Coastal Hazards, Climate Change, and Community Resilience
We have all heard the dire warnings coming at us from all directions – climate change is one of the most important issues facing mankind, and could bring drought, sea-level rise, coastal erosion, flooding, increased coastal storms, rising temperatures, ocean acidification, and other devastating impacts in the coming years. While it is easy to become discouraged and feel like there is nothing that we as individuals can do, the dedicated staff and faculty at the University of Hawai‘i Sea Grant College Program (UH Sea Grant) are tackling these complex issues head-on, and working closely with our partners and policymakers to ensure the communities we serve are adequately prepared for whatever the future brings. In this issue you will read about how UH Sea Grant’s unique research and outreach capabilities are assisting coastal communities become more resilient, how we are assisting residents and decision-makers become more aware of the implications of climate change, and, importantly, have a greater understanding of what changes need to occur today to be prepared for tomorrow.
Above: Hurricanes Iselle and Julio threatened Hawai‘i in August 2014. Iselle weakened to a tropical storm before striking Puna in Hawai‘i County. There was considerable wind damage to roofs and many fallen trees, as well as wave damage to coastal homes. Fortunately, Julio, which weakened only slightly, veered to the east. These systems are a reminder of Hawai‘i’s vulnerability to tropical storms and hurricanes.

Preparing for Natural Hazards

By Dennis Hwang, UH Sea Grant Coastal Hazard Mitigation Specialist

First published in 2007 by the University of Hawai‘i Sea Grant College Program (UH Sea Grant), the Homeowner’s Handbook to Prepare for Natural Hazards is a guide to the science and risk of regional natural hazards that may affect homeowners—for example, hazards relevant to Hawai‘i homeowners include hurricanes, tsunami, floods, and earthquakes. Over 65,000 copies have been printed and distributed to date, and the earlier editions discuss traditional emergency preparation items such as emergency supplies, evacuation plans and evacuation kits, as well as non-traditional items, such as methods for strengthening a home to better withstand hazard events. Addressing non-traditional preparations was viewed as critical because the house is the major investment for many families, and also provides protection from the elements. Moreover, if the house is sufficiently strong, either in its original design or through retrofit, it may be possible to shelter in place during a hurricane. This is a big concern since there is only shelter space for roughly 35 percent of Hawai‘i’s population in public hurricane shelters.

Multiple major and minor updates to the Hawai‘i Homeowner’s Handbook to Prepare for Natural Hazards are available now. For more information visit: http://seagrant.soest.hawaii.edu/publications/Book
Hazards have been made between publication of the first edition and of the current (third) edition. Some highlights from previous editions include:

**First Edition:** Hurricane clips, and over 12 ways to protect windows. Window protection is essential to create a wind and rain resistant envelope around the house during a hurricane—masking tape will not work.

**Second Edition:** More in-depth information on hurricane clips, specifically, the Hawai‘i Plantation Tie (HPT) developed just for Hawai‘i. With the HPT clip and the H3 clip, the majority of single-wall houses in the state can now be retrofitted so that the roof is better able to stay on the house during a hurricane. When Hurricane Iniki hit Kaua‘i, there was a total of over 7,000 houses damaged or destroyed, with many homes having lost their roofs due to a lack of hurricane clips. Since O‘ahu has eight times the number of structures as Kaua‘i, a ballpark estimate of over 50,000 damaged structures resulting from a similar event on O‘ahu is possible; this figure has been confirmed by a Federal Emergency Management Agency (FEMA) risk assessment. The second edition also addressed post and pier retrofits (i.e., houses on “tofu blocks”), which are of benefit during a hurricane or an earthquake so that the house stays on its foundation. Such modification is especially important for those on Maui and Hawai‘i Island, where there is a greater earthquake risk.

The third edition of the handbook is currently online and will be printed in the fall of 2014 with four new appendices. The appendices address a variety of new topics, such as:

Storm Panel Screws: These screws, made by Simpson Strong-Tie, provide a quick way to attach plywood or plastic honeycomb panels to windows (Appendix C).

Asphalt Shingle Roofs and Ridge Vents: This section includes graphical guidance and instructions on how to install a stronger asphalt shingle roof and ridge vent, based on existing FEMA documents (Appendix D).

