riverine and flash flooding, distant swell and very heavy rain. Of course, tsunami are another threat, and we believe (supported by a local interviewees and developers with many years' experience) that is should be included in CIFDP through a collaboration with MRD.

The CIFDP has brought a range of systems and skills and real opportunities for forecasters to make an important difference for the communities. However, project management and more training are needed:

- Training on the use of the SPC Wave and Swell Model is outstanding and the system needs to be installed in the FMS office, rather than a link back to SPC Suva.

- Training on the JMA storm surge model is underway and this model apparently has improved information on wave height.
- The Flood Warning Systems, current and planned should also have training and be fully developed.

Local experience is very important. Especially for the JMA storm surge model because FMS produces its own storm track that must be entered into the model. Even if this becomes automated, local knowledge is still needed for the tropical cyclone (TC) forecasting.

It is also important to recognise that the Fiji RSMC is responsible for Tropical Cyclones in the SW Pacific and through the CIFDP-F project and the JMA Storm Surge Model, RSMC-Nadi will in the near future improve its services to the region by providing storm surge forecasts to the region.

Figure 7.
Hydrometric Network in Fiji
Ref: G. Smart NIWA NZ

60 telemetered stations installed in Fiji with NIWA assistance

4 telemetered stations run by SUTRON

Figure 8
Sharp escarpment from Lake Vatura in headwaters of Nadi and Nawaka river catchments leading to rapid flooding in Nadi and districts (ref Photo R. Canterford 2018)

Figure 9 – photos below.
Photos from Backroad Bridge just outside Nadi showing Nadi River running about 0.5 m and with major floods of 11 m the entire farm and factory areas in the distance are flooded extensively with large impacts on exports.
(ref Photo R. Canterford)

7 GENERAL ASSESSMENT

7.1 Achievements against objectives: Strengths and Weaknesses

The following box outlines the objectives and summarises our overall assessment. More detailed discussion follows which identifies strengths and weaknesses of the total project.

> The CIFDP aims to assist countries with issues of coastal inundation from oceanographic and/or hydrological phenomena, resulting from severe hydro-meteorological events and tsunami, to operate and maintain a reliable forecasting system that helps the national decision-making for coastal management, through:
>
> Identifying the national and regional requirements; **EXCELLENT**
>
> Implementing open-source coastal inundation end-to-end operational forecasting and warning systems; **VERY GOOD**
>
> Developing cross-cutting cooperation among different scientific disciplines and user communities; **GOOD**
>
> Building communication platforms between researchers, forecasters and disaster managers involved in coastal inundation management; **GOOD** and
>
> Providing specialized training for operators, forecasters and disaster managers. **LIMITED**

As a result of this extreme loss of life due to a natural hazard/s and the vulnerability of coastal communities in low lying areas, the CIFDP was designed to facilitate the development of a comprehensive alert and warning system in coastal zones and basins subject to tropical cyclones and storm surges, strong wave action from distant sources (for example rogue waves and tsunami), tidal considerations and jointly with (fluvial) flood events.

This service and its demonstration sub-projects were designed with a view to improving safety-related services for the community. This is a fundamental priority of the WMO and therefore the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) and the WMO Commission for Hydrology (CHy) initiated the CIFDP. Its purpose is to meet challenges of coastal communities' safety and to support resilience building, through enhancing coastal inundation forecasting and warning systems at the national and regional scale.

To meet these needs, the demonstration process has been facilitated primarily by these two WMO Technical Commissions, in cooperation with numerous experts and related institutions in the field of storm surge, wave and hydrological flooding in order to deal with coastal inundation from the viewpoint of the Total Water Level Envelope (TWLE) [3].

While the CIFDP is designed to contribute to the improvement of the interaction of the national operational forecasting agencies (e.g. National Meteorological and Hydrological Services: NMHSs) with Disaster Management Agencies (DMAs), **we have evaluated that role especially through consideration of impact and sustainability.**

While undertaking this evaluation, case studies were also sought and examined in terms of lessons learned and subsequent improvements to the systems and services. They were examined through the lens of each sub-project's integrated coastal management strategy, including the development of preparedness, response and management strategies associated with coastal inundation.

In this assessment we found that the CIFDP phased approach with intermediate deadlines, workshops, local engagement and appropriate interagency agreements is a very good process. It is successful and succeeding in the sub-project locations and expected outcomes, to which the majority of stakeholders are contributing. However, development has been relatively slow for a number of reasons, including the ability to attract suitable funding and project management with sound project plans with attributed experts, volunteers and finances.

Our assessment of the sub-projects found they were quite unique in terms of coastal flooding issues and meteorological causes, even though the common high-level arrangements for the sub-projects were similar (thanks to the well-established procedures for development - Appendix B). In determining if they are sustainable, the institutional collaboration was more consistent across the sub-projects and less critical. Most critical is the capability and capacity of the NMHS who lead and deliver the products. In all cases we found those NHMS very focussed and engaged with the project, with much genuine appreciation for the assistance of the international experts, and agencies such as the National Hurricane Center, the Japanese Meteorological Agency and the Korean Meteorological Agency. We found there were many other agencies that also contributed and some are referred to in the Sub-project analyses below.

The outcomes of the sub-projects for Bangladesh (complete) and Indonesia (near complete) we found to be major improvements in coastal warnings for their vulnerable populations. However, both the Caribbean and Fiji are yet to demonstrate the same high level of service outcomes as they are still working toward attaining operational status. But our assessments of these two sub-projects, based on the interviews and questionnaires, backed up by our site visits, were that they were well on the way to successful implementation.

Summary of Weaknesses

3 The 1st JCOMM Symposium on Storm Surges (2-6 October 2007, Seoul, Korea), taking into account the emerging awareness of the need to promote the storm surge activity, strongly recommended to improve prediction for total water levels that is the real source of risk in coastal areas comprising tide, wave, surge and other factors.

The main weaknesses were found to be in the areas of funding, load on volunteers, load on WMO Secretariat staff (insufficient staffing of WMO Secretariat), time to deliver outcomes, training, lack of integration of hydrological data and models through coupling with inundation modelling in real time, lack of project structure to deliver the system needed (note: we observed a remarkable volunteer spirit of experts and stakeholders to make these projects a success, but this model of operation cannot realistically continue to meet the demand for coastal warning capability for the many countries in need) . We have identified these findings for each sub-project in the next section because they vary in importance and applicability to the unique locations and hazard types. Suffice it to say that, overall, we believe the weaknesses are not “show stoppers” in terms of value.

8 OECD DAC PRINCIPLES OF EVALUATION OF DEVELOPMENT ASSISTANCE: FOR COASTAL INUNDATION FORECASTING DEMONSTRATION PROJECT

In addition to the objectives of this review being to study the details of performance of the CIFDP sub-projects from various perspectives, it is also important to assess the overall project in terms of the standard OECD DAC Principles of Evaluation of Disaster Assistance. This is of value for donors and recipients for considering the criteria of relevance, efficiency, effectiveness, impact and sustainability of these sub-projects and the basis for future investment.

Appendix A provides a complete analysis and evaluation of the principles against these criteria. In summary, the Relevance and Effectiveness were rated very highly based on the interviews, questionnaires and site visits. Product usability ranged from good to promising for the sub-projects still to be completed. Impact was consistently very good to good across all sub-projects. Sustainability was rated similarly. In terms of system performance, these are still being developed for Fiji and the Dominican Republic and couldn’t be determined accurately at this stage. However, for Bangladesh and Indonesia systems performance was rated as very good.

Additionally, the Appendix A has a list of lessons learned and levels of satisfaction. The Lessons Learned are particularly useful for completion of current sub-projects and development of new ones. We have incorporated those reported to us and additional ones from our assessment.

In the questionnaire and in interviews we sought the general level of satisfaction of the various sub-projects. This varied from satisfied to highly satisfied. Note this range also includes differences between some stakeholders as well as the sub-projects.

9 REVIEW FINDINGS

Based on the Individual CIFDP Sub-Project assessments and the above General Assessment, we have consolidated a set of Findings (Table 1) for the overall CIFDP and a set for each of the sub-projects. We have also rated each finding as "Requires attention or treatment in the short term", "Requires consideration in future development" and "Successful finding – must continue".

We have tried to be pragmatic in these assessments, as the systems will no doubt mature over time and to isolate relatively small issues at this stage may detract from, and cause delays in the development and sustainability of the systems. More operational time for each sub-project is needed to assess the capacity of each, and whether these systems can be sustainable. Some of the findings may be obvious to some, but not others. Some findings had differing views from system developers or users, so we weighed these up based on our experience in building and operating similar systems (nationally and internationally), before making a finding (or recommendation for change).

