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Facilitating Effective Utilization of Water Science Research Among Emergency Flood Responders

Research Article

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Abstract

Emergency management practitioners, at all hierarchical levels, consider a communication gap to exist between the critical applied knowledge and understanding among emergency first responders (i.e., in the "social cloud" domain) of the scientific data and derived information available from water science research (i.e., in the "science cloud" domain). We posit that this communication gap and information transparency (i.e., synthesis) does not represent an engineering or hydrologic science problem but rather a translation and interpretation problem. The keys to understanding and resolving this chasm are efficiently and effectively sorting, organizing and synthesizing scientific information into useable, "personalized" packets for first responders and those in the hierarchical emergency management organizations and structures behind them. This approach is necessary to leverage the strengths of first responders and their essential job of saving lives and property in dangerous flooding scenarios. First responders need the results of scientific information, analysis and interpretation to shape their actions and optimize their job performance, based on best practices, in the face of serious high risk floods and ancillary dangers. Situational awareness is a key requirement for the safe deployment and monitoring of first responders. Thus the preferred delivery packet mechanism of the results of scientific information, analysis and interpretation information is through visualizations like 2D Maps, 3D visualization tools, GEO-PDF's as lite Geographic Information Systems (GIS) and so on where "a picture is worth a thousand words" because of how humans, under stress, can quickly process and understand visual information.

Keywords: Translate, Emergency Response, Communication Gap, Flood

1.0 Introduction

According to NOAA statistics, in 2015, water related events alone affected 7 million citizens in 15 states, across the-United States, for an estimated cost exceeding $4.8 billion with 176 lives lost due to flooding alone (NOAA, 2015). Many human lives at risk were saved, but too many were unnecessarily lost, in addition to property, and integrity of the environment. Persistent lack of knowledge and respect, by the public, for the physical dangers associated with the physical forces of swift water flooding likely contribute each year to this loss of life. However, even first responders are not immune to these risks. Police officers have been swept away in their vehicles and drowned, after driving into swift water currents that overtop roadways.

After-Action Reviews (AARs) from past incidents consistently mention "lack of effective communication" as a primary and frustrating issue in responding to incidents (Donahue, 2006). Addressing the communication gap and information transparency (i.e., synthesis) weakness will leverage the increased availability of scientific geographic "big data" from the advancement of processing power, internet-of-things, sensor proliferation and new and emerging models like the National Water Model. The potential to significantly reduce the loss of life, due to flooding, from such information paradoxically rests with simplifying complex science domain data and information (i.e., information transparency or synthesis) so that it can be translated into "socially" applicable domain knowledge and understanding by emergency flood responders. It is not enough to simply "translate" the scientific language into the working language of first responders - it must also be conditioned and algorithmically transitioned through IF-THEN logic and permutation and combination filters into anticipatory computing algorithms where the conceptual decision support system (DSS) is greater than the sum of the inputs and parts that go into a "qualitative water science synthesis" (Riese, 2014).

Figure 1. Anticipatory Computing Translators - (Rosetta Stone Metaphor)

In flood events, any opportunity to leverage the operational capabilities of the interface between the "science domain" and the "social domain" is an opportunity to strengthen and enhance the efficiency and effectiveness of emergency organizations and first responder opportunities to reduce the loss of life.

2.0 Previous Studies

Decisions during active flood disasters have had little support from flood model information (Leskins et al., 2014). Many issues, including communication gaps and the lack of transparency (i.e., synthesis) between the invariant vocabulary of the hydrologic science community and the visual language preferences of flood emergency first responder communities, may partially account for the underutilization of high-value geospatial and temporal data and information from the "science cloud". In other words, not only do the "science cloud" and the "social cloud" not speak the same language when currently communicating about flood emergencies, they do not use the same alphabet or symbols.

Our approach involves focusing on the primary temporal phases of emergency response: (1) the pre-event emergency exercise environment and preparedness phase (2) the live event operational emergency environment phase and (3) the post-event analysis and recovery process management phase.

In comprehensive emergency management, the preparedness phase involves exposing and stress-testing emergency managers and responders to complex, unfolding, high-risk and hazardous situations in order to improve their collaboration and individual responses, as well as help clarify roles and responsibilities.

