

THE DESIGN AND IMPLEMENTATION OF INTEROPERABILITY FRAMEWORK FOR CROSS-NATIONS FLOOD DISASTER WARNING SYSTEM

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ABSTRACT

Information technologies have been widely applied to natural resources and disaster management for decades. This study aims to develop a highly standardized system and to solve the integration problem of two case study watershed at the border of Canada and the U.S. Even both of the contributory countries used OGC standards at designing their own national system, gathering and analyzing the data is complicated because of the differences in realization of the standards. Because of the lack of the cross-border data, flood warning was not able to use data provided by the other country for the same watershed, which caused a lack of service in early warnings. Planning an integrated system also gave the opportunity to improve quality of services and set up new methods and realizations.

KEYWORDS: Interoperability, OGC Standards, Flood Awareness System, Hydro Information

INTRODUCTION

Accessing reliable and up-to-date environmental information is one of the keys at prevention and preparedness planning. Sharing information can be challenging even within an organization because of the various data sources and standards employed at collection; exchanging data with contributors or even across the borders is usually cumbersome.

In these cases usually language barriers, IT issues and legal obstacles are emerging. To reduce barriers international standards and agreements are concluded. To deal with the challenging situation several solutions appeared. As an example, the EU established the Handbook on good practices for flood mapping in Europe (Martini and Loat, 2010) to stimulate trans-boundary operations. European rivers often cross or (partially) form national borders. By the handbook EU initiates bi- or multilateral cooperation within particular watershed or even along the entire river. Next to others Rhine Commission and Safe coast are relevant former examples on trans-boundary flood maps based on INSPIRE (Directive, 2007). As the Final report (ICPR, 2014) also remembers detailed information about flooding are only available due separated internet links to the different countries. TIMIS (AUTH and IBW, 2008; Mujumdar and Kumar, 2012) is a model on both flood hazard mapping and flood forecasting to help EU unifying trans-national issues. This system improved the flood forecast and installed a warning system for small catchments in the Luxemburg, Germany and France. The European Flood Directive (Parliament, 2007) disposes of data sharing between Member States to reduce risk on affected population and to increase effectiveness by reducing spending on common data collection (compared to the costs of separated collection). EFD also admits that common flood response deal with urban areas situated on either side of the border. Trans-

boundary operation may also strengthen co-operation between responsible authorities and increase confidence.

Not only in Europe, but even in America flood means an emerging issue. To handle the large amount of data National Water Information Service (Good all and Horsburgh, 2008) has been established based on USGS data. Databases such like this means a valuable data source for various services. Data-repositories contain hundred-millions of observation data from the past 100 years. For seamless integration CUAHSI HIS (Peckham and Good all, 2013) introduces a use case about using OGC WaterML (Taylor, 2012) schema. Data heterogeneity is also a major challenge at integrating systems, especially in groundwater related topics (Booth et al., 2011; Brodaric and Booth, 2011; BRODARIC et al., 2014; Eric and Boyan, 2011). Data access and readability should be ensured Trans boundary (Klug and Kmoch, 2014). To extend the accessibility of the information web applications have to be built, which also allows data processing in the Cloud (Delipetrev et al., 2014; Evangelidis and Ntouros, 2014). Event-driven architecture helps solving complex tasks reliably and notifies subscribers about observation events (Fan et al., 2013).

This article introduced a novel and highly standardized framework for flash flood emerging response scenario based on the concepts of previous studies. This framework was applied to solve the integration problem of two case study watershed at the border of Canada and U.S. Even both of the contributory countries used OGC standards at designing their own national system, gathering and analyzing the data is complicated because of the differences in realization of the standards. Because of the lack of the cross-border data, flood warning was not able to use data provided by the other country for the same watershed, which caused a lack of service in early warnings. Planning an integrated system also gave the opportunity to improve quality of services and set up new methods and realizations.

SYSTEM DESIGN

Study Area

This study adapted two river basins as area of interest, which is located both in the U.S. and Canada. The Milk River is a tributary of the Missouri River; the basin includes parts of Alberta, Saskatchewan, and Montana. The length of the river is 1,173 km; the extent of the basin is 61,642 km². The Souris River basin includes parts of Manitoba, North Dakota, and Saskatchewan. The river is about 700 km in length and drains about 61,100 km².