Table 1: Findings is presented below with ratings as discussed above:

(red)	Requires critical attention or treatment
(orange)	Requires special consideration for future development
(green)	General finding – to be noted

No		TABLE 1: FINDINGS	Rating
		ALL CIFDP SUB-PROJECTS	
1		The CIFDP phased approach with intermediate deadlines, workshops, local engagement and appropriate interagency agreements was a very good process. It is succeeding in the sub-project locations and expected outcomes, to which the majority of stakeholders are contributing. However, solid project planning and execution would be necessary in the future.	
2		Individual sub-projects are quite unique in terms of coastal flooding issues and meteorological and hydrological causes, even though the common high-level arrangements were similar.	
3		Donor funding has been necessary for the CIFDP success. Both USAID and KMA believe the investment had been effective for the sub-projects with which they have been associated, which means 3 of the 4 sub-projects. Of course, supplemented funding or new funding for projects is essential.	
4		Volunteers, both at the national and international levels, are essential, but were found to be overstretched over the long implementation periods of several years.	
5		CIFDP has made a major capability increase for NMHS involved through access to international expertise in a formal project framework.	
6		New coastal inundation services, including storm surge, swell wave etc, were found in some instances to require a small additional forecaster capacity in the office.	
7		Standard performance objectives should be developed locally and by CIFDP experts for evaluation of success of systems and the coastal inundation forecasts as a product.	
8		Sponsor funding administration places a high transactional cost on the WMO Secretariat, especially if there are delays in some deliverables. However, funding management of the Caribbean sub-project is managed by NHC and this has proved agile and accountable to USAID.	
9		Most critical to success of each sub-project is the capability and capacity of the NMHS who lead and deliver the products.	
10		Large workloads and responsibility for coordination has fallen on the very small number of WMO Secretariat staff. This is exacerbated by their requirement to manage and account for donor funding.	
11		CIFDP has improved cooperation between NHS , NMS and NDMA, but still more is required.	
12		A strong local commitment by all relevant agencies in the country is essential.	
13		There is a need for continued interaction and coordination between coastal surge specialists, meteorologists and hydrologists.	

14		Establishing training programs and periodic reviews of training needs is critical.	
15		While skill scores have been good for researchers and some operational elements, a measure of impacts would be a more appropriate metric for operational value to the country for a cross sub-project analysis.	
16		Some observers feel that there has been too much emphasis on modelling systems rather than long term capability investment. This is not the majority belief.	
17		Robustness should be the ultimate goal but the state-of-the-art in different countries shows that expectations for the sub-project depend on the initial state of readiness or capabilities.	
18		More effort is needed to improve integration of hydrology, particularly hydrological observations and modelling, within the E2E EWS system project design.	
19		Some stakeholders believe that there is a need to be realistic about what can be achieved over 2-3 years and the importance of their commitment to the effort. Expectations need to be managed.	
20		There were mixed comments regarding the inclusion of tsunami warning into the CIFDP set of coastal inundation hazards. Negative comments related to different forecasting processes and lead time, while positive comments related to the parallel warning dissemination mechanisms. Majority view was for integration at least in the warning delivery component of the E2E system.	
21		Lack of training/decision-making is a problem in many countries and will likely remain a problem until positively addressed in any future arrangement.	
22		Maintenance of the system, regular component replacements and upgrades as well as training are all necessary to avoid the coastal forecasting system degrading.	
23		Local forecaster input is important/essential for all sub-projects, especially for impact interpretation when discussing with emergency managers and last-minute observations	
24		Project coordination and management is fragmented within the WMO Secretariat. CIFDP projects come into the Marine Meteorology and Ocean Affairs Division, flooding within the Hydrology and Water Resources Division, but also the CREWS Secretariat is involved in projects that include CIFDP. This lack of coordination and integration of projects and funding coordination is a barrier to establishing standardized funding processing and linking project goals to technical and financial resources within the organization. WMO needs to address future coordination as to how it will handle MHEWS projects, of which CIFDP is extremely important.	
25		CIFDP projects have been successful for 2-sub projects completed and will be successful for remaining 2 projects if training occurs as planned. However, linkage to country ministerial financial support has not proved successful in three of the fur sub-projects. In fact, this shortcoming is widespread deficiency to all MHEWS projects including GFFG and SWFDP projects. This disconnect leads to an unsustainable situation and frequently to failure of operational capability.	
		BANGLADESH	
1		The CIFDP Bangladesh sub-project is the most advanced, having completed operational implementation, Stage 4, in December 2017. All evidence points to a successful outcome for all	

		stakeholders.	
2		Funding by USAID was critical to this sub-project, which covers the whole country which has complex coastal morphology, potentially massive loss of life from inundation from a large number of storms and hazards.	
3		CIFDP is an exemplar in terms of utilising international systems and data.	
4		Since the operation of the system, fewer lives are being lost (26 in 2016 and 2 in 2017) compared to thousands in 1998 and 2007 events. Other factors can contribute to the reduction as well as CIFDP.	
5		More work is required (especially the improved integration of hydrology). This also includes improved bathymetry and DEM resolution and installation of additional tide gauges, with possible remediation of the existing ones.	
INDONESIA			
1		Unique causes of flooding arise from the 100,00 km coastline and land subsidence resulting from development, which increases risk.	
2		The capability and readiness of the Indonesian Meteorological Climatological and Geophysical Agency (BMKG) was a key to its success	
3		Coupling between hydrologic and coastal inundation models was found to be basic and require further work.	
4		Primary funding by BMKG was a key to its success so far and WMO regular budget support was important.	
CARIBBEAN			
1		The major issue is lack of hydrologic models and information. There is an urgent need for hydrologic data for federal agencies and public.	
2		Tourism architects need higher resolution maps for representing infrastructure. They are limited in 1:50,000 resolution. Apparently, there are no lidar data available.	
3		Lack of ongoing coordination between the ONAMET and INDRHI for the CIDFP sub-project. Hydrologic modelling of the Ozama river would be an excellent start of coupling a hydrologic model with the storm surge system.	
4		Stakeholders report reduction in property damages and loss of life, but also improved land-use planning for coastal areas.	
5		An MOU between INDRHI and ONAMET would be a good step to get the process moving for linking hydrology and meteorology.	
6		The CIDFP was stopped from 2012-15 because of a lack of funding until USAID OFDA, with technical cooperation of NOAA, funded the project.	

7		The bathymetric data surrounding DR is an issue. Little data is available. German satellite high resolution DEM data were available and found to be sufficient for model accuracy.	
8		CIFDP-C training is essential and December 2018 workshop has sessions for different institutions. Day 2 and 3 will be training for meteorologists and hydrologists and Day 4 for is designated for Decision makers.	
9		The HURREVAC program would be desirable if FEMA would agree to allow the Dominican Republic access to the software.	
10		NOAA NHC (Rhome) has developed this CIFDP project to gain benefits from DRR Planning Sector as well as Operational Application with the only computer requirement of a routine PC makes this system as a potentially very sustainable system possibly applicable to other Caribbean countries.	
11		Emergency Services (COE) in Dominican Republic works very closely with ONAMET to utilize warnings and execute decisions to minimize losses. This interaction and relationship was demonstrated in the delivery of flash flood warnings to community disaster response centres. It is likely this good relationship will lead to improve coastal flood alerts and warnings once CIFDP-C becomes operational.	
FIJI			
1		Training is a major concern to local staff for Phase 4 (and ongoing) for forecasters, IT, hydrologists, and emergency managers to interpret the coastal inundation information and, as pointed out by forecasters, mass-media training because of the heavy dependence on radio broadcasts.	
2		The Fiji CIFDP has now reached Phase 3 of the four-phase project. However, the training required even in Phase 2 has been lacking.	
3		Linkages between the Nadi catchments stream flow and other coastal flooding is minimal. There are no cross-sectional data and only basic stage and rainfall data, therefore locally considered more as nowcasting than forecasting. There is a need to develop discharge data and hydrological modelling capabilities.	
4		There is an important need for one or two key stream gauge stations (as a minimum). Nadi catchments should be supported with new nearby gauges for some redundancy, given the criticality of early warnings using the current “manual” system.	
5		The expertise of the meteorologists and hydrologists has enabled the preliminary testing and evaluation without the formal training required for a full implementation. But it must be delivered prior to Phase 4.	
6		Progress on the first component of flooding and inundation on the south coast has been significant. With installation of systems in the FMS and receipt of training, it will be complete. However, the system is not installed on computer systems in FMS. There is only a link to Suva. Must be rectified ASAP.	
7		The quality and innovation of the forecasters is at a high level with strong local input and understanding of the models, even if manual intervention is needed (such as accounting for tide heights).	

8		Additionally, the strong and effective leadership of the FMS is very encouraging for the future use and sustainability of CIFDP and for its ability to assist other countries in the region. There is a high level of expertise from the meteorologists (many trained in Australia), hydrologists, technical experts and IT staff.	
9		Tsunami forecasts should be explored in the future for cooperation in message dissemination and flash flooding (possibly utilising cooperative sirens). This would strengthen CIFDP-Fiji.	
10		The CIFDP-Fiji, although not complete, has been a success for the country and meets the outcomes of institutional collaboration markedly. Evidence includes forecasting and publicly warning of a major inundation event in May this year.	
11		Because of its role as a RSMC, the Fiji Meteorological Agency is well placed to assist implementation in other countries in the region.	
12		Forecasters in the FMS report that the storm surge forecasting will be extended to their Pacific region of responsibility through the WMO Tropical Cyclone Watch Programme.	
13		The SPC Wave and Swell Model for the Coral Coast could be extended to the outer islands of Fiji. However, it requires some strengthening to be a full “operational” system.	
14		There is no backup for the Coral Coast swell model; and it relies on global model and satellite data links from NOAA/BoM/Copernicus.	
15		JMA storm surge model and wave and swell model do not have astronomical tides included, so forecasters add these manually to obtain accurate storm surge levels.	
16		The CIFDP has brought a range of systems and skills and real opportunities for forecasters to make an important difference for the communities.	
17		Local experience is very important. Especially for the JMA storm surge model because FMS produces its own storm track that must be entered into the model.	
18		The Fiji RSMC is responsible for TCs in the SW Pacific and through the CIFDP-F project. The JMA SS Model, RSMC-Nadi could in the near future improve its services to the region by providing SS Forecasts to the region	

10 RECOMMENDATIONS and THE WAY FORWARD

As reviewers we were asked to assess the effectiveness, efficiency, impact, relevance and sustainability of the demonstration phase of the CIFDP through is achievements, weaknesses and the current sub-projects.

