STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT
P.O. BOX 621
HONOLULU, HAWAII 96809

STAFF SUBMITTAL

COMMISSION ON WATER RESOURCE MANAGEMENT

August 11, 2015
Honolulu, Hawaii

Requesting Authority for the Chairperson to Enter Into a Planning Assistance to States Agreement with the U.S. Army Corps of Engineers and to Expend $50,000 in Cost-share for an Implementation Plan to Improve the Climate Data Network and Establish a Climate Data Center for the State of Hawaii

SUMMARY OF REQUEST

The staff of the Commission on Water Resource Management (Commission) requests authorization for the Chairperson to enter into a Planning Assistance to States (PAS) agreement with the U.S. Army Corps of Engineers (Corps of Engineers) and to expend $50,000 in cost-share to complete an implementation plan for improving the climate data network and establish an climate data center for the State of Hawaii.

BACKGROUND

The number of rain gage stations in Hawaii has steadily declined since the late 1960's and leveled off around the late 1990's (see Figure 1). This loss of data, especially long-term stations, becomes especially relevant in a changing climate where it is now imperative to continue and re-establish long continuous periods of rainfall and other climate observations/records. In the past few years there have been numerous recommendations from the scientific community, academia and government that Hawaii's climate monitoring network be improved and enhanced. The history of Hawaiian rainfall observation and its importance is neatly summarized in this excerpt from an unpublished special analysis, 50 Rain Gauge Project, by A.G. Frazier, Geography PhD candidate at the University of Hawaii (see Exhibit 1):[1]

> The first rain gauge on record began collecting data in 1837 on the island of O'ahu. Throughout the 1800s, the network of rain gauge stations began to grow and stations were established across the island chain. By the year 1900 there were 108 rain gauges in operation and in 1930, 444 stations were recording data (Figure 1). At its peak, the Hawai'i rain gauge network had over 950 stations recording rainfall observations (in 1968). Many of these gauges were established by the plantations (sugar and pineapple) for the purpose of maximizing crop yields, which required knowledge of water availability. With the demise of the plantations came the loss of rain gauge stations. Over the last 30 years, over 500 stations have been discontinued, leaving the number of rain gauges currently operating at 435. Of these 435 current stations, only 130 of them have data records greater than 50 years; most of these stations were installed in the past 30 years. As the

[1] A.G. Frazier, unpublished special report, May 31, 2015, 50 Rain Gauges Project, An Assessment of Rain Gauge Network Needs in Hawaii, Rainfall Atlas of Hawaii, University of Hawaii at Manoa.

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climate warms, it is essential to monitor rainfall to understand the state of our water resources and how they are changing. By expanding our network of rain gauges, particularly in data-poor regions, this will reduce uncertainty in recharge estimates and provide improved data for climate models to project future rainfall conditions for Hawai‘i.

Figure 1 from the report is reproduced here.

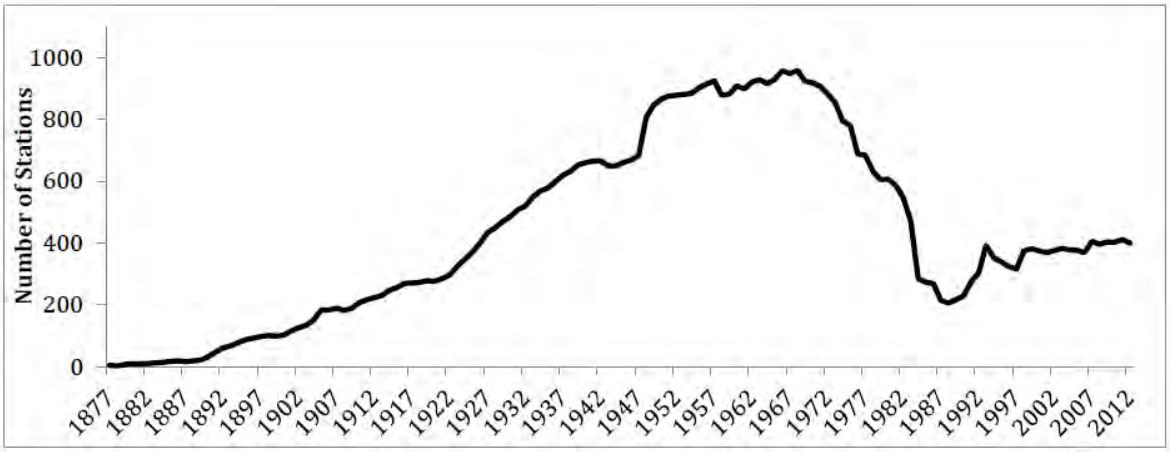

Figure 1. Number of rain gauges operating in Hawai‘i from 1877-2012.

In 2013 the Commission collaborated with the Corps of Engineers and the University of Hawaii to complete the Rainfall Atlas of Hawaii report and interactive website. During the development of this project, researchers found many areas across the state where rainfall data were either deficient or nonexistent. Some of this is due to the decrease in rainfall stations, some of this was due to the perception that data were not needed in some of these areas, and some of this was simply the difficulty in accessing remote locations to set up rain gages. In lieu of empirical data, sophisticated methods were developed to estimate rainfall in these data deficient areas. However, this is no substitute for actual rainfall observations.

NEED TO ENHANCE HAWAII'S CLIMATE MONITORING NETWORK AND ESTABLISH A DATA CENTER

In order to effectively monitor climate change and its impacts, it is critical to have a robust monitoring network in place with long periods of record. Hawaii's landscape is dominated by microclimates, which vary greatly over small geographical areas. This highlights the need for sufficient monitoring to capture the climate variability across the state. It is also recognized that there needs to be an enhancement of climate data observations and a convenient apparatus for archiving and retrieving this data. There are many published reports that recommend improving our climate data collection.

The Climate Change and Pacific Islands: Indicators and Impacts, Report for the Pacific Islands Regional Climate Assessment[2], in its conclusions recognizes the need for improving data collection:

[2] Keener, V. W., Marra, J. J., Finucane, M. L., Spooner, D., & Smith, M. H. (Eds.). (2012). *Climate Change and Pacific Islands: Indicators and Impacts. Report for the 2012 Pacific Islands Regional Climate Assessment*. Washington, DC: Island Press.

> Improving Data Collection
>
> Declines in the total number of observation (measurement) stations in recent decades are a major obstacle to collecting robust data on temperature, rainfall, streamflow, sea level, winds, waves, and other variables needed to understand historic changes in physical and natural systems and to verify models of projected change. Data documenting changes in ocean chemistry and biological productivity are also sparse, and more comprehensive monitoring of shoreline changes is needed. The current lack of funding for maintaining existing monitoring networks and for developing more comprehensive and integrated observation networks across this vast region needs to be addressed urgently.

Water Resources and Climate Change Adaptation in Hawaii: Adaptive Tools in the Current Law and Policy Framework[3] acknowledges the need for improving data collection and suggests achieving this through permit conditions:

> Relatedly, climate change scientists, the Water Commission, the U.S. Geological Survey, and others have acknowledged the important need to maintain a robust network of rain gauges, stream gauges, deep monitor wells, and other indicia of the hydrologic cycle, around the state. For rain and stream monitoring, this is especially critical in areas with an existing long-term data record, where long-term climate-related trends and impacts on water resources can be observed.

The 2012 Hawaii State Legislature also recognized the need for continued climate monitoring when it passed SB2745. The bill was signed into law by Governor Abercrombie as Act 286, Session Laws of Hawaii 2012. The pertinent part here is codified in §226-106(3), Hawaii Revised Statutes:

> **[§226-109] Climate change adaptation priority guidelines**. Priority guidelines to prepare the State to address the impacts of climate change, including impacts to the areas of agriculture; conservation lands; coastal and nearshore marine areas; natural and cultural resources; education; energy; higher education; health; historic preservation; water resources; the built environment, such as housing, recreation, transportation; and the economy shall:
>
> (3) Invest in continued monitoring and research of Hawaii's climate and the impacts of climate change on the State;

During the development of the 2013 Rainfall Atlas of Hawaii, researchers were challenged by the fact that there was no single repository for Hawaiian rainfall data. Much of the data collection effort was devoted to tracking down disparate rainfall sources and manually digitizing the paper records. This emphasized the need for a centralized rainfall data portal that is actively maintained for quality control and to ensure reliable and timely access to the data.

This conspicuous and critical need for improving Hawaiian rainfall data collection and the archiving and dissemination of this information became a forefront issue after the completion of the Rainfall Atlas of Hawaii and its related analysis, 50 Rain Gauges Project[41].

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[3] Richard Wallsgrove and David Penn, *Water Resources and Climate Change Adaptation in Hawai'i: Adaptive Tools in the Current Law and Policy Framework*, (Center for Island Climate Adaptation and Policy, Honolulu, Hawai'i, 2012), *available at* http://icap.seagrant.soest.hawaii.edu/icap-publications *and* www.islandclimate.org.

[4] A.G. Frazier, May 31, 2015, unpublished special report, 50 Rain Gauges Project, An Assessment of Rain Gauge Network Needs in Hawaii, Rainfall Atlas of Hawaii, University of Hawaii at Manoa.

