Model Name: Freshwater Availability

Functional Area: Ecosystem Service

Model Proponents: Coastal Protection and Restoration Authority

Model Developer(s): Denise Reed, University of New Orleans

Please note this is a working-draft document currently undergoing review and revision. The final version will be posted in March 2012 along with the final version of the 2012 Coastal Master Plan.

Table of Contents

1. Background

a. Purpose of Model

The Freshwater Availability Model was based on the concept of habitat suitability index (HSI) models. Through internal discussion among the model developers, modeling efforts were focused on freshwater availability for strategic assets and major population centers in coastal Louisiana.

b. Model Description and Depiction

The Freshwater Availability Suitability Index (SI) is intended to reflect the availability of freshwater for municipal and industrial (M&I) use by urban areas and other facilities as indicated by the 2012 Coastal Master Plan strategic assets database. It is based on 500 x 500m model grid cells and is calculated on an annual time step. The model combines salinity, distance from a strategic asset, and distance from major population centers (areas where population is greater than 50,000) inputs to produce a suitability index for freshwater availability ranging from 0.0 to 1.0.

c. Contribution to Planning Effort

The model provides a prediction of freshwater availability in coastal Louisiana for a 50-year time horizon.

d. Description of Input Data

Data used as input are salinity (ppt), distance from strategic asset (m), and distance from major population center (mi). Salinity is output data from the Eco-Hydrology Model. The distance variables are calculated using GIS shapefiles.

e. Description of Output Data

The output data is a suitability index ranging from 0.0 to 1.0 that represents the availability of freshwater to a 500 x 500m model grid cell. A value of 1.0 indicates the greatest potential for freshwater availability.

f. Statement on the capabilities and limitations of the model

The model is capable of determining the availability of freshwater to a model grid cell in relation to strategic assets and major population centers in order to evaluate the differences between proposed projects.

The model is limited by its focus on predicting freshwater availability around only strategic assets identified by the master plan strategic assets database and major population centers. It is not intended to predict freshwater availability for all areas or to be a comprehensive quantitative model. It functions as a broad planning-level model.

g. Description of model development process including documentation on testing conducted

The model focuses on freshwater availability for strategic assets and major population centers. Therefore, distance factors were included in the model with freshwater closer to strategic assets and/or major population centers given higher scores. The salinity of the available water was also critical in determining if the water source was fresh. Each of these factors were developed as individual suitability indices, and combined arithmetically and geometrically to give a freshwater availability suitability index.

2. *Technical Quality*

a. Theory

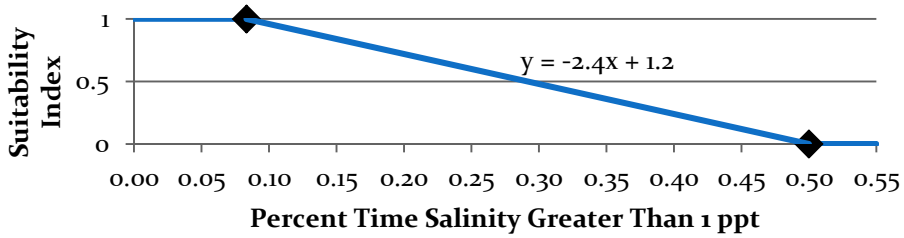
This model was developed in a similar style to habitat suitability indices. The following factors are included in the Freshwater Availability SI Model:

SI_1 - Suitability Index for Salinity

Since freshwater supply is essential for both industry and communities, this variable accounts for the salinity of the water in a model grid cell. It is based on the percent of time the water in each grid is above 1.0 ppt per year based on monthly means. Waters that are not fresh less than 8.3% of the year are ideal and receive an SI of 1.0. If the available water of a model grid cell is not fresh more than 50% of the year, then it receives an SI of 0.0. Water within a cell that is not fresh between 8.3% and 50% of the year are scaled linearly with the equation $SI_1 = (-2.4 * V_1) + 1.2$.

V_1 = Salinity (ppt)

$SI_1 =$ 1.0	for $V_1 \leq 0.083$
$(-2.4 * V_1) + 1.2$	for $0.083 < V_1 \leq 0.50$
0.0	for $V_1 > 0.50$

