13.1 THE APPLICATION OF VIRTUAL GLOBE SOFTWARE IN FORECASTING FLASH FLOODING OF LOW WATER CROSSINGS

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1. INTRODUCTION

Geographic Information System (GIS) viewers including virtual globes are becoming a more integral part of National Weather Service (NWS) operations (Stellman 2009, Smith and Lakshmanan 2006). GIS virtual globes such as Google™ Earth provide the NWS with a valuable tool to observe and analyze hydrometeorological data, enhance situational awareness, and improve flash flood warning decisions and response.

Virtual globes provide a new method of understanding and forecasting flash floods. For the first time meteorologists can "see" a location that is prone to flash flooding. Using virtual globes meteorologists can effectively identify the area at risk to flooding by integrating physiographic, radar and watershed data. This synergy of data provides a more accurate view of what is happening on the ground and a means of assessing the risk to the nearby population and infrastructure.

Flood prone areas including low water crossings can be easily mapped in virtual globes and analyzed for flood potential. Virtual globes will aid meteorologists in the flash flood warning process. Information derived from virtual globes will support meteorologist in determining the location and potential impact of flash floods, and provide more detailed and accurate information that can be included in flash flood warnings. In addition, since the Keyhole Markup Language (KML) file format is standardized, the information can quickly and easily be shared with others outside the NWS. Emergency managers and first responders can use this same data to better react to a flash flood.

Ultimately, virtual globes will be a valuable tool in protecting life and property from flash floods.

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2. FLASH FLOOD ANALYSIS AND APPLICATION

Integrating a complex data set from a variety of resources and observations is necessary to perform successful flash flood warning operations, flood mitigation activities, and effective flood response and recovery.

The data rich environment within virtual globes will enhance NWS flash flood operations and warning services. The integration of multiple geo-referenced layers such as infrastructure, transportation routes, geographical features, geo-political boundaries, flood prone locations, watersheds, etc. provide the NWS with a valuable tool during flash flood events.

Virtual globes aid forecasters in identifying flood behavior factors and assess flood risks. NWS forecasters can take virtual tours of areas at risk from flooding. Forecasters can also analyze antecedent conditions during floods or drought, as well as monitor stream flow and snow pack conditions. By integrating physiographic, socio-economic, and hydrometeorological factors, flash flood warning decisions are improved.

2.1. Identifying Low Water Crossings

NWS offices have utilized virtual globes like Google ™Earth to plot low water crossings which are particularly dangerous during flooding. Viewing this data in a virtual globe results in a greater awareness of flood prone locations, and provides more specific information that can be included in flash flood warnings.

Figure 1: One of many dangerous low water crossings

Low water crossings or bridges pose a serious flooding threat to life in some parts of the United States. Because these low water crossings lie within existing stream beds, they easily become inundated during periods of heavy rainfall. Figure 1 shows the inherent danger with low water crossings. With the help of local emergency management and field surveys, the locations of low water crossings are indentified and plotted within a virtual globe.

Figures 2 and 3 show low water crossings plotted within a virtual globe. A forecaster's awareness of potential flood risks is effectively enhanced by displaying flood prone areas within a virtual globe.

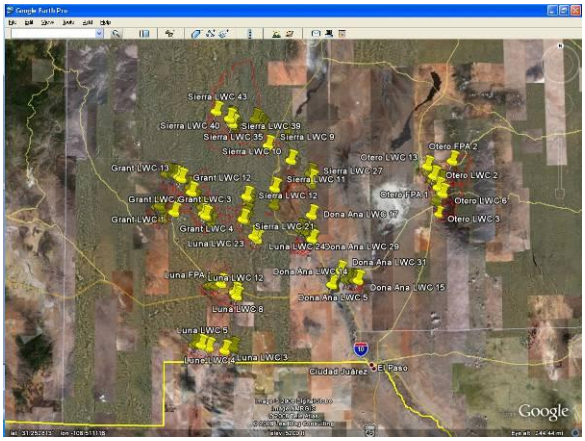

Figure 2: Low Water Crossings plotted in *Google™ Earth*

Low water crossings plotted in a virtual globe are easily shared with other agencies in a KML format. Emergency management, first responders, and transportation departments utilize this data to develop flood mitigation and response plans.

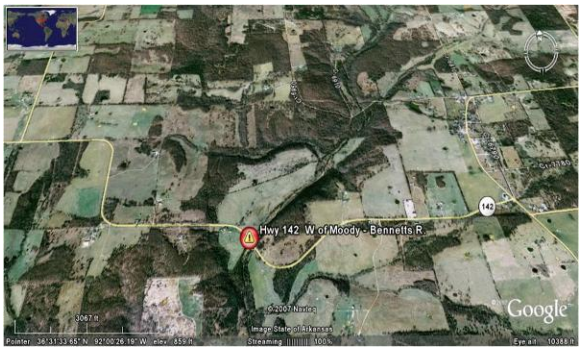

Figure 3: Close up of low water crossing plotted in *Google™ Earth*

2.2. View Basin Locations and Characteristics

Beyond just identifying the location of low water crossings, the watersheds that impact these flood prone locations are identified (Figures 4 and 5). Understanding the locations and characteristics of a particular basin greatly aids a forecaster's flash flood warning decision.

