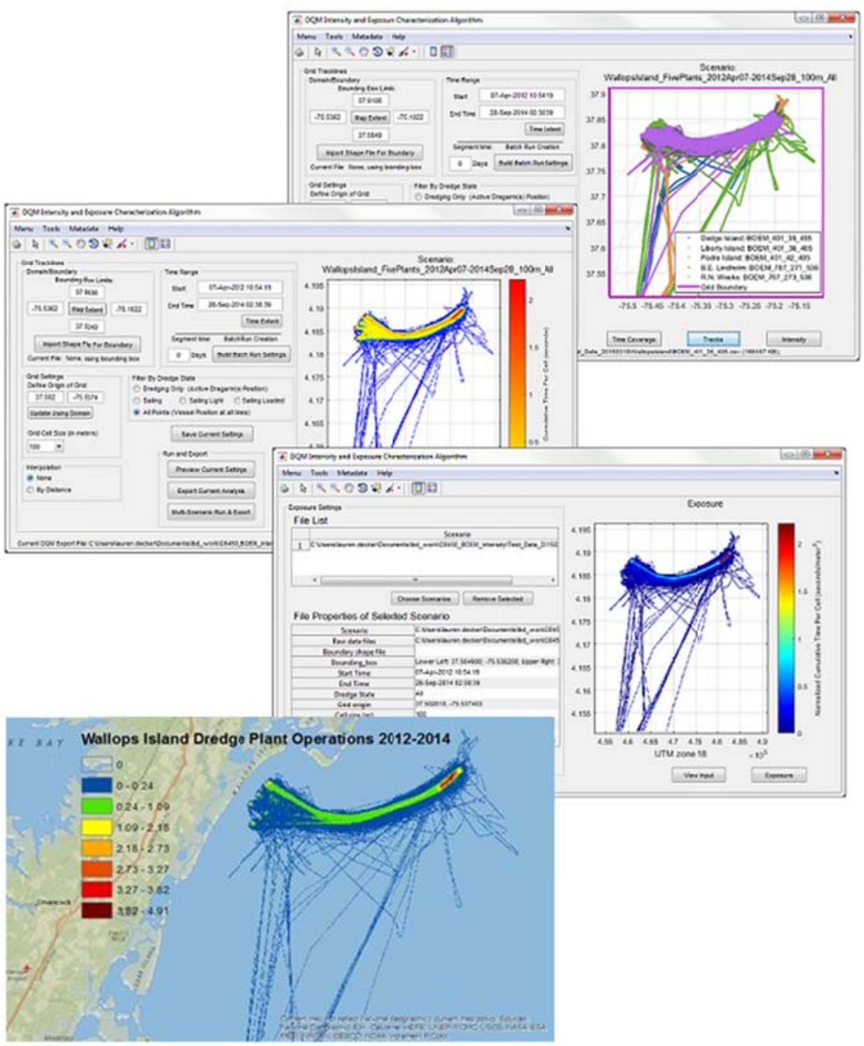
OCS Study
BOEM 2018-019

Using Dredge Plant Operational Data to Measure Dredging Intensity and Cumulative Exposure



US Department of the Interior
Bureau of Ocean Energy Management
Headquarters (Sterling, VA)

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Using Dredge Plant Operational Data to Measure Dredging Intensity and Cumulative Exposure

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DISCLAIMER

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Abbreviations and Acronyms

BOEM	Bureau of Ocean Energy Management
CSV	Comma Separated Values
DOI	US Department of the Interior
DQM	Dredging Quality Management
EPSG	European Petroleum Survey Group
ESPIS	Environmental Studies Program Information System
GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphical User Interface
IDW	Inverse Distance Weighted
IECA	Intensity and Exposure Characterization Algorithms
IOGP	International Association of Oil and Gas Producers
MMIS	Marine Minerals Information System
MMP	Marine Minerals Program
OCS	Outer Continental Shelf
OCS	Outer Continental Shelf
TIN	Triangulated Irregular Network
USACE	U.S. Army Corps of Engineers
UTM	Universal Transverse Mercator

Definitions

CSV: A Comma Separated Values file. In this application there are two uses of the CSV file. The first use is the DQM export file, which is a time series of many different operational parameters. One row of data is one time step with the operational parameters separated by commas; the next row is the next time step. The second use of the CSV files is the gridded outputs of the Intensity and Exposure analysis. Here, rows and columns of data represent spatial dimensions of a single parameter: time-per-cell (Intensity) or time per area per cell (Exposure).

Domain or Boundary: An arbitrary polygon describing the area of analysis, e.g., borrow area or project area. The boundary identifies the region over which to apply a grid and is user defined. In its simplest form, the boundary can be the four corners of a square identifying the extent of a grid.

Dredge Plants: Currently only hopper dredges are considered for this analysis. These vessels can be 20 m wide and 100 m long, with articulating dragheads on either side of the vessel and possibly underneath. All necessary GPS information is reported, as well as many operational variables that allow dredge state to be determined by the DQM Center.

Dredge State: The action of a dredge plant identified by the DQM Center based on operational and proprietary data. There are six states and a cycle increment, which occurs at the end of a disposal event. The states are:

1. Standby/Undetermined
2. Sailing Light
3. Dredging/Loading
4. Turning
5. Sailing Loaded
6. Disposing

Dredging: Any time interval during which the vessel is determined to be actively dredging with any draghead. This activity is calculated by DQM using operational parameters and a series of logical determinations. Active drag arms are not individually identified by the 'Dredging' dredge state; however, additional operational parameters are used to identify active drag arms for this analysis.

Exposure: Cumulative Intensity within a grid cell over multiple analyses, normalized by area of the grid cell. Output units: seconds per meters squared (s/m^2). Processing combines different Intensity runs and uses the same spatial extents. The largest grid cell size in a set of Intensity input grids is used.

Grid Cell: The smallest unit covering an area in a grid. A matrix of cells creates a grid.

Grid Types: A given boundary or domain is divided into cells of a chosen scale, which can range from regular squares to irregular polygon meshes. The choice of grid type may be influenced by the geographic projection. *Equal angle* grids in a Mercator projection are defined by degrees of latitude and longitude and are squares or rectangles, but the area of each cell varies over the grid. Cells are larger near the equator and become narrow as you move toward the poles. *Equal area* grids in UTM projections are squares or rectangles defined by length of each side in meters. One limitation of equal area grids is the discontinuity between UTM zones, which may cause distortion in data spanning multiple zones, and offsets when comparing analyses based in different zones.

GUI: Graphical User Interface, an application interface used to run the IECA.

IECA or Gridding Algorithms: The mathematical methods and equations used to assign point data into defined grid cell locations.

Intensity: Cumulative time spent within a grid cell over the course of a single scenario. Output units: seconds (s).

ISO Metadata: Descriptive information about data; an XML schema for describing data. This project used ISO 19115-2 standards to describe gridded geographic data.

Map Projection: Geographic transformations of latitude and longitude from a sphere to a plane.

Origin: The starting point of grid cells over a given grid. In order to maintain consistent and comparable grids, the origin will be defined by the rounded-down values to the nearest 100 meters in UTM of the lower left corner of the boundary from latitude and longitude units.

Raster: Image files (GeoTIFFs) of data in a matrix of rows and columns. Data is stored on a per-cell basis in these grids.

Scale: Refers to the grid cell area and the length of the sides of the cell. Units can be anything from areas or lengths of the sides in degrees, radians, feet, or meters, depending on the grid type chosen.

Scenario: A set of parameters to construct Intensity grids from unstructured GPS data. A scenario will link data to be referenced in space and time, and the source file. In addition, scenarios identify attributes such as data filters, grid cell sizes, and interpolation schemes to be used during Intensity calculations.

Transit: Any time interval during which the vessel is determined to be sailing either loaded or light, specifically not during identified dredging, turning, or disposal.

Unstructured GPS Data: The data streams (latitude, longitude, and date/time) describing the location of vessel and the locations of up to three dragheads. Data is sampled at 6- to 12-second intervals; sample rate is generally constant, but intervals can be irregular.

Summary

This Inter-Agency Agreement (IA) leverages the US Army Corp of Engineers (USACE) Dredging Quality Management's (DQM) database of non-proprietary operational data from hopper dredges to investigate cumulative use and impact—or dredging Intensity and Exposure—in Outer Continental Shelf (OCS) borrow areas and associated project areas by looking at how much time is spent by hopper dredge plants dredging and/or transiting within those areas. The study developed a mathematical module: the Intensity and Exposure Characterization Algorithms (IECA), which takes the form of MATLAB code that transforms GPS data from hopper dredges that are stored and maintained by the DQM Center into cumulative use maps. The resulting raster dataset is intended to support geospatial analysis in a GIS environment and will allow the Bureau of Ocean Energy Management (BOEM) to investigate hopper dredging activities over more spatial and temporal ranges and support more informed analysis of environmental impacts. The initial research phase of the study delivered the IECA user tool, and BOEM NEPA analysts used and tested it in the process of moving the new tool to BOEM operations. A second phase was added to this study to make refinements to the Graphical User Interface, so the new tool could be seamlessly integrated into BOEM Marine Minerals Program's (MMP's) business processes.

1 Introduction

1.1 Purpose and Objectives

The Bureau of Ocean and Energy Management (BOEM), an agency within the U.S. DOI, is tasked with managing the exploration and development of offshore energy and marine mineral resources on the Outer Continental Shelf (OCS). The BOEM Marine Minerals Program (MMP) oversees the extraction of "non-energy minerals" (primarily sand and gravel) for use in beach nourishment and coastal restoration projects. The Bureau has conveyed rights to dredge millions of cubic yards of OCS sand and must ensure that the removal of any mineral resources is done in a safe and environmentally sound manner (BOEM 2015).

Impacts on the environment from exposure to dredging can be better understood by leveraging data and support from the USACE DQM Program. The mission of the DQM Program is to provide the USACE dredging manager with a nationally standardized low cost remote monitoring and documentation system. This system provides the Corps with timely data access, multiple reporting formats, and full technical support, including dredge certifications, data quality control, database management, and support for the DQM operating system. On board the dredge, sensors continually monitor dredge activities, operations, and efficiency. Information from these sensors is routed to the National DQM Support Center for data processing, storage, and publishing (U.S. Army Corps of Engineers 2015). This report describes another possible use of those data at the National DQM Support Center to support the BOEM MMP.

Currently, BOEM uses data collected by DQM to ensure that dredge contractors are operating within the authorized footprint of identified borrow areas and to obtain the necessary physical/spatial data on the dredging process. Typically, BOEM maps dredge location data to determine where dredges have been operating and monitoring the volumetric change, cut depth, and cumulative use of borrow areas through complementary pre- and post-construction bathymetric surveys. Dredge plant operational data accessed through the DQM database, including dredging locations and vessel positions, provides a platform for development of further analytical tools to monitor, measure, and assess cumulative use and cumulative impacts. The agency has not had a systematic method of tracking the "operational time" of a dredge in a particular location or the cumulative use of a borrow area and transit paths. BOEM needs to be able to more accurately track and document dredging Intensity and Exposure within borrow areas and delineate areas of high traffic use.

This report outlines the development and use of the series of mathematical modules collectively called the Intensity and Exposure Characterization Algorithms (IECA) to spatially estimate the Intensity and Exposure of the environment to dredging activity. The IECA takes unstructured dredge plant operational data that has been exported from the DQM database and aggregates them onto a grid with an arbitrary scale, boundary, and origin using a gridding algorithm that builds Intensity and Exposure estimates during both dredging and transit.

The Bureau can use this Exposure information to document environmental performance, improve environmental analyses and consultations, develop and adapt mitigation strategies, and support good stewardship and management of OCS borrow areas and environmental resources.

1.2 Developed Tools and Deliverables

During this study, a series of specific deliverables were developed, including this documentation on development and construction and MATLAB-based code to perform the calculations. Also, as a "wrapper." a MATLAB Graphical User Interface (GUI) was developed to support ease of use of the developed code.

The MATLAB-based IECA calculates the spatial extent of Intensity and Exposure from dredge plant operational data. Intensity is presented as cumulative time spent within a grid cell over the course of a single scenario. Exposure is presented as cumulative time normalized by area over a grid. Exposure can be calculated from either vessel location or locations of drag arms while actively dredging. The IECA has several input parameters defining constructing of the grid to allow for as much flexibility as possible.

In order to better understand possible uses, and thus necessary tools and input parameters, a series of hypothetical "Use Case Studies" were developed. These hypothetical cases provided focus for a more complete development of the IECA and for understanding possible workflow. These case studies were used to identify available data, tools that were necessary for the calculations, and products that would be useful. The necessary functionality has been identified as:

1) Multi-file usage
   a) Multiple plants
   b) Multiple projects and years
2) Filters based on activity of the dredge plant
   a) Evaluating when and where each drag arm is dredging
   b) Using vessel location during sailing light, loaded, or both
   c) Using vessel location during all periods of activity
3) Defining time ranges
   a) Defining the start and end time of an analysis, which may or may not coincide with the beginning and end of a dredging contract
   b) Dividing a project into multiple well-defined timeframes
4) Defining spatial ranges
   a) Importing a shapefile as a border to identify regions of interest
   b) Identifying a grid origin and grid scale to align separate analyses
   c) Developing interpolation options to either use the data directly from the GPS units on the plants with no changes or to add interpolated GPS points between known locations
   d) Working with data in UTM units so results are in metric units, similar to other analyses
5) Creation of exports for documentation, archiving, and use outside the MATLAB environment
   a) Comma Separated Values (CSV)-formatted outputs of the gridded data
   b) GeoTIFF files of the gridded data
   c) ISO 19115 Metadata

The GUI that was developed as a wrapper around the IECA supports ease of use around this functionality. Appendix 1: Graphical User Interface User Guide and Best Practices; describes how to use the GUI to leverage the functionality in the IECA to accomplish the use case studies. The code itself is described in Appendix 2: Intensity and Exposure Calculation Algorithms Scripting Documentation.

The description of the calculation of Intensity and Exposure, and the GeoTIFF and CSV gridded export formats, has been documented in this report. The ISO 19115 metadata are documented in detail in Appendix 3: ISO 19115-2 Metadata.

1.3 Workflow

The workflow for creating Intensity and Exposure of dredge plant operational data can be reviewed in the overview provided in Figure **1**. The first step is data acquisition, which begins at the USACE DQM database. This is where the USACE maintains operational data from dredging plants and will create non-proprietary-data exports for projects, plants, and time frames for BOEM to use in the IECA. IECA-compatible data from active projects may also be provided to BOEM on a weekly basis by DQM via local USACE District contacts on a per-project basis. Data files are saved onto the user's machine and accessed from the MATLAB environment through a GUI application, the primary method to access the IECA.

The GUI was designed to facilitate processing of data through the IECA. First, it initializes a new "scenario input" file, a set of gridding parameters that contains information about the location of the data file, spatial and temporal ranges, and grid settings. The GUI creates and updates scenario input files with proper formatting, although scenario input files can also be created or edited outside the GUI if so desired. The GUI supports setting up input parameters by allowing a user to select DQM data files to examine, plotting a preview of the GPS time and location data, and displaying the settings options before entering the IECA calculations. The visual track line preview can help the user define the time and spatial extents to use to set up a scenario. Default gridding parameter values are created during the DQM file import, which the user can interactively update through radio buttons, text boxes, and pull down menus. When the user is satisfied with the input parameter settings, the settings are saved to a scenario input file and passed to the IECA where calculations to grid the accumulated time (Intensity) are conducted.

The data exploration phase is when various gridding parameters may be selected and results previewed in the GUI. Modifications can be made to the scenario input file and re-run at any time in this phase, but once data exploration has been completed, the Intensity results are exported for the subsequent exposure analysis. The Intensity data are recorded outside the MATLAB environment in two file types: as gridded CSV files that contain the data and scenario output files that contain the settings. These files can form a library of Intensity analyses that the analyst can select and combine in the Exposure analysis to normalize the data. This way, the Intensity results can be completed for any number of scenarios and data files, and these results may then become the input for the calculation of Exposure. It is recommended that large datasets or ongoing projects be treated in this way, by dividing them into smaller time segments for Intensity analysis using a standardized set of grid settings, and then aggregating the Intensity results at a later time into one or more Exposure analyses.

A user starts a new Exposure analysis by selecting exported Intensity analyses from within the GUI. The Exposure analysis first checks that the selected scenarios are compatible and have similar grid settings, and then the analysis adds the Intensity values together on the largest grid scale of the set. The Exposure algorithm is comparatively simple as the only change it makes to the data is that it normalizes them by dividing the Intensity calculations by their cell area of the grid.

Results are exported from the Exposure analysis in three file types: gridded CSV files structured similarly to the Intensity output, a GeoTIFF file that is a raster-based image containing the actual data and projection information, and the XML metadata using the standard ISO 19115-2:2009 (ISO 2009), a file containing metadata for geographic information with extensions for gridded data. All of these files can be used in further analyses, distribution, and archiving. **Figure 1** shows the outline of this workflow and helps to define the steps for creating Intensity and Exposure from DQM's database exports.

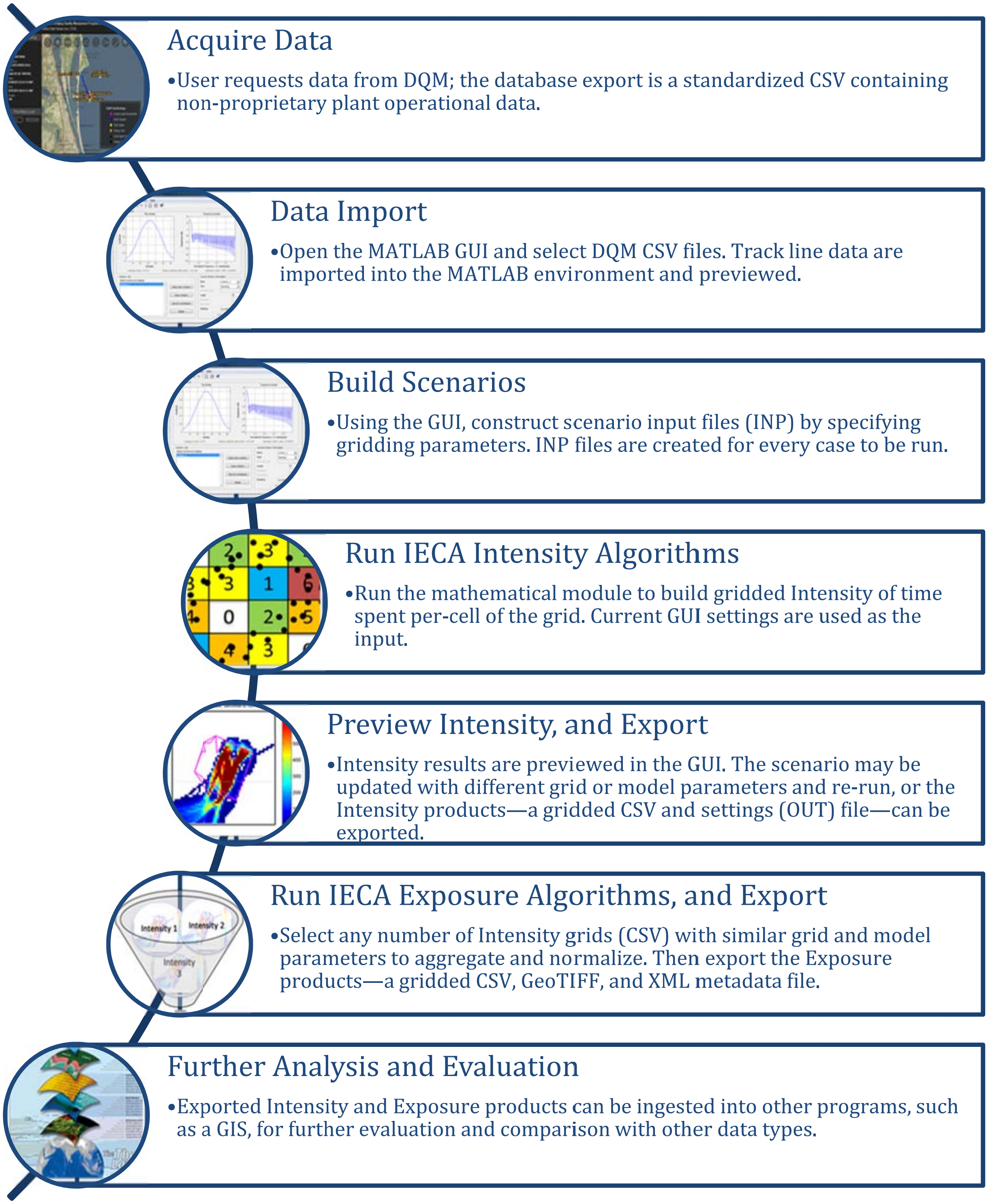

Figure 1. Processing steps from data acquisition to final products for the DQM IECA.

2 Dredging Plants and the Dredging Quality Management Program

Dredging is the act of collecting underwater materials, whether for clearing a channel to improve navigability or collecting sediment such as sand or gravel for land-based use. The main classifications of dredges are hydraulic and mechanical dredges, along with disposal barges. Two main kinds of hydraulic dredges include trailing suction hopper dredges and cutterhead pipeline dredges. Trailing suction hopper dredges are ships with attached drag arms and hoppers. Cutterhead pipeline dredges use long pipes going directly from the dredge site to the disposal site. Cutterhead pipeline dredges are stationary and operate continuously, while hopper dredges are self-contained mobile platforms that can dredge much farther out at sea and transit back to shore for disposal. The other classification is the mechanical dredge, such as dipper dredges and clamshell dredges. Mechanical dredges scoop material with large buckets and place the material into disposal barges, called scows (DQM 2015a).

Currently, the DQM Center maintains information in a database from hopper dredges, scow disposal barges, and cutterhead pipeline dredges with plans to add mechanical dredges. Data are transmitted to the DQM Center at regular intervals over the course of a day. Processing and storage occurs at USACE Mobile District, Operations Division, Spatial Data Branch, Geographic Information Systems Section (CESAM-OP-J-GIS) in Mobile, AL, where Quality Assurance and Quality Control (QA/QC) takes place, as well as calculations of several additional parameters. These proprietary data are prepared for incorporation into the database, and once incorporated, data can be accessed in the web-based DQM data viewer only by authorized Corps personnel and Corps contractors. The viewer is an online GIS-based tool developed by DQM to easily identify active plant locations and review sensor information. From the main interface users can review data load by load, perform database searches, and export data for current and previous projects. This is a valuable tool for authorized BOEM users to preview BOEM-specific non-proprietary project data, though IECA provides BOEM users suitable tools to explore DQM data outside of this web-based environment.

BOEM works with local Districts to receive weekly data exports from the DQM Center for ongoing projects. BOEM can additionally request data of historical or larger datasets, working directly with the DQM Center. The database export from DQM for BOEM is time series data in the proper format for use in the IECA, with location and non-proprietary operational data, as well as several additional calculated parameters that will be discussed in section 2.1 USACE DQM Database Exports; in more detail.

Within this study, only trailing suction hopper dredges are considered. Hopper dredges are complete dredging vessels with the ability to dredge with dragheads at the end of mechanical drag arms, load onto an onboard containment area, mobilize themselves to and from dredging and disposal sites, and pump or dispose material off the plant. There are many sensors monitoring activity on these plants, and data is reported back to the DQM Center regularly during active projects.

Hopper dredge sensors include one main "vessel location" GPS and additional location information for each articulating drag arm, including the latitude and longitude of the draghead. These draghead positions are calculated onboard the dredge for each vessel GPS fix based on plant geometry and drag arm angles. Each drag arm on a vessel also has production information sensors, such as the velocity and density of the dredged material slurry, and a calculation of draghead depth below the surface of the water. Hoppers also have forward and aft draft sensors and forward and aft ullage sensors to measure how full the hopper is.

As a case study during IECA development, data were used from the *Liberty Island* hopper dredge during the 2013–2014 Brevard County beach renourishment project (BOEM 2013). The project was aimed to counter erosion caused by Hurricane Sandy, and over 13 miles of beach on Florida's east coast along the North and South Reach between Port Canaveral and Melbourne were renourished. The *Liberty Island* was operating periodically on this project from November 27, 2013 to April 22, 2014.

The OCS borrow area being dredged was Canaveral Shoals II, and sand was pumped out onto the beaches in several locations (Figure 2) (BOEM 2013). Figure 3 shows the location data from the *Liberty Island* during this renourishment project, and visible features include the location of dredging in the OCS borrow area, transit, and several locations where the plant was located while it was pumping sand out onto the beaches. Four disposal pumpout sites are visible in the North Reach, and two pumpout sites are visible in the South Reach. In addition, transit paths and trips into port are also apparent.

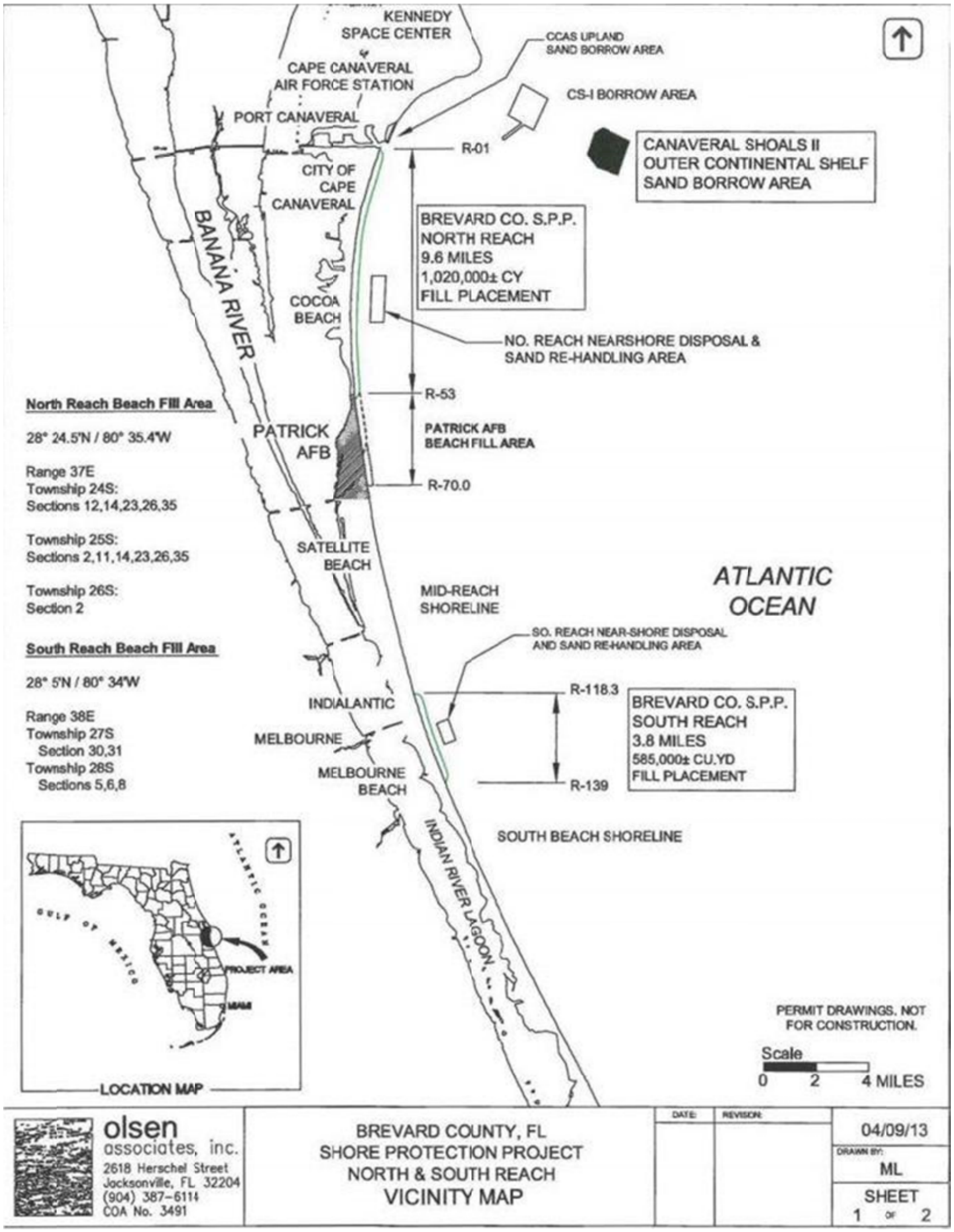

Figure 2. Map of 2013 North and South Reaches Beach renourishment placement sites in Brevard County from the BOEM MOA allowing the use of the Canaveral Shoals Borrow area for sand resources.

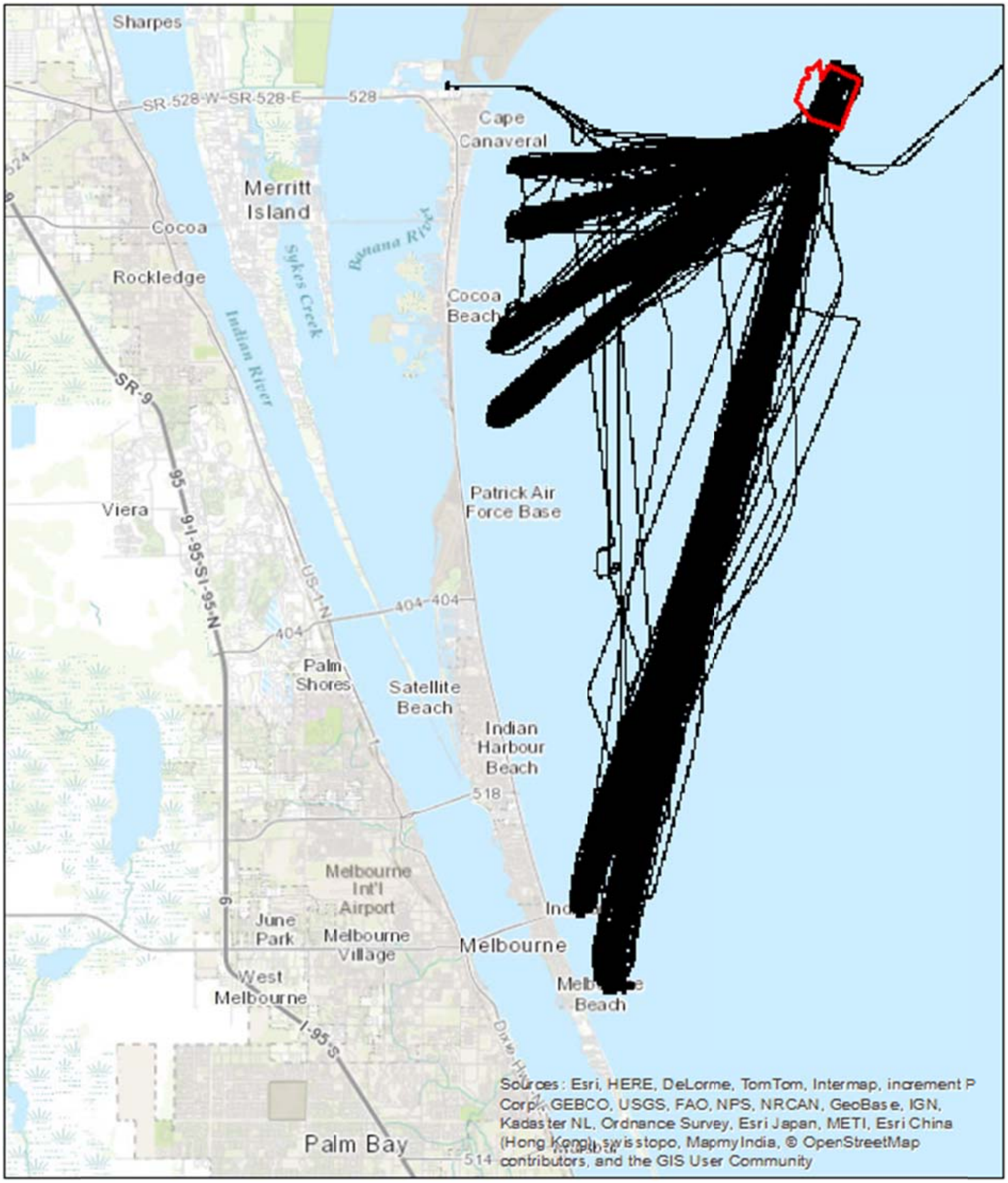

Figure 3. Location data collected from the Liberty Island.

Location data from the Liberty Island are in black, and the Canaveral Shoals II OCS Borrow Area is outlined in red.

The *Liberty Island* is a larger hopper in the Great Lakes Dredge & Docks fleet at 96 m long and 18 m wide with a 6,540 cubic yards (CY) hopper capacity. Below are a picture of the plant (Figure 4) and associated vessel dimensions and operating parameters (Table 1).

Figure 4. The Liberty Island hopper dredge (Great Lakes Dredge & Dock 2015).

Table 1. The Liberty Island hopper dredge dimensions and operating parameters (Great Lakes Dredge & Dock 2015).

LIBERTY ISLAND	Basic Statistics
Length	315 ft (96.0 m)
Breadth	59 ft (18.0 m)
Depth	28 ft (8.5 m)
Draft	28.3 ft (8.6 m)
Dredging Depth	108 ft (32.9 m)
Suction Diameter	31.5 in (800 mm)
Discharge Diameter	30 in (762 mm)
Hopper Capacity	6,540 yd^3 (5,003 m^3)
Total Installed Power	16,566 hp (11,612 kW)

When actively dredging with both drag arms, it was found that the dragheads were typically 25 m apart from each other and 65 m from the vessel location GPS. GPS accuracy is on the order of less than a meter, and per specification set out by DQM, hopper dredges record and report sensor operations every 6 to 12 s (DQM 2015b).

The distance between periodic GPS position reports depends on what the hopper dredge is doing at any particular time, because this determines how it is moving. During the project period in 2013–2014, the plant was operating at speeds between 4 m/s and 7 m/s about 33% of the time, almost exclusively classified as transit (Figure 5). At a reporting interval of 6 s, the location information for the plant is at a geospatial resolution of 24 m to 42 m. Speeds while dredging were usually less than 1.5 m/s; this lower speed results in a tighter geospatial resolution of 9 m or less between reported GPS locations while dredging.

The *Liberty Island* has 1,381,264 database entries between November 2013 and April 2014 for this project. Very high data density in dredging, transiting, and disposal areas is achieved at grid scales larger than 25 m to 50 m. At smaller scales less than 25 m, consideration of additional factors such as plant extent relative to the GPS location (when evaluating vessel position in the analysis), accuracy of the GPS data, temporal and spatial density of the data, and other error sources that are neglected at larger scales, will become increasingly important. Currently, the algorithm takes into consideration the reporting interval and can use GPS data streams from the drag arms. However, the current extent of the plant (physical size and shape around the GPS point fix) is not captured in IECA's location depiction, and location of the dredge becomes less reliable as resolution length approaches the length of the dredge vessel, which includes articulating drag arms. Therefore, the temporal and spatial resolution of the data and plant shape and size become an important consideration when constructing high resolution gridded estimates of Intensity and Exposure.

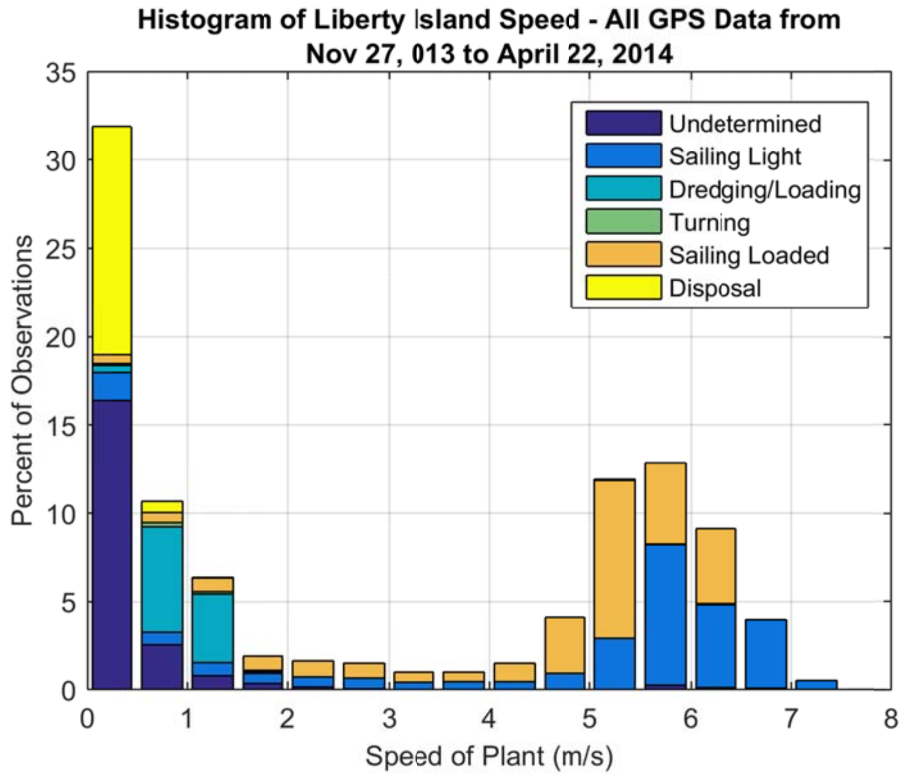

Figure 5. Typical speeds seen from the Liberty Island during the 2013–2014 dredging project.

2.1 USACE DQM Database Exports

The DQM Center uses information on the dredge name and time range to provide BOEM the source data needed for any IECA analysis. Contract numbers and project areas are helpful but not required to identify the relevant data. The source data are non-proprietary operational data acquired by DQM from the system provider—usually a third party contractor that is responsible for installation and maintenance of sensors and equipment—as well as calculated values derived by the DQM processing schema.

The DQM source data is provided to BOEM in a CSV file and organized as a time series with each row representing one database entry for the current operations on the plant. The file has many rows because operations are reported at 6-s intervals. For projects that continue over several months, this can result in very large files. By convention, each file contains only a single contract for a single plant over some time range when the contract was active, up to and including the entire time frame. When source data is needed for analysis of project areas with multiple plants, contracts, and/or years, DQM will compile the source data into several files, which can be read and combined into a single analysis using the MATLAB IECA GUI tool. The set of variables in the DQM export are described in Table 2.

Table 2. Field names and details about the CSV DQM database export.

Variable Name	Data Characteristics	Example Value

Variable Name	Data Characteristics	Example Value
DREDGE_NAME	Text	Liberty Island
DATE_TIME	dd-mmm-yyyy HH:MM:SS	09-DEC-2013 23:20:33
DREDGE_STATE	Integer (0–6)	6
VESSEL_X	Longitude (WGS 84) DD	-80.555581
VESSEL_Y	Latitude (WGS 84) DD	28.095866
PORT_DRAG_X	Longitude (WGS 84) DD	-80.556105
PORT_DRAG_Y	Latitude (WGS 84) DD	28.096257
STBD_DRAG_X	Longitude (WGS 84) DD	-80.556229
STBD_DRAG_Y	Latitude (WGS 84) DD	28.09605
CENTER_DRAG_X	Longitude (WGS 84) DD	-80.556229
CENTER_DRAG_Y	Latitude (WGS 84) DD	28.09605
PORT_DRAG_ACTIVE	YES/NO/UNK	NO
STBD_DRAG_ACTIVE	YES/NO/UNK	YES
CENTER_DRAG_ACTIVE	YES/NO/UNK	UNK
CONTRACT_PERMIT_NUMBER	Text	W912EP-13-D-0007-0006
PROJECT	Text, with quotes	"Brevard County, FL"
LOAD_NUMBER	Integer	48
POINT_ID	Integer	205136368
VESSEL_SPEED	Speed-over-ground in knots	0.2
VESSEL_HEADING	0–360 degrees	120.3
VESSEL_COURSE	0–360 degrees	68
PUMP_OUT_ON	On or off: 1/0	0
VOLUME	Cubic yards	780.283484
DISPLACEMENT	Long tons	5570.860169
DRAGHEAD_DEPTH_PORT	Feet	-2.112439
DRAGHEAD_DEPTH_STBD	Feet	-2.952956
DRAGHEAD_DEPTH_CENTER	Feet	-2.952956

2.2 Assessed States of Dredging

When sensor data from the dredge plant are integrated into the DQM database, a series of calculations are completed. One of these calculations is the dredge state of the plant at every moment during the most recently reported cycle: "DREDGE_STATE". There are six dredge states, as well as a cycle increment, that are determined based on the sensor input reported by the system providers:

1. Standby/Undetermined
2. Sailing Light
3. Dredging/Loading
4. Turning
5. Sailing Loaded
6. Disposing

Each data point is assigned a dredge state value using a series of logical decisions and pattern analysis carried out on proprietary and non-proprietary operational data. Within the database, "Dredging/Loading" identifies times when the plant is determined to be dredging. It does not, however, identify which drag arm is physically dredging at the time. For BOEM's purposes and resolutions of interest, DQM has developed a secondary processing step that is completed during the export from the DQM database. Using drag arm density (proprietary operational data not available to BOEM), activity of individual drag arms is assessed, and the parameters for the port, starboard, and center drag arms are set as true or false at each data point. These are the three resultant fields with the database logic given below.

- PORT_DRAG_ACTIVE
- STBD_DRAG_ACTIVE
- CENTER_DRAG_ACTIVE

If density for a drag arm is greater than 1.1, the relevant drag arm is active ("true"); otherwise, the drag arm is inactive ("false"). The use of these fields greatly increases the spatial accuracy available to the IECA during dredging, as drag arm position can be used in place of vessel position. Drag arm latitude and longitude can be 25 m apart from each other and 65 m away from the vessel location latitude and longitude, as seen in the test case data from *Liberty Island*.

2.3 Linking Marine Minerals Program Information to DQM Contracts

BOEM MMP and USACE DQM Center have created a crosswalk document to associate BOEM lease agreements with DQM contract numbers. The crosswalk is maintained by BOEM with the support of USACE personnel. BOEM can request information from DQM when needed and keep the crosswalk current.

Critical fields that require maintenance are the Lease Number and Project Name. DQM can provide information on the DQM Contract Numbers and the Borrow Areas associated with BOEM Lease Numbers. These fields are saved into the ISO metadata as part of the data products and serve as a reference to other information maintained in other MMP databases. Fields in the crosswalk document are described in Table 3. Many of the fields are intentionally duplicated to identify when BOEM and DQM records overlap and are referring to the same project.

Table 3. Field names, data source, and field's level of importance for the MMP leasing and USACE DQM contracting crosswalk document.

Critical	Source	Field name
	BOEM	US State
✓	BOEM	Project Name
	BOEM	Lease Completed Date
	BOEM	Construction Start Date
	BOEM	Construction Completed Date
	BOEM	Status of Construction
✓	BOEM	Lease No MOA
	BOEM	Dredge/Plant
	BOEM	USACE Project Name / District
	BOEM	Contract No / USACE #
	BOEM	DQM Data File Name
	BOEM	Processed with IECA tool
	DQM	Contract ID
✓	DQM	Contract/Permit Number (DQM)
	DQM	Contract Name
	DQM	Project ID
	DQM	USACE District
	DQM	Contract Type
	DQM	Disposal Type
✓	BOEM/DQM	Borrow Area
	DQM	BOEM Report (T/F)
	DQM	Plant ID
	DQM	Plant Names
	DQM	Start Date
	DQM	End Date

3 Intensity and Exposure Characterization Algorithms

The goal of this study is to take a large number of unstructured, irregular, high density time series GPS data from any number of dredge plants over many projects and time frames and create a product that easily identifies use patterns. This is most readily done by creating structured, regular data products that aggregate information over specified spatial and temporal settings. In this section, we discuss in detail the conversion of time series location data from dredging projects into structured grids of Intensity and Exposure. The method used to accomplish this is a type of direct gridding where all points within cells of a grid are counted. Specifically, the amount of time associated with every point location is summed into a single cell value.

Several basic parameters of the grid were set early on; one such parameter is the use of a Universal Transverse Mercator (UTM) projection system, as discussed in Section 3.3: Map Projection and Grid Type. UTM allows cells to be defined in meters, and cell areas to remain unchanged over the extent of the grid. Grid cell size, domains, and origins are user defined to allow for maximum flexibility. A set of four cell sizes (100 m, 50 m, 25 m, and 10 m) are available, as well as options to increase the resolution of the track line data.

3.1 Methods of Transforming Irregular Data to Structured Data

There are many methods for structuring irregular data; however, most methods have been developed for representing unique location, low-density, continuous, or smooth surfaced data. Direct gridding was identified as the best method and specifics will be reviewed in Section 3.2. Here, five different methods for transforming irregular data are described, ordered from dealing with the highest density of data to the lowest:

Histograms or Direct Gridding
Accumulates values (time) within cells of a grid. This method is the most applicable to aggregating high density large data sets into cells of a grid.

Kernel Density Estimation
Accumulates "kernels," which are smooth distributions around point values, into grids of cells. This method would be supported if there were uncertainty around locations but is much more computationally intensive.

Delaunay Tessellation Field Estimator (DTFE)
A DTFE uses a subsample of points from a continuous underlying function to reconstruct the volume or intensity over the field of uniquely sampled points. Results of this method would most likely be represented in Triangulated Irregular Network (TIN) grid.

Inverse Distance Weighted (IDW) or Shepard's Method
Estimates new values based on the distance-weighted values of a neighborhood of points. Closest points are given the most weight. This method increases data density of very sparse data to get new values, e.g., estimating water velocity using a small array of current meters.

Kriging

Estimates new values based on a Gaussian regression of the known values in the neighborhood of the new point. This increases data density of very sparse data with similar results to IDW.

The ideal product of Intensity and Exposure will show the total amount of time spent in aggregate over particular spatial and temporal ranges. Data density is generally high over the time period of a given contract at most scales, and location data is not necessarily unique. All methods besides direct gridding are considered lower-density data interpolation schemes. The high density data set lends itself well to **direct gridding**; hence, that method was implemented.

Data density for single track lines might be considered low when a cell size reaches a lower limit and GPS points along paths "skips" cells. Time series interpolation schemes for smoothing these types of data will be discussed in Section 3.4, where an interpolation scheme that increases the resolution of the underlying data prior to gridding is described.

3.2 Direct Gridding Transformation

The direct gridding transformation is based on accumulating the time spent within a cell of a grid over the course of a defined dredging scenario, where time and location are defined by GPS points. This transformation takes unstructured spatial and temporal time series data and reduces the data into gridded spatial data, with values of total time. The gridded results (Intensity) are time, in seconds, per cell over the time and spatial extent of the scenario.

Consider the time series t_i, where time spent (t) at every reported location in the series is indexed by $i = 1, 2, \ldots, n$. This series is to be gridded on a grid I, with cells $j = 1, 2, \ldots, m$. Summation of t values into the grid I is as follows:

$$\text{for } j = 1 \text{ to } m, I_j = \sum_{i=1}^{n} t_i \chi_{j,i}$$

where χ_j is a true/false vector of the same length as t, identifying which values of t are within cell j. The time spent (t_i) at every reported location is tested to be in the grid cell (I_j). If t_i is determined to be within the grid cell j, then $\chi_{j,i} = 1$ ('true'), otherwise $\chi_{j,i} = 0$ ('false'). This summation is done for every grid cell in the series $j = 1$ *to* m, and the final result is the grid of Intensity (I) containing total time-per-cell (j).

In order to sum the amount of time spent in each grid cell, a value of time must be assigned to each data point. Reporting intervals for dredge plants are not always a uniform time interval. Instead of applying an identical number of seconds per location, the time is found based on neighboring points. Time spent at a GPS location is calculated using the timestamp of the previous, current, and next GPS points. As illustrated in Figure 6 and the equation below, the time spent at the "current" location is calculated as half the time between the previous and current timestamp, plus half the time between the current and next timestamp.

$$t_n = (S_n - S_{n-1})/2 + (S_{n+1} - S_n)/2$$

Where t_n is the amount of time associated with one location, and S_{n-1}, S_n, and S_{n+1} are the previous, current and next timestamps, respectively, for each GPS location.

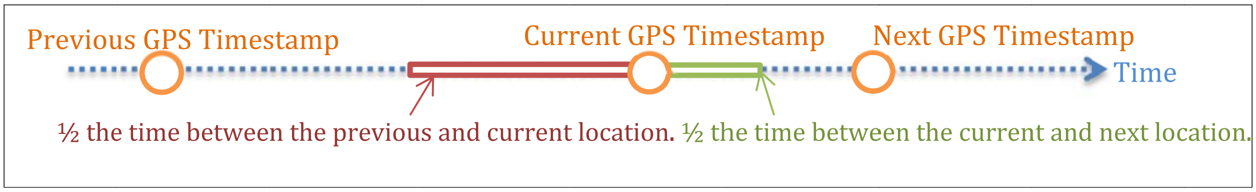

Figure 6. Demonstration of how "time spent at a GPS location" is calculated using irregular reporting periods of GPS locations in time.

The gridded Intensity values are calculated on a per-cell basis, where each cell has an associated area. For this project, an equal area grid and a UTM projection have been chosen, but other grid types and projections may be considered in future development. In Section 3.5, cell size is demonstrated to have a strong effect on the final value, and normalization based on area of the cell is accomplished during the Exposure calculation. Figure 7 shows the progression of processing steps from a plant's path as it moved through a region several times to the GPS-reported locations that are stored in the DQM database. Using those times and locations, the time-per-cell, or Intensity, is calculated. Then, the Exposure analysis is completed using Intensity values as described by the equation:

$$\text{for j} = 1 \text{ to m}, E_j = \frac{I_j}{A_j}$$

where E_j is the Exposure of cell j, and j indexes the largest cell size of the series of input scenarios. I_j is the Intensity in cell j, and A_j is the area of cell j. The Intensity grid in this calculation can be the combination of several scenarios of Intensity $a, b,..., z$:

$$\mathrm{I} = \mathrm{I_a} + \mathrm{I_b} + \ldots + \mathrm{I_z}$$

For the current algorithm, all cells sizes within a single scenario are the same, but in future analyses the cell area may vary over a single grid.