Commission staff met with Dr. Tom Giambelluca, Professor Geography Department, University of Hawaii Manoa and principal investigator for the update of the Rainfall Atlas of Hawaii, and his team to discuss solutions to address this issue. While there was mutual agreement on the need to enhance climate data monitoring and centralize data storage, it was recognized that an implementation plan would be advantageous to work out the many related details, including but not limited to, the prioritization of new stations; establishment of cost estimates for station installation, operation, and maintenance; identification of partners and collaborators to support the expanded program; data storage requirements; and the identification of funding models and entity to host the centralized data portal. To support the development of an implementation plan for enhancing the climate monitoring network, Commission staff contacted the Corps of Engineers Honolulu District inquiring about available Planning Assistance to States funding. The Corps of Engineers responded indicating that there is $50,000 cost-share available in the PAS agreement program. Commission staff worked with Corps of Engineers staff and Dr. Giambelluca to develop a draft project scope of work.

U.S. ARMY CORPS OF ENGINEERS PLANNING ASSISTANCE TO STATES PROGRAM

Section 22 of the Water Resources Development Act of 1974, as amended, authorizes the U.S. Army Corps of Engineers to provide comprehensive water resource Planning Assistance to States and tribes. Section 22 (PAS) projects are typically planning level of detail; and do not include design or construction. The costs for these projects are shared between the federal government (50%) and the non-federal sponsor (50%). The Commission cooperated most recently with the Corps of Engineers to develop the Rainfall Atlas of Hawaii and the Evapotranspiration of Hawaii and their respective studies and interactive websites.

Commission staff is requesting authorization for the Chairperson to enter into a PAS agreement and to expend $50,000 for the non-federal cost-share to complete this project. The total cost for this project is $100,000 including federal and non-federal cost-shares.

SCOPE OF WORK

Early in the process, it was recognized that an implementation plan was necessary to coordinate all of the components for a successful and robust climate observation network and data center. Some key factors drove the development of the scope of work:

- The PAS program may only be used for planning studies
- There are a several distinct and discrete rainfall data collection networks in Hawaii
- There are numerous stakeholders and beneficiaries of the rainfall data
- There is no centralized data portal to access the rainfall data
- Sustained funding is critical for the project success – there are very few agencies and organizations that provide funding for the operation of rain gages/climate stations and the management of the resultant data stream
- There is a universal recognition that the rainfall data network needs improvement and is critical for monitoring climate change
- An implementation plan is necessary

A draft scope of work was developed which consists of 6 task elements and specific deliverables. This is summarized below. See Exhibit 2 for the full draft scope of work.

Implementation Plan: Climate Monitoring Network and Data Center for the State of Hawaii, Section 22 Study

Tasks

1. Research existing rainfall data collection sites
2. Research potential new rainfall data collection sites
3. Research establishment of a data center or other means of collecting and making the data accessible
4. Develop a list of stakeholders
5. Research and identify technological advances (related to rainfall data collection and management)
6. Develop a phased implementation plan

Deliverables

1. An implementation plan that includes a determination of manpower and funding requirements with recommendations on how to obtain the necessary resources.
2. Identification of the pieces that no single agency can fund.
3. Identification of costs and ways to share the information.
4. Draft Memorandums of Agreement that agencies could sign to commit to long term support of a gage.
5. Estimated time frame to complete implementation and description of phases of work if necessary due to funding or resource constraints).

AUTHORITY

Under its general powers and duties, the Commission has the authority to plan and cooperate with federal agencies to plan and coordinate programs for water resources.

§174C-5 (4), Hawaii Revised Statutes (HRS): *(the commission) May contract and cooperate with the various agencies of the federal government and with state and local administrative and governmental agencies or private persons;*

§174C-5 (13), HRS: *(the commission) Shall plan and coordinate programs for the development, conservation, protection, control, and regulation of water resources based upon the best available information, and in cooperation with federal agencies, other state agencies, county or other local governmental organizations and other public and private agencies created for the utilization and conservation of water;*

ENVIRONMENTAL REVIEW CHAPTER 343, HAWAII REVISED STATUTES

Under §343-5(a), HRS, an Environmental Assessment (EA) is triggered with the use of state funds but may be declared exempt from the process if falling into certain exempted classes of action. The proposed action is exempt from an EA, falling under exempt class of action 5.

§11 -200-8(a)(5), Hawaii Administrative Rules (HAR): *Basic data collection, research, experimental management and resource evaluation activities which do not result in a serious or major disturbance to an environmental resource;*.

See Exhibit 3 for 343 exemption notification.

FUNDING

Staff estimates that $50,000 in Commission funding is needed to fulfill the non-federal cost-share requirement to complete this project. The total cost for this project is $100,000 including federal (Corps of Engineers) and non-federal (Commission) cost-shares.

RECOMMENDATIONS

Staff recommends that the Commission:

1. Authorize the Chairperson to enter into a Planning Assistance to States (PAS) agreement with the U.S. Army Corps of Engineers and to expend $50,000 in Commission cost-share to complete an implementation plan for improving the climate data network and establishing a climate data center for the State of Hawaii.

2. Authorize the Chairperson to amend or modify the PAS agreement as may be necessary to accomplish the goals described here, provided that any amendment or modification does not require additional Commission funding.

3. Find and determine that the proposed action is exempt from the requirement to prepare an EA.

The terms of the PAS agreement would be subject to the availability of funding and approval of the Chairperson and the Department's Deputy Attorney General.

Respectfully submitted,

W. ROY HARDY
Acting Deputy Director

APPROVED FOR SUBMITTAL:

SUZANNE D. CASE
Chairperson

Attachments:
Exhibit 1 – 50 Rain Gauge Project
Exhibit 2 – Draft Scope of Work
Exhibit 3 – 343 Exemption notification

50 Rain Gauges Project

Assessment of Rain Gauge Network Needs in Hawai‘i

May 31, 2015

Rainfall Atlas of Hawai‘i, University of Hawai‘i at Mānoa

Background

The first rain gauge on record began collecting data in 1837 on the island of O‘ahu. Throughout the 1800s, the network of rain gauge stations began to grow and stations were established across the island chain. By the year 1900 there were 108 rain gauges in operation and in 1930, 444 stations were recording data (Figure 1). At its peak, the Hawai‘i rain gauge network had over 950 stations recording rainfall observations (in 1968). Many of these gauges were established by the plantations (sugar and pineapple) for the purpose of maximizing crop yields, which required knowledge of water availability. With the demise of the plantations came the loss of rain gauge stations. Over the last 30 years, over 500 stations have been discontinued, leaving the number of rain gauges currently operating at 435. Of these 435 current stations, only 130 of them have data records greater than 50 years; most of these stations were installed in the past 30 years. As the climate warms, it is essential to monitor rainfall to understand the state of our water resources and how they are changing. By expanding our network of rain gauges, particularly in data-poor regions, this will reduce uncertainty in recharge estimates and provide improved data for climate models to project future rainfall conditions for Hawai‘i.

EXHIBIT 1

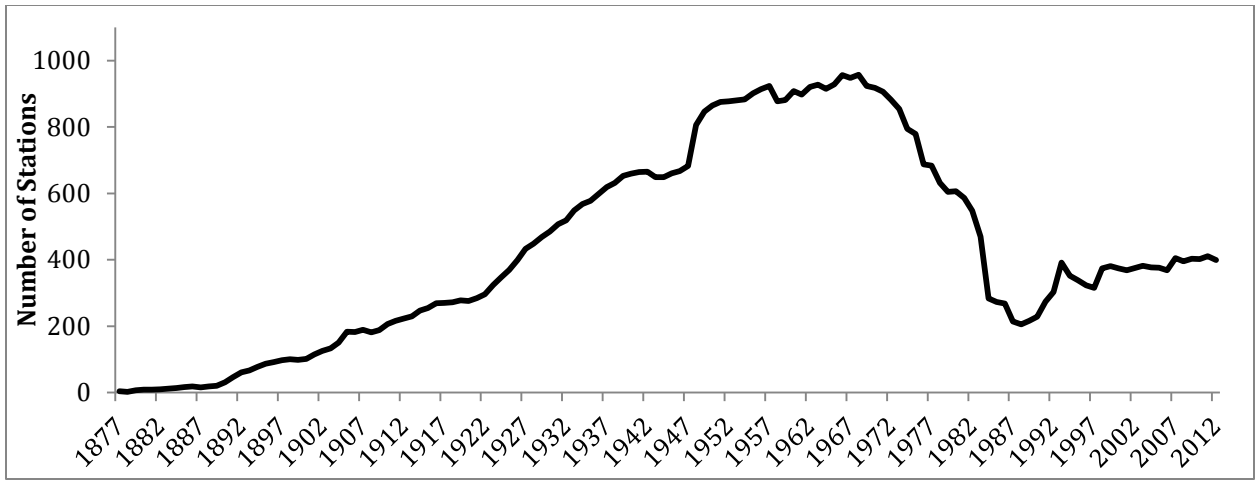

Figure 1. Number of rain gauges operating in Hawai'i from 1877-2012.