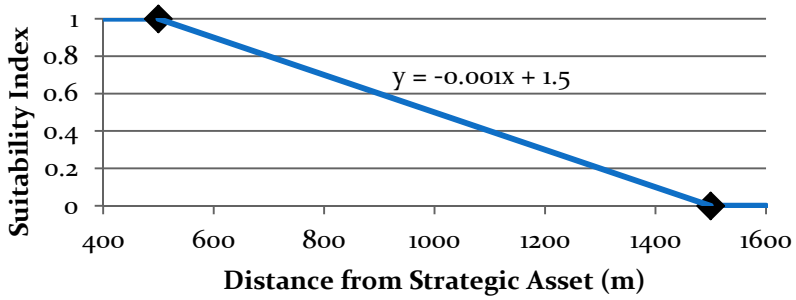


SI_2 - Suitability Index for Distance from Strategic Asset

Proximity to freshwater sources directly influences its availability. Assets located within 500 m of freshwater are scored highest (SI = 1.0). If an asset is located more than 1500 m from freshwater, it receives an SI of 0.0. Those that are between 500 to 1500 m are scaled linearly with the equation $SI_2 = (-0.001 * V_2) + 1.5$.

V_2 = Distance from strategic asset (m)

$SI_2 =$ 1.0	for $V_2 \leq 500$
$(-0.001 * V_2) + 1.5$	for $500 < V_2 \leq 1500$
0.0	for $V_2 > 1500$

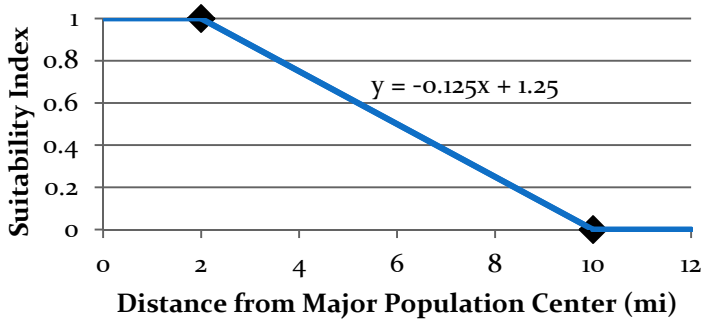


SI_3 - Suitability Index for Distance from Major Population Centers

Just as with industrial assets, the location of a municipality to nearby freshwater sources greatly affects its availability. Municipalities located within 2.0 mi of freshwater are scored highest (SI = 1.0). If a city is located more than 10 mi from freshwater, it receives an SI of 0.0. Those that are between 2.0 and 10 mi are scaled linearly with the equation $SI_3 = (-0.125 * V_3) + 1.25$.

V_3 = Distance from major population center (mi)

$$SI_3 = \begin{cases} 1.0 & \text{for } V_3 \le 2.0 \\ (-0.125 * V_3) + 1.25 & \text{for } 2.0 < V_3 \le 10 \\ 0.0 & \text{for } V_3 > 10 \end{cases}$$



Freshwater Availability SI

The freshwater availability suitability index is a geometric mean of the salinity and the arithmetic mean of the distance functions. The suitability index was constructed in this way since salinity is vital, but the distance from either a strategic asset or municipality is important.

Freshwater Availability SI = $(SI_1 * ((SI_2 + SI_3) / 2))^{1/2}$

b. Description of system being represented by the model

This service reflects the availability of freshwater for municipal and industrial (M&I) use by urban areas and other facilities as indicated by the 2012 Coastal Master Plan strategic assets database. The assets listed in the database fall into one of several categories: production plants, refineries, compression stations, grain elevators, or terminals. All of these assets require freshwater for a variety of uses such as fabricating, processing, washing, diluting, cooling, transporting products, incorporating water into products, or for sanitation needs within the facility (Kenny et al., 2009). Municipalities (communities with populations > 50,000) also require freshwater inputs for domestic, commercial, or public service uses (Kenny et al., 2009). The index is calculated for each 500m cell. A total number of Freshwater Availability Units (FAUs) is calculated based on the sum of SI values for all cells within the area(s) within each vision region. The availability of freshwater for agriculture is reflected in the "Potential for Agriculture/Aquaculture" service.

This model simulates the effects of salinity, distance from strategic assets and distance from major population centers on the availability of freshwater. Each factor is defined as its own suitability index and all of the factors are combined as a freshwater availability suitability index through arithmetic and geometric means.

c. Analytical requirements

In order to adequately investigate the availability of freshwater for municipal and industrial (M&I) use by urban areas and strategic assets, several key factors were identified: salinity, location in relation to major population centers and to strategic assets. These key factors were all included in the modeling effort, and combined depending on their importance to describing the availability of freshwater. The Freshwater Availability Suitability Index is a geometric mean of the salinity and the arithmetic mean of the distance functions. The suitability index was constructed in this way since salinity is vital, but the distance from either a strategic asset or municipality is important.

d. Assumptions

It is based on the assumption that the service provided is greater for freshwater sources that are closer to population centers and strategic assets. Additionally, the freshwater availability suitability index assumes distance from strategic assets and major population centers are compensatory, e.g. a freshwater source near one location type will not be penalized by being distant from the other type, and freshwater sources near both will receive an appropriately higher score.

e. Identification of formulas used in the model and proof that the computations are appropriate and done correctly

The model decision rules that were coded are provided in section 2.a. above. Quality review was performed by both the model coders and CPRA to ensure formulas and computations were correct.

