National Oceanic and Atmospheric Administration
Emergency Response Division
6600 Sand Point Way NE
Seattle WA 98115
http://response.restoration.noaa.gov

Final Report:

WebGNOME Trajectories
ADIOS Oil Database Project

E17PG00026 -- 1/31/2019

From: Christopher Barker
NOAA Office of Response and Restoration
Emergency Response Division
chris.barker@noaa.gov

To: Candi Hudson
Christy Tardiff
John Caplis
Jay Cho
BSEE Oil Spill Preparedness Division

Introduction

NOAA's Emergency Response Division (ERD) has developed oil spill modeling tools to support its job of providing scientific support for oil spill response in the United States. For the past two decades, ERD has made most of these tools available to the public to support oil spill understanding, preparedness and response. In the last few years, ERD has developed an updated modeling system (the GNOME modeling suite or GNOME for short), bringing together oil spill fate, transport, and response options into a single suite of applications. The new system is now more accessible and powerful, and combines the capabilities of its predecessors (GNOME desktop, ADIOS, and ROC) with a new web-based user interface (WebGNOME).

The BSEE Oil Spill Preparedness Division (OSPD) oversees the review and approval of oil spill response plans (OSRPs) which are submitted as a regulatory requirement for offshore oil and

gas facility plan holders. OSPD verifies the preparedness of these plan holders through audits of training and oversight of exercises involving the OSRPs, operational response equipment and personnel, and spill management teams.

While designed primarily to support ERD response modeling needs, GNOME has many potential applications for enhancing oil spill preparedness activities; in particular, WebGNOME could be used as a tool in the development of content for Oil Spill Response Plans (OSPRs), the planning of spill scenarios for exercises, and the training of responders and spill managers on the behavior of oil spills in the environment, the organization of offshore response divisions, and the effective use of response countermeasures. To better address oil preparedness activities, this project focuses on two areas for enhancements to the GNOME modeling suite.

One area of focus is enhancements to the oil database used by GNOME. BSEE OSPD staff and OSRP plan holders can view oils in GNOME's comprehensive and quality controlled digital library of oils that is readily available from any location and can be utilized for spill modeling in WebGNOME. However, a user interface system is needed that will allow users to easily store, maintain, and access comprehensive oil information from various sources and in different formats, as well as create and control access to their own oil properties records that can be easily integrated and used with WebGNOME.

Another area of focus is improved trajectory visualization. While the current WebGNOME oil trajectory visualization presents users with a sense of time and spatial scales for the transport of the spilled oil, it does not provide for any accompanying visualizations of slick thicknesses on the water or the distribution of changing oil properties across the trajectory results. Adding the ability to display these visualizations as part of the trajectory results will significantly enhance the ability to use WebGNOME as both a pre-spill and incident response tool for industry planners, trainers, government regulators and responders.

This report summarizes the scope of work and the implemented enhancements in these two focus areas:

1. Improved Visualization in WebGNOME, and
2. Stand-alone Oil Database Management Software

National Oceanic and Atmospheric Administration
Emergency Response Division
6600 Sand Point Way NE
Seattle WA 98115
http://response.restoration.noaa.gov

Focus Area 1: Improved Visualization in WebGNOME

The scope of this effort is to:

- Develop features into WebGNOME that allow the user to view resulting trajectories for
    - the highest concentration of oil likely to be found;
    - where dispersible oil is likely to be found;
    - where the oil will most like be emulsified; and
    - how the properties of the oil would be distributed.

- Develop visualizations to enhance the user's ability to understand the output by
    - visualizing the bulk concentration of the oil on the water;
    - map colors to physical properties of the elements (for example, emulsified oil, fresh oil, viscosity, thickness); and
    - displaying only the oil that meets certain properties (for example, only the emulsified oil or only the fresh oil).

- Develop algorithms to integrate these features and visualizations into the operational WebGNOME system.

Work accomplished

Similar to other oil spill models, GNOME divides spilled oil into a large number of particles of equal mass that move under the influence of ocean currents, wind drift, and horizontal and vertical mixing. Prior to this project, the individual model particles displayed in WebGNOME were shown as black dots that moved on a map over time (Figure 1). While this provided the user information on how the oil was being transported, it did not show how the oil properties changed over time or how the amount of oil might vary both spatially and temporally as the slick spreads and weathers.

All the graphics shown below were created using the WebGNOME software with the enhancements supported by this project. The application can be found at https://gnome.orr.noaa.gov.

National Oceanic and Atmospheric Administration
Emergency Response Division
6600 Sand Point Way NE
Seattle WA 98115
http://response.restoration.noaa.gov

Visualizing Oil Properties

The first major component of this project involved adding graphical information about the properties of individual particles. These properties may be relevant to response operations (e.g. viscosity) and the enhanced visualizations provide information tailored to the needs of the user.

Users can now choose to color the particles based on a specified property, for example, age, mass, or viscosity.

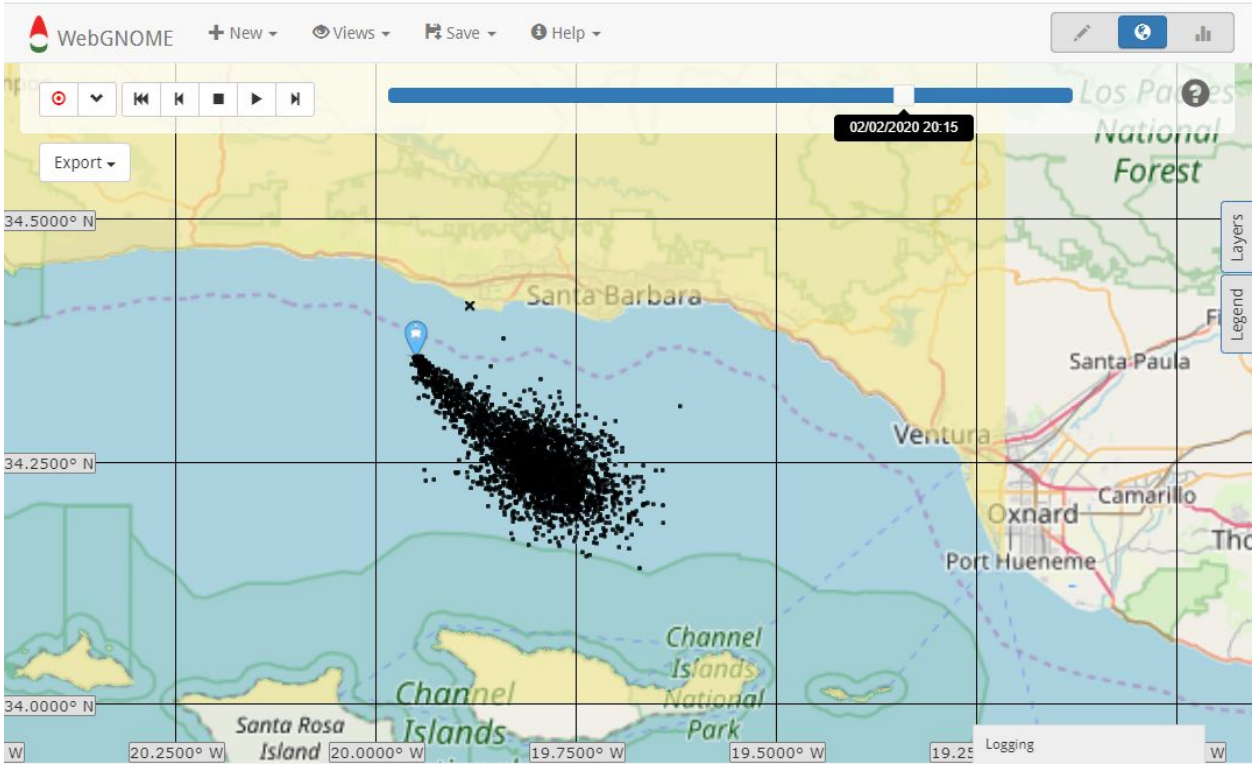

Figure 1: Visualizations in WebGNOME from hypothetical continuous oil release in the Santa Barbara Channel showing output previous to this project.