Gauge Density Recommendations

In order to map rainfall and determine the spatial patterns, interpolation of the point measurements is needed. On small, mountainous islands like the Hawaiian Islands, the spatial patterns of rainfall are very diverse, and a dense network of stations is necessary for more accurate interpolation. Exactly how dense that network needs to be is difficult to quantify, but a report by the World Meteorological Organization (WMO) in 1965 (latest edition published in 2008) identified minimum ideal gauge densities for different climatic and geographic zones. Table 1 shows how an ideal gauge density for small islands is at least 1 gauge per 25 km². The newer editions of the report define "small islands" as having a surface area of less than 500 km² (earlier editions used 20,000 km² as the definition for "small mountainous islands", and stated 25 km² as the minimum density). Though most of the Hawaiian Islands are larger than 500 km², this density was most applicable out of all the regions defined by the WMO. The total area of the Hawaiian Islands is 16,678 km². When the total area is divided by 25

km²/gauge (the ideal minimum gauge density), the number of stations necessary to achieve that density would be around 667 stations.

Region	Minimum Densities Per Station *(areas in km²/gauge)*
Non-Recording (Manual) Gauges:	
Coastal	900
Mountains	250
Interior Plains	575
Hilly/Undulating	575
Small Islands	25
Arid/Polar	10,000

Table 1. Table adapted from Guide to Hydrological Practices, WMO-No. 168.

Current Gauge Density in Hawai'i

Adequate spatial coverage is as important as achieving a minimum station density. Attaining consistent coverage is challenging, however, due to the complex terrain. Some of the most important rainfall areas are in remote parts of the islands, making it difficult to maintain a gauge. Based on the current network of stations, the 25 km² circle accounted for by each station only accounts for 35% of the total area. This means that even though the number of current stations is about 65% of the recommended amount (435 out of 667); the spatial coverage is much less than that. Figure 2 shows the current distribution of rain gauges and lists the number of gauges currently operating on each island. Note how the number of gauges does not necessarily correspond to island size. Ideally, the rain gauge network would consist of at least 667 stations, where each station accounts for no more than 25 km² of land area, and all surface area is accounted for by these 25 km² representative areas. However, this would require the gauges to be arranged on a grid, which is unrealistic given Hawai'i's terrain. Figure 3 shows the 25 km² areas around each current station in yellow, and all areas in blue are in need of rain

gauges. To cover the rest of the "blue" area that currently does not have adequate rain gauge coverage, a minimum of 435 additional gauges would be needed.

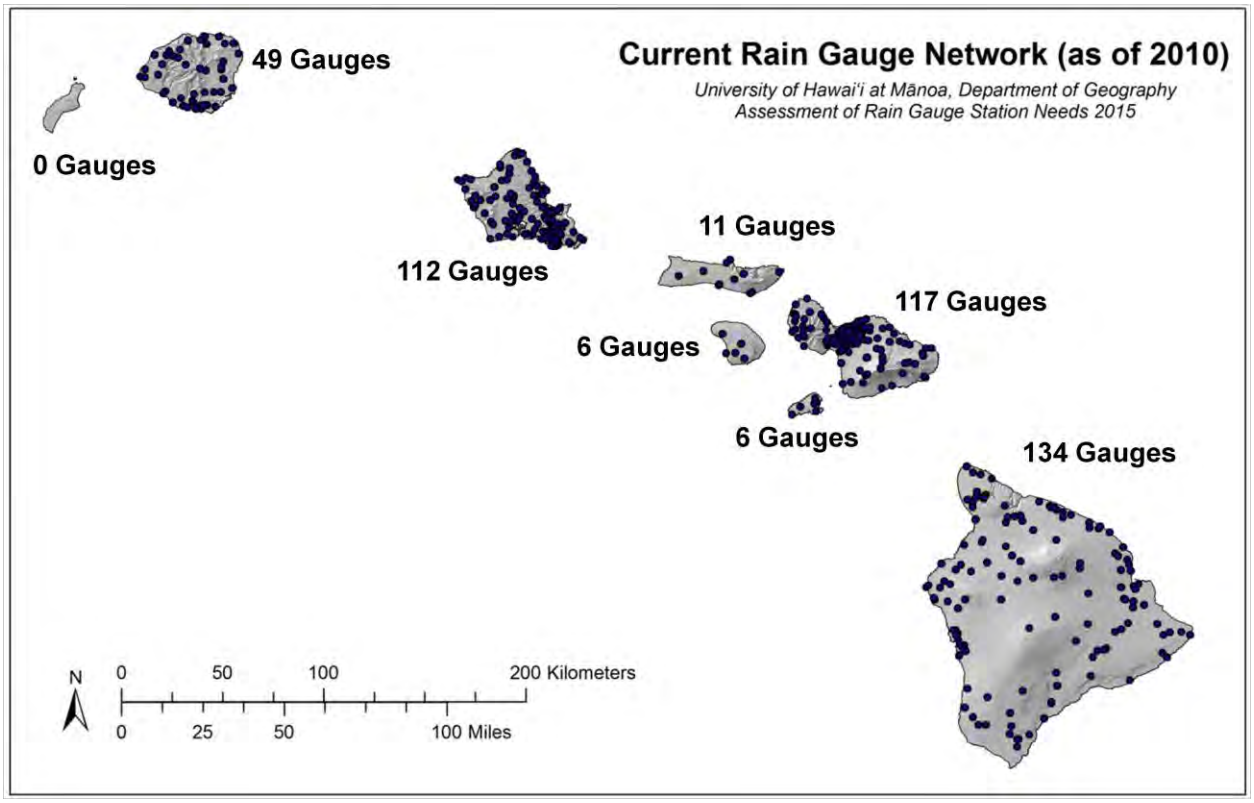

Figure 2. Current network of rain gauges, with number of gauges identified on each island.

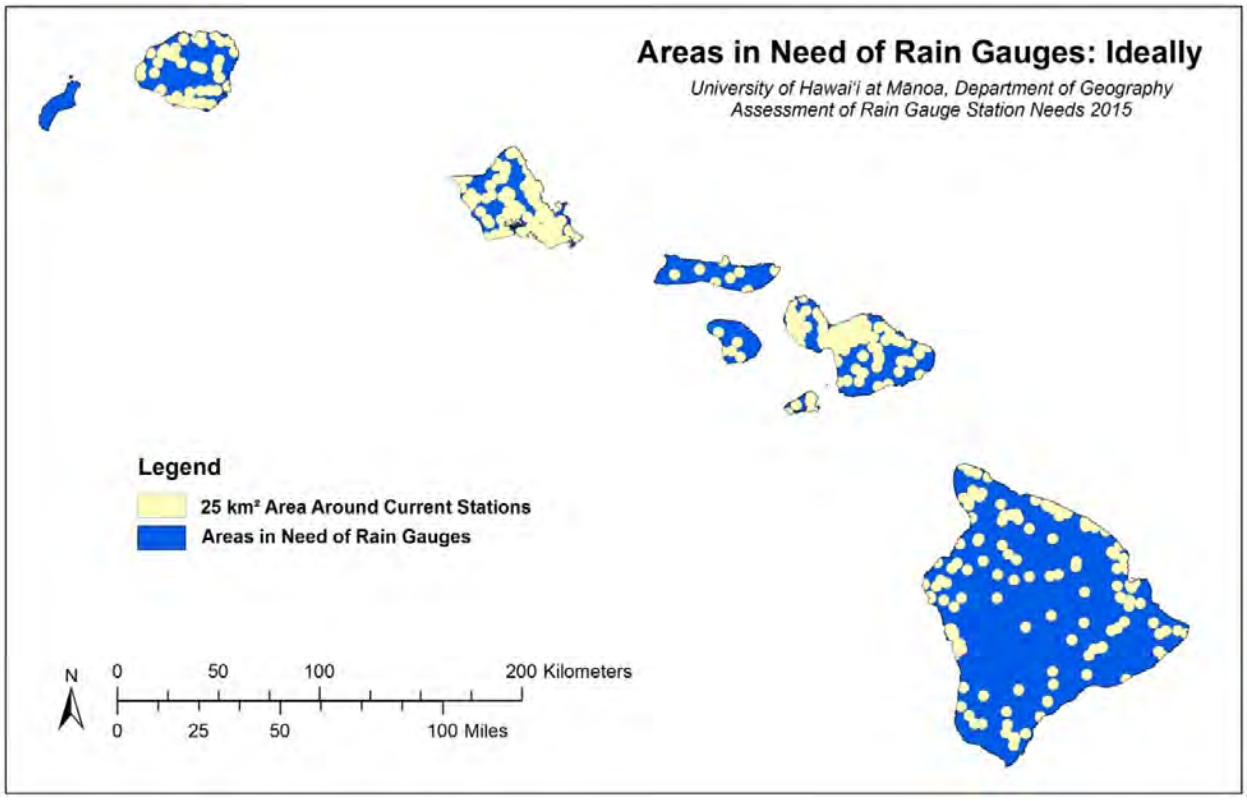

Figure 3. With ideal spatial coverage, the rainfall network would cover all areas in blue. Currently, the network of rain gauges only covers the areas in yellow.