There is a growing trend toward adopting serious game software approaches to significantly enhance the "reality" factor in training simulations (Alhadeff, 2010; Zielke, 2009). A role-playing training software environment referred to as "RimSim" has been developed for hazards faced by Pacific Rim countries, notably earthquakes (Campbell, 2008). Campbell has also written extensively about “Emergency Response and Training" and has gained acceptance for his scholarship by the Department of Homeland Security and USGS (Barrett, 2003). Further justifications and rationale for “Adapting Simulation Environments for Emergency Response Planning” can be found in Campbell's' dissertation (Campbell, 2010).

Other sub-system components for inclusion in a communication gap and information transparency solution knowledge warehouse approach (Yacci, 1999) would include GIS-based network analysis using for example Capacity Aware Shortest Path Evacuation Routing (CASPER) algorithms. CASPER integrates mapping, demographics and efficient evacuation routings to expedite areal movement of large populations quickly to safe zones (Shahabi and Wilson, 2014).

Also pervasive web-based spatial decision support systems (SDSS) could be implemented through the central knowledge warehouse as a mechanism for delivery of critical packets of information to first responders and the public on a need-to-know basis to further reduce the communication gap and information transparency issues (Kochilakis et al., 2016; Jones et al., 2014).

The availability of powerful systems like TETHYS, developed at Brigham Young University that can be called for specific tasks “facilitates the development of cloud-based modeling tools for water resource modeling applications” (Jones et al., 2014).

The architecture and conceptual structure of our software-as-a-service platform approach is supported in the literature as “...game architecture centered on a modeling and simulation infrastructure” (Garro et al.,2013).

The best of computerized implementations, however, cannot ignore human cognitive predispositions and perceptions. The brain science and cognitive psychological literature provided appropriate analytics for human cognitive capabilities (Greitzer et al., 2011).

Funding also validates our approach. Research efforts to bridge the communication gap and information transparency issue and received support and sponsorship, for example, from the Department of Homeland Security [Kielman, 2007]. Adjudication and evaluation of an emergency management organization’s disaster preparedness is another role a computerized knowledge warehouse training infrastructure could rate, monitor and maintain. Curating appropriate knowledge in the repository is another critical function as discussed from an IT management perspective (Meesters, 2014).

We explore the future of visualization and analytics with our suggestion of a three-way factor analysis, using our “Avatar”, a Sanskrit word meaning "the embodiment of a concept" (Merriam-Webster), and its 3D printed object or software models to visualize situational awareness spatially, temporally and in terms of one or more variables (Franklin, 2015).

The literature also supports such a discussion and development through “3D Crisis Mapping for Disaster Simulation training” from an information systems perspective (Meier, 2008; Silvera and Murray, 2009). Finally, a report on simulation by the Department of Homeland Security and a case study from New Zealand, with live call data, provided guidance from previous studies (U.S. Department of Homeland Security, 2007) as to the interim training applicability (and with further development and testing), live command, and control roles (Vaidyanathan, 2010).

3.0 Objective and Scope

The objective and scope of this study is to propose a conceptual model that has the initial capability to integrate (1) training with the ultimate capability to incorporate (2) live event command & control coordination and (3) post-event analysis and recovery process management.

The operationalized intelligent and integrated expert decision support system communicates with just the right person, at just the right time, with only the parsed information that individual requires. Such a repository of best practices and lessons learned could be thought of as a three-dimensional spacetime geodata repository. This three-dimensional platform would scale (1) horizontally to all hazards; (2) vertically to address the critical life saving hierarchical information needs of a myriad of flood water emergency responders, emergency management organizations and populations at risk around (3) a third axis of time (pre-event, event and post-event). Conceptually, all of the processes necessary for these three temporal zones would operate within a comprehensive software shell or environment. That environment would be referred to as a knowledge maker warehouse (Yacci, 1999). It would house the methodologies, heuristics, IF_THEN logic engines and qualitative and quantitative metadata and communication networking capabilities to interconnect, translate and synthesize information from the “science domain” (i.e., hydrologic science) and collect, sort, and store standard operating procedures (SOPs), modifications, as well as best practices for individual jurisdictions through a dynamic, robust, and powerful maintenance module appropriate “social domain” (i.e. flood emergency responders, emergency management organizations and those affected by or exposed to the risks of flooding) and deliver personalized instructions and knowledge to specific emergency responders entitled to share such information. This would serve to streamline and parse the information delivery process as well as provide security of information on a need-to-know-basis only.

