# CEREO Living Atlas

## Final Report

Center for Environmental Research, Education, and Outreach (CEREO)


**Living Atlas Development Team:**

Yaru Gao

Zachary Garoutte

Jonathan Simmons

**Mentor:**

Ananth Jillepalli

CptS 423 Software Design Project II

Fall 2025

# TABLE OF CONTENTS

# I. Introduction

The CEREO Living Atlas is a web-based platform built through collaboration with the Center for Environmental Research, Education, and Outreach (CEREO) at Washington State University. It's intended as a flexible tool for a wide community—researchers, tribal groups, educators, students, and government agencies alike—making it easier to gather, view, and share environmental data relevant to the Pacific Northwest. Providing users with a single, map-focused interface to upload and explore geospatial information. From tracking water quality to monitoring restoration work and community engagement, the platform is geared toward surfacing patterns, highlighting case studies, and guiding decisions with clarity.

For years, environmental datasets were fragmented—tucked away in separate systems, hard to access, and rarely interoperable between institutions. That’s a big part of why the Living Atlas came to be. It offers a public-facing, visual interface where users can submit “cards” packed with metadata, photos, location data, and even links to research. These cards are searchable and filterable by category, tag, or custom fields, giving users a more intuitive and visual way to navigate complex datasets.

The platform didn’t start out this way. What began as a simple data viewer gradually grew into a fully interactive application with strong backend support. During its alpha phase, a number of useful features were introduced: things like account logins, role-specific permissions, bookmarks, sortable cards, thumbnail previews, and an easier submission workflow for spatial data.

Throughout development, CEREO stakeholders—including faculty, student researchers, and external collaborators—voiced a clear need: the platform had to be user-friendly for those without technical backgrounds, but still robust enough for deeper academic or policy-related work. Their input pushed the team to focus on accessibility and scalability while respecting data ownership. These concerns, in many ways, shaped how the system functions today.

# II. Team Members & Bios

Zachary Garoutte is a software engineering student. He is experienced in working with C, C++, C#, Python, Java, SQL, HTML, and CSS. For this project, his responsibilities have been to create a new database and cloud data service for the project, and to add the ability for users to upload thumbnails to cards in the Atlas.

Yaru Gao is a computer science student. He is experienced in working with C, C++, Python, Java, HTML, CSS, and JavaScript. For this project, his responsibilities have been to refine the frontend UI, fix the bugs of the password reset feature and card display feature, and implement a bookmarking feature that users can use to add, remove or sort their favorite cards.

Jonathan Simmons is a computer science student. He is experienced in C, C++, C#, Python, and Java. For this project, his responsibilities have been to add a sorting feature that can organize the

cards in the Atlas by different criteria, such as closest to current location and most recently added, and to add the ability for users to attach files to cards in the Atlas.

# III. Project Requirements Specification

## III.1. Project Stakeholders

The primary stakeholder is the **Center for Environmental Research, Education and Outreach** (CEREO) at Washington State University. CEREO is an organization dedicated to addressing environmental challenges through research and educational support, aiming to develop meaningful solutions for critical environmental issues. Currently, CEREO relies on the Living Atlas as a key research tool. They desire an application that is more functional and user-friendly, enabling broader adoption and improved collaboration among users.

Other stakeholders include both current and future researchers working with CEREO. They could benefit from a more efficient and robust application to enhance their research and collaboration.

## III.2. Use Cases

The use cases for the application are based on a role-based access control system. Any user has access to the map data and can use search functionality on this data. A registered user is a user who has created an account on the website, and these users can login to their account and bookmark data. An authorized user is a user with authority to add data to the map, and view, edit, or remove this data later. An administrator has authority to grant authorization to add data and can edit or remove any current data on the map. Administrative functions are currently planned to be done through the backend, but administrator login may be implemented in the future.

A use-case UML diagram for the Living Atlas is provided in Appendix D.

Add Geospatial Data To Map

| Actors | Authorized user |
|---|---|
| Preconditions | • Be logged in to an authorized user account<br>• On main map page |
| Postconditions | • Geospatial data and attached information card is added to database and is publicly displayed on map |
| Path | 1. Authorized user clicks Add Data option from homepage<br>2. User enters geospatial information such as geospatial data types or map coordinates to establish location for data to be stored on map<br>3. User enters relevant information such as study results to attach to these coordinates as a card<br>4. Optionally upload photo to display on card<br>5. User submits data addition |

| | |
|---|---|
| | 6. Data is displayed on map at given coordinates and new card is added |
| Related Requirements | III.3.1 User Management: Role-Based Access Control<br>III.3.2 Data Management: Geospatial Data Loading & Editing<br>III.3.3 Map & Visualization Features: Interactive Mapping Interface<br>III.3.3 Map & Visualization Features: Picture Data Upload & Display |

View Added Geospatial Data

| Actors | Authorized user |
|---|---|
| Preconditions | • Be logged in to an authorized user account<br>• On main map page |
| Postconditions | • Information cards corresponding to the geospatial data that was previously added by the logged in user are displayed |
| Path | 1. Authorized user clicks View Added Data option from homepage<br>2. Information cards added by the user are displayed |
| Related Requirements | III.3.1 User Management: Role-Based Access Control<br>III.3.3 Map & Visualization Features: Interactive Mapping Interface |

Edit Added Geospatial Data

| Actors | Authorized user |
|---|---|
| Preconditions | • Be logged in to an authorized user account<br>• On main map page |
| Postconditions | • Edit the text and/or photo on an information card previously added by the logged in user |
| Path | 1. Authorized user clicks View Added Data option from homepage<br>2. Information cards added by the user are displayed<br>3. Click Edit option on card to be edited<br>4. User enters updated information for card<br>5. Optionally user uploads new photo for card<br>6. User submits edit |

| | |
|---|---|
| | 7. Information and photo is publicly updated in real time on the card |
| Related Requirements | III.3.1 User Management: Role-Based Access Control<br>III.3.2 Data Management: Geospatial Data Loading & Editing<br>III.3.3 Map & Visualization Features: Interactive Mapping Interface<br>III.3.3 Map & Visualization Features: Picture Data Upload & Display |

Remove Geospatial Data From Map

| Actors | Authorized user |
|---|---|
| Preconditions | • Be logged in to an authorized user account<br>• On main map page |
| Postconditions | • Geospatial data and attached information card previously added by the logged in user is removed from the map |
| Path | 1. Authorized user clicks View Added Data option from homepage<br>2. Information cards added by the user are displayed<br>3. Click Delete option on card to be deleted<br>4. User confirms deletion<br>5. Geospatial data on map is removed from map and the attached card is removed |
| Related Requirements | III.3.1 User Management: Role-Based Access Control<br>III.3.3 Map & Visualization Features: Interactive Mapping Interface |

Bookmark Data

| Actors | Registered user of any authorization |
|---|---|
| Preconditions | • Be logged in to an account<br>• On main map page |
| Postconditions | • Card(s) is added to user's favorites |
| Path | 1. User clicked on the book button on the right sidebar or the double arrow button in the center-right of the screen to open the card container<br>2. Click on the empty bookmark icon on the top right corner of a card to bookmark it.<br>3. Card is added to user's favorites |

| | |
|---|---|
| Related Requirements | III.3.2 Data Management: Data Filtering & Search |

Unbookmark Data

| | |
|---|---|
| Actors | Registered user of any authorization |
| Preconditions | • Be logged in to an account<br>• On main map page<br>• Card(s) is bookmarked by user previously |
| Postconditions | • Card(s) is removed from user's favorites |
| Path | 1. User clicked on the book button on the right sidebar or the double arrow button in the center-right of the screen to open the card container<br>2. Click on the solid bookmark icon on the top right corner of a card to unbookmark it.<br>3. Card is removed from user's favorites |
| Related Requirements | III.3.2 Data Management: Data Filtering & Search |

Access All Bookmarked Data

| | |
|---|---|
| Actors | Registered user of any authorization |
| Preconditions | • Be logged in to an account<br>• On main map page |
| Postconditions | • Information cards previously bookmarked by the logged in user are displayed |
| Path | 1. User clicks View Bookmarks option from homepage<br>2. Information cards bookmarked by the user are displayed |
| Related Requirements | III.3.2 Data Management: Data Filtering & Search |

Search (updated)

| | |
|---|---|
| Actors | Any user |
| Preconditions | • On main map page |
| Postconditions | • Display information cards based on date, location, and other sort and filter options |

| | |
|---|---|
| Path | 1. Optionally click sort option to sort list of cards<br>2. Optionally click filter option to filter list of cards<br>3. Display cards best matching the search criteria |
| Alternate Path | 1. User clicks search bar<br>2. Type keywords to be matched with cards in database<br>3. Display cards relating to keywords<br>4. Optionally click sort option to sort list of cards<br>5. Optionally click filter option to filter list of cards<br>6. Display cards best matching the search criteria |
| Related Requirements | III.3.2 Data Management: Data Filtering & Search |

Reset Password

| | |
|---|---|
| Actors | Registered user of any authorization |
| Preconditions | • On login page or profile page |
| Postconditions | • The user's password is updated |
| Path | 1. User clicks Forgot Password option<br>2. A one-time verification link is sent to the email attached to the user's account<br>3. Click link in email account<br>4. Enter new password<br>5. User submits password<br>6. Login password is updated to new password |
| Related Requirements | III.3.1 User Management: User Registration & Authentication |

Load Spatial Data onto Map

| | |
|---|---|
| Actors | Any user |
| Preconditions | • On homepage |
| Postconditions | • The interactive layers of ArcGIS data are displayed on the map with popup modal ready to open. |
| Path | 1. User clicks on the Browse GIS Data button featured as an earth icon on the left sidebar to open the upload panel.<br>2. Click to expand the main folder or service folder to see the servers/layers |

| | |
|---|---|
| | 3. Click on the load button of a service(s) or the checkbox of a layer(s) to load interactive layers to the map<br>4. Colored areas of loaded interactive layers will gradually appear on the map in a short while |
| Related Requirements | III.3.3 Map & Visualization Features: Interactive Mapping Interface |

Remove Loaded Spatial Data from Map

| Actors | Any user |
|---|---|
| Preconditions | • On homepage<br>• Service(s) or layer(s) are loaded onto the map (see 'Load Spatial Data onto Map') |
| Postconditions | • The interactive layers of ArcGIS data are removed from the map. |
| Path | 1. Click on the Browse GIS Data button on the left sidebar if the upload panel is not open.<br>2. Click to expand the main folder or service folder to see the servers/layers<br>3. Click on the remove button of a service(s) or the checkbox of a layer(s) to add it to the map<br>4. Removes loaded service(s)/layer(s) from the map |
| Related Requirements | III.3.3 Map & Visualization Features: Interactive Mapping Interface |

View layer Information

| Actors | Any user |
|---|---|
| Preconditions | • Colored areas are fully displayed on map, see 'Load Spatial Data onto Map' |
| Postconditions | • A pop-up modal containing information about the layer will be displayed on the map |
| Path | 1. User clicks on the colored areas of loaded interactive layers within the map.<br>2. A pop-up modal that contains detailed information of a layer(s) is open. |
| Related Requirements | III.3.3 Map & Visualization Features: Interactive Mapping Interface |