Solar Photovoltaic Panels: While it is not possible to prevent solar panel damage during a high wind event, the key is to insure the system and make sure it is properly attached to the rafters so they do not blow off during a hurricane (Appendix E).

Working with the Community: If individuals and families are properly prepared, they are better able to help the community during a hazard event. Information on numerous volunteer organizations and programs is provided including those for the American Red Cross, Citizens Emergency Response Teams (CERT), and Hawai‘i Hazards and Resiliency Program (HHARP) (Appendix F).

Appendices E and F are expected to be particularly useful going forward. In the year 2013 alone, over 17,500 solar units were installed statewide, and many of the houses were reroofed beforehand. These modifications provide opportunities for the homeowners to use information in the handbook to strengthen roofs and to ensure the solar panels will not fly off during a hurricane.

Finally, the third edition includes updated sections that provide information related to lessons learned from the Hurricane/Tropical Storm Iselle event. Although many people were prepared, many were not. The homeowner’s handbook reinforces the idea of being prepared before a watch or warning is issued—the goal is to avoid needing to go to the store at that time for water, food, gasoline, or supplies. Additionally, in spite of the fact that Iselle hit Hawai‘i County only as a tropical storm and not a hurricane, considerable tree damage occurred, which is also covered in the handbook, as well as roof damage (especially related to the new Appendix D).
We attribute the success of the homeowner’s handbooks to three reasons. First, it has an easy to understand graphical format, which is more approachable for homeowners who may not have a science background. Second, it contains only the information that is most relevant to the local community. Third, and most importantly, it builds upon strong partnerships with other government agencies, volunteer organizations, and companies that provide technical advice, outreach support, and funding for the different print runs. Some interesting aspects of homeowner’s handbook partners and the roles they play are:

There are 28 key partners who assisted in the development of the homeowner’s handbook, and many of which have been involved since 2007.

One new partner, West Oahu Roofing, is featuring the new guidance for the installation of stronger asphalt shingle roofs on its website (Appendix D), and has written articles in the Sunday paper on the proper methods.

The FEMA Building Science Branch will be contributing funding to print the third edition. Information in Appendices D (roofing) and E (solar photovoltaic panels) may be used to update or create new guidance documents in its division.

Among our long-time partners, Zephyr Insurance holds annual workshops for hundreds of its agents on hurricane science and the home retrofits outlined in the handbook. State Farm provides annual financial support for printing and has new social media initiatives to encourage preparation. Simpson Strong Tie holds an annual workshop for builders and inspectors that cover retrofits in the handbook.

Key long time partners also include the National Weather Service, the Pacific Tsunami Warning Center, and the State Flood Insurance Program at the State of Hawai’i Department of Land and Natural Resources who have contributed maps, figures, and suggestions that have been incorporated in the handbook.

Many of the partners for the Hawai’i handbook have extended this collaboration to other states including Simpson Strong-Tie, American Red Cross, FEMA, and the Coastal Zone Management Program.

Based on the enormous amount of interest in the homeowner’s handbook developed for Hawai’i, Sea Grant programs in many other areas of the country expressed an interest in developing their own state-specific versions. Currently, modified versions of the homeowner’s handbook are available in Mississippi, Alabama, Louisiana, Texas, Florida, Delaware, and Massachusetts. The book is also in the early stages of preparation for New Jersey, Washington, and the Republic of the Marshall Islands. Interest has been expressed for handbooks in the Republic of Palau, the Federated States of Micronesia, and the Republic of the Philippines, especially after Typhoon Haiyan/Yolanda.