National Oceanic and Atmospheric Administration
Emergency Response Division
6600 Sand Point Way NE
Seattle WA 98115
http://response.restoration.noaa.gov

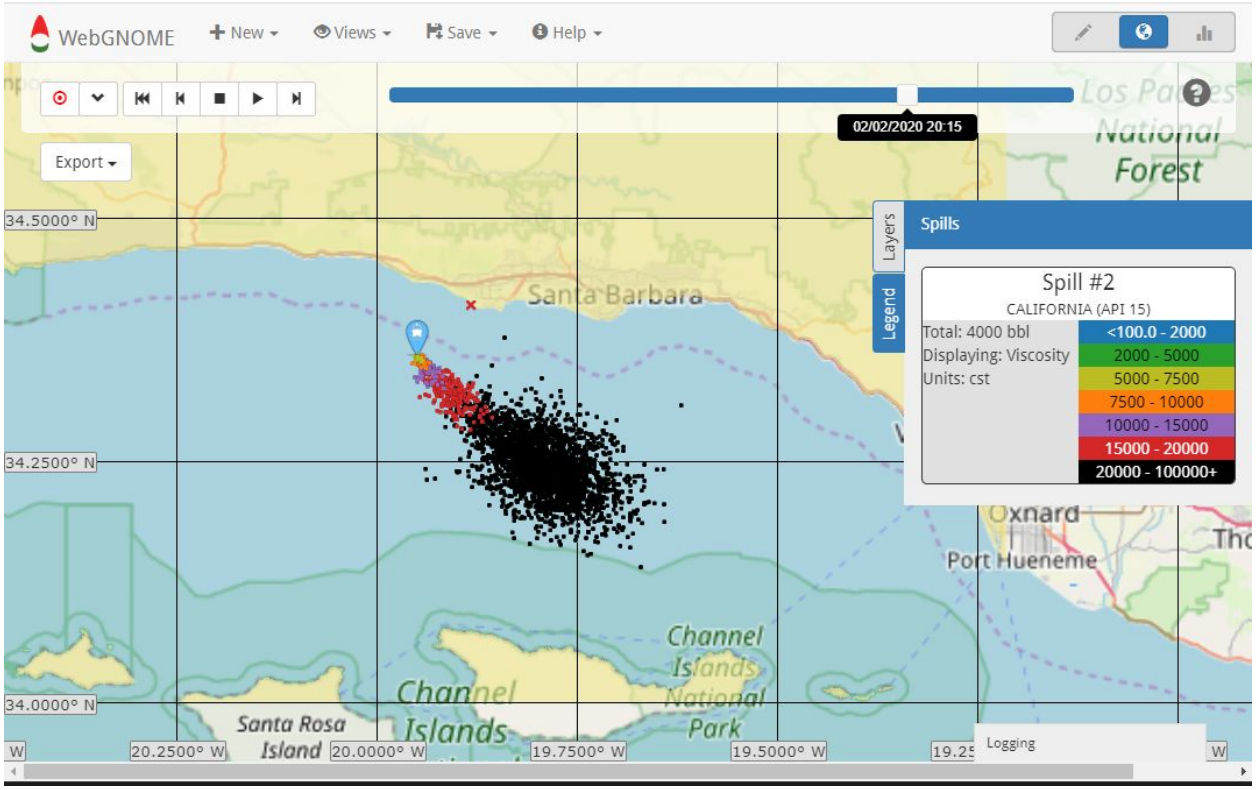

Figure 2: An example visualizations in WebGNOME showing particle styling by oil property. In this case, the colors represent varying viscosity -- as the oil weathers it becomes increasingly viscous.

A user interface was designed within the WebGNOME application to allow users to choose what property to use for visualization, select scale (intervals) to use for coloring, and choose among various colormaps (Figure 3). Feedback was integrated to add additional colormaps and to add “pre-set” scales for properties like viscosity based on operational considerations. The framework allows for easy addition of more pre-set scales as requested by users.

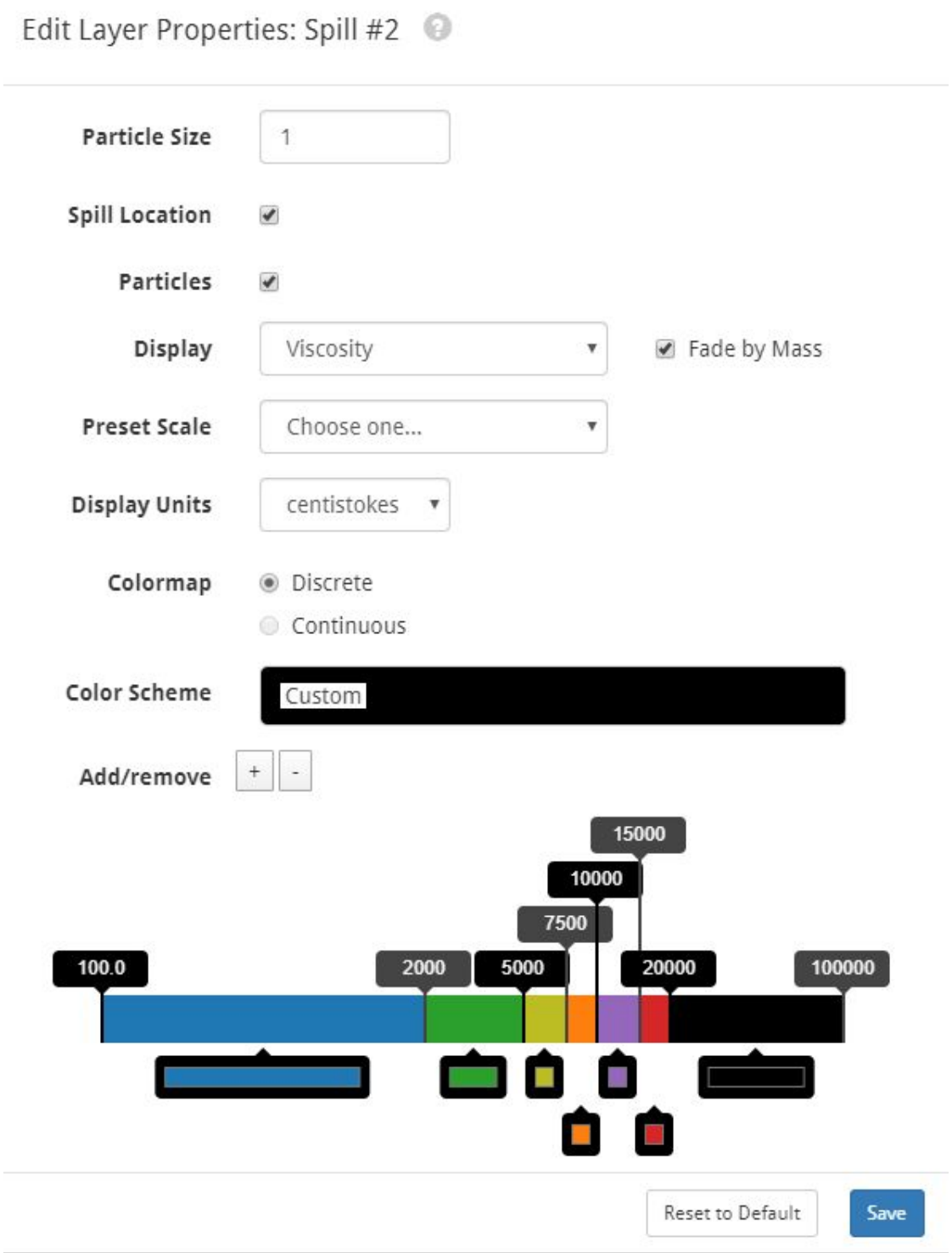

Figure 3: WebGNOME Interface for setting spill visualization options

National Oceanic and Atmospheric Administration
Emergency Response Division
6600 Sand Point Way NE
Seattle WA 98115
http://response.restoration.noaa.gov

These properties can be manipulated to display custom graphs that answer questions like those posed in the scope of work -- for example, where dispersible oil is likely to be found (Figure 4)