Search for a Folder(s)/Service(s)/Layer(s)

| | |
|---|---|
| Actors | Any user |
| Preconditions | • On Upload Panel |
| Postconditions | • The desired folders/services/layers are displayed in the upload panel. |
| Path | 1. Click on the Browse GIS Data button on the left sidebar if the upload panel is not open.<br>2. Enter keyword(s) into the search bar on the top corner of upload panel<br>3. Click on the search icon<br>4. Folder(s)/Service(s)/Layer(s) that match the keyword(s) will be displayed in the upload panel<br>5. Optionally click on the close button next to the search icon to clear search and reset upload panel |
| Related Requirements | III.3.2 Data Management: Data Filtering & Search |

Show Loaded Service(s)/Layer(s) Only

| | |
|---|---|
| Actors | Any user |
| Preconditions | • User opened upload panel<br>• Service(s) or layer(s) are loaded onto the map (see ‘Load Spatial Data onto Map’) |
| Postconditions | • Only loaded service(s) or layer(s) are be displayed in the upload panel |
| Path | 1. Click on the Browse GIS Data button on the left sidebar if the upload panel is not open.<br>2. Check/Uncheck the checkbox below the search bar that has text "Show only services added to map"<br>3. The upload panel will display the loaded service(s) or layer(s) only |
| Related Requirements | III.3.2 Data Management: Data Filtering & Search |

Hide/Display User Defined or Built-in Layers

| | |
|---|---|
| Actors | Any user |

| | |
|---|---|
| Preconditions | • On homepage |
| Postconditions | • Card/Colored Areas will be hidden/displayed on the map. |
| Path | 1. User clicks on the layer button featured as a layer icon on the right sidebar to open the layer panel.<br>2. Check/Uncheck the checkbox of a card or user-added colored areas.<br>3. The selected Cards or Colored areas will be removed from the map or displayed on the map. |
| Related Requirements | III.3.3 Map & Visualization Features: Interactive Mapping Interface<br>III.3.2 Data Management: Data Filtering & Search |

Move Current View to Location of a Card

| | |
|---|---|
| Actors | Any user |
| Preconditions | • On homepage<br>• Card container is open |
| Postconditions | • User's current view is moved to the location of the card he clicked. |
| Path | 1. User clicks the empty space on a card<br>2. User's current view will be moved to the location of that card |
| Related Requirements | III.3.3 Map & Visualization Features: Interactive Mapping Interface |

## III.3. Functional Requirements

The CEREO Living Atlas is a web-based application developed to assist researchers, tribal communities, and government agencies in visualizing and sharing critical environmental data. To ensure the system remains accessible, efficient, and scalable, a structured set of functional requirements has been established.

These functional requirements define the system's essential capabilities, outlining what the application must achieve to effectively meet user needs. They are categorized into three primary modules: **user management, data management, and mapping visualization.**

Each requirement is aligned with stakeholder needs and assigned a priority level based on its significance:

- **Priority Level 0:** Essential, non-negotiable functionality.
- **Priority Level 1:** Important but not critical features.
- **Priority Level 2:** Optional enhancements or future upgrades.

### III.3.1 User Management

- **User Registration & Authentication:**
  - The system must allow users to create accounts and log in securely.
  - Users should be able to reset passwords via email authentication.
  - Emails must be reliably forwarded from the application's Gmail account to WSU emails.
  - Source: CEREO's need for controlled data access and email functionality improvements.
  - **Priority:** Level 0 (Essential)
- **Role-Based Access Control:**
  - The system must differentiate user roles (e.g., researchers, administrators, public users).
  - Certain data upload and modification features must be restricted to authorized users.
  - There is currently no admin login, but this may be required in the future.
  - Source: Stakeholder request for future expansion options.
  - **Priority:** Level 1 (Desirable)

### III.3.2 Data Management

- **Geospatial Data Loading & Editing:**
  - Users must be able to upload geospatial files (e.g., shapefiles, GeoJSON) instead of hardcoding data.
  - Alternatively, geospatial data must be able to be loaded directly from the webserver.
  - The system should support additional data types, such as watershed boundaries.
  - Polygons representing geospatial data should be customizable, such as color coding to represent different environmental factors.
  - Source: Client request for flexible spatial data storage and visualization.
  - **Priority:** Level 0 (Essential)
- **Data Filtering & Search:**
  - Users should be able to filter datasets based on date, location, and environmental metrics.
  - A search function must allow users to locate specific data points easily.
  - Users should be able to bookmark data to make the data easily accessible at a later time.
  - Source: Stakeholder need for enhanced data navigation.
  - **Priority:** Level 1 (Desirable)

### III.3.3 Map and Visualization Features

- **Interactive Mapping Interface:**

    - The map must dynamically display geospatial data and be updated in real-time. Users should be able to toggle interactive map layers and view detailed info about them.
    - The map must include a legend of symbol meanings, categories, and active layers.
    - Source: Usability improvement request from researchers and policy analysts.
    - **Priority:** Level 0 (Essential)
- **Picture Data Upload & Display:**
    - Users must be able to upload images associated with geospatial data points.
    - Ensure smoother handling of image uploads to avoid failures.
    - Source: Client feedback on frontend usability.
    - **Priority:** Level 0 (Essential)
- **Performance Optimization**:
    - The website should be able to work faster and handle a larger user base.
    - Reduce delays in loading data points on the map.
    - Source: Client's primary goal for enhancement.
    - **Priority:** Level 0 (Essential)

## III.4. Non-Functional Requirements

Non-functional requirements are aspects such as performance, security, reliability, and scalability. While the functional requirements define what the system must do, non-functional requirements determine how efficiently and effectively it operates under different working conditions.

To support its expanding user base and large datasets, the CEREO Living Atlas must ensure data integrity, high availability, and an intuitive user experience. Meeting long-term stakeholder expectations requires a strong focus on efficiency, security compliance, and system extensibility.

These requirements are categorized into key areas, including performance, security, cross-platform compatibility, reliability, and future scalability. Each is assessed and prioritized based on its influence on system usability and long-term sustainability.

### III.4.1. Performance & Scalability:

- The system shall support 500+ concurrent users without performance degradation.
- The backend should be optimized to handle large datasets efficiently.
- Source: Client's requirement for scalability.
- Priority: Level 0 (Essential)

### III.4.2. Security & Authentication:

- Email forwarding issues must be resolved to allow WSU emails to receive system messages.
- Future improvements should consider adding email-based user verification.

- Source: Client's security concerns.
- Priority: Level 1 (Desirable)

**III.4.3. Cross-Platform Compatibility:**

- The web application shall function on modern browsers (Chrome, Firefox, Edge).
- The system should support mobile access with a responsive design.
- Source: User accessibility requirements.
- Priority: Level 1 (Desirable)

**III.4.4. Reliability & Uptime:**

- The system shall maintain a 99.5% uptime with failover mechanisms.
- Regular database backups must be implemented to prevent data loss.
- Source: Client expectation for high-availability services.
- Priority: Level 0 (Essential)

**III.4.5. Extensibility & Future Integrations:**

- The system should be modular to allow future integrations (e.g., external GIS platforms).
- API endpoints should be designed for third-party compatibility.
- Source: Long-term system evolution considerations.
- Priority: Level 2 (Stretch Goal)

**III.4.6. Improved Application Accessibility**:

- Develop a standalone WinForms application that wraps the CEREO web application.
- Users can launch the app via a desktop shortcut instead of running npm start in a terminal.
- The application can be easily installed by downloading and extracting a ZIP file from GitHub, providing a more intuitive setup for non-technical users.
- Priority: Level 1 (Desirable)

# IV. Software Design - From Solution Approach

The functionality of the application's system should be focused on providing a user-friendly experience for all users that will be navigating through the Living Atlas, while also accommodating support for features for more technical users, such as adding complex geospatial data types to the database. To achieve an intuitive user interface, we implemented features for loading spatial data including raster layers and metadata from the endpoints of ArcGIS REST webserver of each U.S. state and generate interactive components such as clickable layers and pop-up info modal for the loaded data. Additionally, we will implement features that support uploading spatial data files from other geodatabases such as HydroShare. For users adding data to the database, the system should support upload of shapefiles and/or GeoJSON files to represent the geospatial data as shown on the map. The system will be designed such that these geospatial data files can be transferred from a user upload at the application frontend to the backend and into the database, which the frontend will read from and display its data on the map.

## IV.1. Architecture Design

### IV.1.1. Overview

The Living Atlas is designed with a three-layer architecture, comprising the frontend, backend, and database. The frontend, developed using React.js, delivers an interactive and user-friendly interface, enabling seamless map visualization and intuitive user interactions. On the backend, FastAPI acts as the core intermediary, efficiently managing incoming API requests, authentication, and data processing. Supporting this all is a PostgreSQL database, which securely and effectively stores geospatial data, user credentials, and metadata related to uploaded datasets. This modular approach ensures that each component can be updated or modified independently, enhancing the system's scalability, flexibility, and long-term maintainability.

A diagram of the basic subsystem layers of the architecture can be found in Appendix E.

### IV.1.2. Subsystem Decomposition

The system is structured into three core subsystems: the frontend, backend, and database. The frontend handles data visualization, processes user interactions, and provides tools for data submission. To enhance mapping capabilities, it leverages libraries such as Mapbox and Leaflet.js. The backend manages user authentication, enforces role-based access, validates data uploads, and delivers geospatial data through API endpoints. Meanwhile, the database efficiently organizes structured data, ensuring rapid retrieval and optimized querying through spatial indexing.

#### Frontend Subsystem

The frontend subsystem is responsible for managing user interactions and rendering geospatial data. It consists of key components such as the homepage, an interactive map, and data submission forms. By leveraging API calls, it seamlessly communicates with the backend to

ensure smooth data processing and storage. A diagram of the frontend subsystem can be found in Appendix F.

#### Backend Subsystem

Serving as the system's processing core, the backend manages user authentication, enforces access control, and validates geospatial data submissions. Positioned as the bridge between the frontend and the database, it ensures secure and efficient data flow. To optimize performance, various algorithms are implemented to streamline API request handling and minimize response times. A diagram of the backend subsystem can be found in Appendix G.

#### Database Subsystem

The database subsystem is responsible for securely storing crucial system data, including user credentials, authentication records, and geospatial datasets. Built on PostgreSQL with PostGIS extensions, it is optimized for handling spatial queries with high efficiency. Its scalable architecture enables rapid data retrieval, advanced filtering, and indexing to ensure seamless access to stored information. A diagram of the database subsystem can be found in Appendix H.

## IV.2. Data design

The database design consists of structured tables to store geospatial data, user information, and role-based permissions. The Geospatial Data Table contains dataset entries, including spatial attributes, metadata, and associated files (e.g., shapefiles, GeoJSON). The User Table maintains account credentials, authentication tokens, and access levels. The Permissions Table defines role-based access to ensure only authorized users can upload or modify data. Data indexing and relational integrity are enforced through PostgreSQL with PostGIS, allowing for optimized querying and retrieval of large-scale environmental datasets.