Some interesting facts about these regional handbooks include:

• Texas handbook is offered in English and Spanish
• Marshall Islands handbook will be in English and Marshallese
• Delaware handbook has a climate change component, and discusses Hurricane Sandy
• Louisiana handbook is in its second edition, and draws support from many key partners, including FEMA
• Massachusetts handbook has been very popular—during the 2013 hurricane season, the local Sea Grant offices ran out of 5,000 copies by August. A new print run of 10,000 copies will be finalized by the end of 2014

All homeowner’s handbooks are available as free PDF files online. Readers can obtain the PDF by conducting an internet search for: “Homeowner’s Handbook to Prepare for Natural Hazards,” and including the name of the state of interest. Thank you to UH Sea Grant Communications for sharing the homeowner’s handbook template with other states.
A resident of Hana, a relatively isolated town on Maui’s east side, recently recounted at a community workshop just how taxing and time-consuming it was to get permits to rebuild her family’s home after a destructive fire. In this case, the permitting process alone delayed rebuilding by nearly 10 months. While Hana town itself is isolated, the situation of delayed rebuilding, it turns out, is not an isolated experience. Similar stories have been shared by other Maui residents from around the island. For this Hana resident, a follow-on question emerged: “What will the county do when there are hundreds of houses to rebuild after a disaster? Surely it won’t take 10 months just to get permits when we need to get our families back in their homes?”

These types of permitting delays are one of many challenges that Jim Buika, a coastal zone management planner for the County of Maui and Tara Owens, a UH Sea Grant coastal hazards extension agent, are addressing by guiding a planning process to develop post-disaster reconstruction guidelines and protocols for the County of Maui. In a coastal community, it’s not IF but WHEN the next coastal storm will hit. Hurricane Iniki in 1992 caused extensive damage on Kaua’i, and Hurricane Iselle this past August was a recent reminder of the need to prepare. So, this planning process has initially involved understanding and documenting delays to early reconstruction based on experiences from previous damaging events. The resulting guidelines and protocols will seek to reduce delays and enable the county to offer immediate direction and pre-determined steps to residents to repair or rebuild damaged property. A grant from the NOAA Sea Grant Coastal Storms Program for the Pacific Islands Region has provided the opportunity for the county to take on this critical task.

Buika and Owens, along with a locally-based consultant team, are working with County of Maui staff and Maui communities, including the islands of Moloka’i and Lāna’i, to understand their specific needs and priorities for rebuilding when the time comes. The overarching goal of this effort will be to “rebuild safer, stronger, and smarter” in a planned and efficient manner, especially in sensitive shoreline areas. This planning process aligns nationally with other federal initiatives to encourage community-based recovery planning, including FEMA’s National Disaster Recovery Framework.
Planning for rebuilding is new territory in Hawai‘i, and there is no prescription for how it should be done, and it can sound a lot easier than it actually is. The team has learned that making locally specific guidelines involves difficult decisions and uncovers some significant resource (human and physical) challenges. For example, if damages are regional or island wide, how does the county triage reconstruction? Would a roof replacement garner the same attention and permitting requirements as a home that needs to be mostly rebuilt? This project aims to provide guidance to reduce the deliberation for these kinds of decisions. When will inspections be necessary, especially if inspectors are in short supply? This project expects to propose solutions for critical resource gaps.

But permitting decisions are only part of the challenge. When the time comes, the County of Maui intends to make sure that environmental and cultural resources are protected in the rebuilding process. To incorporate environmental considerations into the process, the project team has devised a “Decision Matrix” that factors in a range of shoreline types of varying sensitivities (examples: pristine sandy beach versus armored coastline) in juxtaposition with damage impact scenarios (examples: roof replacement versus total rebuild). The intent is to carefully balance consideration for both the natural and built environments. For example, how will the county respond when beaches are severely eroded by storm waves and homeowners request shoreline armoring? This scenario isn’t uncommon already—the homes on Sunset Beach, O‘ahu were threatened by severe erosion just last winter—and history has shown that the armoring approach has resulted in winners and losers by protecting private land at the expense of the beach. These scenarios will be addressed by the project, and alternative adaptation strategies will be emphasized.

The “Decision Matrix” has evolved into a game board of sorts, as a tool to collect information from the community about their concerns and priorities. The feedback has been surprising in some cases, so this method of interactivity has turned out to be very insightful. As the project team wrapped up a recent community workshop, a few comments from participants highlighted the challenges with, and the critical need for, this planning process. After thinking through some of the scenarios and decisions, one resident stated, “Well, I think everybody in this room now understands how difficult your jobs really are.” Another resident thanked the staff for “being ahead of the curve for all of us.” As a result of these community workshops, and years of coastal management experience on Maui, the first “Maui County Post-Disaster Guidelines and Protocols” will be drafted by this winter.