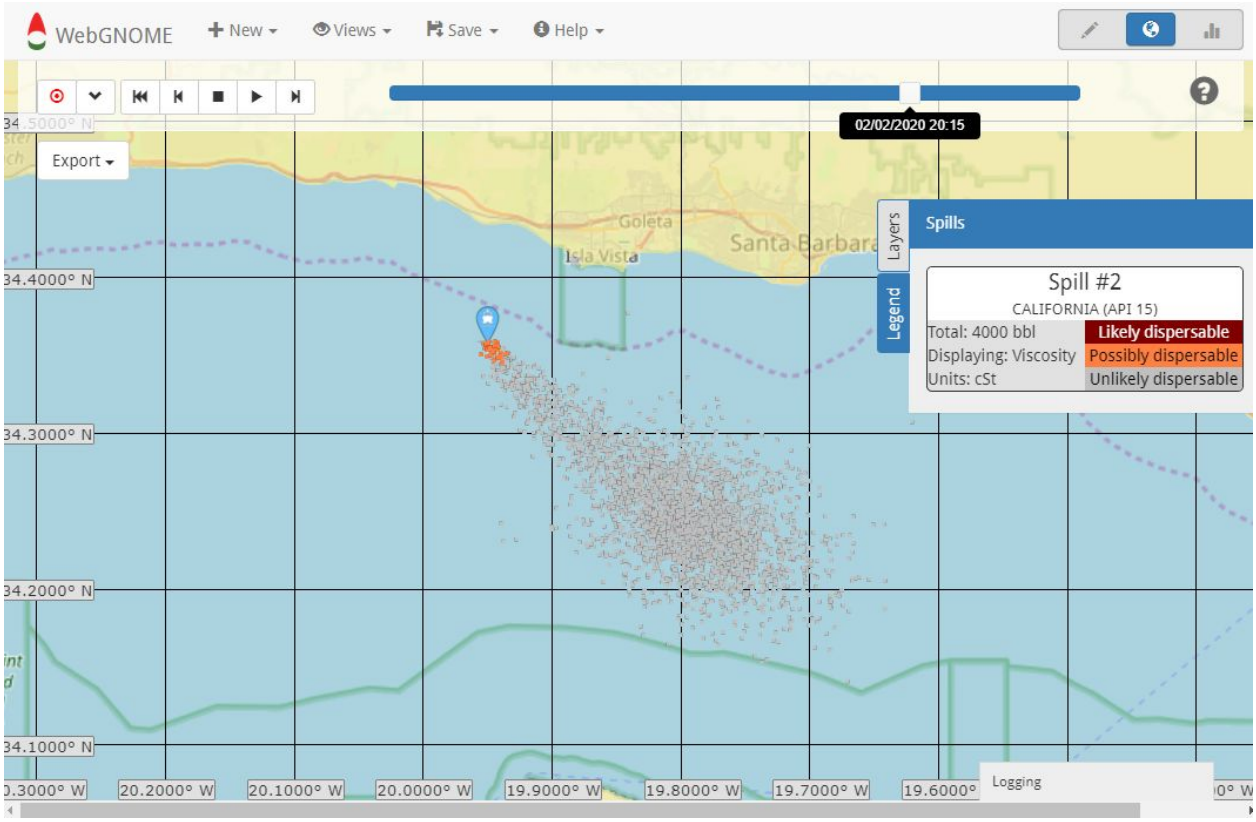

Figure 4. An example custom display for likelihood of dispersibility. The scale considers oil with viscosity under 2000 cSt “likely”, and under 1000 cSt “possibly” dispersible based on industry rules-of-thumb.

Visualizing Relative Oil Concentrations

The scope of the project also included adding visualization for oil concentration, i.e. where is the bulk of the oil. As part of this project, we developed algorithms that use relative particle densities combined with oil mass per particle to determine oil concentration. Particle densities were determined via a Gaussian kernel density estimation (KDE) technique at each particle location. The resulting concentration visualization is shown in Figure 5. Several color scales were provided by BSEE as operationally useful and these were added to the presets.

National Oceanic and Atmospheric Administration
Emergency Response Division
6600 Sand Point Way NE
Seattle WA 98115
http://response.restoration.noaa.gov

Although the original scope of work described “contouring” for emphasizing the regions of differing concentrations, it was decided that coloring the particles based on concentration was a more effective display as it captures the patchiness of the oil distribution while still clearly illustrating the regions of high concentrations. Generating contours at model run time is also computationally expensive. However, model output can be exported from WebGNOME and visualized in our MapRoom software which is freely available. This software provides an interface for making custom trajectory graphics including tools for annotation and contouring. A more comprehensive list of particle properties is also supported along with numerous base maps.

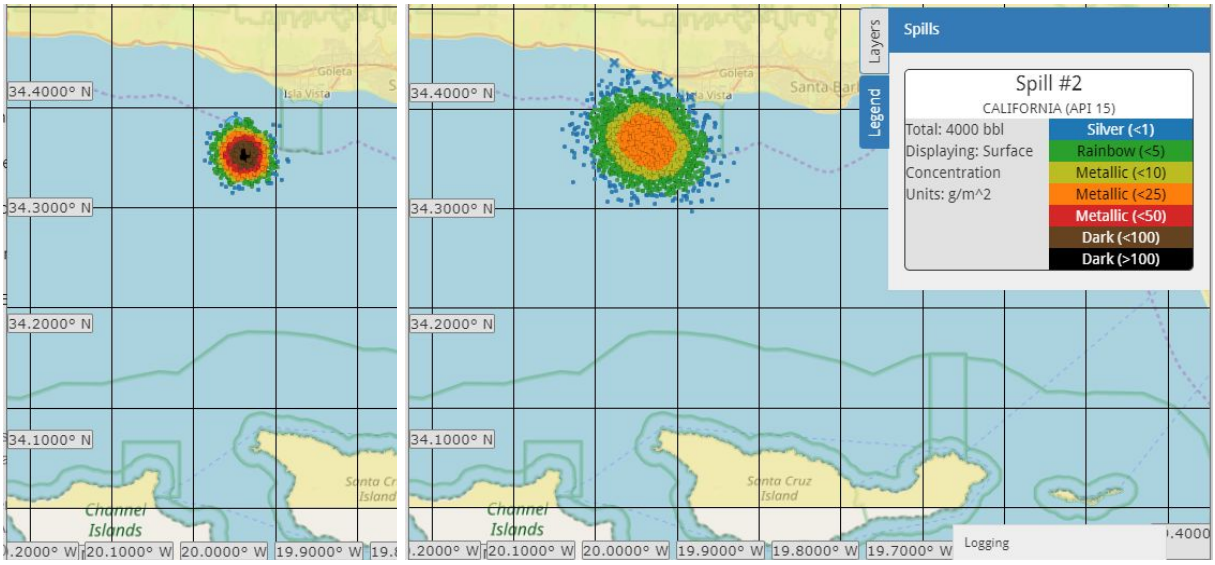

Figure 5: Surface oil concentration based on particle densities for a 1-hr release. The left image is six hours after the start of the release and the right image is 24 hours. The preset color scale based on the Bonn Appearance (oil appearance at different thicknesses or concentrations) is used.

Future Work

As noted previously, it is relatively easy to add user defined custom scales for various oil properties. While the UI does not allow for the user to save custom scales “on-the-fly”, if they are provided to ERD, they can easily be incorporated. If considered desirable, the UI could potentially be enhanced to add this functionality.

We also continue to evaluate algorithms for generating oil concentrations/thicknesses. The KDE approach is suitable for showing relative concentrations as the particles in the model spread.

However, in the case of continuous releases, with oil of differing ages, the approach has some limitations as the kernel used for computing the Gaussian distribution is spatially constant. Hence, as the particles spread over time, the length scale increases. This leads to an unrealistic decrease in maximum concentration for a constant release rate. To get around this, we only compute KDEs for particles of “similar” age -- defined as one hour. So the maximum concentration will be determined by the amount of spreading of particles within a one-hour time frame.

This method of computing concentration is effective for obtaining an overall picture of the relative amount of oil in various regions. However, it may not relate well to the concentration actually observed in the field and encountered by a skimmer. This is because the model tends to spread things uniformly via a random walk and does not include the small scale physical processes that might cause oil to thicken (e.g. Langmuir cells). These concentrations are more representative of the “average” concentration evenly distributed over a length scale determined by the spread of the particles. We continue to evaluate algorithms for better representing oil thickness that are more directly applicable to field observations.