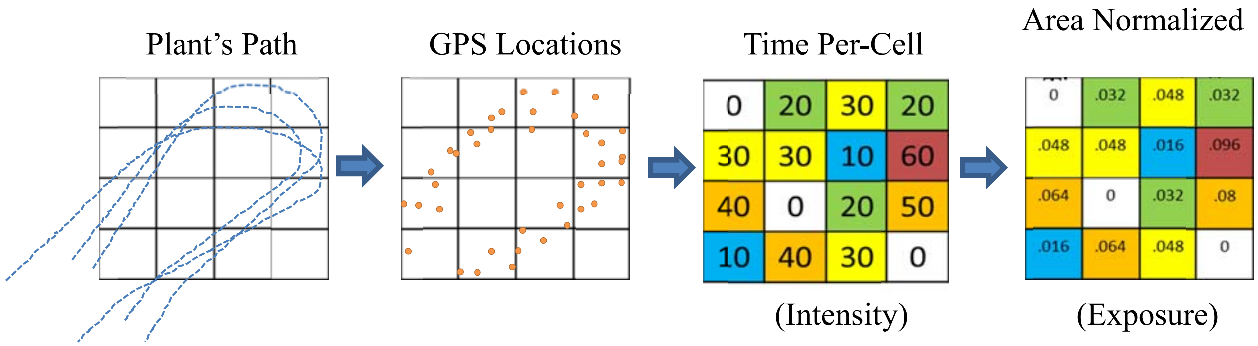

Figure 7. Direct Gridding Transformation visualization, from the dredge plant's actual paths and recorded locations to Intensity and Exposure calculations.

An Exposure grid is the cumulative Intensity within an area (grid cell) over single or multiple Intensity analyses. The cumulative values are then normalized by the area of the cell; the output units are time per area: s/m^2. To combine Intensity factors from different analyses, the same grid origin must be used. However, other parameters like cell size can vary between analyses, at the user's discretion. The resulting cumulative grid will have the largest grid cell size of the set of the inputs. For example, if combining one Intensity analysis with 50 m cells and another with 100 m cells (but with the same grid origin) the output Exposure grid would have 100 m cells.

Gridded data values generally represent either discrete or continuous data. For our purposes the gridded data are discrete data that represent values over the whole of the cell. As a result, cell size impacts analysis results, because in each case the Intensity or Exposure value is assigned equally to the entire grid cell. The user must carefully choose a cell size that is small enough to gain the desired spatial resolution in the results but large enough to avoid the physical constraints of the underlying data sources and to prevent excessive computational load. Locations are identified by coordinates at the center of every grid cell, as opposed to the lower left corner or grid edges.

During processing, all time spent within the cell is totaled (e.g., if a plant moves into port and stays overnight, there might be one cell with very large values, and adjacent cells would contain little or no time). This differs from the assumptions behind continuous datasets, which represent smooth underlying surfaces and whose values are applied only to the center point of a grid cell. Continuous raster data work well with data types such as topography, where smooth transitions between points are effective assumptions.

Below in Figure 8 is an example of discrete results where the value represents the entire cell. These data were processed from a time period when the *Liberty Island* went into port and remained there for several days. There is a single cell that represents about 90 s/m^2 in a grid cell that is 50 m by 50 m, meaning the plant was within that cell for 90 s/m^2 * 2500 m^2 = 225000 s, or just about 2.6 days. The next largest valued cell is 0.07 s/m^2, which is about 3 min in this example.

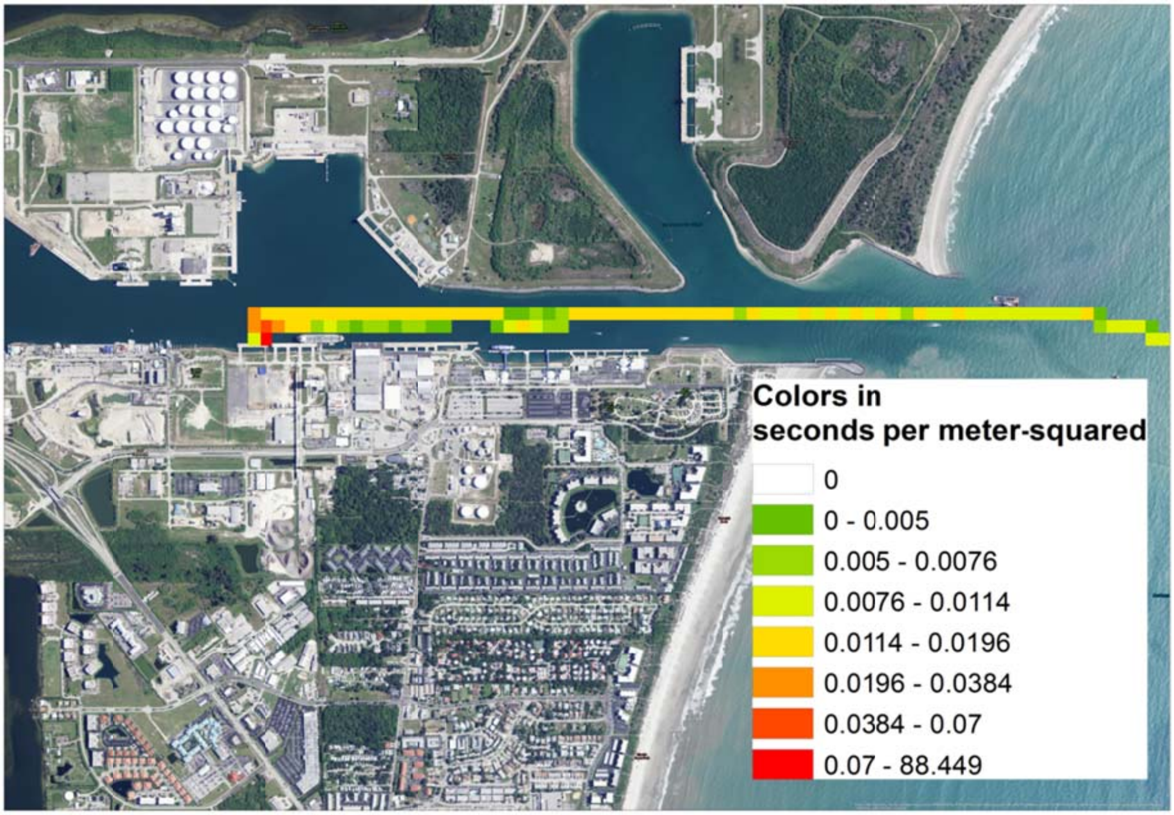

Figure 8. ArcMap image of the Liberty Island Exposure results during a period when the plant went into port and was there for several days.

3.3 Map Projection and Grid Type

Several different kinds of map projections and grid types were reviewed, including the UTM projection system, Mercator projections with equal angle grids, and TINs as the grid, as enumerated in Table 4. In some cases, the grid projection determined the grid type, and so they are described together. The UTM system with an equal area grid was favored by BOEM for several reasons including the fact that complementary data are already in UTM, and using UTM allows the results to be in metric units, so statistics are better visualized and understood. An equal area grid is easiest to implement with a UTM projection system, because positions are already described as distances. A grid cell would be described by the length of each side in meters, resulting in cells of equal area. The UTM projection system deals well with regions encompassed by one UTM zone (6° of longitude wide). If project areas cross UTM zones, it will be difficult to construct a grid without offsets. Under current implementation, only one UTM zone is used per scenario, which is chosen based on the grid origin location.

Mercator projection with an equal angle grid deals well with large regions. An equal angle grid is easiest to implement with a Mercator projection, because positions are described as angles of latitude and longitude. A grid cell would be described by the number of degrees of latitude or longitude spanned by each side, resulting in cells of unequal area. As an equal angle grid, rectangular or square cells will work at any scale, as long as the area of the cells are used to normalize calculated Intensity and Exposure values. This grid type is also straightforward to reproduce across multiple analyses, so that results are comparable with no offsets; however, it was not implemented for this study.

Polygon mesh grid types (such as TINs) on any kind of projection are versatile, but require extra computation to aggregate data into non-uniform grids. The result is also a non-uniform grid which may be awkward to work with in other programs and difficult to align across multiple analyses. The creation, gridding techniques, and use of these networks make them less than ideal to work with for this project.

Table 4. Reviewed grid types.

Projection and Type	Pros	Cons
Universal Transverse Mercator (UTM) projection system, and equal area grid	Likely to be similar to complementary datasets, data can be gridded in metric units (square meters) instead of degrees, and resulting grid is equal area	Overlapping multiple zones will produce errors in grid locations
Mercator projection, and equal angle grid	Simple to reproduce grid, input data is already in latitude and longitude units, can cover large areas	Cell areas change with latitude; results should be normalized by area
Triangulated Irregular Network (TIN), any projection system, unstructured non-uniform grid	Grid scale can change from low to high resolution where needed to keep overall number of points small	Unstructured grid of nodes/lines; baseline computation will be more difficult; comparison between calculations difficult

Development was completed using UTM zones without latitude bands. Data are identified by a zone number and hemisphere, “North” or “South”; for example, the Florida peninsula is located in 17N. In addition to the UTM identification, the International Association of Oil and Gas Producers (IOGP) maintains the European Petroleum Survey Group’s (EPSG’s) Geodetic Parameter Set (usually referenced as EPSG codes). This is a widely used collection of definitions of coordinate reference systems and coordinate transformations (IOGP 2015). MATLAB, ArcMap, and the ISO metadata use these codes to identify the projection.

3.4 Track Interpolation

In aggregate, over the time period of a contract, data density will be high over most reasonable scales. To assess if gridding truly describes the path of a plant, in the next example we will focus on a single transect. When considering the choice of grid resolution, grid cell sizes can be divided into three different classes relating the GPS data resolution to the grid cell resolution:

- Low resolution (large grid cells): Plant location is well defined by the sampling interval within the grid; GPS data resolution is high relative to the grid cell resolution and data can be gridded as-is.
- Medium resolution (medium grid cells): Due to vessel speed and reporting interval plant location may skip intermediate cells when traveling quickly. The solution is interpolation between locations to increase data density along a path.
- High resolution (small grid cells): The physical plant is larger than the grid cells, thus occupying several cells during one reported data point. When examining transit intensity over small grid cells it will become important to account for vessel shape and extent within the grid at every time step. However, it was beyond the scope of the current study to address this issue.

An example of 'medium resolution' is when a plant is transiting at moderate or high speed and cell size is relatively small. The higher transit speed results in larger distances between reported positions, specified to be at a time interval of 6 to 12 seconds for hopper dredges. This means either a larger cell size must be used, or interpolations between reported locations should be implemented. Figure 5 demonstrated transit speeds between 4 m/s—7 m/s by the dredge plant *Liberty Island*, with resulting distances between GPS locations at 24 m—42 m assuming a uniform 6 second reporting interval. When using a cell size that is smaller than this, especially while gridding transit data, an interpolation scheme has been developed to increase the sampling interval (Figure 9). This is a user-defined option within the IECA and is not turned on by default; it does increase calculation time significantly.

To implement this interpolation schema, first a "maximum distance threshold" is defined as half the length of a user-defined grid cell. Then, a distance calculation between every sample in the time series is found and tested. When distances between samples are over the maximum distance threshold, new points are interpolated between GPS locations down to the resolution required. This approach allows already high density data to avoid being processed, saving computational energy and time, while still increasing data density along a path.

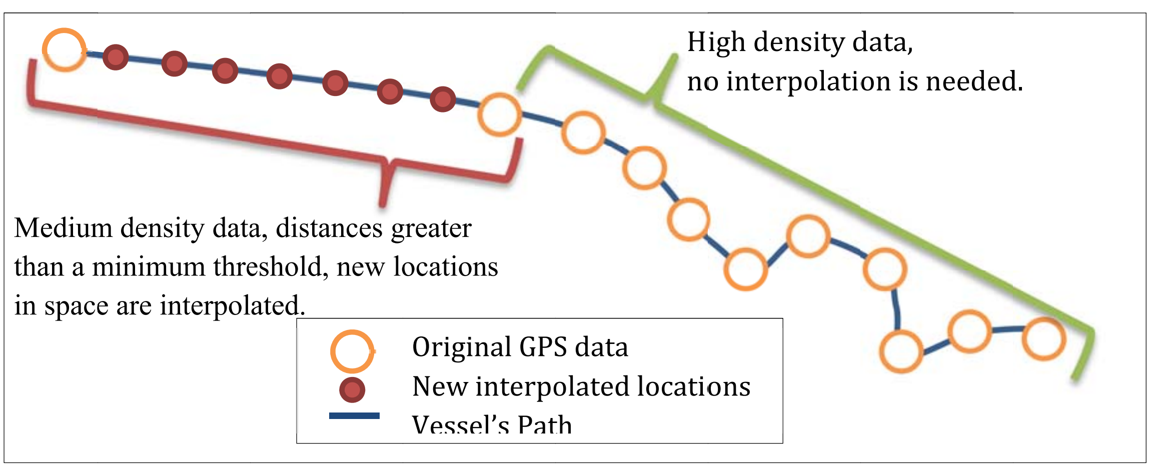

Figure 9. Illustration of an interpolation scheme based on a distance threshold.

The large orange circles represent GPS locations that were reported by the vessel. The first two orange circles have a distance between them that is greater than the maximum distance.

GPS points have a series of values associated with them, and the main values of interest are time and dredge state. The newly interpolated locations also need these identifying characteristics. The value for the time stamps are defined as a linear interpolation between the previous and next GPS location; e.g., if there are three new interpolated locations and the bounding GPS locations have time of 12:00 and 12:04; the three new locations are given timestamps of 12:01, 12:02, and 12:03.

Determining dredge state for interpolated points can be less intuitive. As a matter of consistency, the dredge state of the final point is always used as the state for all new interpolated locations, as illustrated in Figure 10. In the example, all new locations are assigned to dredging, because the next value in the series is labeled as dredging. This was chosen as an attempt to be conservative, because as a dredge is leaving a borrow area, it may stop dredging and speed up for transit. If one location is within the borrow area and identified as dredging, and the next location is outside the borrow area and the plant is not dredging, the original (non-interpolated) data shows compliant operations. Applying the dredge state of “dredging” to interpolated locations would show noncompliant behavior. This is less of a concern in the reverse situation, where the first location is outside the borrow area and identified as not dredging and the second location is within the borrow area and identified as dredging. Typically plants will pause within the borrow area in preparation to dredge, for several seconds or minutes before collecting material. Thus errors of assigning “dredging” incorrectly to interpolated points at the start of dredging activity are likely to be minimal.

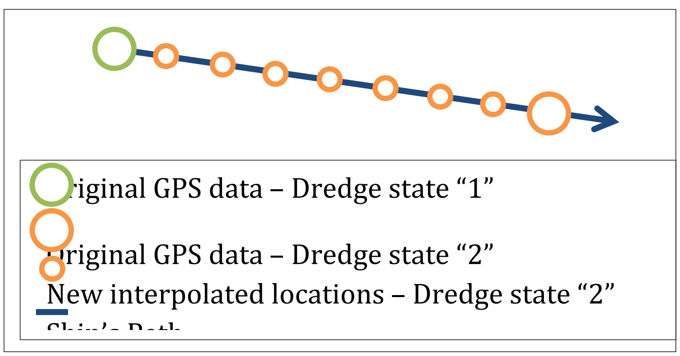

Figure 10. Schematic of how dredge state is assigned for interpolated locations.

Dredge plants can be physically large. To build high resolution grids (with small grid cells) would need spatial interpolation to cover the extent of the plant at every time step. This was not implemented during this project, and at scales below 10–25 meters, plant size, GPS locations, and other factors may limit spatial accuracy. During the design of Intensity scenarios, it is valuable for a user to identify plant specifications, such as in Table 1. The Liberty Island hopper dredge dimensions and operating parameters (Great Lakes Dredge & Dock 2015).. When selecting cell size, it is important to note that cells smaller than the plant size may mischaracterize dredge plant location, particularly with respect to adjacent cells to the GPS location, primarily when using vessel position for the analysis (i.e., not filtering by dredging). That is, when the GPS identifies the vessel location, it is identifying a point, not the footprint of the vessel. When the cell size is 10 m, and the vessel length is 90 m, there will be several cells identified as “empty” by the IECA, when in fact the plant was occupying those locations. This is most clear when investigating transit Intensity, which uses the vessel position in the calculation.

Figure 11 and Figure 12 compare the results of gridding algorithms without and with interpolation applied to a single pass of dredging and transit by the *Liberty Island* through the Canaveral Shoals borrow area. These examples of Intensity use a 10 m cell size, with the same color bar range of 0–20 seconds spent in a 10 m x 10 m grid cell. Figure 11 uses original data, and Figure 12 interpolates between large distances relative to cell size. In Figure 11, during transit, the data becomes sparser relative to the grid cell size, e.g., the location stays 6 s in a cell, skips several cells, and spends 6 s in a later cell. The distance interpolation scheme shown in Figure 12 results in a more continuous track line over the grid with values closer to one or two seconds per grid cell over many more cells.

These examples all use only vessel location for the analysis. The port, starboard, and center drag arms (as applicable to each plant) have their own calculated location streams within the data. When calculating dredging Intensity, position data from all active drag arms are used rather than vessel position. The risk of mischaracterizing location is then greatly reduced due to the much smaller footprint of a draghead as well as the slower speed during dredging resulting in relatively spatially dense data compared to transit.

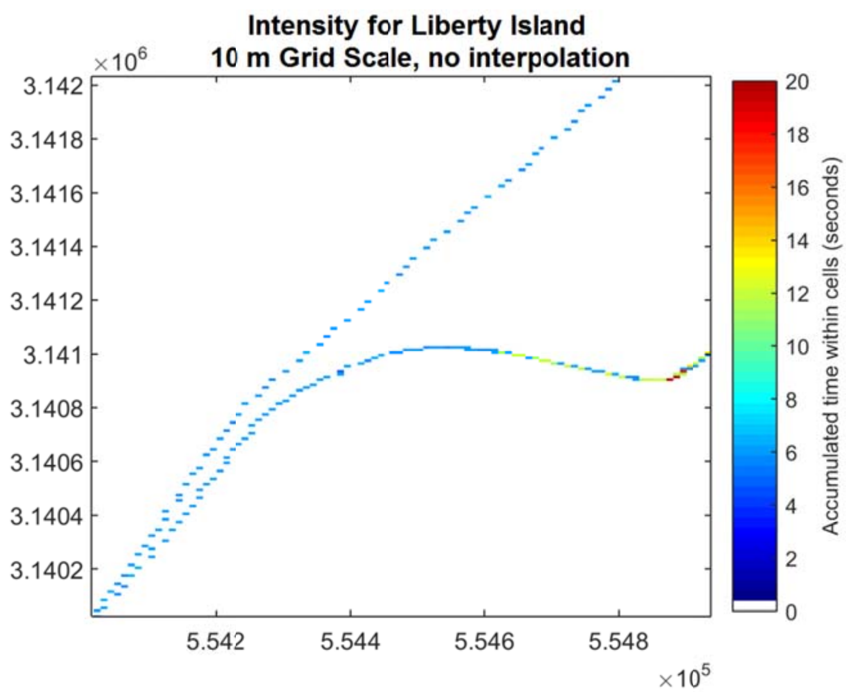

Figure 11. Original GPS location data gridded onto a 10 m cell size grid of Intensity using a single pass of dredging and transit through the Canaveral Shoals borrow area by the Liberty Island.

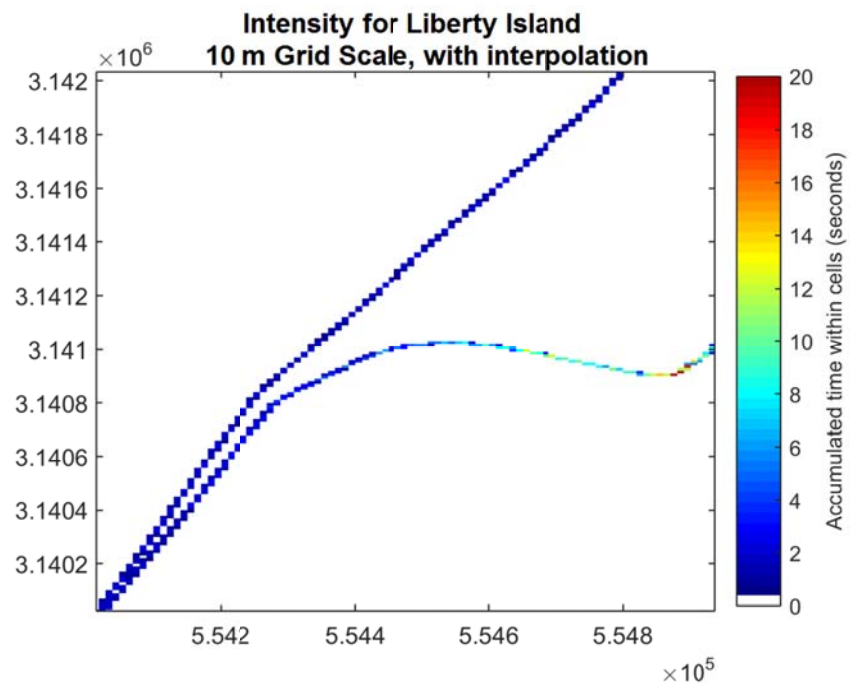

Figure 12. GPS location data interpolated as described in the text then gridded onto a 10 m cell size grid of Intensity using a single pass of dredging and transit through the Canaveral Shoals borrow area by the Liberty Island.

3.5 Flexible Gridding Parameters

Within this section, we discuss IECA model inputs and their effect on the solutions. Several parameters have previously been defined and are not flexible, such as gridding technique and projection. Below is a summary of the flexible gridding parameters and their options used in the IECA to achieve broad utility for many different use cases:

1. Selection of any number of CSV files retrieved from the DQM database
2. Interpolation
    a. Using the plant GPS data with no changes
    b. Interpolating GPS locations so distances between points do not exceed half the length of the grid cell
3. Filter by dredge state
    a. All vessel locations
    b. All transit
    c. Sailing light
    d. Sailing loaded
    e. Dredging
4. Define the domain/boundary (filter spatially)
    a. User-selected polygon shapefile with latitude and longitude
    b. Limits of dredge data latitude and longitude
5. Define grid origin (the lower left corner of the grid defining where grid cells start)
    a. User-assigned coordinates

   b. Defaults to the rounded-down minimum latitude and longitude of domain to the nearest 100 m in UTM
6. Choice of a grid scale from four options covering an order of magnitude:
   a. 100 m
   b. 50 m
   c. 25 m
   d. 10 m

The DQM Center provides source data in CSV files, and any number of these CSV files can be used in an IECA analysis. DQM files can be processed individually to create a number of Intensity outputs equal to the number of source data CSV files. The Intensity outputs can subsequently be combined into a single analytical product during the Exposure analysis. Building scenarios for each CSV file to create many Intensity outputs provides greater flexibility in the creation of Exposure analyses and also optimizes memory use and computing power. Alternatively, CSV files can also be combined in a single scenario to create one Intensity output, which would ensure the consistency of gridding parameters (scenario) and compatibility of the source data files.

In section 3.4, the interpolation method for deriving a higher density dataset over the path of a dredge plant was discussed. This is optional within the IECA, and it is important to note that using this method does add significant computation time to processing.

3.5.1 Filtering by Dredge States

In order to cover the several different GPS data streams and dredge states, there is some flexibility to use data from all the vessel locations, only when the vessel is transiting (all transit, sailing light, or sailing loaded), or only when the plant is dredging. When using all vessel locations, the "VESSEL_X" and "VESSEL_Y" are used with all states of dredging in "DREDGE_STATE" (codes 1–6) in the IECA gridding algorithms. All available fields in the DQM CSV export and code values were discussed in Section 2.1, for reference. When filtering to only transiting, vessel location is used when the dredge state is either sailing light, loaded, or both (codes 2 and 5, respectively). Filtering to dredging only, the IECA uses the GPS data streams from the drag arms, PORT / STBD / CENTER_DRAG_X/Y, and filters to only use data when (1) the dredge state for the plant is dredging, which is code 3, and (2) the individual arm is "actively dredging." There is a single dredge state for the plant as a whole, and that filter is applied to each drag arm along with the individual PORT/ STBD / CENTER_DRAG_ACTIVE filter. The active drag arm data is a true/false (1/0) field, and while dredging the value is set to 1. The active drag arm filters are fields generated by DQM during the export process as discussed in section 2.2 Assessed States of Dredging.

Filter options in the IECA are listed in

Table 5. Each filter option shows which data streams and filter values are used during processing. *All Points, Sailing, Sailing Light, and Sailing Loaded* use the location of the vessel, but filter on different dredge states. *Dredging Only* uses up to three drag arm location data streams instead of the vessel location, and three more filters in addition to the dredge state filter. Most dredge plants will have two drag arms; the IECA will test for a third and include it only if present.

Table 5. Data from the DQM database export that is used in different filter options. Dredge state and the active drag arms are used as filters on the X/Y GPS locations.

Data Streams	Filter Options: **All Points** Vessel Position at all times	**Sailing** Vessel Position while sailing light or loaded	**Sailing Light** Vessel Position while sailing light	**Sailing Loaded** Vessel Position while sailing loaded	**Dredging Only** Position of active drag arms while dredging
VESSEL_X/Y	✓	✓	✓	✓	
DREDGE_STATE 1: Unknown\Standby 2: Sailing light 3: Dredging 4: Turning 5: Sailing loaded 6: Disposing	1,2,3,4,5,6	2,5	2	5	3
PORT_DRAG_X/Y					✓
PORT_DRAG_ACTIVE					1
STBD_DRAG_X/Y					✓
STBD_DRAG_ACTIVE					1
CENTER_DRAG_X/Y					✓
CENTER_DRAG_ACTIVE					1

3.5.2 Grid Origin and Domain

Grid origin is defined as the lower left (most south and most west) location of the grid. This location should not be confused with the location of the lower left cell, which is defined by the center of that cell. The grid origin is the location used to determine all grid cell edges, so it is critical when combining several Intensity grids that their origins are the same; otherwise the cell edges will not line up. The grid origin is recorded as a latitude and longitude in the input file; during the conversion to the UTM grid projection, the origin is always rounded down to the nearest 100 m. This allows for some consistency between analyses and always forces the UTM grids to start on a round number.

The grid domain is defined by a bounding box, or polygon. In the simple bounding box form, the North-South-East-West extents are defined by drawing a box around a region. An alternate method of defining a bounding box is by user input of a polygon shapefile, see section 5 for more detail. This domain is used as a filter to remove GPS data locations outside of the domain. The remaining data are gridded, and the results are identified by locations at the center of each grid cell. The domain is used again as a filter to remove any remaining cells that have their central locations outside the grid. This filtering method creates a conservative estimate of data within the domain. In Figure 13, these ideas and vocabulary are graphically represented to clarify usage.

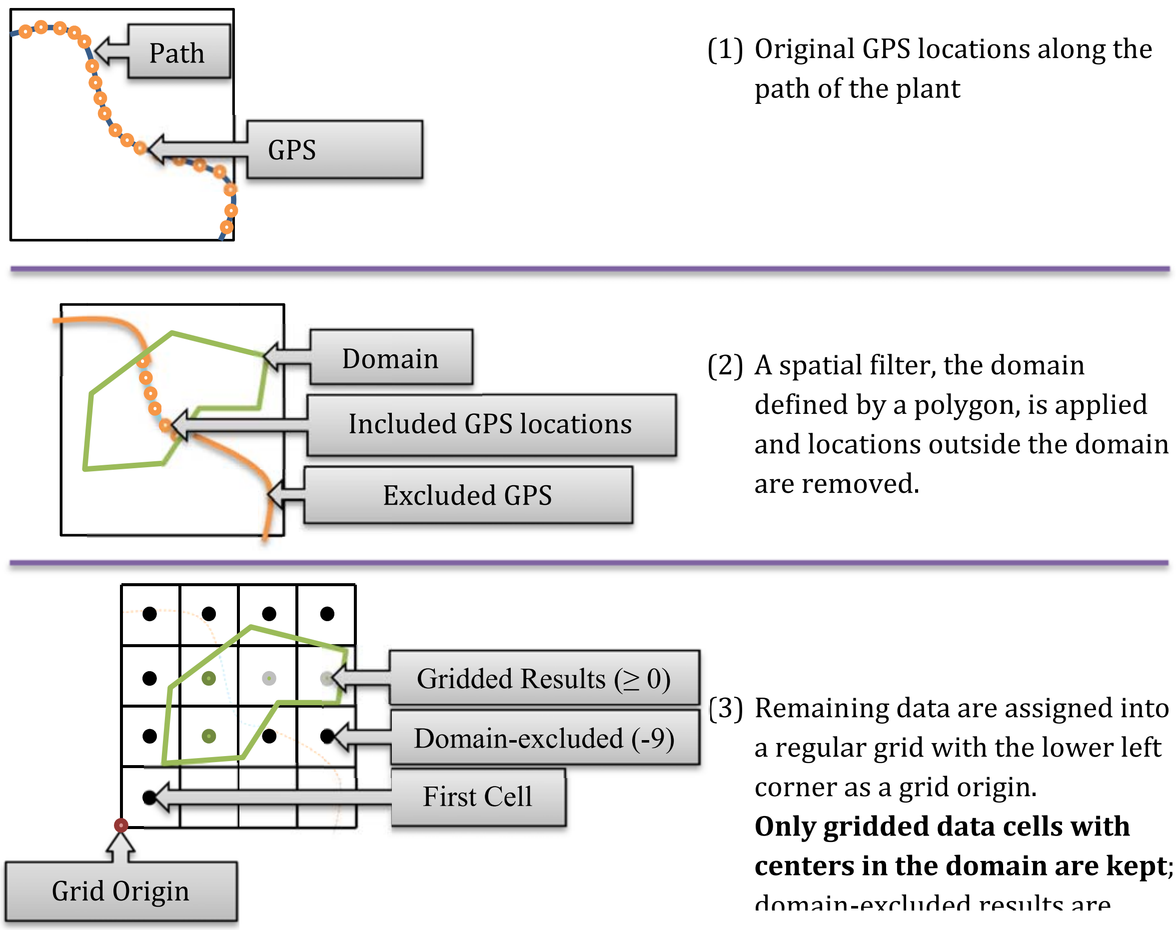

Figure 13. Schematic describing the grid, domain, and effects of domain on results.

Gridded values within the domain are 0 when a plant was never present in the cell; outside of the domain, all cells are given the value "-9" to identify that they were not analyzed.

3.5.3 Scale of Grid Cells

For this study, grid cell sizes cover a range of resolutions from fairly coarse to very fine detail at four different scales. In Figure 14, the effects of grid cell size and normalization on a data set are represented. At coarse grid scales the "accumulated seconds within a cell" derived during an Intensity calculation will have drastically different values across different grid scales.

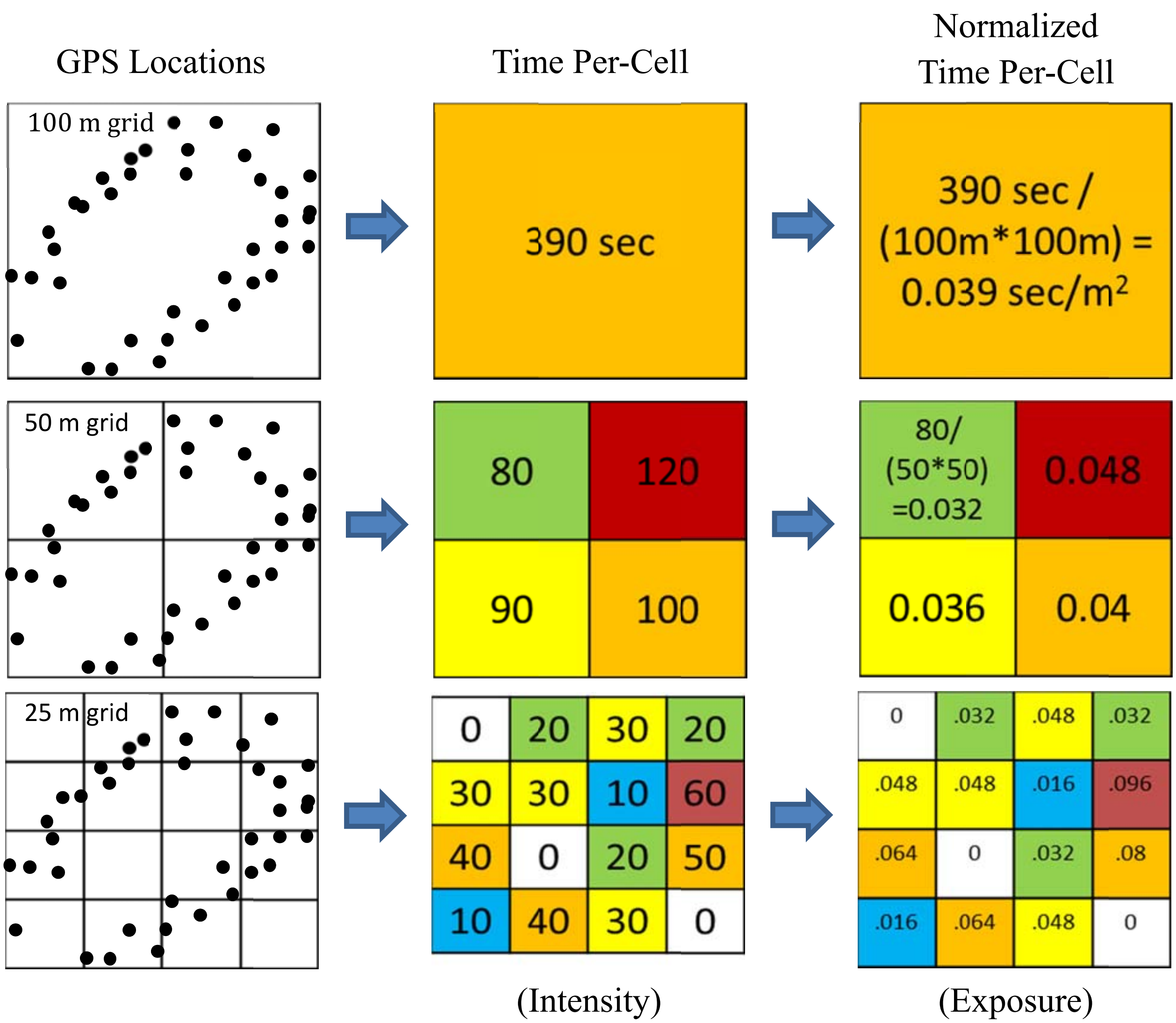

Figure 14. Effects of grid cell size and normalization on the representation of data.

In the example, at the large grid scale the Intensity value is about 400 s. When the cell length is halved the Intensity value is quartered to about 100 s, and when cell length is halved again the values are between 0 s and 60 s per cell. In order to consistently represent the data over different grid resolutions, all values are normalized by the size of the cell during the Exposure calculation. In the example this makes the large cell value go from 390 s (Intensity) to 390 s / 10,000 m^2 = 0.039 s/m^2 (Exposure). The next smaller size cell values become:

- 80 s / 2,500 m^2 = 0.032 s/m^2
- 120 s / 2,500 m^2 = 0.048 s/m^2
- 90 s / 2,500 m^2 = 0.036 s/m^2

- 100 s / 2,500 m^2 = 0.04 s/m^2

The average of these Exposure values is 0.039 s/m^2, which is exactly the same as the larger cell's Exposure value. The smallest cell values also have the same average Exposure, but their individual Exposure values vary between 0 and 0.096 s/m^2.

Normalizing by area leads to more consistent interpretations of results. However, there are still several factors to consider. First is that higher resolution and smaller cell sizes will increase spatial variability. The mean of the cells, and even the order of magnitudes, will be the same for all cell sizes; but for smaller cells, results will have a larger range of values. For lower resolution and larger grid cells, the variability is decreased, but the patterns may be averaged out. This balance of the signal-to-noise ratio should be tested for each dataset to find the best balance.

In addition to considering how the size of the cells affects results, a user should be conscious of the time range of the scenario and how many plants are operating in the area. Both of these factors will drastically change the number of points that are used within the calculation. There is no normalization implemented for time period or number of dredge plants.

The Exposure results are intended to express the use patterns through a consistent means and visualization. If, however, a user is interested in "total time" from Intensity results, it should be simple to complete a reverse calculation on Exposure values as a spatial grid, or the total time over the domain. Every value only needs to be multiplied by the area of the cell to return to units of time-per-cell. Cell area can be found in several locations, such as the metadata or the raster data locations themselves. The Exposure analysis is completed using Intensity values as described by the equation:

$$\text{for j} = 1 \text{ to m}, E_j = \frac{I_j}{A_j}$$

where E_j is the Exposure of cell *j* and where *j* indexes the largest cell size of the series of input scenarios. I_j is the Intensity in cell *j*, and A_j is the area of cell *j*. The Intensity grid in this calculation can be the combination of several Intensity scenarios *a, b,…, z*:

$$\mathrm{I} = \mathrm{I_a} + \mathrm{I_b} + \dots + \mathrm{I_z}$$

To reconstruct the aggregate Intensity results *I* from Exposure as a spatial grid, the reverse calculation can be used:

$$\text{for j} = 1 \text{ to m}, I_j = E_j A_j$$

Or to calculate total time over the entire grid:

$$I = \sum_{j=1}^{m} E_j A_j$$

The four grid cell sizes that have been developed span an order of magnitude from the large coarse resolution of 100 m per side of a cell, to the resolution of 50 m found useful in other applications, and to two very fine resolution scales of 25 m and 10 m.

Figure 15 depicts the actual GPS data that was used as a test case, and we have focused on the Canaveral Shoals II Borrow Area. The black dots representing the GPS location data show high density data within the pink polygon representing the borrow area, which has been used as the domain of the grid.

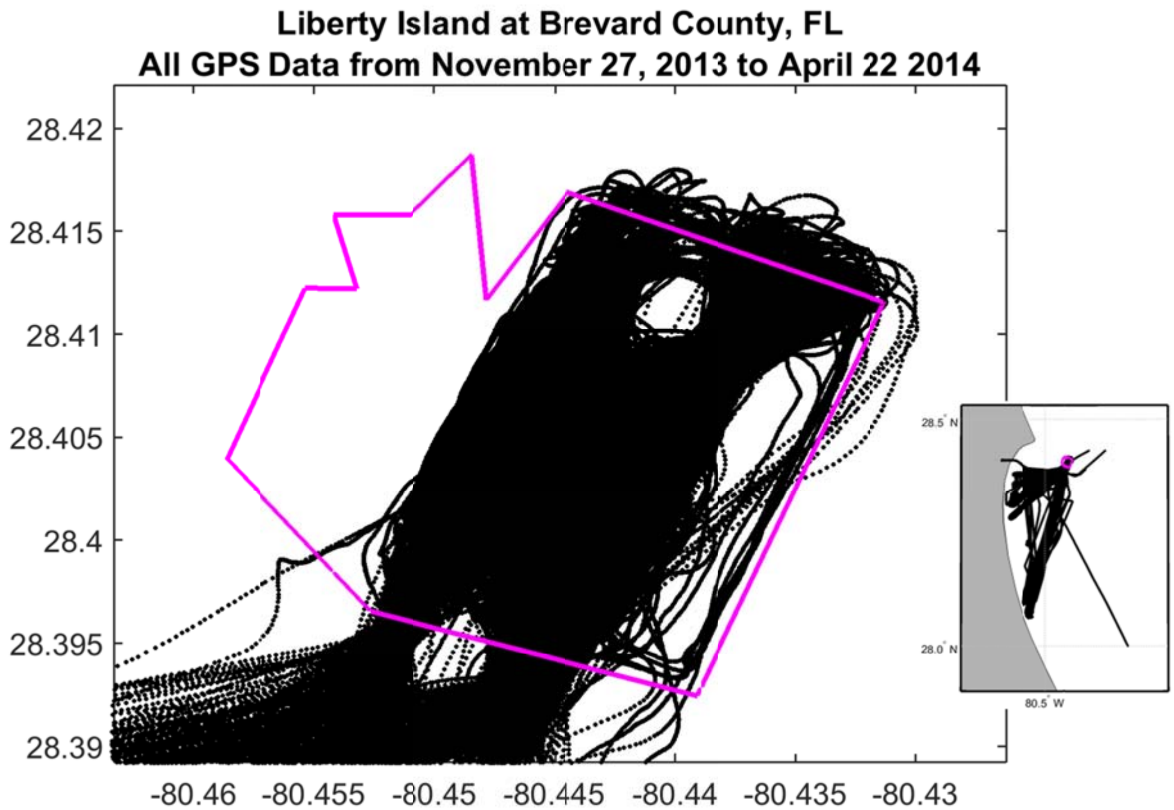

Figure 15. GPS location data from the Liberty Island in the Canaveral Shoals II Borrow Area. The inset map shows the project location along the Florida coast. The pink polygon is the borrow area.

Exposure results for these data are gridded using the four different grid cell sizes and the borrow area is used as the domain in Figure 16, Figure 17, Figure 18, and Figure 19. They demonstrate the appearance of the different resolutions using vessel location data from the *Liberty Island* test case. The results range from fairly blocky (giving broad brush ideas of Exposure), down to a level of resolution where individual track lines are evident.

Although the color scales between the four figures are identical with a range of 0 to 2 seconds per square meter, variability does increase with resolution. The larger cell sizes lead to averaging over larger spaces. The areas represent the same data with the same averages, but the high resolution grids show much more detail and thus variability around the mean. The use cases and other datasets used in conjunction with the Exposure outputs will help to determine the necessary level of resolution for each project.

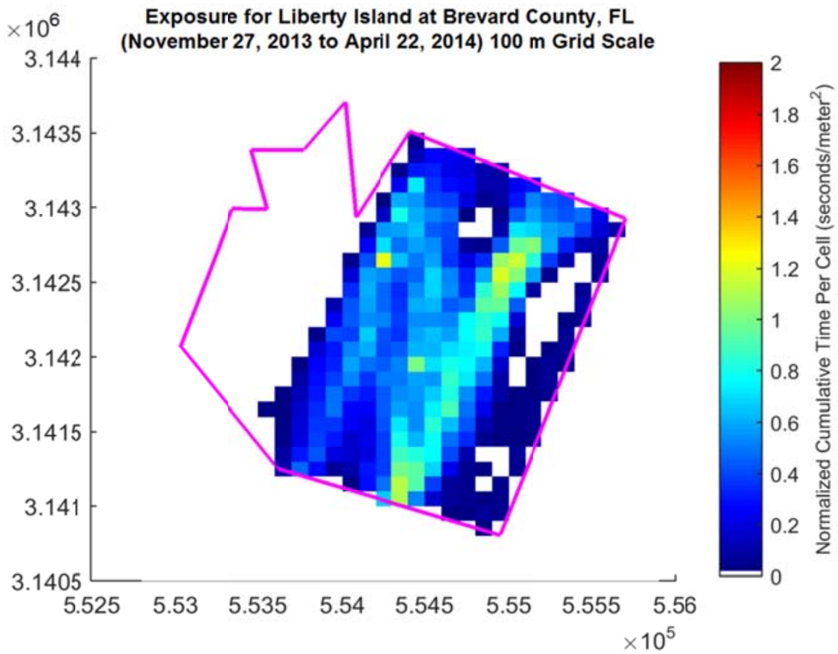

Figure 16. Example Exposure with cell size of 100 m using dredging drag arm data from the Liberty Island test case data.

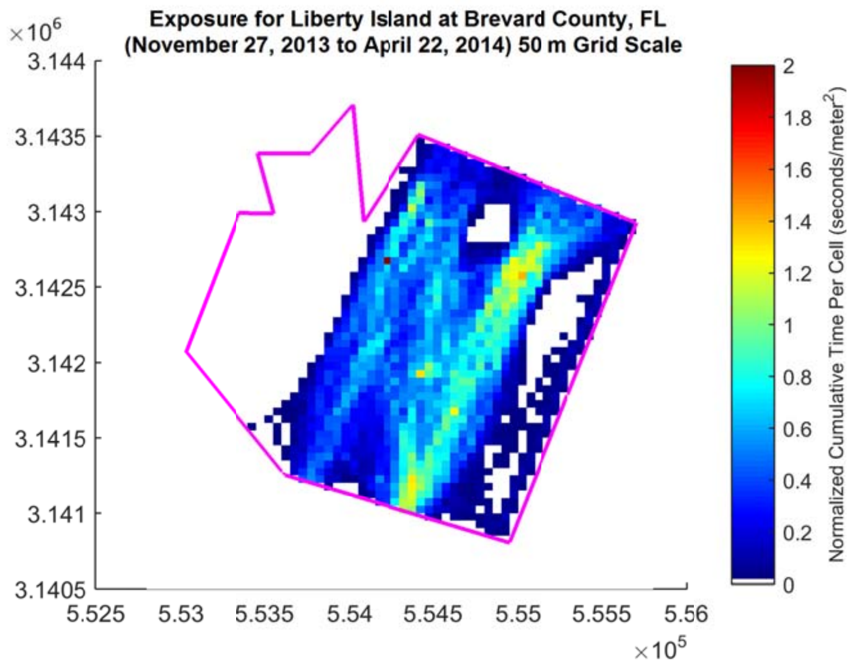

Figure 17. Example Exposure with cell size of 50 m using dredging drag arm data from the Liberty Island test case data.

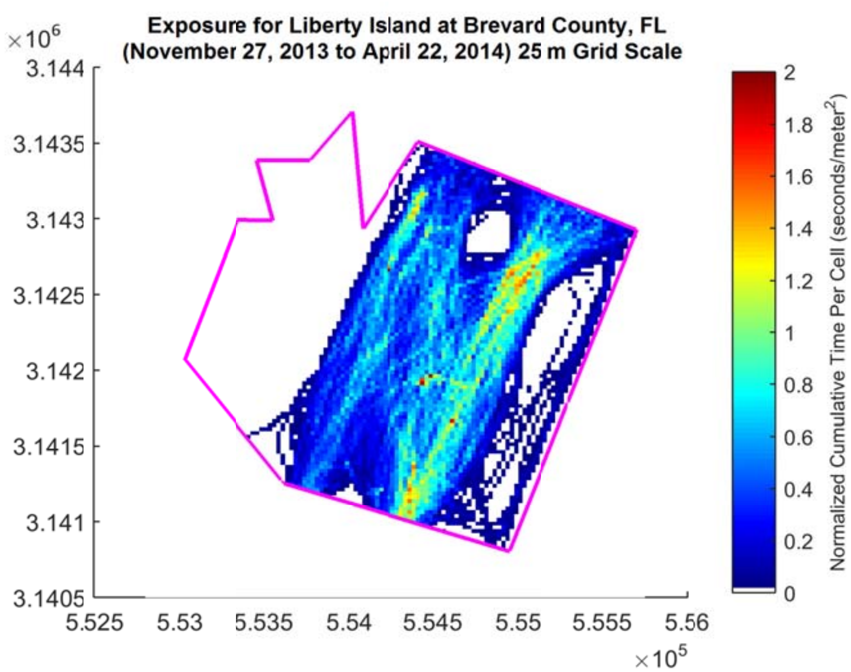

Figure 18. Example Exposure with cell size of 25 m using dredging drag arm data from the Liberty Island test case data.

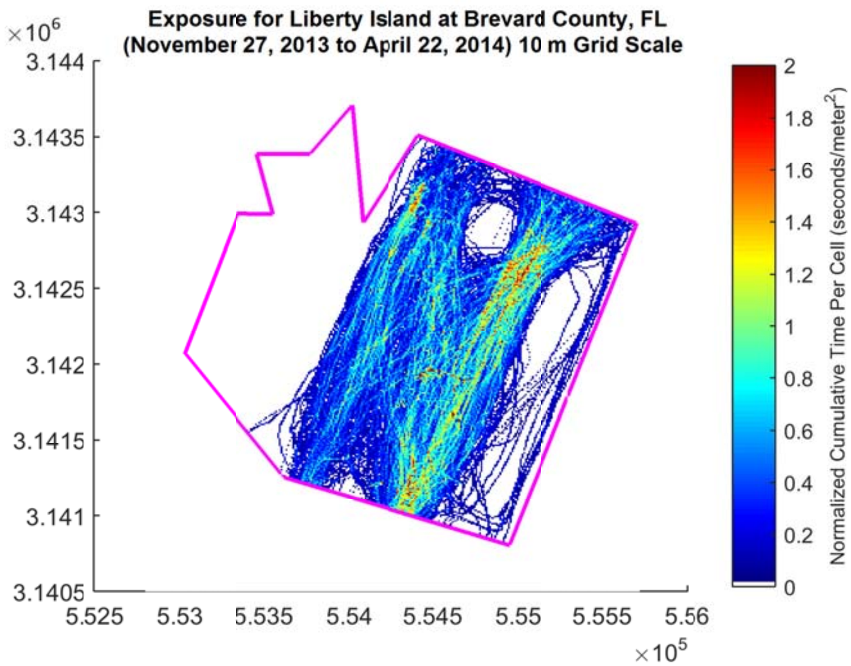

Figure 19. Example Exposure with cell size of 10 m using dredging drag arm data from the Liberty Island.