There will be two major data structures present in the system database: The data structure containing all geospatial data points (including attached card information), and the data structure containing the account information of all users. Each object in the geospatial data structure will contain a shapefile so that the data can be displayed properly on the map in the correct location, and the card information for that data point, which can include the name of the user who added the data, the user's email, the organization who collected study data, a link to the study dataset, the title of the linked dataset, a description of the data set, the data category, and search tags. Each object in the account information data structure will contain a user ID, username, email, encrypted password, and the user's authorization level (view only, authorized to add data, or admin).

## IV.3. User Interface Design

The CEREO Living Atlas provides an interactive web interface for users to explore and manage environmental data. The homepage serves as the main point of interaction. Users can search, filter, and navigate data efficiently, while authorized users can contribute and manage

geospatial information. The features described here align with those listed in the Use Cases section.

The homepage offers several key features. Users can search for data using filters in the top navigation bar. Geospatial data can be added through the “Add” button in the cards section. Viewing data is straightforward, with coordinates and shapes displayed on the left-side map and corresponding cards on the right. Users can also remove data from the same card section. Bookmarked data is accessible in this area as well. For diagrams illustrating these features, refer to Appendix I.

Editing data is available by clicking “Learn More” on a card, which opens a detailed window containing an edit option. Additionally, this window also allows authorized users to delete a card, update information and attached files as needed. For visual references of this feature, see Appendices J and K.

The user center includes account management functions. Password resets require entering the current password and a new one. This ensures security while keeping the process simple. A diagram of this feature can be found in Appendix L.

The homepage navbar provides access to key pages, including the registration page and administrator dashboard. The registration page allows non-logged-in users to fill out a form requesting an account. Submitted requests are sent to the admin panel, where an administrator can approve or deny them. For a diagram of this process, see Appendix M and N, respectively.

The administrator dashboard displays a list of all registered users in the Living Atlas. Admins can manage user accounts by modifying access levels or deleting accounts. This ensures proper role-based access control within the system. For a detailed view of the admin dashboard, refer to Appendix O.

# V. Test Case Specifications and Results

## V.1. Testing Overview

To validate the functionality and robustness of the CEREO Living Atlas alpha prototype, a combination of unit, integration, and manual tests were conducted across both frontend and backend systems. Testing focused on verifying core features such as card creation, thumbnail uploads, user role access, and data filtering. Continuous integration checks ensured the backend builds successfully on every commit. Manual testing also confirmed proper rendering and responsiveness across modern browsers. Together, these tests provide confidence in the stability of the current prototype while highlighting key areas for further refinement in the next development phase.

### V.1.1 Unit Testing

Our team will follow all standard unit testing procedures. Most unit testing will focus on code developed by previous teams, as new development is mostly built using these previously developed units. The previously developed units to be tested include loading a card from the database, adding or deleting a card from the database, adding or deleting an account, submitting a form, and loading the map from Mapbox. It is crucial that these previously developed units are tested as the database host has been switched to Microsoft Azure and these units must still function with the new database for the overall system to function correctly. Some newly developed units to be tested include changing an account's password, sending a reset password email, and loading files and images from the database.

### V.1.2. Integration Testing

Given the multi-layer design of our application, consisting of a FastAPI backend, React Front end and integration with google cloud storage- the integration testing focuses on validating the flow of data between these layers. Unlike a monolithic structure, this modular setup introduces complexities in testing complete workflows and can cause issues with the flow of data between the layers.

The development team will primarily rely on manual testing within local and staging environments to replicate integrated scenarios like form submissions involving file and thumbnail uploads, database entry creation, and frontend content display. At this stage, automated integration testing remains limited due to the complexities of mocking Google Cloud APIs and maintaining database state across different layers. However, specific endpoints may still be tested using tools such as Postman or pytest with FastAPI's TestClient.

Although the ultimate goal is comprehensive end-to-end integration testing across all components, certain elements—like frontend thumbnail display logic—may be tested in isolation when backend deployment or effective mocking proves challenging.

### V.1.3. System Testing

#### V.1.3.1. Functional testing:

Functional testing is carried out manually by developers, following the project's Requirements and Specifications document. Each functional requirement is matched with a specific test case. This includes:

- Creating a card with all metadata fields

- Uploading data files and thumbnail images
- Retrieving and displaying card data, including image previews
- Downloading uploaded files
- Deleting cards and confirming cascade deletions (files and thumbnails)

Tests are validated through the browser interface and network tools like Chrome DevTools or Postman. Any failed tests are documented with clear reproduction steps and assigned back to the original developer for resolution. As the application evolves, the testing plan will be updated accordingly.

#### V.1.3.2. Performance testing:

Performance testing targets two main areas: backend response time and frontend rendering speed.

**Backend testing includes:**

- Measuring FastAPI response times with large payloads (e.g., multi-megabyte uploads)
- Tracking latency when accessing files and thumbnails stored on Google Cloud

**Frontend testing includes:**

- Monitoring load times when rendering pages with numerous cards and images
- Evaluating performance on lower-end devices or slower networks

Manual observations are supported with browser profiling tools like Lighthouse and Chrome DevTools. While not benchmarked against strict numerical thresholds, performance is assessed qualitatively based on overall responsiveness and user experience.

#### V.1.3.3. User Acceptance Testing:

User acceptance testing will be conducted exclusively by the client. Instead of structured forms, feedback will be gathered through direct meetings.

**A. Process**

- The client will test key workflows, including creating, viewing, editing, and deleting cards.
- Particular focus will be placed on new features, such as image upload and thumbnail display.
- Observations and feedback will be shared in scheduled meetings.

**B. Revision Process**

- Developers will document and categorize feedback as bugs, feature requests, or general improvements.
- Actionable items will be tracked in the issue management system (e.g., GitLab Issues).
- Any necessary changes will be implemented and deployed to staging before final release.

The final iteration will be considered complete once the client confirms that all key features function as expected and the user experience meets their needs.

## V.2. Environment Requirements

For the frontend, we are planning to use React, which allows us to utilize tools like Jest and Selenium for testing. These tools facilitate easy testing of our UI across different browsers and JavaScript components. Lighthouse can be used to measure loading times and ensure performance standards are met. For staging environments, we are considering using Docker which will help create containerized versions of the application that can be easily deployed and tested across various machines. For the database, tools like Alembic or Flyway will manage schema changes and seed data during testing. We may switch to other tools as the project evolves, and the tools currently selected are subject to change. Version control is handled through GitHub. There are no specific hardware requirements for the testing environment.

## V.3. Test Results

At this stage, we have not yet begun formal testing of the prototype. No structured test case results are available beyond informal integration testing performed manually with DevTools to verify basic functionality. Formal unit and system testing will be introduced in future sprints, and results will be documented once testing begins.

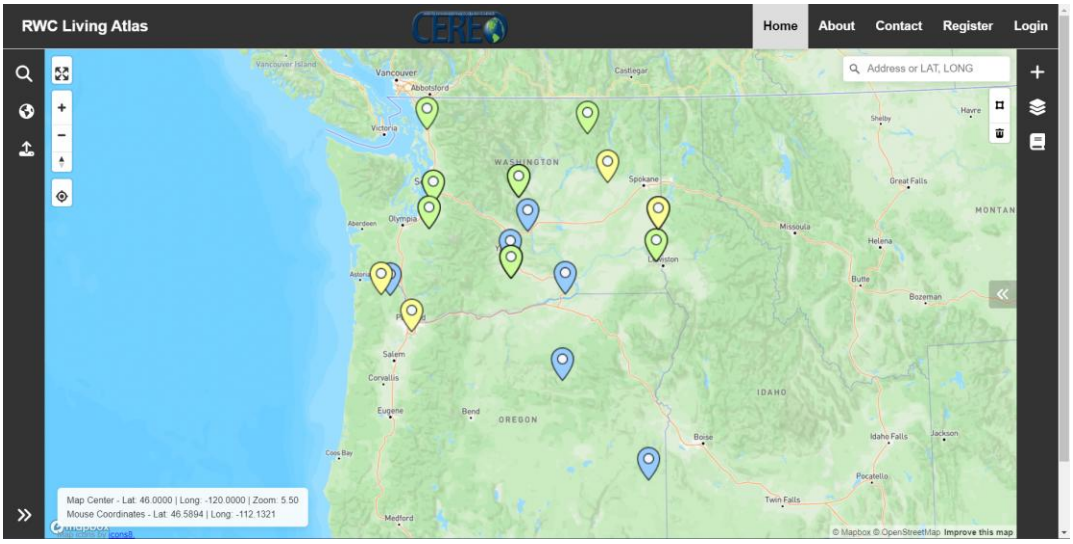
# VI. Projects and Tools used, Libraries, and Frameworks

| Tool/Library/Framework | Quick note on what it was for |
|---|---|
| React.js | Built the frontend user interface and handled dynamic components. |
| Bootstrap / CSS | Provided styling, layout, and responsive design for the web app. |
| FastAPI | Framework used to build the backend API and connect to the database. |
| Microsoft Azure Database | Database for storing card data, user info, and metadata. |
| Google Cloud Storage | Hosted uploaded files and thumbnails for cards. |
| Render | Deployed and hosted the FastAPI backend. |
| Netlify | Deployed and hosted the React frontend. |
| Mapbox GL JS | Displayed interactive maps and supported drawing/viewing markers. |
| Git/GitHub | Version control and team collaboration. |
| Visual Studio Code | Main IDE for frontend and backend development. |

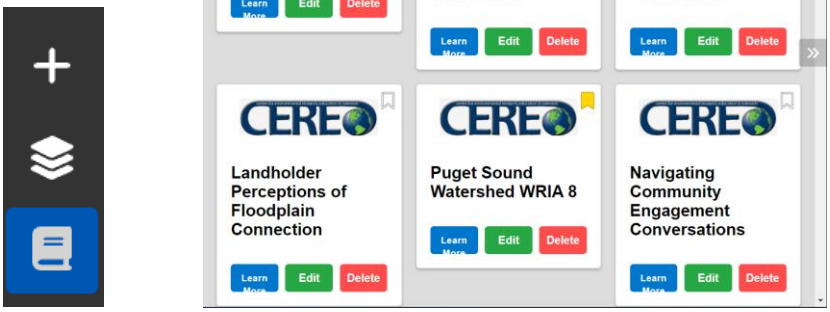
| Language | Usage |
|---|---|
| JavaScript | Frontend (React components, API calls, dynamic UI). |
| Python | Backend (FastAPI routes, database queries, file handling). |
| SQL | Queries for PostgreSQL database operations. |
| HTML5 | Page structure in frontend components. |
| CSS | Styling and responsive design for web app. |

# VII. Description of Final Prototype

The prototype of our web application is designed to centralize environmental and spatial information in one platform. The homepage features a top navigation bar that directs users to other pages, along with sidebars on the left and right that provide key functionalities (see below).