Finally, we also continue to improve the software in many other aspects: from algorithms to user interface and visualization. For example, we are looking forward to continuing our partnership with BSEE as we start work this year on a interface within WebGNOME for initializing spills from remotely sensed data. As we continue development on WebGNOME and the underlying computational core (PyGNOME), we welcome further comments and suggestions that will continue to improve the interface for spill response and preparedness.

Focus Area 2: Stand-alone Oil Database Management Software

The scope of this effort was to:

- Develop a version of the ADIOS Oil Database system which can be installed inside a firewall as an intranet application, or installed on a single desktop machine as a single user application.
- Develop the necessary user interfaces and procedures to add or modify any number of new records to an internal stand-alone ADIOS database, extract a single record for use with the WebGNOME oil spill model, or extract one or more records to provide to NOAA for inclusion in the NOAA-maintained ADIOS Oil Database library of oils.

Work accomplished: ADIOS Oil Database

We have developed the ADIOS Oil Database software: a web-based tool for managing and displaying a repository of the physical and chemical properties of fresh and weathered oils that may be useful in responding to oil spills. NOAA will host a public version of the software to provide the response community with access to a comprehensive database of oil property data. The software was developed as a web application, and can be deployed behind a firewall as an intranet application to manage an internal database. It can also be deployed as a stand-alone desktop application that can be installed on an individual computer to manage a single local dataset. Each of these versions can export individual oil records that can be imported into others' databases, in particular the NOAA-managed master dataset.

The software is currently in a "beta" status: most of the key functionality is in place, and we are working on fixing final bugs, soliciting user feedback, and smoothing out user interface issues. There is a publically available test version up at the URL: https://adios-stage.orr.noaa.gov/. Once the application is more fully tested, a public version will be available at https://adios.orr.noaa.gov/.

We welcome feedback from BSEE on the design of the user interface and database. As we continue development we will be continuously updating the live version with bug fixes and new features, and can provide updated versions of the desktop version if desired.

The overarching goal of this project is to improve the government's ability to mitigate the environmental and human impacts from oil spills. This software was designed to:

- Be available to BSEE, and other third parties, to input, store, and access data useful for spill response and planning
- Be hosted on a local secure network with a web interface that runs on common web browsers
- Provide the flexibility to store data from a wide range of lab protocols
- Allow a user to view the data
- Allow data records on an individual oil to be shared with appropriate members of the oil spill response community

Data Structure

Data is stored in a hierarchical structure with the capability to associate analyses of weathered or fractionated subsamples with the fresh oil analysis in a single record. Each oil record represents a single sample received by a lab for analysis. We designed this for oils supplied by a shipper or producer; however, it could also be used for source samples collected during a spill. Often a lab will split an oil sample into subsamples for weathering studies or fractionation, so we designed the database to associate these subsamples with the original.

Description Of Software

The application is built with a client-server system:

- The Client is a "rich web application" running javascript in a web browser, using the Ember application framework. (https://emberjs.com/)
- The server is written in the Python programming language, using the MongoDB database system. (https://www.mongodb.com/)

MongoDB provides a "schema-less" database that allows a very flexible storage of arbitrary data. This will allow us to easily extend a data record in the future, as additional data becomes available. The server can be configured to provide either a read-only or editable access to the central database.

Deployment

Web Application:

The software can be deployed as a traditional web application, with the server running on a central host, available on the internet. Users can access this database through their desktop web browser. NOAA will host a read-only version of this system, providing public access to NOAA's centrally-managed oil library.

This client-server system can also be deployed by another institution to manage its own library of oil data, behind a firewall for restricted access, or open to the public.

Desktop Application

In addition to the client-server configuration, the software can be bundled up with a single installer for Windows desktop systems. This version has the same user interface as the web version, but will act as a single application on a single workstation, and can be used to manage a local database of oil records. This approach would be suited for managing a smaller database in an institution without the IT resources to manage a client-server system.

User Interface

The user interface has two primary functions: to display data stored in the database (view mode); and to allow the user to enter new data or edit existing data records (edit mode). There is a toggle switch on each individual oil page that switches between modes.

List Page

When the application is launched a list of oil records preloaded in the database appears. In the Beta version this list includes oil records from the ADIOS2 database and data compiled by Environment and Climate Change Canada (ECCC) Emergencies Science and Technology Section. See https://open.canada.ca/data/en/dataset/53c38f91-35c8-49a6-a437-b311703db8c5.

From the list page, the user can search for an existing oil record or add a new record (Figure 6).

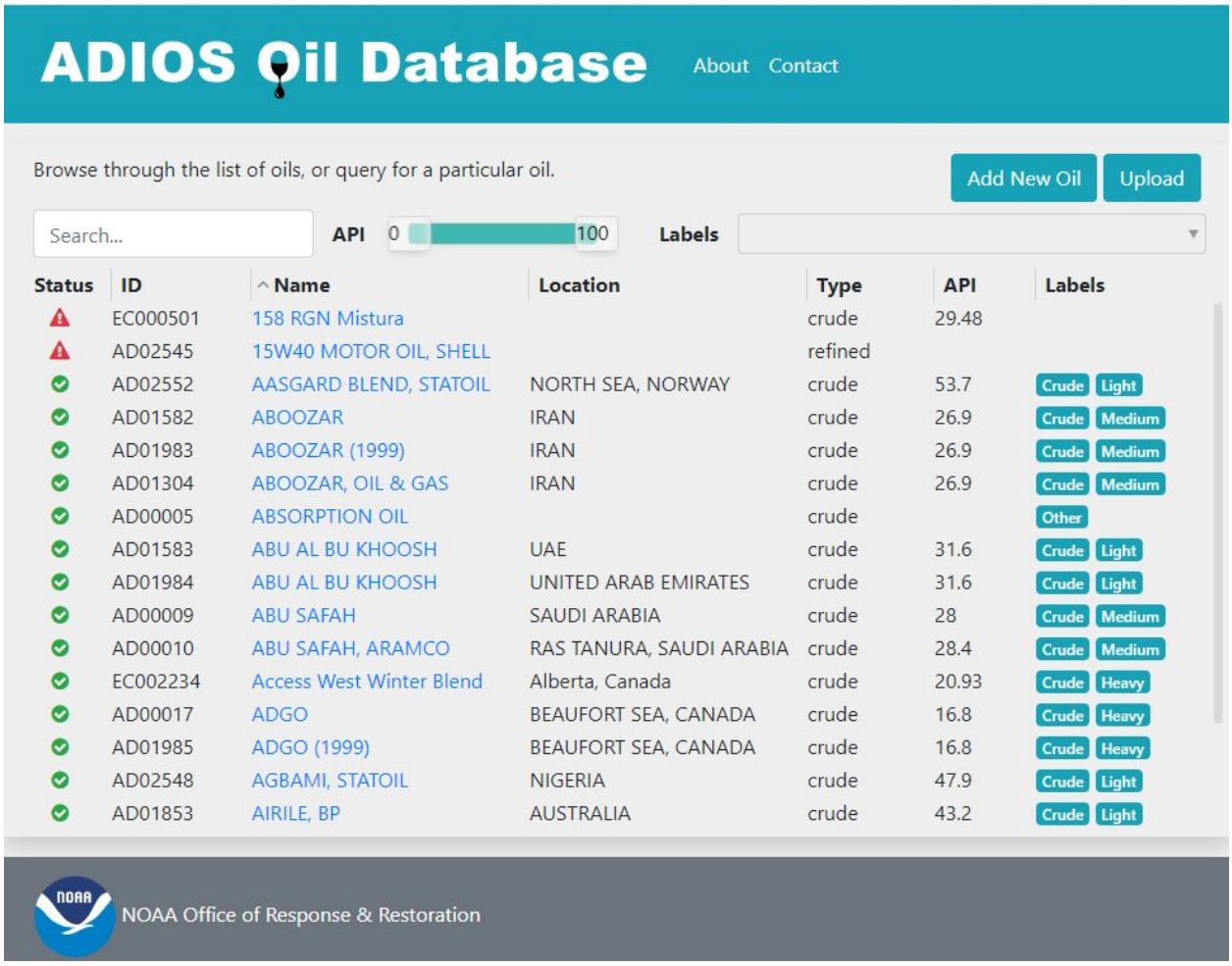

Figure 6: The ADIOS Oil Database List Page

Sort and Filter Functionality

On the List Page, the list of oil records displayed can be sorted and narrowed down in a couple of ways. Each column can be sorted by value: alphabetically for ID, Name, Location, and Type; numerically for API, and by state (OK or Not OK) for Status. Typing into the Search box at the top left will filter the list to show only the records with those characters in the Name or Location fields. The API slider narrows down the list by API Gravity, and the Labels pull-down menu can be used to filter the list by the keywords shown in the Labels column.