4 Data and Products

In this section, we begin to describe in detail how the calculations of the previous section are implemented through the IECA. The implementation is a sequence of steps with a series of initial files, interim products, and final results. Also described are how input and output files are formatted and when they are called. For more details and examples on user workflow and GUI walkthroughs, see Appendix 1: Graphical User Interface User Guide and Best Practices.

During the calculations, a set of files are used and created. Initially, the raw data file is pulled from the DQM database as CSV. A scenario input file is created during processing to document the grid settings and local path location of the DQM CSV, which is a simple text file with an INP extension. Exports of an Intensity run have two files considered to be interim products: the gridded Intensity data as a CSV, and a copy of the INP file with extra metadata notes called an OUT file. During the final Exposure processing, one or more gridded CSV and OUT files are used to build a final data set. Products from the Exposure run are a gridded Exposure CSV, a raster image of the calculated values in GeoTIFF format, and an accompanying ISO metadata in XML format. Each of these file types are discussed in detail in the sections below.

Initial files:

- DQM Database Exports: *.csv
- Saved settings to run the scenarios: *. inp

Interim products

- Gridded Intensity runs: *. csv
- Gridded Intensity saved settings and metadata notes: *. out

Final products

- Exposure runs: *.csv and *.tif (GeoTIFF)
- ISO Metadata: *.xml

The default naming convention used during processing to save scenarios (INP), the resulting gridded Intensity file (CSV), and the output files (OUT) will all use an identical name with different extensions. The default naming convention uses a unique set of "PROJECT" values from the DQM CSV files, as well as a unique set of "DREDGE_NAME" values, then the date start/date end of the scenario; the grid cell size in meters; and finally the dredge state filter (All, Dredging, Sailing, Sailing Light, or Sailing Loaded). An example of how this appears for a single project (Brevard County, FL) and a single dredge plant (Liberty Island) using a 10 m grid and all data points is:

BrevardCountyFL_LibertyIsland_2013Nov27-2014Apr22_10m_All

This default file name is populated in a save dialog window, and the user can modify it as desired.

The final Exposure products—the GeoTIFF, gridded CSV and XML metadata—do not have a separate naming convention and instead use the name of the scenario being evaluated. If there are multiple Intensity scenarios in an Exposure analysis, the first name of the set is used.

4.1 Input/Output Parameters

In the IECA, "scenarios" define what is to be run and how. They include documentation of user settings and raw DQM data file names to be used as input to a DQM-IECA run. For example, a scenario could be created to investigate a project with a focus on understanding where dredging occurred over a defined time period; another scenario could be created using the same project data but focusing instead on transit locations over the same time period.

Settings for a scenario input file include which CSV files from DQM are included, spatial and temporal ranges, grid cell size, whether or not to interpolate tracks, and dredge state filters. Scenario input files are simple text files with an INP extension containing keyword/value pairs, for example:

keyword: value

The MATLAB GUI builds and modifies scenario input files, so format is easily written and read by the code. However, because these are simple text files, a human can read and update files outside the GUI as well. Scenario input files are useful tools for maintaining a record of what was run, and sets of files can be used for batch processing.

Below is an example of the structure of INP files; the square brackets [ ] denote the default values, and the vertical bar | denotes options for the value.

scenario: [full file path]
homeFolder: [folder path]
fileList: [list of files]
boundary_borrowPath: [empty] | full shapefile path
boundary_box_LL_UR: [latMin, lonMin, latMax, lonMax] | empty
timeRange: mm/dd/yyyy HHMMSS, mm/dd/yyyy HHMMSS
DredgeStateName: Dredging | Sailing | Sailing light | Sailing loaded | [All]
gridOrigin_LL: latOrigin, lonOrigin
gridCellSize_m: [100] | 50 | 25 | 10
trackInterpolation: [false] | true

In addition, in the case when MMP data has been linked to the scenario, an early set of metadata is saved in the INP file of the form:

metadata : BOEM_keyword : value
metadata: BOEM_MMP_File: [xlsx file name of BOEM Lease crosswalk with DQM]
metadata: BOEM_BorrowArea: [name of the borrow area]
metadata: BOEM_ProjectID: [name of project]
metadata: BOEM_LeaseNo: [BOEM lease code]

The output files are also text files, and they have the extension OUT. They are copies of the input file, with the addition of metadata notes sections that have the form:

metadata : keyword : value

The current set of metadata notes stored in the output file is:

metadata:dateRun: mm/dd/yyyy HHMMSS
metadata:RawFiles: [full path to the set of CSV files used]
metadata:DREDGE_NAME: [Plant name from the CSV files]
metadata:PROJECT: [Project name from the CSV files]
metadata:CONTRACT_PERMIT_NUMBER: [contract number from the CSV files]

4.2 Intensity and Exposure Results

The first set of interim products is created after a scenario has been run and the data is exported. To run a scenario, the input (INP) file is passed to the IECA, which performs the Intensity calculation and returns gridded Intensity values. Results are previewed, and the user can update the scenario and re-run the Intensity analysis as needed until results are satisfactory. When results are exported, a CSV file and an output file (OUT) are created. This workflow is summarized in Figure 20, shown below.

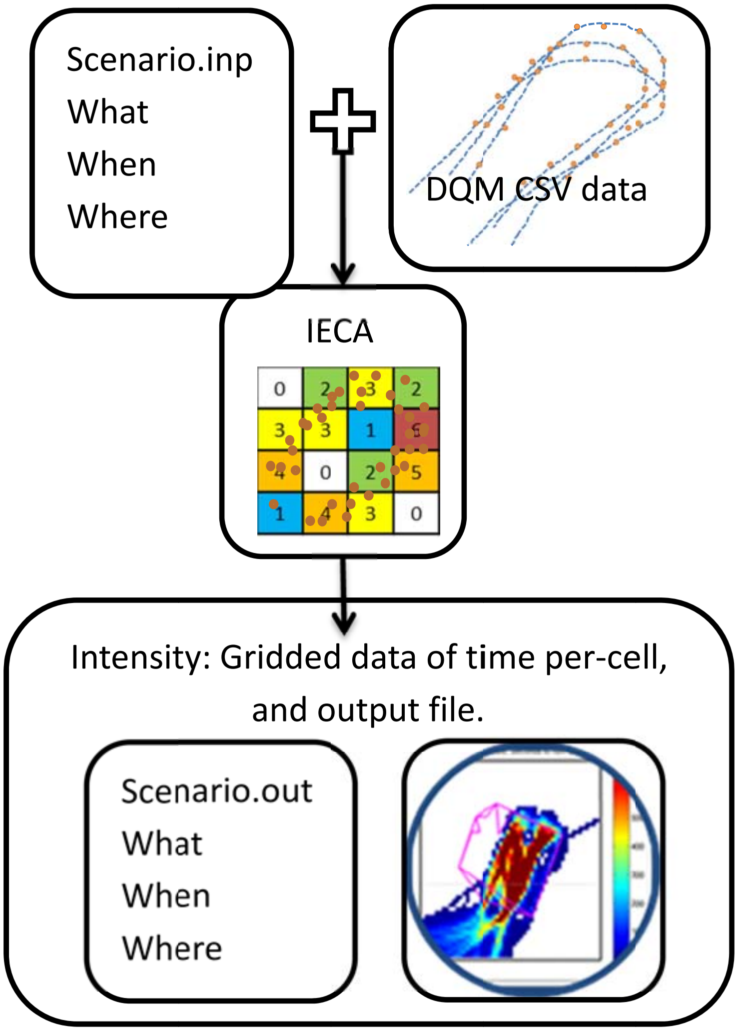

Figure 20. Data flow for creation of Intensity values.

The output (OUT) file copies the input (INP) file settings along with metadata notes such as when the run was completed, which contracts and plants were included in the scenario, etc.

After Intensity analyses have been run and exported, an Exposure analysis can be completed. To accomplish this, Intensity exports are brought back into the MATLAB environment. Any number of Intensity runs can be aggregated as long as the grid settings are compatible. The Exposure analysis checks the selected set of Intensity files for compatibility then aggregates and normalizes values into time per square meter. The results are previewed and can be exported as CSV and GeoTIFF files along with ISO metadata. This workflow is summarized in Figure 21.

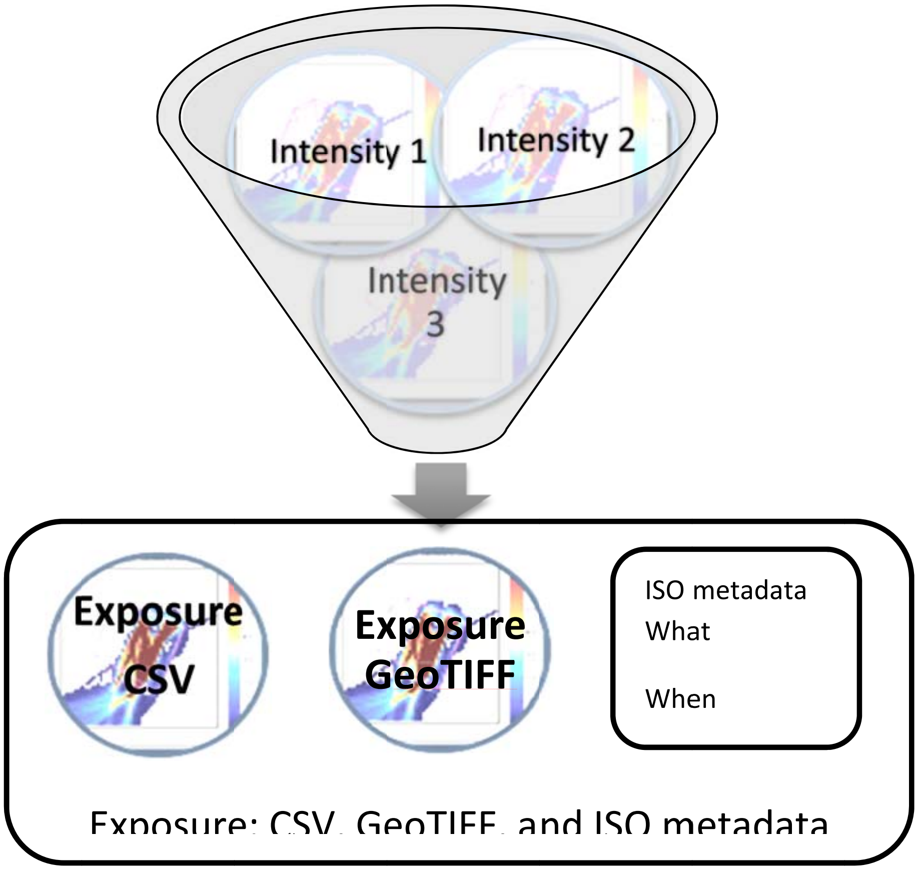

Figure 21. Data flow for creation of Exposure values.

The gridded CSV export of the Exposure analysis is nearly identical in structure to the Intensity CSV. However, the Exposure values are normalized by area whereas Intensity values are not. The header in the Exposure file documents the set of INP files used, and the metadata accompanying Exposure is ISO standard rather than the interim metadata notes contained in the OUT file created with the Intensity export.

4.3 Gridded CSV

The CSV contains the gridded values, a small header, and UTM coordinates embedded as the first value in the rows and columns of the data. The UTM coordinates identify the center of every cell.

Header information of the gridded CSV:

- The number of x and y grid cells and an identifying number: 1 for Intensity, 2 for Exposure
- Lower left corner of the first data point as easting & northing
- Cell size, in meters
- EPSG code to identify projection

- Path and name of the scenario input file
- Path and name of the output file for Intensity, or the ISO metadata file for Exposure

The gridded data is comma separated for each column. Each row corresponds to a new row in the grid. The X and Y UTM grid locations are the first value of each row and column in the grid.

[not a number],	UTM X, UTM X, UTM X, …	
UTM Y, data,	data,	data, …
UTM Y, data,	data,	data, …
UTM Y, data,	data,	data, …

As an example, below is an Intensity export of a file with 209 columns and 444 rows with the first data point in the lower left corner at 538150, 3102850, which is the center of the cell. The cell size is 100 m on a side, and the EPSG code for the projection is "32617," which corresponds to WGS 84 / UTM zone 17 North. The input file that was used in the IECA to build this output has the path and name "C:\Test_Data\liberty_100m.inp", and the associated output file path and name is "C:\Test_Data\exports\liberty_100m.out".

```
 209 444 1

 538150 3102850

 100 100

EPSG:32617

Scenario_Path: C:\Test_Data\liberty_100m.inp

Scenario_Metadata: C:\Test_Data\exports\liberty_100m.out

NaN,        538150.0,  538250.0,  538350.0,  538450.0,  538550.0, …

3102850.0, 0.0,       0.0,       0.0,       0.0,       0.0, …

3102950.0, 0.0,       0.0,       0.0,       0.0,       0.0, …

3103050.0, 0.0,       0.0,       0.0,       0.0,       0.0, …

3103150.0, 0.0,       0.0,       0.0,       0.0,       0.0, …
```

As a note of caution when reviewing the CSV files, the most south, most west location is the top most left data point in the CSV. Northing increases moving down the rows, which is upside down from the way you would view these data in a map.

4.4 GeoTIFF

The GeoTIFF is saved in a raster format with the UTM projection EPSG code, using the GeoTIFF Format Specification (Ritter and Ruth 2000). The raster image is the original data saved in a matrix of cells in rows and columns of the uniform grid. The grid was defined by the origin in the bottom left (most South, most West location), and the number of cells and their size. This file type can be read into most mapping software, such as ArcMap.

The GeoTIFF contains actual values of data with units of seconds per meter squared (s/m^2). This makes the initial color map in Arc a gray scale. Within Arc, values can be classified and color coded for better visualization, while maintaining underlying data.

4.5 ISO 19115-2 Metadata

Development of the metadata was completed using examples provided by BOEM (NGDC 2008) and the ISO 19115-2 workbook (NOAA 2012) prepared by the National Coastal Data Development Center and the National Oceanographic Data Center; both offices within NOAA. During Exposure calculations, default metadata values are captured or identified. Before final export of the Exposure results, fields can be updated interactively in the GUI.

Construction of metadata during the export starts from an XML template created for the IECA output. Fields to be populated during processing are identified within the template by square brackets and contain a field name. During the export of Exposure, the template is read into MATLAB, fields are populated, and a new XML file is saved. The default naming convention is identical to the CSV and GeoTIFF files.

The metadata contain the sections for:

- File administration and identifier fields
- Spatial Representation Information: Digital representation of spatial information in the dataset
- Reference System Information: Identification of the spatial and temporal reference systems used
- Identification Information: Basic information about the dataset
- Content Information: Characteristics describing the feature catalogue, the coverage, and the image data
- Distribution Information: Information about acquiring the dataset
- Data Quality Information: Information on the quality of the data that is specified by a data quality scope; also contains the lineage and processing information
- Metadata Maintenance Information: Information about metadata updates
- Acquisition Information: Information about the acquisition of the data

For more information, please see Appendix 3: ISO 19115-2 Metadata. The metadata template has un-populated fields.

5 MATLAB and the Graphical User Interface (GUI)

A GUI is a way for a user to interact with an application and a visual means to complete a user's workflow with graphics, buttons, and selection options to guide the process. It creates a more intuitive environment to run mathematical code requiring specific formatting and values. The IECA was designed to be optionally accessed without a GUI as well, but the GUI supports the correct formatting and function calls to the program as well as providing visualization tools to assist the user in settings choices. The IECA and GUI were coded as separate sets of files, to allow flexibility in future development of different tools for the IECA.

The workflow for creating gridded products from DQM data previously described in **Figure 1** can be completed by interfacing with the MATLAB GUI. The GUI application has been developed to support construction of and updates on scenario input files, calling the IECA using those inputs, previewing results produced by the IECA, and exporting the final products. Further detail and description of the GUI is contained in Appendix 1: Graphical User Interface User Guide and Best Practices, which includes GUI functionality, workflow, and example use cases.

In summary, the processing steps to create Intensity and Exposure are listed below.

Intensity workflow:

1. New Intensity scenario is opened by selecting DQM data files.
2. Default input parameters are created, and the GUI is populated with these values.
3. Scenario input parameters can be updated in the GUI by the user, and an INP file is saved.
    a. Multiple input files can be created and saved during this step.
    b. Multiple input files for a time series can be created during this step.
4. Intensity results are calculated by the IECA using parameters from the INP file.
    a. Multiple scenarios can be run and exported without the preview during this step.
5. Gridded Intensity values are displayed in a preview window in the GUI.
6. Input parameters can be updated, and the IECA Intensity analysis can be re-run, and results displayed again.
7. Finally, results can be exported to a gridded Intensity CSV file with an associated OUT file.

Exposure workflow:

1. New Exposure scenario is opened by selecting Intensity file(s).
2. Individual Intensity scenarios can be viewed; files can be added or removed from the set.
3. The Exposure calculation is run on remaining files.
4. Metadata can be updated by the user.
5. Results are exported to a gridded CSV, GeoTIFF, and ISO metadata.

5.1 MATLAB Function List

The scripting documentation (Appendix 2: Intensity and Exposure Calculation Algorithms Scripting Documentation) that is associated with this report contains a list of all of the MATLAB script files developed for this project. The appendix contains the name of each file, a description of how the file is called, and a brief description of what the file does. Below is a list of the same files for reference, with the code divided into several different sections. The *Math* functions are the core of the IECA, and do the calculations and transforms on the data. The *Fn* functions—or input/output files—read, write, import, and export data files. The *GUI* functions and scripts are the tools for the Graphical User Interface, which is divided into three groups: overall GUI functionality, the scenario interface, and the Exposure analysis interface.

MATLAB m-files are easily opened and read in text editors. This allows any user, even if they do not have MATLAB, to open and review the code itself. Below is a list of the functions and scripts that have been written for quick guide to finding m-files that are of interest to a user.

Mathematical Module M-Files

DQM_IECA
Math_updateOrigin
Math_increaseResolution
Math_build_UTM
Math_BBox_toUTM
Math_gridCreation
Math_GridData_UTM
Math_calcExposure

Input / Output Functionality

DQM_loadScenario
Fn_readINP
Fn_writeINP
Fn_writeINP_batches
Fn_CombineInputs
Fn_batchRunIECA
Fn_loadCSV
Fn_MMPCrossWalkLoad
Fn_readShapeBoundary
Fn_writeShape
Fn_RemDataOutOfBB
Fn_writeCSV
Fn_exportIntensity
Fn_loadGrid
Fn_exportExposure
Fn_exportGrid_toTIFF
Fn_metadataDefaults
Fn_buildISO_fromTemplate
Fn_getCSVStats
Fn_CSVFileParser
Fn_exposureFilePreTests
Fn_diagnosticRun

Graphical User Interface M-Files

GUI_DQM
GUI_construction
GUI_callbacks
GUI_drawGriddedData
GUI_drawTrackData
GUI_switchView
GUI_diagnosticReview
GUI_contact
GUI_version

Graphical User Interface M-Files for Intensity

GUI_readINP
GUI_selectCSV
GUI_updateScenarioFiles
GUI_importShape
GUI_importShapeForVis
GUI_loadScenario
GUI_testData
GUI_writeINP_dlg
GUI_writeINP_fromGUI
GUI_dlgMoveToExposure

Graphical User Interface M-Files for Exposure

GUI_selectGrid
GUI_removeSelectedScenarios
GUI_selectScenarioFiles
GUI_updateExposureFig
GUI_updateMetadata

6 Summary and Next Steps

The purpose of this inter-agency agreement was to develop a mathematical framework to create cumulative Intensity and Exposure maps from operational dredge monitoring data and improve the ability to examine dredge plant behavior over multiple projects. Data are collected and maintained by the USACE National DQM Center, and prior to this study, no cumulative Intensity and Exposure calculations have been designed for dredge operational data. This report has laid the groundwork for the mathematical framework, workflow, and products, as well as a user application, for BOEM to test and study dredge plant operations. The mathematical modules that were designed for this study have been collectively called the IECA.

Nearly the entire workflow using the IECA can be completed through the use of a GUI, a user application that was designed for this study for use by BOEM. All flexible parameters are able to be easily updated, and results can be viewed before final export.

Some structural decisions on the grid types and methods of transforming irregular data to structured data are built into the IECA and cannot be modified by the user. Other parameters have a set of options (e.g., grid cell size) to allow users flexibility in the final product. By defining the projection as UTM and the shape of cells to be a regular square mesh, the grid type is well suited to building area statistics and comparing to other data sets such as bathymetry grids. In future development, other projections and cell shapes may be investigated.

6.1 Processing Summary

Selecting the grid cell size is a critical step during processing. A fixed series of scales is provided covering an order of magnitude to support the creation of many different kinds of products. The set is: 100 m, 50 m, 25 m, and 10 m. At the 100 m scale general areas of impact can be assessed with less computational burden. Different settings can be tested quickly before increasing the grid resolution. The 50 m scale has been found to be useful among other dredging groups and is on par with the physical scale of most vessels. The 25 m and 10 m scales are very high resolution—data and results should be examined for GPS location accuracy on a plant by plant basis—but the results can show very detailed information of drag arm locations while dredging.

Once a grid is defined, time series data from the DQM database must be transformed into the structured grid. Due to the high data density of the GPS locations over a project contract, the most straightforward method is to use the cumulative time of all the GPS locations within each cell of the grid to define Intensity. The summed values produce a total number of seconds in each grid cell.

In areas of lower-density data caused by some combination of small cell size and increased vessel speeds, the time series spatial resolution can be optionally increased during processing. This step involves adding new interpolated locations between samples down to the spatial resolution of the cell size. When samples are already at high spatial densities, no interpolation is applied. Interpolation is an effective method to populate grid cells along transects. In future development, extrapolating GPS locations to define the shape of the plant may be investigated.

After any number of scenarios has been processed to create Intensity outputs, the Exposure analysis module can be used to aggregate those results into an Exposure data file with normalized results. Grid extents during scenario building and Intensity processing should be set so they are consistent between runs that will ultimately be aggregated into Exposure. To normalize the values when there are different cell sizes in different Intensity runs, cumulative time is divided by the area of the cell. The final result will have the largest cell size of the set of Intensity runs and units of time per area, or sec/m^2. Normalization will also be useful if future development includes investigation of grids with unequal area cells.

After Exposure calculations have been processed and previewed, results can be saved outside of the MATLAB environment by exporting to CSV and GeoTIFF files, which maintain the actual calculated data and can be ingested in a wide array of other programs for further analysis. Documentation associated with the output will be in the ISO 19115-2 metadata standards.

6.2 Future Development

The current opportunities with the IECA and GUI for future development fall into several categories. Several enhancements to the IECA itself may be accomplished after more research has been completed. Many opportunities for development are in the functionality and usability of the GUI. It is currently designed as a simple research tool to help support the creation of scenarios and call the IECA code, but with expanded functionality could have broader utility. Finally, the processing steps completed in the IECA may allow for different kinds of products to be created as a branch off the original code. The following is a list of possible future development ideas and code improvements to enhance the IECA and usability of the tools:

IECA Development

- Develop use of other grid types, such as
  - An equal angle grid (using a Mercator projection)
  - Unstructured non-uniform grids, such as a TIN
- Develop methods to enhance the resolution of the data to be applicable to grid resolutions below 10 m
- Investigate using UTM zone origin as default grid origin
- Enhance shape file handling as a filter
  - Allow user to choose inside vs. outside of polygon
  - Allow complex shapes, e.g., donut
- Add a feature to read in xml metadata and recreate a run
- Require user to enter certain metadata fields and restrict editing of others
- Consider how to optimize naming/content in the case the output GeoTIFFs need to be distributed through an online portal

Enhanced User Experience

- Once we know more about users, customize the interface for different user groups
  - Investigate a "wizard" style workflow rather than the currently implemented "dashboard" style for specific end user groups

- Enhance GUI shape file handling to display a base map in the GUI

Auxiliary Tools

- Add a compliance tool for borrow area in/out determination on non-gridded data
- Add the ability to export filtered, un-gridded data
- Add other flexibility for different kinds of data visualizations

The emphasis of this study was flexibility and simplicity. Cumulative use and impact from operational dredge plant data has not been examined or utilized before, and examples of how data can be included in environmental impact studies or long term monitoring of a borrow area, or used for permits and leasing, are hypothetical. BOEM will now have the opportunity to test and investigate a wide range of practical applications using the provided tools.

7 References

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[NOAA] National Oceanic and Atmospheric Administration. 2012. ISO 19115-2, geographic information – metadata, part 2: extensions for imagery and gridded data. [updated 2012 Jan 1; accessed 2015 Feb 1]. http://service.ncddc.noaa.gov/rdn/www/metadata-standards/documents/MI-Metadata.pdf.

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Appendix A: Graphical User Interface User Guide and Best Practices

Contents

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1 Introduction

This document describes the MATLAB Graphical User Interface (GUI) used to access the Intensity and Exposure Characterization Algorithms (IECA). The functionality and purpose of the user interface's buttons and text boxes are identified, as well as a workflow and best practices to be used to run the GUI. Workflow and products are emphasized, and several case studies are presented to elucidate creation of useful results.

2 The Graphical User Interface (GUI)

A GUI is a way for a user to interact with an application and a visual means to complete a user's workflow with graphics, buttons, and selection options to guide the process. It creates a more intuitive environment to run mathematical code requiring specific formatting and values.

Using the IECA to create gridded products from National Dredging Quality Management (DQM) data can be completed by interfacing with a specially designed MATLAB GUI. The GUI has been developed to support construction of and updates on scenario input files, calling the IECA using those inputs, previewing results produced by the IECA, and exporting the final products. The IECA was designed to be optionally accessed without a GUI as well, but the GUI supports the correct formatting and function calls to the program. The IECA and GUI were coded as separate sets of files, to allow flexibility in future development of different tools for the IECA.

2.1 Installation of the IECA and User Interface Program

There are two methods to accessing the IECA through the GUI. The first option is to install a compiled version of the program, similar to how other software applications function. This involves installing the (free) MATLAB runtime (version 2017a), and then running the program as an executable. The executable file name follows this convention: DQM_IECA_{version}_{releasedate}_{matlabvers}.exe. The second option requires that the full licensed MATLAB program be installed on a user's computer, and the functions are called from within the MATLAB environment.

To install the MATLAB runtime, go to: http://www.mathworks.com/products/compiler/mcr/ and download the R2017a, Windows 64-bit exe file – the executable version was developed on Windows 64-bit operating system running Windows 7. When the file has saved to your computer, double click on the installer and follow the instructions. This should install the background set of MATLAB shared libraries that the IECA is built on, and will allow the compiled version of the IECA to run. The MATLAB runtime only needs to be installed during the initial set up, and after the install a user can simply double click the IECA exe file to run the program.

The other method to access the GUI is within a licensed MATLAB environment. Opening and using the GUI in the MATLAB environment allows for more data manipulation within MATLAB during processing. It is also possible to review step-by-step processing in the code, or to undertake additional development of the code. This is recommended primarily for developers and researchers, not for general users.

To access and run the IECA within the MATLAB environment, the full licensed version of MATLAB 2017a should be installed, along with the Mapping Toolbox. Select the appropriate version for the computer on which it will be installed (e.g. Windows/Linux/Mac, 32/64 bit OS). The set of m-files that comprise the IECA should all be contained in a single folder, and with the MATLAB program open a user should navigate to that folder as the home directory, or add the folder to the MATLAB path. As an example, if the files were saved under your *C* drive in a folder called *IECA_MatlabScripts,* at the command prompt type:

```
>> cd C:\IECA_MatlabScripts\
```

Then, to start the GUI, at the command prompt type:

```
>> GUI_DQM
```

This will initialize a figure window for the GUI as seen in Figure 1, and workflow is the same as running the executable after this point.

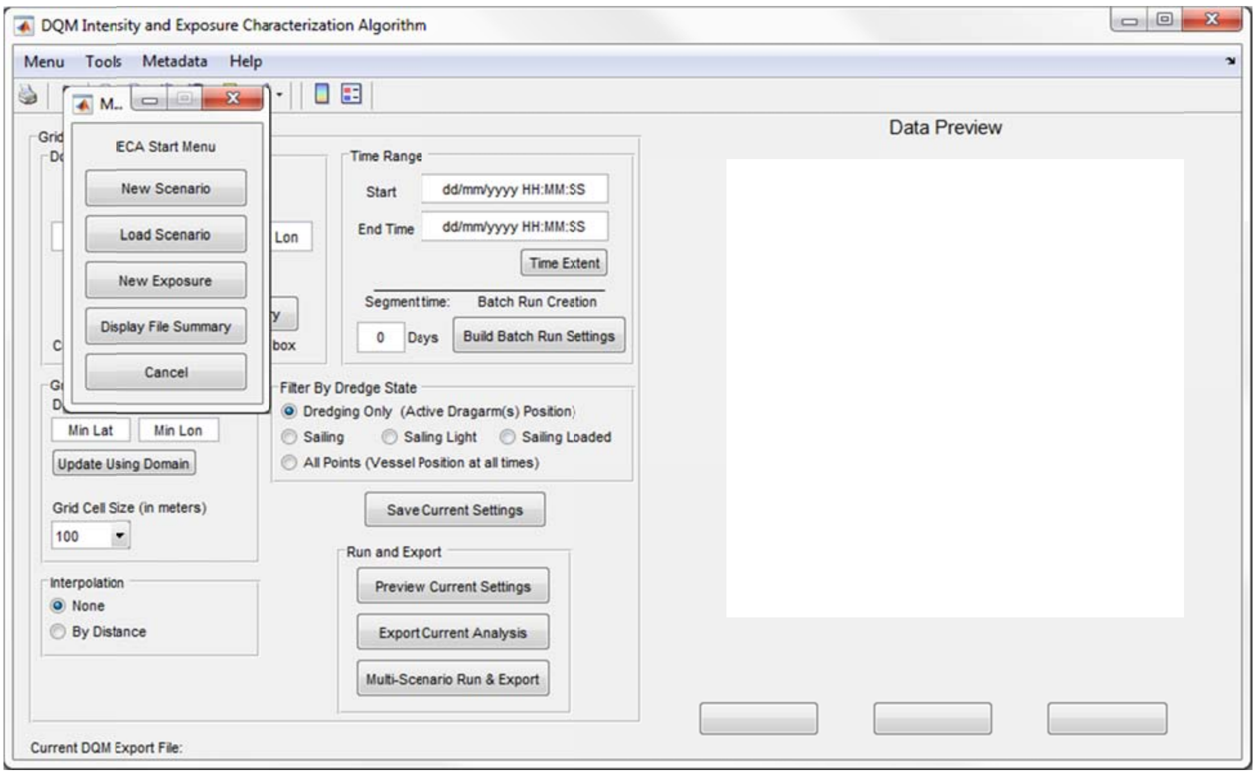


Figure 1. Initial view of the IECA user interface when launching the application.

2.2 Data and Data Management

Prior to using the GUI, the user must acquire project data through a request to the DQM Center. Through an agreement with the DQM Center, the BOEM-format Comma Separated Values (CSV) export has been specifically designed for use with the developed IECA and GUI tools, and contains no proprietary data.

Before working with the data in the IECA tool, users are encouraged to review the delivered CSV file to ensure it matches the requested records and that there are no issues with the data. Inspect the file for project area information, Plant name, contract information and the date range. Visually inspect the data file for any discrepancies and verify there are no defects such as missing data, truncation of the data, or data fields mismatch.

Best Practices: When there are multiple files, review that they do not overlap each other in time. If there are overlaps, one of the original CSV files can be trimmed to exclude the duplicate data. Any time a DQM CSV file needs to be modified, it is advisable to create a copy and update the file's name with a date the modification was made, e.g.

Original name: Contract_Plant_DateRng_MaterialRecoveryData.csv

Revision name: Contract_Plant_DateRng_MaterialRecoveryData_Rev_<Date>.csv

⚠ **Do not save the file to maintain the integrity of the .csv file.** The user is strongly discouraged from opening and saving these CSV files within Excel. The DQM CSV files contain a time field, "DATE_TIME", that Excel automatically reformats and the seconds are truncated after opening and saving. Other fields can sometimes be truncated as well, such as very long numbers. Excel does have a parsing mechanism that allows easy reading of CSV files in a table view, but if these files are viewed in Excel it is not recommended they be saved after opening.

The default folder structure created by the GUI is an Intensity and Exposure folder under a Home folder; the home folder is the folder containing the CSV data file(s) selected by the user.

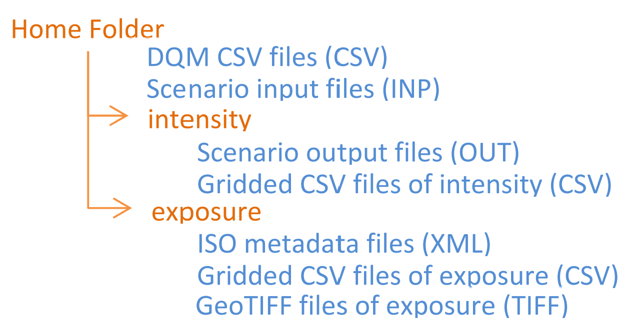


Figure 2. Folder structure for data storage with the IECA tools.

The DQM database export CSV files of interest should be saved into an easily accessed local or network folder with a name and path that won't change. This home folder can be given any name (**without spaces**) and its path is referenced in the processing files – the user is encouraged to create new home folders for different projects. This home folder becomes the basis for the GUI's default folder structure. Before processing, the home folder should contain the DQM CSV file. During processing, two new folders, \intensity and \exposure, are automatically created and a series of processing and final files are saved within this structure (**Error! Not a valid bookmark self-reference.**). Other folders and files can be manually saved into this folder structure as well, such as borrow area shapefiles, or ArcMap projects. The MATLAB program will never delete files, but it will overwrite files that have identical names and extensions.

2.3 Workflow

This section guides the user step by step through the IECA using the MATLAB GUI. Users should have all necessary database export files (CSVs) that are to be used for an analysis within a single 'Home' folder. All outputs from the IECA are saved within this Home folder and subfolders. After data has been acquired, all interactions with the data can be done in the GUI. The following are a series of steps a user would take to run the IECA through the GUI.

2.3.1 Intensity Workflow

1. There are two options to start the GUI using either the compiled exe file, or the MATLAB scrips:
    a. Start the GUI as an executable
        i. Install the MATLAB runtime version 2017a (only needs to be done the first time)
        ii. Open the DQM_IECA_{version}_{releasedate}_{matlabvers}.exe file by double clicking on it
    b. Start the GUI as a MATLAB m-file
        i. Open MATLAB
        ii. Navigate to the directory containing the MATLAB scripts (m-files), you can do this typing cd and the folder location at the command prompt:
        `>> cd C:\IECA_MatlabScripts\`
        iii. Run 'GUI_DQM' at the command prompt by typing:
        `>> GUI_DQM`
2. In the GUI, view the summary information from a series of CSV files using
Menu > **Display DQM CSV File Summary**
3. A new Intensity scenario is initiated by selecting DQM CSV data file(s) from within the GUI. In the Intensity view of the GUI, only one scenario can be viewed and updated at a time. In the GUI, start a new scenario:
    a. Select **Menu** > **New Scenario**
    b. Navigate to the folder containing the CSV files from DQM
    c. Select the files to include in your scenario; use Ctrl key to select multiple files
    Note: **Menu** > **Update files in Scenario** will add and remove files from a scenario
    Note: **Menu** > **Load Scenario** will pull in information from a previously saved INP file
4. The selected DQM files are loaded into MATLAB and default values are determined based on the spatial and temporal extents of these files. If loading a scenario, settings are populated from the input file. The track lines are drawn in the figure window along with the bounding box that is defined using the full extent of the data. Review the settings.
5. Update any input settings values as needed to define the scenario. Settings available to update include:
    a. Domain updates
        i. Bounding box limits: Enter new bounding box minima and maxima or

        ii. **Import Shape File For Boundary**: Navigate to and select a shape file to define the boundary.
            Best Practices: Allow for a buffer of at least a few hundred meters around data.
    b. Time range for the start and end of the scenario
    c. Origin of the Grid
       Best Practices: If you change the bounding box limits, use the **Update Using Domain** button to get a new grid origin.
    d. Grid cell size
       Best Practices: The user must carefully choose a cell size that is small enough to gain the desired spatial resolution in the results, but large enough to avoid the physical constraints of the underlying data sources and to prevent excessive computational load.
    e. Filtering by Dredge State
    f. Whether or not to interpolate between track points
6. Save the IECA inputs in an INP file using the **Save Current Settings** button, naming the scenario. Using this button will build the default naming structure.
7. Run the IECA by pressing the **Preview Current Settings** button. This button will always offer to save or rename an INP file first.
8. Intensity results are calculated by the IECA using parameters from the INP file. For single runs, gridded Intensity values are displayed as a 'heat map' in a preview window in the GUI.
9. Toggle between plots using the **Intensity**, **Tracks**, and **Time Coverage** buttons to review results.
10. Input parameters can be updated, and the IECA can be re-run, and results displayed again.
11. When the results are satisfactory, export the data using the **Export Current Analysis** button, results will be exported to a gridded CSV file with an output file (OUT) into the Intensity folder.
12. Optional: In addition to this basic workflow for Intensity there are a few ways to create multiple scenario input files, and then run those files all at once. Creating and saving the files can be done in two ways:
    a. Multiple input files can be created and saved manually when making related scenarios on the same time range and updating any parameters.
        i. Set desired values and press the **Save Current Settings** button
        ii. Modify parameters and **Save Current Settings** again under a different file name, but the same folder location. This will create multiple INP files within the current folder. This should be done for every iteration a user is interested in running.
        iii. Press the **Multi-Scenario Run & Export** button, and select the set of scenario input files to run. Data will be loaded, run through the IECA, and exported. The user will be automatically moved into the Exposure Analysis view.
    b. Multiple input files for a time series can be created automatically when a user wants to construct Intensity results with the same settings across a series of time frames.
        i. First the overall scenario is defined. Domain, filters, gridding parameters, etc. should all be completed. Set the time range **start** and **end times** fields to cover the entire rage of the series, and insure any/all possible CSV files over that time range have been identified and included in the scenario list.

ii. Once this ‘mega’ scenario is defined it can be divided up into shorter, equal length, scenarios by specifying, in days, the run time segment length of the individual scenarios in the provided box. Set the **Segment time** field, which has units of days, to any number. This will be the number of days that individual scenarios will cover.

iii. Press the **Build Batch Run Settings** button, a series of scenarios are constructed using all the current settings in sequential time ranges based on the start time, segment length, and end time supplied in the GUI. These scenario files are then created automatically and saved into the folder structure. A popup window will give you the option to run the files just created, and Intensity results will be created. The user is ready to move into the Exposure view.

2.3.2 Exposure Workflow

1. A single file or group of exported Intensity CSV files is the input to the IECA for the Exposure calculation, which aggregates and normalizes one or more Intensity files. The Exposure Analysis is a separate view within the GUI, with a different set of options from the Intensity analysis. Skip to the next step if the Intensity workflow automatically updated the GUI to the Exposure view.
   a) A new Exposure is opened by selecting Intensity file(s) to be aggregated and normalized. In the GUI select **Menu** > **New Exposure**
   b) Navigate to the folder containing the output files and gridded CSV files from an Intensity run (this usually in an *intensity*\\ folder)
   c) Select the files to include in the Exposure calculation; use Ctrl to select multiple files
2. The only option to update for an Exposure run is the set of Intensity files to include in the run. Within the GUI a user can review the heat map of Intensity and the input settings for each scenario before running Exposure, and add or remove Intensity scenario files from the set as needed. Add and remove scenarios from the Exposure run using the **Choose Scenarios** button.
3. Remove scenarios by highlighting them in the 'File List' table, and press **Remove Selected**.
4. To display file properties of the selected scenario in the File Properties table and visualize the gridded data, select one scenario and press the **View Input** button below the plotting window.
5. To run the Exposure model with the current set of Intensity files, press the **Run Exposure Model** button. Exposure values are calculated and can be previewed as a heat map in the GUI.
6. At the same time the Exposure values are calculated, a set of default ISO metadata fields are populated. ISO metadata default values can be viewed and updated by the user from the GUI. To update, press the **Update Metadata** button—you can update one section of metadata at a time. <u>Best Practices:</u> do NOT update all the fields; most are populated automatically with information from the files that were used, it is recommended that users have a good understanding of which fields should be updated before changing the default field values (see Appendix 3 for more information).
7. Once Exposure has been run, press the **Export** button. Results are exported to a gridded CSV, GeoTIFF, and ISO metadata files. These products are compatible with and designed for use with prominent GIS applications for further analysis and comparison with other data sets.

3.1 Saved Data and Products

The overall workflow has several points where data are saved. If processing of the files is done in stages or needs to be redone there are several locations where a user can re-enter the processing workflow without having to completely start over. Initially data files are saved from the DQM database, and after data acquisition these files should never be modified. The IECA uses these files as inputs, but never modifies the original files.

The next save point is during the Intensity processing when INP scenario input files are created. Once scenarios have been defined, the IECA can process data and those outputs (gridded CSV and output file) are saved into an 'Intensity' folder. Finally, the Intensity files are further processed and normalized with results (gridded CSV, GeoTIFF, and XML) saved into the 'Exposure' folder (Figure 3).

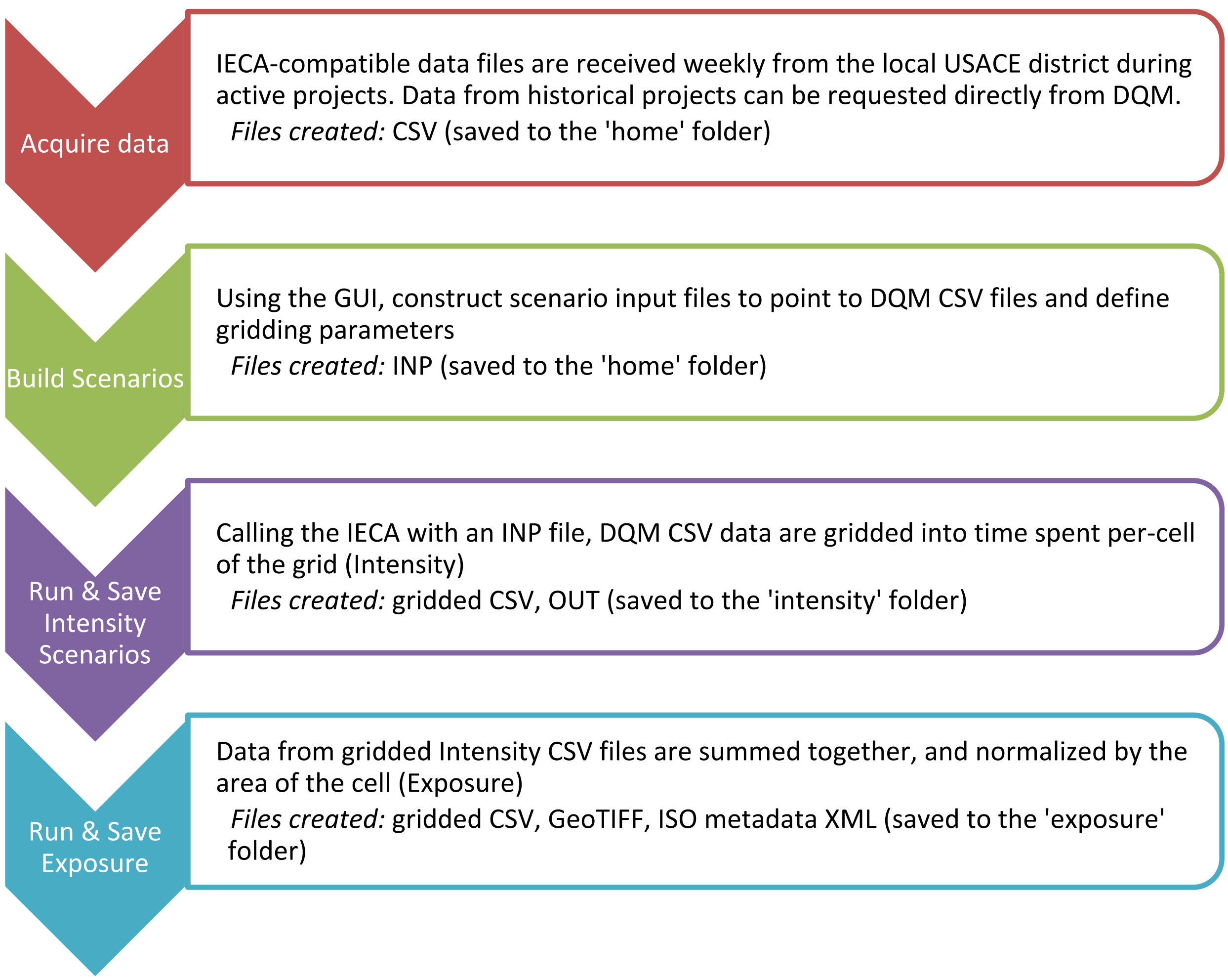


Figure 3. Points within the IECA workflow where data are saved.

Once the IECA processing is complete, statistics can be built from the gridded CSV files, or maps can be created in ArcGIS software. The exported GeoTIFF files constructed in the IECA can be loaded into ArcMap and displayed along with other data layers (see 5.3 ArcMap Processing: Benthic Impacts, Mineral Utilization). One point to make note of is that the gridded CSV files are saved 'upside-down'. That is, the files are read left to right and top to bottom, while map projections are right to left and bottom to top. You can refer to the Universal Transverse Mercator (UTM) grid location embedded in the data as the row and column headers to identify each location (Figure 3):

Description	File
columns rows	`850 578 2`
1st data point in UTM	`666350 3696850`
Cell height/width	`100 100`
Projection code	`EPSG:32617`
Input file name	`Scenario_Path:Island_20170910.out`
File with metadata	`Scenario_Metadata:C:\BOEM\exposure\Island_20170910.xml`
UTM Easting [West > East]	`NaN, 666350.0,666450.0,666550.0,666650.0,666750.0`
Northing [South] data, etc.	`3696850.0, -9.0, -9.0, -9.0, -9.0, -9.0`
	`3696950.0, -9.0, 0.0, 0.0, 0.0, 0.0`
.	`3697050.0, -9.0, 0.0, 0.0, 0.0, 0.0`
.	`3697150.0, -9.0, 0.0, 0.0, 0.0, 0.0`
.	`3697250.0, -9.0, 0.0, 0.0, 0.0, 0.0`
.	`3697350.0, -9.0, 0.0, 0.0, 0.0, 0.0`
.	`3697450.0, -9.0, 0.0, 0.0, 0.0, 0.0`
.	`3697550.0, -9.0, 0.0, 0.0, 0.0, 0.0`
Northing [North] data, etc.	`3697650.0, -9.0, 0.0, 0.0, 0.0, 0.0`

4 Functionality of the IECA Application

Below are the overviews of the GUI for creating scenarios and estimating Intensity (Figure 4), the GUI for Exposure Analysis (Figure 22), and the list of button functionality.

4.1 Intensity Scenario View

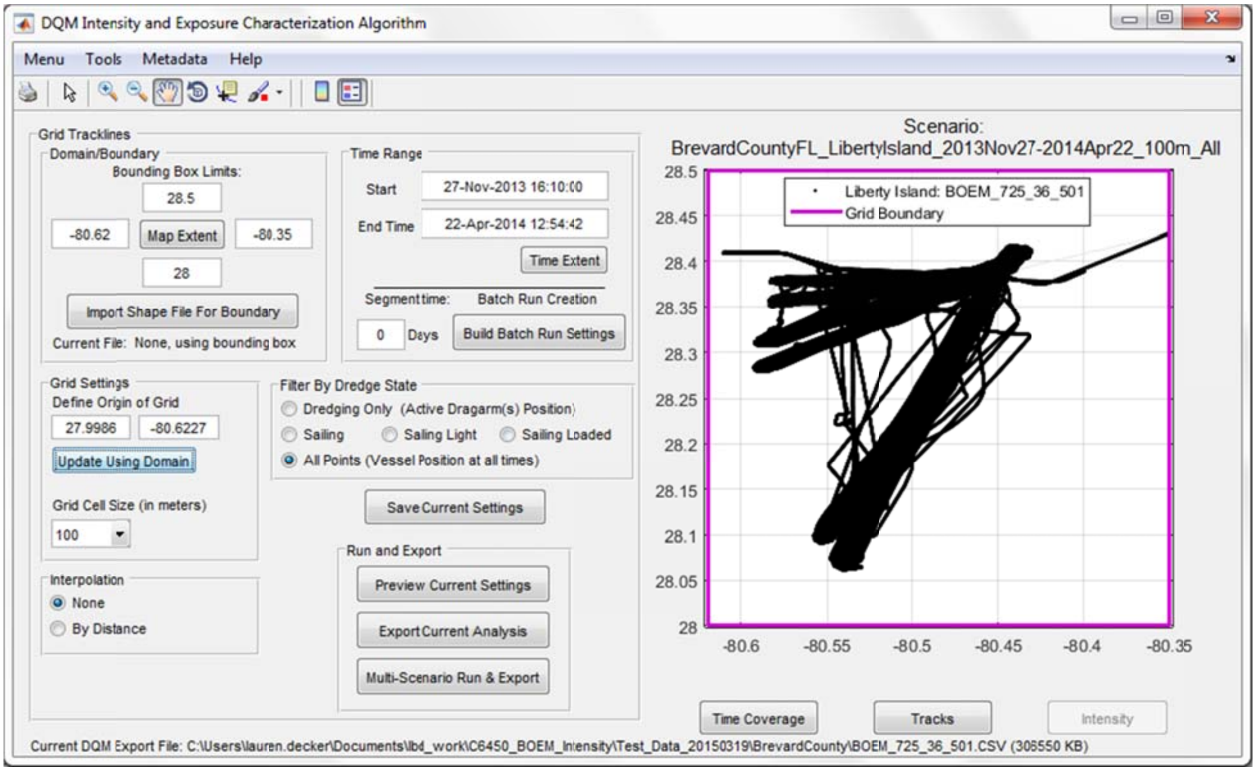


Figure 4. Overview of GUI for scenario creation and estimating Intensity.

