A Participatory Geographic Information System (PGIS) Utilizing the GeoWeb 2.0: Filling the Gaps of the Marcellus Shale Natural Gas Industry

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ABSTRACT

The application of neocartography, specifically through the Web 2.0, is a new phase of participatory geographic information system (PGIS) research. Neocartography includes the encouragement of non-expert participation through visual design (e.g., map layering), and knowledge discovery via the Web. To better understand the challenges from an increase in natural gas extraction in the Marcellus Shale region of the United States, a GeoWeb 2.0 platform titled FracTracker (FracTracker.org) that relies upon PGIS and neocartography was created and implemented in June 2010. FracTracker focuses on data-to-information translation to stimulate capacity building for a range of user types by leveraging the immense benefits of a spatial component. The main features of FracTracker are the ability to upload and download geospatial data as various file types, visualize data through thematic mapping and charting tools, and learn about and share drilling experiences. In less than 2 years, 2,440 registered users have effectively participated in creating 956 maps or 'snapshots' using 399 available datasets. FracTracker demonstrates that participatory, interoperable GeoWebs can be utilized to help understand and localize related impacts of complex systems, such as the extractive energy industry.

Key words: FracTracker - GIS - PGIS - GeoWeb 2.0 - crowdsourcing - neocartography - Marcellus Shale - energy extraction

1. INTRODUCTION

Web Mapping Technologies

Mapping technologies have changed dramatically over the last 5 to 8 years in the Web 2.0 era. The blending of geographic data and abstract information that dominates the Web has been termed the *geographic World Wide Web* or *GeoWeb*. Web 2.0 is the utilization of the Web browser as a platform, and represents dynamic interaction, participatory information sharing, interoperability, and user-center design. The GeoWeb 2.0 therefore embodies the increasingly interactive nature of Web through a geographic foundation. Location-based learning techniques fascinate individuals because the activities rely upon visual abstractions of the real world, e.g., thematic maps. Conceptual knowledge, spatial navigation and relational connections are theorized to be controlled by the hippocampus and ventromedial prefrontal cortex parts of the human brain. These parts of the brain also seem to play an important role with decision making, which could help explain the growth of geographic information on the Web and its utilization by a variety of user groups [1].

Google Earth, ArcGIS Online, and OpenStreetMap are examples of GeoWeb 2.0 experiences. A host of new web technologies, techniques, applications, and subsequent terminology signified a GIS revolution beginning in 2004, focusing on dynamic content and user experience. The GeoWeb renaissance (from GeoWeb 1.0 – static maps and proprietary protocols) encompasses map mashups, geovisualization, crowdsourcing applications, mapping application programming interfaces (API), geotags, folksonomy, volunteer geographic information, neogeography, and neocartography. Driving these rapid advancements has been the increasing popularity of geography or location-based information by non-experts, and its value and ease of use as a means to index and access information through the Web [2].

Participatory Geographic Information System

Participatory Geographic Information Systems (PGIS) and neocartography have been touted to be essential components of an informationally-enabled democracy [3, 4]. Public participatory GIS (PPGIS) and PGIS were originally leveraged by researchers, nongovernmental groups, community based organization and grassroots organizations to help engage the public in achieving the goals of improving transparency of data and influencing policy change [5]. PGIS encompasses the participatory mechanisms through location-based learning tools [6] and provides a social dimension of community empowerment [7]. Top-down PPGIS and PGIS projects have traditionally been a limited hands-on engagement between researchers and a single group or target community. The researchers provide GIS tools, and ask participants to create and design artifacts based upon their geographic knowledge of the subject. These projects have been successful and have often provided the means of gathering knowledge and information that would have otherwise been impossible to obtain by researchers. However, they typically have a limited scope, and are confined to a small demographic or geographic extent. Emerging trends of PGIS research are incorporating bottom-up interaction with the public, or a more hands on social constructivist approach. In essence, the public is taught how to use the provided GIS tools, then encouraged to produce their own GIS [4].