On the basis of our extensive and independent review of the CIFDP and all its sub-projects, we consider that the CIFDP has been a success in reaching its objectives (Appendix B**).** Two of the original four sub-projects are completed or about to be completed, and the remaining two are well on their way to successful completion, provided key steps are achieved in the next 12 months.

We also consider that the impacts and risks of coastal flooding in developing countries are too high to allow this coastal forecasting system to be abandoned. It is now more relevant than ever before with increasing development and vulnerability of the world's coastlines, especially considering increasing impacts of sea level increases and climate change. The originators and visionaries of the CIFDP were ahead of their time in addressing such a complex technical, project driven and policy demanding problem.

The Table 2 below lists all our Recommendations. Those rated as green are the current state of play that we believe should continue with due recognition of areas for improvement. They also list some of the strengths of the CIFDP, which were summarised in Section 7.1. Those in orange really need to be addressed during the completion phases (3 and 4) of the CIFDP-C and CIFDP-F. Those high priority recommendations in red are generally technical ones that should be addressed as soon as possible.

With regard to training, which we have rated as red, Coastal Inundation Forecasting (CIF) is a multidisciplinary forecasting task. It involves meteorologists, hydrologists, NMHS senior managers and emergency managers, who need to consider the impacts on the community with under or over warning, utilising often diverse and incomplete information. As these events are often relatively rare, forecasters may only see a handful of the more extreme events during their careers. Additionally, ground truthing is often sparse.

Training must therefore involve local knowledge of impacts, ability to understand models and the interactions and composite factors of several hazards. It is not just about "service products". We believe therefore that more attention is required to training, capacity building of staff, and coordination and outreach with end users such as DMAs and the media. This is always a problem, even in highly developed countries with sophisticated forecast and information distribution services. We would expect that training for users (first responders, media, DRR higher decision makers) would be an integral part of the roll-out of CIF everywhere. This training should include a broad overview of the input data and products; how they are integrated to give the final output products; the uncertainties of the output products and their relation to the inputs; the applications of the output products; and the value of the products, within the limitations of uncertainty and worth to society. Perhaps external experts could be engaged to do proper benefit analyses of the output products, if effectively applied, to clearly demonstrate their utility.

Secondly, we were asked to determine findings and recommendations on the way forward for the CIFDP. Having assessed that it has been, and continues to be a success, we recommend that it should continue in a re-governed form.

In considering the transition to a new "non-demonstration" paradigm we have also recommended the replacement of the Project Steering Group with that of a Working Group within JCOMM and/or CHy or any new WMO structure.

Meteorological and Ocean Lead (JCOMM) – close collaboration with hydrology

The first scenario we propose is that this should continue to be led by the WMO Department for Weather and Disaster Risk Reduction in close cooperation with the Climate and Water Department. A resolution would be put to Congress jointly by JCOMM and CHy presidents.

However, a new Working Group on Coastal Inundation Forecasting should maintain and build on the successful work of the experts in the current PSG, but also allow new projects to be led by new independent experts both in-country and internationally. This would avoid the heavy workload on the current PSG volunteers.

We have examined the Terms of Reference of the CIFDP PSG throughout our assessment and believe they are suitable to be closely adapted, and adopted, by the new Working Group. The main possible changes would be for increased emphasis on training of national forecasters and further information packages for national disaster agencies, as well as an increased emphasis of integrating hydrological aspects with CIFDP sub-projects. This could be supplemented by a dedicated training expert within the CIF Working Group. The WMO Training unit should also be engaged for advice.

The new governance will also need to be considered in the context of possible integration with the FFGS and SWFDP, as will be determined in PART B to meet the recommendations of the WMO Executive Council Working Group on Disaster Risk Reduction.

By using this new paradigm of governance, strong links will be able to be maintained and strengthened with Sendai Framework, the Paris Agreement and the 2030 Agenda for Sustainable Development.

It should be recognised that the future governance should be adaptive to take account of any new WMO commission structure. Nonetheless, it presents a real opportunity for a "ground floor" establishment of the new CIF Working Group.

In taking this direction, the Coastal Inundation Forecasting services should be a recognised component of a Multi-Hazards Early Warning System.

Hydrological Lead (CHy) – close collaboration with meteorology and oceans

A second scenario is also possible, especially within any new WMO reform structure. Due to the WMO links to the UNISDR being even greater with climate change impacts on coastal communities, their extant standard classification of Natural Hazards is a useful guide for the multitude of hazards and how these are treated. The Emergency Events Database (EM-DAT) initiated by CRED (Centre for Research on the Epidemiology of Disasters and the USAID/OFDA) is the custodian of these standards for disasters. In the associated ISDR[4], flood, landslide, wave action, coastal flood etc are labelled "Perils" of the Hydrological Family of disasters. The use of this classification of perils is consistent with WMO's impact-based forecasting and risk reduction. In this regard the Coastal Inundation Forecasting services could be led within the hydrological areas of WMO.

Although the original vision for CIFDP arose through JCOMM, it has become clear that in the new paradigm of impact-based forecasting that the hazard "on-the-ground" is flooding in the coastal areas. This can be caused by many meteorological, hydrological and geophysical phenomena. As mentioned above this is consistent with the UNISDR/ISDR classifications.

It is clear that this option would still require strong linkages with meteorological and oceanographic experts and modelling systems. It would also help ensure a stronger hydrological focus as CIF moves forward.

Integration into a Multi-Hazard Early Warning System

A third option recognizes that in most countries, the coastal flood warning system is part of the umbrella of a multi-hazard early warning system. In general, NMHS's are mandated to deliver warnings for weather, water and climate hazards including coastal flooding, flash flooding, riverine flooding, storm warnings such as hurricanes or severe thunderstorms, and tsunamis. It seems natural that the CIFDP be integrated into the existing MHEWS at the NMHS. Should this approach be taken, linking to the hydrological services component of the MHEWS will be a challenge and would need focused attention. This is particularly so as meteorological and hydrological warning services may not fall under the remit of one national agency. This integrated services level of delivery of warning systems and services could be considered by WMO at a programmatic level as an alternate management and programmatic structure for not only managing Coastal Flood Warning programs but including severe weather and hydrological warning services as an integrated end-to-end system to be executed by NMHSs. This is an option that could be considered by the various WMO programs and managers to consolidate existing resources into a MHEWS Program or joint or multidisciplinary Working Group or Expert Team. This consolidation could create improved leverage of existing limited technical resources but would not solve the funding issue which is essentially the limiting factor for expansion of CIFDP to the many countries that have

[4] IRDR's main legacy will be an enhanced capacity around the world to address hazards and make informed decisions on actions to reduce their impacts. This will include a shift in focus from response–recovery towards prevention–mitigation strategies, and the building of resilience and reduction of risk through learning from experience and the avoidance of past mistakes.

requested this capability. The funding issue will require a much better education and marketing effort by WMO directed to the donor and financial institution industry explaining the need for countries to implement MHEWS with emphasis of Coastal Flood Warning for countries with significant coastal vulnerabilities such as Island States. As well, funding resources should include funding for project management (eg Project Appointment of staff to handle only the extra budgetary activities).

Comparison of Scenarios

Given these scenario considerations, the most overwhelming imperative is to save lives and property in coastal zones that are becoming even more vulnerable with climate change, and are subject to increasing coastal populations and development. Within the current WMO structure, we believe that the linkages of hydrological modelling (e.g., riverine forecasting and FFGS) with CIFDP would weigh the outcome to scenario two, a hydrology lead, or scenario three, the MHEWS governance. Any new organizational structure of WMO should be considered for the best sustainable outcome for Coastal Inundation Forecasting. Lack of linkage of CIFDP projects to the Ministerial level of the sub project countries threatens the sustainability of the CIFDP operational continuity. A new approach to capacity building needs to be developed based on “lessons Learned” that enhances links to governments owning and operating CIFDP and MHEWS projects in general so that these successful technical systems can be sustained. Whichever scenario is adopted (Part B), an “Implementation Guidance Manual”[5] should be developed to assist new countries or regions in their consideration of pursuing a CIFDP/CIF project. A Task Team should develop the Manual and use the recently developed Hydrology EWS Guidelines as a starting point.

As highlighted in our findings and recommendations, regular budget and donor funding have been and will continue to be a major issue. In CIFDP, we have seen three main funding sources: USAID, KMA and Indonesian self-funding. They have been supplemented by WMO regular budget, but these projects would not have been possible without donor contributions. Funding from various sources such as CREWS, Green Fund, World Bank, WMO VCP are also options. By having an ongoing governance arrangement as discussed above, this may provide a more attractive option

[5] The “CIF Implementation Guidance Manual” should include such features as:
(i) a full Risk Assessment of the coastal natural hazards affecting the country/region;
(ii) determination of stakeholders followed by an inaugural meeting to discuss funding, requirements etc for each and linkages to NMHS and ministerial funding possibilities;
(iii) assessment of all instrumentation, software, forecasting and end user distribution requirements;
(iv) a full cost/benefit study for each hazard and in combination;
(v) a comprehensive examination of donors internally and externally;
(vi) an engagement of experts to advise on best measurements, models and product needs;
(vii) preparation of a formal Project Development Plan (PDP) in consultation with stakeholders and donors;
(viii) desk based scenario testing;
(ix) a field scenario test of the end to end system which would assume particular instruments and models are in place; and
(x) A go/no-go assessment in consultation with the WMO Working Group for CIF.

for donors, especially noting the success of the current projects if properly promoted in terms of minimising community losses.