Below: Homes on the north shore of O‘ahu were threatened by severe erosion in the winter of 2013. Dolan Eversole
The magnitude 9.0 earthquake in Tohoku, Japan on March 11, 2011, resulted in one of the largest tsunamis in recorded history. The earthquake and subsequent tsunami was a very low probability, but extremely high impact catastrophe. Since this event there has been great interest in the geophysical research community to better understand potential sources of large tsunamis.

The Hawaiian Islands have been subjected to large tsunamis in 1946, 1952, 1957, 1960, 1964, and 2011. The largest tsunamis in Hawai‘i were from the 1946 and 1957 magnitude 8.6 earthquakes, which were focused east and west of the East Aleutian Islands, respectively. The region between these areas is focused directly at the Hawaiian Islands; tsunamis from great earthquakes located here pose the most significant threat to Hawai‘i.

It has become increasingly recognized that past inundation modeling for Hawai‘i tsunami evacuations did not consider all possible sources of tsunamis. Existing evacuation zones in Hawai‘i heretofore were based just on re-created historical tsunami events within the past 100 years, i.e., 1946 (West Aleutian), 1962 (Kamchatka), 1957 (East Aleutian), 1960 (Southern Chile), and 1964 (Alaska). The past 100 years does not comprise all possible credible hazard threats. It is more likely that future subduction earthquakes will be different in location and magnitude and not identical to the past.

This recognition has led to an analysis of the potential for other sources of large tsunamis that could affect Hawai‘i in excess of the historical record. The first geophysical analysis of such scenarios was carried out by seismologist Dr. Rhett Butler of the University of Hawai‘i at Mānoa under contract with the Hawai‘i Emergency Management Agency (formerly State Civil Defense). This research included a detailed, systematic analysis of sources of great earthquakes along the Aleutian-Alaskan Arc megathrust subduction zone capable of producing large tsunamis. Characteristics of prior great (magnitude 9.0+) earthquakes in the Pacific Rim were also used as the basis for earthquake fault displacement models, which were reviewed and vetted by a U.S. Geological Survey (USGS) team. Two independent tsunami simulation models (NOAA-SIFT or short-term Inundation Forecasting for Tsunamis and the UH NEOWAVE or Non-hydrostatic Evolution of Ocean WAVE) were used to estimate tsunami inundation in the Hawaiian Islands from this tsunamiogenic region. The focus of this research effort was to estimate the largest tsunami that may impact the state of Hawai‘i from distant, great Aleutian magnitude 9+ earthquakes.

The research suggests:

Great earthquakes along the eastern Aleutian arc pose a credible worst case tsunami threat to Hawai‘i due to their proximity (short, 4.5 hour travel time), historical impact (the...
largest historical tsunamis have originated in the Aleutians), and directional focus of tsunami energy toward the Hawaiian Islands.

The eastern Aleutian region is capable of a giant magnitude 9+ earthquake along a section of the Aleutian island arc directly facing Hawai‘i.

Magnitude 9+ earthquakes in the Aleutians can produce tsunamis in Hawai‘i that substantially exceed current tsunami evacuation maps.

Through the O‘ahu Coastal Communities Evacuation Planning (OCCEP) project (funded by the City and County of Honolulu Department of Emergency Management (DEM) and the O‘ahu Metropolitan Planning Organization (OMPO), UH Sea Grant is communicating these research findings of a Great Aleutian Tsunami (GAT) scenario and the resultant Extended Tsunami Evacuation Zone (ETEZ) on O‘ahu. The project is ongoing and project partners have identified several potential concerns in communicating the GAT and ETEZ:

1. Though an extraordinary event, there is a need to develop a secondary evacuation zone for a GAT event due to the inundation depth and extent, and the potential for great loss of life that would result from a GAT scenario if only the present evacuation zone is used.

2. Confusion (and either panic or disbelief) during evacuation if the public is not well informed on what to do and where to go in the event of a GAT evacuation warning.

3. The public may be confused by an evacuation map depicting an ETEZ without dedicated and widespread outreach and education of the reasons for new (2014) evacuation maps relatively soon after the last map update of 2010.