Analysis

a) Calculating High Priority Need Areas:

Since this goal of installing an additional 435 gauges not realistic in the short term, priority areas were assessed in conjunction with discontinued stations that recorded data over a long period of time. It was determined that it is most important to know the rainfall in these four priority areas:

1) Where people live and work (residential and agricultural lands)
2) High rainfall areas (areas that receive at least 3000 mm annually, as these are important ecological recharge areas)

3) High rainfall gradient areas (500 mm/km rate of change or greater, areas where the rainfall changes drastically over a short area – these areas are sensitive to climate change, and it is important to have high station density for accuracy)
4) Areas within the typical trade wind inversion (TWI) band (between 1800 and 2600 m in elevation – these are areas that are also extremely sensitive to climate change)

These areas were identified and combined using GIS (Geographic Information Systems) analysis. The 25 km² circle areas around each current station were subtracted from these priority areas to yield the most important areas in need of rain gauges (in the short term), hereafter referred to as "High Priority Need Areas". These areas are shown in the appendix maps below.

b) Identifying Long-Term Gauges

To further focus the placement of any new stations in these high priority need areas, another important factor to consider is the large database of historical records that have already been collected. There are many stations with long records that have been discontinued recently (within the last few decades). It would be extremely valuable to re-establish some of these stations so that the records can be continued into the future and not become obsolete for future mapping efforts. All discontinued stations that had at least 30 years of data were selected and are plotted with the top priority "need" areas (as detailed above). From these stations, we identified top priority gauges to re-install on each island based on the record length and location. Priority was given to stations with long record lengths (greater than 50 years of data), stations discontinued within the last 20 years, and stations located in high priority need areas. All stations selected were given a priority ranking of A or B: A = top priority station (long record length, discontinued recently, and/or in an important area); B = "if possible" station.

Another factor to consider when selecting gauges to re-install is accessibility. To assess this, an analysis using Google Earth and Google Maps was conducted to locate all proposed stations and

document how easy or difficult the station would be to access. Accessibility ranking scores were assigned to each station: A = easy access, near a major road; B = difficult to access, requires four-wheel drive vehicle, unsure of road conditions; C = very difficult to access, requires hiking and/or four-wheel drive vehicle. Notes were also provided on directions and road conditions, as well as an exact address if possible. Along with physical access, land permissions need to be determined. However, this aspect of accessibility has not been examined yet.

c) Identifying Other Gauge Locations

In addition to re-installing long-term gauge sites, it is important to consider areas that have never had a rain gauge. To identify locations for new gauges in this category, we calculated the 25 km² circle areas around each proposed station to re-install, and subtracted these areas from the high priority need areas. Looking only at these leftover regions, we determined approximately how many gauges would be needed to fully cover the rest of each island's high priority need areas. Approximate coordinates and temporary names were identified, as well as any short-term gauges that may have existed near that location. Again using Google Earth and Google Maps, accessibility rankings and notes were completed. All proposed gauge locations are shown in the appendices below, and are available as GIS shapefiles.

Results

Table 2 below shows the number of proposed gauge locations to re-install for each island. There are more than 50 total rain gauges that we have identified. Due to accessibility constraints, we anticipate that some of the gauges will not be possible to install at this time. Therefore, we have

proposed alternative locations that will be more feasible. Using the priority and accessibility rankings provided, we hope that this will make it easy to select new gauge locations on each island.

Island	Total # Long-Term Gauges to Re-install	# High Priority (type A)	# Easy to Access (type A)	# Difficult to Access (type B)	# Very Difficult to Access (type C)	# High Priority AND Easy Access (type A & A)
Kauaʻi	7	5	3	3	1	3
Oʻahu	8	7	4	2	2	3
Molokaʻi	7	7	5	0	2	5
Lānaʻi	9	6	4	5	0	1
Maui	14	9	5	3	6	3
Big Island	35	22	18	13	4	10
TOTAL	**80**	**56**	**39**	**26**	**15**	**25**

Table 2. Number of long-term gauges to re-install by island, and number of gauges with different priority and accessibility rankings.

Table 3 below shows the number of additional gauges to install by islands. These are places that do not have a long-term gauge nearby, and some are areas that have never had a rain gauge. The locations for these stations are approximate, and exact coordinates can be determined in the field after installation. Since these gauges will not be replacing a long-term gauge, it is not critical that the location line up exactly with what is proposed here; the technicians can use their best judgment in the field for installation. For a few areas, an exact location is not provided, as the location is extremely remote, and accessibility is questionable. For these regions, local consultation will be needed to determine where it would be possible to install a gauge.

Island	Total # New Gauges	# Easy to Access (type A)	# Difficult to Access (type B)	# Very Difficult to Access (type C)
Niʻihau	3	0	3	0
Kauaʻi	6	0	5	1
Oʻahu	2	0	0	2
Molokaʻi	14	6	6	2
Lānaʻi	1	1	0	0
Maui	14	8	2	4
Big Island	89	20	48	21
TOTAL	**129**	**35**	**64**	**30**

Table 3. Number of new gauges to install by island, and number of gauges with different accessibility rankings.

The maps showing the high priority need areas and locations of proposed gauges are shown in the Appendices:

- **Appendix A** contains the lists of stations to reinstall for each island, as well as maps of all the islands with the locations of proposed gauges to re-install, high priority need areas, locations of current stations, and the 25 km² area the proposed stations would represent.
- **Appendix B** contains maps of the other gauges that should be installed (not re-establishing long-term gauges), as well as their 25 km² area, the locations of proposed gauges from Appendix A, current stations, and high priority need areas.
- **Appendix C** contains the accessibility assessment for each station to re-install (from Appendix A) which includes the Google Earth images for every station location. There are 6 files: 1 for each island.
- **Appendix D** contains the accessibility assessment for each station to in the “other gauges” category (from Appendix B) which includes the Google Earth images for every station location.

There are 8 files: Niʻihau, Kauaʻi and Oʻahu are combined into 1 file; Molokaʻi and Lānaʻi are combined into 1 file; Maui has 1 file; and the Big Island has 5 files.

- **Appendix E** is a spreadsheet containing the coordinates of every proposed station (both categories), as well as the accessibility rankings and notes.

Conclusions

We have identified the top priority locations to install new rain gauges in Hawaiʻi. Since not all of these gauges will be feasible, due to land permits and accessibility, a list of more than 50 gauges has been provided. An important aspect for making this project successful will be collaborating with groups on each island. We can take advantage of local knowledge and reduce costs by enlisting the help of agencies working near these proposed gauge locations. Installing 50 new gauges will not bring Hawaiʻi's gauge network to the ideal density, but if the new gauges are strategically placed in the high "need" areas identified in this project, this improved monitoring effort will make a big difference toward reducing uncertainty in our rainfall estimates. For more information or for questions concerning this analysis, please contact:

Abby Frazier

abbyf@hawaii.edu

References

WMO, 2008 WMO *Guide to Hydrological Practices*, (6th Ed.), WMO, Geneva (2008) WMO-No. 168.

UPDATE TO RAIN GAUGE NETWORK NEEDS: 2015

APPENDIX A

Number of Current Stations (as of 2010): **435**

Number of Current Stations with at least 50 years of data: **130**

Number of Current Stations with at least 30 years of data: **173**

--Most of the currently operating stations were installed within the last 30 years

Of the 435 current stations:

- **134** are on Big Island
- **117** on Maui
- **6** on Kahoolawe
- **11** on Molokai
- **6** on Lanai
- **112** on Oahu
- **49** on Kauai
- **0** on Niihau

RECOMMENDATIONS: Long-term stations to re-install

Numbers by island:

- Niihau: Add at least **one** gauge!
- Kauai: **5** top priority, *+**2** more if possible*
- Oahu: **7** top priority, *+**1** more if possible*
- Molokai: **7** top priority
- Lanai: **6** top priority, *+**3** more if possible*
- Maui: **9** top priority, *+**5** more if possible*
- Big Island: **21** top priority, *+**10** more if possible*

=56 top priority gauges (+21 more if possible)

TOP STATIONS TO RE-INSTALL (BY ISLAND):

KAUAI:

1. **SKN 1086: Wainiha Pow Int**
   Operated from 1907 – 2008 (656 months of data)
   Elev: 238 m
   Coords: 22.14848, -159.567201
2. **SKN 1052: Waiahi Upper**
   1927 – 1986 (694 months of data)
   Elev: 241 m
   Coords: 22.020186, -159.463869
3. **SKN 944: Kekaha**
   1889 – 2000 (1260 months of data)
   Elev: 0.8 m
   Coords: 21.966867, -159.708879
   OR
   SKN 943: Waiawa
   1894 – 2000 (1224 months of data)
   Elev: 3 m
   Coords: 21.971868, -159.720546
4. **SKN 1112: Kealia**
   1899 – 1986 (940 months of data)
   Elev: 5.4 m
   Coords: 22.099507, -159.305538
5. **SKN 1065: Wailua Kai**
   1924 – 2000 (747 months of data)
   Elev: 10 m
   Coords: 22.036817, -159.340538

IF POSSIBLE:

1. **SKN 990.2: H-M Divide**
   1910-1941 (370 months of data)
   Elev: 524 m
   Coords: 22.005193, -159.517202
2. **SKN 1102: Field Makee 2b**
   1921 – 1991 (662 months of data)
   Elev: 142 m
   Coords: 22.123405, -159.350536

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OAHU:

1. **SKN 836: Waiawa**
   1916 – 2007 (984 months of data)
   Elev: 248.5 m
   Coords: 21.458496, -157.923919