From a research perspective, PGIS projects are focused on community empowerment through educational and user-friendly geo-spatial applications. The interdisciplinary nature of this research utilizes community-based participatory research (CBPR) methods, public health disciplines, environmental geography and land use, and geographic information science (GISc). CBPR is conducted as a mutual collaboration between trained experts and members of a community with both parties benefitting equitably [8]. Public health disciplines focus on large groups of people over a defined geographic extent, or health threats posed over a population base. GISc is the study of the theory behind the application and use of geographic information systems. Therefore, a successful public health GeoWeb 2.0 must include an ongoing decision-making process involving trained experts that provide evaluation and feedback and must be accessible to the range of user groups.

Neocartography

The terms *neocartography* and *neogeography* encompass the most recent step-wise advancement of user and geographic information interaction. Di-Ann Eisnor, co-founder of Platial, Inc., describes neogeography as:

> …a diverse set of practices that operates outside, or alongside, or in a manner of, the practices of professional geographers. [9]

The term neocartography has been commissioned by the International Cartographic Association (ICA) as an academic and practical aim that demonstrates the adoption of new mapping activities [10]. The growth of experimental map creation by non-experts sharing information and passing on their understanding through knowledge of place has been profound. The terms described above represent the recognition of the democratizing effect of new technologies that has increased active participation in the world of geography [11]. The efficacy of these models remains in contention by professional protocol standards, though the trend towards immediacy and interpretability of data use are undeniable [12].

Neocartography includes the new approaches of non-expert participation through visual design and knowledge discovery through the Web. Therefore, the PGIS project is no longer confined to a single community or group, but is provided through the web via a GeoWeb. For a GeoWeb to be useful, the content should be user-friendly, adaptable, disseminated instantly, and provide a precision model (peer review and crowdsourcing) for data correction [13]. Specifically, geographic information has benefitted not necessarily in terms of functionality, but in usability, accessibility, and ease of application development [14].

Google Maps Application Programming Interface

Spatially-oriented information and data have become very important in public, private and governmental sectors. *Google Maps*, a Web 2.0 platform, has shown to be successful in similar contexts, especially in disseminating data not just from authorized publishers, but also from volunteers or the public [15]. The *Google Maps* public release application programming interface (API) is a free service, provided that the use is non-commercial, and results in less than 25,000 daily page loads. Because Google maps was built with XML (eXtensible Markup Language), customization was inevitable and first applied to personal GPS location data [16]. The release of the Google Maps dedicated geographic interface which runs in standard web browsers, allowed the general public to view detailed satellite imagery, aerial photography, and basic infrastructure layers that were previously only available to experts.

Google Maps API enabled third party applications and customizable, annotated maps, add-ons, and widgets. The API enabled users to mix or mashup Google base data with any other spatially referenced material. The freedom of unlimited combinations of data sources and information through common open-source standards is central to Google Maps and the Web 2.0 progression.

2. BACKGROUND

Natural Gas Extraction - Marcellus Shale

With increasing energy demand and enhanced extraction technologies, gas exploration in shale formations has increased across the United States in recent years [17]. One such formation, the Marcellus Shale, underlies much of Pennsylvania, New York and West Virginia, and portions of Ohio, Maryland, Virginia, and Kentucky. Current estimates of the methane and other gasses trapped within the formation are approximately 141 trillion cubic feet (tcf) [17]. Sixty percent of PA's land mass is underlain by Marcellus Shale, and drilled wells have increased dramatically since March 2006 (See Figure 1).

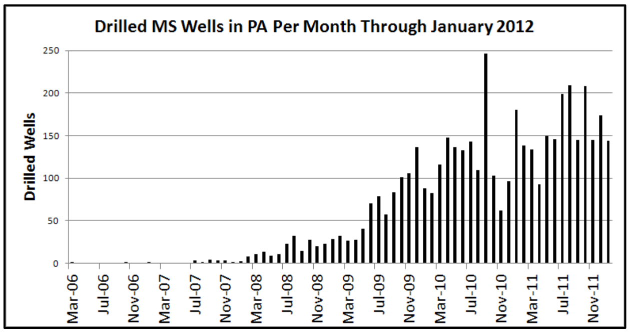

Figure 1. *Drilled Marcellus Shale wells per month in Pennsylvania from March 2006 to December 2011*

There are several factors that have made Pennsylvania a viable area for gas exploration, including: a lack of a severance tax, a variable impact fee (in legislation), economic climate, close proximity to the majority of natural gas consumers, a moratorium that restricts drilling in New York state, and the promotion of domestically manufactured energy as an alternative to foreign sources. Pennsylvania boasts a steadfast heritage of industrial legacy including coal, iron, timber and steel industries. These factors are among the many that have contributed significantly to a proliferative growth of unconventional shale gas drilling in PA in the last five years [18].