Oil Record Page

Once a user has clicked on an oil name, the Oil Record Page for that record comes up. The top half of the page is the Identifying Information, and the bottom half of the page contains physical and chemical properties of the fresh oil and any weathered or fractionated samples derived from that original oil in a tabbed structure.

Identifying Information

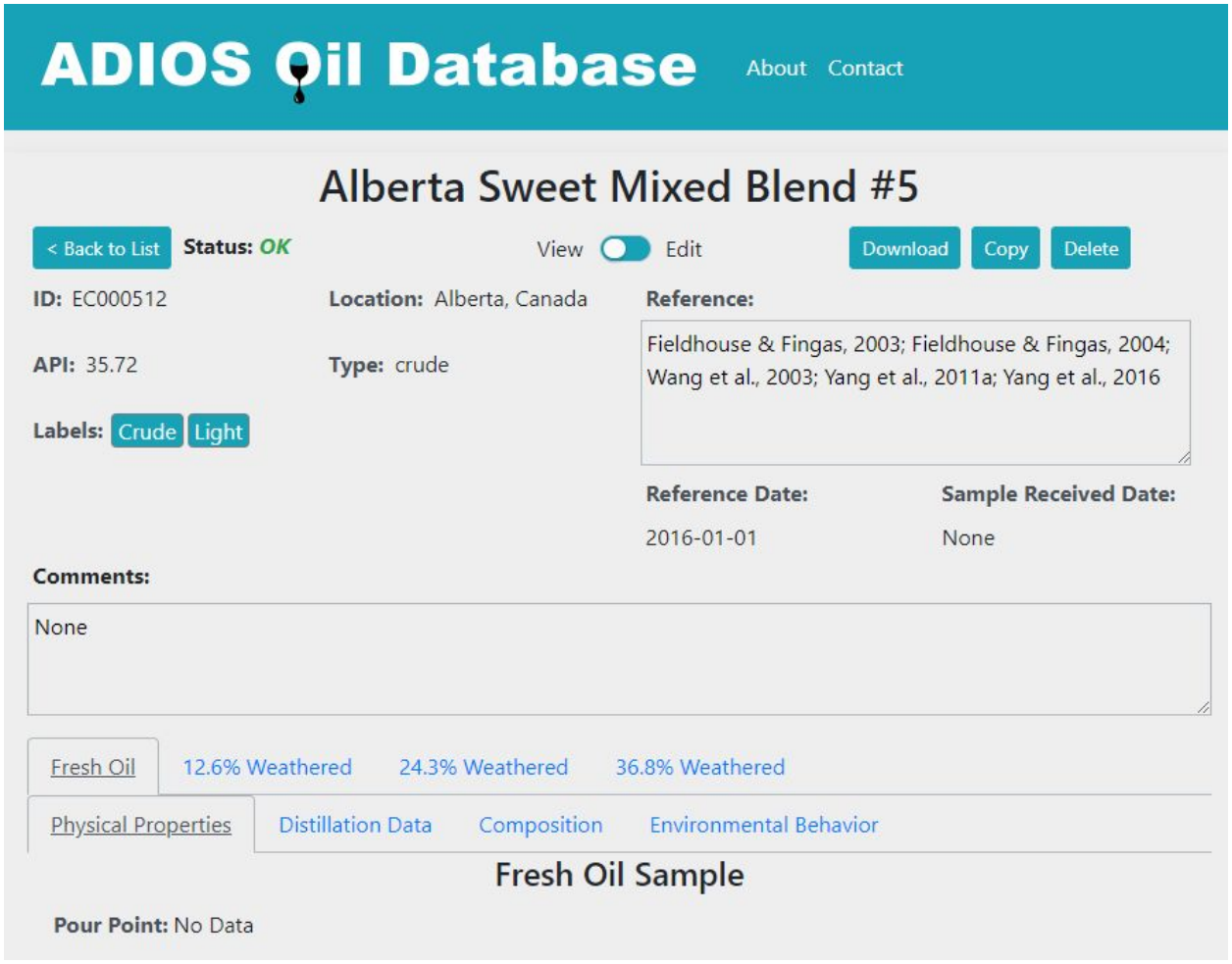

Figure 7: Identifying Information on an Oil Record Page.

A sample record is identified by a name, provided by the originator of the data, and a unique ID number, which is generated by the database software. In addition to these values there are fields of other identifying information that can be populated by the user (Figure 7) including:

- API
    - Used here as an identifier and for the search feature. If there are multiple sub-samples included in the record (weathered samples or distillation cuts), this API gravity should correspond to the fresh whole oil.
- Location
    - Where the sample was collected.
- Type
    - Product Type is a pull-down menu where the user can indicate if the product is a conventional crude oil, a refined product, a bitumen product, or another type not covered. Only one option can be selected.
- Labels
    - A pull-down menu where keywords for searching can be added to the record. Multiple labels can be added to the record.
- Reference
    - Information about the source of the analysis, such as a literature reference.
- Reference Date
    - Date of the literature reference or analysis.
- Sample Received Date
    - Date when the sample was received by the lab that performed the analysis.
- Comments
    - A text field where any user comments can be added.

A validation check is run on a handful of fields whenever a record is created or updated. A list of Warnings or Errors may appear below the Comments field if there are any problems found with the data.

Physical and Chemical Properties

A sample record can have data for one or any number of subsamples. When a new record is created, a subsample tab called “Fresh Oil” is created by default. Subsample data is broken into four categories: Physical Properties, Distillation Data, Composition, and Environmental Behavior, each shown on a different second-layer tab (Figure 8).

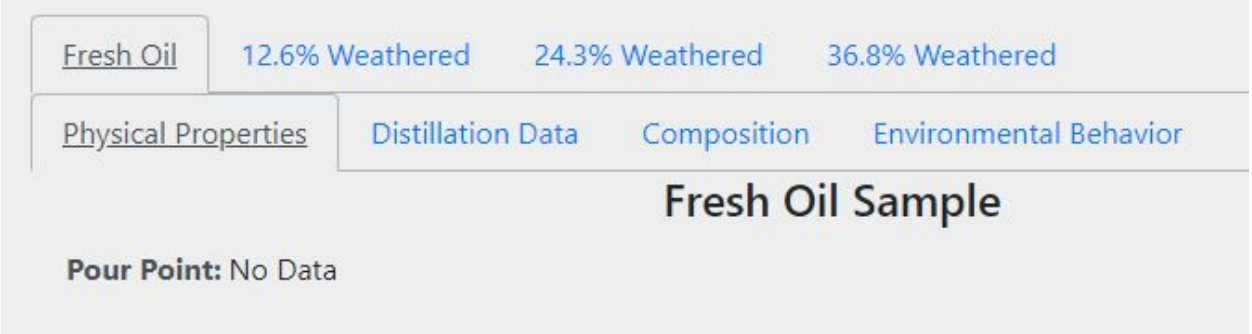

Figure 8: First and second layers of tabs in an oil record. The first layer represents a specific subsample, and the second layer represents a category of properties.

Physical Property data (Figure 9) for the subsamples includes:

- Pour Point
  - The pour point in degrees Celsius, which can be entered as a single number or as a range of values.
- Flash Point
  - The flash point in degrees Celsius, which can be entered as a single number or as a range of values.
- Density
  - A table of densities in g/cm^3 with corresponding temperatures in degrees Celsius. Any number of densities can be added.
- Kinematic and Dynamic Viscosity
  - A table of viscosities in cSt for kinematic viscosity or cP for dynamic viscosity with corresponding temperatures in degrees Celsius. Any number of viscosities can be added.
- Interfacial Tension
  - A table of interfacial tensions where the interface (oil-air, oil-freshwater, oil-seawater) can be selected in a pull-down menu, and the tension values in N/m with corresponding temperatures in degrees Celsius. Any number of interfacial tension values can be added.

