USING A GEOGRAPHIC INFORMATION SYSTEM TO PREDICT FLOW DURATION CURVES AT UNGAGED STREAM SITES IN GUAM

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ALWAYS A NEED FOR HYDROLOGIC INFORMATION

WATER SUPPLY

INSTREAM FLOWS

RESERVOIRS

HYDROPOWER

GUAM FLOW VARIABILITY

DEC. 2015
HYDROLOGIC DATA NEEDS THAT WE CONCENTRATED ON

- AVERAGE FLOWS IN STREAMS
- FLOW VARIABILITY IN STREAMS
WHAT'S THIS PROJECT IS ALL ABOUT

AGE OLD HYDROLOGY PROBLEM

We Can Compute Average Flow and Flow Variability at Gage Sites.
WHAT’S THIS PROJECT ALL ABOUT

UN-GAGED STREAM SITES??
NO DATA

DEC. 2015
GUAM FLOW VARIABILITY
PROJECT GOALS

- DEVELOP AVERAGE FLOW AND FLOW VARIABILITY FOR UN-GAGED STREAM SITES IN SOUTH GUAM
  - FOR ALL POINTS ALONG MAJOR STREAMS
  - FOR SIMILAR SEGMENTS OF STREAMS CALLED REACHES
FIRST STEP WAS TO DEVELOP CURVES THAT DESCRIBE FLOW VARIABILITY AT GAGED SITES
STREAM GAGES USED IN THE PROJECT

<table>
<thead>
<tr>
<th>Stream Name</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aplacho River</td>
<td>2.3</td>
</tr>
<tr>
<td>Umatac River</td>
<td>8.52</td>
</tr>
<tr>
<td>La Sa Fua River</td>
<td>4.42</td>
</tr>
<tr>
<td>Imong River</td>
<td>9.71</td>
</tr>
<tr>
<td>Almagosa River</td>
<td>6.4</td>
</tr>
<tr>
<td>Maulap River</td>
<td>5.09</td>
</tr>
<tr>
<td>Ugum above</td>
<td>24.34</td>
</tr>
<tr>
<td>Ugum River near</td>
<td>29.33</td>
</tr>
<tr>
<td>Pago River</td>
<td>25.7</td>
</tr>
<tr>
<td>Ylig River</td>
<td>27.56</td>
</tr>
<tr>
<td>Finile</td>
<td>1.41</td>
</tr>
<tr>
<td>Inarajan</td>
<td>17.48</td>
</tr>
<tr>
<td>Tianaga</td>
<td>5.61</td>
</tr>
<tr>
<td>Cetti River</td>
<td>4.34</td>
</tr>
<tr>
<td>Geus</td>
<td>3.00</td>
</tr>
<tr>
<td>La Sa Fua River</td>
<td>4.42</td>
</tr>
<tr>
<td>Tolyaeyuus Agat</td>
<td>20.18</td>
</tr>
<tr>
<td>Talofofo</td>
<td>48.76</td>
</tr>
<tr>
<td>Lonfit</td>
<td>10.23</td>
</tr>
</tbody>
</table>

GUAM STREAMFLOW DATA AVAILABILITY (53-82)

MISSING DATA
UMATAC GAGE FLOW DATA FROM USGS WEB SITE

# Data provided for site 16816000

# DD parameter statistic Description
# 01 00060 00003 Discharge, cubic feet per second (Mean)
#

# Data-value qualification codes included in this output:
# A Approved for publication -- Processing and review completed.
# e Value has been estimated.
#

agency_cd site_no datetime 01_00060_01_00060_00003_cd
5s 15s 20d 14n 10s
USGS 16816000 10/1/1952 10 A
USGS 16816000 10/2/1952 7.8 A
USGS 16816000 10/3/1952 7.8 A
USGS 16816000 10/4/1952 6.6 A
USGS 16816000 10/5/1952 8.4 A
USGS 16816000 10/6/1952 5.8 A
USGS 16816000 10/7/1952 16 A
USGS 16816000 10/8/1952 8.9 A
USGS 16816000 10/9/1952 18 A
UMATAK GAGE FLOW DURATION CURVE