Data Inadequacies

In Pennsylvania, the natural gas industry is regulated by the PA Department of Environmental Protection (PADEP) – which among many of its roles, supplies permits for drilling and oversees inspections. PADEP data are 'public' data, though the dissemination procedure has been insufficient with available data being nonexistent in some categories and suffering from a cumbersome downloading process in others. Though vast improvements have been made since the project's inception, access and quality of data and information on operations have been inadequate for public and research needs.

One of the main driving forces for the development of FracTracker was a lack of available data and accessibility related to the practices of the natural gas extraction industry through a process known as hydraulic fracturing in Pennsylvania. For example, preliminary results of a life cycle analysis on the impact of hydraulic fracturing on drinking water resources are finally projected for release in 2012 [19].

The specific data gaps included: explicit location and time of certain gas industry operations, economic and social statistics (e.g. production, infrastructure development, proximity measures, job growth, traffic, and noise), ecological impacts (e.g. frequency of incidents, violations, water use and withdrawals, waste disposal and recycling), emergency preparedness needs and infrastructure requirements. There also exist significant data dissemination impediments that challenge researchers, policy makers, and interested organizations:

- Data originates primarily from authorized sources (top-down approach, proprietary by industry standards);
- There is a wide geographic scope of data and stakeholders;
- Spatial data infrastructure among regulatory bodies is inadequate for the public's use (e.g. electronic reporting of drilling data was not published [20, 21];
- Data and knowledge-sharing was not developed with non-experts in mind; and
- Subject matter is contentious, heightening the potential for misinformation and disinformation [22].

These data gaps, accessibility obstacles, and the industrial expansion trigger concerns about the negative effects that shale gas drilling could have on public health, the environment, economy, and society.

Spatial Context

Activities related to natural gas extraction and the resulting impacts can be analyzed spatially using a GIS. Spatial or geographic data and information are unique in that they reference a point or area on the Earth's surface. The process of drilling a well has many steps throughout its life cycle and spatial context can add much value to the analysis. Geo-referenced, -coded and -tagged data provide the cohesion of data-to-information in a useful GeoWeb application and PGIS project. Fractracker facilitated the development and use of a geovisualization tool and such development was galvanized by the spatial or location-based characteristics of Marcellus Shale drilling activities:

- The drilling operations follow the underlying geologic strata containing the natural gas;
- Networked systems, such as sufficient roadways, must supply resources to the drilling locations;
- Topography is correlated with land use (e.g., drilling is preferred on flat or gently sloping terrain);
- Rural areas (e.g., farms, state parks, open spaces) present fewer obstacles for industry access than urban environments;
- Access to freshwater for permitted surface water withdrawals must be considered; and
- There exist conglomerations of specific companies in certain areas (e.g., headquarters).

With these concerns in mind, FracTracker was launched in June of 2010 by University of Pittsburgh Graduate School of Public Health researchers.

3. FRACTRACKER

To address the data inadequacies and potential impacts specific to natural gas drilling in the Marcellus Shale, a GeoWeb 2.0 platform was created by environmental public health researchers at the University of Pittsburgh Graduate School of Public Health and project partners using a platform designed in collaboration with Rhiza Labs, LLC (Pittsburgh, PA). It was launched in June of 2010 as a PGIS project titled: FracTracker (www.fractracker.org). "Frac" is the colloquial term (also spelled 'frack') for fracturing from the process of natural gas extraction by 'hydraulic fracturing.'