Figure 1: Milk River Basin

Source: http://www.umt.edu/watershedclinic/images/clip_image002.jpg

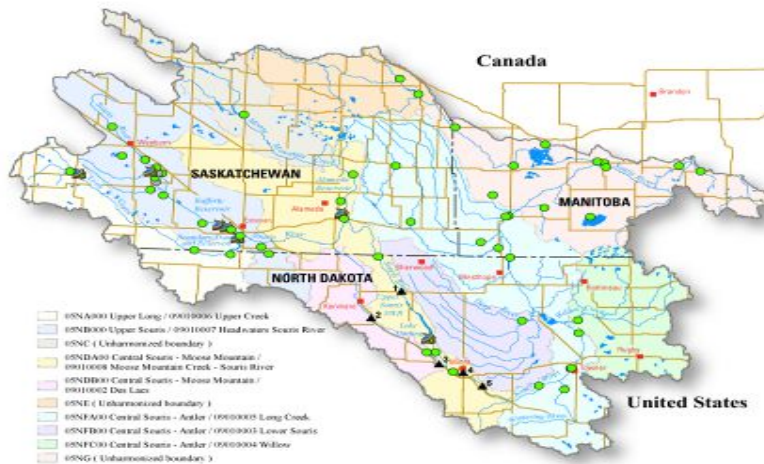


Figure 2: Souris River Basin

Source: <http://nd.water.usgs.gov/floodinfo/souris.html>

For both of the rivers historical flood event data are available, which helped the development process of components, and also used for the scenario design for the experiment of this study. A flood on the Milk River in 2011 has been chosen for the testing and verifying this framework.

Data Source Components

There are few components developed and provided by the U.S. and Canada were adapted for further experiment and defined as the data sources. These data sources were designed and implemented based on different standard protocols, i.e., Sensor Observation Service(SOS) as the common protocol for data publishing, Water Markup Language(Water ML) for data encoding, Web Processing Service(WPS) for real-time data processing...etc.

The table list the name of each component and brief statement about what the component does and/or what kind of information it provides, the organization providing the component, the standard to which the API of the component conforms and the standard to which the output format provided by the component conforms.

Table 1: Pre-Existing Components for the Flood Event and Notification Use Case

Component	Provider	Standard	Output Format
1. Sensor Observation Service (Water Level, Water Flow, historic)	Environment Canada	SOS 2.0	WaterML 2.0
2. Sensor Observation Service (Groundwater Level)	NRCan	SOS 2.0	WaterML 2.0
3. Sensor Observation Service (Water Level, Water Flow)	USGS	SOS 2.0	WaterML 2.0
4. Web Feature Service (Station info)	USGS	WFS 1.1.0	WaterML 2.0
5. Web Processing Service (Upstream geometry NHD/NHN)	NRCan	WPS 1.0	WPS 1.0
6. Web Map Service (Stream segments)	NRCan	WMS 1.3.0	Map image

Framework and Scenario Design

At flood event and notification use case cross-border stream flow and groundwater levels are monitored continuously to detect potential flood events. When a potential flood even is observed an alert service notifies EM (Emergency Management) analysts who have subscribed to be notified of such events. The use case contains three independent activities:

- A monitoring activity regularly checks data streams for changed stream and ground water gauge values and stores water flow and water level information. This activity is also called “Harvester”.
- A subscription process allows subscription to event notification service for emergency management analysts by specifying threshold parameters of monitoring points. The event notification system automatically expands subscription to the upstream of the specified point of interest.
- A notification process compares the observed values to the thresholds to determine if a flood is imminent and notification of the EM analyst is required. This process is also called “Broker”.

Monitoring Activity

Harvester is responsible for getting last value from each station. It uses a Get Records request on CSW to obtain the URLs for the list of available sensor observation services. For each SOS obtained from CSW Harvester reads last observed value by Get Observation request. The red value is compared with the previous ‘last observed’ value from the CSW. If the values are different, Harvester updates the metadata in the CSW file, and sends notification to the subscription broker that the value has changed. When being notified subscription broker compares changed value with threshold registered at each subscription. If the changed value is above the threshold, the broker generates the content of a notification message and delivers it to the WNS to do the notification. The workflow of the Harvester activity is described by Figure 3

