REAL-TIME DEPTH-AREA-DURATION ANALYSIS FOR EAPS AND FLOOD WARNING SYSTEMS

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Abstract

Historically, storm depth-area-duration (DAD) analyses have been computed to aid in the computation of probable maximum precipitation (PMP) estimates that influence the design and operation of hydraulic structures such as dams and weirs. Since DADs require accurate, high resolution precipitation depths in time and space, particularly in areas with the heaviest precipitation, they were always a post-storm exercise. Additionally, a DAD analysis requires a great deal of computing power. However, with the advent of today's computer power and the Storm Precipitation Analysis System (SPAS), DADs can now be computed in near real-time. DADs provide a powerful, objective, easy-to-understand three dimensional perspective of storm precipitation. Unlike point precipitation observations, a DAD provides the areal magnitude of a storms precipitation. A comparison of the areal size, magnitude and duration of an unfolding precipitation event to other historic storm DADs, DAD thresholds for flooding or even the PMP design-based DADs can be made. Near real-time DADs have a number of practical applications, including flood warning systems and emergency action plans (EAPs).

The basis for real-time DADs is gridded precipitation from SPAS, a proven, state-of-the-science tool that has been used, in part, for nearly 10 years for the development of DADs. Utilizing quality controlled radar data and hourly measured precipitation, SPAS determines and utilizes hourly algorithms and spatially varying correction adjustments to produce accurate and reliable precipitation patterns. An overview of SPAS, its unique capability to compute DADs and interpretation of DADs will be provided.

Introduction

In order to combine information of areal precipitation depths over a range of area sizes and varying durations, a technique known as a depth-area-duration (DAD) analysis is preformed. DAD results are presented in tabular as well as graphical form. A DAD curve is a graphical depiction of the gradual decrease of precipitation depth with the progressive increase of the area of the storm or drainage area away from the storm center for a given duration. The computation of DADs requires gridded hourly precipitation at a high spatial resolution. We used the Storm Precipitation Analysis System (SPAS) to create hourly gridded precipitation, but also to compute DADs. A DAD analysis requires a great deal of computing power, however with the advent of today's computer power and the unique capabilities of SPAS, DADs can now be computed in near real-time.

This paper will discuss the utility of DADs for monitoring storms that have occurred, are occurring or are forecasted to occur over a specific region, watershed or catchment. Since a DAD curve objectively defines the areal extent and magnitude of precipitation, we feel the information contained in a near real-time DAD curves could be used for activating emergency action plans (EAPs) and/or initiating flood warnings.

Beta testing of near real-time DADs took place during the summer of 2009 over a watershed in Missouri. This paper and associated presentation will present some of the results from this pilot study.

Storm Precipitation Analysis System (SPAS)

In order to compute DADs high-resolution hourly precipitation grids are needed. Before SPAS, procedures to compute DADs were developed and used by the Weather Bureau and U.S. Corps of Engineers to analyze storms. (World Meteorological Organization, 1986) These analyses, augmented with subjective judgment by qualified hydrometeorologists, resulted in DADs for use in PMP determination. Although sound and respectable for the time, the Weather Bureau and U.S. Corps of Engineers storm methodology was labor intensive, lacked the use of radar, did not have the rain gauge density that we have today and utilized more assumptions than SPAS. Furthermore, there was never any thought of computing near real-time DADs since the computational power of computers did not exist.

Today however, SPAS operates in a near real-time mode. Grounded on years of scientific research and a demonstrated reliability, SPAS is a proven and widely accepted precipitation analysis software program used to create high-resolution hourly and/or sub-hourly precipitation grids and ultimately DAD results. SPAS incorporates weather radar data together with observed precipitation gauge data to compute accurate spatially distributed precipitation. Improved reliability and accuracy is achieved by calibrating the radar with rain gauge observations and then applying local bias corrections to the precipitation field each hour. It is well known, however, that most mountainous areas of the Western U.S. suffer from poor radar coverage due to radar beam blockage. To overcome this issue, SPAS imposes a climatologically-aided spatial interpolation technique that resolves precipitation patterns in complex terrain. This, combined with areas covered by reliable radar data, allows SPAS to create seamless, accurate and reliable gridded precipitation across any type of geography.