FracTracker is a neocartographic PGIS project based upon the principles of crowdsourced geovisualisation that is applicable for all stages of the problem-solving and knowledge building in geographic analysis [23]. Project goals include data aggregation, problem identification, hypothesis generation, knowledge discovery, analysis, presentation and sharing, and evaluation all through Web collaboration. This system was formulated with the capacity to support a hierarchical user type data-to-information concept through a user-centered design process (e.g., map-making, crowdsourcing discourse for a range of user types).

The main components of FracTracker are: a data repository node, a mapping interface, and a website that acts as a content-amalgamation front page. A PGIS assumes an intermediary, and crowdsourced GeoWeb platforms should include peer review management.[1] To coincide with bottom-up PPGIS practice, numerous physical training workshops, live webinars and video and written tutorials were conducted. The following sections describe the conceptual application of FracTracker, and the usability and functional components based upon a PGIS framework.

Conceptual Application of FracTracker

Drilling leases are obtained by gas drilling companies on an individual basis from mineral rights owners. The interaction between the land owner/mineral rights owner (lessee) and the drilling companies in this process is direct, and lease agreements are negotiable and have varied substantially over time and location. This variability can be partly due to information provided to the lessee from the negotiation process, and the current knowledge as well as the desire to access further knowledge and information from other sources (assuming that increased empirically-based information improves the outcome of a decision). Systems that support sound empirical data analysis can be valuable informational and decision making tools.

Although permits to drill are issued by the state, the burden of education relies upon the mineral rights owner (lessee). The burden is compounded by data and information availability and by transparency of industry and regulatory conventions. Figure 2 represents the conceptual application of FracTracker within the industry and regulatory frameworks. FracTracker aggregates data from authorized sources and provides these data and information through an open access system via the Web. Since public knowledge and data were initially scarce, knowledge of community members that had experienced the drilling process became vital pieces of information to collect. A GeoWeb 2.0 model provides aggregated empirical data from data managers and from engaged users, as well as an active participation portion through the online mapping tool concurrent with community-based public health research and PGIS.

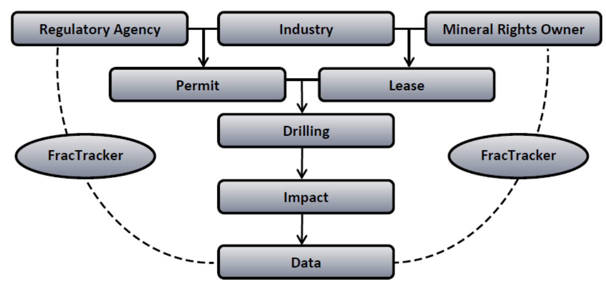

Figure 2. *The process of obtaining drilling permissions in PA, including data feedback loops. FracTracker intervenes primarily during the exchange of data between drilling, regulatory agencies, and mineral rights owners.*

User Groups

Online GIS currently has the largest demographic of users in regards to other types of GIS, including desktop GIS used by experts [24]. FracTracker and other GeoWeb platforms must accommodate a range of users to accomplish effective participation. *High-end users* include GIS specialists who are likely to upload and download and perform analysis within the visualization tool as well as outside of the GeoWeb and will provide results as new datasets. *Regular users* can be civil servants, regulators, cooperating partners, and researchers. This type of user is familiar with online GIS and usually only needs a limited toolset and functions that are repeated regularly. *Casual users* (e.g., residents, business people, and policy makers) use the Web and online GIS irregularly and their computer literacy may be very low. This group might not chose to participate through the data or visualization tools, therefore a web

[1] FracTracker was originally managed by the Center for Healthy Environments and Communities (CHEC) of the University of Pittsburgh Graduate School of Public Health, hosted by the Foundation for Pennsylvania Watersheds, developed by Rhiza Labs, and funded by The Heinz Endowments (THE). As of December 2011, management responsibilities were transferred to a separate FracTracker team with monies from the Community Foundation for the Alleghenies and THE.

page/blog was created to act as the content front page highlighting the outputs from other users. Here data-to-information is interpreted as efficiently as possible by the peer reviewers. Simplified access to the data tool through mobile or portable devices is currently under development.

Full access to the data and visualization tools on FracTracker is limited to registered users, but only a valid email address is necessary to become registered. FracTracker provides a hierarchy of user participation opportunities. The database repository and the visualization tool collectively combined as the 'data tool,' were tailored towards regular and high-end users.