SIMPLE STATISTICAL FLOW VARIABILITY REPRESENTATION

UMATAK FLOW DURATION ALL DATA

Flow

% of time flow is equaled or exceeded

10

80
### Parametric Flow Duration Curve Data

<table>
<thead>
<tr>
<th>GAGE</th>
<th>AVG</th>
<th>0%</th>
<th>10%</th>
<th>30%</th>
<th>50%</th>
<th>80%</th>
<th>95%</th>
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</thead>
<tbody>
<tr>
<td>UMATAC</td>
<td>8.62</td>
<td>563.00</td>
<td>16.82</td>
<td>6.18</td>
<td>3.49</td>
<td>1.14</td>
<td>0.62</td>
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<tr>
<td>IMONG</td>
<td>10.22</td>
<td>498.00</td>
<td>18.96</td>
<td>7.63</td>
<td>4.70</td>
<td>2.35</td>
<td>1.33</td>
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<tr>
<td>PAGO</td>
<td>26.40</td>
<td>2540.00</td>
<td>50.61</td>
<td>15.61</td>
<td>7.76</td>
<td>1.62</td>
<td>0.35</td>
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<tr>
<td>YLIG</td>
<td>28.56</td>
<td>2050.00</td>
<td>54.98</td>
<td>19.84</td>
<td>10.66</td>
<td>2.38</td>
<td>0.72</td>
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<tr>
<td>FINILE</td>
<td>1.40</td>
<td>50.00</td>
<td>2.76</td>
<td>1.32</td>
<td>0.87</td>
<td>0.35</td>
<td>0.13</td>
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<tr>
<td>INARAJAN</td>
<td>17.46</td>
<td>1580.00</td>
<td>30.25</td>
<td>11.88</td>
<td>7.15</td>
<td>2.71</td>
<td>1.46</td>
</tr>
<tr>
<td>TINAGO</td>
<td>5.73</td>
<td>1080.00</td>
<td>10.00</td>
<td>4.00</td>
<td>2.17</td>
<td>0.66</td>
<td>0.31</td>
</tr>
<tr>
<td>GUESS</td>
<td>3.02</td>
<td>550.00</td>
<td>5.38</td>
<td>1.74</td>
<td>0.88</td>
<td>0.23</td>
<td>0.05</td>
</tr>
<tr>
<td>UGUM NR</td>
<td>29.77</td>
<td>1790.00</td>
<td>53.18</td>
<td>26.50</td>
<td>15.62</td>
<td>6.64</td>
<td>4.16</td>
</tr>
</tbody>
</table>

**From Duration Curves:**
- Pick off average, 0%, 10%, 30%, 50%, 80%, and 95% for each gage.

**Plot All:**
- 0% vs average, 10% versus average, 30% vs average, 50% vs average, 80% vs average, and 95% vs average.
WE GET A REGRESSION EQUATION FOR EACH DATA SET
USING PARAMETRIC FLOW DURATION CURVES TO PREDICT DURATION CURVE AT AN UN-GAGED SITE

\[ y = 81.522x^{0.9961} \quad R^2 = 0.7854 \]

\[ y = 1.876x^{0.9939} \quad R^2 = 0.9978 \]

\[ y = 0.769x^{0.9698} \quad R^2 = 0.9767 \]

\[ y = 0.4602x^{0.9449} \quad R^2 = 0.9466 \]

\[ y = 0.1701x^{0.8865} \quad R^2 = 0.7822 \]

\[ y = 0.0618x^{0.9309} \quad R^2 = 0.5643 \]
RECONSTRUCTED SITE FLOW DURATION CURVE FOR AVG. Q = 25 CFS

SITE FLOW DURATION CURVE

FLOW (CFS)

EXCEEDANCE PERCENT
WE ARE $\frac{1}{2}$ WAY THERE

WHAT WAS NEEDED NEXT WAS A WAY TO PREDICT THE AVERAGE FLOW AT OUR UNGAGED RIVER LOCATIONS
WE USED SOME GIS BLACK MAGIC TO GET THE AVERAGE FLOWS
STARTING POINT WAS NORMAL ANNUAL PRECIPITATION (NAP) LINES

from
WERI Technical Report 102
By Guard and Lander
As Modified by M. Lander
DEVELOPED NORMAL ANNUAL PRECIPITATION GRID FROM NAP LINES USING GIS

EACH GRID SQUARE CONTAINS THE VALUE OF THE AVERAGE ANNUAL RAIN FALLING ON THAT SQUARE

USED TOPO TO RASTER TOOL
IF WE COULD ADD UP ALL THE RAINFALL FALLING IN A WATERSHED TO A POINT IN A STREAM

WE WOULD HAVE THE ANNUAL PRECIPITATION INPUT TO THAT POINT
POSSIBLE THROUGH THE “BLACK-MAGIC” OF GIS

USING GIS HYDROLOGY TOOLS

• DEVELOPED DRAINAGE PATHWAYS FOR ALL OF THE STREAMS
• SUMMED UP THE AVERAGE ANNUAL RAINFALL FALLING IN THESE PATHWAYS
• RESULTS WERE AVERAGE ANNUAL PRECIPITATION INPUT TO THE STREAM
FIRST STEP WAS TO APPLY WATERSHED FUNCTIONS TO A DIGITAL ELEVATION MODEL

USING GIS HYDROLOGY TOOLS

- FILLED SINKS IN DATA
- CREATED A FLOW DIRECTION GRID
- CREATED A CELL ACCUMULATION GRID WHICH DEFINED THE STREAM PATHWAYS