4. Currently, there is no distinction for the magnitude of extraordinary events like the GAT scenarios. At present there is a single run-up threshold value of one meter that is used to trigger tsunami evacuation statewide. However, the Pacific Tsunami Warning Center (PTWC) is in the process of developing a warning criteria procedure for GAT events.

5. Given that Hawai‘i tsunami warnings have overestimated run-ups from events over the past 25 years, there may be developing complacency with any warnings regardless of the event.

6. Specific evacuation refuge and route planning has not yet been conducted for the Honolulu urban area including Waikïkï, which adds opportunity and complexity when considering vertical evacuation (i.e., moving to higher floors in tall buildings).

7. Though the annual probability of a GAT event is very low, potential impacts are severe requiring clear messaging and continued preparedness measures.

In response to many of these concerns, the OCCEP is completing updated refuge and route information to be refined through participatory community workshops. Additionally, coordinated messaging on the reasons for preparing this operational contingency plan is being discussed by the Hawai‘i Emergency Management Agency, the four county civil defense agencies, and the PTWC.
In the last ten years, the Gulf region and Eastern seaboard of the U.S. have experienced repeated severe impacts from hurricane inundation including Hurricane Katrina and Rita in 2005, Hurricane Ike in 2008, and Hurricane Sandy in 2012. Much of the devastation was caused by storm surge which exceeded 17 feet in parts of Texas during Ike, and over 27 feet in Mississippi during Katrina. While Hawai‘i did not experience any of the impacts from these hurricanes, the questions arose, what impact would a local hurricane and the resulting storm surge have on Honolulu’s coastline? What will happen to critical infrastructure when an event such as a hurricane or tsunami occurs in areas already experiencing sea-level rise inundation? Since recent global projections anticipate a rise in sea level of one meter or higher by the end of the century, these questions are of critical importance.

In response, the NOAA Sea Grant Coastal Storms Program in the Pacific Islands Region funded a University of Hawai‘i study to assess the risk and vulnerability of urban Honolulu, Hawai‘i. The area chosen for the study stretches between Diamond Head and Pearl Harbor and includes high density development, a large population, major critical infrastructure, and is also at low elevation so it is at high risk. Importantly, the area is also responsible for generating over 43 billion dollars in economic activity annually, and is a major tourism hub for the state.

The questions surrounding climate change and sea-level rise adaptation have brought a lot of focus on what hazard mitigation plans are currently in place. While this study is not a hazard mitigation plan in itself, it generates the data that would be used, and the results from this project are helping to inform successful adaptation and hazard mitigation planning. This is especially relevant as the state develops comprehensive climate change and sea-level rise adaptation strategies. Through targeted outreach to local emergency and resource managers, decision-makers, and affected communities, the approach taken in this project can serve as a roadmap for assessing the impacts of sea-level rise and coastal hazards in other parts of the state.
In an effort to communicate the results of this project, an online mapping tool has been developed to serve as a decision-support tool for local planners and decision-makers. This online resource is available through the Pacific Islands Ocean Observing System website: [http://oos.soest.hawaii.edu/pacioos/projects/slr/](http://oos.soest.hawaii.edu/pacioos/projects/slr/). In addition, the National Oceanic and Atmospheric Administration has produced a suite of sea-level rise inundation maps for Hawai‘i and the Pacific which are also available online at [http://coast.noaa.gov/slr](http://coast.noaa.gov/slr).

This project demonstrates that sea-level rise will significantly increase the impacts of coastal hazards in Honolulu’s urban corridor, the most populated and economically active area in the state of Hawai‘i. The analysis indicates that 80 percent of the area’s economy, nearly half of the population, and much of the infrastructure and land are at risk of inundation. It is clear then that there is a need to develop long-term, risk-based strategies for hazard mitigation, as well as adaptation of systems to reduce the potential for harm. The results of this project can help inform successful adaptation and hazard mitigation planning and the methods and techniques employed in this project can be translated to other coastal communities in Hawai‘i and the Pacific Islands region, as an example.
The island of Kaua‘i, the oldest of the main Hawaiian islands at approximately six million years old, is one of the most remote islands in the world. This remoteness, coupled with the islands’ increasing vulnerability to coastal hazards due to climate change and sea-level rise, prompted the Kaua‘i County Planning Department to take a visionary step in its efforts to help the community prepare.