2. **SKN 880: Kawai Iki**
   1903 – 1954 (620 months of data)
   Elev: 377 m
   Coords: 21.568492, -157.98725
3. **SKN 847: Waialua***
   1901 – 2003 (1140 months of data)
   Elev: 7 m
   Coords: 21.5737, -158.121
4. **SKN 806: Kunia Dam**
   1923 – 1980 (675 months of data)
   Elev: 257 m
   Coords: 21.456834, -158.058919
5. **SKN 881: Helemano Intake**
   1918 – 1979 (703 months of data)
   Elev: 398 m
   Coords: 21.538494, -157.99114
6. **SKN 882: Wahiawa Mauka**
   1906 – 1953 (548 months of data)
   Elev: 374 m
   Coords: 21.513495, -157.945585
7. **SKN 727: Pump 10**
   1911 – 1983 (833 months of data)
   Elev: 9 m
   Coords: 21.335174, -158.107254

IF POSSIBLE:

1. **SKN 865: Poamoho**
   1923 – 1980 (637 months of data)
   Elev: 287 m
   Coords: 21.516273, -158.043917

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MOLOKAI:

1. **SKN 542: Mapulehu**
   1892 – 1973 (746 months of data)
   Elev: 11 m
   Coords: 21.066809, -156.803855
2. **SKN 562: Kipu**
   1930 – 1983 (629 months of data)
   Elev: 392 m
   Coords: 21.163482, -157.020517
3. **SKN 550: Kepuhi**
   1933 – 2008 (496 months of data)
   Elev: 14 m
   Coords: 21.187929, -157.246349
4. **SKN 529: Field 325**
   1929 – 1986 (685 months of data)
   Elev: 99 m
   Coords: 21.125151, -157.062187
5. ***SKN 544: Puu Lua Wailau**
   1923 – 1960 (135 months of data*)
   Elev: 862 m
   Coords: 21.106255, -156.816356
6. ***SKN 541.1: Pepeopae**
   1956 – 1978 (190 months of data*)
   Elev: 1256 m
   Coords: 21.116815, -156.90052
7. **SKN 500: Kumakaipo**
   1933 – 1975 (450 months of data)
   Elev: 18 m
   Coords: 21.121822, -157.297186

*not long term, but extremely poor data coverage in these locations

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LANAI:

1. **SKN 696: R-5 (Keomoku)**
   1914 – 1950 (380 months of data)
   Elev: 1 m
   Coords: 20.8499, -156.827202
2. **SKN 684: R-4 (Lanai Hale)**
   1924 – 2004 (618 months of data)
   Elev: 1021 m
   Coords: 20.811287, -156.872475
3. **SKN 685: Waiakeakua**
   1939 – 2008 (629 months of data)
   Elev: 622 m
   Coords: 20.79462, -156.874973
4. **SKN 650: R-8 (Palikoholo)**
   1914 – 1983 (782 months of data)
   Elev: 378 m
   Coords: 20.763942, -156.968794
5. **SKN 653: 538**
   1935 – 1983 (573 months of data)
   Elev 385 m
   Coords: 20.831555, -156.9647
6. **SKN 694: Mahana (R-9)**
   1934 – 2007 (522 months of data)
   Elev: 459 m
   Coords: 20.864892, -156.908315

IF POSSIBLE:

1. **SKN 686: 533**
   1952 – 1983 (374 months of data)
   Elev: 451 m
   Coords: 20.856555, -156.949148
2. **SKN 693: Koele**
   1892 – 1975 (870 months of data)
   Elev: 534 m
   Coords: 20.837115, -156.916644
3. **SKN 665: 545**
   1926 – 1983 (618 months of data)
   Elev: 384 m
   Coords: 20.787114, -156.931917

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MAUI:

1. **SKN 354: Hana**
   1907 – 1978 (763 months of data)
   Elev: 37 m
   Coords: 20.749577, -155.987205
2. **SKN 259.4: Central Crater**
   1966 – 2005 (431 months of data)
   Elev: 2232 m
   Coords: 20.722082, -156.198582
3. **SKN 341: Honomanu Gulch**
   1933 – 1999 (561 months of data)
   Elev: 1887 m
   Coords: 20.776799, -156.223858
4. **SKN 377: Olowalu Gulch**
   1912 – 1972 (696 months of data)
   Elev: 232 m
   Coords: 20.840639, -156.593579
5. **SKN 481: Nakalaua**
   1933 – 1981 (406 months of data)
   Elev: 1369 m
   Coords: 20.916235, -156.592453
6. **SKN 475: Mokupea**
   1899 – 1988 (949 months of data)
   Elev: 427 m
   Coords: 20.975119, -156.61884
7. **SKN 330: Gomi**
   1900 – 1982 (633 months of data)
   Elev: 1073 m
   Coords: 20.780708, -156.299674

8. **SKN 264: Waihou**
   1934 – 1975 (490 months of data)
   Elev: 1095 m
   Coords: 20.666254, -156.367185
9. **SKN 260.2: Keawakapu Beach**
   1951 – 1982 (362 months of data)
   Elev: 6 m
   Coords: 20.695141, -156.443848

IF POSSIBLE:

1. **SKN 336: Waikamoi Dam**
   1910 – 1980 (622 months of data)
   Elev: 1342.5 m
   Coords: 20.806797, -156.230523
2. **SKN 328: Kula Erehwon**
   1890 – 1953 (733 months of data)
   Elev: 1191.5 m
   Coords: 20.751802, -156.303854
3. **SKN 259.5: Holua Cabin**
   1964 – 1999 (399 months of data)
   Elev: 2108.5 m
   Coords: 20.741525, -156.218025
4. **SKN 301: Ukumehame**
   1929 – 1999 (823 months of data)
   Elev: 18 m
   Coords: 20.803466, -156.587176
5. **SKN 252: Auwahi**
   1925 – 1998 (667 months of data)
   Elev: 602 m
   Coords: 20.620147, -156.328853

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BIG ISLAND:

1. **SKN 181.1: Honokane**
   1905 – 1972 (746 months of data)
   Elev: 246 m
   Coords: 20.145266, -155.73055
2. **SKN 182.1: Awini**
   1905 – 1973 (545 months of data)
   Elev: 541 m
   Coords: 20.168597, -155.712217
3. **SKN 161: Puakea**
   1902 – 1980 (884 months of data)
   Elev: 177 m
   Coords: 20.231928, -155.870544
4. **SKN 199: Kukuihaele Hic**
   1905 – 1994 (964 months of data)
   Elev: 302 m
   Coords: 20.115269, -155.58222
   OR
   SKN 206: Kukuihaele Landg
   1891 – 1993 (1080 months of data)
   Elev: 93 m
   Coords: 20.125268, -155.558887
5. **SKN 212: First Gate**
   1910 – 1981 (828 months of data)
   Elev: 783 m
   Coords: 20.048606, -155.513888

6. **SKN 114: Hope A**
   1909 – 1973 (725 months of data)
   Elev: 1229 m
   Coords: 19.97361, -155.41389
7. **SKN 118: Umikoa**
   1894 – 1976 (968 months of data)
   Elev: 1051 m
   Coords: 19.980276, -155.378891
8. **SKN 117: Halepiula**
   1914 – 1976 (672 months of data)
   Elev: 1750 m
   Coords: 19.928613, -155.390558
9. **SKN 124.1: Keanakolu**
   1915 – 1975 (631 months of data)
   Elev: 1612 m
   Coords: 19.915281, -155.335559
10. **SKN 120: Puu Kihe**
    1915 – 1976 (667 months of data)
    Elev: 2378 m
    Coords: 19.895281, -155.392225
11. **SKN 105: Kemole 2-P Ranch**
    1936 – 1975 (462 months of data)
    Elev: 1453 m
    Coords: 19.931946, -155.532223
12. **SKN 82: Puu Oo**
    1910 – 1974 (599 months of data)
    Elev: 1911 m
    Coords: 19.723625, -155.385559
13. **SKN 94.1: Puu Waawaa**
    1894 – 1997 (1175 months of data)
    Elev: 887 m
    Coords: 19.772793, -155.84222
14. **SKN 68: Holualoa Beach**
    1918 – 1978 (691 months of data)
    Elev: 1 m
    Coords: 19.605305, -155.975547
15. **SKN 75: Ahua Umi**
    1922 – 1982 (724 months of data)
    Elev: 1587 m
    Coords: 19.633634, -155.778885
16. **SKN 73: Puu Lehua**
    1922 – 1983 (723 months of data)
    Elev: 1481 m
    Coords: 19.565306, -155.80555
17. **SKN 17: Moaula Res**
    1911 – 1983 (743 months of data)
    Elev: 554 m
    Coords: 19.198375, -155.527218
18. **SKN 44: Ohaikea**
    1925 – 1977 (610 months of data)
    Elev: 1061 m
    Coords: 19.404617, -155.34992
19. **SKN 58: Ainahou**
    1942 – 1983 (453 months of data)
    Elev: 923 m
    Coords: 19.344204, -155.229443
20. **SKN 90: Wainaku Makai**
    1894 – 1979 (1002 months of data)
    Elev: 25 m
    Coords: 19.738963, -155.09093
21. **SKN 137: Honohina**
    1894 – 1993 (1162 months of data)
    Elev: 73 m
    Coords: 19.921946, -155.153896

IF POSSIBLE:

1. **SKN 159: Mahukona**
   1912 – 1955 (510 months of data)
   Elev: 6 m
   Coords: 20.183599, -155.900543
2. **SKN 178.3: Kalope**
   1937 – 1981 (511 months of data)
   Elev: 1042.5 m
   Coords: 20.075271, -155.763884
3. **SKN 95.1: Puako**
   1939 – 1975 (422 months of data)
   Elev: 0.6 m
   Coords: 19.966946, -155.850828
4. **SKN 70.1: Halepiula Shed**
   1938 – 1974 (429 months of data)
   Elev: 1361 m
   Coords: 19.731963, -155.85722
5. **SKN 72: Hualalai**
   1929 – 2007 (515 months of data)
   Elev: 2498 m
   Coords: 19.688633, -155.870552
6. **SKN 13: Waiubata**
   1939 – 1975 (382 months of data)
   Elev: 405 m
   Coords: 19.096437, -155.567218
7. **SKN 37: Pakao**
   1928 – 1977 (560 months of data)
   Elev: 1534.5 m
   Coords: 19.36864279, -155.463887

8. **SKN 88.1: Kaumana-Hilo Sug**
   1896 – 2006 (805 months of data)
   Elev: 339 m
   Coords: 19.683629, -155.140563
9. **SKN 135: Hakalau Mauka**
   1905 – 1979 (866 months of data)
   Elev: 353 m
   Coords: 19.883617, -155.165563
10. **SKN 222: Kukaiau-H Mill**
    1895 – 1994 (1103 months of data)
    Elev: 277 m
    Coords: 20.026939, -155.342225

IF MAUNAKEA NET GOES IN, WE DO NOT NEED THESE. OTHERWISE:

1. **SKN 80: Kalaieha**
   1915 – 1979 (760 months of data)
   Elev: 2044 m
   Coords: 19.700571, -155.461668
2. **SKN 97: Keamuku**
   1924 – 1981 (653 months of data)
   Elev: 947 m
   Coords: 19.840286, -155.717222
3. **SKN 102.1: Puu Laau**
   1932 – 1977 (429 months of data)
   Elev: 2279 m
   Coords: 19.831952, -155.592224