Unfortunately, the system in its current form limits use to individual with computers and Internet access; therefore, special attention must be paid to types of users specific to the target demographic, as PGIS projects have traditionally provided all necessary resources. With bottom-up PGIS, much more emphasis is placed on knowledge discovery and education, and less emphasis on artifact outputs.

Database Repository

Availability of data in the Marcellus Shale region, let alone a data storage repository node, were certainly needs expressed by scientific researchers, media providers, the public, governmental representatives, and environmental regulatory agencies. Currently 399 (at time of publication) datasets have been uploaded by registered users to FracTracker's data repository or 'data tool.' The data uploading procedure is aided by a step-by-step importing wizard. The process includes a data import user interface that is based upon Federal Geographic Data Committee (FGDC) metadata standards. The process is facilitated by numerous tips and hints provided to the user at each step. During this process, the user can add additional information and tags to help others find and use the dataset. Before publishing a dataset, the user is able to preview how others will see the dataset and if necessary edit the submission. The repository was not envisioned as the optimum data source (by Web 2.0 standards) given that spatially-explicit data is a key criterion. However, geographic layers within the data repository are a necessary component of the mapping tool.

Data and metadata can be imported into FracTracker in six (6) supported formats from a computer or by linking to publically available datasets on the Internet:

- Shapefile (.shp) + dBase (.dbf)
- Comma-separated values (CSV)
- KML – (formerly Keyhole Markup Language) OpenGIS KML Encoding Standard (OGC KML)
- GPX or GPS eXchange Format
- GeoTIFF – Georefferenced raster image file
- XML FGDC (Extensible Markup Language Federal Geographic Data Committee) Metadata

Registered user controls of published data include: extent of optional metadata beyond FGDC standards, attribute labels as search terms, column data types and description, ability to restrict dataset's visibility to 'anyone' or invitation-only groups, and the option to remove self-uploaded datasets. A registered user may download any of the openly visible datasets as: Shapefile, KML, or CSV formats. Once a dataset becomes part of the system, the user may save a dataset to a user group, personal collection, view/add comments, download, or visualize the data via Google Maps service application.

Mapping Capacity

FracTracker is capable of geovisualization mashup that allows high-end users to produce 'snapshots' from uploaded or linked data. (A charting capacity has recently been added to the system by Rhiza, but due to its novelty, use has not yet been analyzed.) Powering the mapping tool is the Google Maps interactive map interface (API) mentioned previously. Datasets within the database repository can be added to the interface and visualized instantly through a definable query and customized with a palette of editing tools. Querying begins by selecting the desired data column from a dataset. Depending on data type, all unique values, a range of defined values, or a graduated or linear spectrum can be selected. Based on the selection, user-defined colors and symbols are customizable with the 'Style Picker.' There are no limits to the number of imported datasets and data values that can be visualized on a single map. For instance, a geographic area may be represented by poverty rates from the US Census Bureau overlain by the National Hydrography Dataset flowlines, PADEP Marcellus drilling permits, Marcellus drilled wells, and environmentally-related violations administered to the industry by the PADEP. Geographically defined visualizations may then be published as snapshots, which can be shared with other FracTracker users within the system or externally via RSS and other sharing networks (described below). To date, 956 snapshots have been published in the FracTracker system.

Website

An electronic social network in the form of a web log (blog) and standalone pages is tethered to the data and mapping tools, serving as the content front page for FracTracker. Website managers act as peer reviewers and content moderators. They collect and decipher crowdsourced knowledge specifically for the casual user and provide active feedback for regular and high-end users. The website also encourages participation by registered users by regularly highlighting insightful user-generated snapshots.

Because most drilling occurs through private leases of land owners dispersed over large geographic areas, communities that are directly affected are fragmented. As a result, there is a communication disparity between those affected by incidents and those who could most benefit from that information. FracTracker's website delivers information and experiences to website visitors from other users, sources, and active participation tools. It also provides a forum to share this information that relies less on geographic location and more on alternative means of visualization, written summaries and analyses, and current scientific understanding and case studies.