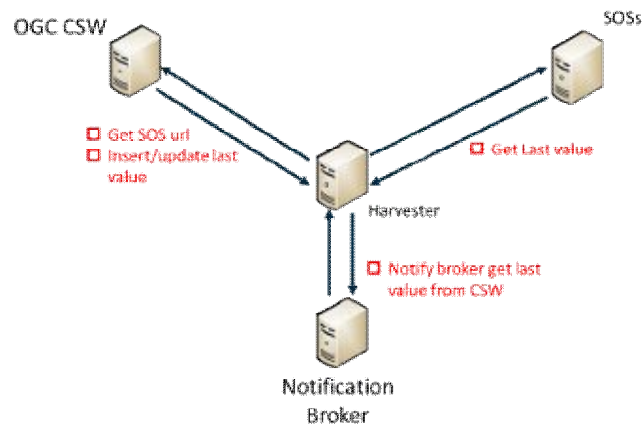


Figure 3: Workflow of Monitoring Activity

Event Notification System

Even notification can be divided into subscription and notification process. The subscription process allows subscription to event notification service for emergency management analysts. Users can subscribe for multiple points of interest with the same account, and will be notified imminent flood on upstream automatically. For subscription an

emergency management analyst has to access the web client to survey water monitoring stations on the map. When analyst selects a station or monitoring point of interest, Notification Broker will send request to the Upstream WPS to find upstream stations, and subscribe user to WNS by the threshold level. WNS sends a subscription status to the emergency management analyst.

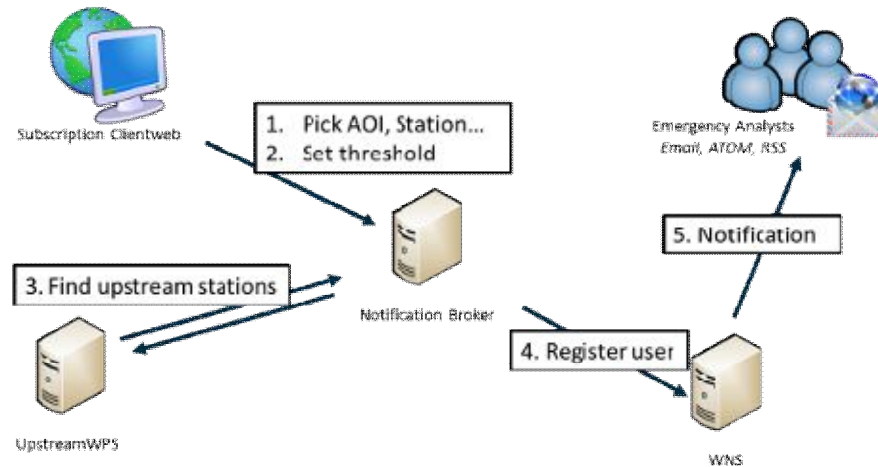


Figure 4: User Interface of Subscription Process

Harvester triggers the entire process by storing last observed value in CSW and notifying Broker. When Broker receives notification, it sends Get Record request to the Catalog Service to get the measurement from CSW. Broker compares the observation data with the thresholds, and generates and sends notification in case of violation. WNS will be triggered by the notification and send alert by email, ATOM and RSS. The content of notification email can be divided into three parts: subscription information, map and station list. At subscription information users can see their subscriptions on Point of Interest and the thresholds they set up. The map contains the entire upstream extend, and the stations which are over threshold will be marked up. The station list enumerates all the upstream stations with their current measurement values about water level, water flow and ground water level, and the update time of observation. Stations exceeding threshold will be highlighted as red in the table. The email contains CAP Alert link, if the role of the user is EM analyst. WNS delivers the event information to the OASIS CAP Alert client automatically, where EM Analyst can set up event descriptions and submit them to the MASAS HUB. The workflow of Event Notification Process is described by Figure 5.

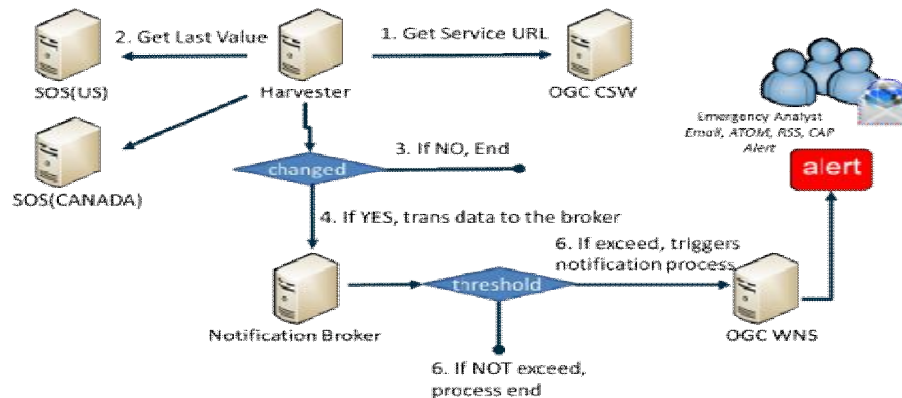


Figure 3: Event Notification Process

IMPLEMENTATIONS

There are four components had been implemented in order to fulfill the needs of a standard based flood warning system, includes a harvester, a catalogue service, an event notification module and an interactive client web.

