Coral Reef Habitat Maps of The Main Eight Hawaiian Islands from Photointerpretation of:

- Aerial Color Photography
- Hyperspectral Imagery
- Ikonos Satellite Imagery

Prepared for: NOAA
Prepared by: Analytical Laboratories of Hawaii
Approach

- Mapping Methods and Standards
- Assessment of Map Accuracy
- Comparison of Accuracy of Maps Prepared from:
  - Color Aerial Photography
  - AURORA Hyperspectral Imagery
  - IKONOS Satellite Imagery
- Production Mapping of NOAA 2000 Data
Ground Control Position Collection

- Identify feature in imagery
- Navigate to and occupy position
- Record all data in GPS data logger
- Enter manual field notes
- Using stationary GPS, acquire minimum of 10 minutes uninterrupted carrier signal
- Collect photographic records of the site
- Post process for differential correction to CORS
- Incorporate data into ArcView GIS and Photoshop format

GCP Data Sheet

Date: _______  Time ________  Initials ________
Unique Site ID _______  Location _________________
Flight Line __________  Frame _________________
X Pixel Position ______  Y Pixel Position ______
Description of Area _____________________________
Comments ______________________________________
Photographic Records Collected for each GCP
Typical Features used for GCPs
Country and Remote Area GCPs
Close-up of Country and Remote Area GCPs
Specific Pixel Selected for GCP
Color Aerial Photograph with Completed GCPs
Distribution of GPS Point Data Acquired on the Island of Oahu During this Work

Legend
- Island of Oahu
- Position of Accuracy Assessment (N=393)
- Position of Ground Control (N=133)
- Position of Ground Validation (N=228)
Color Aerial Photography

Raw Data Scale 1:24,000
Display Scale 1:12,000

Imagery Provided by NOAA
Prototype processing by NOS
http://biogeo.nos.noaa.gov/
AURORA Airborne Hyperspectral Imagery

3 Meter Pixel
72 Bands
Display Scale 1:12,000

Imagery Provided by NOAA
Prototype processing by NOS
http://biogeo.nos.noaa.gov/
IKONOS Multispectral Satellite Imagery

4 Meter Pixel
Display Scale 1:12,000

Imagery Provided by Space Imaging, Inc.
http://www.spaceimaging.com

Prototype processing By NOS
http://biogeo.nos.noaa.gov
Map Preparation Methods

- Delineation of habitat boundaries by photointerpretation of remotely sensed imagery
- Heads up digitizing (Computer Screen)
- ArcView GIS format
- Using NOAA digitizing extension found at:
  
  http://biogeo.nos.noaa.gov/products/apps/digitizer
Coral Reef Habitat Classification Scheme
http://biogeo.nos.noaa.gov/projects/mapping/pacific/main8/classification/

**Unconsolidated Sediments**
- Sand
- Mud

**Submerged Aquatic Vegetation**
- **Macroalgae (fleshy or turf)**
  - Continuous Macroalgae (90%-100% Cover)
  - Patchy (Discontinuous) Macroalgae (50%–<90% Cover)
  - Patchy (Discontinuous) Macroalgae (10%–<50% Cover)
- **Seagrass**
  - Continuous (90%-100% Cover)
  - Patchy (Discontinuous) Seagrass (50%–<90% Cover)
  - Patchy (Discontinuous) Seagrass (10%–<50% Cover)

**Coral Reef and Hard Bottom**
- **Coral Reef and Colonized Hard Bottom**
  - Linear Reef
  - Spur and Groove
  - Patch Reef (Individual)
  - Patch Reef (Aggregated)
  - Scattered Rock and Coral in Unconsolidated Sediment
  - Aggregated Coral
  - Colonized Pavement
  - Colonized Volcanic Rock/Boulder
  - Colonized Pavement with Sand Channels
- **Uncolonized Hard Bottom**
  - Reef Rubble
  - Uncolonized Pavement
  - Uncolonized Volcanic Rock/Boulder
  - Uncolonized Pavement with Sand Channels
- **Encrusting/Coralline Algae**
  - Continuous Encrusting/Coralline Algae (90%-100% cover)
  - Patchy Encrusting/Coralline Algae (50%–<90% cover)
  - Patchy Encrusting/Coralline Algae (10%–<50% cover)