User-centered Design

User-centered design is a definable characteristic of Web 2.0 applications. Map snapshots are the outputs or artifacts created by users using the visualization and data tools. Once these maps are published and shared, they remain tethered to FracTracker by live data connections, meaning that a snapshot will be automatically updated coinciding with a dataset update. The snapshot may be manipulated by other users into a new snapshot using a feature that allows them to base a new visualization on the original map. Users can then re-publish their own visual version of the data along with additional datasets, new visualization styles, or critiques of descriptions. A 'share' button provides the direct coding to the snapshot.

A snapshot may be shared through:

- Link – copying and pasting the snapshot's hyperlink into other applications or websites
- Embed – placing a live, clickable version of the visualization into a webpage
- Thumbnail – adding a static image of the snapshot with the optional legend
- KML – exporting the snapshot to other mapping applications, e.g., Google Earth, NASA WorldWind, ESRI ArcGIS Explorer, Adobe Photoshop, and Yahoo! Pipes [25]

User-centered design is a multi-stage problem solving process that requires participants to analyze and foresee potential outcomes, while actively testing the validity and feasibility of their assumptions based upon interactions with other participants. The snapshot therefore, is a user-created custom representation that ultimately strives to contribute to the geovisualization decision-making paradigm, while providing researchers with volunteered geographic information and knowledge (case studies). User-centered design addresses problem identification, hypothesis generation for researchers and knowledge discovery and evaluation for users. Designing and producing outputs provides an interactive way for non-expert users to get involved through various levels of participation.

4. DISCUSSION

Participation within FracTracker continues to grow steadily with 1,300 registrants in the first five months and more than 2,400 registered users (as of February 7, 2012). Active participation by repeat-users has been difficult to gauge. This can be partly attributed to the complexity of the multi-component system as a whole – data repository, website, and mapping tool. An acknowledged obstacle remains computer and Internet access, as well as minimal GIS knowledge on the part of the user. Researchers continually work with potential and registered users to determine and encourage active participation and identify user interface issues. A more formal assessment is being conducted using an IRB-approved research survey with registered users that will improve the understanding around whether and how FracTracker is being used for decision-making purposes. The results of this study will be published in late 2012.

PGIS should promote a model that drives data improvement from the users by applying pressure on the publishers of the data (crowdsourcing), though this type of model remains contentious. There have been instances where FracTracker users have commented on locations of wells, regarding a location as: spatially inaccurate, not properly represented, or non-existent. There could be various explanations for these issues (e.g. non-natural gas well, improper data collection or management, inaccurately converted spatial precision) which data providers are encouraged to provide.

As with similar crowdsourcing projects, the influx of ideas and the use of FracTracker surged initially and as the process matured, the amount of participation has lessened. We predict FracTracker collaboration has either reached a matured stage of crowdsourced outputs, or users are simply obtaining necessary knowledge and repeat use is not needed. The cause of the former progression is party due from overestimation of the potential of individual ideas and underestimation of feasibility by new users. This leads to a sense of inflated probability of success and the initial surge of contributions. Once the curtailing of expectations occurs through the collective criticisms of participants and peer review, the crowdsourcing model matures leading to decreased quantity and increased quality of outputs [26].

The pattern of reporting of data errors by users will likely be buffered by improvements made in the electronic collection and reporting of data from authorized sources such as the PADEP. On the other hand, the system may simply be too cumbersome for most users to fully interact with, and knowledge discovery for users and data aggregation for researchers may remain our most hopeful outcomes.

User Participation Challenges

To address the lack of intense administrative facilitation as with traditional PPGIS and PGIS projects, FracTracker was created with a hierarchy of user participation intensities, from high-end user map designing to casual user blogging. To coincide with bottom-up PGIS framework, 14 physical training workshops (in various locations throughout Pennsylvania and New York), 8 live recorded webinars, and numerous video and written tutorials were conducted. These have shown to improve user proficiency from preliminary feedback and evaluation.