4.0 Methods

The core of our approach evolves around an ontological knowledge warehouse (Yacci, 1999) of re-useable scenarios, standard operating procedures (SOPs), and best practices ultimately to be delivered in a serious game-like software environment. The feasibility of implementing such an approach in a robust serious game software platform has previously been validated in the literature (Barrett, 2003; Campbell, 2008).

We approach the critical information needs of emergency flood first responders and any documented communication gaps between the water research "science cloud" and the first responder "social cloud" from two general perspectives: (1) the translation of scientific information into language understood by emergency management organizations and (2) the parsing or filtering of the language understood by emergency management organizations into basic need-to-know "packets" of information without extraneous or unnecessary information attached for a particular emergency management role. An analogy might be drawn with the social media "tweet" packet, but customized for emergency management roles.

First responders could then use hydrologic models such as the National Water Model (NWM) more widely and their emergency management organizations could predict unprecedented flood timings, heights, flow rates, and other parameters. It appears from our investigation that the only way the usefulness of water science can be optimized, in flood events, is to assist first responders and the public, by communicating this information in a simplified, parsed and timely manner.

With validated capabilities, vetted by our primary research (i.e., interviews) and secondary research (i.e., literature review), we categorized each capability along 3D spatial thinking dimensions as (1) Temporality (2) Hazard and (3) Hierarchy. Thus by redefining the communication gap to be one of a translation problem between the "science cloud" domain and that of the "social cloud" domain, we have been able to use a Rosetta Stone metaphor at high spatial and temporal resolutions to discover potentially innovative and novel solutions.

We utilized the Rosetta Stone metaphor to guide our thinking visually (see Figure 1) in terms of how to resolve the communication gap and information transparency issues for each knowledge warehouse 3D dimensional information cell in our conceptual (x, y, z) 3D frame of reference. Spatial thinking allowed us to evolve the following sequential 3D information framework.

[A] Temporal (i.e., z axis = time) needs categorized over three longitudinal zones (e.g., **Pre-Event**: improving table top training exercises, **Event:** improving situational awareness **and Post-Event:** quickly accessing costs and applying/processing funding relief).

[B] Hazard (i.e., x axis = type) needs categorized by various types of water related flooding events (e.g., watershed downstream **flooding & swift water** flooding events; **open water "sunny-day"** simplified dam and levee breaching).

[C] Hierarchy (i.e., y axis = level/role)) needs categorized according to the various **parsed information packets (e.g. "tweets")** required for each hierarchical level role with **"need-to-know-only"** information for each emergency management agent or actor to simplify the interaction and to maintain security.

An initial configuration of the conceptual platform could be introduced to work with the NWM and execute pre-planning training (e.g., table top exercises see Figure 2) and eventually be available for real-time situational awareness at all hierarchical levels of emergency management facing multiple water related events, either as single events or as multiple cascading events and either as local, regional or national events given the appropriate super-computing resources. The conceptual platform proposed in this study would also have the capability to offer post event management such as cost analysis tools.

We selected a qualitative research design with a mix of research methods such as Interviews, Observations, and Documentary Analysis in order to support our scientific study objectives of (1) identifying means to improve pre-event training and planning with actual historical scientific data and information; (2) suggesting a migration path to real-time, live event command & control coordination and (3) offering an automated post-event analysis and recovery management practices and processes for expediting the quantifying and qualifying of the maximum emergency financial assistance available.

This research design also allowed us to expedite the study within the tight time and resource constraints associated with a 7-week, rapid prototyping environment. Our working hypothesis was a "communication gap and information transparency (i.e., synthesis)" problem existed that created obstacles for emergency management and flood first responders fully utilizing the significant advances in scientific information, exemplified by the NWM.

We began our investigation with primary research in the form of open-ended personal interviews, using a small convenience sample of emergency managers, first responders and National Water Center scientists and researchers who were amenable to being interviewed by us in support of our research.

The interviews were conducted in the form of face-to-face, open-ended questions using a convenience-sampling frame. Limited by time and resources, we carefully selected a cross section of several key emergency management, operational first responders and scientists for our face-to-face interviews. We formally interviewed

Tuscaloosa County Fire and Rescue Deputy and his staff; the Northport Fire and Rescue Chief and his staff, and the Tuscaloosa County EMA Director as well as water resource and flood scientists at the National Water Center. Informally, we observed and interviewed many first responders during (1) emergency equipment demonstrations and (2) a subsequent emergency planning and preparedness tabletop exercise session in the operations control room of the National Water Center attended by a large number of police and emergency management personnel. After conducting those interviews, along with other informal interviews, it was clear from the information obtained, all interviewees felt there was a serious communication gap and lack of communication (several used the word "empathy") between scientists and first responders.