Depth-Area-Duration

Historically, the purpose of a DAD analysis was to determine the maximum precipitation amounts over various area sizes during the passage of storms of say 6-, 12, or 24-hour durations to aid in the computation of probable maximum precipitation (PMP) estimates. The x-axis of a DAD plot (Figure 1) indicates the maximum average depth of precipitation. This represents the maximum average areal precipitation for a given duration and area size during the life of the storm. The y-axis is the area size. So for example, figure 1 shows that during a 36-hour storm event, the heaviest 12-hour 100 sq-mi precipitation was about 11 inches. Notice that when the area of the storm increases, the depth of precipitation decreases, and when the duration of the storm increase for a given area, the depth of precipitation increases.

a)

MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

Area (mi^2)	Duration (hours)									
	1	2	3	4	5	6	12	18	24	total (36-hr)
1	5.79	6.45	7.26	9.05	10.76	11.97	12.93	16.03	17.33	18.04
10	5.13	5.74	6.68	8.55	9.93	11.04	12.24	15.51	16.94	17.06
20	4.88	5.52	6.61	8.32	9.65	10.66	11.94	15.23	16.67	16.77
30	4.63	5.38	6.48	8.15	9.45	10.43	11.75	14.98	16.51	16.59
40	4.36	5.26	6.37	7.98	9.27	10.24	11.57	14.82	16.37	16.45
50	4.13	5.18	6.28	7.84	9.10	10.09	11.42	14.68	16.27	16.33
60	3.92	5.10	6.19	7.72	8.96	9.95	11.29	14.54	16.15	16.22
70	3.70	5.03	6.11	7.61	8.83	9.83	11.18	14.48	16.04	16.10
100	3.47	4.86	5.84	7.34	8.51	9.52	10.92	14.23	15.73	15.80
200	3.10	4.46	5.53	6.79	7.85	8.89	10.39	13.57	14.95	15.08
500	2.64	3.93	4.95	6.07	7.05	7.82	9.67	12.02	13.45	13.52
1,000	2.13	3.52	4.44	5.43	6.35	6.99	8.92	10.84	12.04	12.15
5,000	1.27	2.09	2.83	3.53	4.16	4.76	6.35	7.68	8.55	8.83
10,000	0.67	1.45	2.00	2.52	3.05	3.48	5.14	6.46	7.08	7.36
20,000	0.36	0.85	1.22	1.59	1.87	2.25	3.88	4.98	5.46	5.71
40,000	0.25	0.50	0.65	0.80	1.11	1.26	2.50	3.20	3.63	3.86

b)