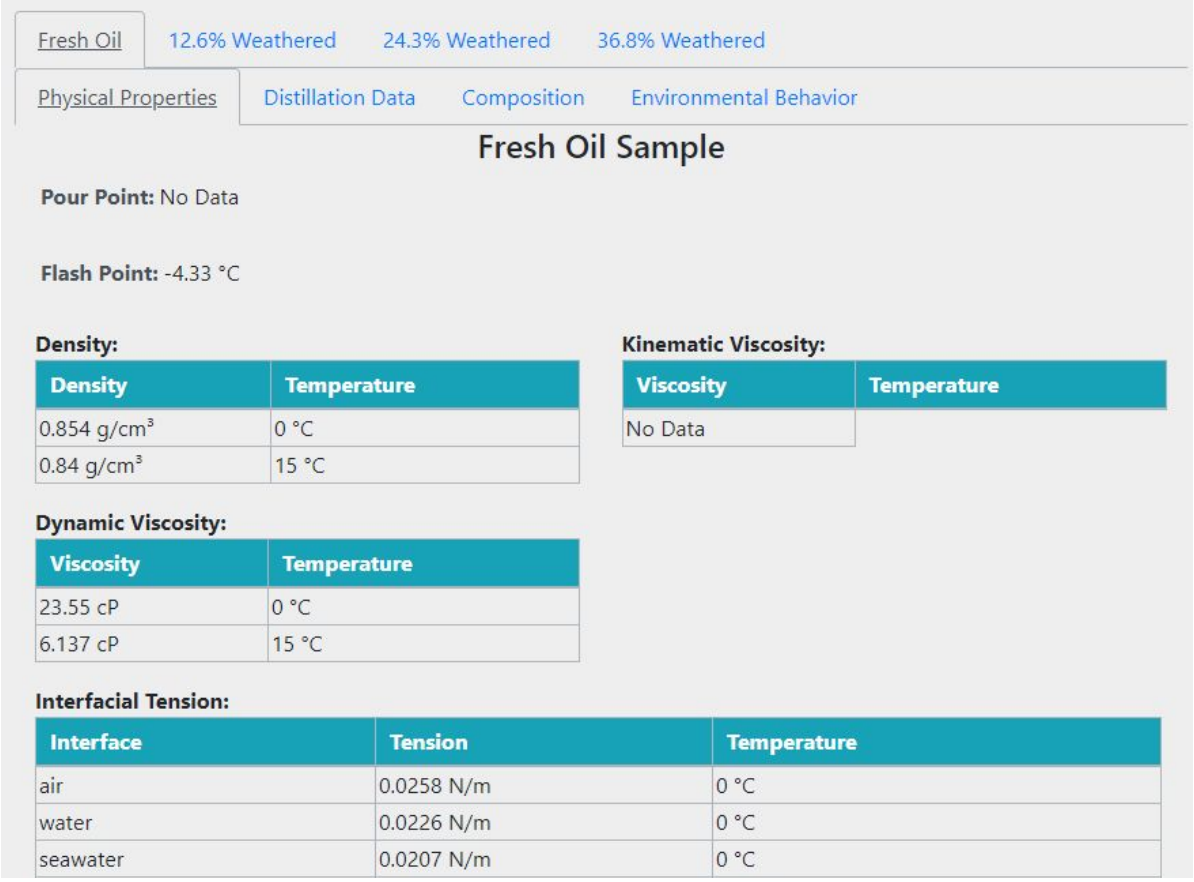

Figure 9: The Physical Properties tab of an oil record.

Some property values are displayed as a range, i.e. a minimum and maximum value for that property. In Edit Mode the user can enter a single value or a range (Figure 10). When the property value is less than or greater than a specific value it is represented with a range where one of the limits is infinity or negative infinity. For example, a flash point greater than 25 °C is entered as a range with a minimum value of 25 and maximum value of infinity.

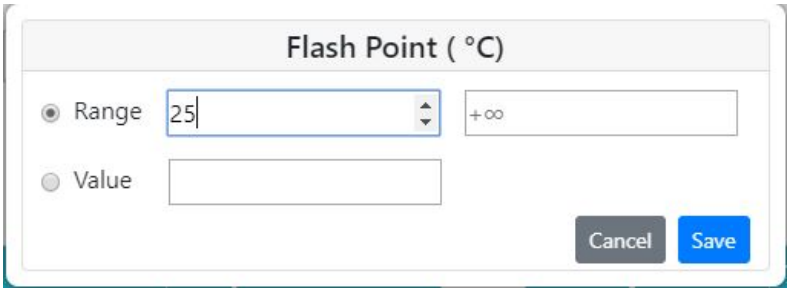

Figure 10: Interface for entering a range of values.

On the Distillation Data tab (Figure 11), data is displayed or entered as a cumulative mass percent with corresponding distillation temperature in degrees Celsius. Any number of distillation cuts can be included in the database and displayed. In future versions there will be an option to display and enter distillation data as a cumulative volume percent as well.

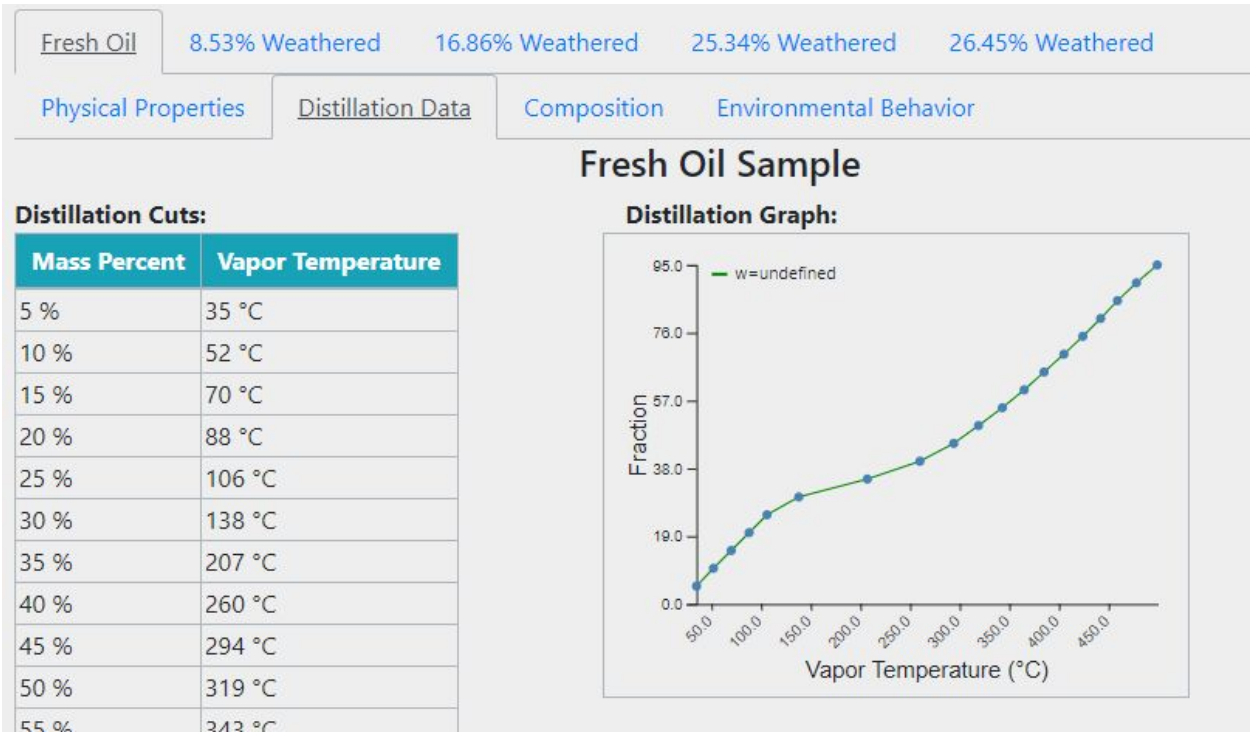

Figure 11: Distillation Data tab

Data on the Composition tab (Figure 12) is presented as tables with preselected analytes that cannot be changed. The following data can be edited and viewed:

- Water Content
  - The water content of the oil in mass percent, which can be entered as a single number or as a range of values.
- Wax Content
  - The wax content of the oil in mass percent, which can be entered as a single number or as a range of values.
- Sulfur Content
  - The sulfur content of the oil in mass percent, which can be entered as a single number or as a range of values.
- SARA Total Fractions

- SARA stands for Saturates, Aromatics, Resins, and Asphaltenes. The method of analysis can vary, which means that different labs might generate different SARA compositions on the same oil. The user should refer to the original reference to learn which method was used for the particular sample.
- This is a table of mass percent values for Saturates, Aromatics, Resins, and Asphaltenes. The names and number of rows cannot be altered.

