Rapid Response Tools and Datasets to support BAER assessment:
Spatial WEPP modeling with QWEPP & the Rapid Response Erosion Database (RRED)

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NASA ARSET Training

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#NNX12AQ89G
Overview

- Importance of BAER
- WEPP (Water Erosion Prediction Project)
- NASA BAER project and the Rapid Response Erosion Database (RRED)
- QWEPP introduction and DEMO
- NASA BAER in action
- Ravel RAT & Apps for BAER
- Fuels planning with NASA BAER project
Introduction

• Forests provide many products as well as ecosystem services
  – Wood
  – Wildlife and fish habitat
  – Recreation
  – Clean water

• Wildfire impacts on watersheds
  – Increased peak flow rates (up to 100x)
  – Increased sediment delivery to streams (up to 1000x)
BAER Teams
(Burned Area Emergency Response)

• Mission: Protect lives, property and natural resources threatened by post-fire flooding and erosion.
• BAER Teams go to work before the fire is out.
• Treatments need to be completed before a major storm in order to be effective.
WEPP (Water Erosion Prediction Project) Watershed Erosion Model

- Climate data
  - Cligen RockClime
  - Climate forecast

- Burn severity map
  - Land Cover Data NLCD or LANDFIRE
  - Disturbed WEPP Land use/management

- Soils STATSGO / SSURGO
  - Disturbed WEPP soil parameters

- DEM

GeoWEPP

Erosion maps
WEPP Versions

• Hillslope
  – Describes a single strip of hillslope
WEPP Versions

• Hillslope
  – Describes a single strip of hillslope

• Watershed
  – Links hillslopes, channels, and impoundments
  – Suits construction sites
WEPP Versions

- **Hillslope**
  - Describes a single strip of hillslope

- **Watershed**
  - Links hillslopes, channels, and impoundments
  - Suits construction sites

- **GIS tools**
  - New QWEPP interface in QGIS
  - GeoWEPP ArcGIS Wizard
  - Online interface for U.S. databases
WEPP Inputs

• Slope
  – Distance - Steepness
WEPP Inputs

• Slope
  – Distance - Steepness

• Soil
  – WEPP Erodibility based on texture and vegetation
  – Soil texture and depth base on Soil Survey
WEPP Inputs

• Slope
  – Distance - Steepness

• Soil
  – WEPP Erodibility based on texture and vegetation
  – Soil texture and depth base on Soil Survey

• Vegetation or Management
  – Initial conditions
  – Vegetation growth and residue decomposition properties
WEPP Inputs

• Slope
  – Distance - Steepness

• Soil
  – WEPP Erodibility based on texture and vegetation
  – Soil texture and depth base on Soil Survey

• Vegetation or Management
  – Initial conditions
  – Vegetation growth and residue decomposition properties

• Climate
  – Daily precip, temperatures and wind speed
WEPP Processes 1

• Rainfall, infiltration, runoff, soil water
WEPP Processes 2

- Rainfall, infiltration, runoff, soil water
- Soil detachment, transport, deposition and delivery
WEPP Processes 3

- Rainfall, infiltration, runoff, soil water
- Soil detachment, transport, deposition and delivery
- Plant growth, evapotranspiration, and senescence
WEPP Processes 4

- Rainfall, infiltration, runoff, soil water
- Soil detachment, transport, deposition and delivery
- Plant growth, evapotranspiration, and senescence
- Residue accumulation and decay
Erosion Processes 1

- Interrill Erosion
  - Raindrop splash
  - Shallow Overland Flow
Erosion Processes 2

- **Interrill Erosion**
  - Raindrop splash
  - Shallow Overland Flow

- **Rill Erosion**
  - Concentrated Channel Flow
  - Assumes about 1 m spacing between rills
    - Varied for roads
Remote Sensing Data

\[
\text{NBR} = \frac{R_{NIR} - R_{SWIR}}{R_{NIR} + R_{SWIR}} \quad \text{(Key & Benson, 2006)}
\]

Where: \( R \) is the reflectance at the satellite in either the near-infrared (NIR) or the shortwave-infrared (SWIR). The change in NBR between the pre- and post-fire conditions is calculated by:

\[
d\text{NBR} = \text{NBR}_{\text{prefire}} - \text{NBR}_{\text{postfire}}
\]
Problem - Spatial process based erosion models are currently under utilized.

