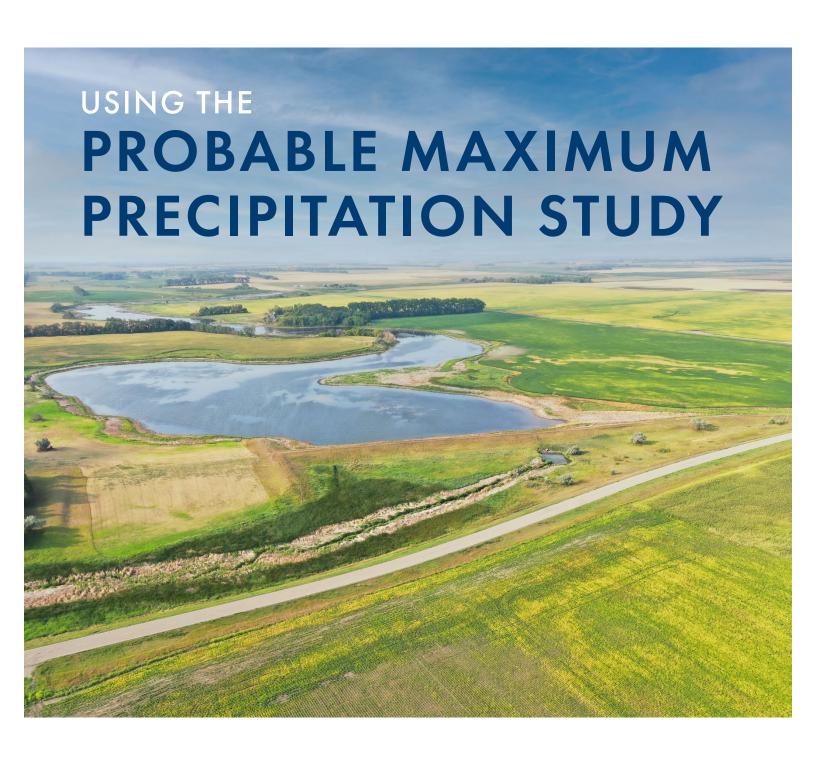
NORTH DAKOTA INTERIM GUIDANCE







INTRODUCTION

In June 2021, the Department of Water Resources (DWR) completed an update of statewide Probable Maximum Precipitation (PMP) data through a two-year PMP study (Study) conducted by Applied Weather Associates (AWA) under contract with the DWR. The Study relies on up-to-date meteorological processes and data from North Dakota and the surrounding region to ensure the best estimate of a natural maximum rainfall. These new datasets will ultimately replace the Hydrometeorological Reports (HMRs) covering North Dakota, derived in the 1970s and 1980s, that were completed by the National Ocean and Atmospheric Administration (NOAA), specifically HMR-48, HMR-51, and HMR-52.

Key stakeholders were involved in the development and review of the Study. These include the following agencies and entities:

- North Dakota Department of Water Resources
- North Dakota State University Climatologist
- · National Weather Service Bismarck Office
- · National Weather Service Grand Forks Office
- United States Army Corps of Engineers
- Natural Resources Conservation Service
- Federal Energy Regulatory Commission
- Houston Engineering, Inc.
- · HDR, Inc.
- BARR Engineering Co.
- RJH Consultants, Inc.

The Study is intended to be utilized by dam owners and the dam design community to help identify appropriate design considerations in the review of potential modifications to existing dams and design of new dams in North Dakota. In addition, the PMP storms and snow water equivalent data will advance hydrologic modeling and analysis for lake and riverine areas throughout North Dakota.

The new PMP estimates are available statewide, including those drainage basins extending across the state border such as the Mouse River, Red River, and Missouri River to Fort Peck. Within that area of interest, PMP values can be estimated for a variety of events. Consistent with the previous HMR studies, summertime rain events lasting up to 120-hours are available. In addition, springtime events or rain on snow events can now be estimated statewide rather than being limited to the Red River and Souris River, as was the case in HMR-48. Temporal and spatial distributions of PMP rainfall events are also available.

