Appledore Island
Sustainability

• Allow SML to support its population

• Provide researchers, students, and professors with what they need

• Have a limited impact on the island, and help keep it similar for future generations
Overview

- Alternative Energy Monitoring
- Data Acquisition and Monitoring
- Gray Water
- Energy Conservation
- Freshwater Pressure Tank Replacement
- Pipe Replacement
- Other Thoughts and Ideas
Alternative Energy Monitoring
- Used to power UNH AIRMAP equipment year-round
- Can also power SML Dorms 2 & 3
Manipulating Solar Data

10,000's of rows of numbers

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Average Daily Sun Irradiance

Date

8/1/08  9/1/08  10/1/08  11/1/08  12/1/08  1/1/09  2/1/09  3/1/09  4/1/09  5/1/09  6/1/09

Sun Irradiance (W/m^2)
Temperature and Efficiency vs. Time

Date

8/1/08 9/1/08 10/1/08 11/1/08 12/1/08 1/1/09 2/1/09 3/1/09 4/1/09 5/1/09

Temperature (°F)

Efficiency

Temperature
Efficiency
June 2009 PV kWh Production

Date

kWh

PV Array 2
PV Array 1
June 2009 PV Efficiency

Efficiency (%) vs. Date

- PV Array 1
- PV Array 2
Questions?
Comments?
Data Acquisition
• Gathered data on all systems: pipe locations, wire paths, etc.

• Collected information about components of each system

• Focused on monitoring freshwater systems: flow, chlorine, depth
• Surveyed all island systems:
  - freshwater
  - saltwater
  - wastewater
  - electricity

• Made a digital map of each system

• Compiled relevant information
  manuals, photos, diagrams
System Design

• Focused on freshwater system

• Based system design on expandability

• Included sensors to monitor:
  depth
  flow
  chlorine residual
Well Depth Sensor
Chlorine Residual Sensor
Cistern Depth Sensor
Digital PLC
Cistern Circulator Pump
Chlorine Injection Pump

Spread Spectrum Radio
Water Main Flow Meter

PLC
SCADA

Display

SCADA might be unnecessary depending on PLC
PLC most likely located in the Radio Tower

Notes
Sensors

- 4-20mA signal

- Signals can be sent over wire or spread spectrum radio
• Spreads signals wirelessly

• We conducted a path study of the island

• Radio, antenna, surge protection, and wires cost around $1,400
Flow Sensors

- Accurate to 1.6gpm for 2” pipe
- Electronic readout on top
Global Water’s WL400 Water Level Sensor submersible pressure transducer consists of a solid state pressure sensor encapsulated in a submersible stainless steel 13/16” diameter housing. The water level gauge uses a marine grade cable to connect the water pressure sensor to the monitoring device. Each of Global Water’s pressure transducers has a two-wire 4-20 mA high level output, five full scales ranges, and is fully temperature and barometric pressure compensated.

### Low Level Range
The water depth indicator is available in a 0-3’ full scale range which is ideal for measuring shallow flows or small water level changes. The 0-3’ range is great for measuring flows in sewers, storm drains, weirs, flumes, lakes, tanks or any water body that is less than 3’ deep. The 0-3’ water monitoring sensor accurately measures small changes in water, even when the water’s depth is only a few inches deep. Other metal foil type sensors typically have serious problems at low level ranges because of crinkling, stretching and drifting.

### Protective Cap
The water sensor also utilizes a stainless steel micro-screen cap to protect the sensing element. This protective cap has hundreds of openings, making fouling the sensor with silt, mud or sludge virtually impossible.

### Technical Specifications
- **High accuracy and reliability**
- **Completely submersible sensor and cable**
- **Compact, rugged design for easy installation**
- **Minimal maintenance and care**
- **Sensor compatible with most monitoring equipment**
- **4-20mA output**
- **Vented cable for automatic barometric compensation**
- **Multiple ranges available from 3’ to 250’**
- **Wet-wet sensor eliminates vent tube concerns**
- **Dynamic temperature compensation system**
- **Not affected by foam, wind or rain**
- **Monitors levels in groundwater wells, rivers, streams, tanks, lift stations and open channels**

### Encapsulated Pressure Sensor
Global Water’s Water Level Sensors are fully encapsulated with marine-grade epoxy. The submersible pressure transducer’s electronics are encased in marine grade epoxy so that moisture can never leak in or work its way down the vent tube to cause drift or level sensor failure (as is the case with other pressure sensors). The vent tube is sealed directly to the sensing element, and any moisture that may enter the vent tube only comes in contact with a silicon sensing device, not the electronics.