The user can click on the book-shaped button located on the right sidebar to open the card container and view all the cards. Users can also drag the left border of the card container to the left to adjust its width (See Appendix E). To see the location of a card on the map, the user can click on the empty space of the card, and the map will center on that card's location.

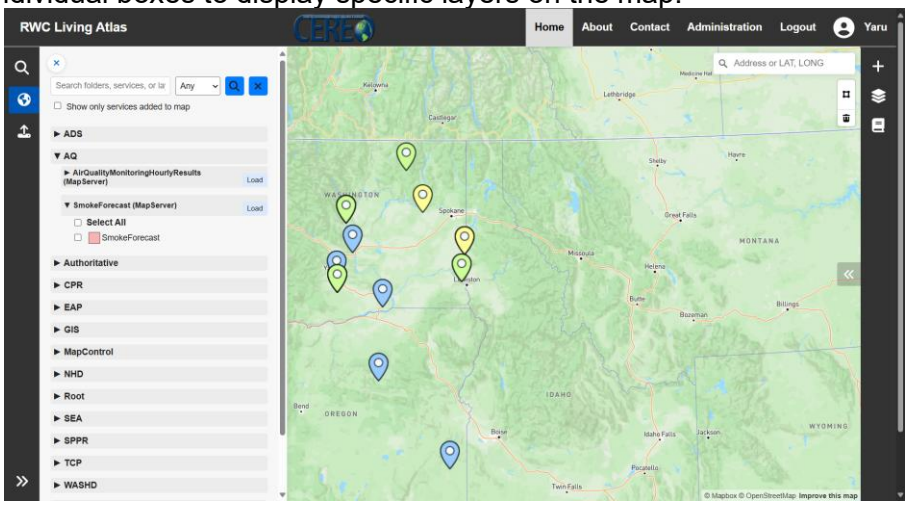



Clicking the "Learn More" button on a card opens an info modal with details about that card (see Appendix T). Authorized admin users can edit or delete a card using the "Edit" and "Delete" buttons respectively (see Appendix U and Appendix V).

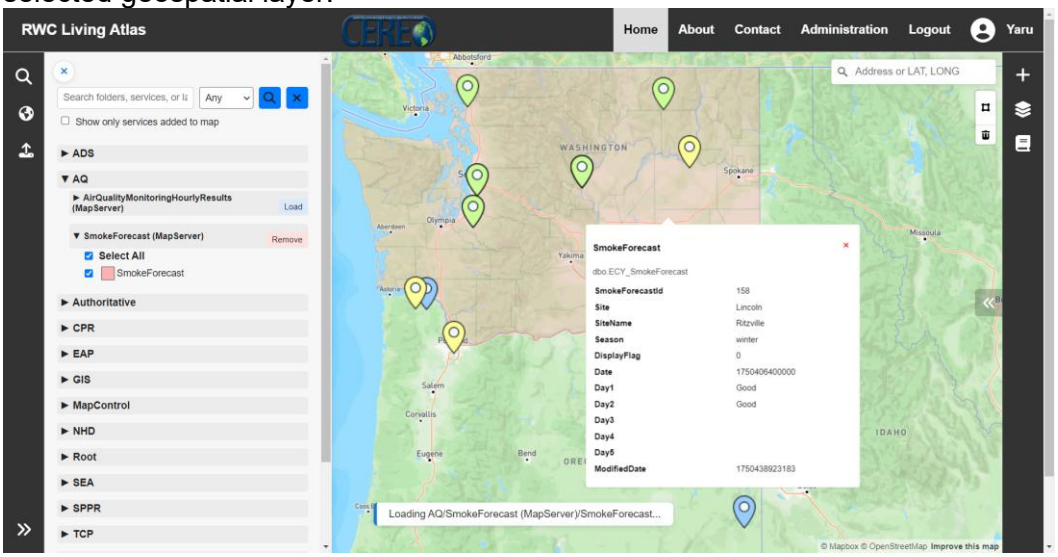
To add a new card, click the plus sign button on the right sidebar. This opens a modal where you can scroll through and fill in all the required information. When finished, click "Submit" to add the card (see Appendix W).

Users can also add or remove a card from their favorites by clicking the bookmark icon in the top-right corner. To view only bookmarked cards, check the “Show Favorites Only” box (see the image above).

To display spatial data from ArcGIS on the map, click the Earth icon on the left sidebar to open the panel. The panel shows data in a folder structure: items like “AQ” are folders, “SmokeForecast (MapServer)” is a service, and each item under a service with a legend is a layer. Users can click “Load” or “Select All” to add or remove all layers under a service or check and uncheck individual boxes to display specific layers on the map.

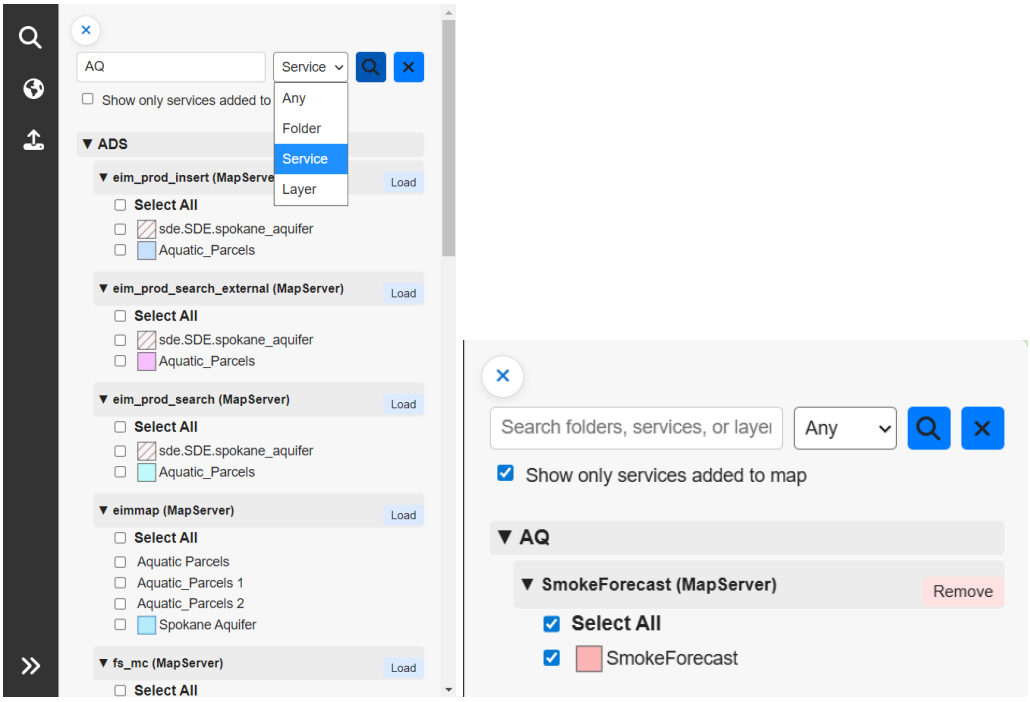



Once the data finishes loading, it appears on the map as colored regions, lines, points, or other shapes. Users can click on these elements to open a pop-up modal displaying details of the selected geospatial layer.




Users can search for a specific folder, service, or layer by entering keywords into the search bar and clicking the search button. The panel will then display all matching results. To narrow the search scope, users may also select an option (folder, service, or layer) from the drop-down

menu. To clear the search, click the “x” icon next to the search bar to reset the panel to its default view.




Additionally, checking the “Show only services added to map” box will display only the services that have already been loaded onto the map.

For testing, since formal unit, integration and system testing has not yet been implemented, all tests were conducted manually using DevTools and backend logs (see Appendix S).

# VIII. Social Responsibility and Broader Impacts

CEREO (Center For Environmental Research, Education, and Outreach) is dedicated to addressing environmental challenges through research and educational support, aiming to develop meaningful solutions for critical environmental issues. The Living Atlas will help CEREO in their mission by providing an easy-to-use interface to view important data sets for our local waterways and other environmental features. Researchers will be able to use the Living Atlas to enhance collaboration with other researchers, as the user-contributed data of other researchers will be easily viewable. Tribal communities will be able to use the Living Atlas to monitor the local ecosystem, identify environmental concerns, and address critical issues. Government agencies will also benefit from the Living Atlas because making these data sets easily accessible to them will give them greater confidence to invest in environmental solutions with CEREO as there is evidence that these funds are being utilized effectively. By fostering collaboration and transparency for environmental data, the Living Atlas will support cooperative and informed decision-making. While developing the Living Atlas, our team always kept in mind that this application must be accessible and useful to our key stakeholders, that being environmental researchers, tribal communities, and government agencies, as we believe that is our responsibility as software engineers. By making the user interface easy-to-use while providing a large amount

of accessible information for our stakeholders, we achieve our goal of putting our work towards improving the world we live in.

# IX. Product Delivery Status

The Living Atlas has already been delivered to our client, and they have been actively using the product. While the initial version of the system has been functional, our team has continued to make numerous frontend improvements, feature additions and stability updates based on feedback. These changes are ongoing but are expected to be wrapped up and fully polished within the next month to month and a half.

The project was demonstrated to the clients during our scheduled check-ins, and handoff will be made directly to the CEREO research team for continued use.

**Project Location Information**

1. **Source Repositories**
    a. Frontend (React, deployed via Netlify) https://github.com/WSUCptSCapstone-S25-F25/-cereo-fullstackapp-
    b. Backend (FastAPI, deployed via Render): https://github.com/WSUCptSCapstone-S25-F25/-cereo-fullstackapp-/tree/main/LivingAtlas1-main/backend

2. **Equipment Storage Location**

    a. No physical equipment was required or left with the client. All project components are hosted online through Netlify, Render, Google Cloud Storage, and Microsoft Azure.

3. **Materials Needed to Rebuild the Project**

    a. Source code for both frontend and backend (available in GitHub repositories).

    b. Google Cloud service account credentials for file and thumbnail uploads.

    c. PostgreSQL database schema (stored in backend documentation and repository).

    d. Deployment instructions for Netlify (frontend) and Render (backend).

**Installation and Setup Instructions**

Detailed instructions for installing and running the project locally, as well as redeploying to

cloud services, are included in the project's README files within the repositories. This documentation covers environment setup, database connection, credentials configuration, and deployment steps so that future users can rebuild the system from the ground up if necessary.

# X. Conclusions and Future Work

## X.1. Limitations and Recommendations

Performance can be noticeably limited at times, for example, loading times for map pins and added data layers may be long, and they will not appear on the map immediately. This may affect the application's goal of being easy-to-use and user-friendly. These performance issues should be a priority to address because as the amount of data in the Living Atlas increases, these loading times may get worse. The best course of action would be to begin comprehensive performance testing to find the potential cause of the issues and make changes accordingly.

Every user should be able to attach a file to a card that they upload. The current practice for Living Atlas users wanting to attach a data set to their card is to include an external link that will lead to the data set. However, if users could attach the file itself to the card, then other users would be able to download the data set directly from the Living Atlas. This would make data easily accessible for all users.