**Other**
- Land
- Emergent Vegetation
- Artificial
- Unknown
Coral Reef Zone Classification Scheme

Land
Vertical Wall
Shoreline Intertidal
Reef Flat
Lagoon
Back Reef
Reef Crest
Fore Reef
Bank/Self
Bank/Shelf Escarpment
Channel
Dredged
Unknown
Mapping Standards

Spatial Quality

Imagery: Defined by provider
Digitizing accuracy (1 meter RMS)
Digitized at scale of 1:6,000
Accuracy assessment GPS (2-5 meters)

QA/QC

Void polygons
Overlapping polygons
MMU: 1 acre
Clean polygons
Adjacency
Concatenated field
Standardized table format

Metadata

CSDGM standard parsable - no errors
Map review
Kaneohe Bay
Coral Reef Habitats

LEGEND
28 Coral Reef Habitats
- Sand
- Mud
- Seagrass/10%<50%
- Seagrass/50%<90%
- Seagrass/Continuous
- Macroalgae/10%<50%
- Macroalgae/50%<90%
- Macroalgae/Continuous
- Encrusting Coralline Algae/10%<50%
- Encrusting Coralline Algae/50%<90%
- Encrusting Coralline Algae/Continuous
- Linear Reef
- Spur and Groove Reef
- Patch Reef (Individual)
- Patch Reef (Aggregated)
- Aggregated Coral
- Scattered Rock/Coral in Unconsol. Sediment
- Colonized Pavement
- Colonized Volcanic Rock/Boulder
- Colonized Pavement with Sand Channels
- Uncolonized Pavement
- Reef Rubble
- Uncolonized Volcanic Rock/Boulders
- Uncolonized Pavement with Sand Channels
- Land
- Hardened Shoreline
- Fish Ponds
- Emergent Vegetation
- Other Man Made Features
- Unknown
Kaneohe Bay
Coral Reef Zones

LEGEND
13 Coral Reef Zones
- Island Vertical Wall
- Shoreline Intertidal
- Lagoon
- Reef Flat
- Backreef
- Reef Crest
- Forereef
- Shelf
- Shelf Escarpment
- Dredged
- Channel
- Land
- Unknown
Color Aerial Photography

Pixel size: 1 meter
Display Scale 1:12,000

Imagery Provided by NOAA
Prototype processing by NOS
http://biogeo.nos.noaa.gov/
Coral Reef Habitat Map
Prepared from Photointerpretation of Color Aerial Photography
AURORA Hyperspectral Imagery
Deep water bands
Pixel size: 3 meters
Display Scale 1:12,000

Imagery Provided by NOAA
Prototype processing by NOS
http://biogeo.nos.noaa.gov/
AURORA Hyperspectral Imagery
Shallow water bands
Pixel size: 3 meters
Display Scale 1:12,000

Imagery Provided by NOAA
Prototype processing by NOS
http://biogeo.nos.noaa.gov/
Coral Reef Habitat Map
Prepared from Photointerpretation of AURORA Hyperspectral Imagery

LEGEND
- Sand
- Mud
- Seagrass/Continuous
- Seagrass/10%-50%
- Seagrass/50%-90%
- Macroalgae/Continuous
- Macroalgae/10%-50%
- Macroalgae/50%-90%
- Encrusting Coralline Algae (Cont)
- Encrusting Coralline Algae (50%-90%)
- Encrusting Coralline Algae (10%-50%)
- Linear Reef
- Spur and Groove Reef
- Patch Reef (Individual)
- Patch Reef (Aggregated)
- Coral Head (Individual)
- Coral Head (Aggregated)
- Scattered Rock/Coral in Unconsolidated Sediments
- Colonized Pavement
- Colonized Volcanic Rock/Boulder
- Colonized pavement with Sand/Surge Channels
- Uncolonized Pavement
- Reef Rubble
- Terrigenous Rubble
- Uncolonized Volcanic Rock/Boulders
- Uncolonized Pavement with Sand/Surge Channels
- Land
- Hardened Shoreline
- Fish Ponds
- Emergent Vegetation
- Other Man Made Structures
- Unknown
IKONOS Multispectral Imagery
Pixel size: 4 meters
Display Scale 1:12,000