**Rock House Fire**  
Date: April 9, 2011  
Location: Fort Davis, TX  
Size: 314,444 acres; 127,250 ha  
Hospital Canyon: 536 acres; 217 ha  
BAER Team: National Park Service

**High Park Fire**  
Date: June 9, 2012  
Location: West of Fort Collins, CO  
Size: 87,284 acres; 35,322 ha  
BAER Team: Forest Service
Two Case Studies: Rock House Fire / High Park Fire

Tip 1: Have the model you want installed and functioning!

Installation of model
ESRI software can be difficult to install

Model already installed and ready to go!

Tip 2: Have inputs ready!

All inputs had to be gathered after the fire:
- Soils and land cover take time to build;
- Soils data need processing to get key values;
- Land cover and soil files need to be modified by burn severity!

Most inputs prepared ahead of time
- Land cover and DEM prepared;
- Soils were mapped and data organized;
- Still have to modify land cover and soils by burn severity!
Spatial process-based erosion models are underutilized due to time constraints;

• Prepare datasets and tools before the fire occurs!

• Modelers also need to prepare the model and practice before hand!
Modeling Datasets

- Burn Severity: User Supplied & Monitoring Trends in Burn Severity project
- Soils: USDA SSURGO and STATSGO datasets
- Land cover: Existing Vegetation Type (EVT) data from the LANDFIRE
- 30m & 10m DEM data from the United States Geological Survey (USGS) Seamless Data Warehouse.
Burned Area Emergency Response

Spatial WEPP Model Inputs Generator

Upload BARC Map

Select a raster file to upload:

Specify the values of burn severity classes in the uploaded raster. Any value that is not Low, Moderate, or High will be reclassified as Unburned:

- Low: 2
- Moderate: 3
- High: 4

Optional parameters:

- Buffer my burned area by 10 pixels
- EPSG code (SRID):

For best results, your BARC map should have 30-meter pixels. BARC maps with a pixel size other than 30 meters will be resampled to 30 meters, which may result in misalignment of the output data compared to the original BARC map.

A private key will be generated which grants you future access to your uploaded data. Only this key can be used to access the BARC map you uploaded and it will expire, along with your uploaded data, after 14 days. Within that time, use this key instead of uploading the file again.

Cancel  Upload
Soil Burn Severity (SBS) Map

Most soil burn severity (SBS) maps are derived from Landsat data – so if you are creating the SBS map leaving it in the native projection and raster format is best!

• Data needs to be in a classified raster format with three classes represented numerically – low, moderate and high
• Best if raster has a resolution of ~ 30 m
• Projection needs to be standard – UTM nad83 or UTM wgs 84 work best
RRED creates WEPP linkage files!
BAER Teams can focus on modeling!
• Rapid Response Erosion Database Example
QGIS Spatial interface for WEPP

QWEPP

• Easy to use geographical interface for the Water Erosion Prediction Project!
QWEPP

• In order to utilize QWEPP users will need **QGIS software** installed and the **QWEPP plugin**.

• You need the .NET Framework and at least 250 MB of hard drive space.

• For QGIS installation software and instructions go to: [http://www.qgis.org/en/site/forusers/download.html](http://www.qgis.org/en/site/forusers/download.html).
QWEPP Software Components

- QGIS—provides the GIS framework for display, tools for assembling and manipulating spatial data.
- QWEPP – plugin to collect user inputs, run model and assemble results.
- USDA-ARS TOPAZ - uses DEM to delineate channels, delineate watershed from outlet, create the topographic slope files needed to run WEPP.
- Topwepp2 – create WEPP inputs from gridded data and translate between TOPAZ watershed files to WEPP model inputs.
- WEPP – Process based erosion model!
Spatial Inputs from the French Fire (CA, 2014) Soils DEM Land cover