App security and data integrity are limited in the current system. The web server and database lack defenses against common attacks such as SQL injection or denial-of-service (DoS). The reset password feature, which relies on SMTP, could also be vulnerable if not configured securely. Improvements such as stronger encryption, TLS for email delivery, rate limiting, and two-factor authentication (2FA) would help protect user data and build confidence as the application grows.

Currently, the Living Atlas relies on fetching toggleable layers from the ArcGIS REST server. While this provides live updates, the approach has limits. Raster layers are made interactive by overlaying transparent vector layers, which works for sparse data but struggles when features are dense or overlapping. Rendering raster layers as colored regions can also be slow, and users may wait before data appears. To improve this, future work could explore caching frequently used raster data or integrating ArcGIS feature services for more robust handling. Additionally, users should be able to upload their own GIS files so they can share data as toggleable layers, rather than relying only on developer-added pins or ArcGIS services.

The current fetching logic also has challenges. Service URLs are saved locally, which risks becoming outdated if ArcGIS changes or adds new services. A more dynamic update process is needed so the system can periodically re-fetch and refresh the catalog. Beyond REST services, other ArcGIS data types such as feature servers could be incorporated to expand interactivity and make spatial data more versatile.

## X.2. Future Work

Future developers of the Living Atlas could consider expanding the accessibility of this project by making it compatible with more platforms. The website functions on mobile devices but it could be more accessible to mobile users by resizing UI elements on smaller screens or developing a dedicated mobile application. Future teams could also develop dedicated Living Atlas software so that the application can be accessed outside of a browser. Giving users more options in how the Living Atlas can be accessed will expand its user base which leads to more data and collaboration.

Beyond accessibility, future work should consider commercial or institutional adoption. With additional investment, the Living Atlas could be hosted on dedicated infrastructure with higher reliability, stronger security, and custom domain integration. Commercialization opportunities could include subscription-based hosting for research institutions, integration with state or tribal monitoring systems, or partnerships with environmental agencies.

# XI. Acknowledgements

We would like to thank the 2023 development team, including Joshua Long, Mitchell William Kolb, Sierra Amelia Svetlik, Flavio Alvarez Penate, Wyatt Croucher, and Phearak Both Bunna, for laying the groundwork of the Living Atlas project. Their contributions provided the base on which we were able to continue building and improving the system. We also thank the 2024 development team members, Bryce Moser and Silas Peterson, for their work in refining the platform and adding new features.

We are grateful to our sponsors, Dr. Jan Boll and Dr. Julie Padowski from the Center for Environmental Research, Education, and Outreach (CEREO), for their valuable feedback and guidance. Their input helped shape the direction of the project and identify areas for improvement.

Finally, we thank our mentor, Ananth Jillepalli, for keeping the team on track, providing clear instructions, and guiding us through the development process. His direction was key in helping us move the project forward.

# XII. Glossary

**API (Application Programming Interface)** – A set of rules and protocols that allow different software applications to communicate with each other.

**Backend** – The server-side logic of an application responsible for processing requests, handling data storage, and managing business logic.

**Columbia River Basin** – A geographic region covering the watershed of the Columbia River, which is the primary focus of the Living Atlas for water quality data.

**Database** – A structured collection of data stored electronically, which in this case includes geospatial data, user credentials, and metadata.

**FastAPI** – A modern web framework for building APIs with Python, known for its speed and ease of use.

**Frontend** – The part of the application that users interact with directly, typically consisting of a graphical user interface (GUI).

**Geospatial Data** – Information that includes geographic location attributes, often represented using coordinates and spatial features.

**GeoJSON** – A format for encoding geographical data structures using JSON.

**GIS (Geographic Information System)** – A system designed to capture, store, manipulate, analyze, and display spatial or geographic data.

**Leaflet.js** – An open-source JavaScript library used for interactive maps.

**Living Atlas** – A geospatial web application designed for visualizing and sharing environmental data, focusing on water quality in the Columbia River Basin.

**Mapbox** – A mapping platform providing tools for designing and implementing custom maps.

**Metadata** – Data that provides information about other data, such as descriptions, timestamps, and ownership details.

**PostGIS** – A spatial database extender for PostgreSQL that enables advanced geospatial queries.

**PostgreSQL** – An open-source relational database system used for managing structured data.

**Role-Based Access Control (RBAC)** – A security mechanism that restricts access to system functions based on user roles.

**Scalability** – The ability of a system to handle growth in users, data, or computational workload without performance degradation.

**Shapefile** – A common geospatial vector data format used for geographic information system (GIS) applications.

**Spatial Indexing** – A technique used in databases to optimize spatial queries, improving the efficiency of geographic data retrieval.

**User Authentication** – The process of verifying the identity of users before granting access to the system.

**REST** - A style for building web services using standard HTTP methods like GET, POST, PUT, and DELETE.

**ArcGIS** - A software platform by Esri for mapping, analyzing, and sharing geospatial data.

**Raster Data** - A grid-based format for storing spatial data, often used for images like satellite photos or elevation models.

**Metadata** - Descriptive information about data, such as source, format, time, and author.

**Web Server** - A system that delivers web pages or services to clients over the internet using HTTP/HTTPS.

**Endpoints** - Specific URLs in an API where requests can be sent to perform actions or retrieve data.

# XIII. References

Bruegge, Bernd., Dutoit, Allen H.. Object-oriented Software Engineering: Using UML, Patterns, and Java. United Kingdom: Prentice Hall, 2010.

Lethbridge, Timothy Christian., Laganière, Robert. Object-oriented Software Engineering: Practical Software Development Using UML and Java. United Kingdom: McGraw-Hill Education, 2005.

Li, Eldon Y. "Software testing in a system development process: A life cycle perspective." *Journal of Systems Management* 41, no. 8 (1990): 23-31.

# XIV. Appendix A – Team Information

Zachary Garoutte (left), Jonathan Simmons (middle), Yaru Gao (right)

# XV. Appendix B - Example Testing Strategy Reporting

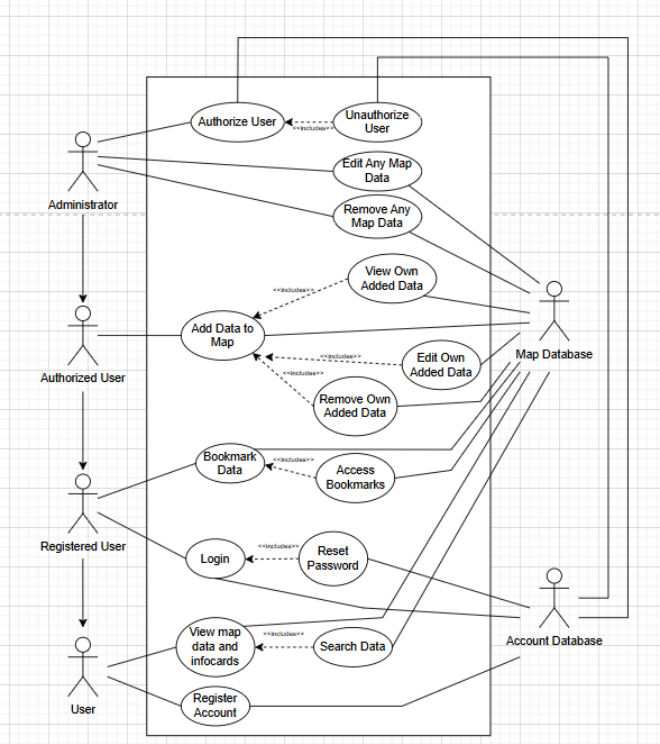
Our team has not yet performed formal unit testing or gathered user feedback other than from the client but only manual testing using browser DevTools. However, we plan to introduce unit testing in a future sprint, which we believe in crucial as our database has swapped hosts and we need to ensure all features still function. For user acceptance testing, feedback will be gathered through direct meetings with the client and testing will be considered complete once the client confirms that all key features function as expected and the user experience meets their needs. For more information about our testing plans, see Section V.

# XVI. Appendix C - Project Management

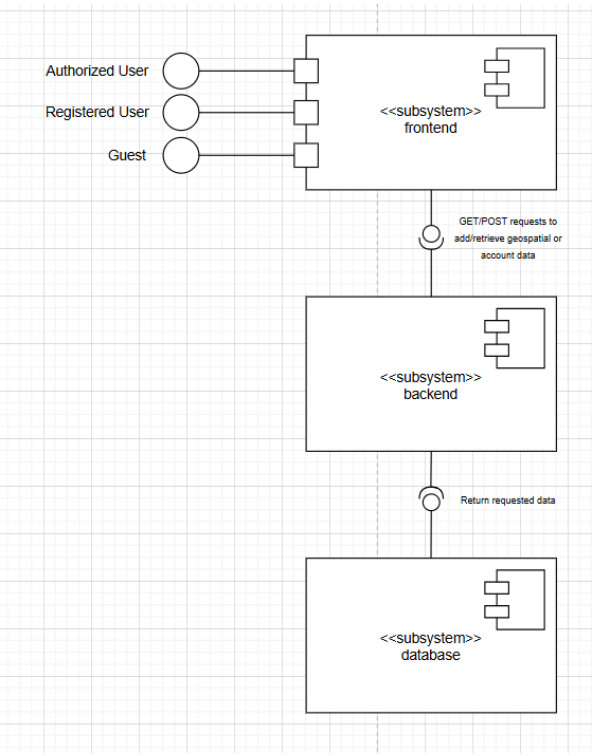
The recurring schedule for our team consisted of both a weekly client meeting with Julie Padowski and Jan Boll from CEREO and a weekly meeting with our mentor Ananth Jillepalli. Both of these meetings are conducted remotely via Zoom. The client meetings mainly consist of demonstrations of recently develop features and bug fixes by our team where we can receive feedback on these changes. These meetings have been beneficial to the development process as consistent feedback helps us better understand client expectations so we can update our process to meet them. The mentor meetings mainly consist of our mentor ensuring that all team members are contributing to the project and that our time spent in development meets expectations. The mentor meetings have also been beneficial to our team as our mentor as they keep us on schedule and can give us reminders for upcoming key deadlines. We do not have a scheduled meeting with only team members but there has been frequent communication via Discord throughout active development. Our team makes use of our GitHub repository's issues and projects board to organize all current features and bug fixes in development and assign each one to a team member. Using these tools have been very useful for our team as they provide a clear guide for what should be worked on next. Screenshots of the issues and projects board we have used are shown in Appendix R. We also made frequent use of email with both the client and our mentor for questions outside of our scheduled meeting times.