Imagery Provided by Space Imaging, Inc.
http://www.spaceimaging.com

Prototype processing by NOS
http://biogeo.nos.noaa.gov/
IKONOS Multispectral Imagery
Shallow water processing
Pixel size: 4 meters
Display Scale 1:12,000

Imagery Provided by Space Imaging, Inc.
http://www.spaceimaging.com

Prototype processing by NOS
http://biogeo.nos.noaa.gov/
IKONOS Multispectral Imagery
Shoreline Processing
Pixel size: 4 meters
Display Scale 1:12,000

Imagery Provided by Space Imaging, Inc.
http://www.spaceimaging.com

Prototype processing by NOS
http://biogeo.nos.noaa.gov/
Coral Reef Habitat Map
Prepared from Photointerpretation of IKONOS Satellite Imagery

LEGEND:
- Sand
- Mud
- Seagrass/Continuous
- Seagrass/10%-50%
- Seagrass/50%-90%
- Macroalgal/Continuous
- Macroalgal/10%-50%
- Macroalgal/50%-90%
- Encrusting Coraline Algae (Cont)
- Encrusting Coraline Algae (50%-90%)
- Encrusting Coraline Algae (10%-50%)
- Linear Reef
- Spur and Groove Reef
- Patch Reef (Individual)
- Patch Reef (Aggregated)
- Coral Head (Individual)
- Coral Head (Aggregated)
- Scattered Rock/Coral in Unconsolidated Sediments
- Colonized Pavement
- Colonized Volcanic Rock/Boulder
- Colonized pavement with Sand/Surge Channels
- Uncolonized Pavement
- Reef Rubble
- Terrigenous Rubble
- Uncolonized Volcanic Rock/Boulders
- Uncolonized Pavement with Sand/Surge Channels
- Land
- Hardened Shoreline
- Fish Ponds
- Emergent Vegetation
- Other Man Made Structures
- Unknown
Ground Validation Points

Selected to explore specific habitat types
Kona Test Area Location

Island of Hawaii
Coral Reef Benthic Habitat Point and Area Assessments

Kona Coast, Hawaii
Coral Reef Benthic Habitat Point and Area Assessments

Kaneohe Bay, Hawaii

Legend

Survey Area

Location of Habitat Assessment

N=393
Coral Reef Benthic Habitat
Point and Area Assessments

Motokai, Hawaii

Legend

- Survey Area
- Location of Habitat Assessment

N=231

Area Impacted by Mud
1) Molokai Test Area

2) Digitized Detailed Habitat Map

3) Detailed Habitat Map Aggregated to Major Habitats
   Generate 50+ random sites per major habitat type

4) Occupy accuracy assessment sites and conduct benthic habitat assessment
Boats used Ranged from 36 foot Radon to Ocean Kayak
Field Data Collected at Each Habitat Assessment Site