The recently published "Multi-hazard Early Warning Systems: A Checklist" by WMO (2018)[6] based on the outcomes of the Multi-hazard Early Warning Conference, 22-23 May 2017, Cancun Mexico, outlines the fundamental elements (checklist) for an MHEWS based on many natural hazards and capabilities of nations. It is a modern and well thought out set of criteria. They include four elements with component attributes. These include:

(i) Disaster risk knowledge;
(ii) Detection, monitoring, analysis and forecasting of the hazards and possible consequences;
(iii) Warning dissemination and communication; and
(iv) Preparedness and response capabilities.

It is clear from our analysis of the fundamental elements and the component attributes that the CIFDP meets all requirements for a MHEWS (stand alone or integrated with other MHEWS), but there are some areas that may need strengthening in the still-to-be completed Fiji and Dominican Republic sub projects. For example, in number two of the fundamental elements, the "Detection and monitoring components", these latter sub-projects need to be enhanced with additional ground truth and monitoring instruments, as recognised in our findings. In future, and in combination with other potential components of an End-to-End MHEWS such as flash and riverine flood forecasting (e.g., FFGS) and SWFDP, this can be explored further.

	TABLE 2		
	Sub-Project	**RECOMMENDATIONS**	**Rating**
1	All current	The CIFDP has reached a stage of maturity and impressive success against its original objectives such that it should NOT be considered "demonstration" in future.	
2	CIFDP-C CIFDP-F	CIFDP-Caribbean and CIFDP-Fiji are clearly progressing substantially and should continue with "demonstration" being removed from their titles in order to raise their profile nationally and within government.	
3	All current	It is strongly recommended that integration and linkage with hydrologic observations and modelling be standard protocol for all future project design systems and be retro fitted into the 4 existing sub projects.	
4	All current	Training for operators and decision-makers MUST be boosted through engagement of the WMO Training Programme as a facilitator, utilising expertise of the donor component systems (such as Storm Surge modelling). A dedicated expert officer in the implementation is necessary.	

[6] https://library.wmo.int/doc_num.php?explnum_id=4463

5	All current and future	Current and future projects should avoid private companies recommending their own component solutions unless they are internationally utilised by "donor" NMHS who can provide sustainable support.	
6	All current and future	Volunteers, national and international, are essential but should not be taken for granted in project planning over long periods.	
7	All current and future	WMO Secretariat staff must be augmented by donor-funded project staff. This should not be ignored. When budgeting new projects, funds for project manager and administrative support should be included.	
8	All current and future	Provision for regular external (to the NMHS) follow up for Monitoring and Evaluation or "audit" purposes should be built in to project plans to consolidate plans and maintain in-country profile.	
9	All current and future	If not a role already for the NMHS, tsunami warning procedures, albeit a different phenomenon with shorter lead time, should be considered for incorporation into CIF plans, especially the benefits of public message distribution and sirens.	
10	Future	Identification of sponsors and funding arrangements should be "locked in" prior to the commencement of a new project. The success of sponsors such as USAID and KMA should be used as examples of "large payoffs" for targeted funding.	
11	Future	Additional forecasting staff, although relatively small (approximately one full time equivalent (FTE) staff member) must be planned for in the NMHS which is taking on the CIF role in the future. Necessary to avoid failure of the system, which relies on local input.	
12	Future linkage to Sendai and DRR	CIFDP and its outcomes should be promoted as a concrete example of addressing the Sendai Framework for Disaster Risk Reduction 2015-2030 Targets and Priorities for Action. In particular the Target: "Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030."	
13	Future Direction	A "WMO Coastal Inundation Forecasting Implementation Guidance Manual" (WMO CIF Implementation Guidance Manual) should be developed by 2020 to capture the fundamentals of CIFDP and be recognised as a WMO contribution to the Sendai Framework for Disaster Risk Reduction and in recognition of the United Nations International Strategy for Disaster Reduction (UNISDR), specifically the IRDR (Integrated Research on Disaster Risk). We recommend a Task team be established to accomplish this task and the starting point should be using the Guidelines to establishing E2E EWS as a basis but adapted to coastal system.	
14	Future Governance	Replace the CIFDP Project Steering Group role with the appropriate WMO Working Group or Expert Team with JCOMM, CHy or a new WMO commission restructure.	
15	Future Governance	Within the WMO CIF Implementation Guidance Manual, recommend a group of international scientific and project experts be identified to coordinate new implementations. These may include some current members of the PSG.	

16	Future Direction	Due to the reliance of these CIF systems on external global models, satellite and other data, all systems must have in place a backup link. This is a relatively unique aspect, but critical because of the catastrophic nature of events.	
17	Future integration	Subject to the outcomes of the Part B assessment of coordination with FFGS and SWFDP, at least the FFGS and riverine flooding should be component of the WMO CIF Implementation Guidance Manual.	
18	Future "home"	Integrate the Coastal Inundation Forecasting as a recognised "impact based" service component for Multi-Hazards Early Warning Systems.	
19	Future Organization and Funding	WMO is fragmented on how projects are set up and managed. This has to change. It is a barrier to effectively managing multiple projects, bringing in the correct technical resources needed and is extremely ineffective use of the scant technical resources available to meet project direction needs. CIFDP, SWFDP and FFGS are all E2E EWS projects that need coordination. Also donor funding management strategy needs to be established as to how funds are marketed and managed for MHEWS projects.	
20	Sustainability	Lack of linkage of CIFDP projects to the Ministerial level of the sub project countries threatens the sustainability of the CIFDP operational continuity. A new approach to capacity building needs to be developed based on "lessons Learned" that enhancers links to governments owning and operating CIFDP and MHEWS projects in general, so that these successful technical systems can be sustained.	

11 CONCLUSIONS

This assessment has followed the requested ToRs of the WMO to determine the performance of the Coastal Inundation Forecasting Demonstration Project (CIFDP) over the last 10 years and recommend a way forward based on our findings and recommendations.

In undertaking the study, we were grateful to the large number of developers, experts and end users who participated in interviews and an extensive questionnaire. The questionnaire was based on the fundamentals of the OECD DAC Principles for Evaluation of Development Assistance, focussing on relevance, efficiency, effectiveness, impact and sustainability.

We have concluded that the CIFDP has been very successful and has been particularly well managed throughout. It was initiated in 2009 by forward thinking experts and has become even more relevant today.

We were impressed by the level of cooperation in the four countries where sub-projects were implemented; and the fact that two of those countries have now successfully completed their systems.

In summary we believe that the CIFDP can and should move away from "demonstration" to a WMO operational template End-to-End Early Warning System, or Multi-Hazard Warning System, such that it can benefit from direct capacity building and allow more systems to be implemented in other countries. To this date it appears that the governance of the sub-projects has been sound and all-inclusive of stakeholders and implementation has been meticulous, albeit there is a need to more adequately strengthen the hydrological aspects.

Nonetheless, in moving forward the governance needs to change and be incorporated with a multidisciplinary Working Group of WMO. New projects would then have “independent” project experts and the implementation would be overseen by this new WMO Coastal Inundation Forecasting Task Team or a MHEWS Task Team.

Again, funding and additional resources should be achievable in the right stable governance arrangements. It is important for WMO to recognize the need to improve awareness and educate finance institutions of the importance of MHEWS with emphasis of Coastal Early Warnings to Islands and countries with significant coastal vulnerability. Our report makes those recommendations in the “Way Forward”.

12 APPENDIX A

Assessment for the CIFDP against OECD Principles of Evaluation of Development Assistance:

APPENDIX A	
OECD DAC PRINCIPLES OF EVALUATION OF DEVELOPMENT ASSISTANCE **FOR COASTAL INUNDATION FORECASTING DEMONSTRATION PROJECT**	
1. Relevance & Effectiveness	**Evaluation**
Main Findings **Rating**: Highly Relevant, very effective.	The CIFDP was found to be highly relevant for all sub-projects. The two countries that have it implemented (Bangladesh and Indonesia) have reported positively from all sides: forecasters, developers and users. This is documented in the final/near final reports. The other systems in development: Dominican Republic and Fiji have reported it as being extremely relevant and having met, to this stage, expectations and objectives. They already have some relevant and promising case studies. More work to be done. There is a desire for Dominican Republic and Fiji to indeed extend the capability of the current systems, although embryonic, to other countries/areas in their countries or regions. In country experts recommend that additional training (even for end-users and the media) is that CIFDP has, and will, enhance relevance. When examining Bangladesh, for example, the strong belief (supported by good statistics) is that the new service can reduce loss of life (see main report). It was found that the outputs of the new services are consistent with the planned outcomes. There is no doubt the original aims of the project to evaluate and assess stakeholder requirements was met. Effectiveness was measured in terms of meeting objectives and can this be reproduced in other locations/countries, which was commented upon by many respondents. We felt that designers/ developers/implementers were slightly less positive than the users in country and therefore we (as reviewers) felt it was "effective". This is understandable in that they had to break new ground in establishing the services. However, the users (NMHS) could see the value of the

<table>
<tr><td></td><td>service “on the ground” for their populations and rated them as highly effective. Overall, we therefore rate is as very effective.