# XVII. Other Appendices

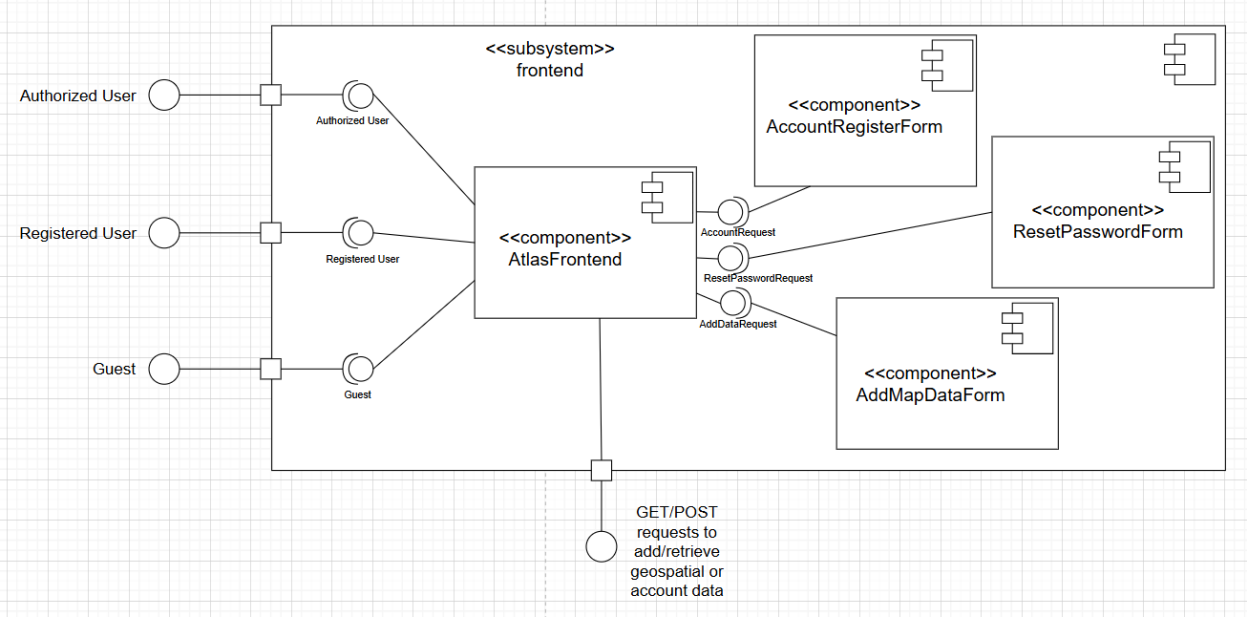
## Appendix D: Use Case Diagram



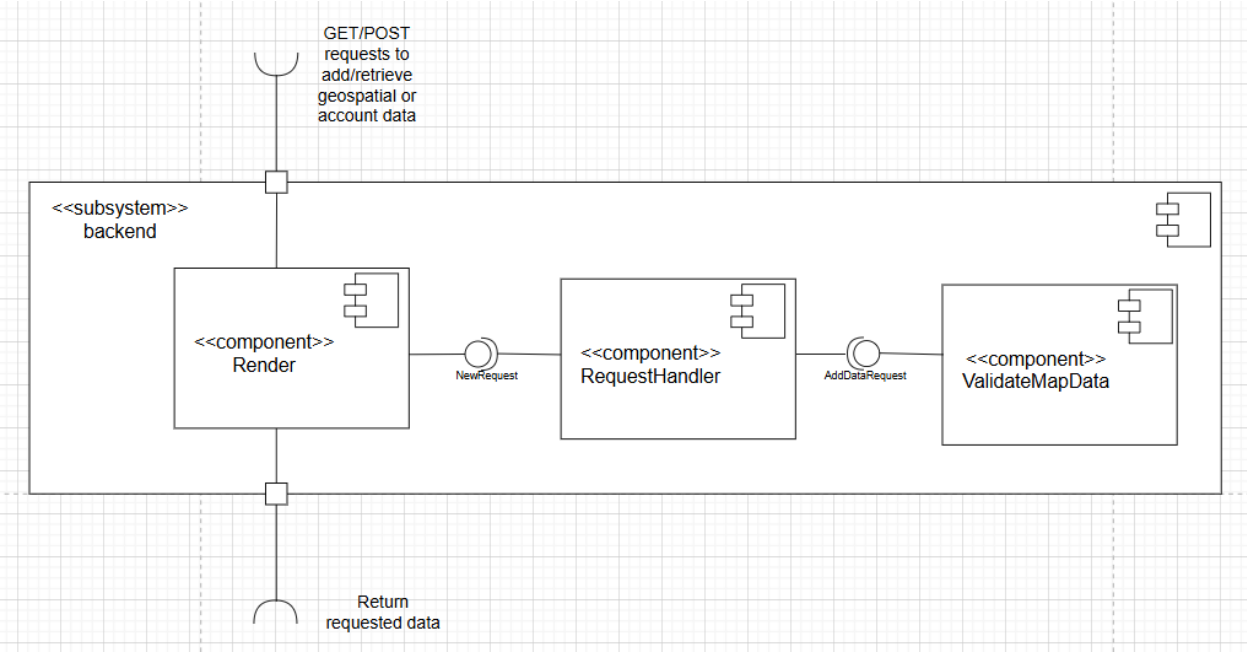

## Appendix E: Architecture Design Overview Diagram



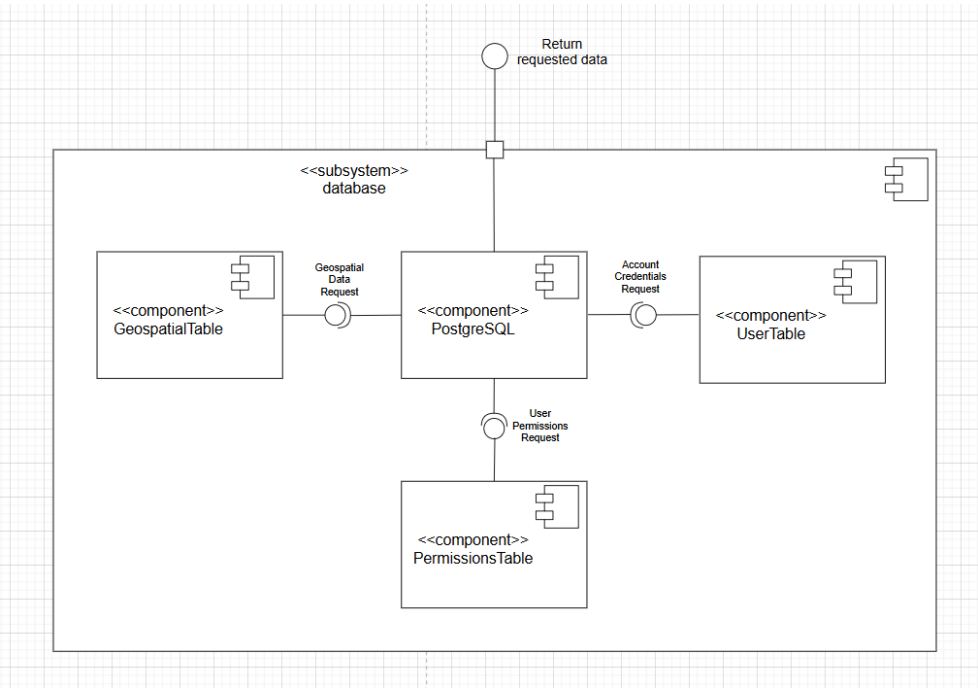
## Appendix F: Frontend Subsystem Diagram



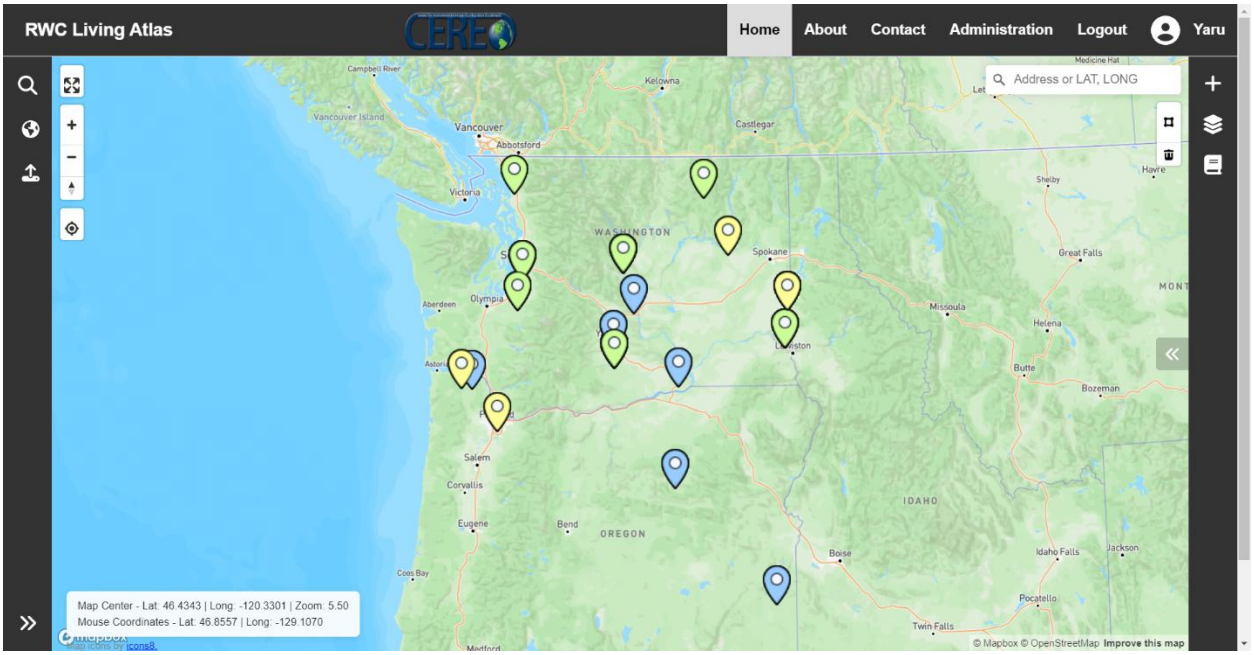

## Appendix G: Backend Subsystem Diagram



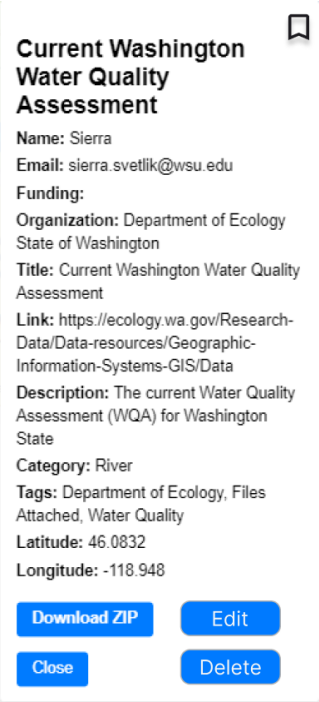
## Appendix H: Database Subsystem Diagram



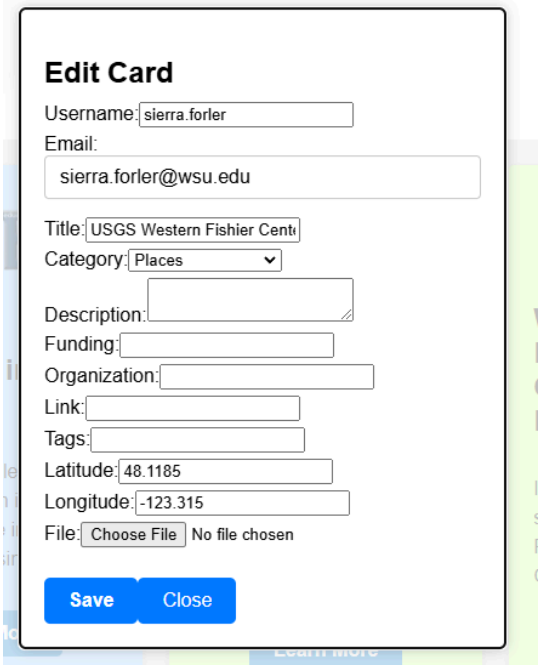

## Appendix I: Mock-up diagram of the homepage, illustrating search, filtering, data addition, viewing, removal, and bookmark access.