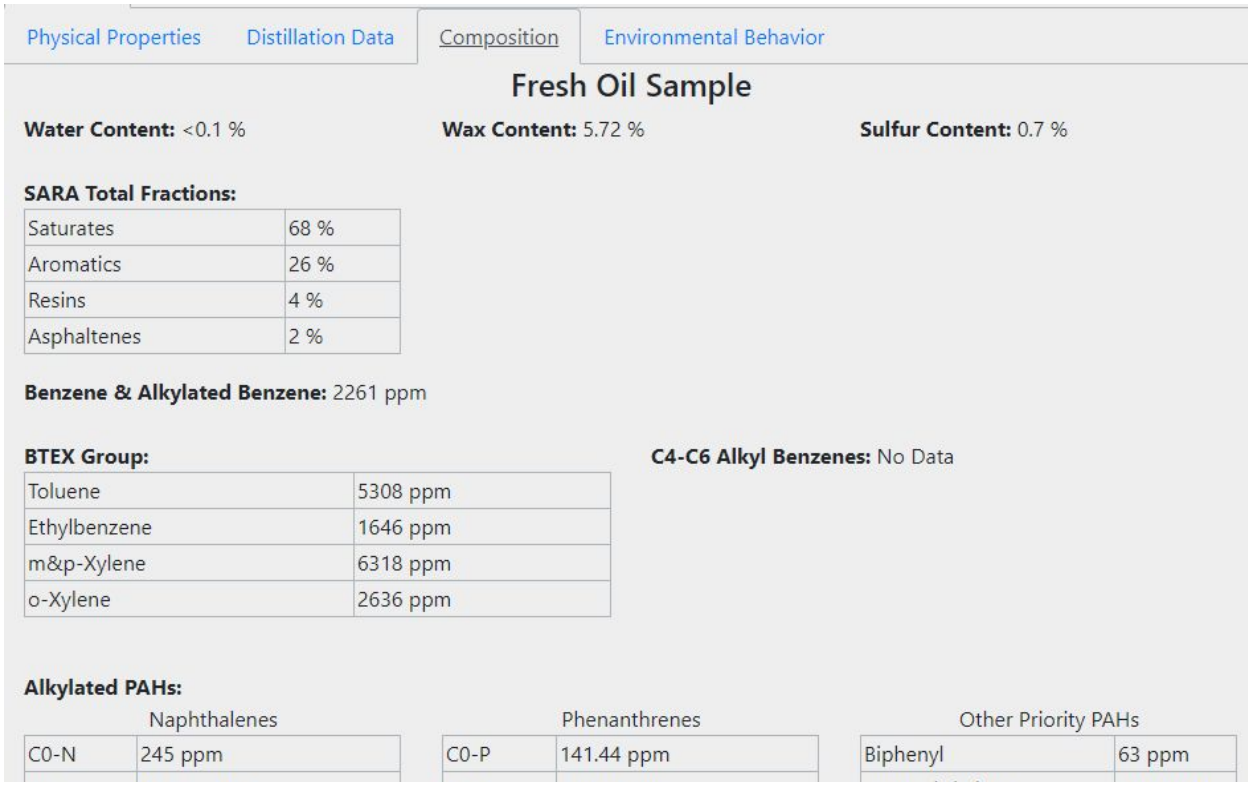

Figure 12: Composition Data tab

Some of the composition data are not editable in the current version but all will be editable in the next version:

- Benzene and Alkylated Benzene
  - The combined concentration in ppm of benzene and alkylated benzenes in a sample.
- BTEX Group
  - A table which includes concentrations in ppm of toluene, ethyl benzene, and xylenes.

- C4-C6 Alkyl Benzenes
    - A table which includes concentrations in ppm of Isopropylbenzene, Propylbenzene, 3&4-Ethyltoluene, 1,3,5-Trimethylbenzene, 2-Ethyltoluene, 1,2,4-Trimethylbenzene, 1,2,3-Trimethylbenzene, Isobutylbenzene, 1-Methyl-2-isopropylbenzene, 1,2-Dimethyl-4-ethylbenzene, Amylbenzene, n-Hexylbenzene
- Alkylated PAHs
    - Tables showing the concentrations in ppm of parent and alkyl homologs of Naphthalene, Phenanthrene, Fluorene, Chrysene, Benzonaphthothiophene, and Dibenzothiophene, as well as other priority PAHs such as pyrogenic PAHs.
- Alkenes
    - Tables showing the concentrations in ppm of C8 through C44 alkanes (mixed isomers), as well as pristane and phytane
- Biomarker concentrations
    - A table showing the concentrations in ppm of 21 important biomarkers

A limited amount of data about the behavior in the environment is included under the Environmental Behavior tab, which is not editable in this version but will be in future versions:

- Chemical Dispersibility
    - The effectiveness in percent of the named dispersant
- Emulsion Properties
    - Detailed rheological data about emulsions formed by the oil as measured by Environment and Climate Change Canada, as well as their qualitative description of the stability of the emulsion.

Analytical methods used to collect the data are not included in the database but can be found by referring to the reference cited on the oil sample page.

User Interface Design

The user interface can be used to view data in the database, edit data in an existing oil record, create an oil record from a copy of an existing oil record, or create a completely new oil record.

Editing an oil sample record is accomplished by toggling the view/edit switch on any of the sample oil pages (Figure 13). Additional subsamples can be added, and existing subsamples

can be deleted. All the editable fields appear in boxes. Labels can be added from a pick list or deleted. Data can be appended to some tables, and/or table entries deleted. Data that is stored as ranges can be edited as a range or a single value.