The GUI in Figure 4 creates and updates scenarios as well as visualizing the raw (Tracks) and calculated (Intensity) results. Its functionality is as follows:

(1) **Menu** Options

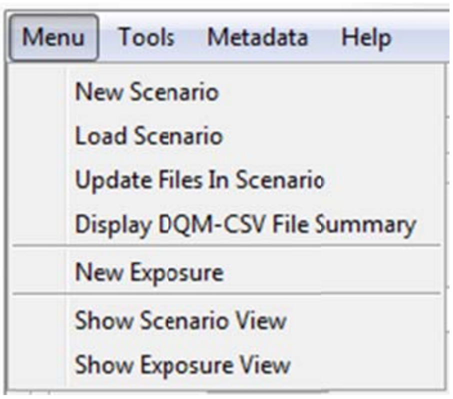


Figure 5. Menu: Menu options drop down.

a. **New Scenario**: Define a new Intensity scenario by choosing DQM exported raw data files to load.

b. **Load Scenario**: Load a previously saved INP or OUT file; when an OUT file is chosen the results from the processing are also loaded.

c. Update Files In Scenario: Change which files are referenced in the INP file.

d. **Display DQM CSV File Summary**: Quick information from any DQM CSV file, including the name of the dredge plant, project area, contract, and time range of the file. This option is purely for reference information and does not inform any other part of the GUI.

e. **New Exposure**: Moves the user to the Exposure view, and allows selection of OUT files to be compiled into an Exposure calculation.

f. **Show Scenario View**: When a user is in the Exposure view, this option will toggle back to the Scenario (Intensity) view. This will only save a single Scenario in memory.

g. **Show Exposure View**: When a user is in the Scenario view, this option will toggle to the Exposure view. If scenario parameters were updated, Intensity will be recalculated before moving to Exposure.

(2) **Tools**

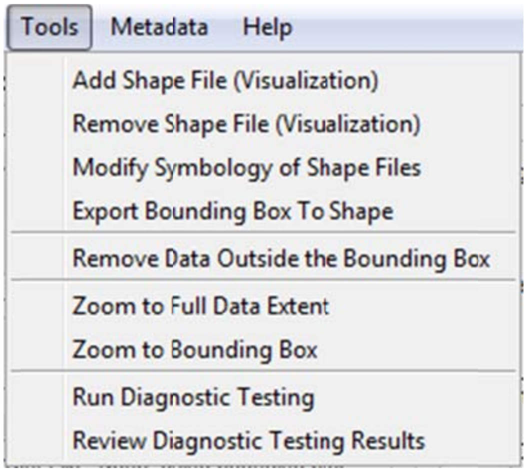


Figure 6. Menu: Tools drop down.

a. **Add Shape File (Visualization)**: Select a shapefile to display that will only be used in the visualizations, not in the IECA algorithms.
b. **Remove Shape File (Visualization)**: Select and remove shapefiles that are only being used for visualizations.
c. **Modify Symbology of Shape Files**: Update the color and line style of shapefiles that are being used for visualizations.
d. **Export Bounding Box To Shape**: Takes the current bounding box and exports it to a shapefile. The user can name and import the shapefile as either a visualization or a domain for IECA calculations.
e. **Remove Data Outside the Bounding Box**: Removes location data from the current session (not from the data file) to clean up data for easier review.
f. **Zoom to Full Data Extent**: Updates the visualizations zoom level to show all data from the current DQM data file.
g. **Zoom to Bounding Box**: Updates the visualizations zoom level to show the extent of the current bounding box.
h. **Run Diagnostic Testing**: Runs a test on the current computer to see how long some files will take to process. Builds ‘spoof’ data sets and processes them, recording how long it took to run the IECA algorithms.
i. **Review Diagnostic Testing Results**: Simple pop up plots showing the time taken to run the IECA diagnostic testing.

(3) **Metadata**

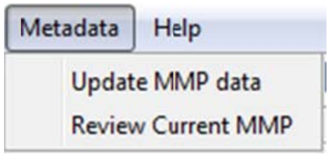


Figure 7. Menu: Metadata drop down.

Update MMP data: Pull data in from the BOEM–DQM crosswalk document, linking BOEM projects and lease numbers to DQM data. BOEM lease no., project name, and borrow area name are saved in the ISO metadata in the final products.
Note that the crosswalk document will need to be updated with new project information after the start of a new contract.

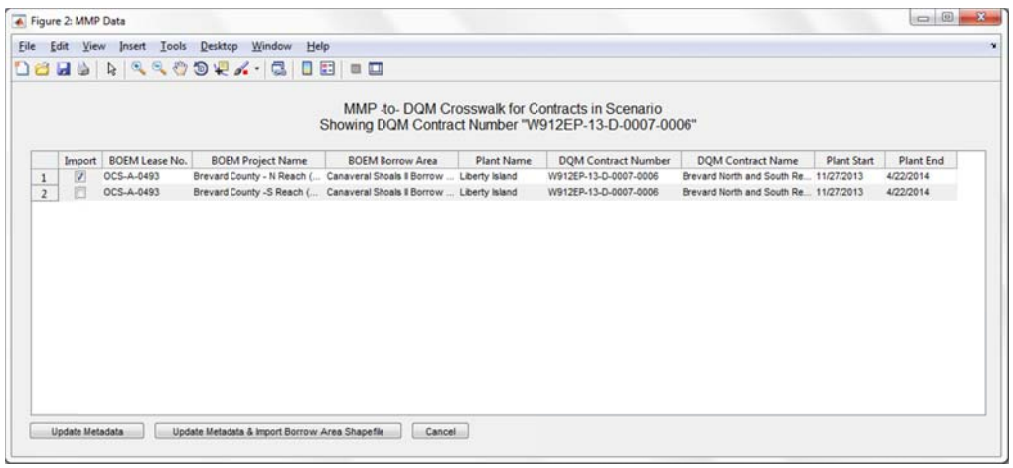


Figure 8. Pop up window: MMP to DQM Crosswalk view.

a. **Review Current MMP**: Pop up window shows the MMP data that has been attached to the current file, and has the option to remove the data that has been attached.

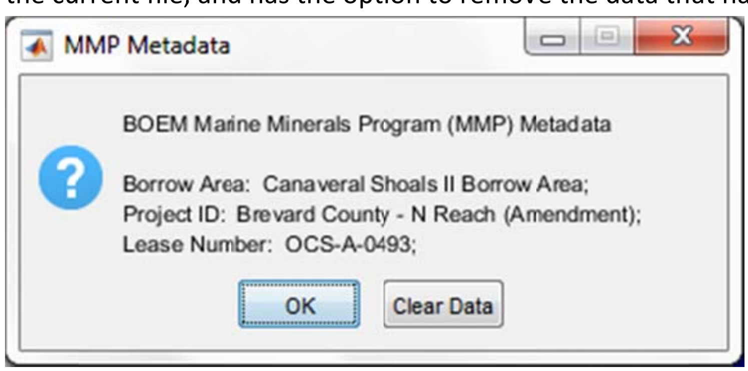


Figure 9. Pop up window: MMP information attached to the current Scenario.

(4) **Help**

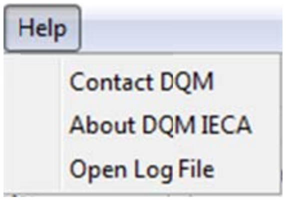


Figure 10. Menu: Help drop down.

a. **Contact DQM**: Displays the DQM website URL.
b. **About DQM IECA**: Displays the DQM IECA version number and date last updated.
c. **Open Log File**: Opens in a text editor the log file record of button-presses and messages that MATLAB produces and saves while running the GUI. This file can be referenced in the case of reviewing methods that were used when processing, de-bug issues/program crashes, etc.

(5) Visualizations

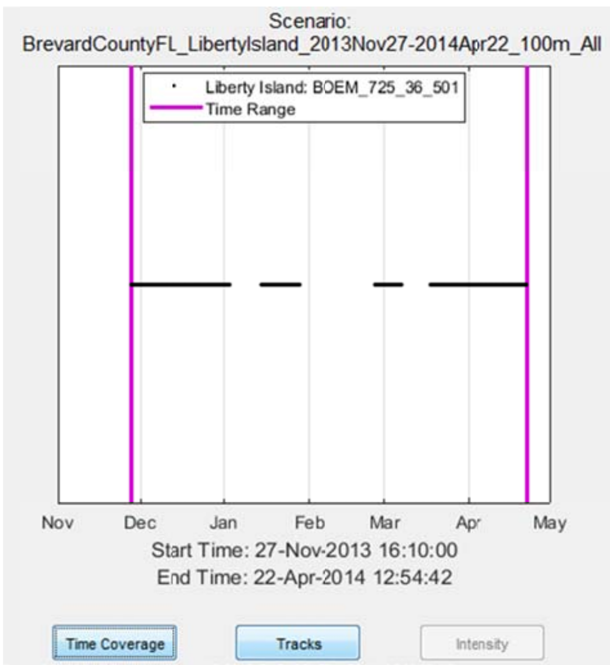


Figure 11. Zoom of GUI: visualizations window, time series data.

a. **Time Coverage**: Displays the time covered by each file; data are represented by points.

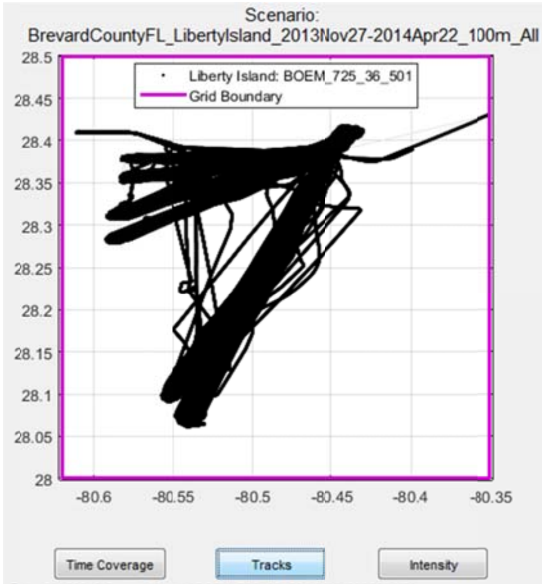


Figure 12. Zoom of GUI: visualizations window, track data.

b. **Tracks**: Displays latitude and longitude GPS position, data are represented by:
   i. Faint gray lines showing the track.
   ii. Black (single file) or Colored (multi-file) points.
   iii. Dark gray points for entire files that are excluded due to scenario parameters (all data within the file are entirely outside the spatial or temporal domains).
   iv. Pink line representing the boundary.

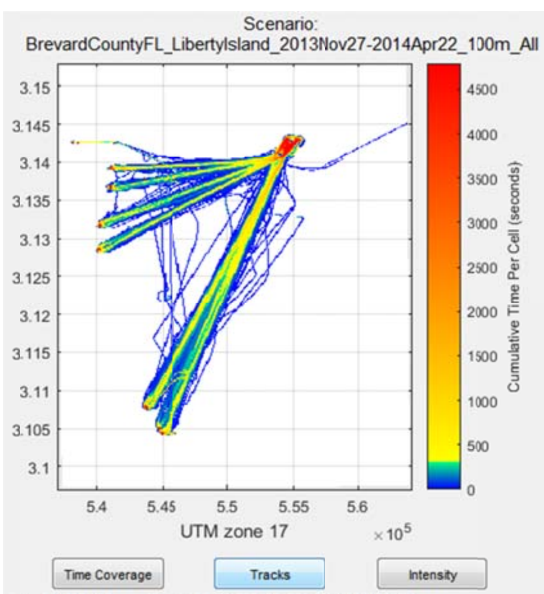


Figure 13. Zoom of GUI: visualizations window: Intensity heat map.

c. **Intensity**: After Intensity values have been calculated, displays the heat map of cumulative time per cell in seconds.

(6) Domain/Boundary: when these values are updated, the pink boundary in the visualization is updated. When the scenario is run the boundary will be used to filter the data.

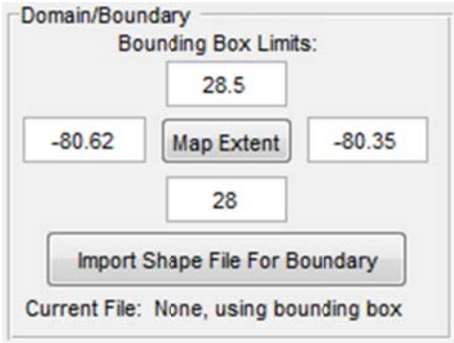


Figure 14. Zoom of GUI: Domain selection.

a. Option one: Input min and max latitude and longitude values to define a bounding box in the four provided text boxes

North Extent

West Extent East Extent

South Extent

b. Option two: Zoom to the extent of interest in the visualization window, and select the **Map Extent** button. This will populate the N-S-E-W bounding box limits and set the scenario domain to that region.

c. Option three: Press **Import Shapefile For Boundary** button to navigate to a file that contains vertices defining a closed boundary; when a shape file is selected it will display the file path and name in the "Current File" area

(7) Grid Settings

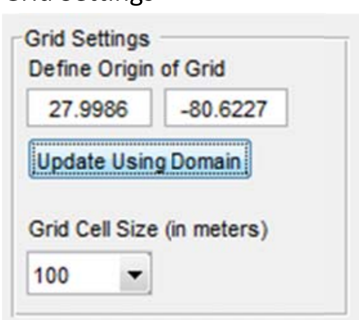


Figure 15. Zoom of GUI: Grid Settings.

a. Define Origin of Grid: Input latitude and longitude point coordinates. The **Update Using Domain** button bases the origin off the most South and most West extent of the domain in UTM. A 100 m buffer is applied and values are rounded down to the nearest 100 m in UTM; the function returns the values in latitude and longitude.

b. **Grid Cell Size (in meters)**: Pull down menu to select from the options 100, 50, 25 and 10.

(8) Time Range

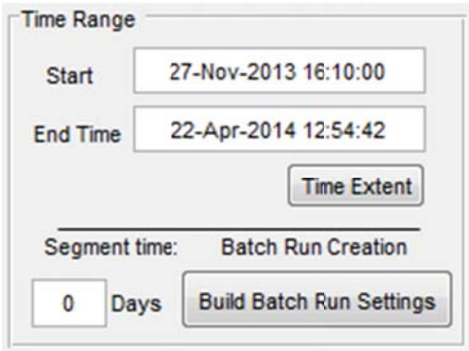


Figure 16. Zoom of GUI: Time Range settings.

a. Every scenario will have a **Start**/**End Time**, and the format is specifically:
dd-mmm-yyyy HH:MM:SS
day – three letter month – full year hours : minutes : seconds
b. **Time Extent**, similar to **Map Extent**, will update the start and end times of a scenario based on the visualization window when plotting '**Time Coverage**'.
c. **Segment time**: (optional) identifies the segment length, in days, when creating a batch time series of scenarios.
d. **Build Batch Run Settings** (optional): creates the scenario input files of the specified time interval based on the batch run time '**Segment time**' length value, and starting and ending based on the **Start** Time and **End Time**. All other settings are taken from the current choices on the GUI and are identical among the multiple scenario files.

(9) Filter By Dredge State: Radio button options between the available filters

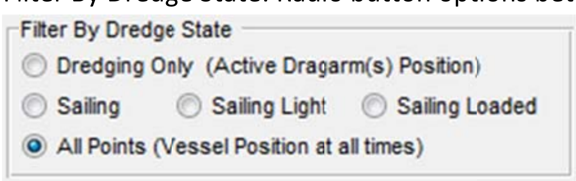


Figure 17. Zoom of GUI: Dredge State filters.

a. **Dredging Only** – uses drag arm(s) position only while arm is actively dredging – DQM-determined Dredge State is "Dredging" and the drag arm activity indicator is "true" for that arm.
b. **Sailing** – uses vessel position while in transit, both light and loaded – DQM-determined Dredge State is "Sailing Light" or "Sailing Loaded".
c. **Sailing Light** – uses vessel position only while in transit and the hopper likely contains little or no dredged material – DQM-determined Dredge State is "Sailing Light".
d. **Sailing Loaded** – uses vessel position only while in transit and the hopper likely contains dredged material – DQM-determined Dredge State is "Sailing Loaded".
e. **All Points** – uses vessel position at all points regardless of Dredge State.

(10) Interpolation

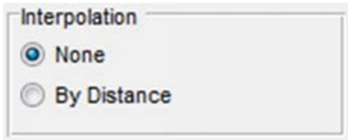


Figure 18. Zoom of GUI: Interpolation option.

a. **None**: No interpolation - use the original GPS location data.
b. **By Distance**: Interpolate along track lines where necessary to ensure distances between points are no larger than ½ the size of the cells.

(11) **Save Current Settings**

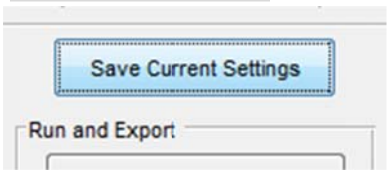


Figure 19. Zoom of GUI: Save Current Settings button.

Creates an INP file using the default naming structure:
unique set of “PROJECT”; unique set of “DREDGE_NAME”; the Date start - Date end; then the Grid Cell Size in m; and finally the Dredge State filter (All, Dredging, or Sailing light/loaded)
<Project>_<Plant>_<start Date>-<end date>_<cell size>m_<Dredge State filter>
Example: BrevardCountyFL_LibertyIsland_2013Nov27-2014Apr22_10m_All

(12)Run and Export

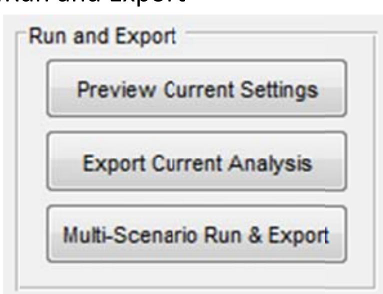


Figure 20. Zoom of GUI: Run and Export buttons.

a. **Preview Current Settings**: Calls the IECA to build Intensity using the current settings, and displays a heat map of cumulative time per cell, in seconds.
b. **Export Current Analysis**: Saves the Intensity results to a gridded CSV file, along with an OUT file containing settings and some values for the metadata.
c. **Multi-Scenario Run & Export**: Option to run and export multiple scenarios at once (batch process) without a preview.

(13) Current File

Figure 21. Zoom of GUI: current file(s) display.

Displays the DQM export files that are being referenced, and their size in KB.

4.2 Exposure View

The GUI for Exposure Analysis completes calculations on previously saved Intensity scenarios. An overview of the user interface is shown in Figure 22. Its functionality is as follows:

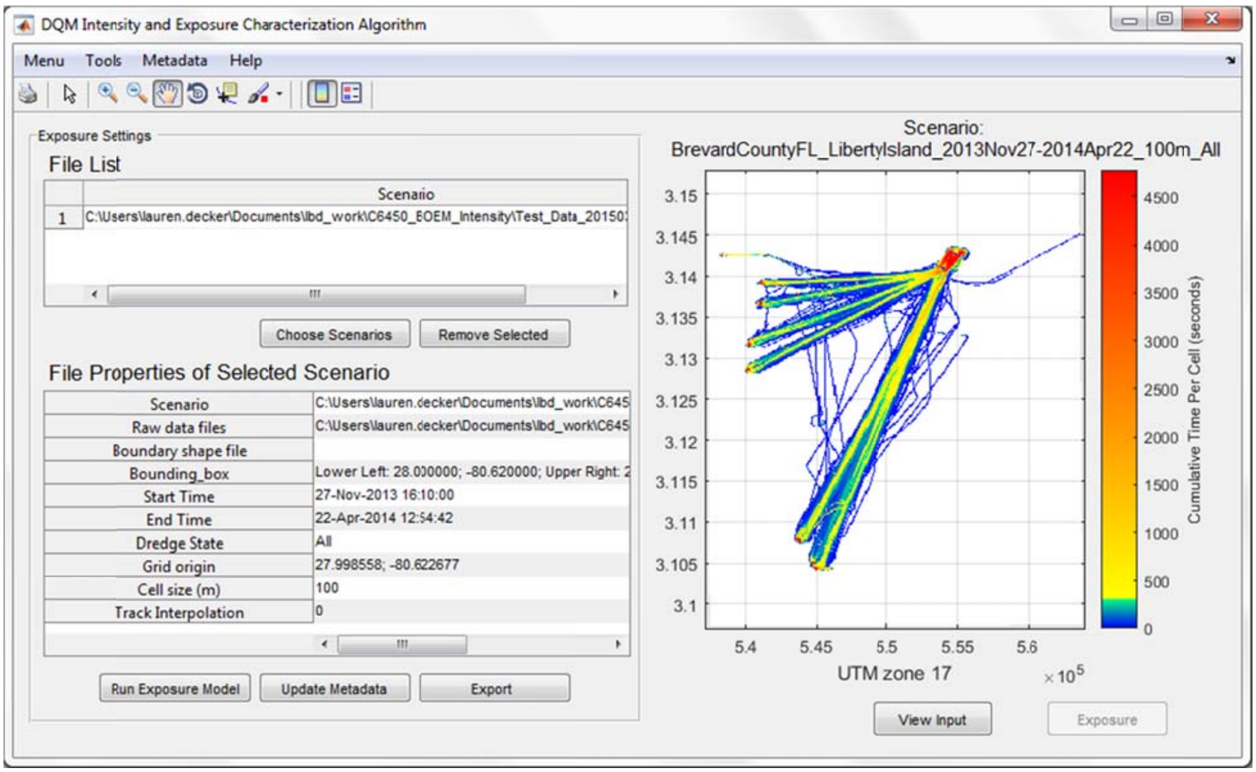


Figure 22. Overview of GUI for Exposure Analysis.

(1) File List

Figure 23. Zoom of GUI: Exposure file list.

Displays the Intensity scenarios to be aggregated into an Exposure

a. **Choose Scenarios**: Allows user to add and remove scenarios in the current folder from the Exposure Analysis.

b. **Remove Selected**: Removes the currently highlighted scenario from the list.

(2) Visualizations

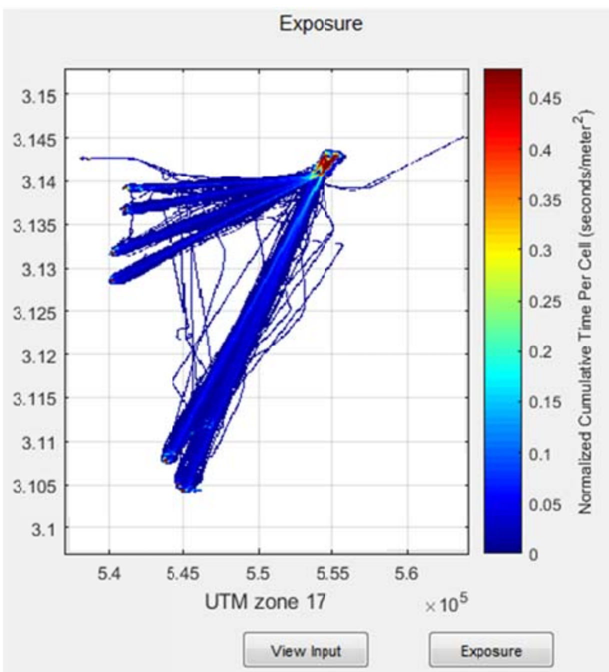
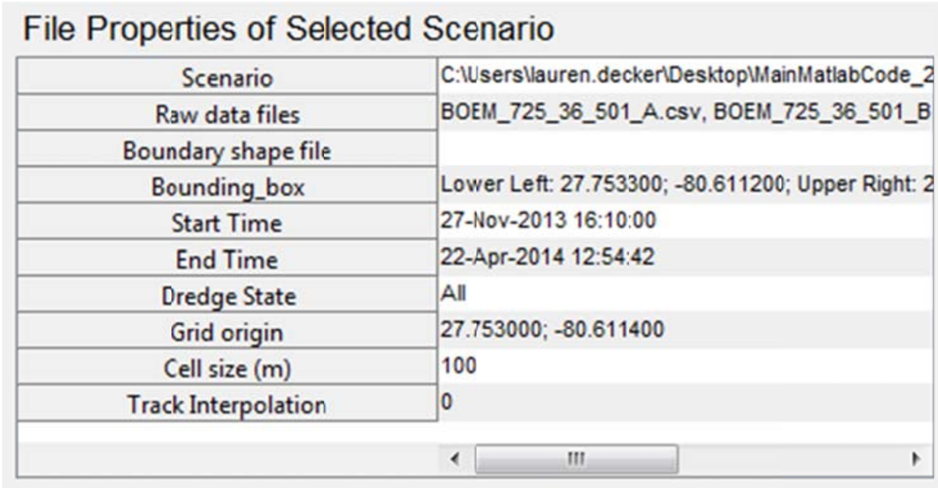


Figure 24. Zoom of GUI: visualization of Exposure results and Intensity inputs.

a. **View Input**: Updates the GUI to display the currently highlighted Intensity scenario from the File List table. Note that this button also updates the parameters displayed in the "File Properties" window.

b. **Exposure**: After an Exposure run has been completed, this updates the window to show the Exposure heat map

(3) File Properties of Selected Scenario



File Properties of Selected Scenario

Scenario	C:\Users\lauren.decker\Desktop\MainMatlabCode_2
Raw data files	BOEM_725_36_501_A.csv, BOEM_725_36_501_B
Boundary shape file	
Bounding_box	Lower Left: 27.753300; -80.611200; Upper Right: 2
Start Time	27-Nov-2013 16:10:00
End Time	22-Apr-2014 12:54:42
Dredge State	All
Grid origin	27.753000; -80.611400
Cell size (m)	100
Track Interpolation	0

Figure 25. Zoom of GUI: File Properties of a Selected Scenario.

(4) Displays the INP file properties of the Intensity scenario selected in the File List; one file's properties are shown at a time. The user can review each file's properties by highlighting a new scenario in the File List, and pressing the **View Input** button. Note that this button will display the selected file's properties as well as updating the Intensity preview figure.

(5) Run, Update Metadata, and Export

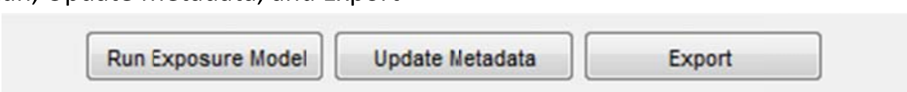


Figure 26. Zoom of GUI: Run Exposure Model, Update Metadata, and Export buttons.

a. **Run Exposure Model**: Calls the Exposure calculation using the current set of Intensity scenarios in the File List as input, and displays the resulting Exposure heat map in the visualization window
b. **Update Metadata**: Displays a menu of ISO metadata sections for the user to review and update from the default values created during an Exposure run – further description is below
c. **Export**: Creates a gridded CSV of Exposure, along with a GeoTIFF and associated ISO metadata output

(6) Update Metadata – detail

Figure 27. Pop up window: ISO Metadata sections that a user can update.

Displays choices of ISO metadata sections the user can choose from to review and update the default values created during an Exposure run. A full list of sections and values that can be edited from the GUI are seen in Table 1. Section titles are also shown in Figure 27. The user must pick one section to edit at a time. When a section is chosen, the ISO metadata template section with tags and default values is displayed (Figure 28). The user can review and update the fields as necessary and then press "OK" to save; this process must be repeated for each section to be updated. The example shown in Figure 28 is for the section **datasetsInfo**.

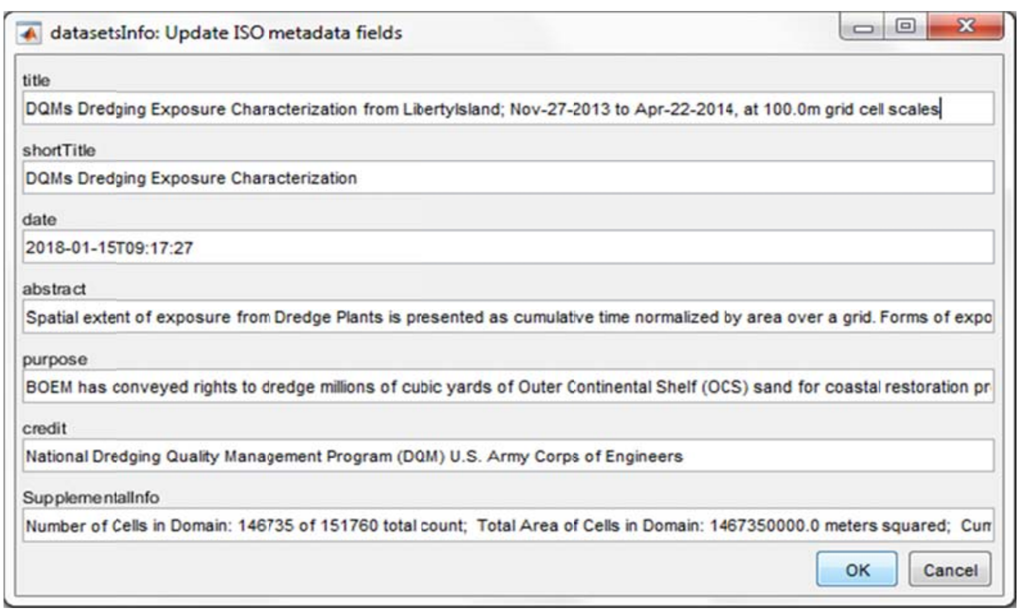


Figure 28. Pop up window: example of an ISO metadata section (datasets Info) while updating.

Below are the metadata sections and fields that can be updated from the GUI; see Appendix 3 for more information.

Table 1. Metadata fields with values that can be reviewed within the GUI.

Review	Code name
	spatialRepresentationInfo
	dimensionSize_row
	gridSz_row_km
	dimensionSize_col
	gridSz_col_km
	referenceSystemInfo
	ESPG_code
	datasetsInfo
✓	Title
✓	shortTitle
	Date
✓	Abstract
✓	Purpose
✓	Credit
	SupplementalInfo
	descriptiveKeywords
	thesaurusName_DQM_Info
	Borrow
	Plant
	contractNum
✓	ISOCountrySubdivisionCode
✓	FIPS_StatePostalCode
✓	FIPS_StateFIPSCode
✓	FIPS_CountyFIPSCode
✓	FIPS_CountyName
✓	FIPS_ClassCode
	MMP Data Source
✓	BOEM_BorrowArea
✓	BOEM_LeaseNo.
✓	BOEM_ProjectID
✓	BOEM_MMPFile
✓	BOEM_MMPFileDate

Review	Code name
	DataExtent
	northBoundingLatitude
	eastBoundingLongitude
	southBoundingLatitude
	westBoundingLongitude
	start
	end
	TransferOptions
	size
	url
	Lineage
✓	dateOfCSVPull
	dateOfIntensityRun
	CSVFilesUsed
	ScenarioFilesUsed
	inpFileSettings
	dateOfExposureRun
	PlantNames
	brokenBestPractices
	OutOfUTMZone
	MuiltiGridCellSize
	MultiDredgeState
	MuiltiTrackRez
	MultiBB
	TimeRngOverlap

5 Case Studies

5.1 Project Monitoring Sequence

5.1.1 Situation

BOEM is monitoring an active project. On a weekly basis CSV files are delivered by DQM that contain the most recent activity. In order to integrate the data in a consistent product to show progress and cumulative activity, a set of files are created that can review in a GIS mapping system.

5.1.2 Initial Setup: Weekly Dredging Impact Products

(1) For new projects, when an initial weekly deliverable (CSV file) is received, create a new folder for the project to contain all the data files and products.
(2) Start the GUI.
(3) Select **New Scenario** in the initial opening menu; or from **Menu** > **New Scenario** within the GUI.

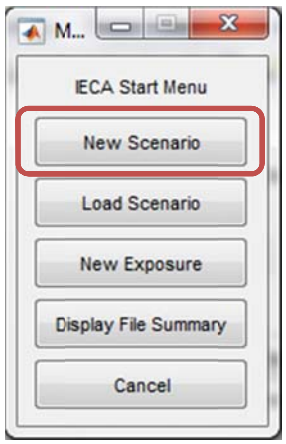


Figure 29. Monitoring sequence exercise: initial pop up window of the IECA GUI.

(4) Navigate to and select the DQM CSV data file from the folder location it was saved in. The map will populate with the new data, and default values will be initialized.
(5) Import the BOEM Marine Minerals Program metadata, and borrow area shapefile for this project.
   a. Go to **Metadata** > **Update MMP data**

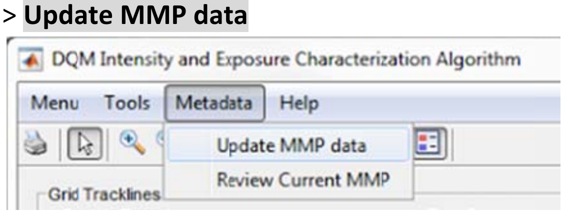


Figure 30. Monitoring sequence exercise: update MMP data

   b. Navigate and select the most recent "crosswalk" document that links BOEM lease numbers with DQM Contract numbers. This should be an Excel document that is updated manually as new BOEM projects begin.

c. Review the options listed. The code will use the DQM contract number in the input CSV file as a filter to reduce the number of choices shown; when it uses this method the title will say: Showing DQM Contract Number "xxx". However, if there are no entries in the crosswalk document that match the DQM contract number from the input CSV data file, no filter will be applied and all projects will be listed. This is usually an indication that the crosswalk document should be updated to include a new DQM contract and BOEM lease relationship.
d. Identify the specific project to use, then cross check with BOEM records that the BOEM metadata information is correct. The Lease number, Project Name, and Borrow Area are all included in the final ISO metadata products. If any of these values is inaccurate, update them in the Excel crosswalk document.
e. Select the appropriate entry, and press **Update Metadata & Import Borrow Area Shapefile** in the pop up window.

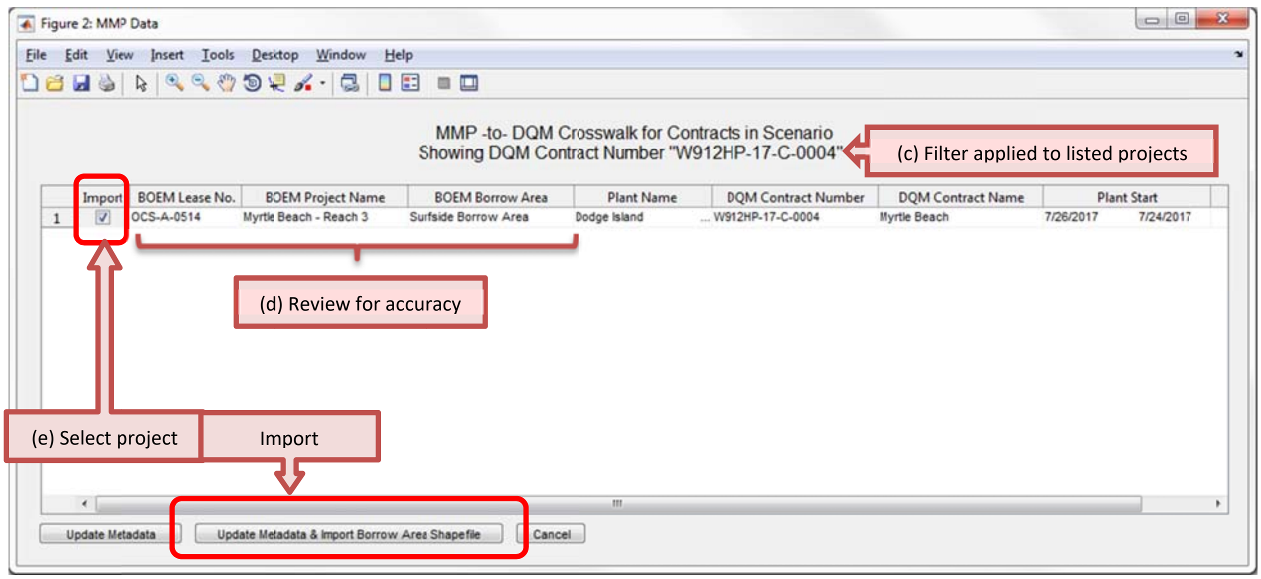


Figure 31. Monitoring sequence exercise: select MMP data

f. Navigate to and select the lease areas shapefile, select open. Once imported, there should be a visualization-only-shapefile showing the borrow area associated with the BOEM lease number. Visualization shapefiles, as opposed to boundary shapefiles, are indicated in the plots legend as a "Shapefile: <name of shape file>". They are not used in the IECA algorithms to filter data. *Note: the MMP shape file may need to be updated as new projects begin.*

(6) Set up the bounding box (area of interest) by reviewing where data are located in the data file, and where anticipated project areas may extend to.

a. Save the bounding box for this project as a shape file, so it can be referenced in other scenarios or other mapping programs.
   i. Go to: **Tools** > **Export Bounding Box To Shape**
   ii. Update the default name of the shapefile to: Boundary_FullExtent_<Name Of Project>
   iii. Save the shape file in the 'Home folder' with the DQM CSV file

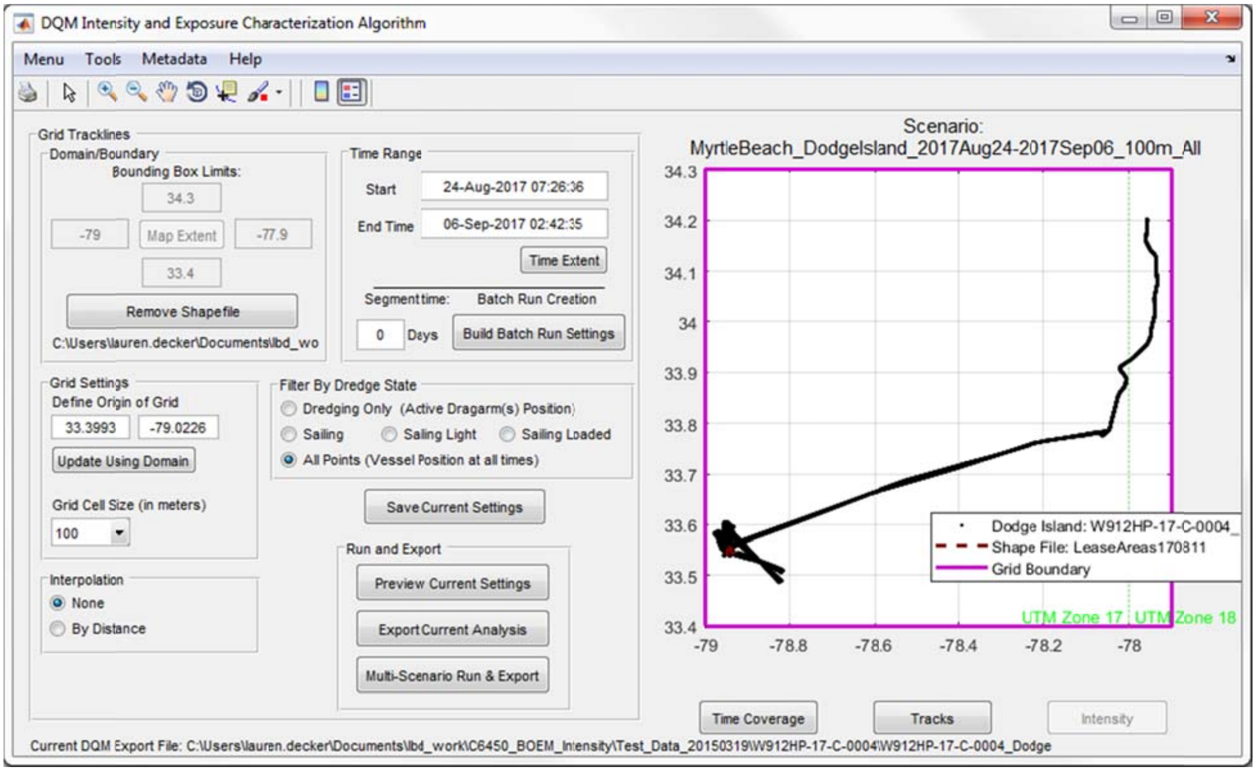


Figure 32. Monitoring sequence exercise: defining the bounding box.

b. **Optional step** if the grid is too large to calculate Intensity: reduce the domain size by focusing on dredging area and save the new, smaller bounding box for this project as a new shapefile.

   i. Go to: **Tools** > **Export Bounding Box To Shape**

   ii. Update the default name of the shapefile to: Boundary_DredgeAreaFocus_<Name Of Project>

   iii. Save the shape file in the 'Home folder' with the DQM CSV file

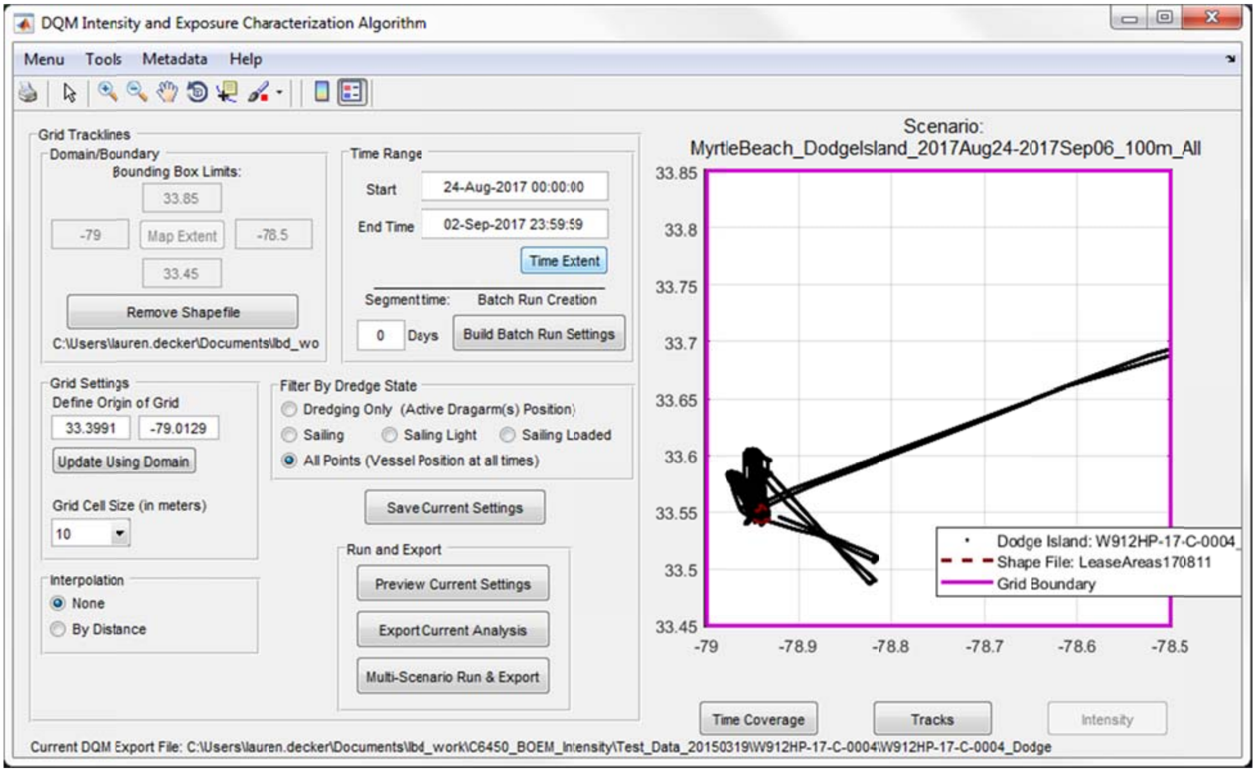


Figure 33. Monitoring sequence exercise: defining a reduced size bounding box.

c. Update the domain used in the scenario to the shapefile that was just created. Press the **Import Shapefile For Boundary** button on the GUI. Then navigate to and select the shape file just created.

d. Double check that the grid origin is correct by pressing the button **Update Using Domain**. The domain should have been updated while boundary map extents were being updated.

(7) Setting Time Increments: set the time to exact week-long increments

a. Set the **Start** Time: Sunday of the current week, hour 00:00:00

b. Set the **End Time**: Saturday of the current week, hour 23:59:59

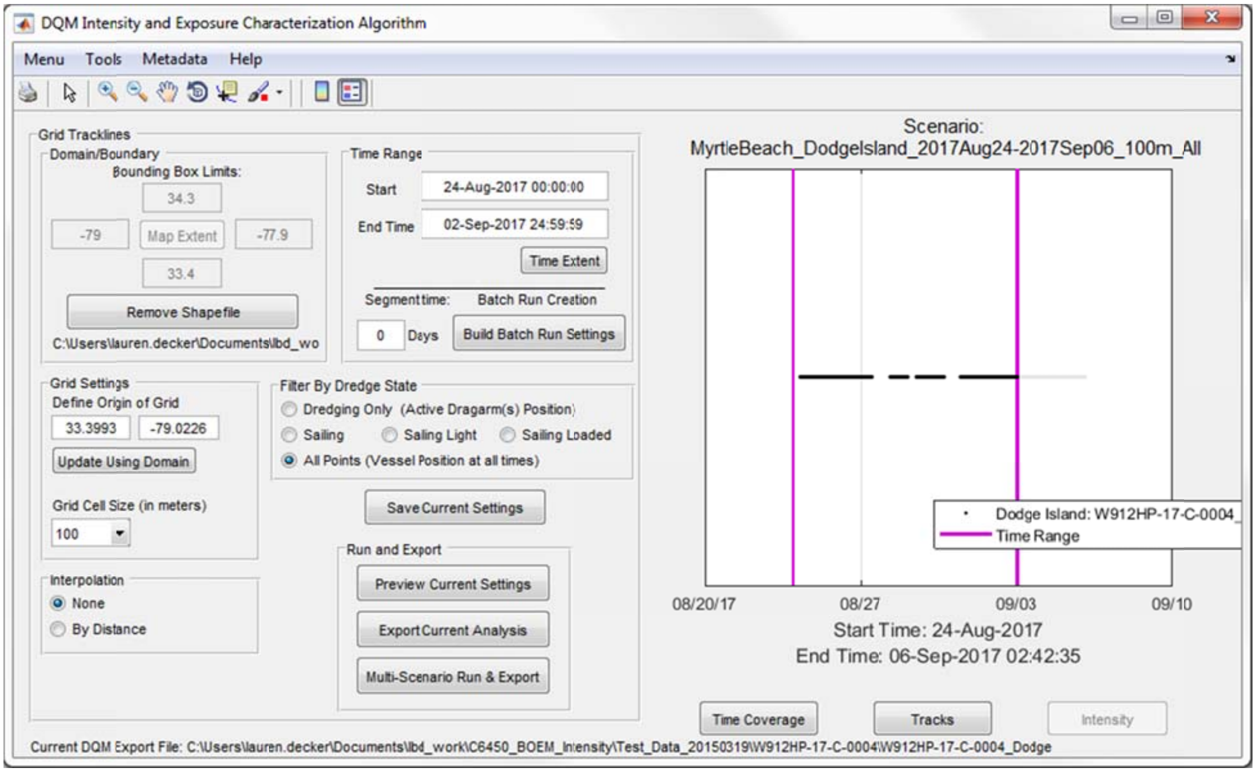


Figure 34. Monitoring sequence exercise: defining the time range.