<table>
<thead>
<tr>
<th>Site Data</th>
<th>Habitat Data</th>
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<tbody>
<tr>
<td>• Site ID</td>
<td>• Point Habitat Type</td>
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<tr>
<td>• Study Area</td>
<td>• Area 1 Habitat Type</td>
</tr>
<tr>
<td>• GPS Date</td>
<td>• Area 2 Habitat Type</td>
</tr>
<tr>
<td>• GPS Time</td>
<td>• Dominant Coral Species</td>
</tr>
<tr>
<td>• GPS Position</td>
<td>• Dominant SAV Species</td>
</tr>
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<td>• GPS Statistics</td>
<td>• Estimated Coral Cover</td>
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<td>• Depth</td>
<td>• Estimated SAV Cover</td>
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<td>• Photo Information</td>
<td>• Area Description</td>
</tr>
<tr>
<td>• Assessment Method</td>
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</table>
Aggregated Coral
Aggregated Coral
Seagrass 10% - <50%
Fleshy Macroalgae
Macroalgal Turf
Fleshy Macroalgae and Filamentous Turf
Fleshy Macroalgae
Covered with Sediment
Fleshy Macroalgae in the Upper Intertidal and Encrusting Coralline Algae in the Mid Intertidal
Encrusting Coralline Algae on Relic Coral Reef
Colonized Volcanic Rock and Boulders
Uncolonized Volcanic Rock and Boulder
Reef Rubble
Emergent Vegetation
Emergent Vegetation
Summary of Habitat Types Encountered During Accuracy Assessment
Field Data Collection for all Test Sites

<table>
<thead>
<tr>
<th>Habitat Type (Major Habitats in Bold Face Type)</th>
<th>Kona</th>
<th>KBay</th>
<th>Maui</th>
<th>Molokai</th>
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<tr>
<td>Unconsolidated Sediment</td>
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<td>97</td>
<td>136</td>
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<td>136</td>
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<tr>
<td>Mud</td>
<td>3</td>
<td>52</td>
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<td><strong>Submerged Aquatic Vegetation</strong></td>
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<td>Continuous Seagrass (90%-100%)</td>
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<td>81</td>
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<td>52</td>
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<td>Patchy Macroalgae (50%-%90%)</td>
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<td>43</td>
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<td><strong>Coral Reef and Hardbottom</strong></td>
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<td>191</td>
<td>106</td>
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<td>Spur and Groove</td>
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<td>Patch Reef (Individual)</td>
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<td>Patch Reef (Aggregated)</td>
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<td>Aggregated Coral</td>
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<td>Col. Volcanic Rock/Boulder</td>
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<td>20</td>
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<td>Col. Pav. With Sand Chan.</td>
<td>1</td>
<td>39</td>
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<td>Reef Rubble</td>
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<td>10</td>
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<td>Uncol. Pavement</td>
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<td>Uncol. Volcanic Rock/Boulder</td>
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<td>4</td>
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</table>
North End of Kona Coral Reef Benthic Habitat Map
Prepared from Photointerpretation Remotely Sensed Data

Legend
- Sand
- Mud
- Encrusting Coralline Algae (Cont)
- Encrusting Coralline Algae (50%-90%)
- Encrusting Coralline Algae (10%-50%)
- Spur and Groove Reef
- Colonized Volcanic Rock/Boulder
- Reef Rubble
- Uncolonized Volcanic Rock/Boulders
- Land
- Hardened Shoreline
- Other Man Made Structures
- Unknown
Detailed Habitat Class Accuracy of Coral Reef Habitat Map of Kaneohe Bay  
Prepared from Color Aerial Photography

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<thead>
<tr>
<th>POLYGON ATTRIBUTES</th>
<th>AgCr</th>
<th>Artf</th>
<th>ColPv</th>
<th>ColPvSC</th>
<th>HMacAl</th>
<th>InPtrf</th>
<th>LCorAl</th>
<th>LMacAl</th>
<th>LSeaGr</th>
<th>MMacAl</th>
<th>Mud</th>
<th>RR</th>
<th>SAND</th>
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Overall Accuracy of Detailed Habitats: 75%
Major Habitat Class Accuracy of Coral Reef Habitat Map of Kaneohe Bay
Prepared from Color Aerial Photography