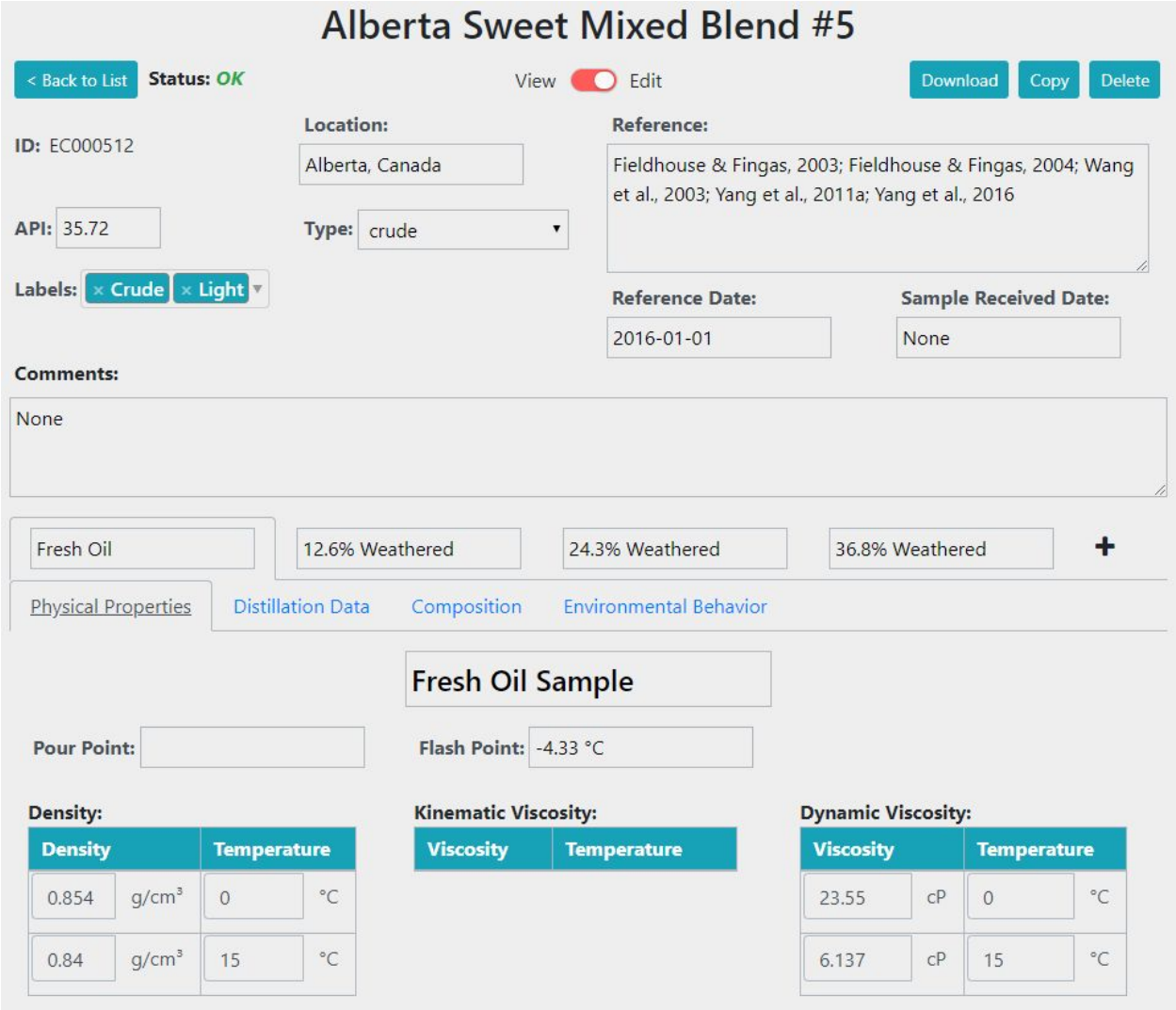

Figure 13: An oil record in Edit Mode.

The user can copy an existing oil sample record, rename it, and edit the data. When an oil sample record is copied, the software assigns a new ID number to that record with an “XX” prefix. We designed the interface to facilitate entering data on a new oil sample; this feature is included on the Oil List page (Figure 14). The “Add New Oil” button creates a page with empty data fields that can be easily edited.

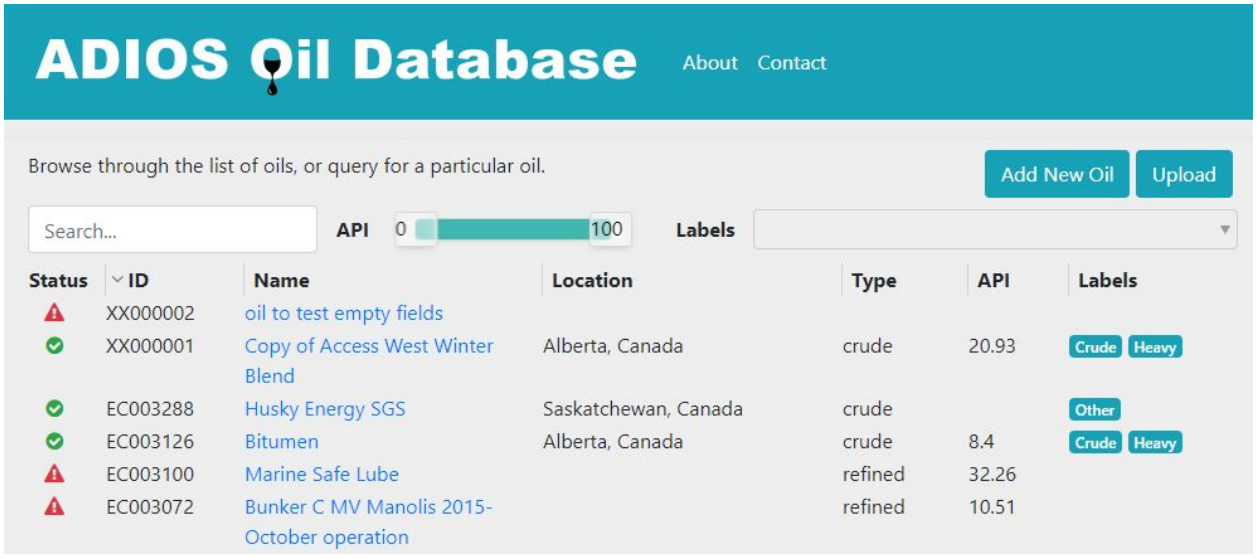

Figure 14: The List Page showing user-added records and the Add New Oil and Upload buttons.

Import/Export Features

On the page for each oil record, there is a “Download” button that allows the user to export that entire record as a JSON (JavaScript Object Notation) file. On the main List Page, there is an “Upload” button that allows a user to upload a data record in the same format. This allows a user of one set of data, perhaps on a secure system, to export a record that can then be easily brought in to another institution’s database.

JSON (https://www.json.org/json-en.html) is a text-based data interchange format that is very popular for modern software, particularly web-based systems. The JSON data model is very flexible, and well suited to complexly-structured data. Its flexibility allows us to add additional data fields in the future without hampering the ability to read older records.

Use of the format not only enables communication between the client and server of the ADIOS OIl Database, but also can be used to pass data to other systems. NOAA is working with other groups, including the Canadian and Norweigan meteorological offices, and the RPS Group (developers of the OilMap software) on standardizing the format for easier interchange between modelers.

Future Work

The ADIOS Oil Database software developed under this agreement will continue to be used and updated by the Office of Response and Restoration for spill response needs. We are actively continuing in-house usability testing and fixing any remaining bugs that are reported. We can also continue to incorporate changes based on BSEE feedback.

In the next year, we intend to link the ADIOS Oil Database to WebGNOME to make full use of the data from industry sources and ECCC. We also intend to provide a public link to the data stored in our database and streamline the data transfer process so parties involved in an active spill response can quickly upload data which OR&R can use during spill response operations.

One of the major features under initial development is a validation system, which will provide users feedback as to how complete a data record is and alert them to possible errors in the dataset.

Work on the application will continue for years to come to satisfy the needs of the response community. We intend to develop collaborations to expand the number of high-quality records, and will make modifications as appropriate to serve the needs of the wider oil spill community. We intend to continue the working relationship with BSEE to improve the software in ways that will make it more useful for spill response and preparedness.

Related Efforts

NOAA is involved in a number of related efforts for working with oil data. We are under way on a project funded by Canada's Department of Fisheries and Oceans (DFO) Multi-partner Research Initiative (MPRI) (managed by Dr. Ken Lee). This project has three primary components:

- A gaps analysis, examining what oils are already in currently available datasets, and what types of oils are likely to be spilled in the US and Canada. The goal is to identify where the gaps are in NOAA's database so that we can work to fill those gaps. This analysis is currently underway.
- A Response Oil Assay Workshop: NOAA's Emergency Response Division (ERD) hosted a two-day workshop on Jan 14-15, 2020 in Seattle, Washington, to identify the ideal set of physical and chemical properties of oil to be included in the new ADIOS Oil Database. The meeting brought together a broad cross-section of stakeholders in the international oil spill response community, including field responders, modelers, response planners,

and analytical chemists; attendees spanned government, academia, the petroleum industry, and private consultants. There was also international participation, with representatives from Norway, France, and Canada in attendance in addition to the U.S. contingent.

- A sampling and chemical analysis effort wherein ERD sources samples of the oils identified in the gaps analysis as being missing from the database, and sends the samples to labs to have the most response-relevant properties measured. These new chemical analyses will be added to the ADIOS Oil Database. This part of the project will begin during the second year of funding.

The January workshop also served as an opportunity to introduce this new software to the community. There was a great deal of interest, and we look forward to improving it with the input from a broader community of users.

There is also an initiative currently being led by ExxonMobile and RPS to better understand the state of the art for emulsification modeling, and determine a way to move forward. This effort will likely lead to a desire to standardize laboratory emulsification methods. We intend to work with this community to make sure that any new lab data can be managed and presented by the ADIOS OIl Database.