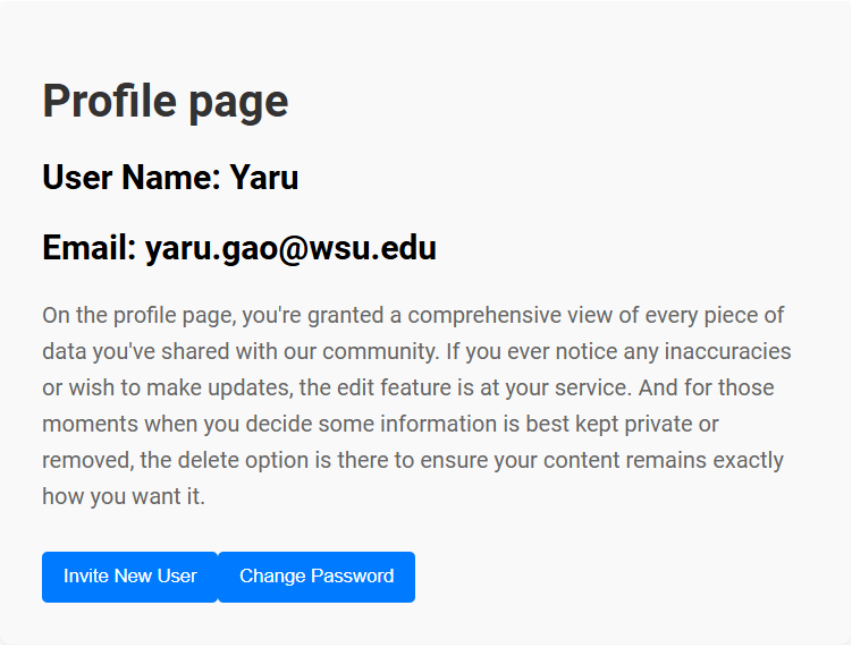
Appendix J: Mockup diagram of the "Learn More" window, showing the edit option for modifying geospatial data.

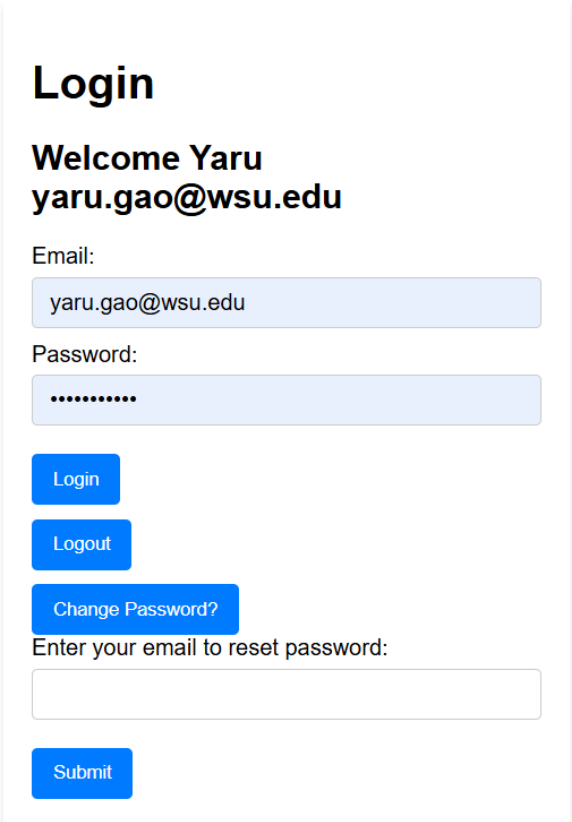



Appendix K: Mockup diagram of the edit functionality within the "Learn More" window.

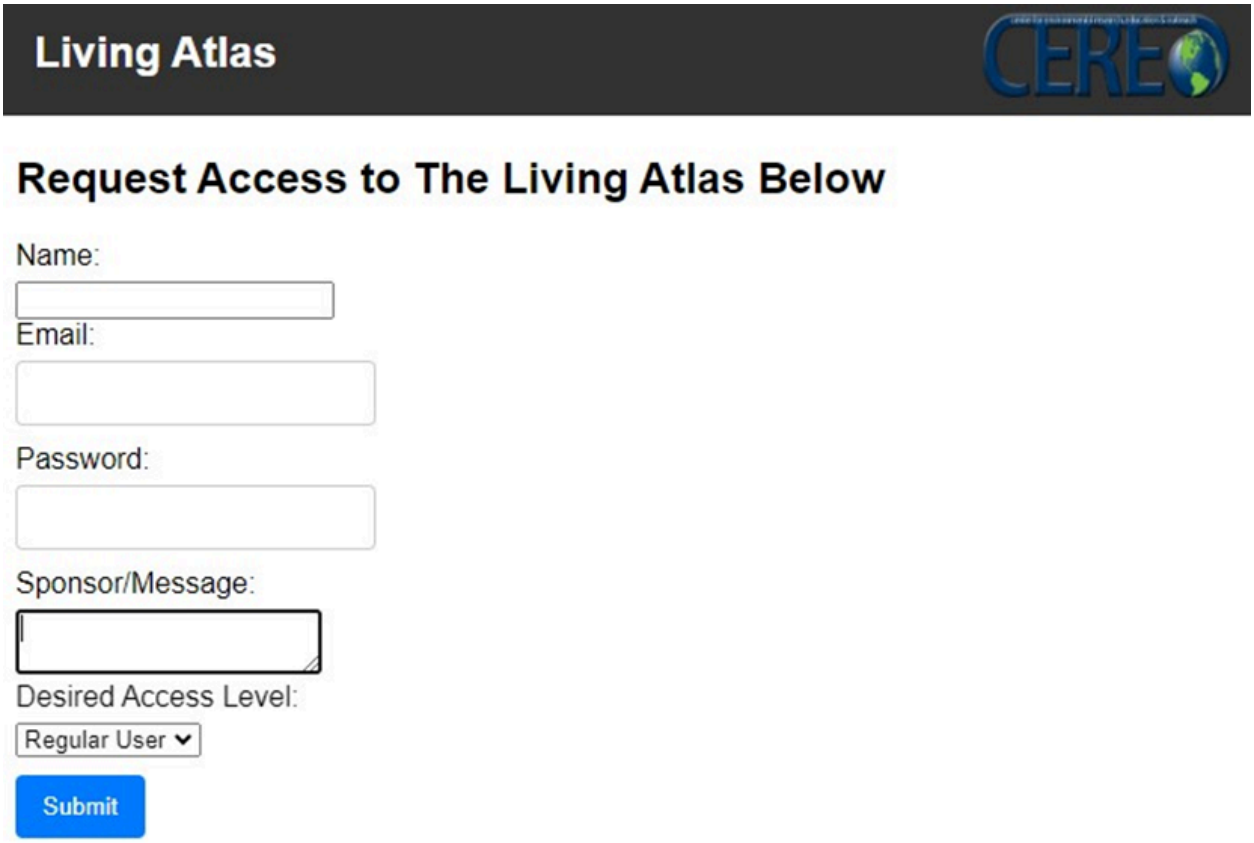


Appendix L.1 and L.2: Mockup diagram of the user center, depicting the password reset process.

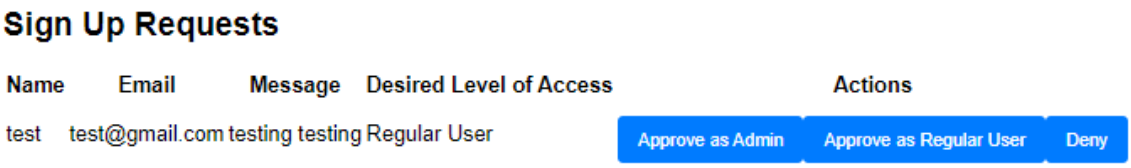


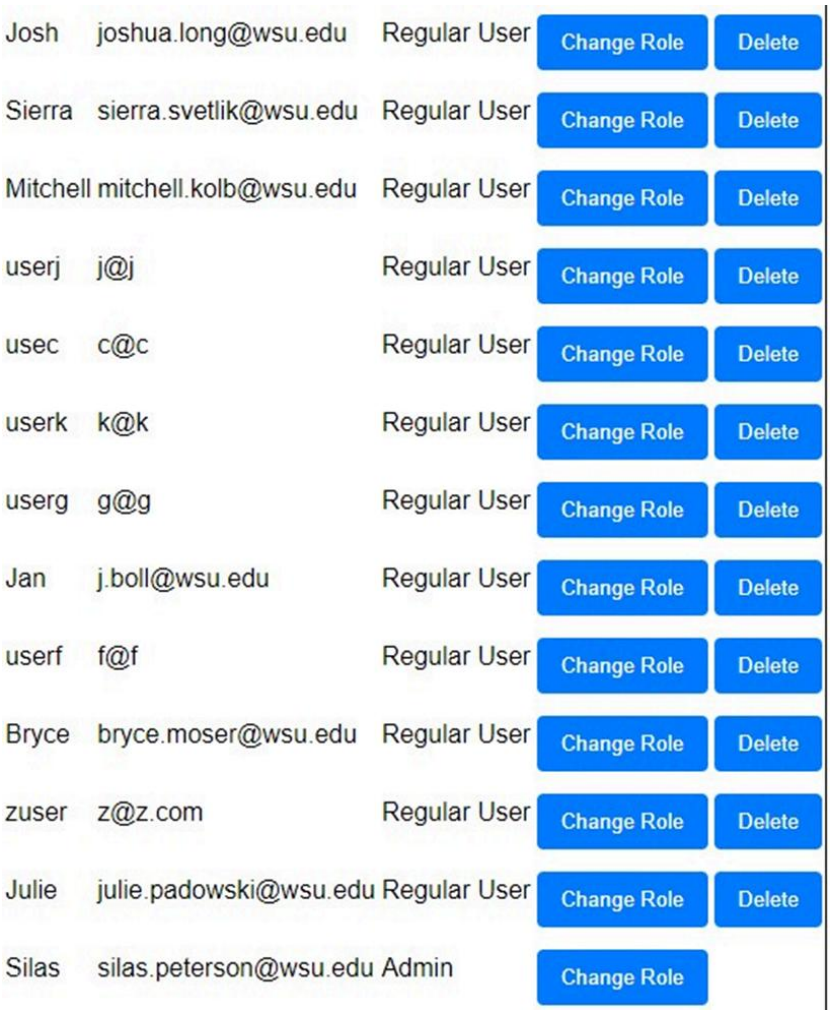
Appendix M: Mockup diagram of the registration page, showing the user account request form.