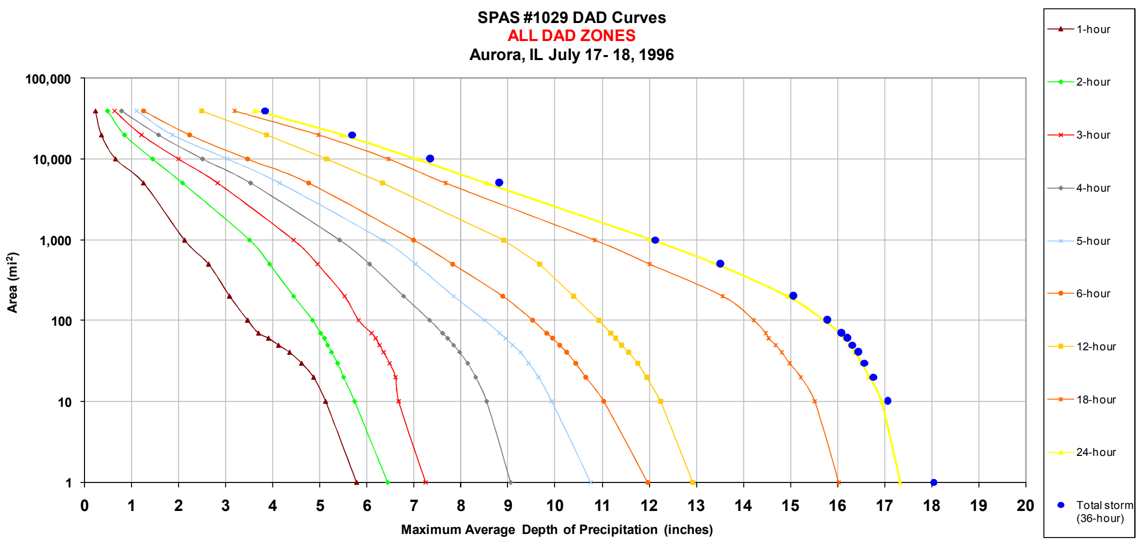

Figure 1: Typical DAD plot (a) and corresponding table (b).

For PMP studies, storm-centered DADs are preformed which means the DAD analysis domain is centered geographically over the area with heaviest precipitation. This was done to capture the heaviest precipitation, regardless of its location. The concept of real-time DADs however, does not need to be constrained by the location of the storm center. For flooding concerns in a specific catchment or basin, a real-time DAD analysis would be constrained to its boundary.

The power of DADs lies in their objective characterization of storms' precipitation. Utilizing radar and/or precipitation gauge information alone does not give an objective sense of a storms areal impact. For instance, a highly localized, extreme storm, sampled by just a single rain gauge, could be inferred as a potentially serious storm, when in reality the areal extent of the storm is too small to cause significant flooding. Similarly, a large, widespread storm could imply serious flooding, but it depends on the amount of precipitation. Although this may seem intuitive, it is difficult to accurately and objectively ascertain the areal extent and magnitude of precipitation over a given catchment by simply evaluating weather radar loops and/or measured precipitation reports. With a trained eye and some defined thresholds, a DAD plot contains a wealth of information.

Figure 2 illustrates how the DAD reacts to two different storms. On the left panel, a highly localized storm is shown; note the scale bar for a sense of this storm's size. The corresponding DAD (below the map) indicates a rapid decrease in precipitation with increasing area size. On the right side a much more widespread storm is shown; here the DAD plot indicates a slower decrease in precipitation with increasing area size. For instance, the 24-hour 1000-square-mile precipitation for the localized storm is 6.75", while the widespread storm has a 24-hour 1000-square-mile precipitation of 12.00 inches. Similarly, at the smaller area sizes, the 1-hour 10-square-mile precipitation is 3.90" and 4.83" for the localized and widespread storms respectively. Knowing this objective information about the storm helps to determine its impact.