The Kaua‘i coastline is susceptible to a variety of natural hazards, including coastal storms, high wave events, flooding, coastal erosion, and tsunamis. All of these hazards threaten lives, property, the natural environment, and, ultimately, economies. Increasing development in coastal areas not only places more people and property at risk to coastal hazards, but it can also degrade the natural environment and interfere with nature’s ability to protect the human environment from severe hazard events. For instance, seawalls can contribute to beach erosion and inhibit the beach’s ability to absorb storm energy, thus exposing buildings to the full force of wind and waves. Development can also degrade wetlands that serve as important buffers against storm surge and other types of flooding. So, while little can be done to prevent coastal hazard events, their adverse impacts can be reduced through proper planning.

To effectively plan for short- and long-term coastal hazard impacts from climate change, the Kaua‘i County Planning Department turned to the University of Hawai‘i Sea Grant College Program (UH Sea Grant) for assistance. It commissioned Ruby Pap, a UH Sea Grant coastal land use extension agent based on Kaua‘i, to coordinate a technical study, synthesizing all of the relevant coastal hazard science, and provide a suite of policy and planning options to consider when incorporating sea-level rise into the Kaua‘i General Plan (GP) update. Although the current GP does address coastal hazards such as coastal erosion, it does not specifically recognize climate change and sea-level rise and its potential to exacerbate existing coastal hazards.

In response, Pap, along with a team of experts from Sea Grant in both coastal hazards science and planning, produced the Kaua‘i Climate Change and Coastal Hazards Assessment (KC3HA). The Sea Grant team included Tara Miller Owens, coastal processes and hazards specialist on Maui; and on O‘ahu, Matthew Gonser, community planning and design extension agent; Bradley Romine, coastal management specialist; Andrew Bohlander, shoreline specialist; Dolan Eversole, NOAA Coastal Storms Program Pacific Islands regional coordinator; and Dennis Hwang, coastal hazard mitigation specialist. Also, the
An important goal of the project is to improve Kaua‘i’s community resilience and preparedness to coastal hazards and changing climate through better understanding and utilization of coastal hazard information and planning tools. To achieve this goal, the Sea Grant team undertook the following actions. First, they developed an inventory and assessment of planning information and data products supporting the integration of science-based coastal hazards information in land use planning through the Kaua‘i GP update. Second, a gap analysis was conducted that identified gaps in planning information, guidance, and policy. Third, sea-level rise inundation maps were created for selected geographic areas on Kaua‘i, utilizing Geographic Information Systems (GIS) data developed by the University of Hawai‘i Coastal Geology Group for the National Oceanic and Atmospheric Administration’s Digital Coast Sea Level Rise and Coastal Flooding Impacts Viewer. The maps provide examples of what planners may create utilizing the GIS data and the tools suggested in the report. These maps may be used in the GP update process as a preliminary screening tool for sea-level rise inundation hazards, and to identify areas where future hazard, risk, and vulnerability assessments and other planning efforts should be focused.

Lastly, the team identified resources and techniques to address the identified problems and gaps and developed planning and policy recommendations for the Kaua‘i GP update. Outreach and workshops with county stakeholders provided important input for this step.

The study found that addressing climate change related coastal hazards, such as sea-level rise, does not necessarily require the development of new programs. Kaua‘i already experiences and has the framework for addressing coastal flooding and wave inundation, erosion, inland flooding, and wind. These hazards will be exacerbated by climate change, and while little can be done to prevent coastal hazard events, the study provides data, tools, and recommendations for planners and the community to reduce their adverse impacts through proper planning.

The study was recently selected for presentation at the Biennial Meeting of the Coastal Society and National Summit on Coastal and Estuarine Restoration in Washington, D.C. in November.