(8) Set filter by Dredge State to "**Dredging Only**"

(9) Set the **Grid Cell Size** to 10 meters

(10) Keep interpolation off (default)

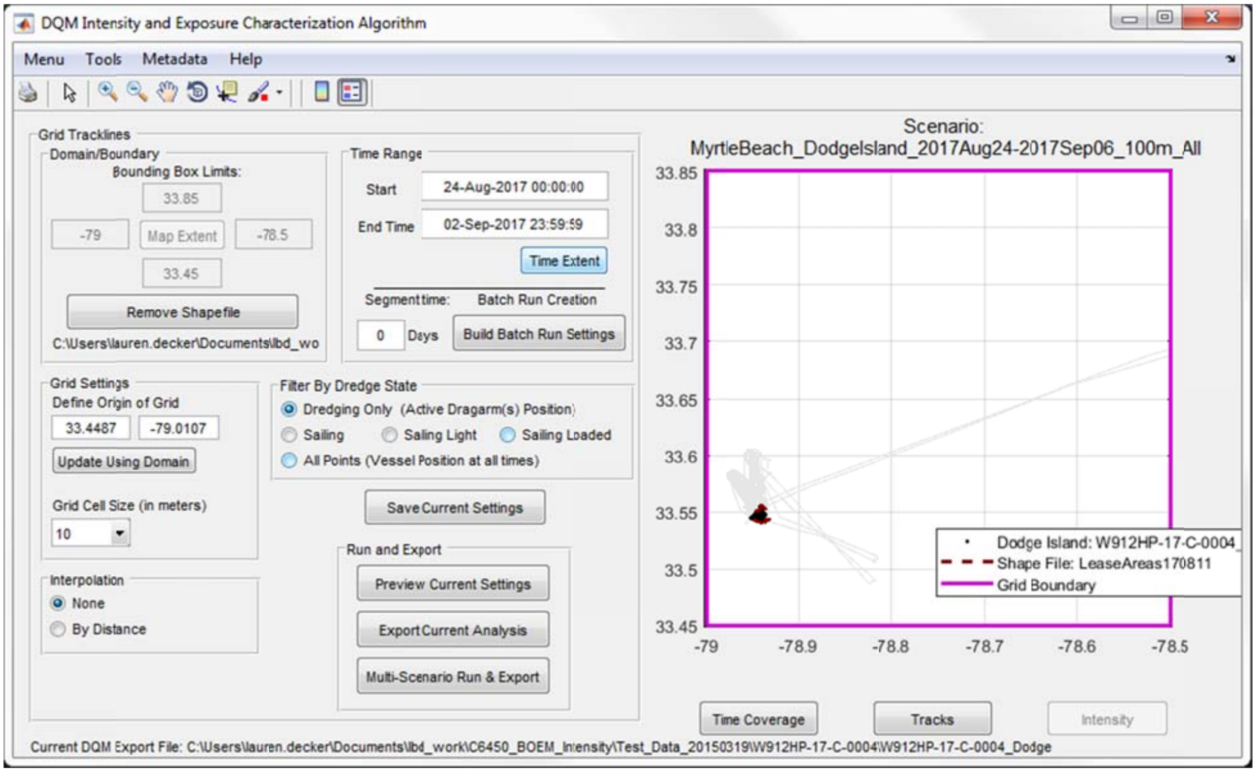


Figure 35. Monitoring sequence exercise: defining parameters.

(11)Press the **Tracks** button, and review your data using the **zoom tool**.

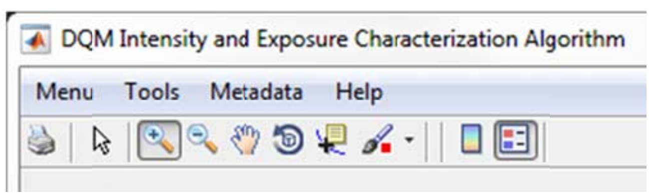


Figure 36. Monitoring sequence exercise: tools menu.

The plot will show exactly the data that will be used in the IECA processing, which for “Dredging Only” will be the position of each drag arm with an activity indicator of “true” while the plant was identified as dredging.

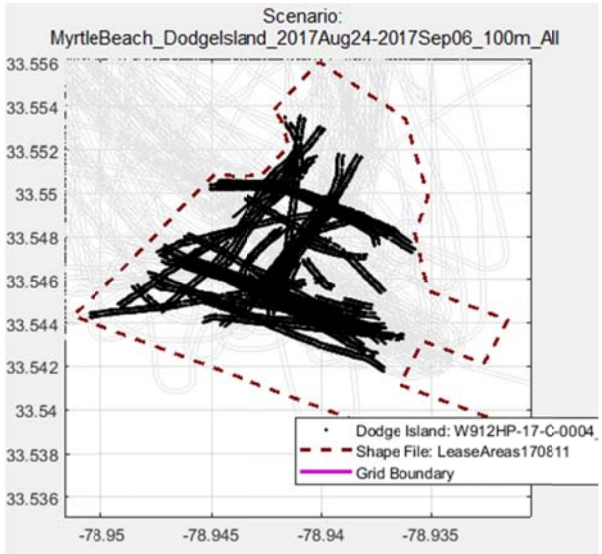


Figure 37. Monitoring sequence exercise: visualization of point data before Intensity is calculated.

(12) Run a preview of the first results - when grid extent is large or cell size is small this may take a few minutes.

a. Press **Preview Current Settings**
b. When the calculation is complete the plot will update with the Intensity results; a pop up box will ask "Would you like to move to the Exposure Analysis?" If you would like to review before moving on, choose "No" and after review press the button **Export Current Analysis** and move to the next step. Otherwise, press "Yes" on the pop up window.
c. Create a folder called "Dredging" under the Home folder; and save using the default name (location_plant_stDate-edDate_10m_Dredging.inp)
d. When the grid is saved, a pop up window will say "Export Complete!" and show the path where the files were saved.

(13) In the Exposure view for this example there should only be one scenario; review the file properties of the scenario then press **Run Exposure Model**.

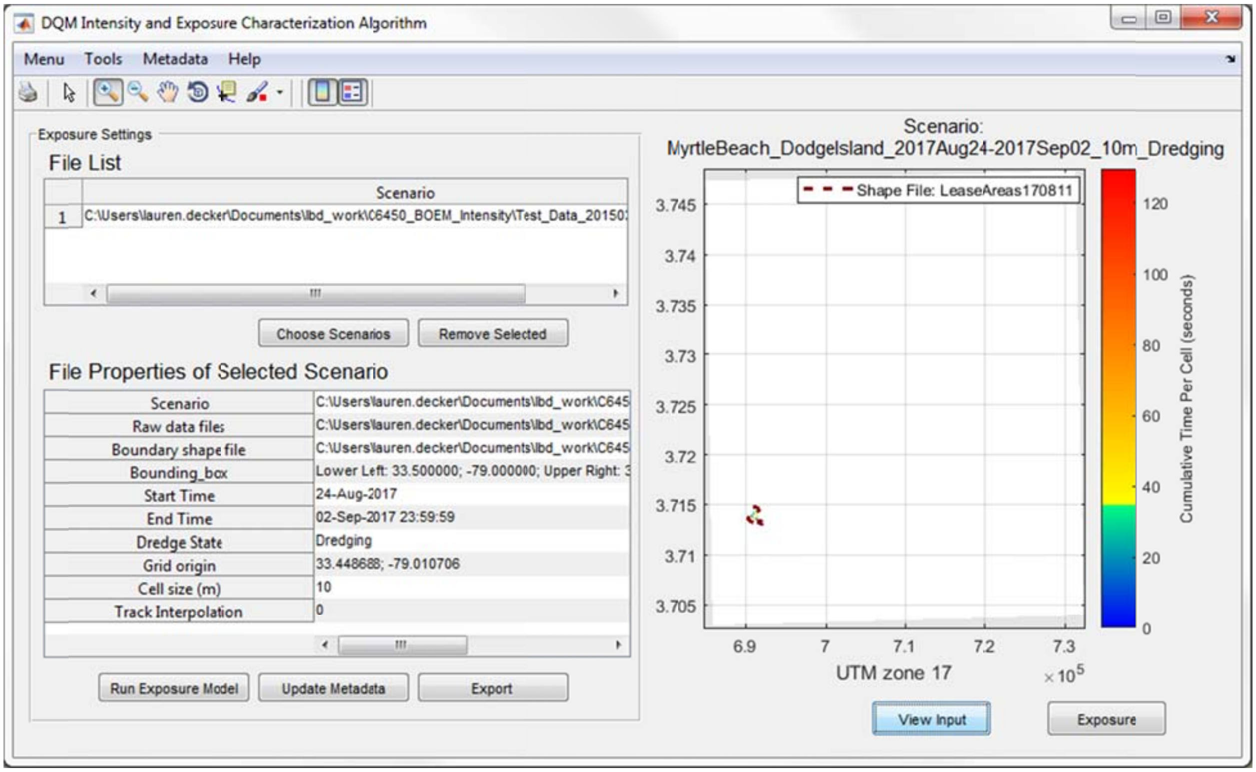


Figure 38. Monitoring sequence exercise: Exposure view showing one scenario.

(14)Once the run is completed, a pop up window will say "Exposure Calculation Complete;" press **OK**.

(15)To update the metadata before the final products are created, select **Update Metadata** from the GUI, then select which section to update from the pop up menu.

Figure 39. Monitoring sequence exercise: update the metadata.

a. Review “datasetInfo” and update as necessary. This section has the title, abstract, and supplemental information.

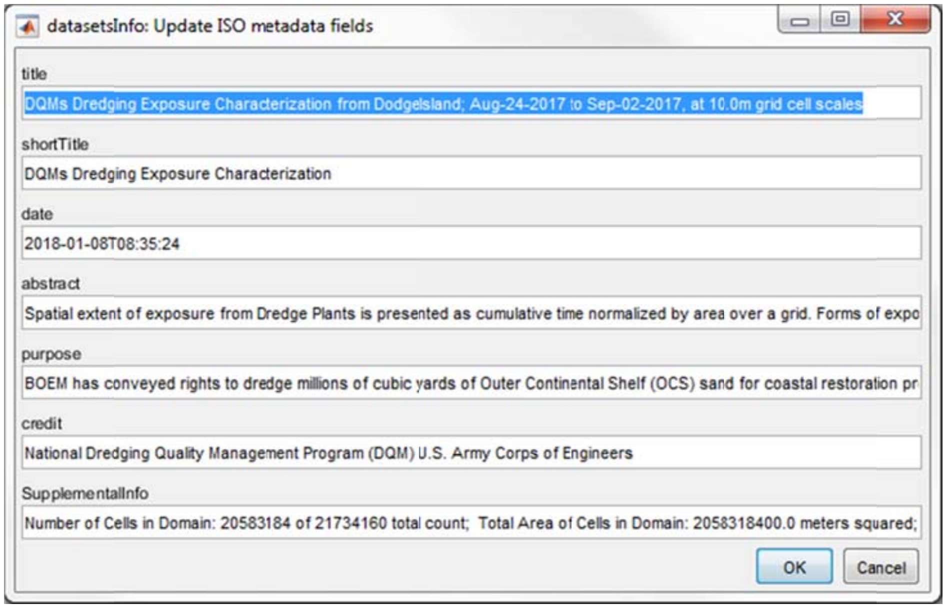


Figure 40. Monitoring sequence exercise: update the metadata 'dataset information' section.

b. The Descriptive Keywords section contains the FIPS codes, which are not automatically updated but just use an example set. These values should be updated.

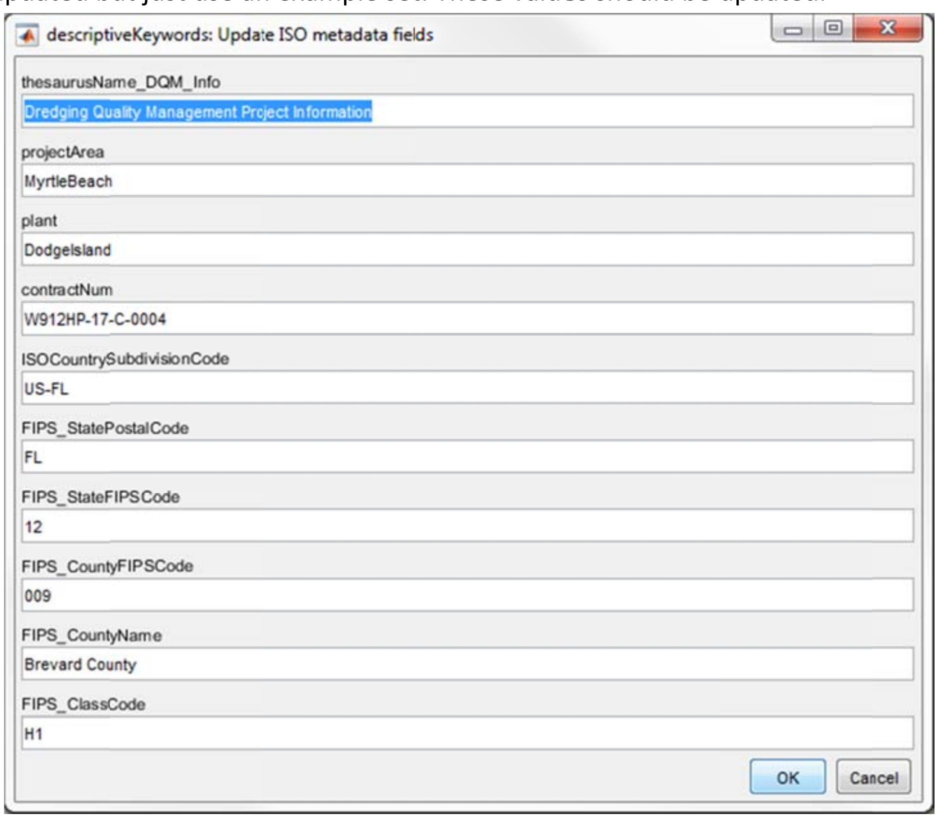


Figure 41. Monitoring sequence exercise: update the metadata 'descriptive keywords' section.

(16) Finally to export the file, press **Export**, and use the default location to save the files, which should be [HomeFolder]\Dredging\exposure. A pop up window will say "Export complete!" and show the names of the files created, and the folder location where they were saved.

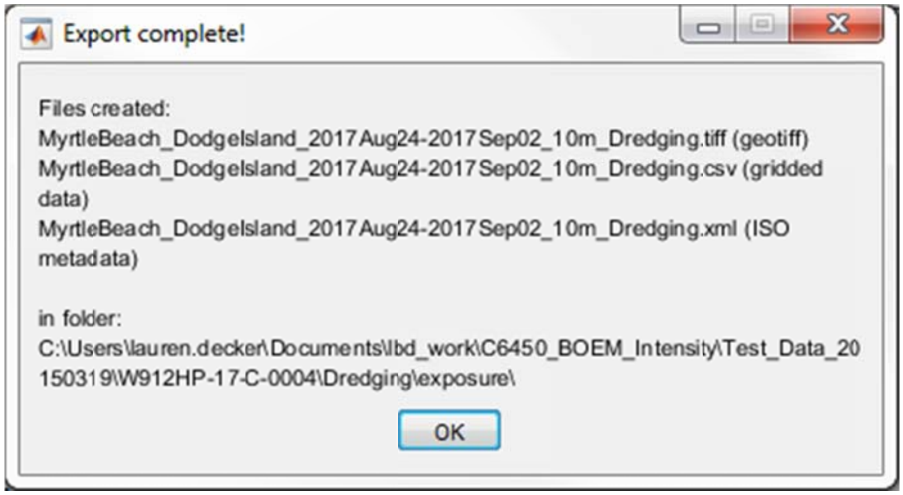


Figure 42. Monitoring sequence exercise: review the final set of files created.

5.1.3 Continuing Weekly Dredging Impact Products

(17)For continuing projects, when a weekly deliverable (CSV file) is received, save the file into the folder for that project.

(18)Start the GUI

(19)Select **Load Scenario** in the initial opening menu; or from **Menu** > **Load Scenario** within the GUI

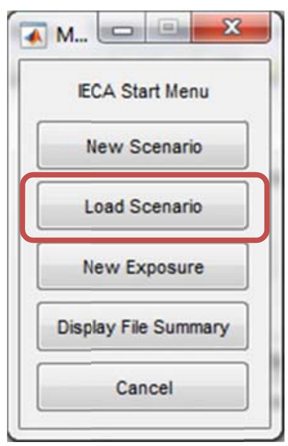


Figure 43. Monitoring sequence exercise: continuing weekly projects by loading previous weeks Scenario.

(20)Navigate to the project folder, and within the Dredging folder for the project, select the most recent inp file.

(21)In the GUI, go to **Menu** > **Update Files In Scenario**

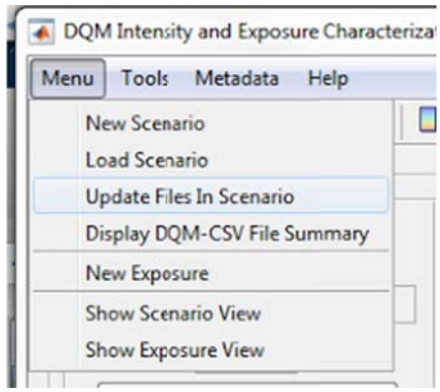


Figure 44. Monitoring sequence exercise: update the files in the loaded Scenario.

(22)In the pop up window, hold the shift key while selecting the new CSV file. This keeps previous CSV files and adds on the new one. Press **OK**.

(23)A check on the new file is done by the program; if the new file is not included in the time range of the previously run scenario a warning box will pop up:

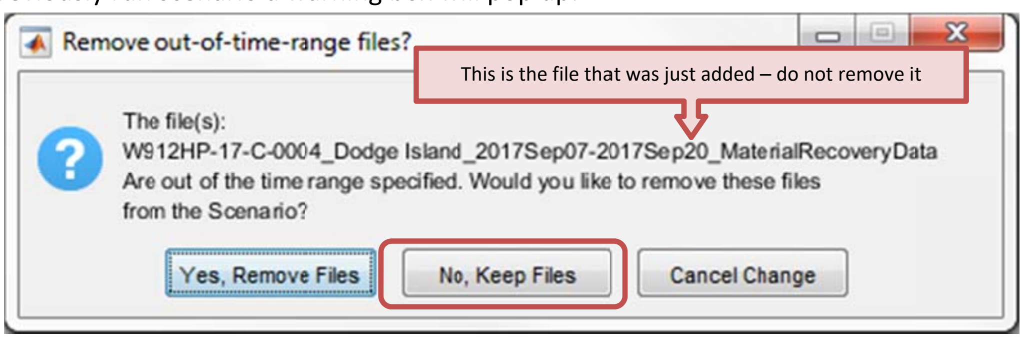


Figure 45. Monitoring sequence exercise: an auto-check reviews date range of input files and might throw a time range warning while loading new files.

PRESS **NO, KEEP FILES** AT THIS TIME.

(24)Setting Time increments: set the time to exact week-long increments

a. Set the **Start** Time: Sunday of the current week, hour 00:00:00
b. Set the **End Time**: Saturday of the current week, hour 23:59:59

If the ‘Remove out-of-time range files?’ window pops up after you have set BOTH the START & END times, you CAN remove the files when they are referencing files from previous deliverables that ended before the current scenario.

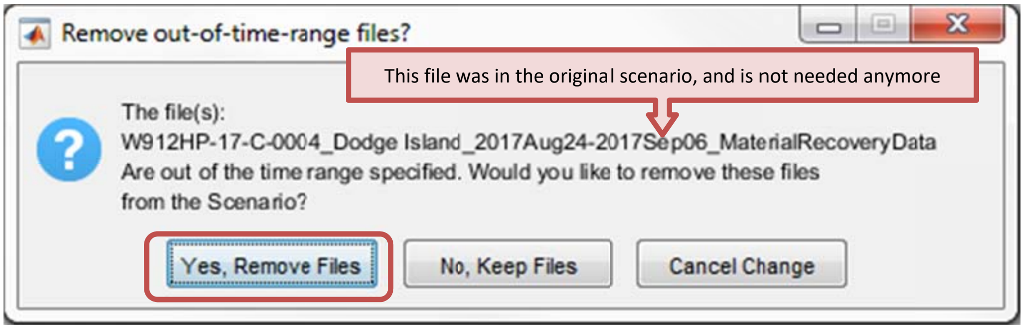


Figure 46. Monitoring sequence exercise: the time range check may pop up again after the new time ranges have been set—check if the file is the previous weeks file and remove it.

DQM will deliver data files that are about a week long, but not exact time frames. This means a week-long scenario can, and usually will, involve multiple DQM CSV files that span the specified time range. You can review the time coverage plot for reference.

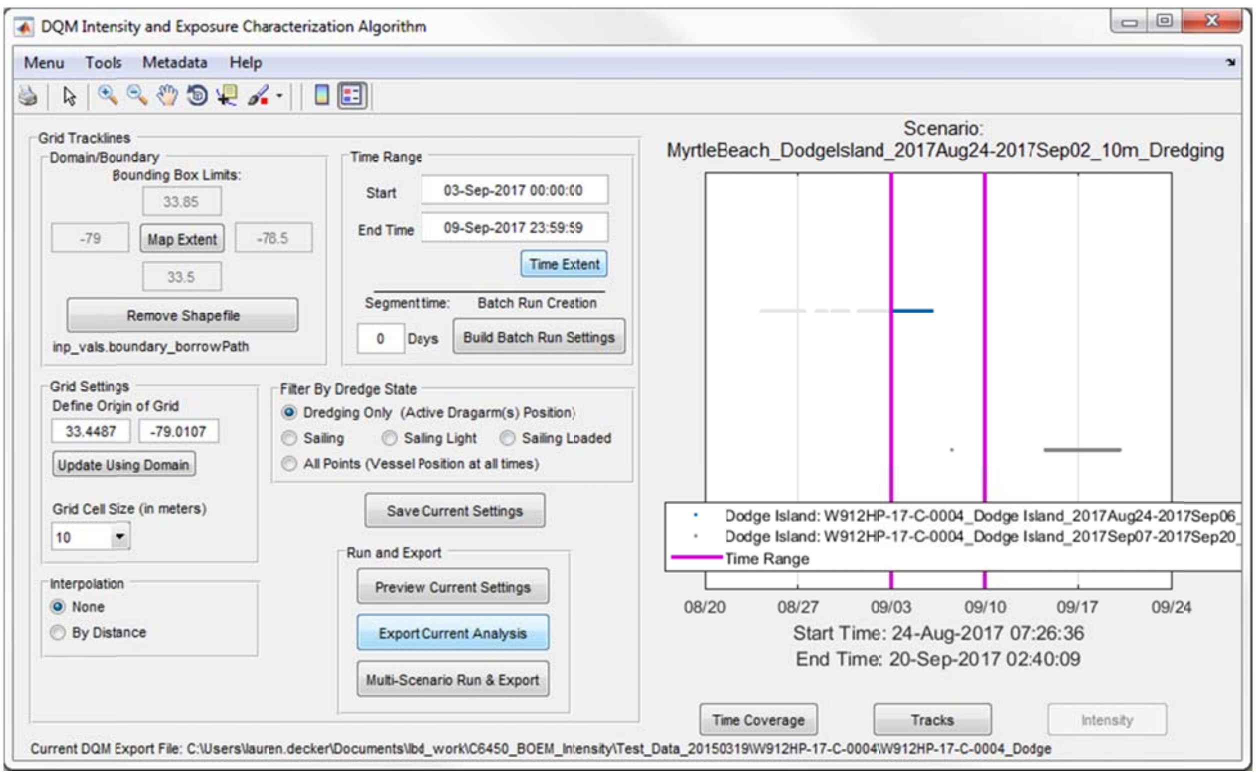


Figure 47. Monitoring sequence exercise: reviewing multiple input files for time overlap before combining into Intensity results.

(25) Press the **Tracks** button, and review your data using the zoom tool. The plot will show exactly the data that will be used in the IECA processing, which for "Dredging Only" will be the position of each drag arm with an activity indicator of "true" while the plant was identified as dredging.

(26) Run a preview of the first results—when grid extent is large or cell size is small this may take a few minutes.

a. Press **Preview Current Settings**

b. When the calculation is complete the plot will update with the Intensity results; a pop up box will ask "Would you like to move to the Exposure Analysis?" If you would like to review before moving on, choose "No" and after review press the button **Export Current Analysis** and move to the next step. Otherwise, press "Yes" on the pop up window.
c. Save using the default name (location_plant_stDate-edDate_10m_Dredging.inp) in the 'Dredging' folder.
d. When the grid is saved, a pop up window will say "Export Complete!" and show the path where the files were saved.

(27)In the Exposure view there should only be one scenario, review the file properties of the scenario then press **Run Exposure Model**.

(28)Once the run is completed a pop up window will say "Exposure Calculation Complete;" press **OK**.

(29)To update the metadata before the final products are created, select **Update Metadata** from the GUI, then select which section to update from the pop up menu.
a. Review "datasetInfo" and update as necessary. This section has title, abstract, and supplemental information.
b. The Descriptive Keywords section contains the FIPS codes, which are not automatically updated but just use an example set. These values should be updated.

(30) Finally to export the file, press **Export**, and use the default location to save the files, which should be [HomeFolder]\Dredging\exposure. A pop up window will say "Export complete!" and show the names of the files created, and the folder location where they were saved.

5.1.4 Cumulative Impact Products

(31)In the GUI select **Menu** > **Show Scenario View**

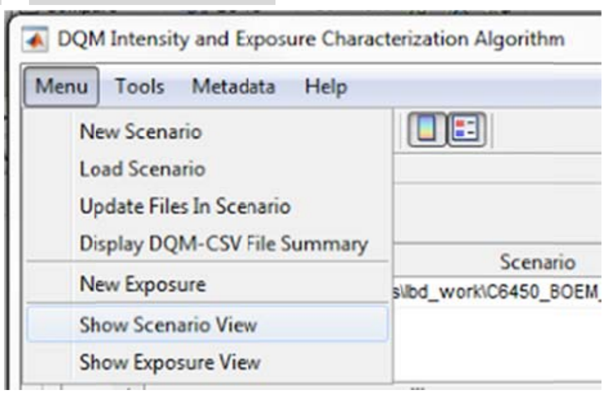


Figure 48. Monitoring sequence exercise: show scenario view menu item.

(32)Set filter by Dredge State to **All Points (Vessel Position at all times)**

(33)Set the **grid cell size** to 50 meters.

(34)Make sure the bounding box is consistent with other scenarios.

(35)Run a preview of the first results—when grid extent is large, or cell size is small this may take a few minutes.
a. Press **Preview Current Settings**.
b. When the calculation is complete the plot will update with the Intensity results; a pop up box will ask "Would you like to move to the Exposure Analysis?" If you would like to review

before moving on, choose “No” and after review press the button **Export Current Analysis** and move to the next step. Otherwise, press “Yes” on the pop up window.

c. Create a folder called “AllPlantLocations” under the Home folder (note – your default location will be under the “Dredging” folder at this point; navigate up to the Home folder before creating the new ‘all’ folder). Save using the default name (location_plant_stDate-edDate_50m_All.inp)

d. When the grid is saved, a pop up window will say “Export Complete!” and show the location where the files were saved. Press **OK**.

(36)In the Exposure view there should only be one scenario. Add all other scenarios from this project: press **Choose Scenarios**, and **Select All**, then **OK** on the selection pop up window.

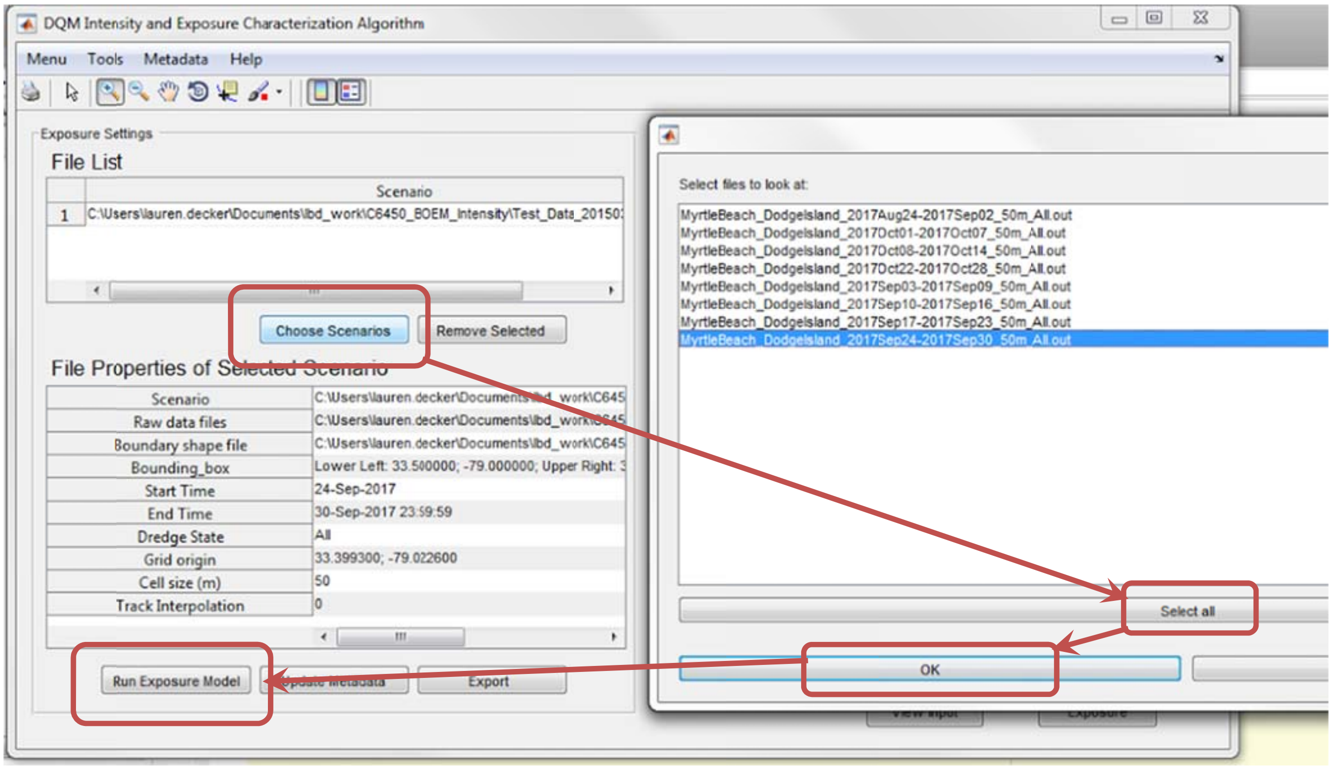


Figure 49. Monitoring sequence exercise: add in all Intensity Scenarios to the cumulative Exposure.

(37)Then run Exposure for the cumulative set: press **Run Exposure Model.** All of the previously run scenarios for this project should be using the same domain, grid origin and cell size. This allows easy aggregation in the Exposure model to build the project cumulative set.

(38)Once the run is completed, a pop up window will say “Exposure Calculation Complete;” press **OK**.

(39)To update the metadata before the final products are created, select **Update Metadata** from the GUI, then select which section to update from the pop up menu.

a. Review “datasetInfo” and update as necessary. This section contains title, abstract, and supplemental information.

b. The Descriptive Keywords section contains the FIPS codes, which are not automatically updated but just use an example set. These values should be updated.

(40) Finally to export the file, press **Export**. Use the default location to save the files, which should be [HomeFolder]\AllPlantLocations\exposure. A pop up window will say "Export complete!" and show the names of the files created, and the folder location where they were saved.

(41)This completes the processing in the IECA. The products have now been created and saved, and the GeoTIFF contains all the necessary information to open and project the data in other software like ArcGIS and Google Earth. The ISO metadata file is a valid 19115-2 format, but files should always be reviewed. The gridded CSV file can be opened as a spreadsheet like Excel if simple tasks to build statistics or check data values are needed.

5.2 Benthic Impacts, Mineral Utilization

5.2.1 Situation

A borrow area has been surveyed before and after a project with side scan sonar, giving high resolution detail on changes in bathymetry. Building a dredging Exposure Analysis at a similar grid scale as the survey allows direct comparison of time spent dredging to bathymetry change based on the survey.

5.2.2 Tools

- Creating products that can be imported and used in ArcMap, to be compared to other datasets
- Evaluating when and where each drag arm is dredging during a project

5.2.3 Steps Through the Application

1) Start the GUI
2) In the GUI, view summary information from the CSV file to be used
   Menu > **Display DQM CSV File Summary**

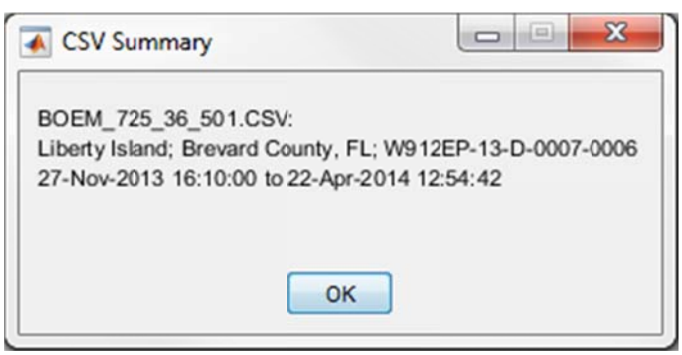


Figure 50. Benthic impacts exercise: data file summary of DQM CSV files.

3) In the GUI select **Menu** > **New Scenario**

   a) Navigate to the folder containing the CSV files from DQM

   b) Select the file to include in the scenario: *BOEM_725_36_501.CSV*; the input settings are updated with limits based on the CSV files. In the figure window the pink square identifies the bounding box along with the track lines of the vessel.

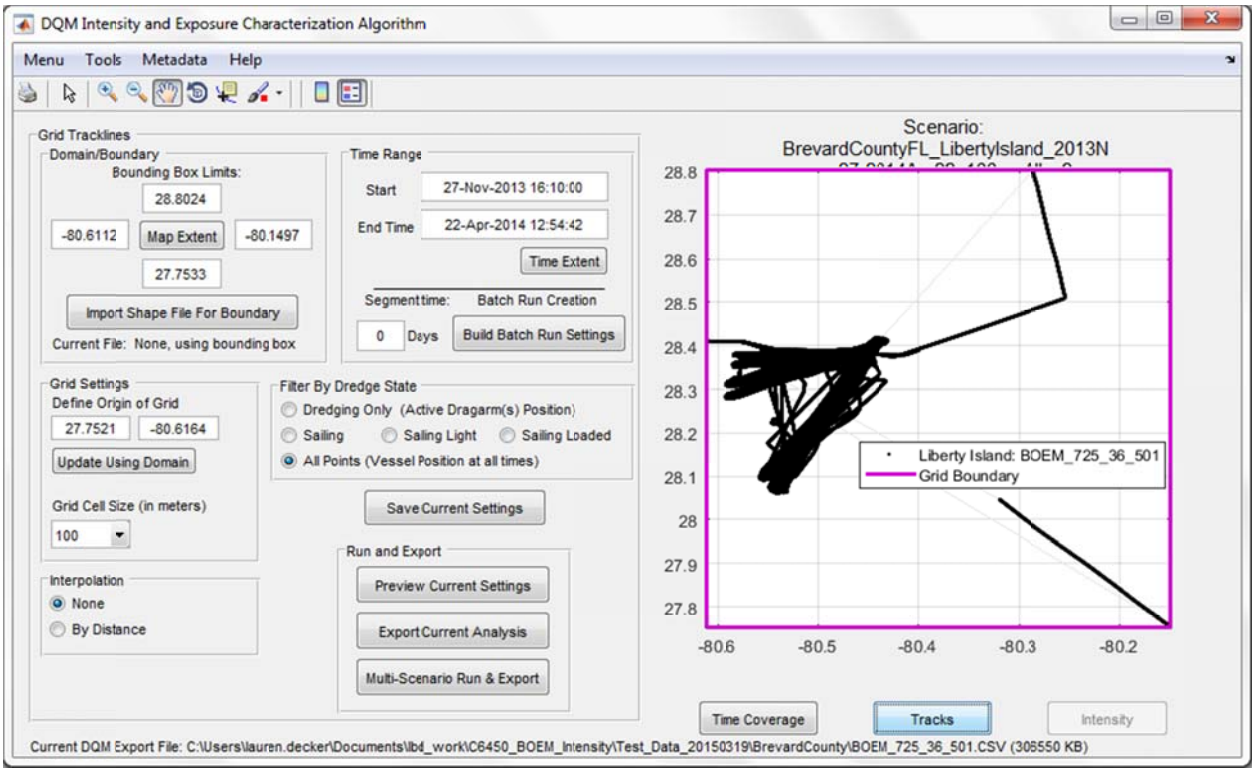


Figure 51. Benthic impacts exercise: default Scenario view.

4) Update values as needed to define the new scenario
   a) Update the bounding box limits to:
      South = 28
      North = 28.45
      East = -80.4
      West = -80.6112 (no change)
   b) Press the **Update Using Domain** button to get a new grid origin
   c) **Grid cell size**: change to 25 (meters)
   d) Filtering by Dredge State: change to **Dredging Only**

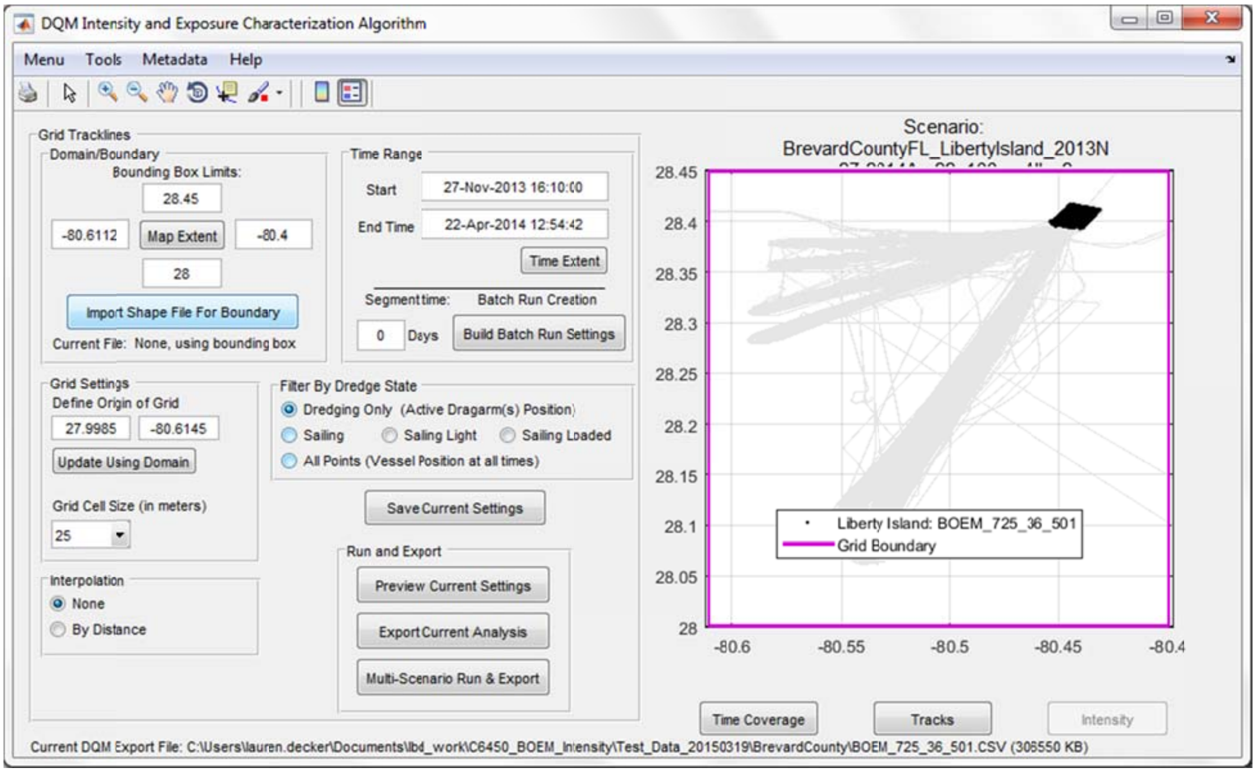


Figure 52. Benthic impacts exercise: Scenario view with the updated settings.

5) Save the IECA inputs in an INP file using the **Save Current Settings** button, using the default name to save your scenario of the form Project_Plant_start-end_cellSz_Filter "BrevardCountyFL_LibertyIsland_2013Nov27-2014Apr22_25m_Dredging.inp"

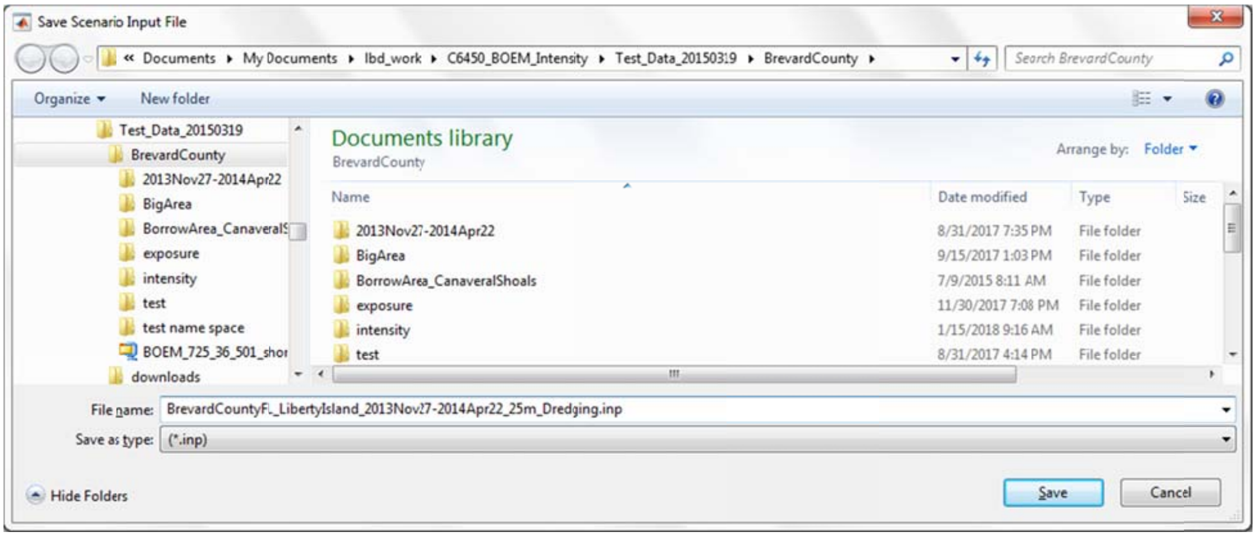


Figure 53. Benthic impacts exercise: saving the INP file.

6) Run the IECA by pressing the **Preview Current Settings** button.
(When the "Start New Exposure?" window appears, Press '**No**')
The results are plotted in the figure window, and because only locations of active dredging were used in the analysis, it is a small area in the window. This display will vary based on the size of the borrow area relative to the bounding box, and the location of the grid origin. This view shows the Intensity, but the track line data can also be reviewed by selecting the button below the axis called "Tracks". You may zoom in on the area using the magnifying glass (zoom) tool if needed.

7) Export the data using the **Export Current Analysis** button. First another 'Save Scenario' window will appear with the current name of the scenario – this is used as a backup if the INP file had not previously been saved; press **OK**. When the "Start New Exposure?" window appears, Press '**Yes**'. Another pop up window will appear to indicate the export was completed. Data are by default exported to an "intensity" folder under the Home folder, and the pop up window will state the full path and file name of the exported file.

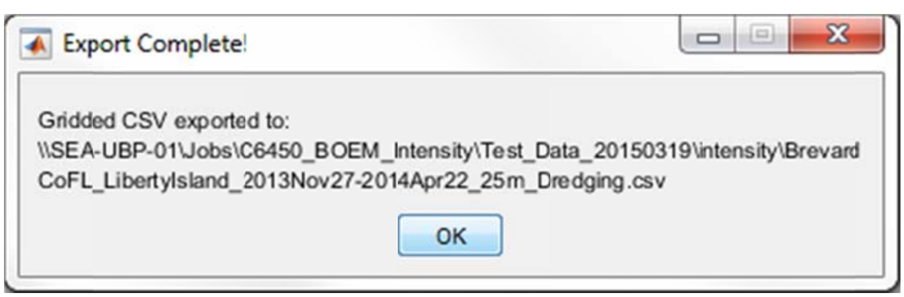


Figure 54. Benthic impacts exercise: Intensity results were exported.

8) The GUI should be in the Exposure view with the last scenario's Intensity data shown. If not, in the GUI select **Menu** > **New Exposure**

   a) Navigate to the folder with the output files and gridded CSV files from the Intensity run that was just exported. (This should be in an *intensity*\ folder under your Home folder with the raw CSV data.)

   b) Select the file to include in your scenario: BrevardCountyFL_LibertyIsland_2013Nov27-2014Apr22_25m_Dredging.out

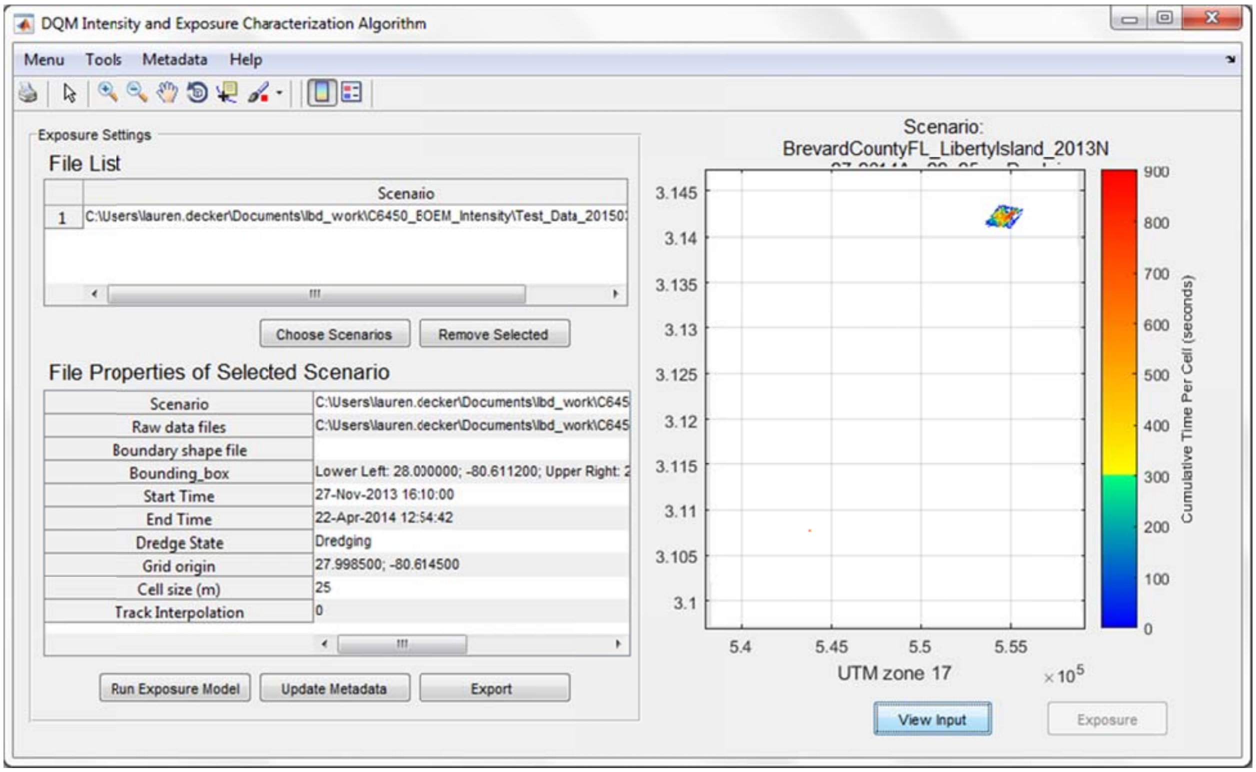


Figure 55. Benthic impacts exercise: Exposure view after loading in the previously run Intensity data.

9) To run the Exposure model with the current set of Intensity files (in this example, one file) press the **Run Exposure Model** button. A pop up window will appear to indicate the processing is done.

Figure 56. Benthic impacts exercise: popup windows while calculating Exposure.

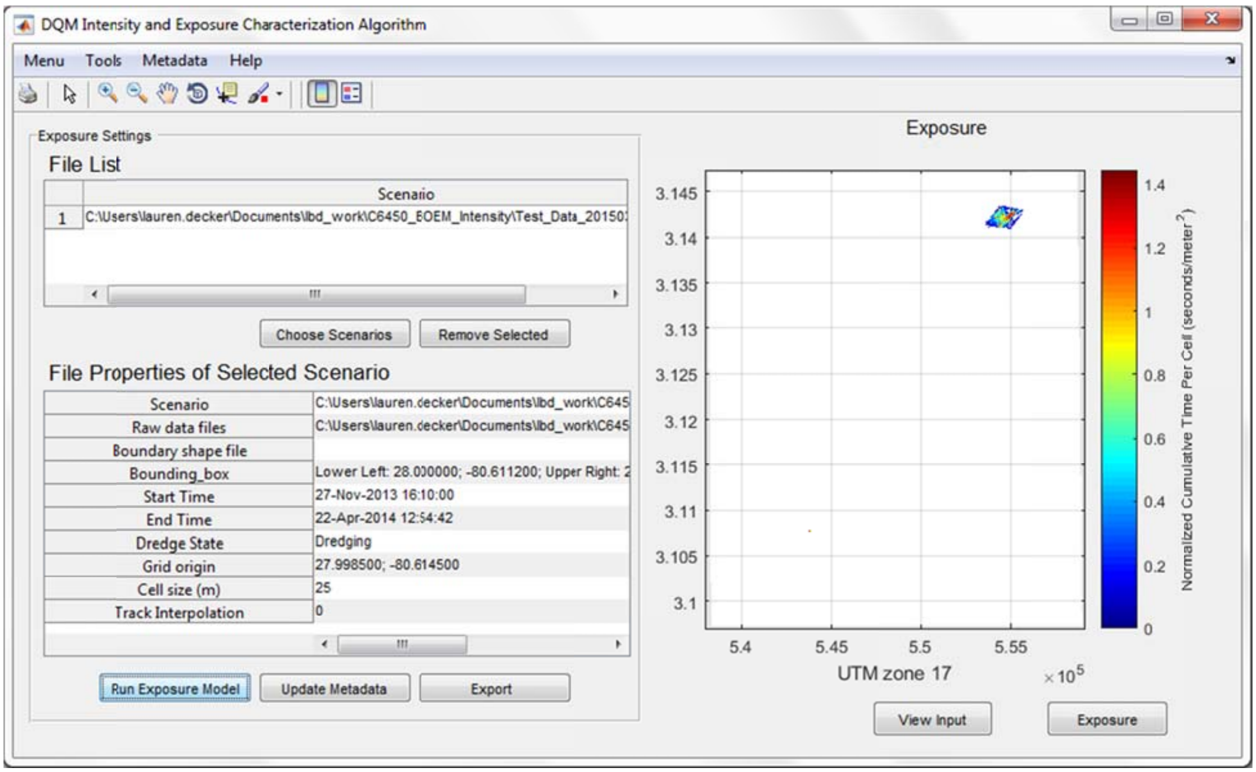


Figure 57. Benthic impacts exercise: Exposure results displayed in the figure window.