Results of this analysis reflect the current standard of practice used for defining PMP, including comprehensive storm analysis procedures, extensive use of geographic information systems (GIS), explicit quantification of orographic effects, updated maximum dew point for storm maximization, development of snow water equivalent (SWE) and temperature time series climatologies, and improved understanding of the weather and climatic conditions related to extreme rainfall and rain-on-snow throughout the region.

The Study includes two GIS tools to allow evaluation of the PMP for individual basins: a PMP Tool and a Snowmelt Tool. The PMP Tool incorporates current standard-of-practice used for defining the PMP, including comprehensive storm analysis procedures, while the Snowmelt Tool provides detailed evaluations of the snow water equivalent (SWE) and associated temperature time series. The tools and detailed Study documentation can be found here.

The DWR has regulatory authority for the issuance of construction permits for the construction or modification of dams, holding ponds, lagoons, or dugouts in accordance with North Dakota Century Code (N.D.C.C.) § 61-16.1-38. PMP analysis is required as part of obtaining a construction permit for certain classifications of structures. This interim guidance was developed to provide technical direction on performing

a PMP analysis using the study results. In addition, this interim guidance discusses the specific requirements related to PMP analysis for dam design, including interim spillway design criteria. Dam designers and owners will have the flexibility to now utilize the Study's results in conjunction with updated freeboard criteria to allow for more complete and technically sound application of the results of the updated Study. However, those who wish to continue to use the HMR information may do so while continuing to follow the guidelines set forth in the *June 1985 North Dakota Dam Design Handbook* (Handbook). See the section on Dam Design Implications at the end of this document for specific guidance regarding the use of the Study results for dam design purposes.



USE OF THE PMP STUDY TOOLS

Dam designers that will use the Study's GIS tools should have the objective of identifying the most extreme precipitation that can occur within an individual basin. Several storms should be analyzed using the PMP Tool and Snowmelt Tool to find the controlling storm (i.e., the most severe storm event possible).

The PMP Tool can analyze three types of storms: general, local and cool season. The general storm is typically a frontal storm and occurs over one to several days. Local storms are convective and occur in shorter time frames. The cool season storm is typical of rainfall in the winter or spring that may happen while the ground is still frozen. The cool season storm is used in conjunction with output from the Snowmelt Tool to model rain-on-snow events.

The guidelines below should be followed when performing a PMP analysis using these Tools. However, the user is responsible for determining which storm is most appropriate to use for their basin and project.

For All Basins

- The local storm should be evaluated separately from the general storm, and the results should not be combined.
- Engineering judgment must be used to select an appropriate basin size category, with basins larger or smaller than 100-square miles being a general threshold that helps define what is required for the PMP analysis. Typically, the designer should consider multiple storm types for basins near this size limit to verify that an appropriate storm was selected as the controlling storm.
- 3. Evaluate 2-hour, 6-hour, 24-hour, and 72-hour storm events as appropriate for the specific basin.
- 4. Consider that a smaller, more intense local storm over only a portion of the basin could be controlling for any basin size.



For Basins 100-Square Miles Or Larger

- 1. Analyze the cool season storm and the general storm.
- 2. Analyze alternative spatial patterns or break up the PMP analysis on a sub-basin level.

For Basins Smaller Than 100-Square Miles

- 1. Analyze the local storm and the general storm.
- 2. The general storm should not be used for basins 20 square miles or smaller.

Temporal Distributions

- 1. The critically stacked temporal distribution pattern is the most conservative temporal distribution.
- 2. Results from other temporal patterns associated with each storm type within the PMP Tool may be used for design as appropriate, provided the results in the checking file for that storm indicate "PASS". The precipitation results based on other temporal distribution patterns may be more realistic than the critically stacked pattern and can be used to refine the PMP analysis.
- 3. For regulatory purposes, as described in the section of this document on Dam Design Implications, the critically stacked temporal distribution is accepted for use by the DWR. The user must provide the DWR with a documented explanation justifying the use of a temporal distribution that is different than the critically stacked distribution.