Our research approach was not statistically significant and does not constitute a random sample, nor should any of our results be inferred to the general emergency management population across the country. To do so would invoke an exception fallacy. More qualitative and quantitative research must be done to further validate and study the statistical significance among relationships and variables.

From an observational design perspective two keynote speakers further supported our hypothesis. Mayor Walter Maddox of Tuscaloosa (discussed what happens when there is "no" communication in an emergency event because of massive destruction from the EF5 tornado of April 27, 2011 (see supplementary details). During another presentation, James Spann, a local Birmingham TV meteorologist gave an impassioned presentation challenging scientists, himself included, to get out of their labs and into the field to better understand the value of their work and to find ways of interfacing with first responders.

With our working hypothesis validated by our primary research interviews, our secondary research and literature review all supported the Rosetta Stone metaphor and conceptual model as a method of thinking about connecting the research from hydrologic science with the operational needs of emergency responders. Our secondary research focused on the following keyword topic search swarms: (1) serious game, agent-based, simulation software and emergency response planning, (2) temporal benefits from enhanced response time evidenced from lessons learned documentation, (3) utilization of semiotics and anticipatory computing for “geo-big-data”, 3D visualizations and cognitive best practices for such visual analytics, (4) web-based modeling and simulation for decision support systems, and (5) utilization of flood models in emergency flood response planning.

We quickly determined the conceptual knowledge warehouse (Yacci, 1999) platform would require extensive software programming resources and planning. We were given access to the University of Alabama’s Center of Advanced Public Safety, but because of the scale and scope of the knowledge warehouse and the limited rapid-prototyping timeframe, the project was too large to obtain a working prototype for a capstone presentation. Therefore, we pivoted and opted to visualize through a mocked-up, proof of concept knowledge warehouse "platform" (via a free web page design site called WIX.com). Using this website development package, we were able to present the major visual components of our conceptual approach and address the research question of "How can utilization of water science research among emergency flood responders be effectively facilitated?" [see supplementary materials for more information].

The web-based visualizations simulate geo-visualizations-as-a-service, flood information-as-a-service and other combinations of potential web apps on cloud-hosted services. These are gaining popularity and momentum in the literature also (Xicheng et al., 2016). Our simplified IF-THEN logic engine approach was also supported in the literature by robust adaptive strategies (Kwakkel, 2016), with other promising theoretical approaches including semiotics and anticipatory systems (Nadin, 2009).

In terms of the knowledge warehouse model, the objective was to provide proactive, predictive algorithms in an ecological anticipatory computing environment (Nadin, 2015) that could significantly increase the value of scientific data and information to flood responders and result in measurable community flood resiliency.

During a live emergency flood event, the knowledge warehouse (consisting of a translation mechanism) could utilize anticipatory computing (Nadin, 2009) algorithms to provide data to help with situational awareness based on the location, nature, and severity of the event being monitored. It would use lessons learned from previous events, and possibly data mining algorithms, to help dispatchers and responders anticipate what to look for and where to go next.

Such a software environment or platform would be anchored with a robust training module to provide the training needs of first responders with data for realistic simulations in familiar geographic settings, again provided by the National Water Model. In preparing for an event, emergency managers and responders could participate in and experience real-time exercises for their own local conditions to clarify their roles and responsibilities.

Next in studying the possible strategies and alternatives, we utilized a geospatial information science frame of reference and followed a sequential research approach. One strategy discussed was to increase the number of tabletop-exercises-as-a-service to meet the needs of first responders for improving preparedness in protecting vulnerable population groups. A tactic was to provide real-time pre-planning simulations through serious game software (Campbell, 2008). A second strategy was to create innovative utilizations of informatics to improve situational awareness and improve proactive opportunistic flood evacuation and rescue attempts. One tactic discussed was to provide "reverse look-up" (the water depth for a GPS location is used to create an on-the-fly updated flood map) to improve first responders' situational awareness (e.g., windshield survey methods). A second tactic was to provide deliverable preventable actions, education, planning, and training programs.

In terms of fault tolerance and redundancy, if conditions were such that communications were down, there is a strategy to use battery powered mobile client side devices to operate standalone GEO-PDF's (a form of lite geographical information system-GIS), on a first responder's personal BYOD (bring you own device).