Soils

DEM

Land cover

Post fire land cover
- Water
- Developed
- Pavement
- Barren
- Forest
- Chaparral
- Short Grass
- Tall Grass
- Shrub
- Low Severity
- Moderate Severity
- High Severity
WEPP Linkage files

- Simple text files
- Four files
  - landcov.txt
  - landusedb.txt
  - soilsmap.txt
  - soilsdb.txt
Land Cover linkage files

**landcov.txt - Notepad**

11 Open Water
12 snow/Ice
22 Developed - Low Intensity
23 Developed-Roads
31 Barren
40 Young Forest
41 Forest
52 Chaparral
70 Short Grass
71 Tall Grass
73 Shrub
81 Pasture/Hay
82 Cultivated Crops
91 Wetlands
100 Low Burn Severity
111 Open Water
112 snow/Ice
122 Low Burn Severity
123 Developed-Roads
131 Barren
140 Low Burn Severity
141 Low Burn Severity
152 Low Burn Severity
170 Low Burn Severity
171 Low Burn Severity
173 Low Burn Severity
181 Low Burn Severity
182 Low Burn Severity
191 Low Burn Severity
200 Moderate Burn Severity
211 Open Water
222 Moderate Burn Severity
223 Developed-Roads
231 Barren
240 Moderate Burn Severity
241 Moderate Burn Severity
252 Moderate Burn Severity

**landusedb.txt - Notepad**

- Low Burn Severity|FC_85%.rot
- High Burn Severity|FC_25%.rot
- Moderate Burn Severity|FC_60%.rot
- Chaparral|Mokelumne\Chaparral.rot
- Open Water|GeoWepp\grass.rot
- Forest|Mokelumne\Forest Perennial.rot
- Young Forest|Mokelumne\Young Forest.rot
- Short Grass|Mokelumne\Short grass.rot
- Tall Grass|Mokelumne\Tall grass.rot
- Shrub|Mokelumne\Shrub.rot
- Developed - Low Intensity|Mokelumne\Short grass.rot
- Developed-Roads|Pavement.rot
- Barren|Mokelumne\Barren.rot
- Pasture/Hay|Mokelumne\alfalfa with cuttings.rot
- Cultivated Crops|Mokelumne\winter wheat, mulch till CA.rot
- Wetlands|GeoWepp\grass.rot
- snow/ice|GeoWepp\grass.rot
Soil linkage files
TOPAZ inputs: CSA, MSCL

- **CSA**: Critical Source Area
  - Determines when a channel forms
  - Current default setting is 30 ha

- **MSCL** – Minimum Source Channel Length
  - Minimum channel length needed to initiate a channel
  - Current default is 100 m
TOPAZ inputs: CSA, MSCL

CSA 5 ha
MSCL 60 m

CSA 5 ha
MSCL 100 m

CSA 30 ha
MSCL 100 m
Watershed vs. Flowpath

Watershed Method

- Each hillslope has one:
  - Slope profile
  - Dominant land cover
  - Dominant soil type

- Offsite assessment as the spatial results represent the sediment yield that leaves each hillslope

Flowpath Method

- Each flowpath has its own slope profile
- Each pixel keeps its land cover and soil type
- Flowpath converge so they are aggregated
- Onsite assessment as the spatial results represent erosion or deposition occurring in each raster cell of the subcatchment
Watershed vs. Flowpath

Watershed Method
- Less spatial resolution
- Faster, example 2 year run in 0:17 seconds

Flowpath Method
- More detail
- Longer to run, example 2 year run in 3:24 minutes
QWEPP DEMO

- Rapid Response Erosion Database
- QWEPP Example

NASA BAER in Action!

for **Fuels Planning**
- Mokelumne
- Flagstaff

for **BAER Teams**
- Canyon Creek, OR
- Clearwater, ID
- Butte, CA
- Valley, CA
- French, CA
- Happy Camp, CA
- Silverado, CA
- King, CA
- Soberanes, CA
- Fish, CA
- Cedar, CA

for **Validation study**
- High Park, CO
Canyon Creek Fire

Cover Settings provided by BAER Team:

- Low burn severity - 75% cover
- Moderate burn severity - 55% cover
- High burn severity - 20% cover
- Mulch – 80% cover