Harvester

A Harvester has been implemented as mediation components between SOS, Catalog and Notification module. Several capabilities have been developed in these components.

- Get “End points” information from Catalogue service. (self-triggered each day)
- Get “Last Value” from different SOS which is registered to CSW. (self-triggered every 5 minutes)
- Compare the latest “Last Value” with previous “Last Value”.
- Trigger Notification module if the latest “Last Value” is unequal.

Catalogue Service

An OGC Catalogue Service has been implemented in this study based on the open source pycsw. The pycsw catalogue is an OGC CSW server implementation written in Python and is certified OGC Compliant. Operationally, the catalogue was used to support the following activities:

- Register all services that been applied in this study into catalogue to make them discoverable.
- Use the CSW to get the list of services and stations within the AOI.
- Periodically update the water monitoring station metadata to include the last observed value.

Event Notification Module

We established a web notification component within the Event Notification Module, which completely following OGC WNS standards. Its primary function within the system is to send notification emails to the subscribers whenever the broker declares that a notification is required.

The emails sent by the web notification component contents a link with CAP Alert in case of user is an EM Analyst. Following the link allows the analyst to use OASIS CAP Alert client, and set up event parameters. WNS delivers information into CAP Alert client, so EM Analyst should only fill in other descriptions, such like type of event status (urgency, severity and certainty), add contact information and event expire time. Once alert submitted to this client, information will be published due the MASAS HUB. Cross this tool we can transfer information from WNS to MASAS system.

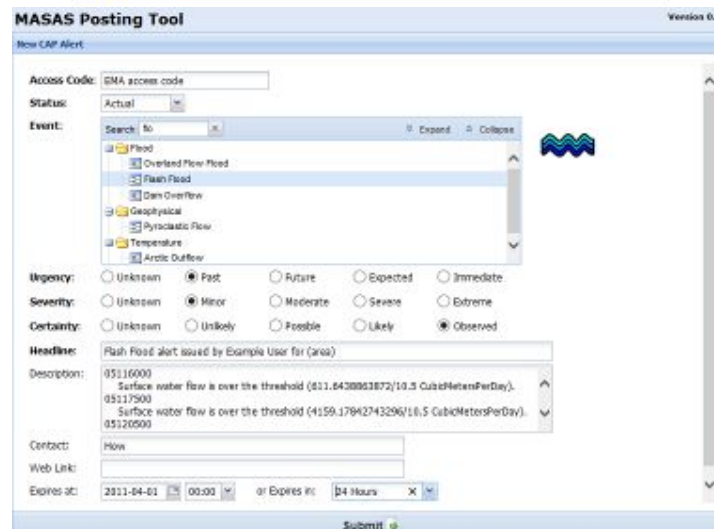
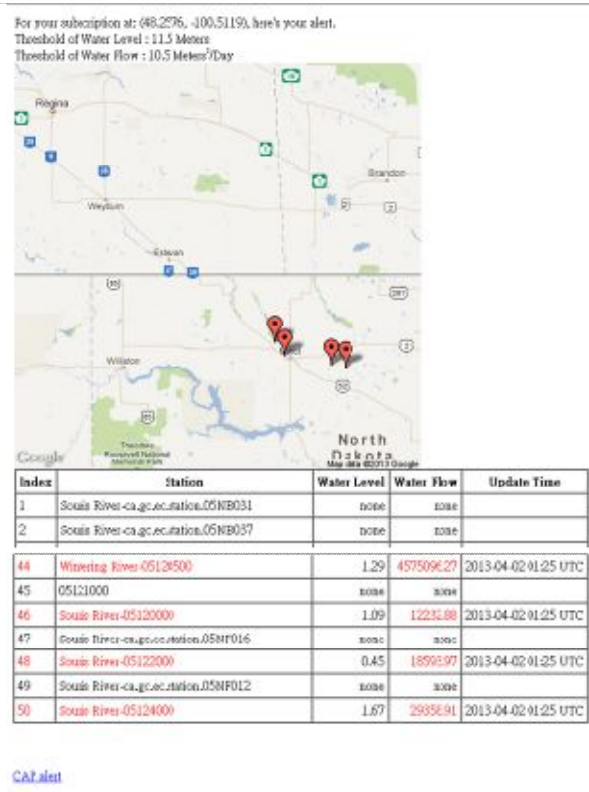


Figure 4: Once the Observation Exceeds Threshold, Event Notification Module will Send an Email to Subscriber with a Link to CAP Alert Setting Interface

Client Web

Client has been developed as the interface to let emergency management analyst (EM analyst) to observe the entire picture of monitoring stations that cross the boundary via connecting to OGC Web Feature Services provided by the U.S. and Canada. An EM analyst can select point of interest either a monitoring station, then set up the thresholds and notification frequency.