Our conceptual model is by definition an intelligent and integrated knowledge warehouse that would need to operate with multiple hierarchical levels of connections, reporting and visualizations (see Figure 1) for both manually triggered or algorithmically acquired data and information utilizing a sophisticated integrated and intelligent Decision Support System.

The conceptual model would store templates with generally accepted emergency management procedures and check lists to execute once an incident was reported. Over time the conceptual model (i.e. knowledge warehouse) would be populated with data from various sources including, but not limited to: (1) activity logs from dispatchers around the state that could be automatically imported using FTP (file transfer protocol) once a standard data file structure was established among participating agencies, (2) media files (photos and video gathered from previous disasters, training videos, etc.), (3) training manuals and documents from different agencies.

Post-event, the warehouse would have a robust maintenance feature to allow for gathering and curation of data and materials. Data governance would be a key component of the curation process. As the data grow in volume, they could be provided in many different formats from many different sources. Curation guidelines would have to be established by a committee of stakeholders, where those guidelines would be implemented through stored procedures in the database or through user intervention (maintenance module).

There have been few studies in the literature that directly address the growing communication gap between science researchers and first responders. Thus the study has the potential to make a contribution toward increasing the applied value of engineering hydrologic science in assisting first responders mitigate flood effects.

Our investigation supports the notion that with efficient delivery of sensor derived data and information from the science domain to the social domain in simplified and parsed language and visualizations, nodal and proactive options for action can be offered to those in the social domain exposed to mitigating or reacting to flood risks real-time. Parsing information down to need-to-know and just-in-time filtering techniques and state-of-the-art IF-THEN logic algorithms, fills the perceived needs of first responders and other practitioners.

All of the first responders associated with this investigation consistently ranked the need to close the communication gap between researchers and practitioners as the top priority. Also the main findings suggest further research opportunities exist for (1) developing and testing visual stories like "ESRI Story Maps" (See Figure 2), (2) improving the delivery and reality of pre-planning tabletop exercises (i.e., TTX). [NB: Tabletop exercises are group simulation exercises to work through the details of an emergency situation] (3) Reverse lookup, inundation-mapping on-the-fly through first responder windshield survey methods and (4) spatial-temporal visualizations using locational 3D semaphore object analytics to provide emergency personnel at different hierarchical levels with enhanced visual perceptions and situational awareness.

The primary motivation for the study was to help connect the efforts of hydrologic science with the needs of first responders in serving the interests of public safety. First our theoretical approach creates an enhanced training simulation operationalized as an intelligent & integrated expert decision support system that provides analog and/or digital connections to each critical agent(s) in a flood water emergency response situation including the public. This facilitates controlling the information flow such that just-the-right quantity and quality of information is "pushed" to just-the-right person at-just-the-right-moment, as required (Keen, 1980). We simulate the training functionality of this approach with a web-based WIX.com webpage application applied to local flooding (Kochilakis, 2016). Through the National Water Model (NWM) "distance" training could be accomplished "locally" for any training group within the NWM watershed by means of virtual training exercises.

The conceptual platform discussed in this study is distinguished from other efforts through the use of an integrated expert system, logic engine, data/knowledge repository with a robust and powerful maintenance module that provides a Knowledge Warehouse (KW) capability (Yacci, 1999), scalable in three-dimensions. The conceptual platform can be thought of as a three-dimensional space-time geodata repository. This three-dimensional platform would scale (1) horizontally to all hazards; (2) vertically to address the critical lifesaving hierarchical information needs of a myriad of flood water emergency responders, emergency management organizations and populations at risk with a (3) a third axis of time (pre-event, event and post-event).

With the significant increase in sensor/system generated geo-big-data and the potential rewards for improving communications between the "science cloud" and "social cloud" more research has fertile ground to explore. Also, recent hydrologic science advancements and developments e.g., the National Water Model (NWM) with other expected future extensions, creates the potential to dramatically strengthen the general knowledge and understanding of first responders about the hazards of flooding and how to proactively mitigate the associated risk. Finally, and importantly, with knowledge and awareness come advanced warning time intervals for proactive flood inundation effects abatement (Cencerrado, 2014).

To summarize, we see our model distributing scientifically manufactured "data and information" products to social "applied knowledge" customers in a similar way to the classic marketing problem, between producers and consumers with respect to serving different "needs" (Maslow, 1943).