### Output Signals
The WL400 water pressure sensors have a two-wire 4-20 mA output signal that is linear with water depth. 10 to 36 VDC is required to operate the depth level sensor, so the WL400 submersible pressure transducer can be operated from 12 or 24 VDC systems. The 4-20 mA signal can run up to 3,000’ from the sensor to the logging device. Common twisted pair or electrical extension cord wire may be spliced to the vented cable once the cable is out of the water. The 4-20 mA signal may be converted to 0.5 to 2.5 VDC by dropping the current signal across a 125 ohm resistor.
Chlorine Residual Sensor

- Siemens SFC Controller
- Free Chlorine Module
Controller
Phoenix Contact ILC 170
Questions?
Comments?
Gray Water
Flush Options

• Rainwater Collection

• Crystal Lake

• Low Flush Toilets
Flushed Survey Results

Our week long survey asked people to make a check mark when they flushed

Average Daily Freshwater Usage Per Capita = 24.67 gal/day

Average Daily Gallons Flushed Per Capita = 10 gal/day

40% of freshwater usage goes to toilets

Eliminating freshwater flushing will reduce dependence on R/O in dry season!
Gallons Flushed per Day For the Entire Island

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<td>526.4</td>
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<tr>
<td>Sunday 7/5</td>
<td>406.6</td>
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</tbody>
</table>
Gallons Flushed per Week by Building

Total = 4176 gallons/week
Rainwater Collection

• Runoff from roofs can be gathered

• Water is not potable without treatment, but usable for toilets

• White and Star Island use rainwater collectors
Existing Bartels Cistern

• Most likely left over from the Lifesaving Station

• Two chambers side by side

• Dimensions of each cistern: 9’x6’x5.5’

• Total volume of 4,443 gallons
Bartels Rainwater Collector

• Demand of 1,900 gallons per month

• Would meet 70% of Bartels’ monthly demand, or 100% if 2 of 4 toilets were low-flush

• Would have to be opened a month beforehand
Determining Runoff

- Calculated runoff in two ways:
  - paper (shown left)
  - using rainfall data
- 1470 gallons per month (95% rainfall collected)

Sizing of Rainwater Storage Units for Green Building Applications
Yiping Guo, M.ASCE; and Brian W. Baatz, M.ASCE

Abstract: Green building design principles advocate the use of rainwater storage units to collect roof runoff during nonwinter seasons for landscaping, landscape maintenance, and/or maintenance purposes, either in the form of rain barrels for smaller scale applications or cisterns for larger scale applications. This not only saves water which would otherwise be supplied from municipal water distribution systems but also reduces storm-water runoff which would otherwise be handled through storm-water management systems. The size of the storage unit needs to be commensurate with the area of the roof and the desired water use rate. The local climate has an influence on the required size and operational use rate as well. In this paper, analytical formulas are derived to estimate the required rainwater storage volume as a function of desired water use rate, reliability and local climate. By deriving these formulas, local climate characteristics are represented by probabilistic models and incorporated into the stochastic description of storage size and operational procedures and requirements.

Introduction
The management and use of water within a building and its surrounding landscape is one component of green building design and operation (Kibert 2003). One of the objectives of green building design is to minimize the use of treated water for landscaping, landscape maintenance, and/or maintenance purposes. The cost and energy use inherent with the treatment and distribution of water can thus be reduced. An efficient approach to minimize treated water use is the integration of a rain barrel in a house setting or a cistern in a larger building context. Rain barrel or cistern is often positioned during nonwinter seasons to collect and store rainwater from the roof of the building for use on dry days between successive rainfall events. In addition, this water-saving practice will also divert roof runoff away from storm-water collection systems and reduce the volume of runoff that needs to be managed. Therefore, rain barrels and cisterns can be viewed as miniature multi-purpose storm-water management facilities, and green buildings can form part of a community’s best management practices for storm-water management.