There are numerous GeoWeb applications on the web, and many places for individuals to obtain information about this topic. GeoWebs are beneficial participatory tools in theory, though attracting and maintaining active participation does not always occur. An active peer review management and moderator components are necessary to guide user inputs and outputs and training. These aspects of user engagement remain difficult to evaluate, though the numbers of users, datasets, and published snapshots have been growing steadily. Nevertheless, the discourse surrounding the geovisualization decision-making paradigm within FracTracker is substantial and should continue to be researched.

As researchers sought to roll out the FracTracker mapping system as quickly as possible, the decision was made to employ Rhiza Labs' extant and proprietary *Insight* platform, rather than developing a new application internally. While this approach allowed researchers to improve data accessibility to the target audience much more rapidly than would otherwise have been possible, there were some burdensome consequences for FracTracker, in that any adjustments to the system were made by developers at Rhiza, on a timeline and at a price of their choosing. Therefore, the FracTracker team had little influence on the end user experience in practice, which is admittedly cumbersome.

While FracTracker has largely succeeded in improving access to geospatial data, users interested in exploring impacts of oil and gas extraction must first learn some basics of GIS visualization techniques in general, as well as specific commands and procedures of the *Rhiza Insight* (now *Upshot*) platform. The protocol has called for live training workshops whenever requested by community stakeholders. Because the platform is accessed almost entirely through the web browser, however, some users may engage with the system, not having had any training. This is an admitted benefit and limitation of a GeoWeb for PGIS research. On the one hand, access is free and open to anyone with Web access; however, unbridled use has lead to seemingly unproductive user outputs. While in line with FracTracker's mission, this inevitable misuse points to how the cumbersome end user experience can be an impediment to data accessibility in and of itself, and further exemplifies the need for an active moderating body.

Future Considerations

Regardless of the platform's limitations, the project partners and software developer continue to assess the needs of the system and its users. A GeoWeb platform relies upon expediency and participation from both the technological and live communication standpoints. Assuming adequate funding continues, these lines of communication will support the adaptability of FracTracker to reflect the variability of the issues, status of regulations, industry transparency, data characteristics, geographic context, and user profiles. Future considerations for the application of this tool include the following:

- Continued introduction and implementation of FracTracker within communities of interest in the Marcellus Shale region (regulatory agencies, environmental monitors and organizations, citizens monitors, industry stakeholders, emergency responders, and policy-makers),
- Introduction of the system to users within other gas-producing regions when requested,
- Data convergence from the communities of interest,
- Improved user interface design – including a more user friendly data import wizard,
- Support of Microsoft Excel formats for data import,
- Increased server space as database needs to grow with increased user participation and data storage,
- Indexing of datasets and snapshots for improved navigation and use,
- Continual development of the charting and graphing tools currently in beta,
- Improved scope and usability directives for non-educated users, and
- Continual evaluation of current and future needs.

5. CONCLUSION

The movement towards neocartography in addressing challenges stems from locative media growth, affordability and ubiquity of global positioning systems (GPS) and advancements of Web 2.0 technologies. The application of neocartography, specifically through the Web 2.0 is a new application phase of PGIS research. Empowerment through a creative design mechanism (e.g., making maps) can occur because the process is engaging and personalized. FracTracker is an attempt at a PGIS project using neocartography principals entirely through the Web.

In less than 2 years, 2,440 registered users have effectively participated in creating 956 snapshots using 399 available datasets within FracTracker. Initial outputs from the project revealed the potential costs and benefits of natural gas drilling in Pennsylvania. New data streams have been discovered through FracTracker's collaborative environment, while also providing insight into case studies from impacted individuals. Land use change, economic and political spectrums, and human and environmental public health impacts have been topics of informed discussion and design by FracTracker's participants.

The spatial nature of drilling activities endorses a GIS. The theory of a hierarchical participatory GeoWeb focuses on data-to-information translation for capacity building for a range of user types by leveraging the immense benefits of a spatial component. An appropriate GeoWeb participatory system must dynamically reflect the topics of concern while attempting to identify public and stakeholder interests [27]. FracTracker exists to improve data and information discovery and sharing among its users through an empowerment design process entirely on the Web. The system has demonstrated that participatory, interoperable GeoWebs can be utilized to help understand and localize related impacts of complex systems – such as the extractive energy industry, though active peer review and moderating components are essential for data and knowledge progression.

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