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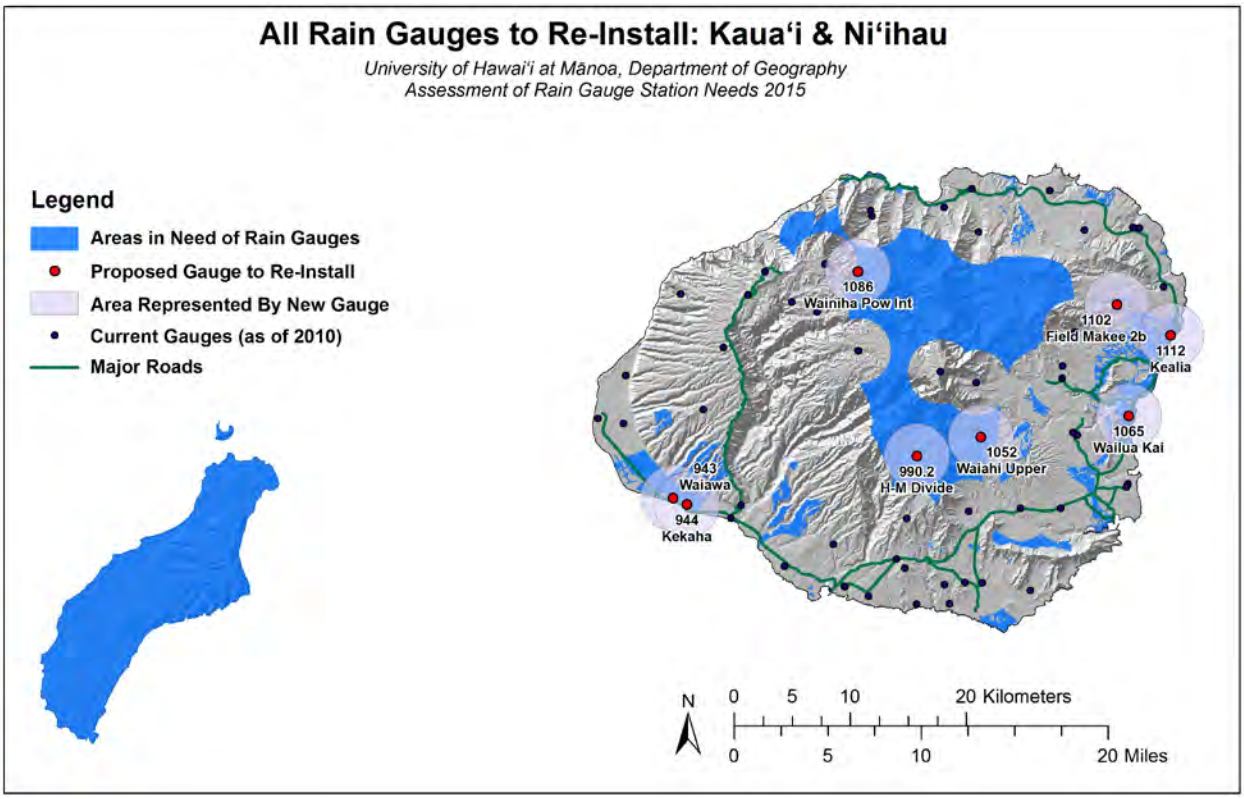
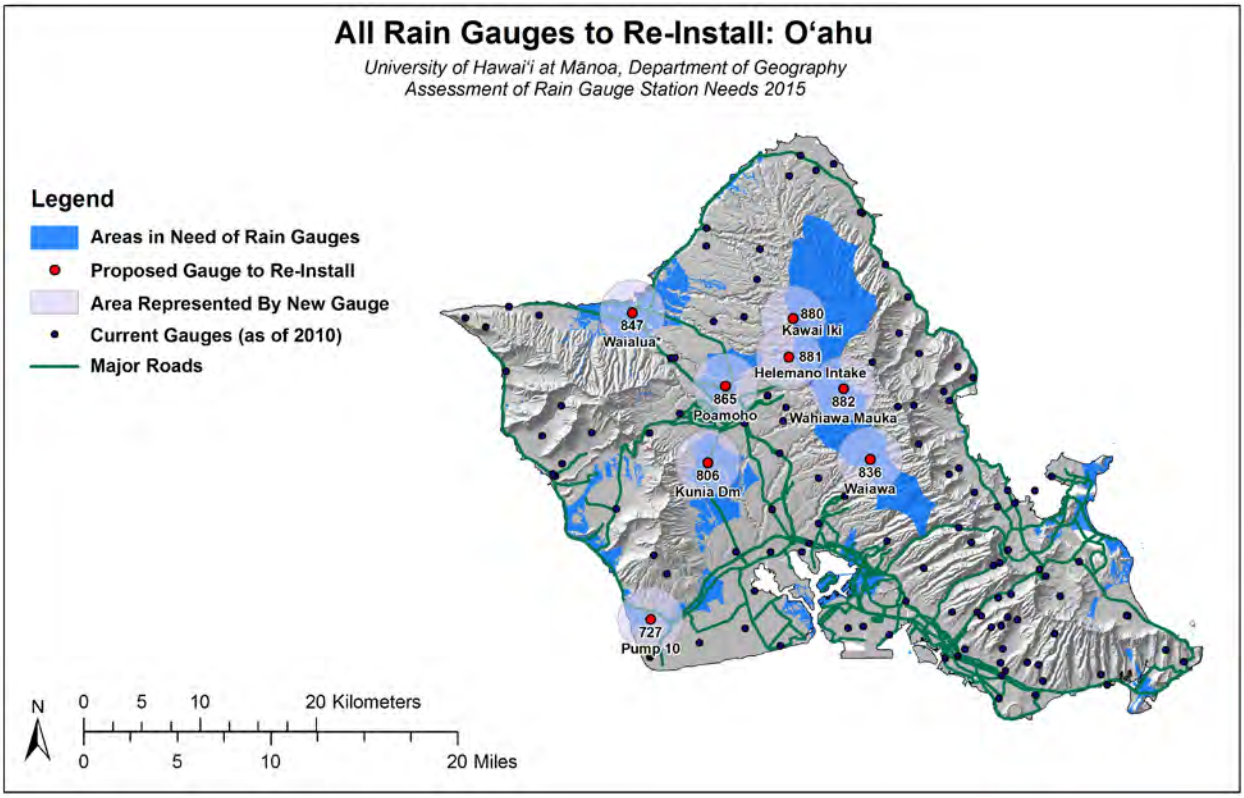
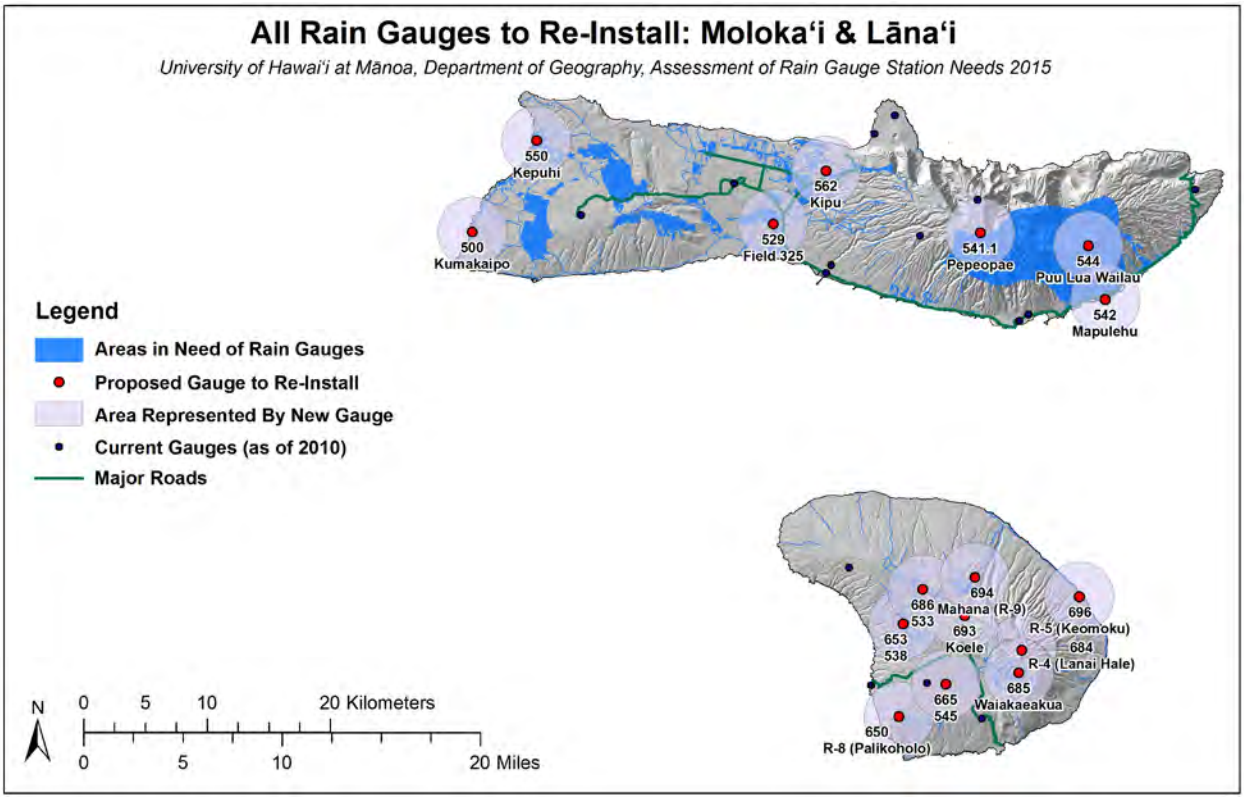
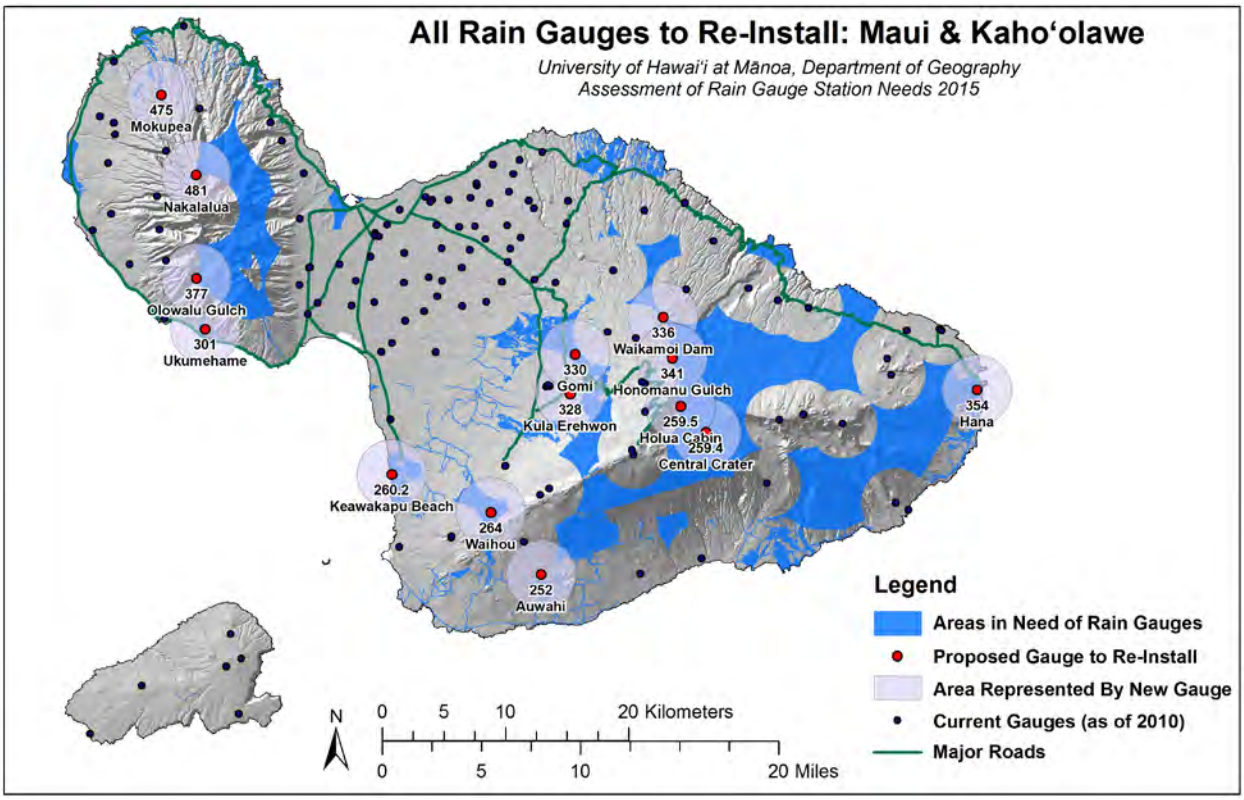
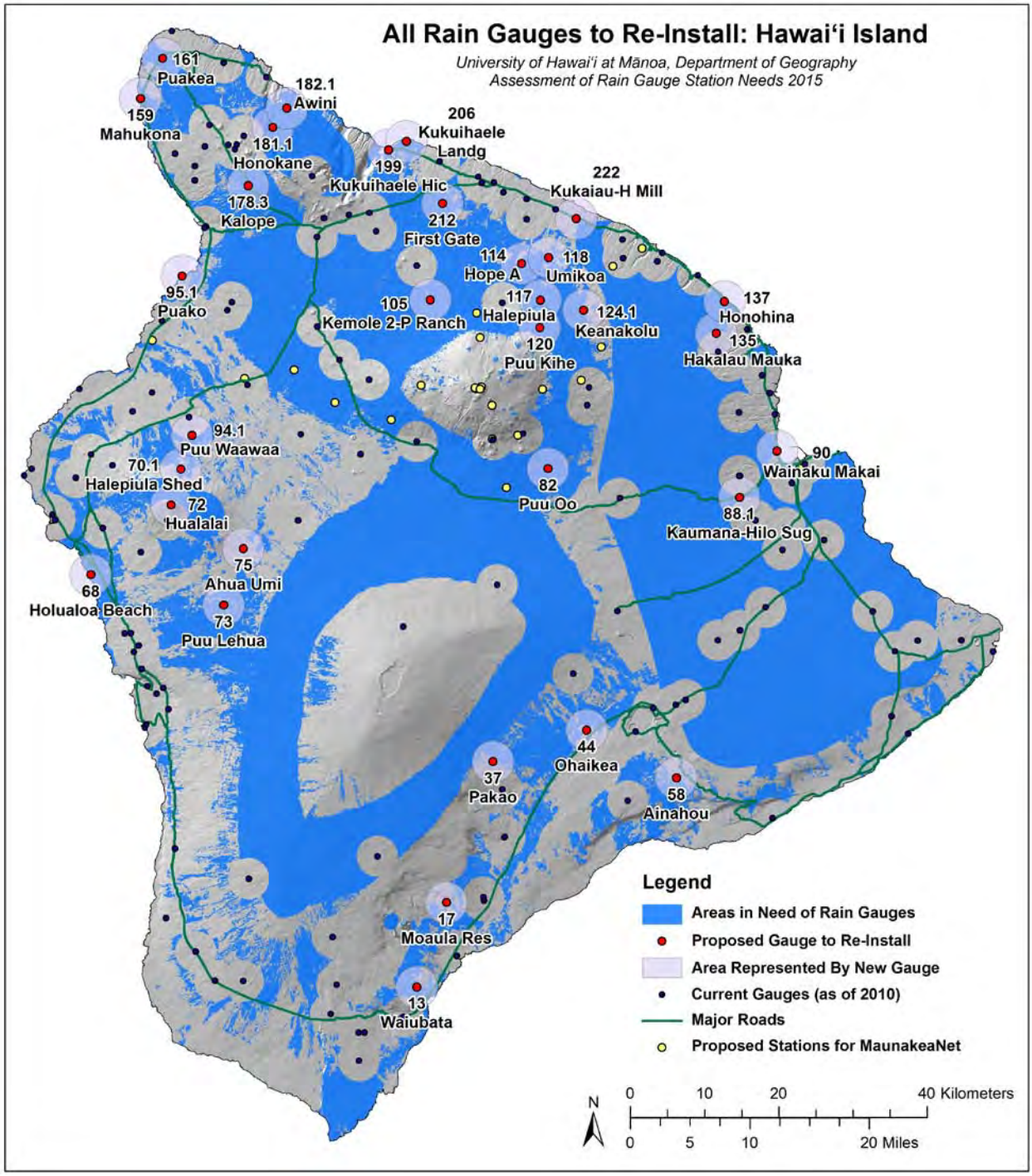
Need Areas & Proposed Station Maps