The size of the rain barrels and cisterns (hereafter referred to as storage units) needs to be commensurate with the area of the roof and the desired water use rate. The local rainfall characteristics throughout the nonwinter season also affect the size required and the reliability of a storage unit to supply water when needed. In fact, sizing of rainwater storage units for green building applications is a miniature hydrologic engineering design problem. It could be solved in an ad hoc way because of its small scale. For individual buildings, the possible optimizing or over-sizing caused by using an inaccurate design approach may not result in significant economic or environmental losses. However, the cumulative losses may become significant as the sum of the storage volumes increases.

Similar to the hydrologic design of storm-water management facilities, an accurate approach to sizing rainwater storage units is to use a computer program to simulate their hydrologic operations under local climate conditions. Continuous simulation using long-term historical rainfall series needs to be conducted to determine the performance statistics of rainwater storage units of different sizes. These performance statistics could be used as a basis for design. Given the small scale in most green building applications, the use of computer simulation is obviously too time consuming for engineers or architects. A more appealing approach may be the use of analytical equations that consider the basic hydrologic operation of a rainwater storage unit and simultaneously account for the influence of local climate conditions. One such equation was developed by Liu et al. (2000) for the sizing of cisterns to collect rainwater from agricultural fields for crop use during dry periods. In their study, failure probabilities of the irrigation system were defined first; a series of simulation modeling experiments using historical rainfall records at a farm were conducted, and a regression equation was then developed based on simulation results. This equation relates cistern size to rainwater collection area, failure probability, and the area to be irrigated. Their simulations used rainfall records from one location and considered a single crop. Therefore, the resulting equation is applicable only for the specified location and crop.

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Grand Total = $ 888.19
Crystal Lake

- Large freshwater basin
- Historically had many uses
- Wildlife
Determining the Area

- Used topographic map of the island to determine area
- Assumed a depth of 2 feet
- Found an area of 22,187.5ft²
Crystal Lake Experiment

- Looked at feasibility of using the lake as a water supply
- Inquired about the structure of the lake
- Tried to determine the effect of withdrawing water from the lake
• Tried to factor in evaporation and rainfall
• Assumed no input or output

• Used topo map to estimate rain basin
Water Level Fluctuations

Date

Gauge Reading (in)
Crystal Lake Control

Goal:

Observe Crystal Lake’s natural water level fluctuations
Water Level Fluctuations: Control

Gauge Reading (in)

Date

Measured
Predicted
Fig. 7. Variation in δ18O (‰) isotope ratio of water sampled from three locations on Appledore Island, ME. Ground water pumped from the SML well was sampled between 6/14/2007 and 2/21/2008. At Broad Cove, groundwater from a 2 ft. depth was sampled three times from 6/14/2007 to 7/1/2007. Surface water in Crystal Lake was sampled from 6/14/2007 to 2/21/2008.

The amplitude of variation in these ratios is used as an indicator of the water's residence time. Crystal Lake shows variability characteristic of low residence time, while the SML well displays a longer residence time, as compared to Figure 5.

Data and graph courtesy of Jonathan Felch, and Dr. Matt Davis, UNH, 2007.
Crystal Lake Summary

Our Findings

• No record of lake going dry
• Low residence time
• Experimental Results
• Lake Ecology

Our Conclusions

• Crystal Lake has Input and Output
• Would be suitable source for toilet water
Reuse of Existing Equipment
SML Crystal Lake Water System Flow Diagram

SML Crystal Lake & Graywater
Water System
Flow Diagram

Process Key
- Water Flow
- Switch Controls
- Overflow Water

Notes
- Float switch set to 2/3 tank capacity to allow for gray water collection
- If overflow tank is used, switch must be manually operated to drain water
- Existing salt water lines to toilets utilized to carry water
Pump Considerations

- Existing wastewater pumps would be more than sufficient for Crystal Lake.
Pump Location

Required Buoy Diameter

\[
\text{diameter} = 2 \left( \frac{3m}{2\pi \rho} \right)^{\frac{1}{3}}
\]

\[
\text{diameter} \approx 0.6\text{meters} \approx 1.8\text{ft}
\]

Existing buoy will suffice!
Grey Water Flushing

- Kiggins Common’s kitchen and showers produce 220 gal/day of grey water
- Can be easily connected to proposed Crystal Lake flushing system
- Re-using grey water would prolong life of leach field
Float switch set to 2/3 tank capacity to allow for gray water collection.