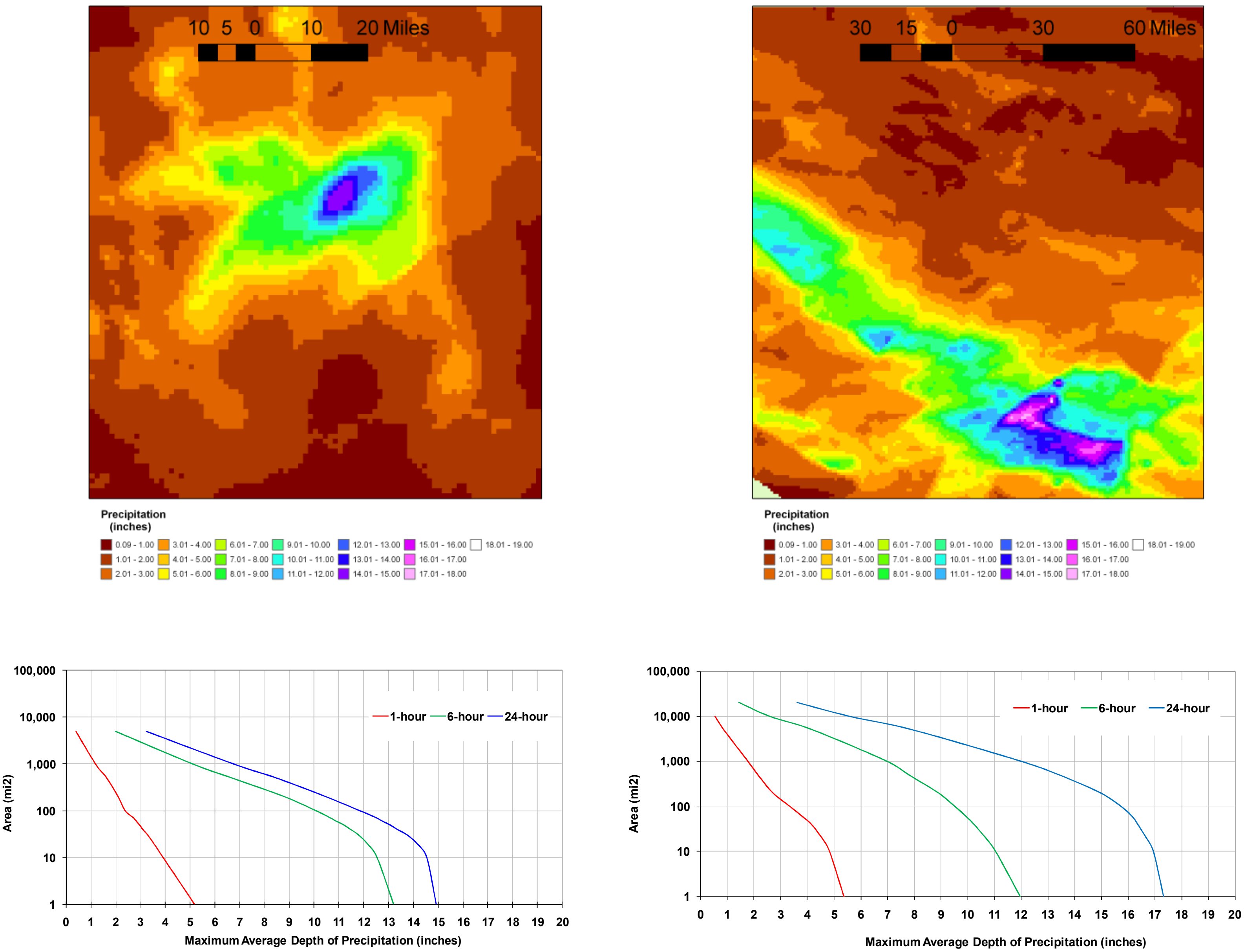

Figure 2. Spatial pattern and magnitude of precipitation vs. DAD plot for a highly localized, smaller storm (left) and a larger storm (right). Note the difference in spatial scale.

The hydrologic response to specific DADs must be determined beforehand so near real-time DADs can be evaluated against calibrated DADs. Determining DADs for past events requires the analysis of historical storms, which SPAS was originally designed to do. Figure 3 shows the 1-hour depth-area curve associated with the heaviest historical storm of record. Knowing the hydrologic response of this event will help decision makers when this DAD is approached or exceeded in the future.

Near Real-Time DADs

Since DADs are an important guide for the design and regulation of hydrologic structures, their use in near real-time can provide powerful, quantitative precipitation information to emergency managers, flood forecasters and dam owners. The term near real-time refers to a period of about 2-12 minutes ago. In other words, near real-time DADs are produced two to about 12 minutes after the last precipitation analysis, which occur on an hourly basis.