The entire report is available online at: http://seagrant.soest.hawaii.edu/publications
Coral reefs are clearly the first line of defense in tropical environments against a range of coastal hazards. Research has demonstrated that most wave energy is dissipated on the reef crest, which contrasts with the perception that shoreline protection is best carried out along the shore. For developing countries the rationale for reef management has traditionally centered on food security. In recent years due to accelerated shoreline erosion, this has broadened significantly to include protection from coastal hazards. Protection of existing coral reefs is therefore a priority for most Small Island Developing States (SIDS) in particular, which is largely demonstrated through efforts to both designate marine protected areas and implement protected area management plans. Nowhere is this more urgent than in low-lying atolls such as the Republic of the Marshall Islands (RMI), and many agencies are making good progress towards achieving Micronesian Challenge targets for 2020. However, there are many more vulnerable shoreline areas with adjacent coral reefs that will not be protected and managed under this designation.

Through these efforts, the University of Hawai‘i Sea Grant College Program’s (UH Sea Grant) extension program in the Marshall Islands is striving to make a difference, largely through the guidance provided in a recent guidebook titled A Landowner’s Guide to Coastal Protection. Project by project, and little by little, agencies and landowners are starting to make resource management decisions away from hard methods of shore protection such as seawalls, and towards softer approaches such as berm-building and vegetation planting. Looming over this effort, however, are challenges related to finding continued sources of good aggregate for a wide variety of construction projects, both for households and for larger infrastructure development initiatives.

Currently there are large dredging projects for sand along parts of Majuro’s lagoon shoreline. The RMI Environmental Protection Agency (EPA) is working towards implementing new regulations that will allow dredging only away from shorelines. In the interim, additional measures to mitigate dredging impacts on coral reefs are needed. These have historically only involved limited measures in using locally-constructed silt curtains to keep some of the silt away from reefs, and some coral remediation work after the dredging is complete. Notably, past works have resulted in significant mining of live coral with unrealistic expectations that fisheries habitat and shoreline protection services could be restored.

To the credit of the RMI EPA and local contractors, this trend is now starting to change. UH Sea Grant was given
the opportunity to assess coral reef conditions at the proposed dredge site of Lojemwa on Long Island in Majuro. In conjunction with the RMI EPA, adjusted boundaries were approved subject to significant coral relocation ahead of time. This was a first for the Marshall Islands. UH Sea Grant was asked to assemble a team and carry out the work. Divers and snorkelers from the Marine Resources Authority, EPA, College of the Marshall Islands, U.S. Embassy, and the Marshall Islands Mariculture Farm carried out relocation over three days of half a dozen large table corals, and upwards of 50 other colonies of variable sizes. High school students from the Majuro Cooperative School also assisted. After this, over another four days of diving, much of the coral was transplanted at an up-current site 500 feet away which continues to be in need of additional coral.

This is still a work in progress. By no means is the dredge site devoid of coral, as common Majuro coral such as *Porites rus* was left in place. This allowance is a reasonable trade-off between protection and extraction, and reflects the reality often seen in developing countries. Majuro coral is generally considered to be limited in habitat quality compared with other species, and has proliferated in abundance along with blue-green algae and macroalgae as pollution and ad hoc development have altered the species variety and growth form diversity of lagoon corals over the last several decades. The shoreline protection service of the relocated coral and the to-be-dredged Majuro coral is partially replaced via the dredge platform, which will remain as a jetty. The large table corals were mostly relocated with their bases intact, and floated with locally-adapted lift bags with the assistance of a small boat. Other colonies were strategically secured on elevated reef surfaces in the new area, and smaller ones along with broken pieces inserted into wet concrete in 2x2 foot forms. These concrete rectangle colonies will be completely overgrown in a year, and are heavy enough to withstand all but the most extreme swell activity.

One of the most significant outputs of this process has been the outstanding enthusiasm and effort by all divers and snorkelers. Some participants have commented that they did not know that many types of coral could be carefully handled in this way, and still live and grow. It is expected that the continuing outcomes of this work will be other coral transplantation projects that will not need the assistance of UH Sea Grant. Coral transplantation work does not need dredging to be the catalyst for action, and can be a very useful activity in protected and unprotected areas alike. Endorsement by several different Marshall Island agencies, including the Coastal Management Advisory Council, is a significant step forward in moving away from fortification as the desired method of protection against coastal hazards. A small step in terms of area covered, but a giant leap in changed behavior!
Na mea like ‘ole

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