Precipitation: 2.5 inches in 6 hrs with a peak intensity 1.25 in/hr, and a time to peak of 0.3 of the duration
Canyon Creek – single storm event
Canyon Creek – mulch treatments
Canyon Creek – predicted reduction in erosion due to proposed mulching
Valley & Butte Fires in California

Post Fire Erosion Modeling for Valley Fire

Calfire SBS hillslope erosion yields for Butte Fire

Valley perimeter  
Valley_SBS_sed.tif
Mg / ha year
0 - 1  
1.1 - 2

Butte Calfire sediment
Mg / (ha yr)
0 - 0.5  
0.51 - 1  
1.1 - 2  
2.1 - 5  
5.1 - 10

11 - 25  
26 - 50  
310 - 500  
510 - 680

0 - 5 Kilometers

0 - 7 Kilometers
French Fire (5,600 ha)

Soil burn severity map
Landsat and EO-1

Predicted Erosion rates

Post-fire erosion 1st year
Mg/ha

- 0 - 0.5
- 0.51 - 1
- 1.1 - 2
- 2.1 - 5
- 5.1 - 10
- 11 - 25
- 26 - 50
- 51 - 75
- 76 - 100
- 110 - 200
- 210 - 500
- 510 - 930

8/12/14
Not burned
Low severity
Moderate severity
High severity
2
Kilometers

Tour Guide 5/20/1993 37°16'13.54" N 119°22'42.95" W elev. 5641 ft eye alt. 32205 ft
Happy Camp (54,200 ha)
<table>
<thead>
<tr>
<th>Return Period (years)</th>
<th>Runoff Volume (m³)</th>
<th>Sediment Leaving (t)</th>
<th>Peak Runoff Rate (m³/sec)</th>
<th>Daily Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>769.1</td>
<td>33.5</td>
<td>0.4</td>
<td>46.1</td>
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<tr>
<td>2</td>
<td>3077.8</td>
<td>121.8</td>
<td>1.5</td>
<td>57.9</td>
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<tr>
<td>4</td>
<td>7000.7</td>
<td>252.3</td>
<td>3.1</td>
<td>68.9</td>
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<tr>
<td>5</td>
<td>8927.3</td>
<td>323.3</td>
<td>3.8</td>
<td>72</td>
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<tr>
<td>10</td>
<td>17004.8</td>
<td>608.2</td>
<td>6.8</td>
<td>92.5</td>
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<tr>
<td>20</td>
<td>33334</td>
<td>1280.2</td>
<td>12.5</td>
<td>104.7</td>
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<tr>
<td>25</td>
<td>37193.2</td>
<td>1326.1</td>
<td>13.8</td>
<td>110.8</td>
</tr>
</tbody>
</table>
King Fire (39,500 ha)
### Appendix B—Soil Burn Severity Field Data Sheet and Key

#### Soil Burn Severity Assessment Field Data Sheet

<table>
<thead>
<tr>
<th>Observation point</th>
<th>Ground cover (1)</th>
<th>Surface color and ash depth (2)</th>
<th>Soil structure (3)</th>
<th>Roots (4)</th>
<th>Soil water repellency (5)</th>
<th>Observed soil burn severity class (6)</th>
<th>Photo #</th>
<th>Other comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXAMPLE</td>
<td>20 to 50%</td>
<td>white, 1 mm</td>
<td>no change</td>
<td>intact</td>
<td>1 mL surf</td>
<td>Mod</td>
<td>23</td>
<td>homogenous</td>
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</tr>
</tbody>
</table>

#### Site characteristics:

- Aspect (deg):
- Slope %:
- Slope length (ft or m):
- Slope position: Lower, Middle, Upper, Ridge, Other
- Soil texture class: clay loam, silt loam, loam
- Surface rock %:
- Soil comments:
Field App for BAER Teams
Enable Modelers

• Training Manual available!
• Training webinar this winter
• MTRI’s NASA BAER team is ready to help with modeling
Ravel RAT
Ravel Risk Assessment Tool

Dry Ravel Inputs:

- **DEM** - 10 Meter Digital Elevation Map.
- **Burn Severity Map**
- **Parameter file**
  - Mean stem diameter of vegetation (0.05 m)
  - Vegetation density (1 plant/m²)
  - Burn Depths
  - Bulk density of soil (1300 kg/m³)
  - Static friction angle \( \alpha \) (34°)
  - Kinetic friction angle (31.1°)
Ravel RAT
Ravel Risk Assessment Tool

To set processing bounds, use the boxes below OR click on the solid square tool in the map to draw. Click the tool again to redraw.