Out methodology has specifically addressed each issue through a knowledge warehouse and intelligent & integrated expert decision support system platform. A website proof of concept is provided in supplementary materials to demonstrate the flow and logic of such a model. Finally, an innovative three-dimensional semaphore object is tested on the platform as a potential emergency management decision making tool (Kochilakis, 1980) called "Avatar" to allow visual semaphore type object representation of the unfolding events for various emergency management roles.

5.0 Findings

5.1. Description of Results

The investigation to date has identified two main results (1) what is needed and (2) by whom.

5.1.1. Result #1 – "What is needed?"

A higher frequency of regular pre-planning opportunities (i.e., table top exercises) for practicing and integrating with the latest engineering science advances exemplified by the National Water Model.

5.1.2. Result #2 – "Who needs what?"

The hierarchical structure of emergency management organizations (from on-the-ground first responders to chiefs and directors) dictates the need for various types of pre-planning information and services for different roles within each organizational structure and job function.

In pre-event planning exercises, emergency response groups review and discuss the actions they would take in a particular emergency, testing their emergency plan in an informal, forgiving environment (UWPD, 2012). Tabletop exercises have recently taken on a new, modern approach with software emulation referred to as "RimSim" (Campbell, 2010, 2013). "RimSim" is a simulation-based software platform designed specifically for countries around the Pacific Rim and their emergency management organizations, to facilitate pre-planning exercises associated with hazards that affect the area, such as earthquakes. Their approach, however, does not have the advantage of using real data and thus adopts a single scenario with fictitious place names, events and scenarios (Campbell, 2013).

Using ESRI's ArcGIS Online Story Map Interface we demonstrate a series of tabletop exercises, to describe flood scenarios. In our conceptual model tabletop exercises would use real data from the National Water Model's archives in order to better prepare first responders with actual events. We simulate this capability with the WIX hypothetical platform showing prototype inundation mapping libraries with a series of scenarios delivered through the Story Maps (See Figure 2).

5.2. Interpretation

5.2.1. Interpretation of Result #1 "What is needed?"

Based on our investigations, we believe an intelligent transfer mechanism (a knowledge warehouse (Yacci, 1999) is needed to facilitate the instantaneous "translation" of scientific data and derived information (science cloud) - across the communication gap between the two domains - and into the parsed and simplified packet of knowledge and understanding in the social cloud that can be immediately applied to actions and activities by first responders and the public at large. Social language typically involves parsed "road signs", visual maps and media such as flood inundation maps. In addition, since the National Water Model covers all of the contiguous United States, any first responder within that area, utilizing the proposed Tabletop Exercises-as-a-Service would be able to train with their own local and familiar real-time data.

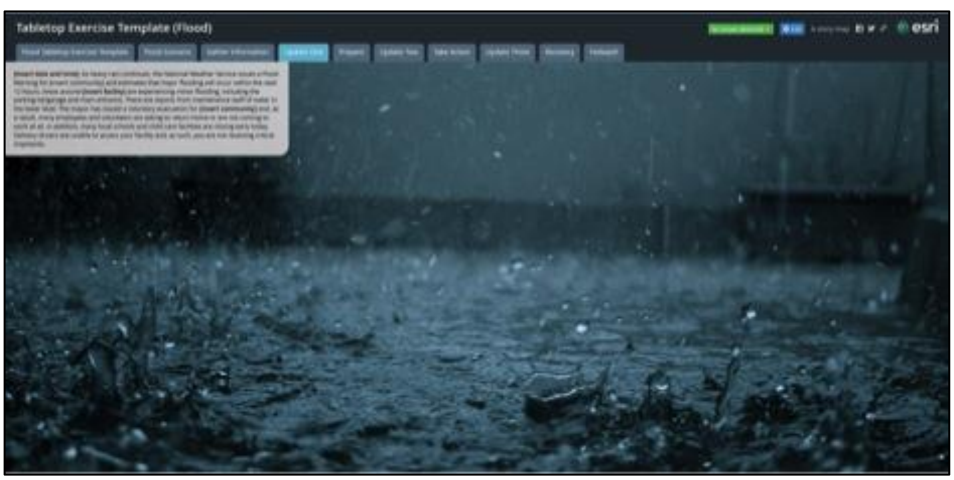

Figure 2. : Sample of Tabletop Exercise Story Map (http://arcg.is/29sE921)

5.2.2. Interpretation of Result #2 "Who needs what?"

In summary our web-based proof of concept demonstrates how our approach could resolve a number of communication, interpretation and understanding bounding issues.