10) Once the Exposure has been run, metadata defaults have been created that can be updated by pressing the **Update Metadata** button. One section of metadata can be updated at a time.
11) Once the Exposure has been run, press the **Export** button in the GUI to save the gridded CSV output, the GeoTIFF file, and the ISO metadata.
    The first pop up window asks for a file name for the output; the default value is the file name of the first scenario. In this example the analysis only used one file, so the default file name is sufficiently descriptive; press **OK** to keep the default.
12) A pop up window will appear indicating the export was successful, and will show the names and location of the files that were created. Exposure files are always created in a new folder under the Home folder called "Exposure".
13) This completes the processing in the IECA. The next section will describe processing the GeoTIFF in ArcMap, and comparing it with other datasets.

5.3 ArcMap Processing: Benthic Impacts, Mineral Utilization

1) The exported GeoTIFF files constructed in the IECA can be loaded into Arc and displayed with other data layers.
    a) In an explorer window, navigate to the export folder containing the GeoTIFF. With ArcMap open, drag and drop the GeoTIFF into the map area of the Arc interface. It will display a large (mostly black) gray scale image of Exposure.
    b) Other files can also be dragged into the map window of ArcMap for display, such as the borrow area shape file.
    c) The pre-dredge survey is also available for this example; find the file: FL_Brevard_PreDredgeSurvey_2013_OCS_A_0493.asc
    d) A base map can also be added. Go to *File* > *Add Data*… > *Add Basemap*, and select 'Topographic' from the options.

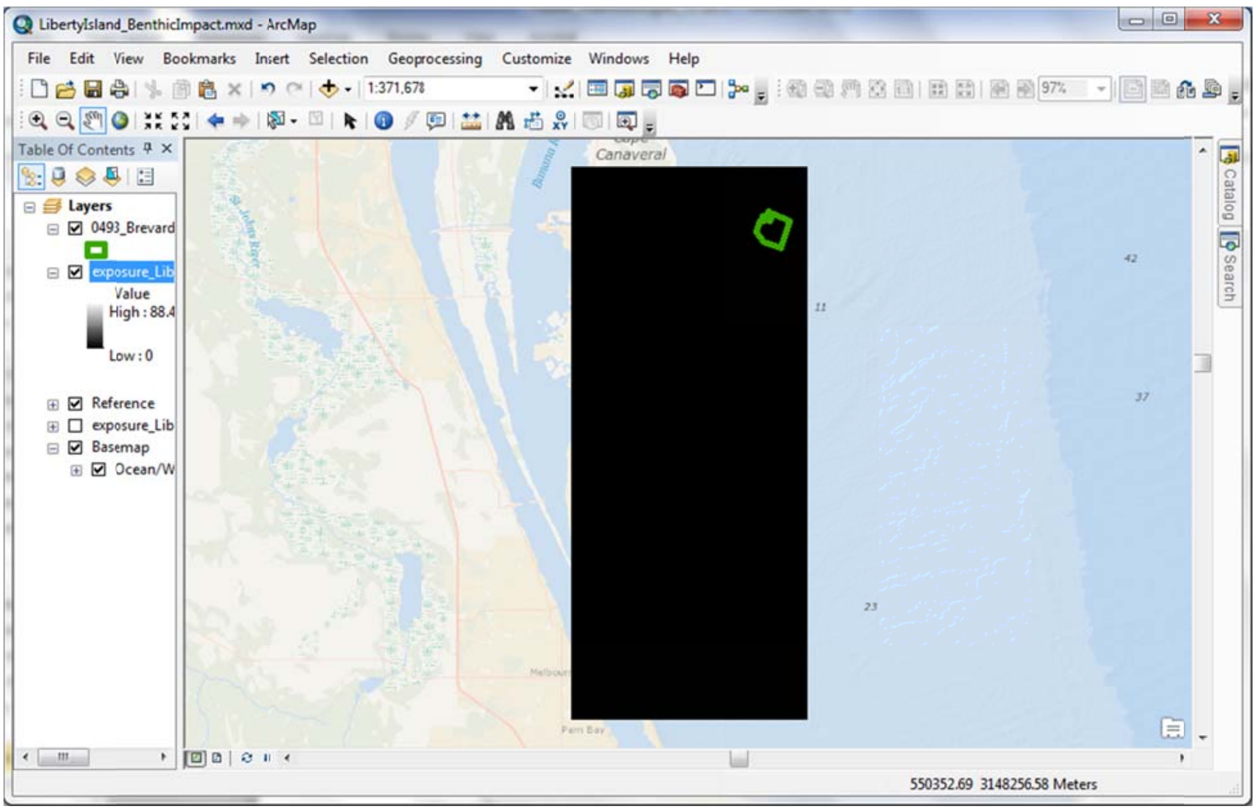


Figure 58. AcrMap exercise: screen shot after loading data and adding a base map and borrow area shapefile.

2) One way to apply a color scale to the gray scale image is to draw the raster grouping values into classes, making a "Classified" image. To create raster groups:
   a) Go to *Geoprocessing* on the menu bar, and open the *ArcToolbox*; then navigate to:
      Data Management Tools >
      Raster >
      Raster Properties >
      Calculate Statistics

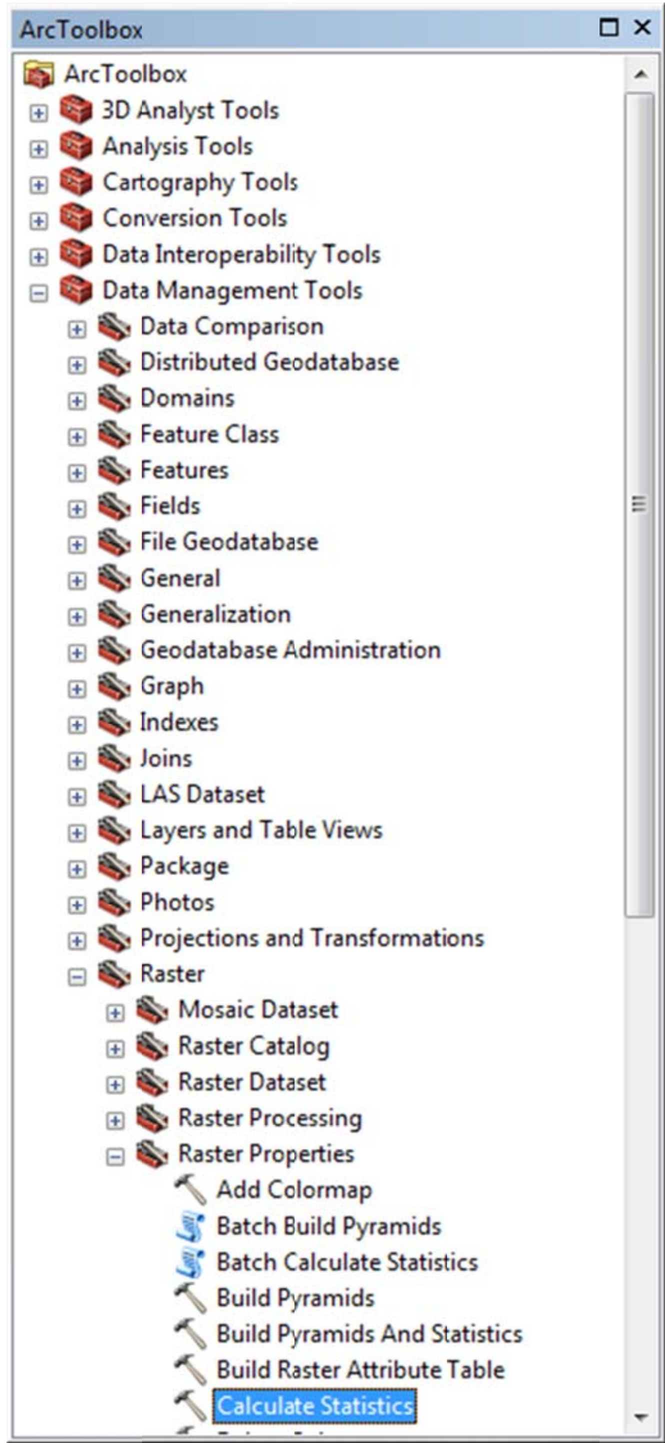


Figure 59. ArcMap workflow: Calculate Statistic in the Geoprocessing menu.

b) Select the GeoTIFF file (you can drag and drop the file into the selection window), and run the statistics.

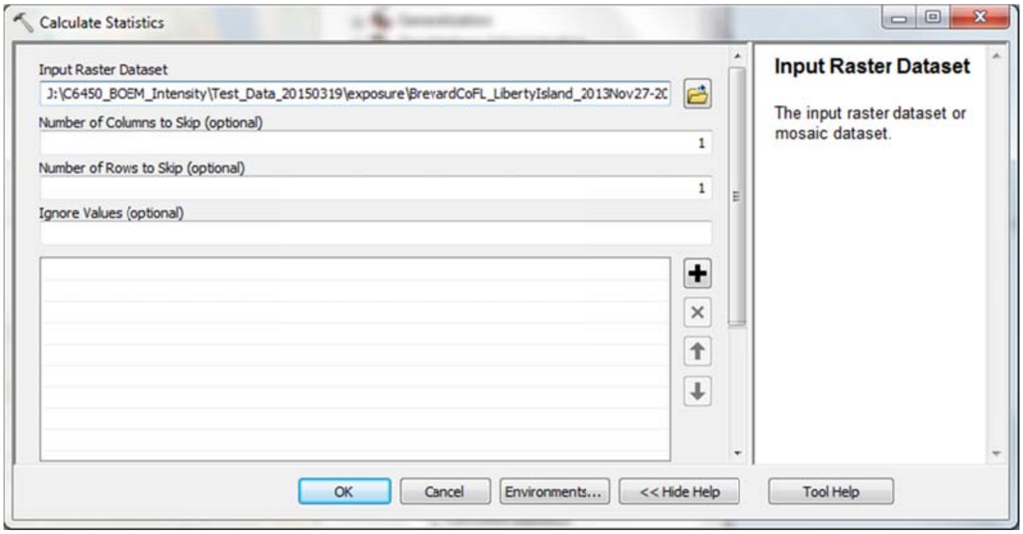


Figure 60. ArcMap exercise: Calculate Statistics pop up.

3) Once the statics are calculated, open the *Layer Properties* of the GeoTIFF file by double clicking the name of the file in the Layer pane on the left side of the main window.

4) Go to the *Symbology* tab, and click on *Classified* in the left window pane.

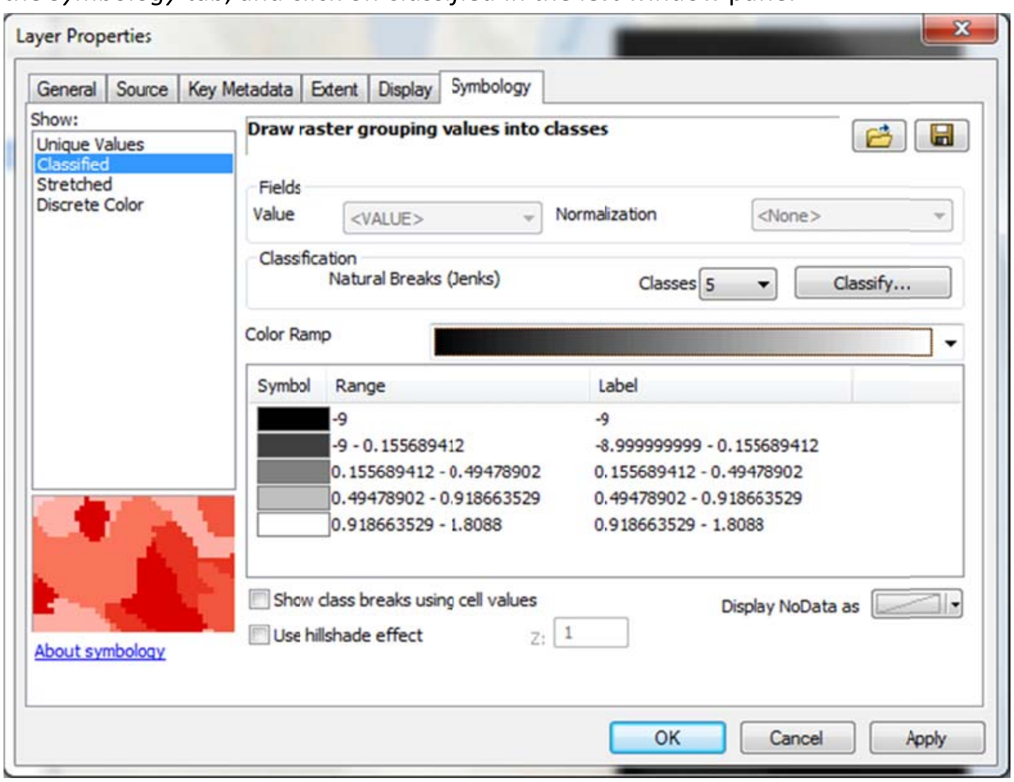


Figure 61. ArcMap exercise: setting symbology of raster data.

5) Press the *Classify* button, and in the Classification window, press the *Exclusion…* button. Type in the Excluded values: “-9 - 0”; then press OK

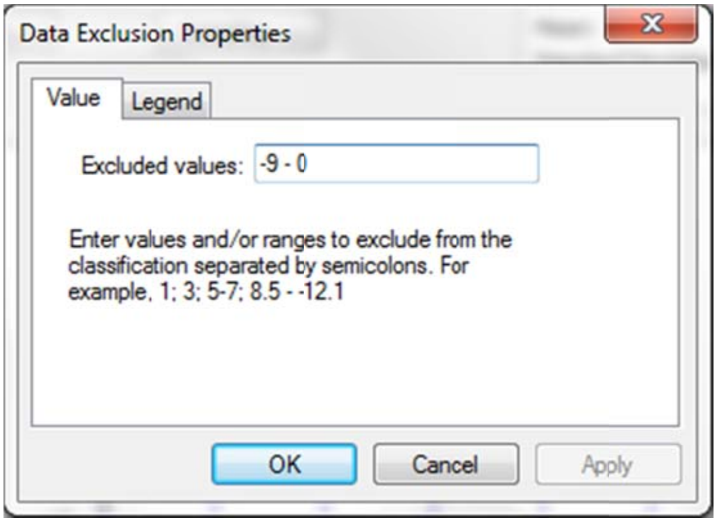


Figure 62. ArcMap exercise: Data Exclusion Properties pop up menu.

6) Back in the Classification window, change the *Method* to *Equal Interval* and the number of *Classes* to *10*, and then press OK.

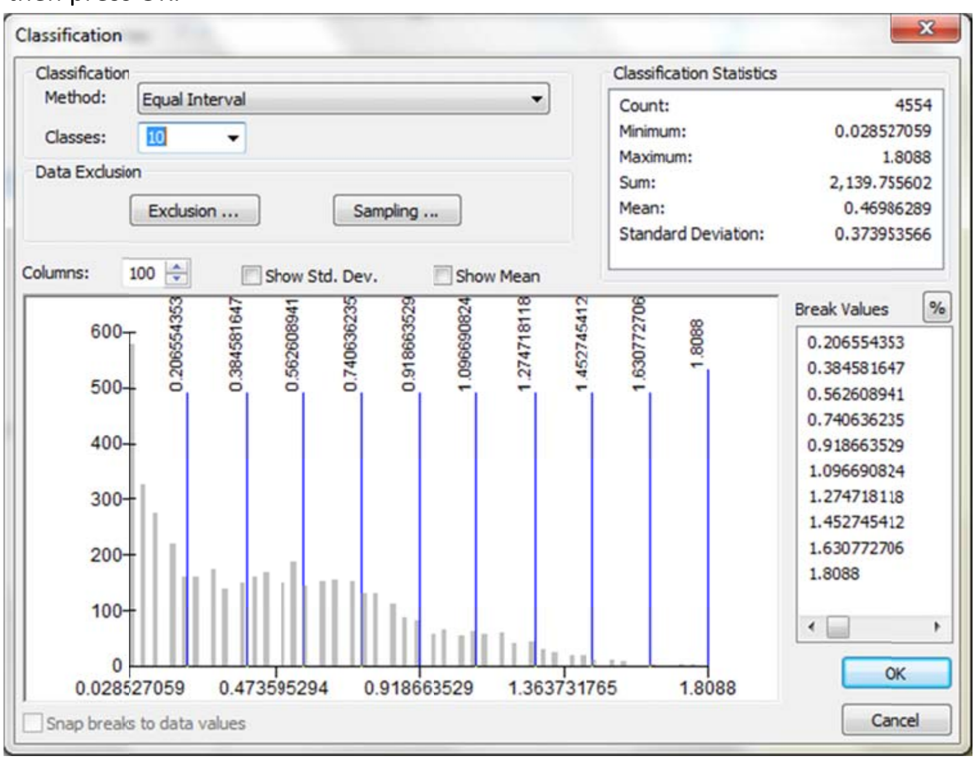


Figure 63. ArcMap exercise: Classification method for coloring raster data.

7) Back in the Layer Properties window, change the color ramp, and press OK

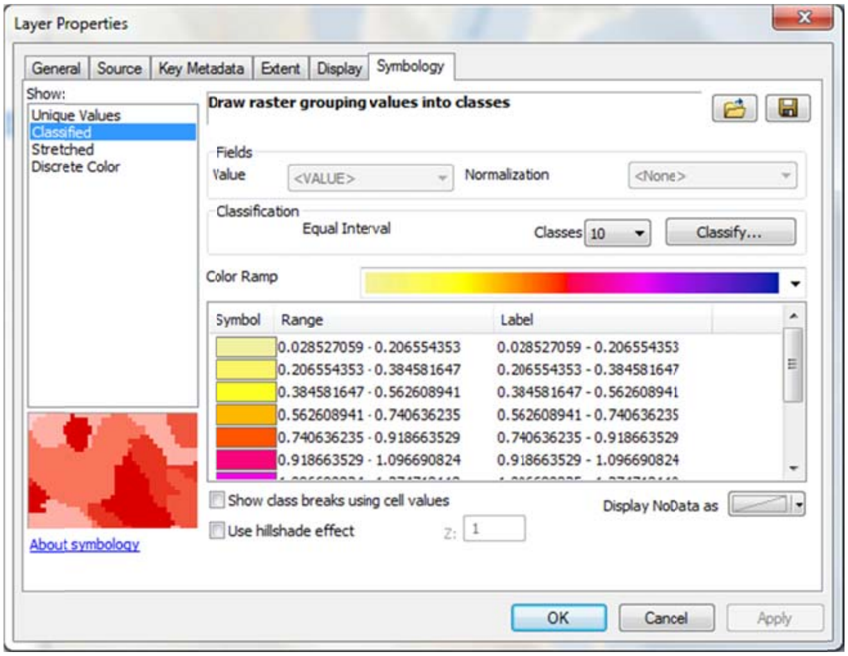


Figure 64. ArcMap exercise: color map in Symbology tab.

8) At this point, a user can update the number of “classes”, change color ramps, and change the ranges each class covers, as desired. When completed, press OK to go back to the main window.

9) Use the ‘zoom to layer’ function on the borrow area shapefile to get a close up view of your results:

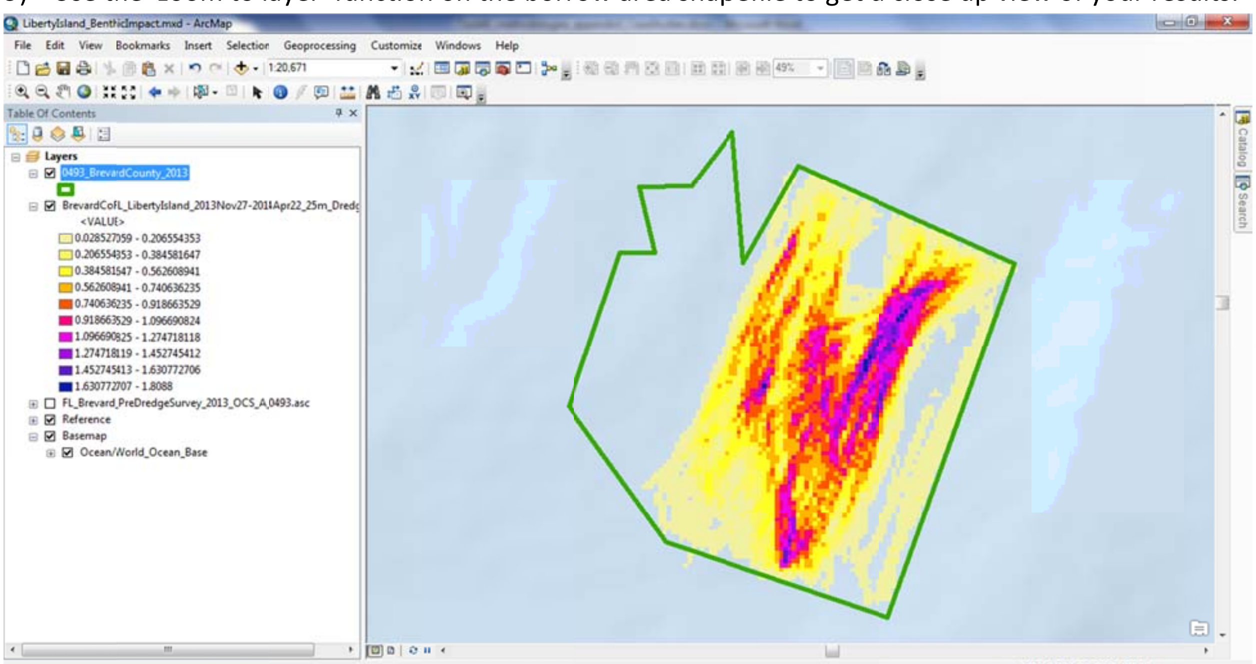


Figure 65. ArcMap exercise: color map applied to raster data.

10) Apply the ‘stretched’ color ramp to the pre-dredge benthic survey: Double click on the pre-dredge benthic survey file in the *Layers* window pane, go to the *Symbology* tab, and select *Stretched* in the left window pane. Update the color ramp, and press OK.

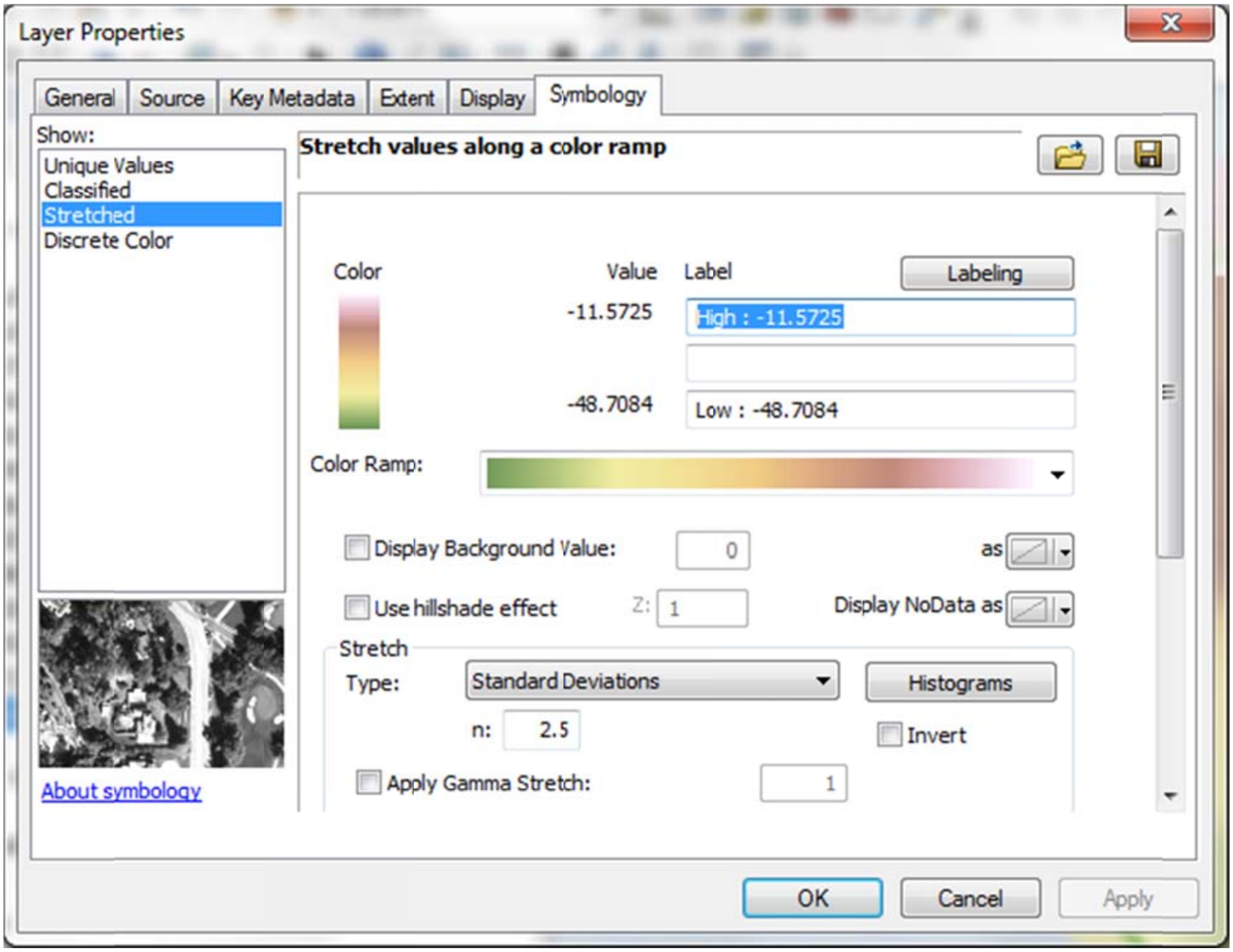


Figure 66. ArcMap exercise: picking the color map for benthic survey data.

11) Depending on how the layers are displayed, the dredge survey and the Exposure layers will overlap – toggle the values on and off using the checkboxes in the *Layers* pane to visually compare.

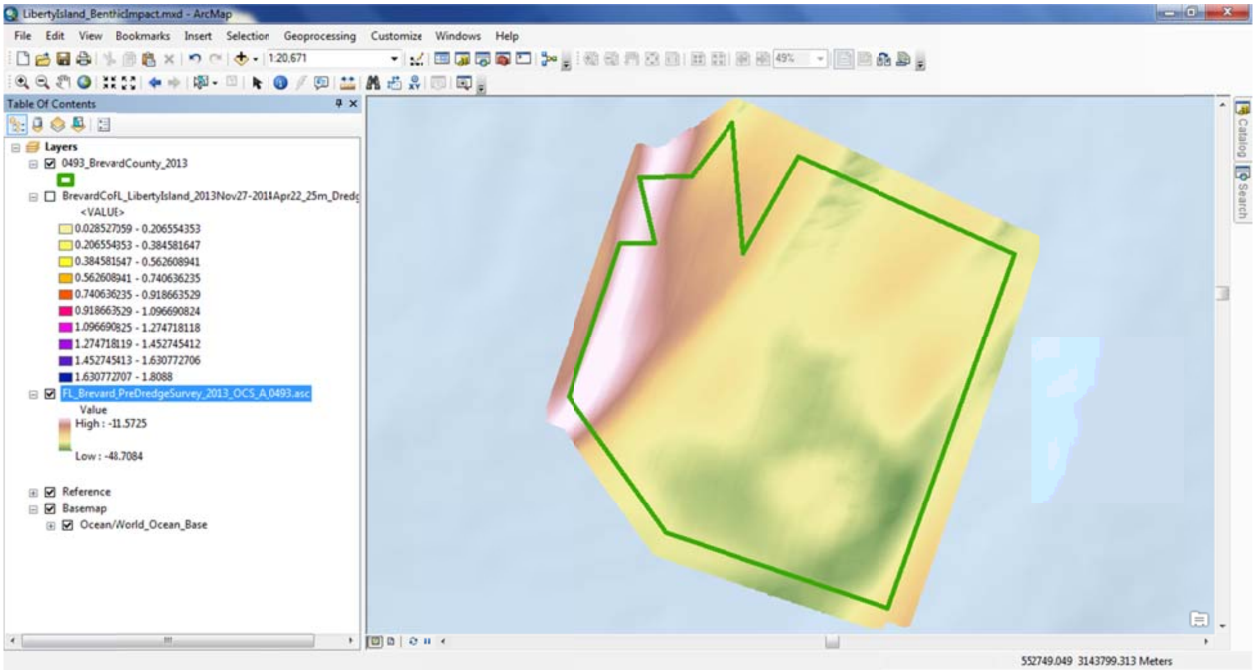


Figure 67. ArcMap exercise: color map applied to benthic survey data.

This completes the benthic impacts, mineral utilization case study.

5.4 Strike Risk With Vessels

5.4.1 Situation

During migration periods, risk of impacts of transiting vessels with megafauna increase. To quantify the risk both spatially and temporally, the cumulative time and area spent sailing is calculated on biweekly basis (every two weeks) during known migration intervals. During ‘sailing,’ dredge plants are typically traveling at greater speeds compared to other activity types such as dredging or disposing.

5.4.2 Tools

- Dividing a project into multiple well-defined timeframes using batch processing
- Using vessel location during sailing
- Using the MATLAB environment to work with processed data

5.4.3 Steps Through the Application

1. For this example, start the GUI in the MATLAB environment (r2017a) by typing at the command prompt:

```
>> GUI_DQM
```

2. In the GUI, select **Menu** > **Load Scenario**
    a. Navigate to the folder containing the DQM CSV files and the INP file created in the previous case study.
    b. Select the input file (from the previous case study): *BrevardCountyFL_LibertyIsland_2013Nov27-2014Apr22_25m_Dredging.inp*

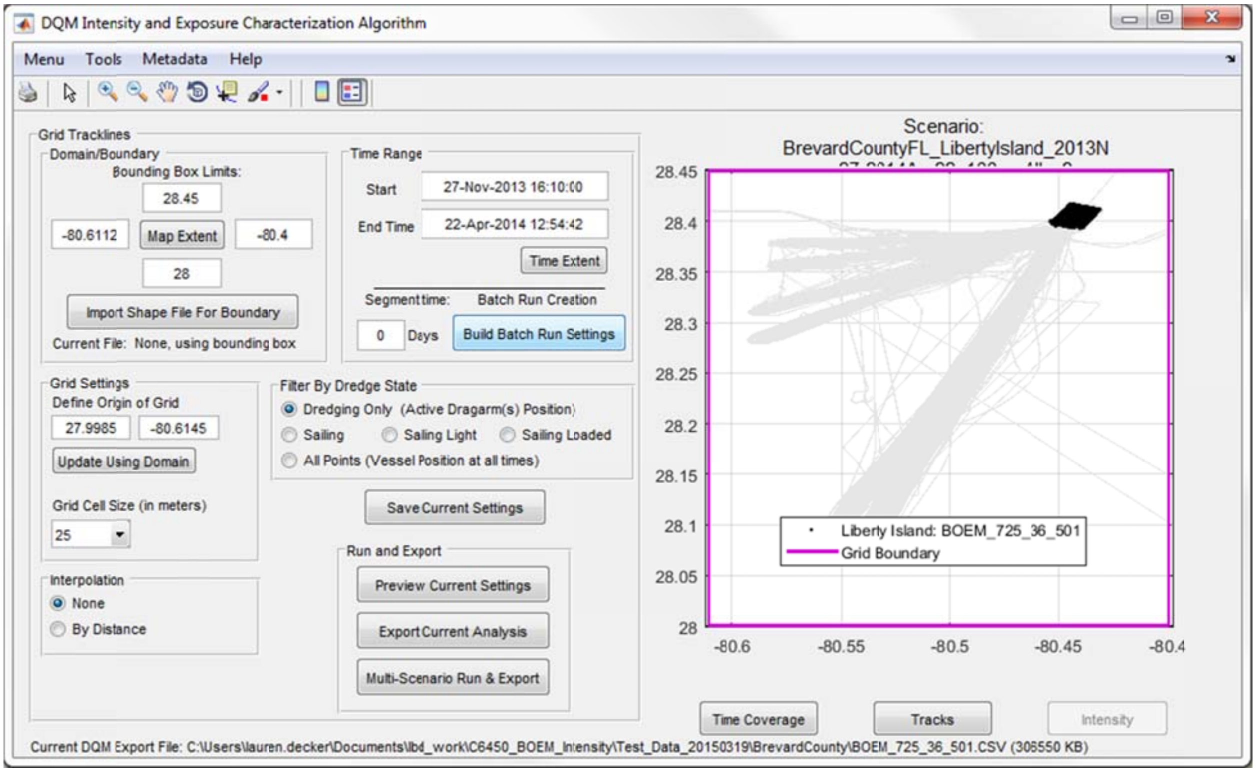


Figure 68. Strike risk exercise: initial DQM GUI view.

3. After reading the preview data, the input settings are updated with limits based on the scenario input file, instead of the DQM CSV files. It is possible to continue to use most of the same input values, but update 'Filter By Dredge State' to **Sailing** Only.
4. Build multiple scenario inp files to cover a range of time:
   a. Set the time range start and end times to cover the entire rage of the series, and make it a round number:
      Start Time: 27-Nov-2013 00:00:00
      End Time: 23-Apr-2014 00:00:00
   b. Set the **Segment time**, which has units of days, to 15. This will be the number of days that individual scenarios cover.

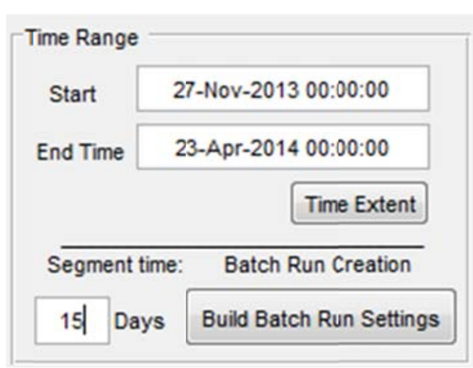


Figure 69. Strike risk exercise: setting time range for batch processing.

5. Press the **Build Batch Run Settings** button.
6. A pop up window to name the set of scenarios will appear. This is the base name used to name all the scenarios, the final set of scenarios are named in the form baseName_BatchRun_seqNum At the prompt, enter: BrevardCountyFL_LibertyIsland_25m_Sailing
and press **OK**

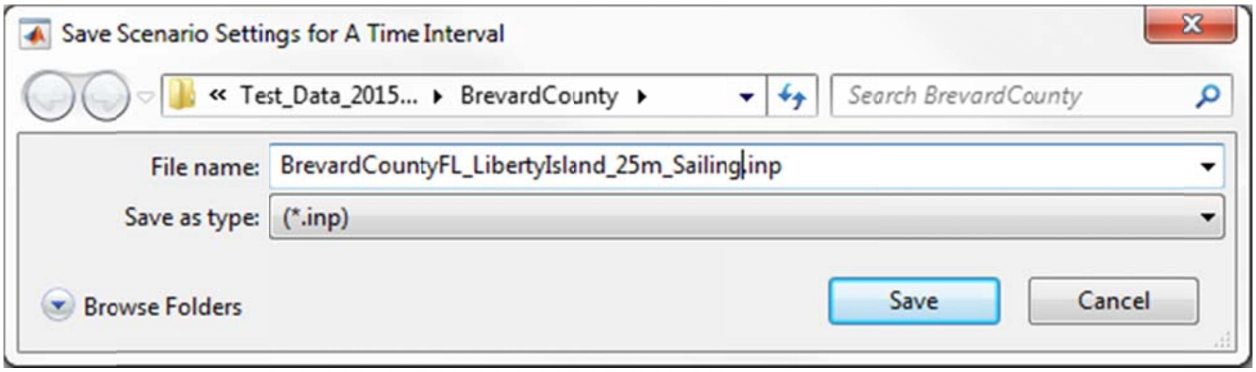


Figure 70. Strike risk exercise: save the scenario settings.

A series of scenarios are constructed using all the current settings with updated time ranges based on the start time, segment length, and end time supplied in the GUI.

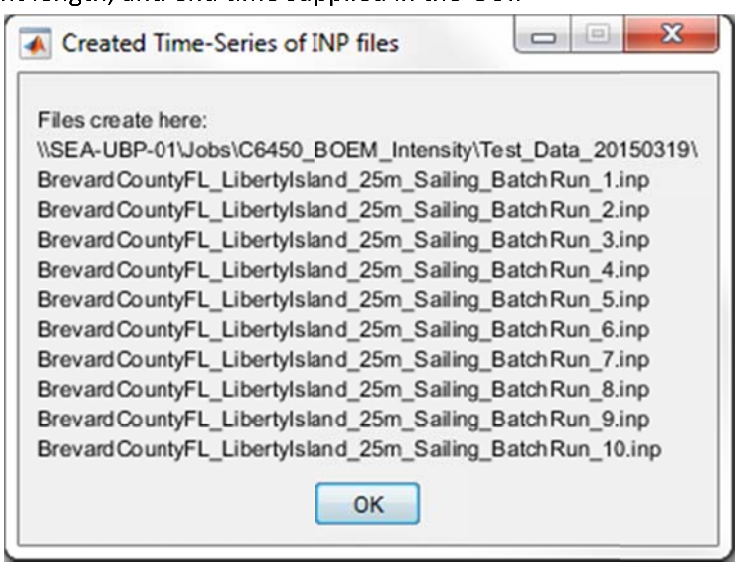


Figure 71. Strike risk exercise: pop up showing batch inp files created.

a. Perform a Multi-Scenario Run & Export by pressing the **Run Scenario Batch** button in the pop up window. When using the prompt, the application will select the set of scenario input files that were just created, process them, and then take you to the Exposure view.

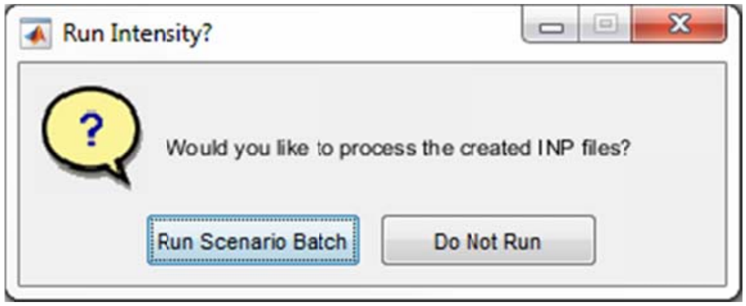


Figure 72. Strike risk exercise: 'Run Intensity?' pop up to run all batch files.

An alternate way to run a series of files in a batch or sequence is on the main GUI by selecting the **Multi-Scenario Run & Export** button. The user will navigate to the Home folder, and select any set of scenario input files to run. Again, data will be loaded, run through the IECA, and exported. After running any multi-scenario set, the GUI will move to the Exposure view without previewing Intensity results.

7. To display file properties of the selected scenario in the lower table and visualize the gridded Intensity data, select the scenario and press the **View Input** button below the plotting window.

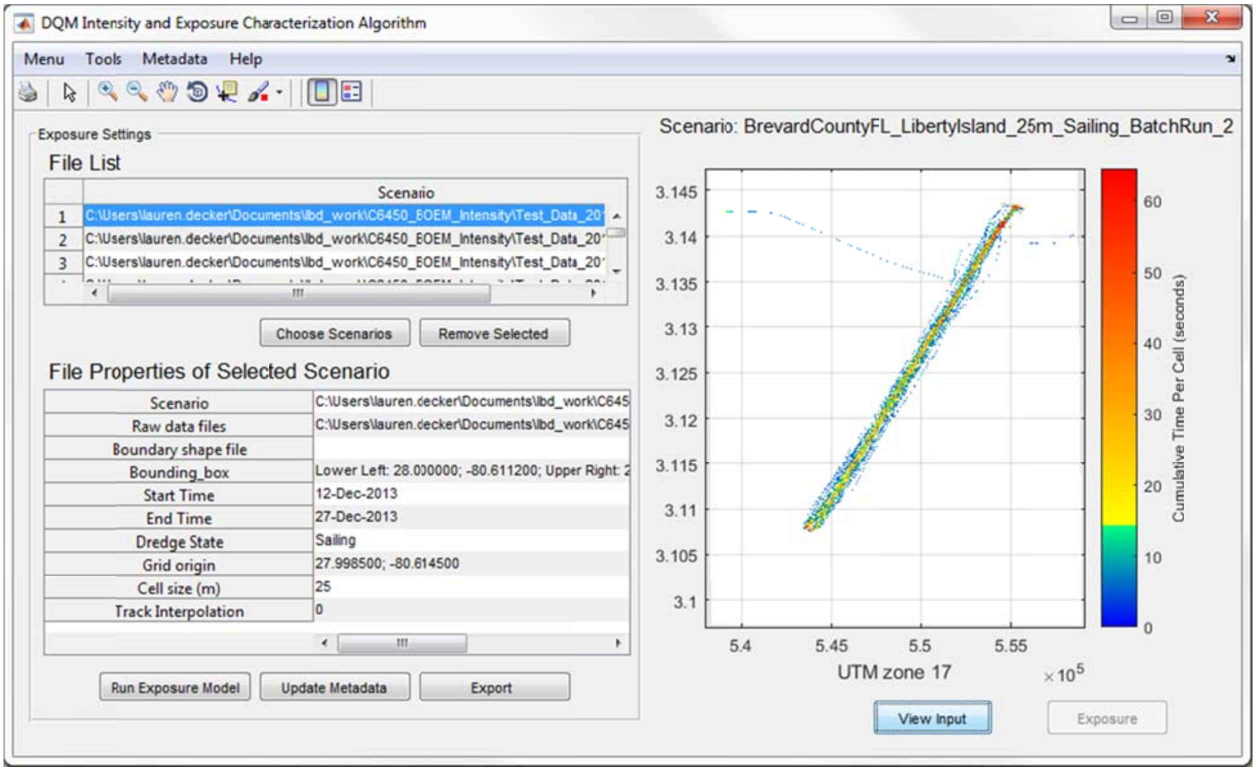


Figure 73. Strike risk exercise: Exposure view showing batch results.

8. At this point in the processing, a series of Intensity values has been calculated and exported into gridded CSV files, then brought back into the MATLAB environment as a set for an Exposure Analysis. Because we are running the GUI in the full MATLAB environment, we have access to variables in the workspace for additional calculations. Two variables that currently exist in the MATLAB environment are "gridStruct," containing the gridded data in a structured array, and "inp_vals," containing the input values that were used to run the scenarios. A combination of these two variables can be used to extract some cumulative statistics for each scenario. This can also be performed with the gridded CSV Intensity files in a program like Excel, but for the purpose of this example the MATLAB procedure will be described. To get the total time of each scenario, sum every value in the gridded Intensity data, which has units of seconds. In this case the data were filtered during the Intensity analysis to use only Dredge State Sailing, making the result the total transit time during each period.

At the MATLAB command line, copy and paste the following code:

```
for ii = 1:size(gridStruct,2)
 % Pull data out of the sparse, gridStruct variable
 oneScen = full(gridStruct(ii).Data(:));

 % save the total value of all transit time for this scenario
 oneScenSum = sum(oneScen);

 % save the time this scenario started/ended
 scenSrtTime = inp_vals(ii).timeRange(1);
 scenEndTime = inp_vals(ii).timeRange(2);

 % format print to the screen the results
 fprintf('%s to %s: %1.2f (days of transit time)\n',...
 datestr(scenSrtTime)',...
 datestr(scenEndTime)',...
 oneScenSum/60/60/24)
end
```

The following will print at the command line. These data are the start and end time of each scenario, and the total transit time during that scenario. You will notice that 10-Feb-2014 to 25-Feb-2014 has no data. During the processing that time period was found to have no data, and a file was not created.

```
27-Nov-2013 to 12-Dec-2013: 7.68 (days of transit time)
12-Dec-2013 to 27-Dec-2013: 8.72 (days of transit time)
27-Dec-2013 to 11-Jan-2014: 3.98 (days of transit time)
11-Jan-2014 to 26-Jan-2014: 6.88 (days of transit time)
26-Jan-2014 to 10-Feb-2014: 0.11 (days of transit time)
25-Feb-2014 to 12-Mar-2014: 4.55 (days of transit time)
12-Mar-2014 to 27-Mar-2014: 4.44 (days of transit time)
27-Mar-2014 to 11-Apr-2014: 7.09 (days of transit time)
11-Apr-2014 to 23-Apr-2014: 6.18 (days of transit time)
```

9. Run the Exposure model for each scenario; there is no batch functionality in the Exposure interface. Files should be identified and exported one at a time:
    a. Press **Choose Scenarios**, and only select the first file in the set *BrevardCountyFL_LibertyIsland_25m_Sailing_BatchRun_1.out*
    b. Press the **Run Exposure Model** button to run the Exposure model with the current Intensity scenario.

c. Once the Exposure has been run, metadata defaults have been created that can be updated by pressing the **Update Metadata** button.

d. Once the Exposure has been run and metadata updated, press the **Export** button to save the gridded CSV output, the GeoTIFF file, and the ISO metadata.

e. Go back to step *a* and repeat this sequence for each scenario in the set.

10. The GeoTIFF files can now be loaded into ArcMap and toggled on/off to view each time period. This gives a spatial view of each scenario, and where the plant was traveling during that time period.

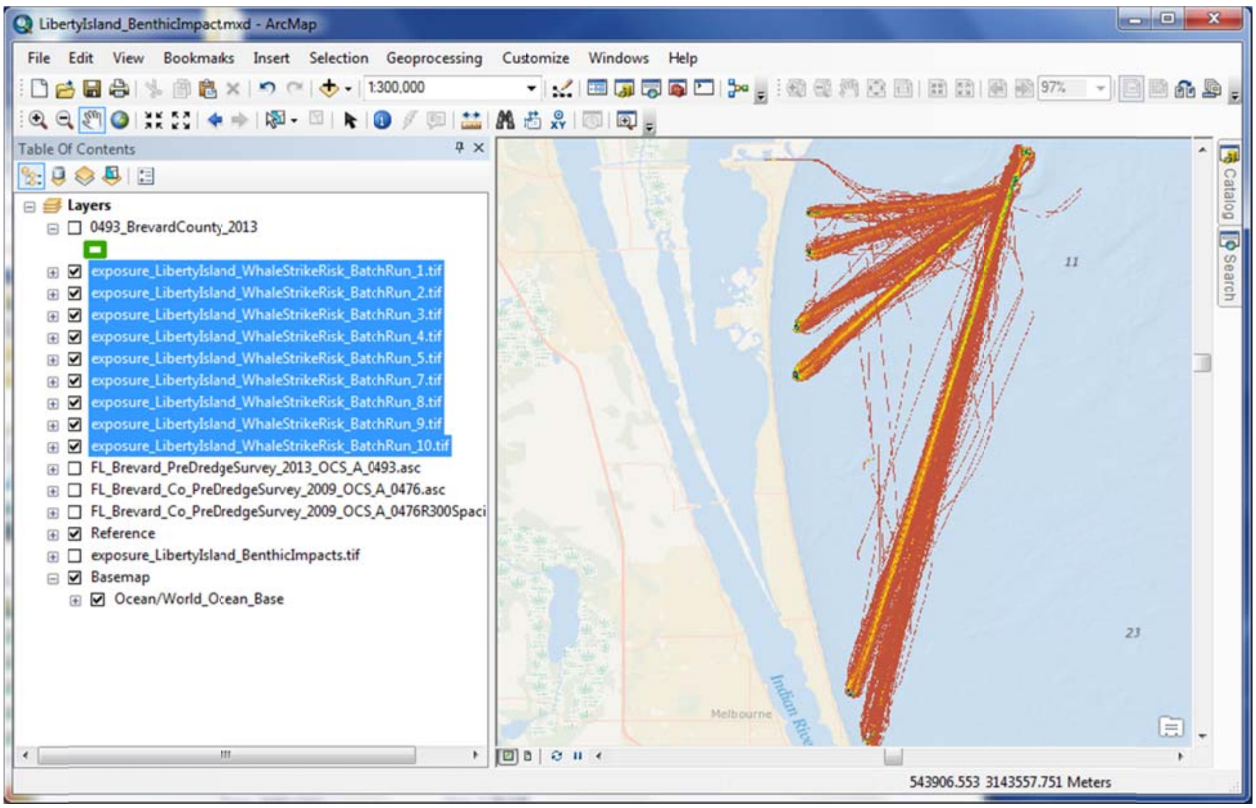


Figure 74. Strike risk exercise: batch files in ArcMap.

This completes the Strike risk with vessels case study.

5.5 Exposure of Sensitive Areas to Dredge Plant Activity

5.5.1 Situation

A sensitive or protected area* (eel grass, clam bed, etc.) has a well-defined border. Times a plant are in or near the area are used to build a 'heat map' to identify possible impacts from vessel activity.

*The 'sensitive or protected area' used in this example was created specifically to show functionality of a shape file as a border around the data set; the area is completely fictitious.