The leadership and experience of the country NMHS has been a major contributing factor to the relevance and effectiveness.</td></tr>
<tr><th>2. Product Usability</th><th>Evaluation</th></tr>
<tr><td>Main findings

RATING: <u>Good</u> for Bangladesh and Indonesia. <u>Promising</u> for Dominican Republic and Fij, with some successful events already.</td><td>Based on interviews, questionnaires and comments during site visits and workshop reports, the completed/near complete sub-projects have useable products and valuable input to existing products. Forecasters can utilise model outputs to tailor products, but more can now be done. Enhanced training would be valuable here.

Coupling between hydrologic and coastal inundation models is often minimal which remains a problem in terms of usability. However, the integration by local forecasters mitigates this for the time being.

Both the Dominican Republic and Fiji are showing some real innovation in terms of products. Fiji, a little more advanced, uses media and FMS Director and others as spokespeople to maximise the benefits for the vulnerable communities and tourists on its southern coastline.

Comments were received from forecasters for these sub-projects that the products were not very “user friendly” due to their technical nature. That is why some information is integrated into standard products like severe weather bulletins. This of course should continue, but stand-alone simpler graphics and text would be valuable.

Experience in Bangladesh (completed) from decision makers is that they are very satisfied with products while for Indonesia it is good so far and will be confirmed a final meeting in January 2019.

Adequacy of decisions concerning issuing alerts or warnings derived from CIFDP products is case and location dependent. They are very good in Bangladesh and Indonesia, but due to the Phase 2/3 in Dominican Republic and Fiji it depends where, for example Fiji’s southern coastline (Coral Coast) is adequate for decision makers but its western coastline near Nadi is limited at this stage. Progress is good and in two years this will be significantly improved with an operational JMA storm surge model set of products.

It is clear that manual input to products can, and is, done by forecasters. This is critical for last minute observations and quality control. Some models also require manual input (eg JMA Storm Surge for Tropical Cyclones requires manual input from TCs at this stage) as well as tidal information.</td></tr>
</table>

3. Impact	**Evaluation**
Main findings **RATING:** Very Good for Bangladesh and Indonesia. Good examples already, very promising for Dominican Republic and Fiji upon completion.	The main impacts of CIFDP were seen as: − Reduction in lives lost due to coastal flooding based on statistical evidence, lead time of warnings as well as local stakeholder views; − scientific forecasts to provide essential guidance on impacts with greater confidence and acceptance by communities; − alerts and forecasts have been welcomed by all stakeholders - there was essentially little information prior to CIFDP with major loss of life and property; − strengthened community of ocean/hydro/meteorological forecasters in the country/region; − heightened awareness of emergency services in NMHS role and services in CIF. The government, media and other Stakeholders report reduction in property loss and loss of life. Additionally, they report improved planning for coastal areas. The NMHS also report increased capacity and capability due to capacity building of international experts, governments and donors. They now have access to new international modelling for some hazards.
4. Sustainability	**Evaluation**
Main findings **RATING**: Very Good for all sub-projects	All sub-projects have clear evidence of sustainability. The major reason is that coastal inundation forecasting is now seen by the emergency services and the community as a major deliverable by the counties NMHS. In the short term (2-3 years) there will need to be some funding and/or expert support for the existing sub-projects to take them through the "bedding-down" of the systems with perhaps some adjustment to models, training etc. Clearly any system/process must be continually reviewed and tested. New software needs to be continually updated/added. This is always a challenge, but the fact that the NMHS is the custodian of the system, and WMO continues to be providing international oversight at the same level as other forecasting services is a strong indicator that this will be achieved. In this regard, the importance of the new governance model will be important to the existing sub-projects as well as new ones.

5. System Performance	**Evaluation**
Main findings **RATING:** <u>Very Good</u> for Bangladesh and Indonesia. As the other sub-projects are still in development, to be determined.	The completed systems (Bangladesh) and near completed Indonesia have been assessed as having sound system performance. Both systems are to yet have a formal integration from the hydrology component, but apart from this the systems are very much based on international models and support data. We have not received any negative comments on performance or witnessed any. Performance modelling is mainly about fine-tuning models, which is an ongoing function and requirement. As for the Dominican Republic and Fiji, they are still in the mid-period of the project. From the on-site visits we were impressed with their performance, but the full systems are not yet operational. Operationalisation is expected within the next two years. When training is considered as part of system performance, there is a major need to boost this to maximise the benefits of the systems.
6. Lessons Learned	**Evaluation**
List of the reported and assessed lessons learned – of concern and of value.	1. Coupling between hydrologic and inundation models needs to be established immediately along with an MOU between the hydrology agency and meteorological agency in-country if they are not already part of the NMHS. 2. Project management needs to be established early after the agreed strategic partnership. We believe that although the strategic and concept design is solid (Appendix B) and can be utilised as it stands, the unique requirements, differing hazard <u>impacts and agency responsibilities within each country MUST have an established Project Plan. This Project Plan will include sound governance and representation across agencies where appropriate.</u> It should include a Steering Group of high-level officials in-country with a possible representative from a donor or external expert (eg from a NMHS with experience in CIF). A reference group of experts should also be appointed to assist in technical questions if they arise, but they should not be doing the work of the project team. 3. Training was found to be lacking in most areas in some of the sub-projects. When a CIF commences in a new country (if this does occur), a training specialist should be consulted (including the WMO). 4. Donor funds are critical for development to support software

	systems and experts. These should be included in the Project Plan and be attributed to each key area of the project for acquittal purposes and to control spending. 5. For the current projects funding was found to be an issue and the lesson learnt was that this translated to heavy workloads on volunteers over long periods. It also placed pressure on the WMO secretariat and impacted their other responsibilities. The WMO Secretariat should only have an advisory role on projects, versus actually managing projects, if the CIF program is to continue in a new form (which will ultimately be the decision of Congress). 6. Stakeholders should be aware at the commencement that projects can take several years to implement. Expectations need to be managed. 7. Local forecaster input to models and messaging is critical in these systems and should be allowed for in the project planning. 8. Maintenance of the systems must be accounted for in the project planning. 9. In some countries, significant inundation/ flooding events may be infrequent but have major consequences (high risk). In these situations, readiness can drop away unless trialled (such as tsunami readiness exercises). 10. A strong local commitment has been a fundamental lesson which must be "non-negotiable" in new systems.
7. Level of Satisfaction & Areas of Improvement: From Highly satisfied to satisfied. [Improvement under part 6, lessons learned.]	All comments received and all interviews registered a level of satisfaction ranging from "satisfied" to "highly satisfied". Areas of improvement are mostly provided in the "lessons learned" above. These lessons were the areas that "qualified" the level of satisfaction. The areas of satisfaction that were the highest were in the NMHS and the response agencies. Developers tended to be more circumspect (just "satisfied") perhaps because they had a clearer "line of sight" to the individual systems during development. Donors were similar. However, it was encouraging that the "outcome" side of the service and the forecasters providing the service had the higher level of satisfaction. When queried further during interview, they believed it was because they had not previously (to CIFDP) had this level of international cooperation and engagement with experts directly "into their NMHS", plus of course the benefits of actually being able to provide a critical service that was previously lacking or non-existent.

13 APPENDIX B – CIFDP Implementation Plan

(Reproduced from 2018 update on jcomm.info/CIFDP)

Objectives and Scope:

The CIFDP aims to assist countries with issues of coastal inundation from oceanographic and/or hydrological phenomena (see Figure A1 below), resulting from severe hydro-meteorological events, **to operate and maintain a reliable forecasting system that helps the national decision-making for coastal management**, through

- Identifying the **national and regional requirements**;
- Implementing **open-source** coastal inundation end-to-end operational forecasting and warning systems;
- Developing **cross-cutting cooperation** among different scientific disciplines and user communities;
- Building **communication platforms** between researchers, forecasters and disaster managers involved in coastal inundation management;
- Providing **specialized training** for operators, forecasters and disaster managers.

The main focus of the CIFDP will be to **facilitate the development of efficient forecasting and warning systems for coastal inundation** based on robust science and observations. The CIFDP should:

- Identify and support end-user needs;
- Encourage full engagement of the stakeholders and partners in the CIFDP from early stages, for the successful development and implementation of national sup-projects;
- Transfer technology to the adopting countries;
- Facilitate the development of a comprehensive Storm Surge Watch Scheme (SSWS) in basins subject to tropical cyclones and storm surges, jointly with (fluvial) flood events;
- Facilitate the development and implementation of warning services;
- Support coastal risk assessment, vulnerability and risk mapping to be used by national disaster management authorities, and for the development of integrated coastal zone management plans;
- Assist improved and informed decision-making for coastal inundation management.

Expected Outcome and Deliverables:

The major expected outcomes of the CIFDP include the following:

- Technology development and transfer, including training, which would enhance the capabilities of responsible national agencies to produce and provide integrated coastal inundation forecasting and warning services;
- Established procedures, best practices and outcomes of CIFDP will serve as guidelines to other countries to develop and improve their related service capabilities, and furthermore, contribute to building specific criteria for designated WMO Regional Specialized Meteorological Centres (RSMCs) to provide NMHSs with advice on coastal inundation forecasting and warnings;
- CIFDP implementation would create synergies with the ongoing regional and global programmes and activities; for example, enhancing effective use of improved Numerical Weather Prediction (NWP) products by building a "cascading forecasting process" for coastal processes with the WMO Severe Weather Forecasting Demonstration Project (SWFDP) process, and providing technical requirements to develop the regional SSWS;
- Communication platforms, which would improve interactions of responsible national agencies and partners (e.g. governmental forecasting agencies, agencies responsible for disaster management, Civil Protection Agencies, media), will provide a mechanism for continuous improvement in updating user requirements, technical needs, and user feedback.