N 34.621681
W -110.457738 E -110.430660
S 34.621802

Area of bounding box: 0.156 µm²

Burn impact depth (mm) 0.2
Vegetation density (stems/m²) 1
Static friction angle (°) 20

Bulk density (kg/m³) 1.36
Mean stem diameter (cm) 0.05
Kinetic friction angle (°) 27

RUN DRY RAVEL

Valid range: 26° to 36°

The static friction angle of the ravel material is the maximum angle at which ravel material can accumulate before it starts sliding. For this reason it is also known as the angle of repose.

Ravel will not originate on hill sides with slopes less than the static friction angle. In the San Diego Experimental Forest in Southern California, the static friction angle of ravel ranged between 29° and 34° degrees.
RRED for fuel planning

- Mokelumne Watershed in the Sierra Mountains in central California
  - 5500 km²
  - Vegetation: oak savannah to evergreen forest
  - 800-1430 m elev.
Key Question

• How can we
  – quantify the benefits of fuels treatments, and
  – use those benefits to pay for fuels treatments;
  – thereby reducing the risk of wildfires and associated loss of environmental services?
Approach

• Determine hillslope-scale sediment production for:
  – Current conditions in the absence of fire;
  – After a fire assuming current fuel conditions;
  – After fuel treatments;
  – After a fire following treatments;

• Need to use three models:
  – FLAMMAP to predict fire severity
  – FSIM to predict fire probability
  – WEPP Watershed to predict erosion
FLAMMAP Fire Spread Model

• Main inputs:
  – Forest structure/fuels
  – Fuel moisture
  – Slope aspect and steepness
  – Average wind direction

• Key outputs for each grid cell (typically 90-m):
  – Flamelenlength (ft)
  – Mean fire line intensity ($W \text{ m}^{-2}$ or $W$ per unit length)
WEPP (Water Erosion Prediction Project) Watershed Erosion Model

• Main inputs:
  – Stochastic climate (50 years)
  – Topography (typically from 30-m DEM)
  – Soil properties (texture, % rock, and burn severity)
  – Ground cover (linked to land cover & fire severity)

• Main output:
  – Sediment production by hillslope polygon
    (~6 ha for this study)

Klamath Complex Fire, California
Weather stations used to generate climate statistics, and spatially distributed using PRISM.
Land cover: Existing vegetation cover map was simplified to the categories in WEPP.
Output and Input: Flame length predictions reclassified to burn severity

For the Mokelumne Basin
12% of the area predicted not to burn
41% predicted to burn at low severity
29% moderate severity
18% high severity
For the Mokelumne Basin
12% of the area predicted not to burn
48% predicted to burn at low severity
28% moderate severity
12% high severity
Inputs: Soils modified by burn severity and land cover
Inputs: 30-m National Elevation Dataset
Results: Predicted annual hillslope-scale erosion for current land cover (NO Fire)
Results: Predicted first-year hillslope erosion AFTER burning, no treatment
Predicted first year erosion if selected hillslopes are treated
### Summary of Results

<table>
<thead>
<tr>
<th></th>
<th>Current Condition</th>
<th>Fire Following Current Condition</th>
<th>Treatment Effects</th>
<th>Fire Following Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Erosion in Basin</td>
<td>0.67 Mg/ha</td>
<td>32 Mg/ha in year 1</td>
<td>0.69 Mg/ha</td>
<td>26 Mg/ha in year 1</td>
</tr>
<tr>
<td>Range</td>
<td>0 – 84 Mg/ha</td>
<td>0 – 566 Mg/ha</td>
<td>0 – 84 Mg/ha</td>
<td>0 – 535 Mg/ha</td>
</tr>
<tr>
<td>Standard Dev</td>
<td>3.0 Mg/ha</td>
<td>55 mg/ha</td>
<td>2.5 Mg/ha</td>
<td>44 Mg/ha</td>
</tr>
</tbody>
</table>