If overflow tank is used, switch must be manually operated to drain water.

Existing salt water lines to toilets utilized to carry water.
Low Flush Toilets

• Use 1.6 gallons per flush (gpf)

• Most existing toilets use 5 gpf

• Typically cost around $450
Wastewater Testing

• Placed control well (shown), and test wells around leach field

• Surveyed wells, and determined flow of groundwater

• Tested wells for fecal coliforms

• Also tested existing wells by K-House leach field
Water Flow Direction

Groundwater Level: -21.1”

Groundwater Level: -42.0”

Groundwater Level: -50.4”

Groundwater Level: -28.3”
Leach Field Fecal Coliform Count

Test 1: 10
Test 2: 4,600

Test 1: 950
Test 2: 490

Test 1: 500
Test 2: 560

Test 1: NR
Test 2: 1,830,000

Test 1: NR
Test 2: 15,600

Control Well

Well 1
Well 2
Well 3
D-Box

Count = coliforms / 100 mL
NR = Count not Readable
K-House Composting Toilet Testing

• Manufactured by ClivusMultrum

• Solid waste is composted

• Lechate is sent back to gray water line

• 2008 interns found elevated fecal coliform levels

• Lechate taken from holding tank (shown) and sent to Eastern Analytical Inc. (EAI) for testing
Composting Results
Questions?
Comments?
Energy Conservation
Energy Efficiency
WHAM
Water Heater Analysis Model

• Determines power consumption of a water heater
Sources of Data

- Surveys placed by all sinks with hot water
- Information from manufacturers
- Estimated values

Are You Using Hot Water?

Your beloved engineering interns are working to determine how much hot water is being used.

If you can write down approximately how long you use the hot water, we would greatly appreciate it.

Thanks, Dan, John, Josh, & Anna.

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<th>Length</th>
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</thead>
<tbody>
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<td>Minute</td>
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</table>
Sources of Data

• 40 gallon tank
• 10kWh draw per day
• Usage of 5 minutes per day
• Cost of $4.30 per day
• Top floor sink takes nearly a minute get hot
Sources of Data

‘On Demand’ vs. Existing Water Heater

Energy Usage vs. Daily Use: Palmer-Kinney

- Daily Kilowatt-Hour

- Time (min.)

- Energy Usage

- Existing Water Heater

- On-Demand Water Heater
Cost Savings

- Cost Savings per year is $300-$400 per year depending on usage (based on three months of usage)
- Assumes $0.43/kW-hr
- Also assumes comparable usage
- Large spike in power consumption
Kitchen Power Draws

![Bar chart showing the comparison between advertised and measured power draws for various kitchen appliances.](chart.png)

- **Toaster**: Advertized 1.745 kW, Measured 1.68 kW
- **Icemaker**: Advertized 1.46 kW, Measured 1.06 kW
- **Walk-In Evaporator Fans**: Advertized 0.39 kW, Measured 0.32 kW
- **Freezer Fans**: Advertized 0.36 kW, Measured 0.32 kW
- **Reach-In Fridge**: Advertized 1.12 kW, Measured 1.31 kW
- **Freezer**: Advertized 1.49 kW, Measured 2.18 kW
- **Walk-In Refrigerator**: Advertized Not Available, Measured 2.18 kW

Legend:
- Red: Advertized Draw (kW)
- Blue: Measured Draw (kW)
Other Large Power Draws

- Pole Barn Lights 1.75kW
- Well Pump 373W
- Cistern Pump 746W
- Salt Water Pump 5.5kW
Ceiling Occupancy Light Sensor