Strategic Approach for Project Implementation:

The general strategy for CIFDP, as adopted by the 4th session of JCOMM (May 2012, Yeosu, Republic of Korea), is as follows:

- The Project would be implemented under each regional/national Sub-Project, launched for a country that meets the essential requirement. This implies initiation of a national agreement between national institutions with relevant responsibilities, and the establishment of a National Coordination Team (NCT) led by the national operational agency responsible for coastal inundation forecasting, usually a NMHS;
- The Project would be designed based on users' perspectives, requirements and capacities, considering existing and available open-source techniques. Final products of the Demonstration Project should be operated and maintained by national operational agencies which have the responsibility/authority for coastal inundation warnings;
- The procedures/best practices developed through Sub-Projects should be applicable to other (neighbouring) countries with common issues and interests, and should be closely linked to and cooperating with related projects and activities.

The Sub-Projects of CIFDP are to be implemented in a **phased approach**, which provides opportunity to adjust the scope of the next phases to fit the prevailing requirements. Not only the final results of the Project, the accomplishment of each phase will serve the target country a useful exercise to raise the issue of coastal inundation management within its governments and among wide range of multidisciplinary communities, and to take steps toward the integrated forecasting and warning services.

National Commitment:

CIFDP is implemented through each **Sub-Project initiated by a country**, with leadership and participation from operational forecast agency(ies), with the following requirements:

- Given mandates/responsibilities for coastal inundation forecasting and warning services;
- Availability of qualified staff to run the system in 24/7 mode, with appropriate infrastructure for operational services, including sufficient computing power and communication bandwidth to run the operational systems;
- Commitment to sharing all data and information relevant to the inundation forecast process.

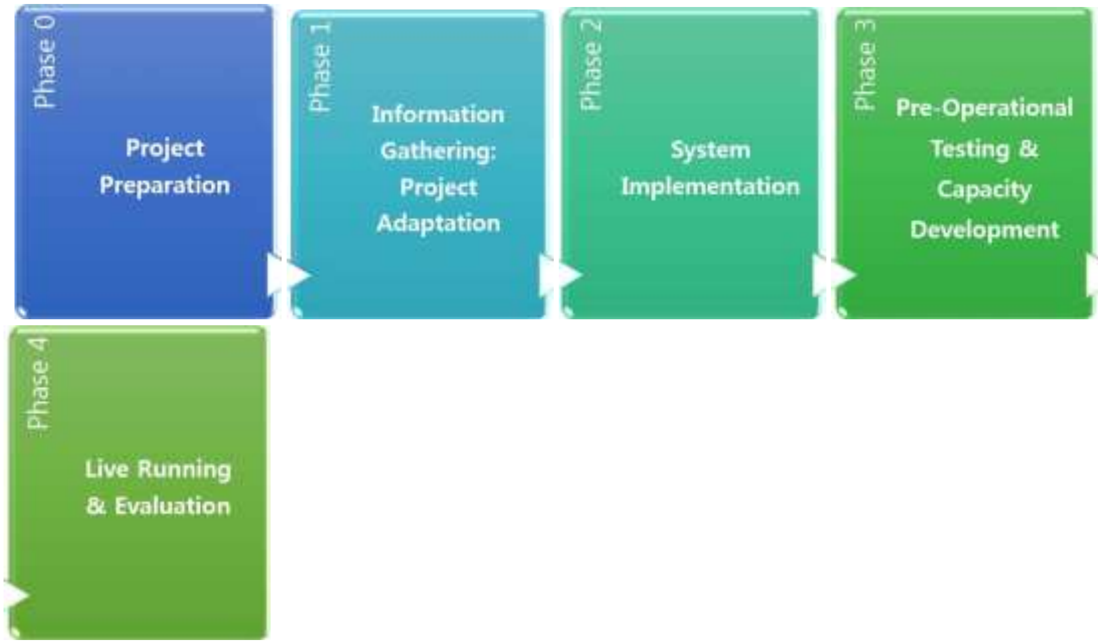
In the framework of JCOMM and CHy, the **NMHS** in cooperation with other national stakeholders, should play a key role in developing, implementing and applying the results of this Project. The NMHS and other national stakeholders including responsible national agencies will establish a Sub-Project National Coordination Team (NCT) to lead the Sub-Project implementation, with guidance by the PSG for each Phase (see section 3.4). Close cooperation with the **national authorities for coastal disasters risk and emergency management** as well as other stakeholders will ensure that user requirements are fully taken into account in the technical development.

It is strongly recommended that members of a NCT, particularly those of the NMHSs and other responsible forecasting agencies, are selected with a view of their continuing involvement in all Phases of the Sub-Project implementation, in order to ensure the efficient and effective implementation of the Project.

User commitment is key; to ensure usability and sustainability of the outcome/results of the project, the end users will be involved from the early phases of project planning. The national and regional implementers should play the main role in identifying users and user requirements

CIFDP Project Implementation:

The Project for each region/country will be implemented in a **phased approach** that leaves scope for adjustment in the next phases to fit the prevailing requirements:



Phase 0: Project Preparation

Before the actual start of the CIFDP, an **Initial National Agreements** at the political level should be prepared.

- based on a high level definition of the operational scope for the national sub-projects;
- to ensure commitment and coordination of the national agencies;
- to ensure free and open exchange of data and information required for implementing a coastal inundation forecast project.

Phase 1: Information Gathering - Project Adaptation

Initial Assessment:

- Assess and describe national capabilities in the fields of coastal flood risk, inundation forecasting and related emergency management structures;
- Compile a high level inventory of the institutional end-users' information and communication needs for emergency management during extreme coastal flooding events - initial **User Requirements Plan (URP)**, to be updated through all Phases of implementation;
- Combining both assessments will demonstrate where the CIFDP could provide added value.

A Stakeholders Workshop is a key milestone in Phase 1 to deliver the outcomes of Phase 1. It also contribute to the following objectives:

- wider introduction of the CIFDP;
- information collection on stakeholder needs and requirements;
- obtaining agreement and commitment on the project objectives;
- Interaction with and input from RSMC and other relevant data producing agencies will be actively sought and encouraged

Definitive National Agreement (DNA):

- Based on the initial/updated sub-project plan arising from the Stakeholder Workshop(s), a definitive commitment is to be obtained from the national government including the responsible national forecasting/warning agencies, to carry out the subsequent phases of the CIFDP Sub-Project, to ensure a long-term coordination between the national agencies within the National Coordination Team (NCT).

Sub-project National Coordination Team (NCT):

- Based on the updated Project Plan at the Workshop(s), the membership and a Terms of Reference (ToR) will be be agreed along with the DNA, responsible for the timely project implementation at the national level under the guidance and advice of the PSG.

National Capacity Assessment (NCA) and User Requirements Plan (URP):

- Following the Stakeholders Workshop, a full information collection should be undertaken by the NCT. The National Capacity Assessment (NCA) is a review of the existing technical capacity and capability within a country, as it will be applied to the development of a sustainable, operational coastal inundation forecasting system. It should particularly address the gaps in the present capacity and what is required to implement a robust and accurate forecast system.
- In parallel with the NCA, identification and documentation of user requirements should be carried out on a continuous basis through the User Requirements Plan (URP); to take into account the needs of disaster management agencies, emergency measures organizations, disaster risk reduction initiatives, of relevant national, regional and international agencies.

Development of Sub-Project Plan (by NCT)

- Based on the results from the Stakeholders Workshop(s) and follow-up, the sub-project plan will be documented by the NCT, describing:
    - definition of organisational setting, and assessment of responsibilities;
    - current status of technical and institutional capabilities, gaps and needs (cross-reference to the NCA);
    - initial specification for forecasting/warning models and system components, and associated requirements (to be basis of the System Design in Phase 2);
    - working arrangement for sub-project implementation;
    - plans to identify financial and human resources required for project implementation (e.g. draft funding proposal).

Project Phase 1 Review and Approval (by PSG)

- The compiled deliverables of Phase 1- including the DNA (and the establishment of NCT), NCA, URP and sub-project plan - will be reviewed by the PSG, to decide upon the proceeding to the next phase of the project.

Phase 2: System Implementation

Implementation Kick-off

- Prior to implementation, a kick-off meeting will be held to confirm the system implementation approach and the forecasting system setup, as defined in the updated implementation plan. The outcome should include the **System Design / specification for national coastal inundation forecasting (CIF) system**, and updated **URP**. The system developer(s) should be selected and agreed through this meeting. The sub-project Plan is to be updated according to the development of the project.

Model & System Development

- At this stage, the system developer(s) should work with the NCT in consultation with the PSG to carry out / implement a (pre-)operational forecasting system, as agreed through the System Design.

- Building (Pre-)Operational Forecasting System
- Hardware setup
- System Testing and Exercise (pre-test as a demonstration)

User Products

- Feedback both from system operators (forecasters) and users of the CIF information should be collected and documented, as part of implementation and evaluation of the project, based on the URP.
- Development of coastal inundation scenarios (based on historical events) will be carried out in collaboration with disaster management authorities, following existing guidelines.