- Steep, relatively bare areas are predicted to have high erosion rates regardless of burning.
## Summary of Results for Treatment Area

<table>
<thead>
<tr>
<th></th>
<th>Current Condition</th>
<th>Fire Following Current Condition</th>
<th>Treatment Effects</th>
<th>Fire Following Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Erosion in Basin</td>
<td>0.40 Mg/ha</td>
<td>46 Mg/ha in year 1</td>
<td>0.69 Mg/ha</td>
<td>26 Mg/ha in year 1</td>
</tr>
<tr>
<td>Range</td>
<td>0 – 84 Mg/ha</td>
<td>0 – 566 Mg/ha</td>
<td>0 – 84 Mg/ha</td>
<td>0 – 535 Mg/ha</td>
</tr>
<tr>
<td>Standard Dev</td>
<td>2.5 Mg/ha</td>
<td>69 mg/ha</td>
<td>2.5 Mg/ha</td>
<td>36 Mg/ha</td>
</tr>
</tbody>
</table>
Are the results reasonable?
(average value of 32 Mg ha\(^{-1}\) yr\(^{-1}\))

- Average annual first year post-fire erosion values observed recently in California:
  - Mixing Fire were 6-13 Mg/(ha yr\(^{-1}\))
  - Cannon Fire were 2.5-15 Mg/(ha yr\(^{-1}\))
    - closest site
  - Cedar Fire 19-46 Mg/(ha yr\(^{-1}\))

**Avg. Prediction for Mokelumne Fire 32 Mg/(ha yr\(^{-1}\))**

- In all cases, the observed climates were drier (604 mm, 658 mm, and 398 mm respectively) than the Mokelumne Basin which ranged from 799 mm to 1438 mm.
How do we put wildfire erosion in context?

• Wildfire is part of disturbance driven forest ecosystem

• An “average annual” erosion from fire can be estimated by:

  \[
  \text{Avg Erosion} = \text{Wildfire Erosion} \times \text{Probability}
  \]
“Average Annual” Erosion

\[
\text{Average Erosion}_{cc} = E_{cc\_fire} \times bp_{cc\_fire} + (1 - bp_{cc\_fire}) \times E_{nf} \quad \text{(Eq 1)}
\]

\[
\text{Average Erosion}_{tr} = E_{tr\_fire} \times bp_{tr\_fire} + (1 - bp_{tr\_fire}) \times (24 \times E_{nf} + E_{tr})/25 \quad \text{(Eq 2)}
\]

where:
- \( E_{cc\_fire} \) is the mapped post-fire erosion rates for current conditions.
- \( E_{tr\_fire} \) is the mapped post-fire erosion rates following fuel treatments.
- \( E_{tr} \) is the mapped erosion rates due to the effects of the fuel treatments.
- \( E_{nf} \) is mapped erosion rates for current conditions in the absence of fire.
- \( bp_{cc\_fire} \) is the mapped probability of fire under current conditions.
- \( bp_{tr\_fire} \) is the mapped probability of fire following fuel treatments.

For treated portion of the watershed

\[
\text{Average Erosion}_{cc} = 0.64 \ \text{Mg yr}^{-1} \ \text{ha}^{-1}
\]

\[
\text{Average Erosion}_{tr} = 0.52 \ \text{Mg yr}^{-1} \ \text{ha}^{-1}
\]
Fuel Planning Conclusions

1. FLAMMAP and WEPP can be used to quantify the changes in fire severity and erosion associated with fuel reduction treatments;

2. Knowing the distribution of potential erosion is useful to forest and watershed managers;

3. Managers can expect a significant reduction (19%) in sediment delivery with fuel treatment;
Thank you

Be Prepared!

- Have the data ready
- Have plan to incorporate Earth Observations
- Have your model installed and ready!

Questions?

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http://geodjango.mtri.org/geowepp