In addition to the location and coverage of the basin, several physiographic factors contribute to flash flood potential within a particular drainage basin. Virtual globes provide a means of assessing basin slope and geometry that determine such behavior as the speed and concentration of runoff. Land use, vegetation and infrastructure which play an important factor in runoff behavior can also be inferred by viewing virtual globes.

Utilizing virtual globes to analyze basin characteristics yields important information about the hydrologic response and flash flood potential inherent to a specific basin and low water crossing.

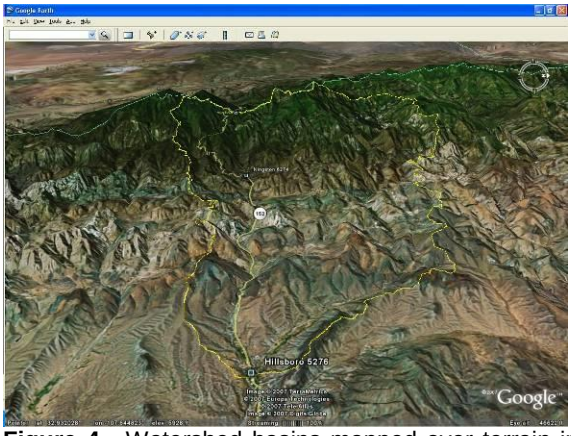

Figure 4: Watershed basins mapped over terrain in *Google™ Earth*

Figure 5: Low water crossing mapped with corresponding watershed in *Google™ Earth*

2.3. Flash Flood Analysis

NWS forecasters can effectively utilize virtual globes to analysis the flood potential for a given low water crossing or watershed. Integrating low water crossing locations and basin characteristics with hydrometeorological data greatly improves a

forecaster's understanding of a flood event (Smith 2003).

Radar data including one hour rainfall rates is easily incorporated into virtual globes like Google™ Earth to analyze the potential of flooding and its impact. Rather than just viewing radar data, NWS forecasters view where the rain is falling and where flood waters will go. Overlaying radar precipitation estimates over the basin, flood potential and severity are more accurately assessed (Figure 6).

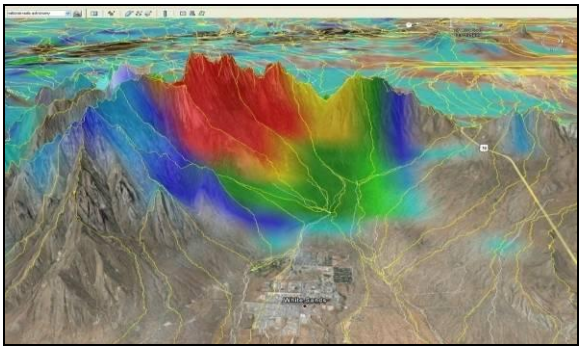

Figure 6: Radar estimated storm total rainfall overlaid on *Google™ Earth.*

Virtual globes provide an environment to assess the potential impact, and support strategic and tactical response during a flood event by integrating multiple datasets. Geographic layers overlaid with radar products can be utilized to perform risk assessment for the purpose of issuing flash flood warnings and collaborating with local emergency management.

Identifying the flash flood risk of specific basins, streams, communities, urban areas, recreational areas, transportation routes and low water crossings can be performed within a virtual globe. Knowing where and what the storm will impact heightens situational awareness and improves warning services.

2.4. Flash Flood Warnings

Integrating information gleaned from virtual globes, will lead to more specific and timely flash flood warnings. Flash flood warnings can be issued for smaller geographical areas based on basin coverage's and flood prone areas that are more readily viewed in virtual globes. Also, specific locations of streams, roads, low water crossings identified in virtual globes can be included in flash flood warnings

Virtual globe's and the KML format will provide the means of disseminating and viewing flash flood warnings graphically. A visual display of the warning will clearly indicate locations at risk from flash flooding.

Flash flood warning polygons overlaid with known flood prone areas such as low water crossings will support a more informed emergency response. Warning information enhanced through the use of virtual globes will enable emergency responders and the general public to better understand the potential magnitude and impact of flash flooding, and promote appropriate action before flash flooding occurs.

Utilizing virtual globes will aid the NWS in providing more accurate, timely and detailed flash flood warnings, thus leading to more effective response by those in harm's way.

2.5. The Future of Flash Flood Warnings

A detailed flash flood risk analysis derived from the utilization of virtual globes and other GIS applications will lead to more specific information being disseminated to the public in both text and graphical format. Flash flood warning text will contain specific information detailing streams, flood prone locations, transportation routes, and low water crossings.

Detailed flood data will be depicted graphically via the internet and GIS applications such as Google™ Maps API. Figure 7 shows a demonstration of GIS enhanced warnings. The graphical warning web page will combine warning polygons, flash flood risk analyses and census data. Combining warning polygons and census data will depict the population, homes, etc. under direct threat from flash flooding. Development of Google™ Maps API will provide the capability of integrating radar, warning polygons and low water crossings.