All Rain Gauges to Re-Install: Molokaʻi & Lānaʻi
University of Hawai'i at Mānoa, Department of Geography, Assessment of Rain Gauge Station Needs 2015
550
Kepuhi
562
Kipu
500
Kumakaipo
529
Field 325
541.1
Pepeopae
544
Puu Lua Wailau
542
Mapulehu
694
686
Mahana (R-9)
696
R-5 (Keomoku)
533
693
653
Koele
684
538
R-4 (Lanai Hale)
685
665
Waiakaeakua
545
650
R-8 (Palikoholo)
Legend
Areas in Need of Rain Gauges
Proposed Gauge to Re-Install
Area Represented By New Gauge
Current Gauges (as of 2010)
Major Roads
N
0 5 10 20 Kilometers
0 5 10 20 Miles


All Rain Gauges to Re-Install: Maui & Kahoʻolawe
University of Hawai'i at Mānoa, Department of Geography
Assessment of Rain Gauge Station Needs 2015
475
Mokupea
481
Nakalalua
377
Olowalu Gulch
301
Ukumehame
336
Waikamoi Dam
330
Gomi
341
Honomanu Gulch
328
Kula Erehwon
259.5
Holua Cabin
259.4
Central Crater
354
Hana
260.2
Keawakapu Beach
264
Waihou
252
Auwahi
Legend
Areas in Need of Rain Gauges
Proposed Gauge to Re-Install
Area Represented By New Gauge
Current Gauges (as of 2010)
Major Roads
N
0 5 10 20 Kilometers
0 5 10 20 Miles


All Rain Gauges to Re-Install: Hawai'i Island
University of Hawai'i at Mānoa, Department of Geography
Assessment of Rain Gauge Station Needs 2015
161
Puakea
182.1
Awini
159
Mahukona
206
Kukuihaele
Landg
181.1
Honokane
199
Kukuihaele Hic
222
Kukaiau-H Mill
178.3
Kalope
212
First Gate
114
Hope A
118
Umikoa
95.1
Puako
105
Kemole 2-P Ranch
117
Halepiula
124.1
Keanakolu
137
Honohina
120
Puu Kihe
135
Hakalau Mauka
94.1
Puu Waawaa
70.1
Halepiula Shed
72
Hualalai
82
Puu Oo
90
Wainaku Makai
88.1
Kaumana-Hilo Sug
75
Ahua Umi
68
Holualoa Beach
73
Puu Lehua
44
Ohaikea
37
Pakao
58
Ainahou
17
Moaula Res
13
Waiubata
Legend
Areas in Need of Rain Gauges
Proposed Gauge to Re-Install
Area Represented By New Gauge
Current Gauges (as of 2010)
Major Roads
Proposed Stations for MaunakeaNet
N
0
10
20
40 Kilometers
0
5
10
20 Miles

DRAFT 7-28-15

Hawaii Water Resources

Planning Assistance to States

Scope of Work

1. PROJECT NAME: Implementation Plan: Climate Monitoring Network and Data Center for the State of Hawaii, Section 22 Study

2. PROJECT AUTHORITY: Planning Assistance to States (PAS), Section 22, Water Resources Development Act (WRDA) of 1974.

PURPOSE: Develop an implementation plan to enhance the climate monitoring network across the state of Hawaii to provide information to manage the State's water resources and monitor long-term climate change impacts to Hawaiian rainfall. The network would consist of rain gages and other instruments distributed throughout the State to provide adequate geographic coverage and long-term records of climate data across the islands. This project will also develop a plan to establish a centralized data center or web portal to collect and manage the data and facilitate access for the Commission on Water Resource Management as well as the public.

TASKS:

1. Research existing rainfall data collection sites.
   1.1. Identify existing rain gages (and other instruments, observation sites/platforms important to monitoring climate change) and observers – agency / organization responsible for the operation and maintenance of the instruments.
   1.2. Develop a prioritized list of current monitoring stations and networks which are essential for long-term climate monitoring (e.g., NOAA Coop, HaleNet and HAVONet).
   1.3. Identify operation and maintenance costs and issues related to long-term continuation and maintenance of the essential monitoring stations and networks.
   1.4. Determine where existing data are housed and the willingness of the operator to share the data for the purposes of populating the centralized data center in a timely manner.
2. Research potential new rainfall data collection sites.
   2.1. Identify locations of key rain gages needed. (Map analysis from Giambelluca and Frazier 50 Rain Gages project)
   2.2. Develop prioritization criteria and determine the relative priority of new gages.
      2.2.1. Research land ownership and permission for proposed sites
   2.3. Develop cost estimates for the new gages
      2.3.1. Precipitation gage cost (actual device cost)

EXHIBIT 2

2.3.2. Telemetry or other means of sending data to the data center
2.3.3. Manpower requirement to Install new batteries, check data logger problems/issues, general maintenance
2.4. Identify potential stakeholders willing to fund, operate, and monitor gages.
2.5. Outline the resources already contributed and identify the resources needed to complete/enhance the network. The goal for initial implementation would be to establish state wide coverage. Additional gages could be added in the future to enhance the network.

Note: There are already many rain gages in operation maintained by various agencies and volunteers. Some of these have a long period of record and many are already located in important places. However, there are still places where there is no information available. The contractor will work closely with the Commission on Water Resource Management staff and Dr. Thomas Giambelluca to determine where gages are currently located, where others are needed, and who could possibly "own" them. Selecting sites for new gauges should take into account long-term gages that were discontinued, as well as the spatial gaps in current coverage.

3. Establish a data center or other means of collecting and making the data accessible.
   3.1. Research existing models of centralized rainfall data portals – including any existing Hawaiian data centers, i.e., Pacific Islands Climate Change Cooperative efforts to establish a climate change monitoring network
   3.2. Research funding models for the portals
   3.3. Provide for a means for the data to be shared State wide
   3.4. Identify potential hosts for the data center
   3.5. Identify costs to establish the data center and manpower to maintain and operate the data center.
   3.6. Identify the types of products or applications that may be developed or desired to facilitate download and transmission and to aid in future research and studies.

4. Develop a list of stakeholders:
   4.1. Agencies / organizations already operating rainfall gages.
   4.2. Users of rainfall data
   4.3. Form a cooperative group of stakeholders consisting of Federal, State, local agencies and NGO's that have a need for rainfall data. (List from Neal)
   4.4. Conduct a series of meetings with key stakeholders for the purpose of developing an implementation and funding plan

5. Research and identify technological advances that could:
   5.1. Improve the network functionality

5.2. Reduce the overall cost of implementation (low costs sensors, improvements in telemetry technology, engage schools to operate a gage, citizen science, others)
5.3. Enhance current technology
5.4. Make data management and sharing less costly
5.5. Automate data collection (e.g., telemetry options) and upload to portal
5.6. Automate updating the Rainfall Atlas of Hawaii database

6. Develop a Phased Implementation Plan with the following components:
   6.1. Identify key stakeholders
   6.2. Observation instrument / hardware requirements
   6.3. Observation platform operation and maintenance requirements
   6.4. Data center institution, staffing, physical space and computer hardware requirements
   6.5. Self-sustaining funding plan
   6.6. Implementation schedule
   6.7. Recommendations

DELIVERABLES:

1. An implementation plan that includes a determination of manpower and funding requirements with recommendations on how to obtain the necessary resources
2. Identification of the pieces that no single agency can fund
3. Identification of costs and ways to share the information.
4. Draft Memoranda of Agreement that agencies could sign to commit to long term support of a gage.
5. Estimated time frame to complete implementation and description of phases of work if necessary due to funding or resource constraints)

SCHEDULE: Work will commence after the execution of the Cost Sharing Agreement and will be completed within 12 months.

PROJECT FUNDING:

The Hawaii Water Resources Section 22 Study will be cost shared at 50% Federal and 50% non-Federal. The State of Hawaii, Department of Land and Natural Resources, Commission on Water Resources (CWRM) is the non-Federal sponsor for the project. The total project cost is $100,000 with $50,000 being provided by the Federal Sponsor and $50,000 being provided by the non-Federal Sponsor.

Exhibits

50 Rain Gage Project paper

EXEMPTION NOTIFICATION

Regarding the preparation of an environmental assessment pursuant to Chapter 343, HRS and Chapter 11-200, HAR

Project Title:	Implementation Plan: Climate Monitoring Network and Data Center for the State of Hawaii.
Project / Reference No.:	Not Applicable
Project Location:	Statewide
Project Description:	Develop an implementation plan to enhance the climate monitoring network across the state of Hawaii and establish a centralized data center.
Chap. 343 Trigger(s):	Use of State Funds
Exemption Class No.:	In accordance with Hawaii Administrative Rule Section 11-200-8(a)(5), this project is exempt from the preparation of an environmental assessment pursuant to Exemption Class No. 5, that states "Basic data collection, research, experimental management, and resource evaluation activities which do not result in a serious or major disturbance to an environmental resource;"
Consulted Parties:	Not applicable.
Recommendation:	It is recommended that the Commission find that this project will have minimal or no significant effect on the environment and is presumed to be exempt from the preparation of an environmental assessment.

Suzanne D. Case, Chairperson
Date 8/3/15

EXHIBIT 3