• Easy to install

• Good for the Commons’ bathrooms

• Cost $59 each

• Savings of around $100 a year given 14 hours of use
Freshwater Pressurization
Freshwater Pressure Tank Replacement

- Current tank volume is approximately 840 ft³
- Supplies about 1200 gallons of fresh pressurized water
- Needs replacing because the tank is corroding
Freshwater Usage

[Graph showing freshwater usage with dates from 27-Apr to 6-Jul, and gallons used from 0 to 3000, with population and gallons used indicated by different colors.]
Freshwater Usage

Bivariate Fit of Water Usage By Population

Correlation

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<th>Variable</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Correlation</th>
<th>Signif. Prob</th>
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<td>1331.983</td>
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Water Usage Trends

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<th>Gallons</th>
<th>Cubic ft.</th>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sun 7/5/09</td>
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<td></td>
</tr>
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</table>
Pressure Tank Size

\[ V = \frac{V_m}{\left(1 - \frac{P_1}{P_2}\right)} \]

where:

- \( V \) = pressure tank volume, gallons (m³)
- \( V_m \) = 15 minutes storage at the peak hourly demand rate, gallons (m³)
- \( P_1 \) = minimum absolute operating pressure, psi (kPa)
  - = gauge pressure plus 14.7 (101.3 kPa)
- \( P_2 \) = maximum absolute pressure, psi (kPa)
  - = gauge pressure plus 14.7 (101.3 kPa)

The design of bladder-type pressure tanks must also consider the number and size of tanks to provide pump protection and the precharged air pressure of the tank.
Variable Frequency Drive
SML Freshwater System Flow Diagram

SML Fresh Water System Flow Diagram Option 1

Process Key
- Main Water Flow
- Alternate Flow

Notes
Reserve pressure tank allows for continued operation in case of main tank failure or maintenance
Questions?
Comments?
Pipe Replacement
Sewage Pipe Replacement

- SML wants to replace existing concrete wastewater pipe
- Determined best size for a new pipe
# Cornell University Shoals Marine Lab

Total Wastewater Design Flow Projections and Allocation of Wastewater Generation (Points of Origin)