Capacity Development and Training

- Throughout the system implementation phase, appropriate training for system operators/professionals should be carried out. Training at this stage will be the basis of more extensive formal training in Phase 2, targeting forecasters/operators and CIFDP focal points, operators of key NCT members/institutions, system operators of neighbouring countries (as potential users) and operators of other CIFDP sub-projects.

Sub-Project Plan Update

- Based on the results from the implementation of the prototype, the sub-project plan will be updated and detailed for the remaining phases of the CIFDP. It is expected to include:
  - acceptance testing plan
  - plan for the operational system set-up
  - input/addition/edition to User Requirement Document
  - human resource development and training plan

Project Phase 2 Review and Approval (by PSG)

- The compiled deliverables of Phase 2- Implementation report (by System Developer(s) and NCT) including the progress report and pre-test results, updated sub-project plan, updated URP - will be reviewed by the PSG, to decide upon the proceeding to the next phase of the project.

Phase 3: Pre-Operational Testing & Capacity Development

The objective of Phase 3 is to transfer the developed tools and methods in the previous phase to an operational forecasting and warning system. It should include development of operational procedures, development of service products for coastal inundation management, acceptance testing and capacity development. A major event in this phase of the project is the **simulation of an extreme inundation event using the CIF technology involving all key stakeholders from the forecasters to the end users at local level**. Phase 3 should be concluded with the CIF system going live at the national level.

Developing System User Guidelines

- User and support documentation should be completed at this stage, documenting procedures and best practices to use the developed CIF tools for issuing forecasts and warnings.

Further Training Material and Capacity Development

- An important part of training for operators ("on-the-job" training) were taken place in Phase 2. In this Phase, the task should focus on formal training of national agency professionals and key stakeholders, on the operation / maintenance / future development of the CIF technology, and on the use of forecasting products in inundation management procedures.

Acceptance Testing

- A formal acceptance procedure will be followed to test whether the developed system is ready to be used operationally. The test procedure will have been specified under Phase 2.

End-to-End Forecasting Simulation Event

- A major milestone for Phase 3 is the simulation of an extreme inundation event using the CIF technology, involving all key stakeholders from the forecasters to the end users at local level.

Handover and Going Live

Project Phase 3 Review and Approval (by PSG)

- The compiled deliverables of Phase 3- results of the simulation test, system user guidelines and sub-project plan - will be reviewed by the PSG, to decide upon the proceeding to the next phase of the project.

Phase 4: Live Running & Evaluation

The CIF system is ready to be in operation at this Phase. The Project will focus on accommodating user requirements and change requests at this Phase. Through national/international demonstration and discussion, the implementing country and PSG will complete the project evaluation, and build an outlook to future benefits and enhancements

System Updates, Support & Maintenance

Follow-up training

Project evaluation workshop & international conference

Project wrap-up

14 APPENDIX C – QUESTIONNAIRE IN SHORTENED FORMAT

Coastal Inundation Forecasting Demonstration Project (CIFDP)
QUESTIONNAIRE

[TO BE COMPLETED AND SENT TO CIFDP ASSESSMENT TEAM BY 14 SEPTEMBER 2018]
YOUR TIME TO COMPLETE THIS QUESTIONNAIRE IS CRITICAL FOR THE DEVELOPMENT OF SYSTEMS TO FORECAST THESE DANGEROUS HAZARDS.
WE THANK YOU.

DEPENDING ON YOUR ROLE IN CIFDP, PLEASE ANSWER EITHER PART (A) OR PART (B).
Please note that your response will be confidential. We realize there are a lot of questions and we very much appreciate you taking time to **answer as many of these questions as you can**.

Introduction

An independent review of the CIFDP concept has been recommended by CHy-15 (2016), JCOMM-5 (2017), and the WMO Flood Forecasting Initiative - Advisory Group (2017). The ongoing sustainability of the CIFDP and in particular the 'demonstration' aspect, and its governance, needs to evolve with various options to be explored, for example: is there evidence to suggest that the CIFDP remains a an appropriate approach to these hazards, and if so, what governance structure is recommended to ensure the projects continue to be sustained and provide benefits in the long-term; and whether other sub-projects should be initiated, and if so, how would they be effectively managed? The external review is being carried out by a team of the following two independent professionals:

CIFDP Assessment Team:
- Dr. Ray Canterford, Meteorological Hazards Specialist, Australia
- Curtis B. Barrett, USA, Hydrometeorological Advisor, USAID OFDA

As part of this independent review, a questionnaire has been prepared. The questions set out in the questionnaire aim to collect your views on the Coastal Inundation Forecasting Demonstration Project (CIFDP), from a variety of perspectives.
You received this questionnaire because your opinion is deemed highly significant and relevant to the review team and will be a valuable input to the CIFDP external review.
You are kindly requested to fill out the form with respondent's information, answer the questions to the section (Part A or B) that relates to you to the best of your knowledge, and submit the document to the following e-mail addresses: cubarrett@usaid.gov and grant.ray@optusnet.com.au.
You are also requested to submit your answers at your earliest convenience, but not later than 14 September 2018. The cumulative analysis and result of your responses will be included in the Assessment report which will be produced by mid-October 2018.
Respondent Information
Please, fill out the following form: **TABLE 1**

FULL NAME	
ORGANISATION	
POSITION	
HIGHEST EDUCATIONAL LEVEL DEGREE	
NUMBER OF YEARS WITH CIFDP	
SUB PROJECT INVOLVEMENT (circle as appropriate).	Bangladesh / Fiji / Indonesia / Caribbean/ Other?
YOUR CURRENT RESPONSIBILITY AND ROLE WITHIN THE CIFDP (mark with an X)	**(A) DESIGN, DEVELOPMENT, IMPLEMENTATION AND SUPPORT** (NOAA/NWS, WMO, USAID/OFDA, CHy, JCOMM, IOC) - designer

	- developer - implementer **(B) OPERATION, MAINTENANCE AND USE** (National Meteorological and Hydrological Services (NMHSs), National Disaster Management Agencies (NDMAs), other users) - operator / forecaster - IT technician - maintenance technician - DB administrator - disaster manager / civil protection agent - other (specify):

OVERVIEW AND STRUCTURE OF THE QUESTIONNAIRE

The questionnaire is divided into two different sections (A and B). **<u>You are only requested to answer one of the sections, A or B, listed in Table 1</u>**, depending on your responsibility and role within the CIFDP (as marked in the Respondent's Information – Table 1, above).
Please, answer Section (A) if you put an X in any of the categories under the title "Design, Development, Implementation and Support", and answer Section (B) if you put an X in any of the categories under the title "Operation, Maintenance and Use".
In order to give your answers, simply position the cursor below each question and use as many paragraphs as necessary.

(A) DESIGN, DEVELOPMENT AND IMPLEMENTATION

If your role is listed in Part A of Table 1, please answer the following questions:

<u>A1: COMPLETE OR NEAR COMPLETE CIFDP SYSTEMS: IF YOU ARE INVOLVED IN THE SUB-PROJECTS FOR BANGLADESH AND INDONESIA</u>

(1) <u>For Bangladesh and Indonesia:</u> Is the CIFDP providing adequate guidance and information to allow issuing credible coastal inundation/flood alerts and warnings to users? If not, what are the issues?

Very Good	Good	Reasonable	Not good	poor

Circle as appropriate and provide comments/reasons
Comments:

(2) <u>For Bangladesh and Indonesia</u>: Do you think that National Disaster Management Agencies (NDMAs) of the countries with implemented CIFDP are fully satisfied with its products? If not, please describe why, and what do you think could be done to overcome such dissatisfaction?

Very satisfied	Good	Reasonable	Not good	Not satisfied

Circle as appropriate and provide comments/reasons
Comments:

(3) <u>For Bangladesh and Indonesia:</u> What additional activities/outputs can make the CIFDP more consistent with its objectives? If any, please explain what you would like to see as such additional activities/outputs. To what extent does the CIFDP achieve its objectives? If there are any issues - please describe briefly.
(4) <u>For Bangladesh and Indonesia</u>: How would you improve the work processes of CIFDP in any of the following areas: data management, modelling approach, final products (incl. format and dissemination), implementation process, operational run, and training program? Or, do you think the present approach is adequate? Please explain briefly each point, if you think that it could be more efficient or effective.
(5) <u>For Bangladesh and Indonesia:</u> Is there an operational performance monitoring of CIFDP (i.e. such as skill scores). If so, how well has the system performed? If not, please explain.
(6) <u>For Bangladesh and Indonesia:</u> Please, explain briefly your views on the robustness of the CIFDP. For example: how does the system operate with less data than the system was designed for (in some cases no operational data are available)? How stable is the software (If software is involved)? Is the system or technique reliable, that is the system

has little down time? Is the system helpful in providing information during extreme events such as the 100-year flood or more severe events?
(7) For Bangladesh and Indonesia: Is there a need to modify or adjust the forecasting technique (such as recalibration of parameters) to improve coastal flood forecasting performance, or any other chain of forecasting process? Is yes, please explain how it is done or how it should be done.