5.5.2 Tools

- Importing a shapefile as a border to identify regions of interest
- Using vessel location during all periods of activity

5.5.3 Steps Through the Applicatio:

1. Start the GUI
2. In the GUI select **Menu** > **New Scenario**
   a) Navigate to the folder containing the relevant CSV files from DQM
   b) Select the file to include in your scenario: *BOEM_725_36_501.CSV*; the input settings are updated with limits based on the CSV file. In the figure window the pink square identifies the bounding box along with the track lines of the vessel.
3. Update values as needed to define the new scenario.
   a) Update the bounding box to a shapefile: press the **Import Shapefile For Boundary** button
      i) Navigate to the *testPolygons* folder
      ii) Select the *example_2Polygons.shp* file
      iii) The 'Bounding Box Limits' values that would define the extent of the domain are now grayed out, and the **Import Shapefile For Boundary** button now says **Remove Shape file**; the text below this button identifies the full path of the shape file being used. To remove the current shape file press the **Remove Shape file** button, and the settings will revert to the bounding box limits.

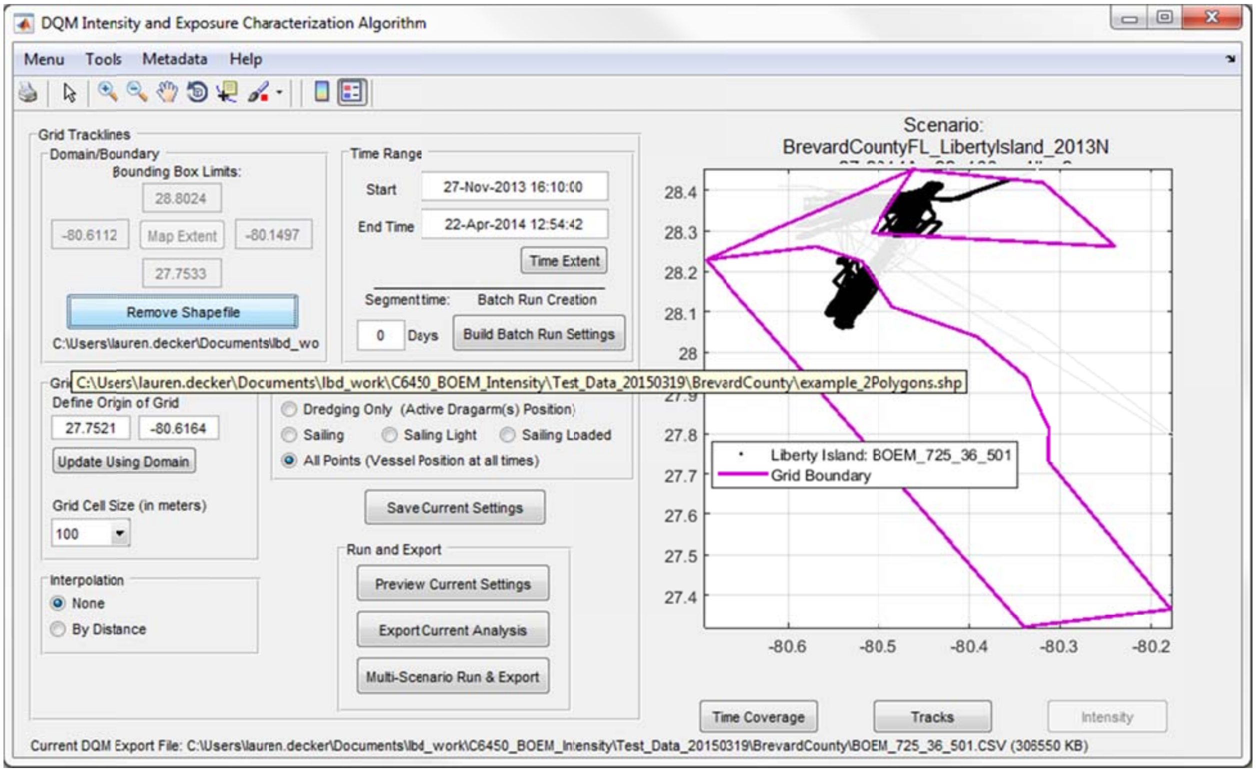


Figure 75. Exposure of protected area exercise: GUI after applying a shapefile boundary.

b) Press the **Update Using Domain** button to get a new grid origin. The new grid origin will be calculated based on the full extent of the shape file to return the lower left corner of the grid.

4. Save the current Scenario: press the **Save Current Settings** button, and save this scenario as *BrevardCountyFL_13Nov27-14Apr22_100m_All_PolygonBoundary*
5. Press the **Preview Current Settings** button to run the IECA. When the pop up window ‘Start New Exposure?’ appears, select **Yes**.

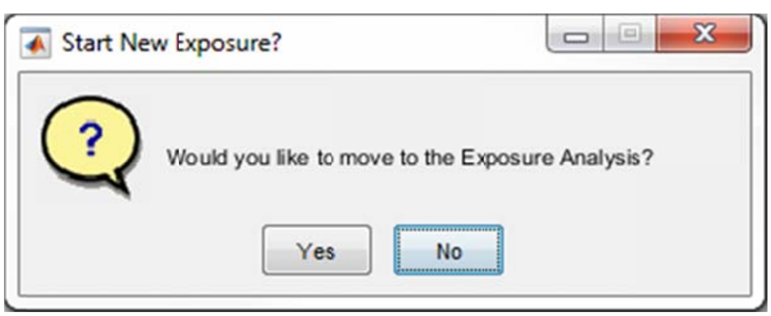


Figure 76. Exposure of protected area exercise: moving to the Exposure Analysis view, pop up window.

The option to rename the file pops up; keep the current name, press **OK**. Data are automatically exported to a CSV file in the Intensity folder.

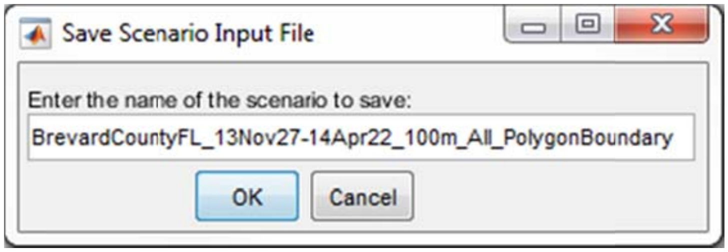


Figure 77. Exposure of protected area exercise: saving the INP file before moving to the Exposure Analysis view.

6. The view updates into the Exposure Analysis with the scenario already loaded. Once the preview is created, use the zoom tool (from the top menu bar) to zoom in the figure window.

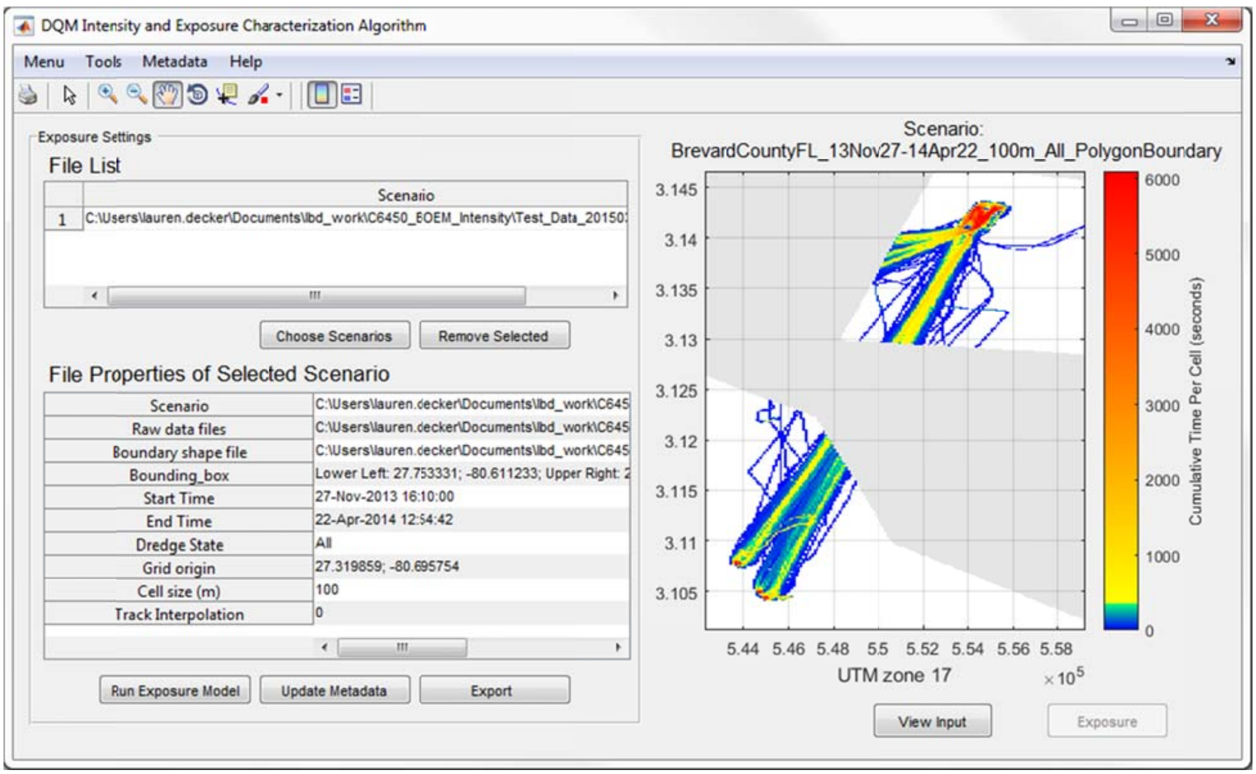


Figure 78. Exposure of protected area exercise: initial Exposure Analysis view, showing Intensity input.

7. Press the **Run Exposure Model** button; a pop up window appears when the processing is complete.

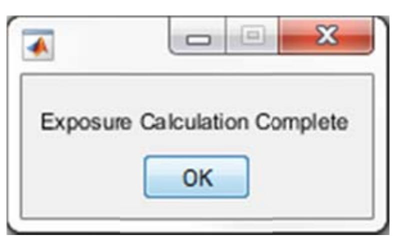


Figure 79. Exposure of protected area exercise: pop up notification that calculations are complete.

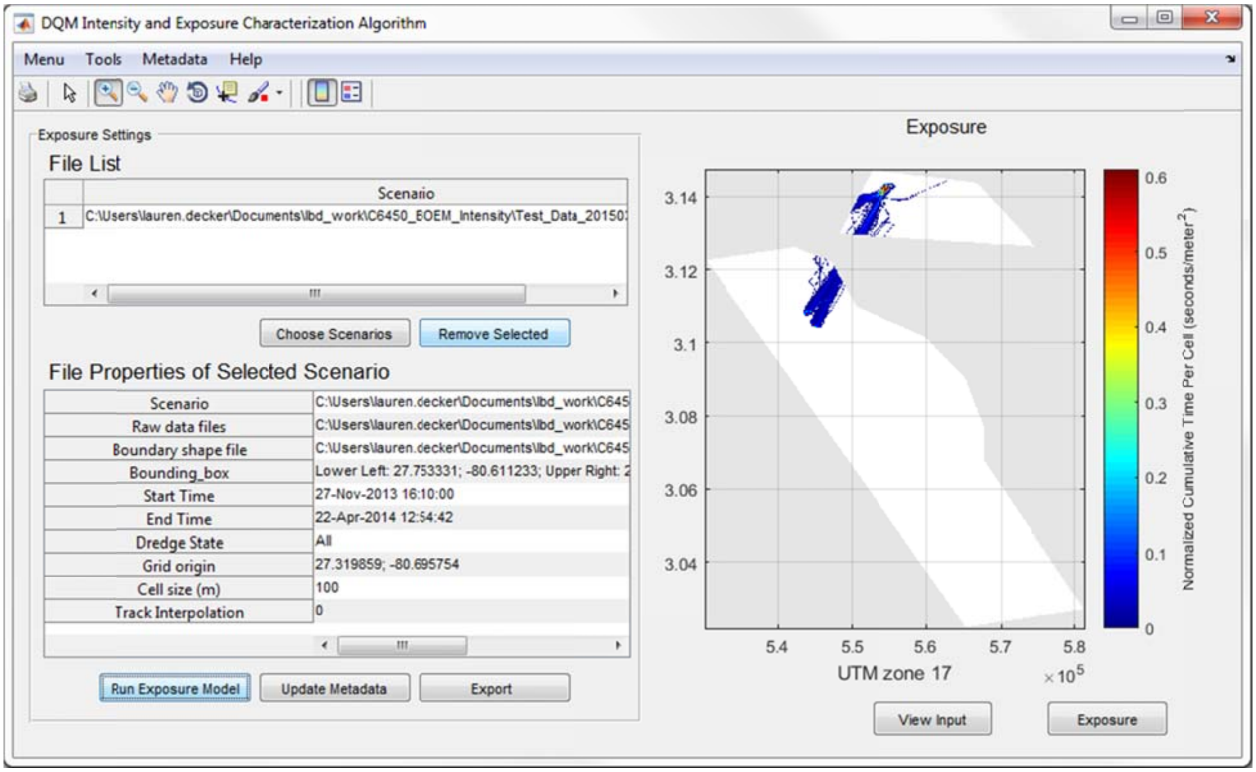


Figure 80. Exposure of protected area exercise: GUI showing completed Exposure calculation.

8. Press the **Export** button to save the GeoTIFF, CSV, and XML metadata files. Keep the default name that was also used to define the scenario file.
   BrevardCountyFL_13Nov27-14Apr22_100m_All_PolygonBoundary

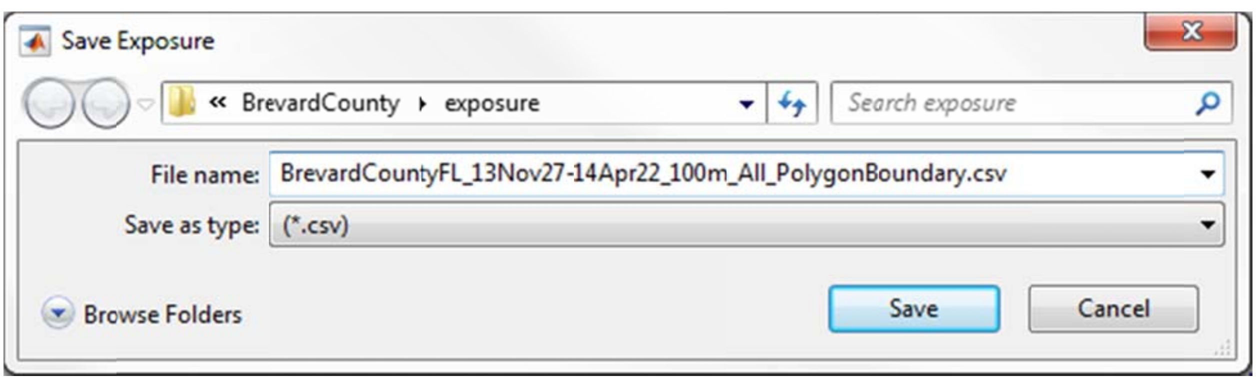


Figure 81. Exposure of protected area exercise: exporting the Exposure data to data products outside of MATLAB.

Exports are saved into the Exposure folder, and can be brought into a GIS for further review. This completes the Exposure of sensitive areas to dredge plant activity case study.

5.6 Exposure of Turtles to Dredging Activity

5.6.1 Situation

A region has been dredged for several years by multiple plants in or near a turtle habitat. Identifying when the plants are actively dredging to quantify area and cumulative time dredging will show general risk to turtles.

5.6.2 Tools

- Evaluating data from multiple plants
- Evaluating data from multiple projects and years
- Evaluating when and where each drag arm is dredging

5.6.3 Steps through the application

1. Start the GUI
2. In the GUI, view summary information from the CSV file to be used
    a. **Menu** > **Display DQM CSV File Summary**
    b. Navigate to the folder containing the CSV files from DQM
    c. Select the files: BOEM_273_536.CSV, BOEM_271_536.CSV, BOEM_42_405.CSV, BOEM_36_405.CSV, BOEM_35_405.CSV:

Figure 82. Exposure to dredging exercise: DQM CSV data file summary.

3. In the GUI select **Menu** > **New Scenario**
   a. Navigate to the folder with the CSV files from DQM
   b. Select the file to include in your scenario: *BOEM_273_536.CSV, BOEM_271_536.CSV, BOEM_42_405.CSV, BOEM_36_405.CSV, BOEM_35_405.CSV*; the input settings are updated with limits based on all the CSV files. The time range is large, from 2012 to 2014. In the figure window the pink square identifies the bounding box along with the set of colorful track lines of the vessels.

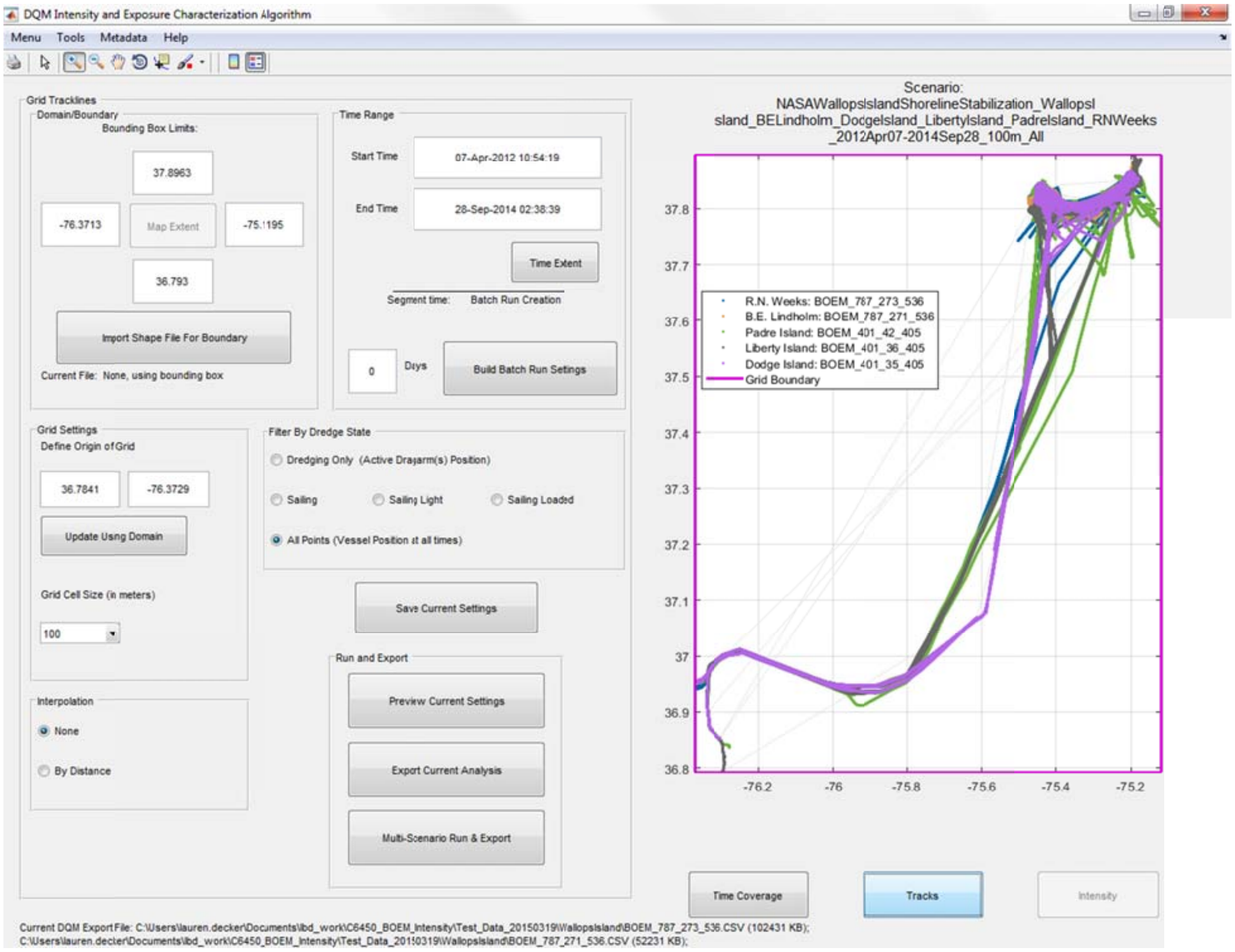


Figure 83. Exposure to dredging exercise: new scenario view showing several hoppers.

4. Update the Dredge State filter to **Dredging Only** and then press **Tracks**. You can zoom in to see the small area of Dredging in the figure window.

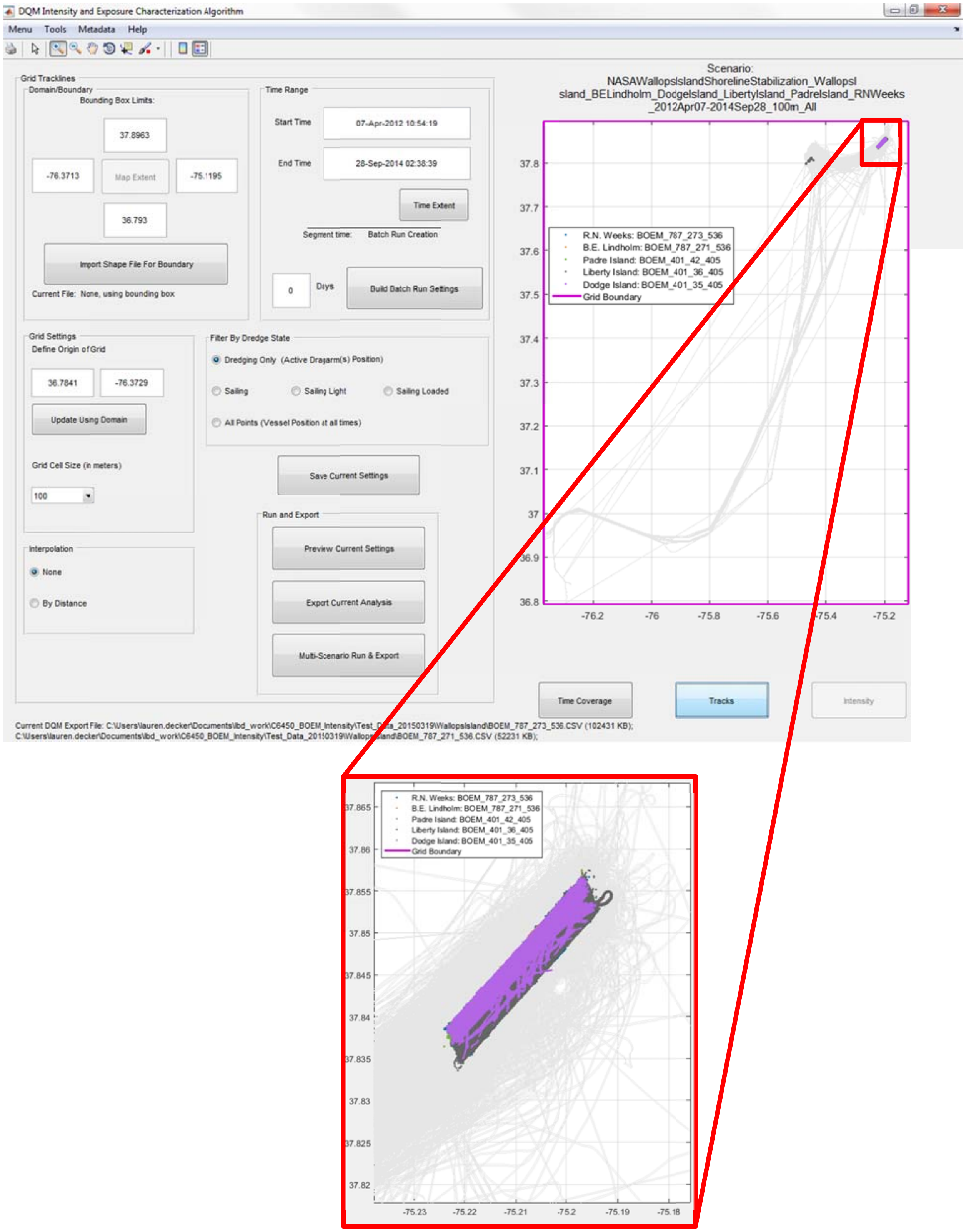


Figure 84. Exposure to dredging exercise: zoom after applying the "dredging only" filter.

5. This reveals that the selected files cover a large area and the area of interest for dredging will be a small area in the upper right corner. Define a better boundary for the domain based on the visible extent. Update scenario inputs:
    a. Bounding Box Limits:
       North = 37.86
       South = 37.83
       East = -75.19
       West = -75.23
    b. Under Grid Settings, press the **Update Using Domain** button to get a new grid origin.
    c. **Grid Cell Size**: Change to 50 (meters)

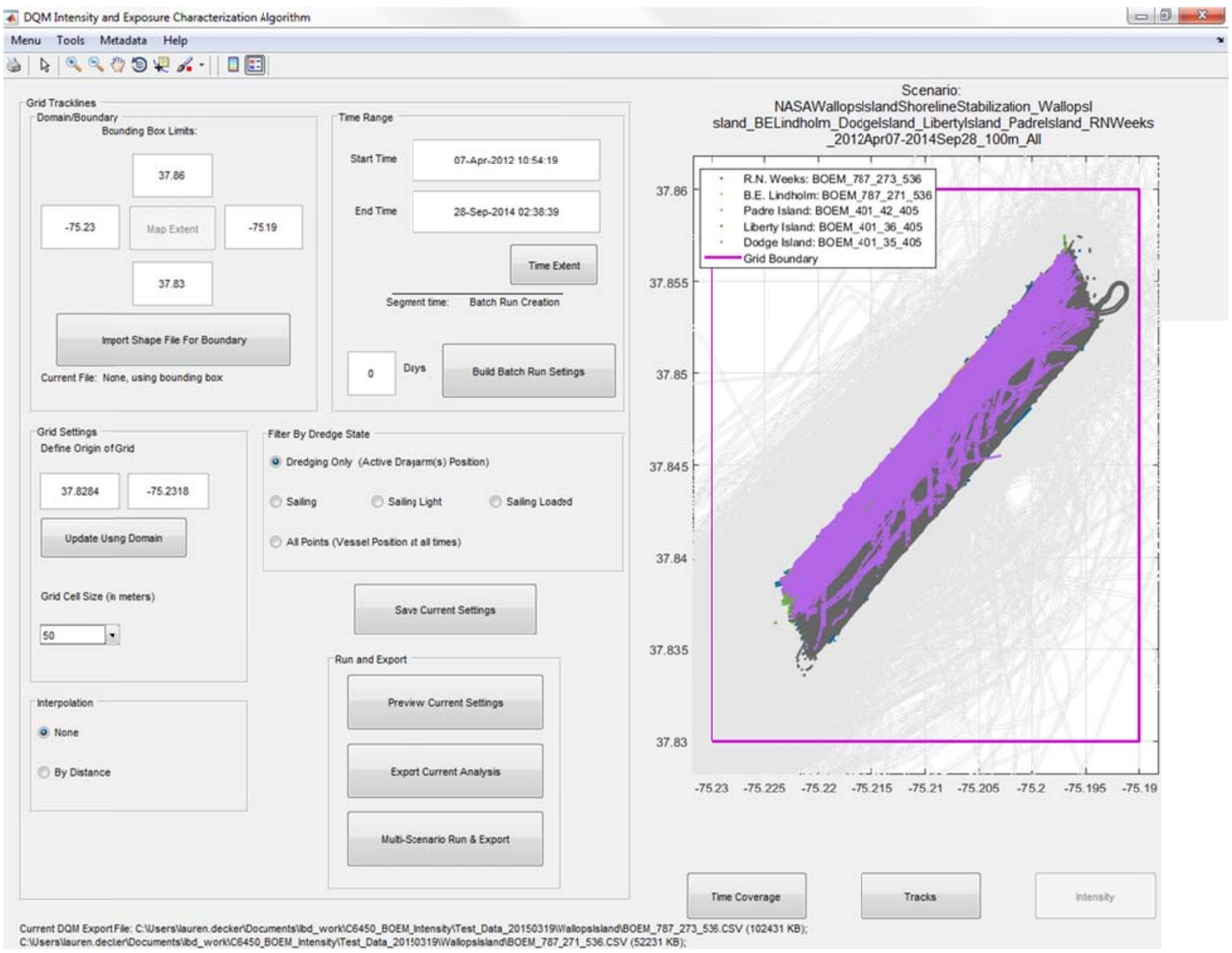


Figure 85. Exposure to dredging exercise: an updated domain based on dredging location and area of interest.

6. Press **Save Current Settings**
7. The default name to save your scenario is of the form Project_Plant_start-end_cellSz_Filter; which is a unique list of the projects: *NASAWallopsIslandShorelineStabilization* and *WallopsIsland* ; then a unique list of the dredge plants: *B.E.Lindholm*, *DodgeIsland*, *LibertyIsland*, *PadreIsland*, and *R.N.Weeks*; this makes the name very cumbersome:

   NASAWallopsIslandShorelineStabilization_WallopsIsland_B.E.Lindholm_DodgeIsland_LibertyIsland_PadreIsland_R.N.Weeks_2012Apr07-2014Sep28_50m_Dredging

   Reduce it to: *WallopsIsland_5Plants_2012Apr07-2014Sep28_50m_Dredging* and press **Save**.

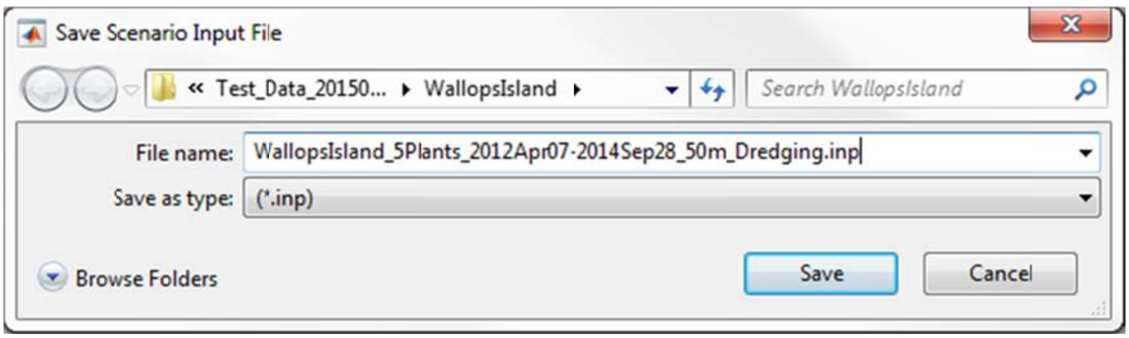


Figure 86. Exposure to dredging exercise: Save Scenario input file.

   Now, press **Preview Current Settings**; and move to the Exposure view.

8. The view will change to the Exposure view, with the one scenario we just ran loaded.

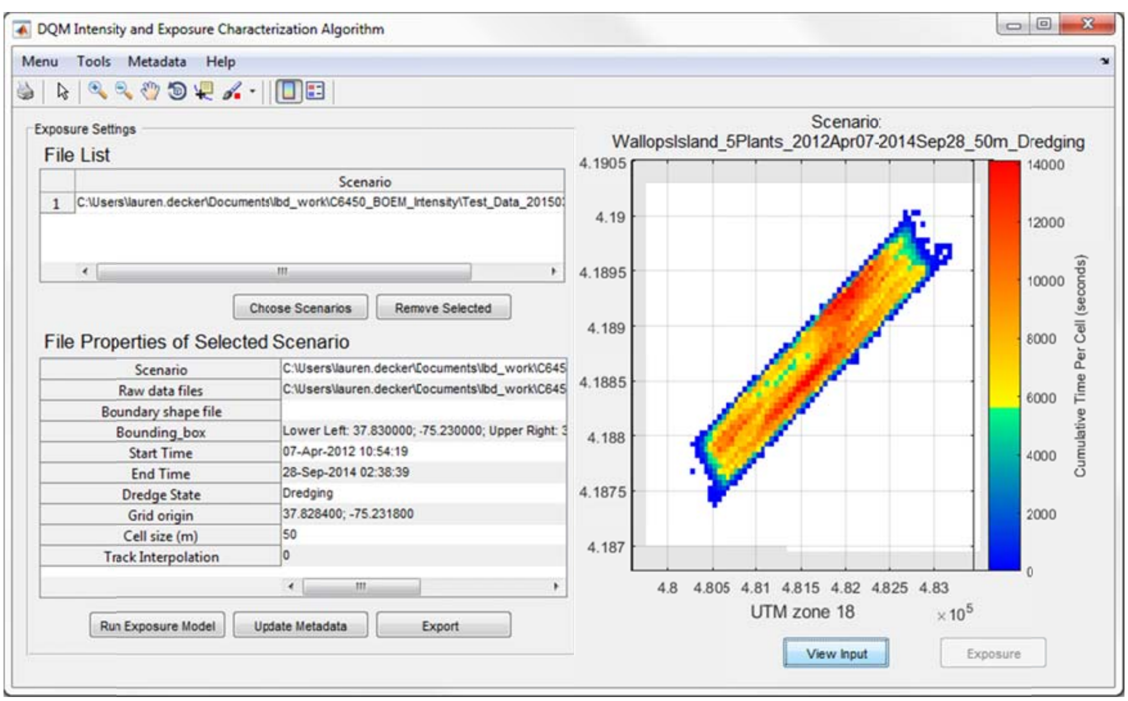


Figure 87. Exposure to dredging exercise: initial Exposure Analysis view showing Intensity input.

9. **Run Exposure Model**, with the current file.

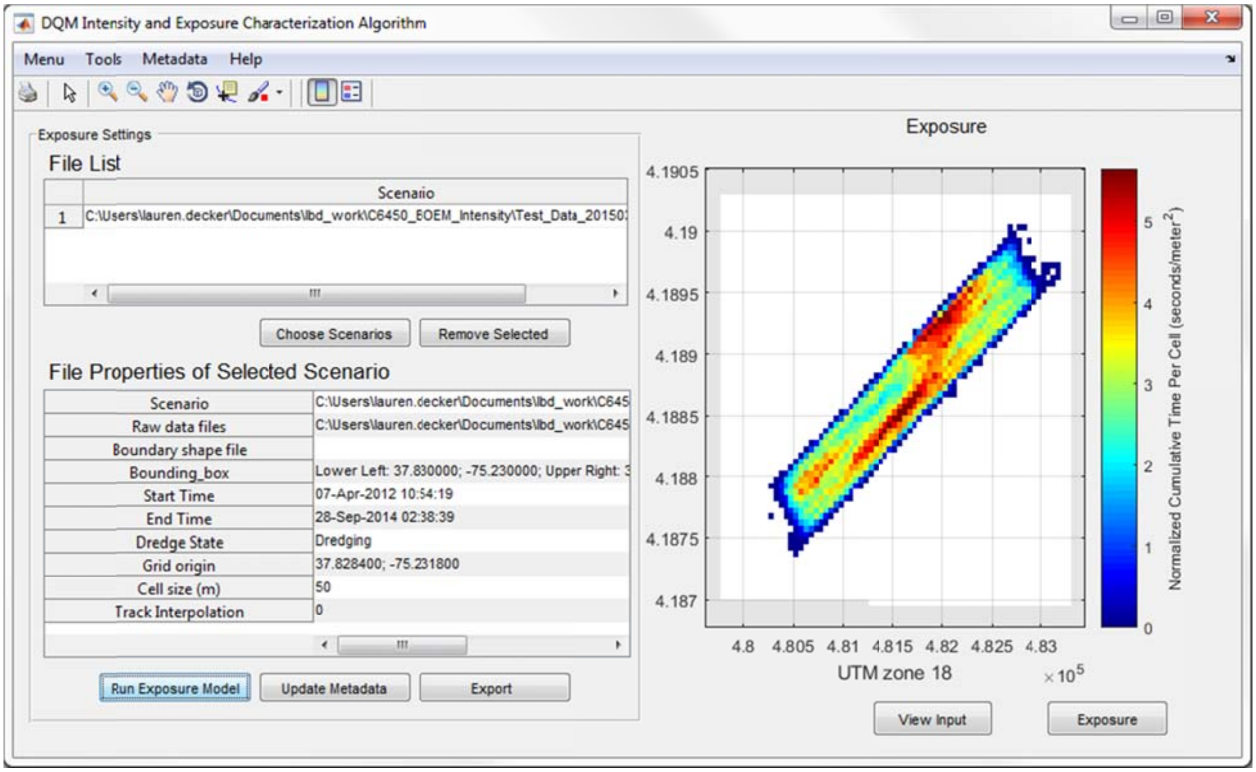


Figure 88. Exposure to dredging exercise: Exposure Analysis view showing Exposure results.

10. **Export** the data.

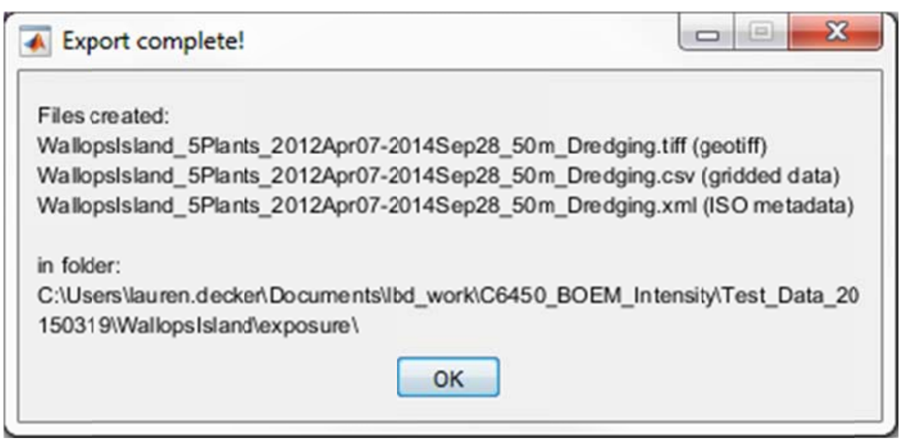


Figure 89. Exposure to dredging exercise: notification that Exposure results have been exported, and a list of the names of those files and folder location.

This now completes the processing in the IECA. The GeoTIFF can next be imported into ArcMap and assigned a color map, as seen in Figure 90 and Figure 91. Zoom out to get a better geographical sense of the location that is being dredged. Additional files can be imported into ArcMap for comparison, and further analysis can be conducted.

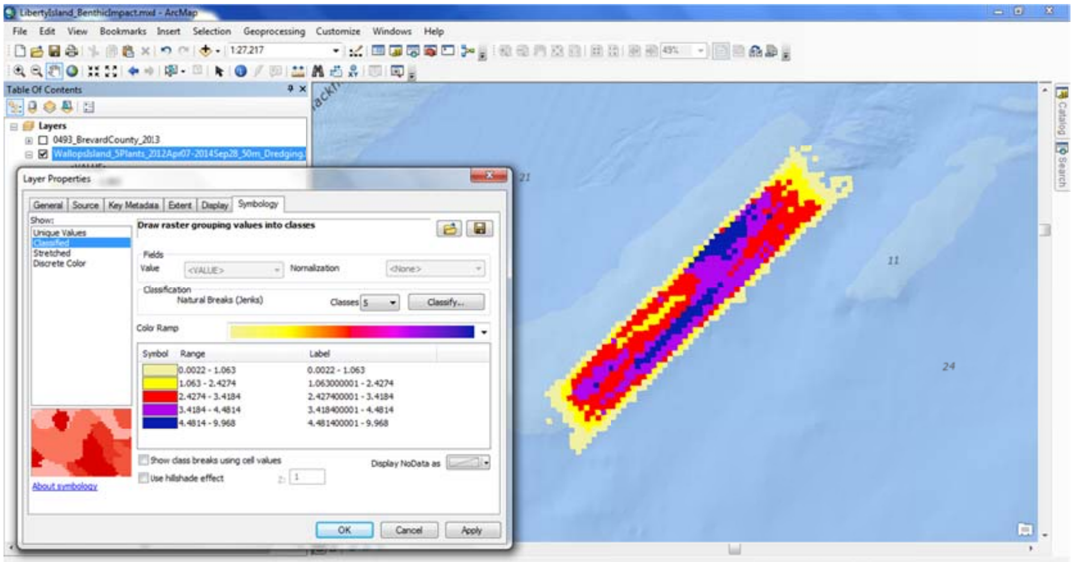


Figure 90. Exposure to dredging exercise: ArcMap showing the GeoTIFF data that was exported from the IECA GUI, and the color scale.

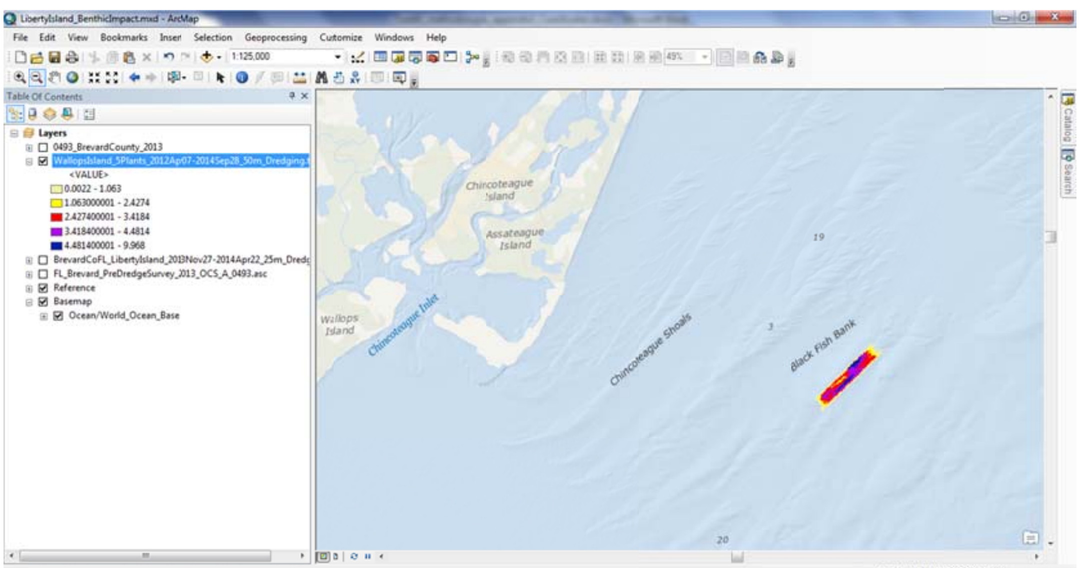


Figure 91. Exposure to dredging exercise: zoom out of the GeoTIFF data with a base map.

This completes the Exposure of turtles to dredging activity case study.

The case studies presented in this document are intended to elucidate functionality and workflow for the IECA. For additional support please refer to the main document.

Appendix B: Intensity and Exposure Calculation Algorithms Scripting Documentation

Contents

List of Tables

1 Introduction

This document describes the MATLAB scripts that are used in the Intensity and Exposure Characterization Algorithms. There are three main sections of code:

- Mathematical Module M-Files
- Input / Output Functionality
- Graphical User Interface M-Files

The mathematical module m-files are all of the form *Math_***.m,* in that all the files begin with the word 'Math'; similarly, input / output functions all begin with the letters "Fn", and the Graphical User Interface (GUI) m-files all begin with the letters "GUI" . This naming convention separates the files for easier identification.

The dependency report section documents relationships between the m-files. The dependency report identifies which files are called by and from other m-files.

After the dependencies are described, this document is organized by the three sections of code, and within each section, files are loosely sorted by the order in which each file is called during a typical workflow. Every m-file is described in the format:

Name of the file

Example of how the file is called in the script, usually of the form:

```
function [output variables] = Name of the file(input variables)
```

A brief description of what the file does.

Development was conducted on a Windows 64-bit operating system running Windows 7, MATLAB version r2017a. MATLAB m-files are not a binary proprietary compiled format; they are easily opened and read in text editors. This allows any user, even if they don't have MATLAB, to open and review the code itself. This document can be used as a simple and quick guide to finding m-files that are of interest to a user.

2 Dependency Report

The MATLAB functions (m-files) used in the IECA are presented below in Table 1 with their list of dependences.

Table 1. Dependency report of MATLAB files, which functions they call, and what functions call them.

MATLAB File	Called Functions	Calling Functions
DQM_IECA	DQM_loadScenario Math_GridData_UTM Math_build_UTM Math_gridCreation Math_increaseResolution	Fn_batchRunIECA Fn_diagnosticRun GUI_callbacks
DQM_loadScenario	Fn_loadCSV Fn_readINP Fn_readShapeBoundary Math_BBox_toUTM Math_build_UTM Math_updateOrigin	DQM_IECA Fn_diagnosticRun GUI_callbacks GUI_loadScenario GUI_selectCSV GUI_updateScenarioFiles
Fn_CombineInputs		Fn_batchRunIECA GUI_callbacks
Fn_MMPCrossWalkLoad		GUI_callbacks
Fn_RemDataOutOfBB		GUI_callbacks
Fn_batchRunIECA	DQM_IECA Fn_CombineInputs Fn_exportIntensity Fn_loadGrid	GUI_callbacks
Fn_buildISO_fromTemplate		Fn_exportExposure
Fn_diagnosticRun	DQM_IECA DQM_loadScenario GUI_drawGriddedData GUI_drawTrackData Math_BBox_toUTM Math_build_UTM Math_updateOrigin	GUI_callbacks
Fn_exportExposure	Fn_buildISO_fromTemplate Fn_exportGrid_toTIFF Fn_writeCSV	GUI_callbacks
Fn_exportGrid_toTIFF	\map\map\maprasterref.m \map\mapformats\geotiffwrite.m	Fn_exportExposure
Fn_exportIntensity	Fn_loadCSV Fn_writeCSV Fn_writeINP	Fn_batchRunIECA GUI_callbacks GUI_dlgMoveToExposure

MATLAB File	Called Functions	Calling Functions
Fn_getCSVStats	Fn_loadCSV	GUI_callbacks
Fn_loadCSV		DQM_loadScenario Fn_MMPCrossWalkLoad Fn_exportIntensity Fn_getCSVStats GUI_selectCSV GUI_writeINP_dlg
Fn_loadGrid	Fn_readINP Math_BBox_toUTM Math_build_UTM Math_gridCreation	Fn_batchRunIECA GUI_dlgMoveToExposure GUI_loadScenario GUI_selectGrid GUI_selectScenarioFiles Math_calcExposure
Fn_metadataDefaults	\map\mapproj\minvtran.m	Math_calcExposure
Fn_readINP		DQM_loadScenario Fn_loadGrid
Fn_readShapeBoundary	\map\mapformats\shaperead.m	DQM_loadScenario GUI_importShape GUI_importShapeForVis Math_BBox_toUTM Math_updateOrigin
Fn_writeCSV		Fn_exportExposure Fn_exportIntensity
Fn_writeINP		Fn_exportIntensity Fn_writeINP_batches GUI_writeINP_dlg
Fn_writeINP_batches	Fn_writeINP	GUI_callbacks
GUI_DQM	GUI_callbacks GUI_construction	

MATLAB File	Called Functions	Calling Functions
GUI_callbacks	DQM_IECA DQM_loadScenario Fn_CombineInputs Fn_MMPCrossWalkLoad Fn_RemDataOutOfBB Fn_batchRunIECA Fn_diagnosticRun Fn_exportExposure Fn_exportIntensity Fn_exposureFilePreTests Fn_getCSVStats Fn_writeINP_batches Fn_writeShape GUI_callbacks GUI_contact GUI_diagnosticReview GUI_dlgMoveToExposure GUI_drawGriddedData GUI_drawTrackData GUI_importShape GUI_importShapeForVis GUI_loadScenario GUI_readINP GUI_removeSelectedScenarios GUI_selectCSV GUI_selectGrid GUI_selectScenarioFiles GUI_switchView GUI_testData GUI_updateExposureFig GUI_updateMetadata GUI_updateScenarioFiles GUI_version GUI_writeINP_dlg GUI_writeINP_fromGUI Math_BBox_toUTM Math_build_UTM Math_calcExposure Math_updateOrigin	GUI_DQM
GUI_construction		GUI_DQM
GUI_contact		GUI_callbacks
GUI_diagnosticReview		GUI_callbacks

MATLAB File	Called Functions	Calling Functions
GUI_dlgMoveToExposure	Fn_exportIntensity Fn_loadGrid GUI_switchView GUI_updateExposureFig GUI_writeINP_dlg	GUI_callbacks
GUI_drawGriddedData		Fn_diagnosticRun GUI_callbacks GUI_loadScenario
GUI_drawTrackData		Fn_diagnosticRun GUI_callbacks
GUI_importShape	Fn_readShapeBoundary Math_BBox_toUTM Math_build_UTM	GUI_callbacks
GUI_importShapeForVis	Fn_readShapeBoundary Math_build_UTM	GUI_callbacks
GUI_loadScenario	DQM_loadScenario Fn_loadGrid GUI_drawGriddedData GUI_readINP	GUI_callbacks
GUI_readINP		GUI_callbacks GUI_loadScenario GUI_testData
GUI_removeSelectedScenarios	GUI_updateExposureFig	GUI_callbacks
GUI_selectCSV	DQM_loadScenario Fn_loadCSV	GUI_callbacks
GUI_selectGrid	Fn_loadGrid	GUI_callbacks
GUI_selectScenarioFiles	Fn_exposureFilePreTests Fn_loadGrid	Fn_exposureFilePreTests GUI_callbacks
GUI_switchView		GUI_callbacks GUI_dlgMoveToExposure
GUI_testData	GUI_readINP Math_build_UTM Math_updateOrigin	GUI_callbacks
GUI_updateExposureFig		GUI_callbacks GUI_dlgMoveToExposure GUI_removeSelectedScenarios
GUI_updateMetadata		GUI_callbacks
GUI_updateScenarioFiles	DQM_loadScenario	GUI_callbacks
GUI_version		GUI_callbacks
GUI_writeINP_dlg	Fn_loadCSV Fn_writeINP	GUI_callbacks GUI_dlgMoveToExposure

MATLAB File	Called Functions	Calling Functions
GUI_writeINP_fromGUI		GUI_callbacks
Math_BBox_toUTM	Fn_readShapeBoundary Math_build_UTM	DQM_loadScenario Fn_diagnosticRun Fn_loadGrid GUI_callbacks GUI_importShape Math_calcExposure
Math_GridData_UTM	Math_build_UTM Math_gridCreation	DQM_IECA
Math_build_UTM	\map\map\wgs84Ellipsoid.m \map\mapdisp\defaultm.m \map\mapproj\mfwdtran.m \map\mapproj\utmzone.m	DQM_IECA DQM_loadScenario Fn_MMPGISLoad Fn_diagnosticRun Fn_loadGrid GUI_callbacks GUI_importShape GUI_importShapeForVis GUI_testData Math_BBox_toUTM Math_GridData_UTM Math_updateOrigin
Math_calcExposure	Fn_loadGrid Fn_metadataDefaults Math_BBox_toUTM \map\map\polybool.m	GUI_callbacks
Math_gridCreation	\map\map\areamat.m \map\map\deg2km.m \map\map\meshgrat.m \map\map\spzerom.m \map\map\wgs84Ellipsoid.m	DQM_IECA Fn_loadGrid Math_GridData_UTM
Math_increaseResolution	\map\map\gcwaypts.m \map\map\legs.m	DQM_IECA
Math_updateOrigin	Fn_readShapeBoundary Math_build_UTM \map\mapproj\minvtran.m	DQM_loadScenario Fn_diagnosticRun GUI_callbacks GUI_testData

3 Mathematical Module M-Files

The mathematical module m-files are the core of the Intensity and Exposure Characterization Algorithms. The files in this section are ordered in the way they would generally be called during the Intensity calculation, then the Exposure calculation. A general overview of the IECA order of calculations follows. The scenario input file location (the full path), is passed to the DQM_IECA function. This function loads the scenario input file and calls all the necessary scripts. If the user has selected the option to interpolate GPS locations for distances larger than the half the cell size, it will be completed on the latitude and longitude values as the first step. Then, the locations and domains are brought into UTM coordinate systems. An empty grid with the correct scales and domain is created next, and, finally, the values are transformed and saved into the grid.