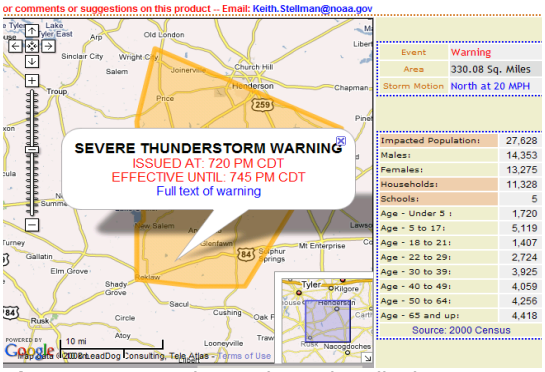

Figure 7: GIS enhanced warning display

2.6 Post Storm Verification and Analysis

Determining the occurrence, location and impact of a flash flood can be difficult. It is not uncommon for a flash flood warning to go unverified for several days after a flood event has occurred. Many floods occur in rural locations making verification difficult. With the

aid of virtual globes NWS forecasters can better verify the occurrence of flash floods. By overlaying GIS datasets like flash flood guidance exceedance grids or CoCoRaHS data (figure 8), forecasters can narrow the geographic search for flooding. Utilizing virtual globes forecasters can call local businesses in the affected area in an attempt to verify a flash flood event.

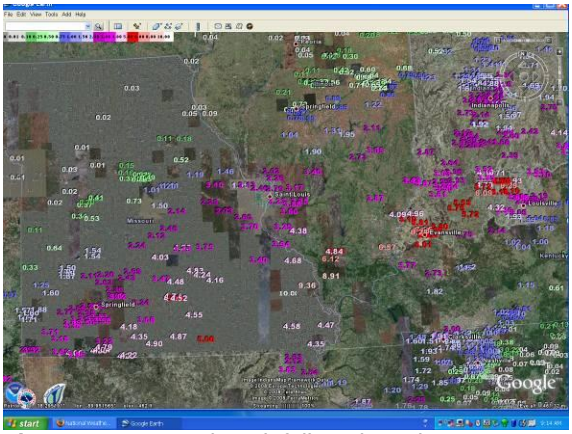

Figure 8: CoCoRahs rainfall total overlay

Virtual globes also provide a useful platform for post storm analysis. With virtual globe's ability to overlay various GIS datasets, forecasters now have a unique platform to overlay satellite images, radar data, and hurricane tracks or flood damage photos. Not only do these overlays help forecasters better understand what happened during a flood, but with the standardized KML file format, datasets can be shared with emergency managers and the general public.

Using virtual globes as a teaching platform in a post flood environment will help forecasters, emergency responders and the public to better anticipate flooding problems in the future. Figure 9 depicts the use of a virtual globe for a post flood survey.

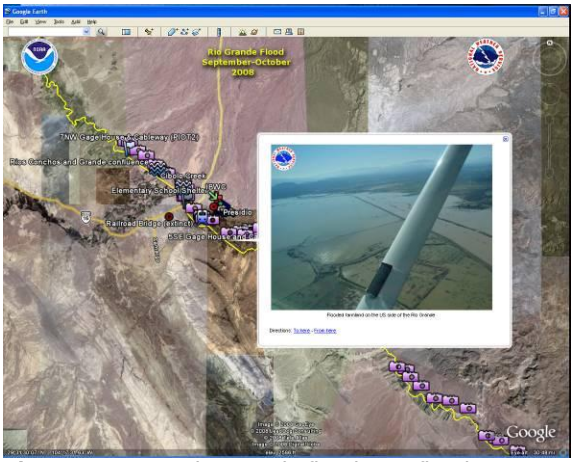

Figure 9: 2008 Rio Grande flood post flood survey

3. SUMMARY

Flash flooding of low water crossings pose a significant threat to life in some parts of the United States. The utilization of virtual globes provides an effective tool to better identify and analyze these flood risk locations.

Virtual globes can aid NWS forecasters during flash flood events. Virtual globes such as Google™ Earth provide an easy-to-use GIS platform useful for the integration of weather data with geospatial information. The synergy of data and capabilities within a virtual globe will enhance the NWS's ability to identify and better understand those locations prone to flash flooding including low water crossings. The use of virtual globes within a NWS operational environment has the potential to improve situational awareness and flash flood warning decisions.

Additionally, virtual globes have the potential to enhance NWS products and services where the integration of meteorological and GIS information is especially helpful. The utilization of virtual globes and the KML format will be useful in providing decision support to emergency management and responders during flash flood events.

Ultimately, virtual globes can play an integral role in issuing and delivering more effective flash flood warnings for the protection of those at risk from flash floods.

4. ACKNOWLEDGEMENTS

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Special thanks goes out to the NWS Google™ training team for their hard work in developing training used by all of NOAA.

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