3. System Quality

a. Description and rationale for selection of supporting software tool/programming language and hardware platform

Building on the ecological modeling application development performed for the Everglades modeling community, Java was used as the programming language inside the Eclipse RCP environment which supports plug-in software development. This approach facilitated the construction of software suites which execute the specific decision rules provided by subject matter experts allowing an end-user to choose which of the ecosystem services models to run.

b. Proof that the programming was done correctly

All software products are the result of multiple programmers working in concert. As part of the code development process, code classes are either team developed which ensures multiple individuals real-time code review or when individually coded are spot checked prior to production builds and exports.

c. Availability of software and hardware required by model

The choice of Java as the development platform ensures the broadest execution platform. These software suites can run on desktops with the following operating systems: Windows XP, 7 (32 and 64 bit), Apple OSX (32 and 64 bit), Linux. Furthermore, these Java executables could be easily re-compiled to run on Windows or Linux Application Servers.

d. Description of process used to test and validate model

These models were tested prior to production release with fabricated data built according to the data descriptions provided by the various teams. The absence of “real” data made pre-

production testing far less effective than it could have been had there been high quality test data.

Ideally, model outputs would be validated by comparing the model predictions to observations made in the field but that is not possible with this model. The second best validation is based upon comparison of modeled predictions to what is expected given the known inputs. We followed this latter approach and used known spatial patterns and temporal patterns in input to predict patterns in freshwater availability.

e. Discussion of the ability to import data into other software analysis tools (interoperability issue)

Being standards compliant with international modeling data standards ensures rather broad interoperability. Unidata actively supports netCDF read/write libraries for C++, Java, C# and Fortran programming languages across multiple operating systems. Additionally, netCDF is natively consumable by commercial software product such as ESRI ArcMAP and MatLab. Furthermore, the Everglades Joint Ecologic Modeling community has backed a USGS software development effort resulting in EverVIEW which brings an open-source visualization platform solution to the complex realm of binary modeling data.

4. Usability

a. Availability of input data necessary to support the model

The input files required to run this model are available through the CPRA.

b. Formatting of output in an understandable manner

The output data is a suitability index ranging from 0.0 to 1.0 that represents the freshwater availability of a 500 x 500m model grid cell. The output files are in netCDF format and can be viewed using EverVIEW or ArcGIS.

c. Usefulness of results to support project analysis

In general, this model responds to projects which would result in increases or decreases in available freshwater as well as projects that are within a certain distance from strategic assets and major population centers. Therefore, projects such as diversions that would increase freshwater near such locations would drive changes in model results for a particular area.

d. Ability to export results into project reports

The model output is in netCDF format, which provides both a graphical and tabular representation of the model results that can be incorporated into reports. Model outputs can also be imported into ESRI ArcMap.

e. Training availability

Training for model usage can be provided through CPRA.

f. Users documentation availability and whether it is user friendly and complete

There are currently no user's guides or technical manuals to support the model; however, the model does have a help screen that explains how to convert model inputs into the necessary format as well as which files are necessary to run the model.

g. Technical support availability
Access to technical support can be provided through CPRA.

h. Software/hardware platform availability to all or most users
The ecosystem services modeling suite, being coded in Java, will run on most operating systems.

i. Accessibility of the model
Access to model and associated installation and execution files can be provided through CPRA.

j. Transparency of model and how it allows for easy verification of calculations and outputs
Model decision rules are documented in section 2a. Model HSI values must be between zero and one.

5. Sources of model uncertainty
All relationships in this model are sources of potential uncertainty.

6. Suggested model improvements
The model could be improved by performing additional research or data collection on the relationship of the variables in the suitability indices. In addition, the model could potentially be improved by the adding other contributing variables.

7. Quality review
Specific quality review procedures for the Freshwater Availability Model to support the 2012 Coastal Master Plan included comparing modeled predictions with expected outcomes given the known inputs. The modeling team used known spatial patterns and temporal patterns in input to predict patterns in potential for agriculture/aquaculture.

8. Uncertainty analysis
No uncertainty analysis was performed for this model.

9. References
Kenny, J.F., Barber, N.L., Hutson, S.S., Linsey, K.S., Lovelace, J.K., and Maupin, M.A. 2009. Estimated use of water in the United States in 2005. U.S. Geological Survey Circular 1344: 52 p.