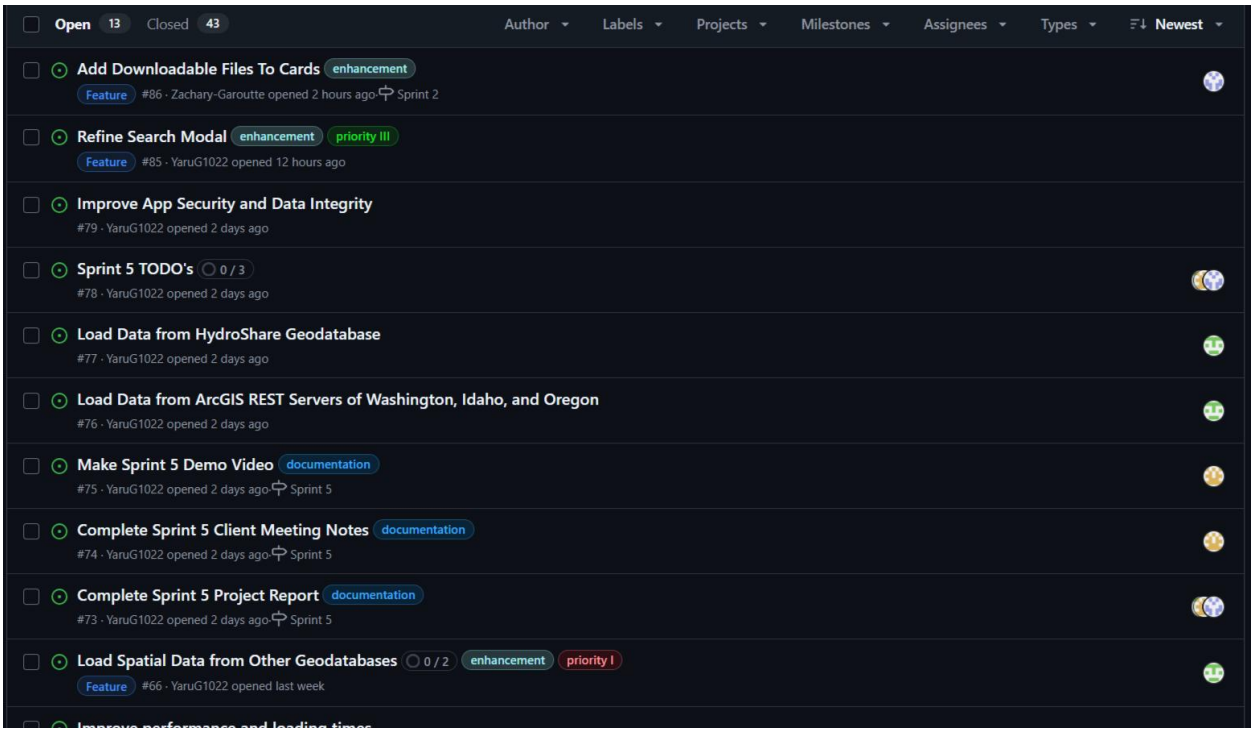

Appendix N: Mockup diagram of the administrator panel, illustrating user request approvals.

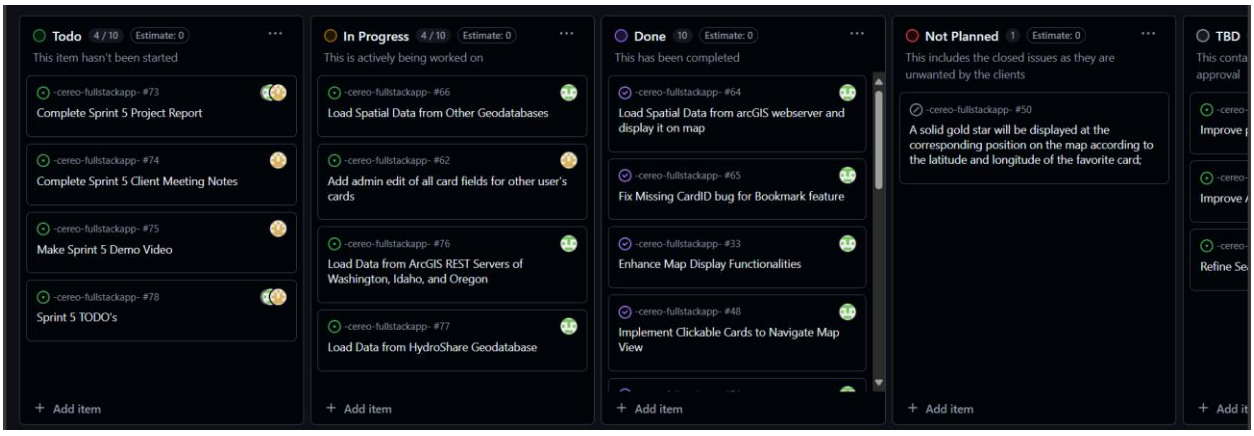


Appendix O: Mockup diagram of the administrator dashboard, showing user management features for modifying access levels and deleting accounts.

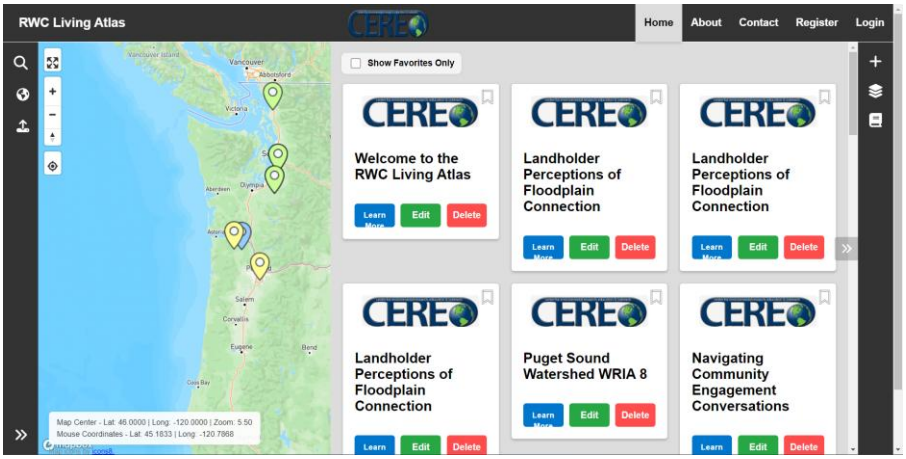


Appendix P.1 and P.2: The GitHub issues board used to organize development on this project, and the project board that the issues are organized into.

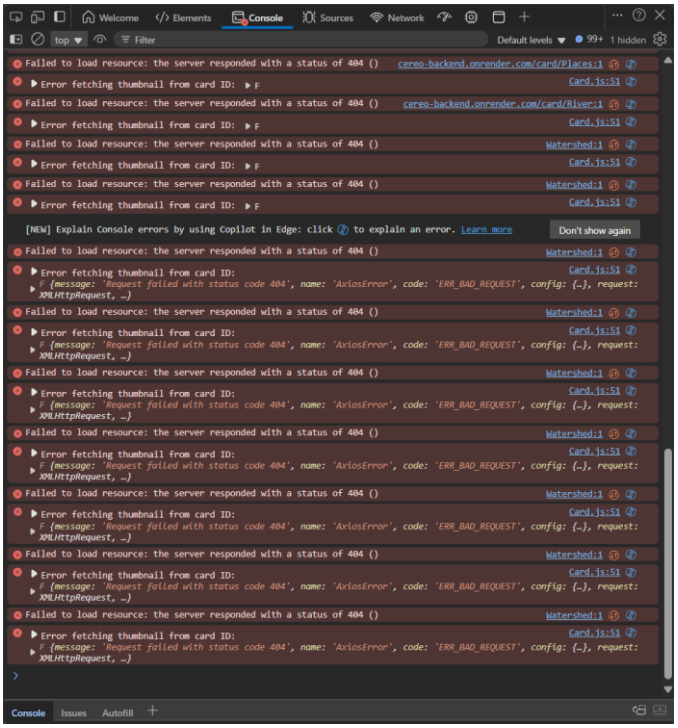


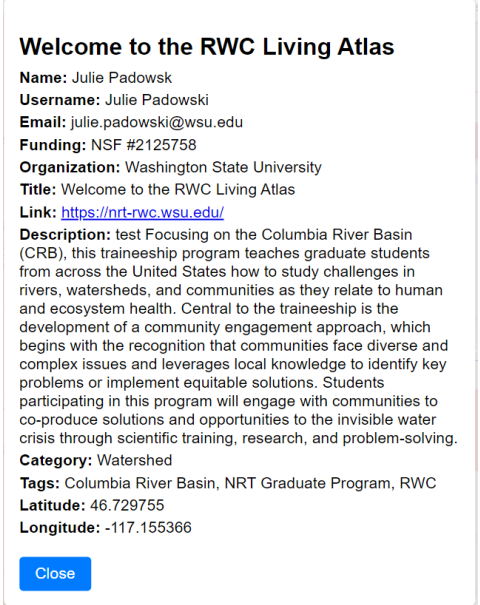
Appendix R: Drag the left edge of card container to expand it.



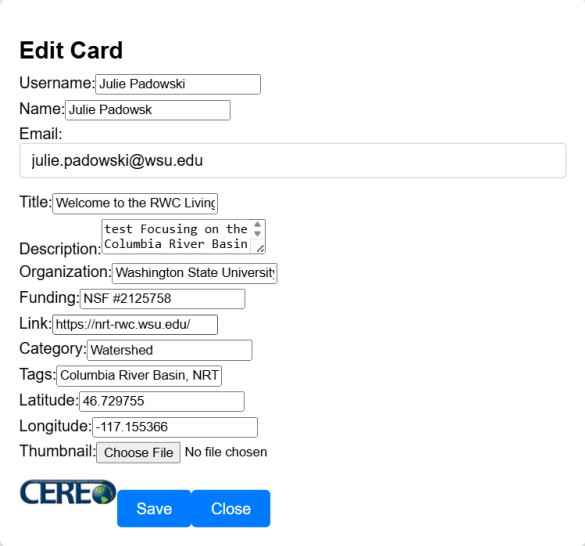

Appendix S: Example usage of DevTools for testing



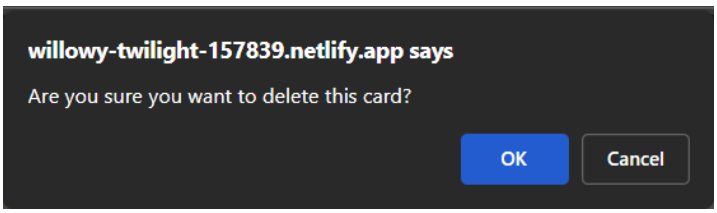
## Appendix T: Learn-More Modal of a Card




## Appendix U: Edit Modal of a Card




## Appendix V: Delete Pop-up of a Card



Appendix W: Add-Card Button (left) and Modal (right)