The Exposure calculation is contained in a single file where many tests are completed to make sure a user is aware of any differences between files that may be of concern. When cell sizes of the selected set of Intensity scenarios are different, the values are aggregated into the largest cell size.

3.1 DQM_IECA

```
function [gridStruct, inp_vals, flist, BBPoly] = DQM_IECA(varargin)
```

[gridStruct, inp_vals, flist, BBPoly] = DQM_IECA(scenarioPath)

[gridStruct, inp_vals, flist, BBPoly] = DQM_IECA(inp_vals, flist, BBPoly)

Dredging Quality Management's Intensity and Exposure Characterization Algorithms (DQM-IECA)—this is the main function to construct gridded data from 'raw' tracks from dredge plants. The only required input is the file location for the scenario. This function does a 'clean load' of an INP file and all data files specified. It constructs a bounding box in space and time and removes any data in the raw CSV files that falls outside of that box. If the resolution of the data is to be interpolated between distant points, the interpolation script is called before sending the tracks to the gridding algorithm. Returned values are the accumulated times the dredge plant spent in cells of a grid in the gridStruct variable, along with the INP values that were loaded and the CSV file data that was gridded.

3.2 Math_updateOrigin

```
function [gridOrigin_lat, gridOrigin_lon, zoneUsed] = Math_updateOrigin(inp_vals)
```

When the minimum latitude and longitude values of the bounding box are updated, this script updates the grid origin variable input_vals.gridOrigin_LL to better align with the new limits.

3.3 Math_increaseResolution

```
function [latVec, lonVec, timeVec, DredgeState, varargout] = Math_increaseResolution(...
 latVec, lonVec, timeVec, DredgeState, filtDS, distThresh, dontInterpThresh, varargin)
```

This function is a pre-processing step to gridding data. When data sampling is sparse compared to grid size, this function interpolates to maximum distance thresholds.

Low resolution: Plant location is well defined by the sampling interval within the grid, data can be gridded as-is.

Medium resolution: Plant location skips cells when it is travelling quickly due to the reporting interval, a simple interpolation scheme is implemented to increase the sampling interval down to the approximate resolution of the grids.

High resolution: The physical plant is larger than the grid cells, and its shape must be taken into account. *not implemented here*

To increase data resolution, first distance between each location is found. For distances greater than a defined threshold, new locations are added along with appropriate associated data such as time stamp and dredge state. The defined distance threshold implemented in this release is half the length of the side of a grid cell.

3.4 Math_build_UTM

```
function [X, Y, utmstruct] = Math_build_UTM(latVec, lonVec, varargin)
```

[X, Y, utmstruct] = Math_build_UTM(latVec, lonVec)

[X, Y, utmstruct] = Math_build_UTM(latVec, lonVec, zone)

Converts latitude and longitude vectors into UTM. The 'zone' input variable can be a UTM zone number without the latitude band OR the EPSG code as a string, e.g., 'EPSG:32XXX'. Only conversion from WGS 84 to UTM is supported:

EPSG:32600: WGS 84 / UTM grid system (northern hemisphere)

EPSG:32700: WGS 84 / UTM grid system (southern hemisphere)

3.5 Math_BBox_toUTM

```
function [BBPoly] = Math_BBox_toUTM(inp_vals, ZONE)
```

Receives a defined boundary, either from a user-identified shape file or defined from bounding box min/max values. If the INP file contains a user-identified shapefile, it will always use that as the domain; if the field is empty, the function will use the latitude/longitude bounding box.

Returns positions of the original boundary and a calculated 'buffer' region in both latitude/longitude and UTM coordinates. The buffer region is defined by determining a centroid of the original boundary points and pushing out about 200 m away from the center point in both latitude and longitude. A convex hull is wrapped around the set of points and the points in that convex hull are returned. Both the boundary and the buffer are converted to UTM (using the 'zone' provided) and returned in the structured array.

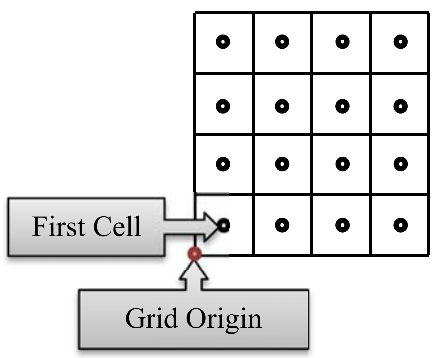
The output variable BBPoly contains: lat, lon, Buffer_lat, Buffer_lon, X, Y, Buffer_X, Buffer_Y

3.6 Math_gridCreation

```
function [gridStruct] = Math_gridCreation(origin, boundary, scale, type)
```

Creates a grid with the following required elements:

(1) An 'origin', the lower left hand location of the grid
    [lat, lon] or [Y, X]
(2) A 'boundary', which can be as simple as the minimum and maximum of latitudes and longitudes OR as complicated as a polygon vector of a borrow area
    [lat1, lon1; or [Y1, X1;
    lat2, lon2] Y2, X2]
(3) A 'scale', which is the size of the grid cells - in METERS
    [100], [50], [25], or [10]
(4) A 'type' of grid: 'UTM', 'equal_angle' (Note: Only UTM is implemented in this release.)
    In UTM grid construction 'origin' is forced to be a round number, floor(origin) is used. Also, the 'origin' is the most south and most west location of the grid. The first data point is centered in the first cell, so the first point is origin + scale/2, as depicted below:



3.7 Math_GridData_UTM

```
function [grid_time, YGrid, XGrid] = Math_GridData_UTM(...

        latVec, lonVec, timeVec, filteredSet_TF, UTMZone, origin_UTM, binSize_m)
```

Accumulates/aggregates the amount of time the vessel was located within cells of a grid. The variables passed should be latitude, longitude, the MATLAB date-stamp of observations, a true/false variable indicating which data points are inside/outside the filter area, UTM zone, the origin of the grid to build, and length of the sides of the cells (assuming squares, and meters). The time vector is used to find times between samples. Time located near one sample is assumed to be half of the time spent between the previous sample and itself, plus half the time spent between itself and the next sample.

```
Time: 3 3+5 5+2 2
Samples(X): X---|---X-----|-----X--|--X
```

The locations in latitude and longitude are converted into UTM, and the data are filtered by the filteredSet_TF variable. The limits of the grid are the origin values (in UTM) passed into the function as [X, Y]; to the ceiling of the largest UTM X and Y location to the nearest km: floor(min(points_km)) to ceil(max(points_km))

UTM GPS locations are then indexed into the grid defined by the limits and the bin size (binSize_m). The times associated with each GPS point are summed together using the indexing. The result is a grid of time spent within a cell: grid_time. YGrid, XGrid are the UTM grid coordinates.

3.8 Math_calcExposure

```
function [exposureStruct] = Math_calcExposure(listOfOutFiles)
```

The main calculation that runs and constructs Exposure model results.

Loads any number of Intensity CSV data files; tests to make sure the grid origins, cell scales, etc. are the same; then sums the grids and normalizes to cell size. Metadata defaults are also built.

Notes:

(1) Grid origins must match between files to do calculations. Exposure will not be calculated otherwise.
(2) When not all cells sizes are the same between grids, the largest grid size is used and all finer grids resolutions are lowered.
(3) A series of warnings are displayed, but calculations are still completed if any of the following apply:
   - Scenarios are using multiple dredging states.
   - Scenarios are using both increased and original track resolution.
   - Scenarios are using multiple domains.
   - Dredge/Time Scenario Overlap, i.e., the same raw data may be included in more than one scenario in the set.

---

4 Input / Output Functionality

While the 'Math' functions of the IECA do the major calculations, the Fn (Function) series of files does the major overhead of reading, writing, loading, and exporting to and from the MATLAB environment.

4.1 DQM_loadScenario

```
function [inp_vals, flist, BBPoly, visTools] = DQM_loadScenario(filePathINP, varargin)
```

[inp_vals, flist, BBPoly, visTools] = DQM_loadScenario(filePathINP, {dataStream1, dataStream2, etc...})

[inp_vals, flist, BBPoly, visTools] = DQM_loadScenario(inp_vals, {dataStream1, dataStream2, etc...})

[inp_vals, flist, BBPoly, visTools] = DQM_loadScenario([], {dataStream1, dataStream2, etc...})

The function DQM_loadScenario reads parameters for DQM_IECA input files. Input files allow the user to save different scenarios, run batch modes, see old settings used for runs, and also provide the ability to run models without the use of a GUI.

Current list of possible data streams:

- DREDGE_NAME
- CONTRACT_PERMIT_NUMBER
- PROJECT
- DATE_TIME
- POINT_ID
- DREDGE_STATE
- VESSEL_X
- VESSEL_Y
- VESSEL_SPEED
- VESSEL_HEADING
- VESSEL_COURSE
- PUMP_OUT_ON
- PORT_DRAG_X
- PORT_DRAG_Y
- STBD_DRAG_X
- STBD_DRAG_Y
- CENTER_DRAG_X
- CENTER_DRAG_Y
- LOAD_NUMBER
- VOLUME
- DISPLACEMENT
- DRAGHEAD_DEPTH_PORT
- DRAGHEAD_DEPTH_STBD
- DRAGHEAD_DEPTH_CENTER
- PORT_DRAG_ACTIVE
- STBD_DRAG_ACTIVE
- CENTER_DRAG_ACTIVE

4.2 Fn_readINP

```
function inp_file = Fn_readINP(varargin)
```

inp_file = Fn_readINP

inp_file = Fn_readINP(filePath)

The function Fn_readINP reads parameters for DQM_IECA input files. Input files allow the user to save different scenarios, run batch modes, see old settings used for runs, and also provide the ability to run models without the use of a GUI.

4.3 Fn_CombineInputs

```
function inp_vals = Fn_CombineInputs(inp_vals, inp_vals_temp, CFIdx)
```

inp_vals = Fn_CombineInputs(inp_vals, inp_vals_temp, CFIdx)

The function Fn_CombineInputs integrates the input values from the new "temps" into the full inp_vals set under any condition.

4.4 Fn_writeINP

```
function Fn_writeINP(filePath, inp_vals)
```

The function Fn_writeINP updates parameters for DQM_IECA input files. Input files allow the user to save different scenarios, run batch modes, see old settings used for runs, and also provide the ability to run models without the use of a GUI.

4.5 Fn_writeINP_batches

```
function INPFileName = Fn_writeINP_batches(inp_vals, timeInterval, fileNamesAndRngs)
```

This function builds a series of inp files broken up in time to use as inputs for a model batch run. The variable inp_vals is the 'master' list of files, time extents, boundary, etc. The variable timeInterval is the interval, in days, by which to divide the master file. The variable fileNamesAndRngs contains each file name and date range.

4.6 Fn_batchRunIECA

```
function [inp_vals, gridStruct, BBPoly] = Fn_batchRunIECA(varargin)
```

[inp_vals, gridStruct, BBPoly] = Fn_batchRunIECA

[inp_vals, gridStruct, BBPoly] = Fn_batchRunIECA(filename)

Prompts the user to select the set of batch run INP files to process using the DQM_IECA.

4.7 Fn_loadCSV

```
function CSV = Fn_loadCSV(CSVFullPath, rowsToKeep, varargin)
```

CSV_Data = Fn_loadCSV(CSVFullPath, rowsToKeep)

CSV_Data = Fn_loadCSV(CSVFullPath, rowsToKeep, {dataStream1, dataStream2, etc...})

Returns the data associated with the data streams from the selected CSV files; when no header names are given all the data is loaded.

rowsToKeep can be set to:
1 : load all the data
2 : load only the first line of data
3 : load the first and last line of data from a file

4.8 Fn_readShapeBoundary

```
function boundary = Fn_readShapeBoundary(varargin)
```

boundary = Fn_readShapeBoundary

boundary = Fn_readShapeBoundary(filePath)

boundary = Fn_readShapeBoundary(MMP_load_TF, LeaseNo)

Uses the shaperead function to pull in XY information from a shape file, and save it to a structured array, along with the file name (requires MATLAB mapping tool box). When MMP_load_TF and LeaseNo are included, function will filter down sections of the shapefile imports when loading in MMP.

4.9 Fn_RemDataOutOfBB

```
function flist = Fn_RemDataOutOfBB(BBPoly, flist)
```

flist = Fn_RemDataOutOfBB(BBPoly, flist)

Removes all data outside of bounding box in the data currently loaded. This does not remove the data from the file; only the data currently within the session is removed.

4.10 Fn_writeCSV

```
function fileName = Fn_writeCSV(scenario, homeFolder, data, XGrid, YGrid, EPSG_code, int1_exp2)
```

Writes out the data from a gridded array into a CSV file. A small header in the CSV includes a few pieces of information to recreate the grid, and links to the inp file and the output metadata file are also included. Data has the X and Y (row/column) location data included in the gridded dataset as the first value in the row or column.

Header information:

Line 1: The number of x and y grid cells, and an identifying number: 1 (Intensity) or 2 (Exposure).
Line 2: Lower left corner of grid as easting and northing. (Location of first data point - NOT origin.)
Line 3: Grid resolution (in meters)
Line 4: Projection as an EPSG code
Line 5: Name of the scenario file
Line 6: Metadata file

4.11 Fn_exportIntensity

```
function Fn_exportIntensity(gridStruct, inp_vals)
```

Exports the gridded Intensity data into a CSV file with a small header, using Fn_writeCSV. Also builds the output (OUT) file.

4.12 Fn_loadGrid

```
function [gridStruct, inp_vals, BBPoly] = Fn_loadGrid(outPath)
```

Loads in gridded CSV files from either Intensity or Exposure runs. The only necessary input is the path to the 'out' file that was created during export. No new processing steps are completed, only grid creation to load the CSV data into, so all the projections are included.

4.13 Fn_exportExposure

```
function Fn_exportExposure(exposureStruct)
```

Exports the calculated Exposure from gridded scenarios. It exports the gridded CSV, just like the Intensity data, but it also exports a raster image (a GeoTIFF) and the ISO metadata. The function requires the user to supply the file base name for the three exports.

4.14 Fn_exportGrid_toTIFF

```
function Fn_exportGrid_toTIFF(gridStruct,fileName)
```

Exports the gridded data into a GeoTIFF file, with a grayscale colormap of the actual data values.

4.15 Fn_MMPCrossWalkLoad

```
function [CrWlkFig_h, uitable_CrWlkData, CrWlk_Data, filename] = Fn_MMPCrossWalkLoad(inp_vals)
```

[CrWlkFig_h, uitable_CrWlkData, CrWlk_Data] = Fn_MMPCrossWalkLoad(inp_vals)

Allow the user to pull in the Marine Minerals Program (MMP) GIS master data to help generate relevant scenarios and Exposure analyses. These data include the borrow area shape file with polygon features for each borrow area and attribute table. This will allow the user to do the following:

a. Visualize the borrow area in the GUI map.
b. Cross walk the corresponding borrow area name to the USACE contract number and the BOEM lease number.
c. Construct the IECA Exposure metadata with fields such as BOEM lease number, project, and borrow area name.

4.16 Fn_metadataDefaults

```
function metadata = Fn_metadataDefaults(ALL_inp_vals, exposureStruct, brokenBestPractice)
```

This function is called during the Exposure run to build defaults for the ISO metadata.

4.17 Fn_buildISO_fromTemplate

```
function Fn_buildISO_fromTemplate(homeFolder, fileName, Metadata)
```

Called during Exposure export, this function takes the metadata for the run, reads in template information from an XML file and populates all fields in the template marked with [*]. All such fields should have one of the following to populate the template:

- automated information
- default information and/or
- user defined information

The fileIdentifier is automated from a random UUID.

Fields like metadata creation date, spatialRepresentationInfo, etc. are also automated using information saved during processing. The title, abstract, purpose, etc. have default values that can be updated during processing by updating the metadata structure. Some fields have no default values, as in some of the descriptive Keywords that should be populated during processing by updating the metadata structure.

NOTE: if you are adding new fields to the metadata, you will need to update the information in two places: (1) the metadata_template.xml (2) Fn_metadataDefaults.m

---

4.18 Fn_getCSVStats

```
function Fn_getCSVStats
```

Pulls the first and last line from a DQM CSV file to give the Plant Name, contract, and location along with the time range of the data.

4.19 Fn_diagnosticRun

```
function didRun = Fn_diagnosticRun(axH)
```

didRun = Fn_diagnosticRun(axH)

Creation of a sequence of data files and input settings to run diagnostic tests to estimate a computer's capability to run the IECA. The result is a matrix of the amount of time to load/run many different scenarios. Questions this diagnostic test tries to answer:

- How long does each file take to load, as both a CSV & MAT?
- How long does each file take to calculate Intensity with default settings?
- How much longer does calculation take for each smaller grid cell size?
- How much longer does calculation take when increasing the area covered (number of cells) in the grid?
- How much calculation time is added when applying distance interpolation of the data?

The results are saved as: '\IECA_DiagnosticTesting\diagnosticReview.mat' – to review them, run the following plotting function:

[gcsPick, intPick] = GUI_diagnosticReview([pwd '\IECA_DiagnosticTesting\diagnosticReview.mat']);

---

5 Graphical User Interface M-Files

This section and the next two sections all identify and describe the code that is used for the application interface. Within the set of GUI-related files, there are files that are used to create the main GUI or are used in all interfaces, and there are files that are only called in the "Intensity" or "Exposure" interfaces. These sections have been broken out.

5.1 GUI_DQM

```
GUI_DQM
```

The GUI_DQM script constructs the application interface or GUI for the DQM Intensity and Exposure Characterization Algorithm. This is the front-facing tool to allow ease of access to the MATLAB functions that calculate both Intensity and Exposure from dredging.

5.2 GUI_construction

```
GUI_construction
```

This script builds a UI control system, and contains a list of every button name and button location. It does not build the callbacks for buttons.

5.3 GUI_callbacks

```
GUI_callbacks
```

This script builds a UI callback system for all the buttons in the GUI; it is a switch-case list for each button in the GUI.

5.4 GUI_drawGriddedData

```
function axes_griddedData = GUI_drawGriddedData(gridStruct, inp_vals, axH, colorbarType, BBPoly, visTools)
```

Takes data from the gridded and processed DQM data and plots a pcolor plot of the grid. This function requires an axis handle, and will remove all axis handles on the parent figure that are not tagged. Then it will create a new axis with the same position as the axH passed in to construct the figure. This function updates the master GUI figure window when gridded data is processed using the gridding algorithms.

5.5 GUI_drawTrackData

```
function axes_trackData = GUI_drawTrackData(flist, axH, isTrack, boundary, visTools, ax, inp_vals)
```

axes_trackData = GUI_drawTrackData(flist, axH, isTrack, boundary, visTools, ax, inp_vals)

Takes data from the imported DQM CSV files and plots either track lines or time ranges of the data. This function requires an axis handle, and will remove all axis handles on the parent figure that are not tagged. Then it will create a new axis with the same position as the axH passed in to construct the figure. This function updates the master GUI figure window with DQM position data:

VESSEL_X/Y or

PORT_DRAG_X/Y, STBD_DRAG_X/Y, CENTER_DRAG_X/Y.

Or the dates of samples: DATE_TIME.

5.6 GUI_switchView

```
function GUI_IECA = GUI_switchView(GUI_IECA, GUIView)
```

This script will switch the buttons to make sure you are looking at either the (1) 'gridding Intensity' view or the (2) 'Exposure modelling' view.

Components that change between views: the active panel, plotting button labels, plotting button functionality

5.7 GUI_contact

```
GUI_contact
```

Display a dialogue box from the GUI that has the contact information (website) for DQM.

The script is called from the help menu.

5.8 GUI_version

```
GUI_version
```

Display a dialogue box from the GUI that describes the current version.

The script is called from the help menu.

5.9 GUI_diagnosticReview

```
function [gcsPick, intPick] = GUI_diagnosticReview(diagRevFileLoc, varargin)
```

Loads the diagnostic results, and plots the time to load and process data files with file size along one axis and grid size along the other axis. Initially default values (grid cell size is 100m; interpolation is off) are used in the figure; UI controls allow the user to view diagnostic results from other cell size choices, or with track line interpolation turned on.

6 Graphical User Interface M-Files for Intensity

These are the sets of files that are used during the loading, processing and exporting of Intensity in the application interface.

6.1 GUI_readINP

```
function [GUI_IECA] = GUI_readINP(GUI_IECA, inp_vals)
```

This function takes all the values from the INP files and updates the GUI.

6.2 GUI_testData

```
function [new_inp_vals,flist,GUI_IECA] =
 GUI_testData(B,new_inp_vals,orig_inp_vals,flist,BBPoly,GUI_IECA)
```

Test sequence when loading in new CSV files to include in a scenario, or when updating the parameters of the scenario. GUI_testData tests parameters like time ranges, spatial limits, and grid origin for inclusion in the scenario.

6.3 GUI_selectCSV

```
function [inp_vals, flist, BBPoly, visTools] = GUI_selectCSV
```

[inp_vals, flist, BBPoly, visTools] = GUI_selectCSV

Uses UI tools to allow a user to navigate to and select CSV files for use. Builds a default INP (input file) for the DQM_IECA containing the folder, files, and default settings, and returns the INP's parameters/folders/default values. Time coverage data - as in the specific intervals where data were recorded - is displayed in the current figure axis (should be the GUI) to visualize data coverage by plant and date range per file.

6.4 GUI_updateScenarioFiles

```
function [inp_vals, flist] = GUI_updateScenarioFiles(inp_vals, flist)
```

Add and remove DQM CSV files from current scenario.

6.5 GUI_importShape

```
function [GUI_IECA, inp_vals, BBPoly] = GUI_importShape(inp_vals, GUI_IECA)
```

When a shape file is being used for a scenario domain, this script updates the input values along with the buttons in the GUI when loading the file. It also updates buttons to allow for the removal of a shape file when it is already loaded.

6.6 GUI_importShapeForVis

```
function [GUI_IECA, inp_vals, visTools] = GUI_importShapeForVis(
 removingFiles_TF, inp_vals, GUI_IECA, visTools, [MMP_LeaseNo])
```

This function updates the scenario visualization shapefiles in the GUI. It also allows for the removal of a shape file when it is already loaded. When an MMP_LeaseNo is also input, the shapefile is trimmed down to the shape associated with the lease number of interest.

6.7 GUI_loadScenario

```
function [GUI_IECA, inp_vals, flist, gridStruct, BBPoly, visTools] = GUI_loadScenario(GUI_IECA)
```

User selects the specific file(s), .inp/.out files are loaded into the GUI along with the DQM CSV file and if it is an .out file the gridded data set is also read in and plotted.

6.8 GUI_writeINP_dlg

```
function inp_vals = GUI_writeINP_dlg(inp_vals)
```

Saves an inp file with a new name

6.9 GUI_writeINP_fromGUI

```
function [inp_vals] = GUI_writeINP_fromGUI(GUI_IECA, inp_vals)
```

Takes all the values from the GUI and updates the INP files.

6.10 GUI_dlgMoveToExposure

```
GUI_dlgMoveToExposure
```

This script is run after an Intensity analysis or after the export of an Intensity analysis within the GUI. A dialogue box asks the user whether to move to the Exposure analysis. If 'No' is selected the user is free to continue to work in the Intensity framework updating settings and doing more previews, and exporting/moving to the Exposure analysis can be done from other menus and buttons. If 'yes' is selected, the interface changes to the Exposure view and the current data are used as the basis for the Exposure analysis.

7 Graphical User Interface M-Files for Exposure

The second view of the application interface is the 'Exposure' view. These files are used when constructing an Exposure analysis in the GUI.

7.1 GUI_selectGrid

```
function [inp_vals, gridStruct, BBPoly] = GUI_selectGrid
```

Uses UI tools to allow user to navigate to and select specific files (Intensity scenarios) to run through the Exposure algorithm. Returns the set of INP's parameters/folders/default values.

7.2 GUI_removeSelectedScenarios

```
function [GUI_IECA, inp_vals, gridStruct] = GUI_removeSelectedScenarios(GUI_IECA, inp_vals,
gridStruct)
```

Quick removal of highlighted scenarios in the table 'File List' in the GUI view from the current Exposure run.

7.3 GUI_selectScenarioFiles

```
function [inp_vals, gridStruct, BBPoly] = GUI_selectScenarioFiles(inp_vals, gridStruct, BBPoly)
```

Add and remove scenario files in the current Exposure analysis.

7.4 GUI_updateExposureFig

```
function [GUI_IECA, curFile] = GUI_updateExposureFig(GUI_IECA, inp_vals)
```

Function to update the plot and table window for the Exposure GUI. If a table and axis window are passed in, it plots the first file and populates the table.

7.5 GUI_updateMetadata

```
function metadata = GUI_updateMetadata(metadata)
```

Updates the defaults for the ISO metadata that were constructed during the Exposure run, in the function Fn_metadataDefaults.m. First a menu appears with a choice of metadata sections available to update; when a selection is made, the fields and current values of that section are displayed in an input dialogue box, where values can be edited. Values are saved and updated to the Exposure structure, and will populate the XML template during export of the Exposure run.

Appendix C: ISO 19115-2 Metadata

Contents

List of Tables

1. Introduction

In this appendix, the metadata is described and presented in its XML format. The metadata files were created based on the **ISO 19115-2:2009 Geographic information - Metadata - Part 2: Extensions for imagery and gridded data** schema.

During the processing of an Exposure analysis in the IECA, several default metadata values are created. The parameter names in Table 1 represent these metadata values and are used to populate the metadata template.

During the export of Exposure results, at the time the metadata file is created, MATLAB reads in the metadata_template.xml file line by line. When the code identifies square brackets [*] it looks up the parameter name inside the square brackets and replaces the name with either a calculated or default value.

In Table 1 below, the status column represents whether a user should or should not update metadata values. The options for "status" are as follows:

- Review: Initialized during default setup with default value—user is expected to manually update them for more accurate or user friendly values.
- Do not edit: Initialized & calculated during default setup based on data—user should not edit.
- Not available: Created during metadata creation—user cannot edit values before metadata is created, and user should not edit.

The parameter name column is the value in square brackets [*] in the metadata template that is replaced. The example value column shows what a final result may look like in one example case (some entries are truncated here to save space). The parameter name is a code that MATLAB uses to identify what to replace; values are frequently grouped into sections like 'datasetsInfo' with a title, abstract, and purpose. If new parameters are added, or these parameter names are altered, they must be updated in both the template and MATLAB code.

Table 1. Metadata values created during an Exposure Analysis.

<table>
<tr><th rowspan="2">Status</th><th>Parameter Name</th><th>Example Value</th></tr>
<tr><th colspan="2">Description</th></tr>
<tr><td rowspan="2">Not available</td><td>UUID</td><td>58953ddb-0fd3-44b0-9e03-e941835e63c5</td></tr>
<tr><td colspan="2">The Universally Unique Identifier to find and track the metadata; a file identifier.</td></tr>
<tr><td rowspan="2">Not available</td><td>metadataCreationDate</td><td>7/21/2015</td></tr>
<tr><td colspan="2">Date that the metadata was created.</td></tr>
<tr><td rowspan="2">Do not edit</td><td>spatialRepresentationInfo.dimensionSize_row</td><td>265</td></tr>
<tr><td colspan="2">Dimension size - the number of grid cells along the east-west direction.</td></tr>
<tr><td rowspan="2">Do not edit</td><td>spatialRepresentationInfo.gridSz_row_km</td><td>50</td></tr>
<tr><td colspan="2">Data resolution - the width of individual cells.</td></tr>
<tr><td rowspan="2">Do not edit</td><td>spatialRepresentationInfo.dimensionSize_col</td><td>723</td></tr>
<tr><td colspan="2">Dimension size - The number of grid cells along the north-south direction.</td></tr>
<tr><td rowspan="2">Do not edit</td><td>spatialRepresentationInfo.gridSz_col_km</td><td>50</td></tr>
<tr><td colspan="2">Data resolution - the height of individual cells.</td></tr>
</table>

Status	Parameter Name	Example Value
	Description	
Do not edit	referenceSystemInfo.ESPG_code	32617
	The European Petroleum Survey Group (ESPG) code to describe the map projection.	
Review	datasetsInfo.title	DQMs Dredging Exposure Characterization at 100.0 m grid cell scales from...
	The title of the dataset.	
Review	datasetsInfo.shortTitle	DQMs Dredging Exposure Characterization
	The short title of the dataset.	
Do not edit	datasetsInfo.date	7/13/2015
	Date that the raw data was saved.	
Review	datasetsInfo.abstract	Spatial extent of Exposure from Dredge Plants is presented as ...
	The abstract for the data.	
Review	datasetsInfo.purpose	BOEM has conveyed rights to dredge millions of cubic yards of ...
	The purpose for the data.	
Review	datasetsInfo.credit	National DQM Program U.S. Army Corps of Engineers
	The source of the data.	
Do not edit	datasetsInfo.SupplementalInfo	Number of Cells in Domain: 42357 of 44250 total count; Total Area ...
	Extra information associated with the data.	
Do not edit	descriptiveKeywords.Borrow	Brevard County, FL
	The Borrow area name.	
Do not edit	descriptiveKeywords.plant	Liberty Island
	The Dredging Plant name.	
Do not edit	descriptiveKeywords.contractNum	W912EP-13-D-0007-0006
	The DQM contract number.	
Review	descriptiveKeywords. thesaurusName_DQM_Info	Dredging Quality Management Project Information
	The title of the keywords set.	
Review	descriptiveKeywords. ISOCountrySubdivisionCode	US-FL
	Place keywords, for the country and state.	
Review	descriptiveKeywords. FIPS_StatePostalCode	FL
	Place keywords, FIPS state postal code.	
Review	descriptiveKeywords. FIPS_StateFIPSCode	12
	Place keywords, state FIPS code.	

Status	Parameter Name	Example Value
	Description	
Review	descriptiveKeywords. FIPS_CountyFIPSCode	9
	Place keywords, county FIPS code.	
Review	descriptiveKeywords. FIPS_CountyName	Brevard County
	Place keywords, FIPS county name.	
Review	descriptiveKeywords. FIPS_ClassCode	H1
	Place keywords, FIPS class code.	
Not available	datasetsInfo.environmentDescription	filename: BrevardCountyFL_LibertyIsland_ 2013Dec09-2013Dec10_50m_All.tiff
	Description of the data, the name of the GeoTIFF file.	
Review	MMPDataSource.BOEM_BorrowArea	Canaveral Shoals II Borrow Area;
	BOEM specific metadata, name of the borrow area.	
Review	MMPDataSource.BOEM_LeaseNo	OCS-A-0493;
	BOEM specific metadata, lease number.	
Review	MMPDataSource.BOEM_ProjectID	Brevard County -S Reach
	BOEM specific metadata, the project identifier.	
Review	MMPDataSource.BOEM_MMPFile	BOEMLeasecrosswalkwithDQM.xlsx
	BOEM specific metadata, the name of the cross walk documentation used to connect the BOEM project to the DQM contract.	
Review	MMPDataSource.BOEM_MMPFileDate	2017
	BOEM specific metadata, the file date of the cross walk document.	
Do not edit	MMPDataSource.BOEM_processStepStart	Linking the MMIS to DQM product -->
	Uncommenting the BOEM MMP metadata section, completed when MMP metadata has be attached to the Exposure analysis.	
Do not edit	MMPDataSource.BOEM_processStepEnd	<!--
	Uncommenting the BOEM MMP metadata section, completed when MMP metadata has be attached to the Exposure analysis.	
Do not edit	DataExtent.westBoundingLongitude	-80.5661
	Geographic bounding box: west longitude.	
Do not edit	DataExtent.eastBoundingLongitude	-80.43
	Geographic bounding box: east longitude.	
Do not edit	DataExtent.southBoundingLatitude	28.0871
	Geographic bounding box: south latitude.	
Do not edit	DataExtent.northBoundingLatitude	28.4124
	Geographic bounding box: north latitude.	
Do not edit	DataExtent.start	Dec-09-2013
	Temporal extent: start time of the data.	
Do not edit	DataExtent.end	Dec-10-2013
	Temporal extent: end time of the data.	

Status	Parameter Name	Example Value
	Description	
Do not edit	TransferOptions.size	0.14572
	Size of the GeoTIFF file.	
Review	TransferOptions.url	http://www.boem.gov/Marine-Minerals-Program/
	URL to find or request the data.	
Review	lineage.dateOfCSVPull	1985-03-20T00:00:00
	When data was received data from DQM, creation date of the file.	
Do not edit	lineage.dateOfIntensityRun	2015-07-13T13:24:09
	When the Intensity values were created.	
Do not edit	lineage.CSVFilesUsed	C:\Data\BOEM_725_36_501_oneRun.CSV
	The name and path of the gridded Intensity CSV file.	
Do not edit	lineage.ScenarioFilesUsed	C:\Data\intensity\BrevardCou…
	The name and path of the INP scenario file.	
Do not edit	lineage.inpFileSettings	scenario: C:\Data\intensity\BrevardCou…
	Values from the INP file settings.	
Do not edit	lineage.dateOfExposureRun	2015-07-21T12:57:32
	Date that the Exposure analysis was run.	
Not available	lineage.ExposureFileName	BrevardCountyFL_LibertyIsland_2013Dec09-2013Dec10_50m_All.tiff
	The name of the GeoTIFF file of Exposure data.	
Do not edit	lineage.PlantNames	Liberty Island
	Name of the Dredging Plants involved in the Exposure analysis.	
Do not edit	brokenBestPractice.List	Warning - Broken Best Practice, see Resource Constraints for more information
	Warning in the Exposure calculation process step that a best practice was broken at some point during processing.	
Do not edit	brokenBestPractice.OutOfUTMZone	Disclaimer - Broken Best Practice: The bounding area extended out of the UTM zone that the…
	Disclaimer that the data spans multiple UTM zones.	
Do not edit	brokenBestPractice.MultiGridCellSize	Disclaimer - Broken Best Practice: Not all cells sizes used in the creation of this…
	Disclaimer that the cell sizes from several different Intensity results do not match.	
Do not edit	brokenBestPractice.MultiDredgeState	Disclaimer - Broken Best Practice: Multiple filters of Dredge State were included in the…
	Disclaimer that multiple dredge states were used in different Intensity results.	

Status	Parameter Name	Example Value
	Description	
Do not edit	brokenBestPractice.MultiTrackRez	Disclaimer - Broken Best Practice: Both original DQM Latitude and Longitude, and…
	Disclaimer that both increased data resolution and original resolution in position data were used in Intensity results.	
Do not edit	brokenBestPractice.MultiBB	Disclaimer - Broken Best Practice: Multiple domains were included in the creation of…
	Disclaimer that multiple domains were used in different Intensity results.	
Do not edit	brokenBestPractice.timeRngOverlap	Disclaimer - Broken Best Practice: There are overlapping time ranges of scenarios used…
	Disclaimer that multiple time ranges were used in different Intensity results.	

2 XML Metadata Template

On the following pages, the unpopulated ISO metadata template is presented in text format.

[datasetsInfo.title]

Metadata:

File identifier: [UUID]
Language:
Language Code: eng: USA
Character set:
Character set code: utf8
Hierarchy level:
Scope code: dataset
Metadata author: title: pointOfContact
US-DOI/BOEM Bureau of Ocean Energy Management, U.S. Department of the Interior
Responsible party: uuid: d96543ee-7e31-4a41-bed5-48b9e8fb120a
Organisation name:
US-DOI/BOEM Bureau of Ocean Energy Management, U.S. Department of the Interior
Position name: Marine Minerals Program Geologist/ Physical Oceanographer
Contact info:
Contact:
Address:
Electronic mail address: marineminerals@boem.gov
Role:
Role code: pointOfContact
Date stamp: [metadataCreationDate]
Metadata standard name:
ISO 19115-2 Geographic Information - Metadata - Part 2: Extensions for
Metadata standard version: ISO 19115-2:2009(E)

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Spatial representation info:

Grid spatial representation: uuid: b949647a-48e0-47ed-99ed-480a996ec174
Number of dimensions: 2
Axis Dimension Properties:
Dimension:
Dimension name:
Dimension name type code: row
Dimension size: [spatialRepresentationInfo.dimensionSize_row]
Resolution: uom: meter [spatialRepresentationInfo.gridSz_row_km]
Axis Dimension Properties:
Dimension:
Dimension name:
Dimension name type code: column
Dimension size: [spatialRepresentationInfo.dimensionSize_col]
Resolution: uom: meter [spatialRepresentationInfo.gridSz_col_km]
Cell geometry:
Cell geometry code: area
Transformation parameter availability: true

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Reference system info:

Reference system:

Reference system identifier:

RS Identifier:

Authority:

Citation:

Title: European Petroleum Survey Group (EPSG) Geodetic Parameter Registry

Date: 2008-11-12

Date type:

Date type code: publication

Cited responsible party:

Responsible party:

Organisation name: European Petroleum Survey Group

Contact info:

Contact:

Online Resource:

Online Resource:

Linkage:

URL: http://www.epsg-registry.org/

Role: missing

Code: [referenceSystemInfo.ESPG_code]

Code Space: urn:ogc:def:crs:EPSG

Version: 6.18.3

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Identification info:

Data identification:
Citation:
Citation:
Title: [datasetsInfo.title]
Alternate title: [datasetsInfo.shortTitle]
Date: [datasetsInfo.date]
Date type:
Date type code: creation
Cited responsible party:
Responsible party:
Organisation name:
US-DOI/BOEM Bureau of Ocean Energy Management, U.S. Department of the Interior
Position name:
Marine Minerals Program Geologist / Physical Oceanographer
Contact info:
Contact:
Address:
Electronic mail address: marineminerals@boem.gov
Role:
Role code: originator
Abstract: [datasetsInfo.abstract]
Purpose: [datasetsInfo.purpose]
Credit: [datasetsInfo.credit]
Status:
Progress code: onGoing
Point of contact:
Responsible party:
Organisation name:
US-DOI/BOEM Bureau of Ocean Energy Management, U.S. Department of the Interior
Position name:
Marine Minerals Program Geologist / Physical Oceanographer
Contact info:
Contact:
Address:
Electronic mail address: marineminerals@boem.gov
Role:
Role code: pointOfContact
Resource maintenance:
Maintenance information:
Maintenance and update frequency:
Maintenance frequency code: asNeeded
Descriptive keywords:
Keywords:
Keyword: USACE National Dredging Quality Management Program
Keyword: BOEM Marine Minerals Program

Keyword: Dredging
Keyword: Dredging Exposure
Keyword: Intensity and Exposure Characterization Algorithms
Keyword: [descriptiveKeywords.projectArea]
Keyword: [descriptiveKeywords.plant]
Keyword: [descriptiveKeywords.contractNum]
Type:
Keyword type code: place
Thesaurus name:
Citation:
Title: [descriptiveKeywords.thesaurusName_DQM_Info]
Date: unknown
Descriptive keywords:
Keywords:
Keyword: DQM
Keyword: Dredge Quality Management
Keyword: Dredge
Keyword: Dredging
Keyword: Intensity
Keyword: Exposure
Keyword: Ocean bottom
Type:
Keyword type code: theme
Descriptive keywords:
Keywords:
Keyword: [descriptiveKeywords.ISOCountrySubdivisionCode]
Type:
Keyword type code: place
Thesaurus name:
Citation:
Title: ISO Country Subdivision Code (ISO 3166-2)
Date: unknown
Descriptive keywords:
Keywords:
Keyword: [descriptiveKeywords.FIPS_StatePostalCode]
Keyword: [descriptiveKeywords.FIPS_StateFIPSCode]
Keyword: [descriptiveKeywords.FIPS_CountyFIPSCode]
Keyword: [descriptiveKeywords.FIPS_CountyName]
Keyword: [descriptiveKeywords.FIPS_ClassCode]
Type:
Keyword type code: place
Thesaurus name:
Citation:
Title: FIPS Codes for Counties and County Equivalent Entities
Date: 2010
Date type:
Resource constraints:
Constraints:

Use limitation: None
Resource constraints:
Legal constraints:
Access constraints:
Restriction code: otherRestrictions
Resource constraints:
Security constraints:
Classification:
Classification code: unclassified
Language:
Language Code: eng: USA
Character set:
Character set code: UTF8
Topic category:
Topic category code: oceans
Topic category:
Topic category code: environment
Topic category:
Topic category code: geoscientificInformation
Environment description: [datasetsInfo.environmentDescription]
Extent:
Extent:
Geographic element:
Geographic bounding box:
West bound longitude: [DataExtent.westBoundingLongitude]
East bound longitude: [DataExtent.eastBoundingLongitude]
South bound latitude: [DataExtent.southBoundingLatitude]
North bound latitude: [DataExtent.northBoundingLatitude]
Temporal element:
Temporal extent:
Extent:
Time period:
Description: ground condition
Begin date: [DataExtent.start]
End date: [DataExtent.end]
Supplemental Information: [datasetsInfo.SupplementalInfo]

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Content info:

MI_CoverageDescription:

Attribute description:

Exposure to dredging, time per area; normalized by area to 1 m^2

Content type:

Content type code: physicalMeasurement

Dimension:

MI_Band:

Descriptor:

Aggregated time of a dredge plant, or dragarms of a dredge plant, within a grid cell over a specified time period, then normalized to the area of the cell with units of seconds per meter squared.

Value unit:

gml:DerivedUnit:

Identifier:

gml:derivationUnitTerm: uom: s

gml:derivationUnitTerm: uom: m

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Distribution info:

Distribution:

Distributor:

Distributor:

Distributor contact:

Responsible party:

Organisation name:

US-DOI/BOEM; Bureau of Ocean Energy Management, U.S. Department of the Interior

Position name:

Marine Minerals Program Geologist / Physical Oceanographer

Contact info:

Contact:

Address:

Electronic mail address: marineminerals@boem.gov

Role:

Role code: distributor

Distributor format:

Format:

Name: TIF

Version: inapplicable

Distributor transfer options:

Digital transfer options:

Transfer size: [TransferOptions.size]

Online:

Online Resource:

Linkage:

URL: [TransferOptions.url]

Protocol: http

Name: Bureau of Ocean Energy Management Website

Description: Marine Minerals Program Webpage

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Data quality info:

Data quality:
Scope:
Scope:
Hierarchy level:
Scope code: dataset
Extent: xlink: #boundingExtent
Level description:
Scope description:
Dataset Set:[UUID]
Lineage:
Lineage:
Statement:
Operations and production data are provided by dredging vessels through the USACE Dredgeing Quality Management system. The DQM program determines dredge state and active drag arms based on the provided data. Data are stored in the DQM database.
Process step:
LE_ProcessStep:
Description: Received data from DQM
Rationale: To collect archived data from database for analysis
Date and time: [lineage.dateOfCSVPull]
Source:
LE_Source:
Source citation:
Citation:
Title:
USACE Dredging Quality Management Program: Dredging quality assurance monitoring database
Date: 2006-04-17
Date type:
Date type code: publication
Cited responsible party:
Responsible party:
Organisation name:
National Dredging Quality Management Support Center (DQM), USACE
Role:
Role code: author
Process step:
LE_ProcessStep:
Description: Create first aggregate product: Intensity
Rationale: Griding location data into time spent per-cell.
Date and time: [lineage.dateOfIntensityRun]
Source:
LE_Source:
Description:
File Name: [lineage.CSVFilesUsed]

processingInformation:
LE_Processing:
Identifier:
Identifier:
Code:
File Name: [lineage.ScenarioFilesUsed]
softwareReference:
Citation:
Title: Intensity and Exposure Characterization Algorithms
Date: 2017
Date type:
Date type code: creation
documentation:
Citation:
Title:
Using Dredge Plant Operational Data to Measure Dredging Intensity and Cumulative Exposure
Date: 2017
Date type:
Date type code: creation
Other citation details: OCS Study BOEM 2017-xxx
runTimeParameters: [lineage.inpFileSettings]
Process step:
LE_ProcessStep:
Description:
Create the final aggregate product: Exposure; [brokenBestPractice.List]
Rationale:
Normalize gridded intensity field(s) into single Exposure grid.
Date and time: [lineage.dateOfExposureRun]
Source:
LE_Source:
Description:
File Name: [lineage.ScenarioFilesUsed]
processingInformation:
LE_Processing:
Identifier:
Identifier:
Code:
File Name: [lineage.ExposureFileName]
softwareReference:
Citation:
Title: Intensity and Exposure Characterization Algorithms
Date: 2017
Date type:
Date type code: creation
documentation:
Citation:
Title:

Using Dredge Plant Operational Data to Measure Dredging Intensity and Cumulative Exposure
Date: 2017
Date type:
Date type code: creation
Other citation details: OCS Study BOEM 2017-xxx
output:
LE_Source:
Description: [lineage.ExposureFileName]

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Metadata maintenance:

Maintenance information:
Maintenance and update frequency:
Maintenance frequency code: notPlanned
Metadata author:
Responsible party:
Organisation name:
US-DOI/BOEM Bureau of Ocean Energy Management, U.S. Department of the Interior
Position name:
Marine Minerals Program Geologist / Physical Oceanographer
Contact info:
Contact:
Address:
Electronic mail address: marineminerals@boem.gov
Role:
Role code: custodian
acquisitionInformation:
MI_AcquisitionInformation:
platform:
MI_Platform:
Identifier:
Identifier:
Code: [lineage.PlantNames]
description: [lineage.PlantNames]
instrument:
MI_Instrument:
Identifier:
Identifier:
Code: GPS receiver
type: GPS receiver
instrument:
MI_Instrument:
Identifier:
Identifier:
Code: Gyro
type: Gyro
instrument:
MI_Instrument:
Identifier:
Identifier:
Code: Tide gauge
type: Tide gauge
instrument:
MI_Instrument:
Identifier:
Identifier:

Code: Hull Status (Open/Close Status of Hopper)
type: Hull Status (Open/Close Status of Hopper)
instrument:
MI_Instrument:
Identifier:
Identifier:
Code: Draft Sensor
type: Draft Sensor
instrument:
MI_Instrument:
Identifier:
Identifier:
Code: Ullage Sensor (Hopper Level Sensor)
type: Ullage Sensor (Hopper Level Sensor)
instrument:
MI_Instrument:
Identifier:
Identifier:
Code: Inclinometer (Draghead Depth Sensor)
type: Inclinometer (Draghead Depth Sensor)
instrument:
MI_Instrument:
Identifier:
Identifier:
Code: Slurry Density Meter
type: Slurry Density Meter
instrument:
MI_Instrument:
Identifier:
Identifier:
Code: Slurry Velocity Meter
type: Slurry Velocity Meter
instrument:
MI_Instrument:
Identifier:
Identifier:
Code: Tachometer (Pump RPM)
type: Tachometer (Pump RPM)
instrument:
MI_Instrument:
Identifier:
Identifier:
Code: Refractometer (Salinity)
type: Refractometer (Salinity)

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Department of the Interior (DOI)

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management (BOEM)

The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.

BOEM Environmental Studies Program

The mission of the Environmental Studies Program is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments. The proposal, selection, research, review, collaboration, production, and dissemination of each of BOEM's Environmental Studies follows the DOI Code of Scientific and Scholarly Conduct, in support of a culture of scientific and professional integrity, as set out in the DOI Departmental Manual (305 DM 3).