<table>
<thead>
<tr>
<th>POLYGON ATTRIBUTES</th>
<th>FIELD ASSESSMENT</th>
<th>Row Totals</th>
<th>User's Accuracy</th>
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<tr>
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<td>Coral Reef and Hard Bottom</td>
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<td>Producer's Accuracy</td>
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<td>89%</td>
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Overall Accuracy: 90.8%
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<tr>
<th>TEST AREA</th>
<th>IMAGERY TYPE</th>
<th>ACCURACY STATISTICS</th>
<th>Major Habitats</th>
<th>Kappa</th>
<th>Tau</th>
<th>Detailed Habitats</th>
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<td>Major Habitats</td>
<td>Kappa</td>
<td>Tau</td>
<td>Detailed Habitats</td>
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<td>Color</td>
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<td>81.4%</td>
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<tr>
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<td>0.83</td>
<td>80.0%</td>
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<td>Color</td>
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<td>0.87</td>
<td>80.1%</td>
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<tr>
<td></td>
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<td>0.83</td>
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<td>All Areas Combined</td>
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<td>0.82</td>
<td>0.83</td>
<td>74.1%</td>
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Comparison of Accuracy of Coral Reef Habitat Maps Prepared from Color Aerial Photography, Hyperspectral IKONOS Satellite Imagery

<table>
<thead>
<tr>
<th>Location</th>
<th>Image Type</th>
<th>Color</th>
<th>IKONOS</th>
<th>HSI</th>
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<tr>
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<td>HSI</td>
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</tr>
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<td>Color</td>
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<tr>
<td></td>
<td>HSI</td>
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<td>Color</td>
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<td>HSI</td>
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Difference Significant, p<0.05
## Summary of Spatial Accuracy of GPS Field Data

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<tr>
<th>Control Type</th>
<th>RMS Value (meters)</th>
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<td>Benchmarks Vertical RMS</td>
<td>1.67</td>
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<tr>
<td>Benchmarks Horizontal RMS</td>
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<td>30</td>
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<tr>
<td>Occupation of a Waypoint From a Boat</td>
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<tr>
<td>Occupation of a Waypoint on Land</td>
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</tbody>
</table>
Coral Reef Habitat Map
Island of Niihau
Compliant with NOAA Reef Mapping Standards and Habitat Classification Scheme for The Eight Main Hawaiian Islands

65 Square Kilometers of Reef Area Mapped
Coral Reef Habitat Map
Island of Kauai
Compliant with NOAA Reef Mapping Standards and Habitat Classification Scheme for The Eight Main Hawaiian Islands

125 Square Kilometers of Reef Area Mapped
Coral Reef Habitat Map
Island of Oahu
Compliant with NOAA Reef Mapping Standards and Habitat Classification Scheme for The Eight Main Hawaiian Islands

349 Square Kilometers of Reef Area Mapped
Coral Reef Habitat Map
Island of Molokai
Compliant with NOAA Reef Mapping Standards and Habitat Classification Scheme for The Eight Main Hawaiian Islands

112 Square Kilometers of Reef Area Mapped
Coral Reef Habitat Map
Island of Maui
Compliant with NOAA Reef Mapping Standards and Habitat Classification Scheme for The Eight Main Hawaiian Islands

Island of Maui

56 Square Kilometers of Reef Area Mapped
Coral Reef Habitat Map
Island of Lanai
Compliant with NOAA
Reef Mapping Standards and
Habitat Classification Scheme for
The Eight Main Hawaiian Islands

Island of Lanai

18 Square Kilometers of Reef Area Mapped
### Area of each Major Habitat Class Mapped for each Test and Production Area (Sq. Km.)

<table>
<thead>
<tr>
<th>Map Type</th>
<th>Map Title</th>
<th>Coral Reef and Hard Bottom</th>
<th>Submerged Aquatic Vegetation</th>
<th>Unconsolidated Sediment</th>
<th>Total Area Per Map</th>
<th>Total Per Map Type</th>
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<tbody>
<tr>
<td></td>
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<td>Total Mapped for Maui</td>
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<td>9.05</td>
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<td>26.84</td>
<td>22.66</td>
<td>79.35</td>
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**Total Mapped in Test Areas**  
130.69  83.39  105.94  320.02

**Total Mapped in Production**  
415.54  171.04  204.25  790.83

**Total Area Mapped During Contract**  
1110.85
Products Generated During this Work

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<th>Quantity</th>
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<td>Ground Validation Points</td>
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<tr>
<td>Production Maps with Metadata</td>
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<td>Project Completion Report</td>
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