The primary UX is based on Twitter's Bootstrap (see <http://getbootstrap.com/2.3.2/>) and the map component leverages Leaflet and associated plugging (see <http://leafletjs.com/>).

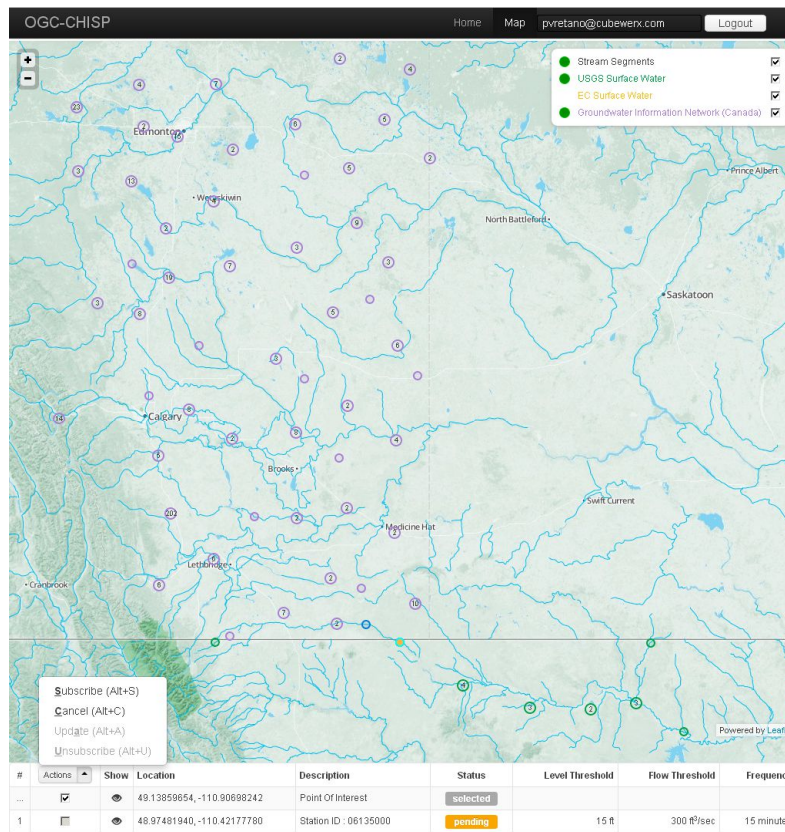


Figure 5: EM Analyst can Log into Client by Email and Easily Subscribe Stations or Point of by Click on the Interactive Map

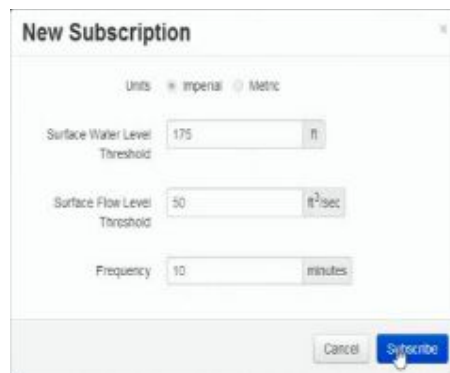


Figure 6: A New Subscription Includes Threshold of Surface Water Level, Flow Level and Frequency that Once Observation Exceeds Threshold

CONCLUSIONS

This study introduced and implemented a novel and standardized framework to conquer the issues while confront with flash flood, cross-nationality and interoperability. An interactive map based subscription client was implemented to provide the interface for EM analyst to observe monitoring conditions, subscribe stations of points of interest; A scheduling

harvester program was developed to solve the backend performance and trigger the entire process; A catalogue service played a role as an endpoint repository; A notification module that implemented based on OGC Web Notification Service. In this study, we have proved information technology standards applied to the interoperability between loosely coupled components is practical and applicable to solve the issue that cross boundary information seamlessly exchange.

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