A2: IF YOU ARE INVOLVED IN ANY OF THE SUB-PROJECTS (FIJI, CARIBBEAN, BANGLADESH AND INDONESIA.
(8) What are main impacts and benefits for a country that has either implemented or planning to implement the CIFDP? What aspects of NMHSs service has or will be expected to occur after implementation?
(9) What potential improvements to the CIFDP are needed (considering new potential functionalities and products of CIFDP such as Tsunami?). Are there other functionalities needed that are not available or being currently developed?)
(10) How does the forecaster use, or is planning to use the CIFDP system to construct Coastal inundation/flood warning products? Is there a clear Standard Operating Procedure to execute CIFDP? Are there sample products you could provide us? Please explain.
(11) Would you please describe the level and type of training or education required, or expected to be required, for users such as both decision-makers and mass-media to understand the uncertainties of Coastal inundation flood warning products, their limitations and benefits? Is this a problem?
(B) OPERATION, MAINTENANCE AND USE
If you marked your role in Part B of Table 1, please answer the following questions:
This Part (B) is structured in the following topics:

- Relevance & Effectiveness
- Product Usability
- Impact
- Sustainability
- System Performance Evaluation
- Lessons Learned
- Level of Satisfaction & Areas of Improvement
- Additional Information

Within each topic, **a maximum of three questions** are included. At the end of the questionnaire (under Additional Information) you will have the opportunity to add further comments and views on aspects not fully reflected in the questions or not covered in your previous answers, keeping in mind that your opinions should help the reviewers to make a more thorough assessment of the overall System characteristics.
There are many questions and not all of them may be applicable to your role within the CIFDP. We very much appreciate you taking the necessary time to answer as many of the applicable questions as you can. We also kindly ask you to be as straightforward and concise as possible in your answers.

1 Relevance & Effectiveness
Relevance is understood as the extent to which the CIFDP is an appropriate approach to mitigate coastal flood losses in your country or region and is adequately serving the needs of communities at risk.
Effectiveness is a measure of the extent to which the CIFDP in your country and region attains its objectives, keeping in mind that the CIFDP is a tool necessary to provide operational forecasters and disaster management agencies with real-time informational guidance products pertaining to the threat of coastal inundation/flooding caused by approaching storms combined with tidal effects and or geologic events such as earthquakes that can trigger Tsunamis.
In your opinion:
(i) Is coastal inundation/flooding really an issue in your country / region? Please explain briefly.
(ii) To what extent have the CIFDP objectives (below) been achieved so far in your country / region?

(iii) How effective are the products and information of the CIFDP in reducing (or planning to reduce) the impact and effects of inundation and flooding? Can you provide a specific example or case study?

CIFDP Objectives: aims to assist countries with issues of coastal inundation from oceanographic and/or hydrological phenomena, resulting from severe hydro-meteorological events, to operate and

2 Product Usability

This section deals with the usability of CIFDP products in terms of their ability to form the basis for making decisions. In your opinion:

(i) How "user friendly" is the CIFDP system (product console, dashboard, etc.)? Please explain.

ii) Does the CIFDP design allow product adjustments based on the forecaster's experience with local conditions, incorporation of last-minute local observations (e.g. non-traditional data), or local observer reports. To what extent are these possibilities being effectively used? Please explain.

(iii) Do you use the CIFDP to generate information on alerting on potential coastal flooding and inundation over the next 24/48 hours? How is it used?

- Do you generate surge forecasts? Y/N
- Do you account for tidal influence? Y/N
- How do you communicate the impact of the coastal flooding trigger (such as a hurricane) to the coastal infrastructure? Comment:
- Do you run dynamic hydrologic models or use procedures to predict the storm surge effect moving upstream on rivers that are affected by surges? Y/N. If so, how do you do it?

3 Impact

Impact refers to the changes produced by the CIFDP in your country / region, directly or indirectly, intended or unintended. In your opinion:

(i) What were (or expected to be) the main impacts of the CIFDP in your country / region, directly or indirectly, intended or unintended?

(ii) Has there been an observable reduction of coastal inundation/flood losses after the implementation of the CIFDP in your country / region? Or in general, have you received any feedback or reaction from users on the value of these products to your user community? Is there a specific example you can give?

(iii) Are the uncertainties embedded in coastal inundation/flood alerts and warning products properly delivered to users and `considered in the decision-making process, and sufficiently understood by mass media? Please explain.

4 Sustainability

Sustainability is the ability of the CIFDP system to be maintained in the future at least at the current level of functionality.

(i) In your opinion, are the benefits of the CIFDP in your country / region likely to continue? If not, what are the weak links in keeping the system operating and maintained in the future?

(ii) Is the need for human and financial resources a cause of concern in your country / region? If so, is there any strategy in place to deal with this problem?

(iii) Training programs are a fundamental part of sustainable systems. Have the training courses for CIFDP been adequate for forecasters to operate the system and use the system to its potential? Would staff require further training? Please explain.

5 System Performance Evaluation

As you know CIFDP can be based on tropical storm strength and movement (path) which contains significant uncertainty at times. Other triggers can include hazards such as large ocean waves and riverine coastal flooding, each with their own uncertainty. Performance evaluation is sometimes, though not exclusively, conducted through the computation of skill scores such as probability of detection and false alarm ratio.

(i) Have performance evaluations been conducted on a regular basis in your country / region? If yes, would you briefly comment on the main findings, to the best of your knowledge? Could you share your results?

(ii) If there are no quantitative studies of performance verification, would you please explain why this is the case?

(iii) To the best of your knowledge, how well does the system perform? Consider the accuracy or credibility of the forecasts, the lead time provided for users to make decisions, and the reliability and confidence users may have at this time. Also, consider impacts and benefits for your country, and major limitations of CIFDP available functionalities. Please, justify your answer.

6 Lessons Learned

Lessons learned refer to the knowledge or understanding gained by experience. This section deals with the information that reflects both the positive and negative experiences, gained by yourself and others, after some years of CIFDP operation in your country / region.

(i) Please provide the main lessons learned (at least two) in the years of operation of the CIFDP in your country / region, in relation with the role you have within the system. Have these helped improve the system? Please explain.

7 Level of Satisfaction and Areas of Improvement In this section, the level of satisfaction with the CIFDP in your country and region is surveyed, and there is also the opportunity to include potential areas needing improvement and suggestions on increasing the benefits of the system.

(i) In your opinion, what is the general level of satisfaction with the CIFDP in your country / region? Choose from very low through very high, and justify your answer.

(ii) Do you know how users use the warnings or products? Can you provide illustrations of how users make decisions or take actions based on products?

(iii) Do you think that NDMAs in your country are fully satisfied with CIFDP products? If not, please describe why and what you think could be done to overcome such deficiencies.

8 Additional Information

This section is intended to allow you to add further information on the CIFDP or on the provision of Coastal flood forecasting and warning in your country and region, regarding aspects not covered in the previous sections that, in your opinion, may serve to make a more thorough assessment of the overall CIFDP or alternate forecast systems.

(i) Please add additional information.

THANK YOU FOR YOUR TIME AND CAREFUL EVALUATION

15 APPENDIX D

Table of Officers consulted throughout the CIFDP Assessment

Entity	Person consulted: including interviews, questionnaires and/or visits
WMO Commission for Hydrology (CHy)	Dr Harry Lins President CHy
	Dr Yuri Simonov CHy CIFDP PSG Co-Chair
	Dr Graeme Smart CHy CIFDP PSG member
WMO/IOC JCOMM	Mr Johan Stander JCOMM Co-President (WMO)
	Mr Val Swail JCOMM CIFDP PSG Co-Chair
	Dr Peter Dexter JCOMM Co Former -President (WMO)
	Prof Don Resio JCOMM CIFDP PSG (former) Co-Chair (retired)
	Dr Nadao Kohno - Metocean modelling and forecasting expert (ETDRR)
CIFDP PSG Members (not listed above) and additional sub-project experts.	Dr Linda Anderson-Berry - Social science expert- Aust. Bureau of Meteorology
	Dr Paul Davies - Hydrometeorological modelling and forecasting expert
	Dr Monika Donner - Hydrological modelling and forecasting expert.
	Dr S.H.M Fakhruddin - Hydrological modelling and forecasting expert
	Mr Jamie Rhome – Meteorological modelling and forecasting expert USA NHC
	Mr Deepak Vatvani – Hydrological and metocean modelling expert
	Sub-project experts and advisors.
	Mr Miguel Campusano - ONAMET, Dominican Republic (Sub-Director)
	Dr Cesar Toro - IOC Caribe
	Dr Nadao Kohno - Metocean modelling and forecasting expert (ETDRR)
	Mr Mikhael Entel - Aust. Bureau of Meteorology modelling expert
	Mr Ravind Kumar (Director) Fiji Meteorology Service (FMS)
	Mr Misaeli Funaki – FMS lead forecaster (completing Masters in Korea)
	Mr Stephen Meke – FMS senior forecaster

	Mr Amit Singh – FMS senior forecaster
	Mr Ardash Kumar – FMS Head of IT
	Ms Swastika Devi – FMS Head of Hydrology
	Mr Len Bale – FMS Senior Systems Analyst
	Mr Jens Kruger SPC (Manager, Ocean and Islands)
	Mr Herve Damlamian SPC (Oceanographer, Ocean and Islands)
WMO Secretariat (MMO/WDS)	Dr Sarah Grimes (A/Chief, Marine Meteorology and Ocean Affairs Div (MMO)
	Ms Adriana Oskarsson (Administrative Assistant, MMO Division since 2015)
	Dr Xu Tang (Director, Weather and DRR Services)
	Dr Boram Lee (former MMO Science Officer, 2012 to 2015)
WMO Secretariat (Hydrology/CLW)	Dr Paul Pilon (Chief, Hydrology and Water Resources (HWR))
	Mr Giacomo Teruggi (Science Officer, HWR)
	Mr Claudio Caponi (Snr Scientific Officer, Climate and Water Dept)
	Dr Johannes Cullmann (Director, Climate Land Water)