Since near real-time DAD plots would become too cluttered if with multiple durations shown, near real-time DAD applications reflect different depth-area plots for different durations. Utilizing real–time hourly, high-resolution precipitation grids from SPAS, a DAD analysis can be conducted in near real-time, for any given time step and for any given watershed. For instance, Figure 3 illustrates a series of four sequential hours of depth-area curves for the 1-hour duration. One can see from this figure the storm intensifying (depths increasing with time) and approaching the storm of record for this watershed.

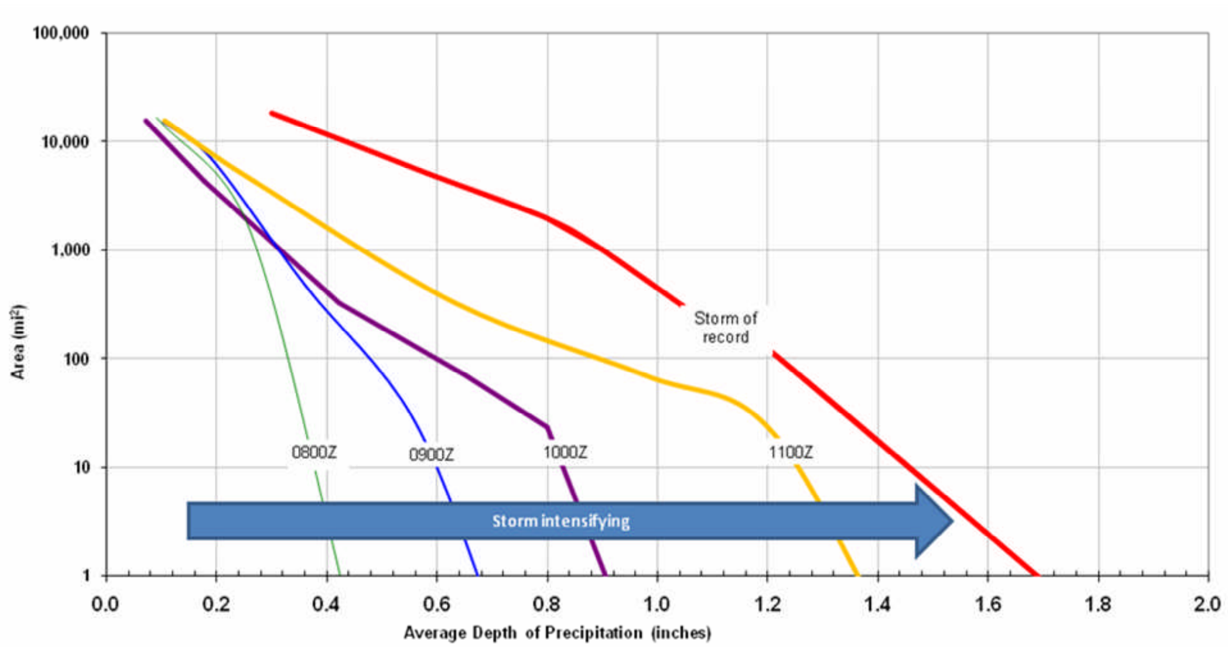

Figure 3. Illustration of four sequential hours of depth-area curves for the 1-hour duration.

Although a DAD is a meteorological (as opposed to hydrological) tool, it together with known hydrologic responses of historical storms, provide an uncomplicated means for objectively assessing precipitation in space, time and magnitude.

Conclusions

Historically, depth-area-duration (DAD) analyses have been computed to aid in PMP computations, but this paper illustrates the value of near real-time DADs for use in activating EAPs and flood warning/monitoring systems. Precipitation in space, time and magnitude are collectively illustrated in a DAD plot. Unlike point precipitation observations and radar loops, a DAD provides a three dimensional perspective of the precipitation.

With beta testing of near real-time DADs complete, a focus on forecasted DADs is the next investigation. Short term (<1 day) depth-area information would provide valuable information about a storms forecasted impact, giving dam owners, emergency personal and the public time to react. EAPs or flood warning systems could be triggered when real-time or forecasted DADs approach, exceed or meet re-defined thresholds.