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Type/Use</th>
<th># Beds</th>
<th>Classroom seats</th>
<th>Existing Plumbing Facilities (3/5/2009)</th>
<th>Potential Design Flow (see letter for analysis of generation)</th>
<th>TOTAL GPD</th>
<th>% Allocation at Location</th>
<th>Proposed GPD</th>
<th>Disposal System #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiggins Commons</td>
<td>Kitchen/Dining/Shower/ Central Toilets</td>
<td>0</td>
<td>120</td>
<td>5 toilets, 7 showers, 14 sinks, commercial dishwasher, mop basin</td>
<td>3,500 gpd Total campus flow island wide</td>
<td></td>
<td>25%</td>
<td>875</td>
<td>#1 Proposed</td>
</tr>
<tr>
<td>Dorm 1</td>
<td>Student Housing</td>
<td>20</td>
<td>-</td>
<td>2 toilets, 4 sinks</td>
<td>20 @ 25 gpd</td>
<td>500</td>
<td>15%</td>
<td>75</td>
<td>#1 Proposed</td>
</tr>
<tr>
<td>Dorm 2</td>
<td>Student Housing</td>
<td>20</td>
<td>-</td>
<td>2 toilets, 4 sinks</td>
<td>20 @ 25 gpd</td>
<td>500</td>
<td>15%</td>
<td>75</td>
<td>#1 Proposed</td>
</tr>
<tr>
<td>Dorm 3</td>
<td>Student Housing</td>
<td>20</td>
<td>-</td>
<td>2 toilets, 4 sinks</td>
<td>20 @ 25 gpd</td>
<td>500</td>
<td>15%</td>
<td>75</td>
<td>#1 Proposed</td>
</tr>
<tr>
<td>Founders</td>
<td>Housing</td>
<td>39</td>
<td>-</td>
<td>5 toilets, 10 sinks</td>
<td>39 @ 25 gpd</td>
<td>975</td>
<td>50%</td>
<td>#1 Proposed</td>
<td></td>
</tr>
<tr>
<td>Hamilton</td>
<td>Classroom/Offices</td>
<td>0</td>
<td>30</td>
<td>1 toilet, 1 sink</td>
<td></td>
<td>50</td>
<td>100%</td>
<td>#1 Proposed</td>
<td></td>
</tr>
<tr>
<td>Grass Lab</td>
<td>Apt/Lab</td>
<td>2</td>
<td>10</td>
<td>2 toilets, 3 sinks, 1 washing machine</td>
<td>2 @ 25 gpd</td>
<td>50</td>
<td>100%</td>
<td>125</td>
<td>#1 Proposed</td>
</tr>
<tr>
<td>Palmer-Kinne</td>
<td>Lab/Library/Classroom</td>
<td>0</td>
<td>50</td>
<td>2 sinks</td>
<td></td>
<td>20</td>
<td>100%</td>
<td>#1 Proposed</td>
<td></td>
</tr>
<tr>
<td>Laughton</td>
<td>Lab/Library/Classroom</td>
<td>0</td>
<td>50</td>
<td>1 sink</td>
<td></td>
<td>20</td>
<td>100%</td>
<td>#1 Proposed</td>
<td></td>
</tr>
<tr>
<td>Bartels</td>
<td>Staff Housing</td>
<td>13</td>
<td>-</td>
<td>4 toilets, 2 showers, 6 sinks, 1 washing machine</td>
<td>13 @ 25 gpd</td>
<td>325</td>
<td>50%</td>
<td>560</td>
<td>#2 Proposed</td>
</tr>
<tr>
<td>Kingsbury House</td>
<td>N/A</td>
<td>11</td>
<td>-</td>
<td>On existing septic with composting toilets</td>
<td>11 @ 25 gpd</td>
<td>275</td>
<td>50%</td>
<td>140</td>
<td>#6 Existing</td>
</tr>
<tr>
<td>Ross’s Pole Barn</td>
<td>Maintenance storage</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Population</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Overnight residents</td>
<td></td>
<td>125</td>
<td></td>
<td></td>
<td>3,125 gpd</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day Trippers</td>
<td></td>
<td>20</td>
<td></td>
<td></td>
<td>14 gpd</td>
<td>275</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Total Campus wastewater generation projection | 3,400 gpd |

25% Reduction +/- due to composting toilets

⇒ TOTAL DESIGN WASTEWATER FLOW FOR SUBSURFACE WASTEWATER DISPOSAL

2,500 GPD

1,455 GPD

1See letter of March 6, 2009 to Jim Jacobson

2See Memo from Ross Hansen

3See letter of March 6, 2009 to Jim Jacobson and Table 1 in letter
Manning’s Equation

\[ Q = \frac{1.49}{n} \cdot \left[ \frac{\theta - \sin(\theta)}{8} \cdot D^2 \right]^{5/3} \cdot \left[ \frac{D \cdot \theta}{2} \right]^{-2/3} \cdot S^{1/2} \]

- Island daily flow is 1455 gallons
- 4 inch pipe flowing at maximum capacity (1/2 full) can contain a flow of 6902 gallons/day
- 6 inch pipe flowing at maximum capacity (1/2 full) can contain a flow of 20350 gallons/day
- Peak flow is 750 gallons/hr
Suggestions for Future Projects

• Alternate storage for renewable energy
• Expansion of existing renewable energy
• Tidal Power
• Monitoring/Designing Data Collection System
• White Island Infrastructure
Thank You

Kevin Jerram (K2)  Jon Durand
Mike Rosen        Fred Chellis
Ross Hansen       J.B. Heiser
Mike Dalton       Denny Taylor
Tom Johnson       Kathy Mandsager
Nancy Kinner     Lee Consavage
Hanna Wingard     Abigail Kirtch
Kipp Quinby       Matt Height
Hal Weeks          Steve Tapley
Dan (White Island) Joseph Ranahan
Willy Bemis       SML Staff
Kevan Carpenter   SML RIFS
Karen Garrison    Shoal’s Marine Laboratory
Dave Murley       And Many, Many, More……especially Bob
Paul Roy