GUAM LIDAR DATA
COMBINED THE FLOW DIRECTION GRID WITH THE PRECIPITATION GRID

USING GIS HYDROLOGY TOOLS

CREATED A WEIGHTED ACCUMULATION GRID BY SUMMING AVERAGE PRECIPITATION IN THE STREAM PATHS
RESULTS WAS THE ANNUAL PRECIPITATION INPUT ALONG THE STREAM PATHWAYS

PRECIP INPUT 59.39 CFS-YR

NOTE: UNITS = AVERAGE ANNUAL FLOW IN CFS REQUIRED TO EQUAL THE POTENTIAL ANNUAL VOLUME OF RAINFALL FLOWING PAST THAT POINT IN ONE YEAR

ALSO COMPUTED DRAINAGE AREAS ALONG ALL THE STREAMS
COMPARED AVERAGE PRECIPITATION INPUT TO AVERAGE ANNUAL FLOW

<table>
<thead>
<tr>
<th>Drainage Area (SQ. MILES)</th>
<th>Precipitation Input (CFS)</th>
<th>Average Flow (CFS)</th>
<th>Runoff Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>UMATAE</td>
<td>16.62</td>
<td>8.62</td>
<td>0.52</td>
</tr>
<tr>
<td>IMONG</td>
<td>16.51</td>
<td>10.22</td>
<td>0.62</td>
</tr>
<tr>
<td>PAGO</td>
<td>40.91</td>
<td>26.40</td>
<td>0.65</td>
</tr>
<tr>
<td>YLIG</td>
<td>46.53</td>
<td>28.56</td>
<td>0.61</td>
</tr>
<tr>
<td>FINILE</td>
<td>2.06</td>
<td>1.40</td>
<td>0.68</td>
</tr>
<tr>
<td>INARAJAN</td>
<td>33.46</td>
<td>17.46</td>
<td>0.52</td>
</tr>
<tr>
<td>TINAGO</td>
<td>14.73</td>
<td>5.73</td>
<td>0.39</td>
</tr>
<tr>
<td>GUESS</td>
<td>7.08</td>
<td>3.02</td>
<td>0.43</td>
</tr>
<tr>
<td>UGUM NR TALOFOFO</td>
<td>59.39</td>
<td>29.77</td>
<td>0.50</td>
</tr>
</tbody>
</table>

\[
\text{Runoff Factor} = \frac{\text{Average Flow}}{\text{Precipitation Input}}
\]
Developed an average flow vs precipitation input relationship.

\[ y = 0.5152x \]

\[ R^2 = 0.9692 \]

Average Flow = 0.5152 X Average Annual Precipitation Input

\[ R^2 = 0.9692 \]
APPLIED THE GIS RASTER CALCULATOR TOOL TO COMPUTE AVERAGE FLOW

AVERAGE FLOW COMPUTED FOR ALL POINTS ALONG ALL STREAMS

Average Flow = 0.5152 X Precipitation Input
USED RASTER CALCULATOR TOOL AGAIN TO COMPUTE FLOW DURATION VALUES ALONG THE STREAMS.

DURATION VALUES COMPUTED FOR ALL POINTS ALONG ALL STREAMS.
FLOWS IDENTIFIED IN ALL STREAMS IN SOUTH GUAM
ROAD BRIDGE ISSUES

STREAM

FILLED AREA

ROAD FILL

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GUAM FLOW VARIABILITY

DEC. 2015
ISSUES WITH GIS

ACCUMULATION FUNCTION

• ELEVATION GRID FILE VERY LARGE
• THE ACCUMULATION FUNCTION WOULD NOT RUN TO COMPLETION
• WE RESAMPLED THE ELEVATION DATA

GUAM LIDAR DATA
1M GRID 1.9 GB
SIMILAR STUDIES DONE FOR POHNPEI AND KOSRAE, FSM

ISLAND OF POHNPEI, FSM

ISLAND OF KOSRAE, FSM
FOR MORE DETAILS SEE WERI TECHNICAL REPORTS

http://www.weriguam.org/


• Prediction of Flow Duration Curves at Ungaged Sites on Guam Report #154, 2015.
GIS MAPS ON LINE

DIGITAL ATLAS OF SOUTHERN GUAM

http://south.hydroguam.net/

http://south.hydroguam.net/map-hydrology-drainage-streamflow.php
THANKS TO

• WERI and the USGS Water Institute Program that funded the project
• USGS Pacific Island Water Science center who with the support of WERI and the Government of Guam maintain the stream flow gaging net work in Guam
• Dr. Nathan Habana at WERI for keeping my ARCMAP GIS program updated and helping with the LIDAR Elevation Data
• All the Government of Guam Agencies who’s forward thinking funded the development of the LIDAR Elevation data
THANKS FOR YOUR TIME

QUESTIONS OR COMMENTS