- It provides first responders and emergency managers access to a user friendly visual interface that is deliverable on a need-to-know basis by organization (NGO's, Police, EMA, and Fire and Rescue) further stream lining extraneous unnecessary details and information to groups not requiring such information. [see supplementary materials for more information]
- It provides online tabletop exercise templates (powered by the ESRI Story Map Interface) that can be tailored to the real-time conditions in a specific community across the USA.
- It provides a "simulated" knowledge warehouse that categorizes information using an IF-THEN algorithmic logic engine.
- For example, IF a dam breaches, THEN certain actions must be taken by swift water response crews, public works, police and so on. These actions are taken from best practices and lessons learned that are detailed in the accumulating After Action Reports (AARs).

6.0 Conclusion

The scientific information needs of emergency flood responders and their management hierarchical infrastructures can be met through a comprehensive "intelligent" mechanism; to use a metaphor, a Rosetta stone concept that we propose as the Knowledge Warehouse (KW). The KW instantly interprets, parses and connects appropriate pre-defined "sources" of information with pre-defined "applications" of information based on the specific emergency responder role being supported. Only this type of approach (initially for training purposes only) will eventually close the communication gap between the science and social domains while simultaneously improving the knowledge, understanding and abilities of flood water emergency responders, emergency management organizations and populations at risk to respond to the effects of uncontrolled flooding and/or hazardous swift water conditions.

Our methods intend to open lines of communication between water resource experts and emergency managers and responders. By translating the most up-to-date hydrologic models and scientific information into the language of emergency flood responders through standard operating procedures (SOPs); this platform has the ability to prepare emergency responders at every hierarchical level for a far more effective and efficient response. Given emergency management's interdisciplinary nature, it is well positioned also to interface with other disciplinary sources of information to facilitate the common goal of saving lives and property.

The CUAHSI Summer Institute at the National Water Center at the University of Alabama in Tuscaloosa in 2015 and 2016 has provided the opportunity to freely explore, discover and examine this topic from many perspectives. And by utilizing rapid prototyping methodologies, for uncovering potential innovative breakthroughs, we have discovered fresh perspectives from a transdisciplinary, collaborative team approach, in terms of the nagging and persistent communication gaps being experienced by first responders today.

6.1 Looking Forward

Other promising ideas for further research, generated from this study include:

- **GEO-Portable Document Formatted GIS Map Layers** - for client-side lite GIS where pre-calculated geospatial information can be stored with no requirement for network connection if services are down due to emergency conditions.
- **Reverse-Lookup** - shows how flood conditions verified as ground truth by first responder crews (using standard Windshield Surveys), in real time, can play an important role in recasting the geographical

situational awareness event scene and potentially uncovering weaknesses in prediction while identifying just-in-time opportunistic rescue and rcover opportunities as dynamic conditions unfold.

- **Distant Training & Learning** - applying real-time streams of national water model data to tabletop training exercises-as-a-service would allow first responders anywhere in the USA to train for their "local" flood hazards.
- **Real Time** - through testing and development, LIVE real-time command and control could eventually be deployed from such a platform to effectively organize and manage simultaneous "live" hazards events (e.g. tornados, fires, simultaneous flooding, dam breach and so on).
- **Avatar** – Spacetime three-way factor analysis of complex geo-big-data could simplify complex situations to one visualization.
- **iMDE** – Integrated Mapping Demography and Evacuation planning
- **iSIM** – Integrated Simplified Inundation Mapping to evaluate dam breach scenarios.
- **COST** – Flood Damage Estimator to quickly estimate and apply for emergency funding from appropriate authorities.
- **Site Locator** – A siting approach could be developed that looks not only at population density and drive time for siting new Rescue Service facilities, but also weights (using GIS buffered layers) the flood and hazard spatial temporal risks by location.

Supplementary Materials

- Mayor Maddox at the National Water Center – Tuscaloosa, AL June, 2016 https://www.youtube.com/watch?v=mPcUDIXX2G4
- More information - both Figures 1 and 2 are available online at http://liamgesahc.wix.com/translator-ttx;
- ESRI Story Maps Tabletop Exercises are available at http://arcg.is/29sE921 and http://arcg.is/29sFRAc

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