Cool Season Storms

- The cool season hydrograph, derived using cool season rainfall values from the PMP Tool, must be modeled in conjunction with results from the Snowmelt Tool. Snowmelt results are given in depth of runoff per day. The snowmelt should be modeled as baseflow when developing the basin response. The four input variables in the Snowmelt Tool are the start and end date of the melt, the rain-on-snow event duration, and the melt coefficient.
 - a. In the Snowmelt Tool, snowmelt can begin between March 1 and June 1, depending on the basin's size and location. An iterative process should be used to identify start and end dates that maximize the volume of snowmelt based on snow water equivalent and the temperature time series. Iterating through the snowmelt coefficients over the season (March 1 to June 1) will narrow the start date search. The date that snowmelt begins can be determined by looking for the first date that snowmelt occurs in the Snowmelt Tool output table. In the example below, the start date of the melt would be March 28.
- b. To model a rain-on-snow event for determining the cool season PMP, a rain-on-snow event should be added using the Snowmelt Tool, which increases snowmelt for the duration of the event. The snowmelt end date should be late enough to ensure all snowmelt accumulation is accounted for.
- c. The melt coefficient sets the conditions for the melt and should be conservatively assigned. If a rain-on-snow event is being considered, larger coefficients ripen the atmospheric and snowpack conditions to yield a higher meltrate. The "clear sky" melt coefficient is not applicable for modeling a rain-on-snow event.

More detail on how to use the PMP tool and the Snowmelt Tool is available in the tools' documentation that can be found here.

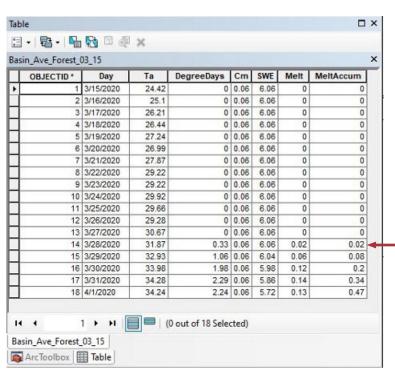


Figure 1 - Example Snowmelt Tool output table.



DAM DESIGN IMPLICATIONS

The results of the Study will ultimately supersede previous guidance for determining PMP values provided by HMR-51, HMR-52, and HMR-48. The DWR's intent is to require the use of the Study results at a future date in conjuction with a comprehensive dam design guidance update. However, there is flexibility to use either the Study results or the HMRs for an interim period. During this interim period, it is strongly recommended that the Study results be used for dam design, as the Study provides the most accurate, updated PMP estimates available for North Dakota.

The Study results are applicable to the design of high hazard dams and medium hazard dams where current spillway design standards are based on PMP values. Previously, the HMRs were utilized for the selection of the PMP value, which was then used by dam designers to meet the freeboard and velocity design requirements given in the Handbook, and shown in Figure 2. This included the fraction of PMP process that is no longer considered appropriate with the current state of the dam design practice. For an interim period, the freeboard and velocity criteria shown in Figure 2 may continue to be used in conjunction with PMP data from the HMRs. However, the percentages of the PMP shown in Figure 2 are not a technically sound approach for use with the Study results, so freeboard criteria based on Selecting and Accommodating Inflow Design Floods for Dams (FEMA P-94), FEMA, August 2013, will be used in conjunction with the Study results. Further details on these requirements are outlined below.

Table 5-1. Suggested Precipitation	Criteria
For Spillway Design 1 2 3	

Dam Design	Principal	Emergency Spillway Criteria		
Classification ⁴	Spillway ⁵	Velocity ⁶	Freeboard ⁷	
ı		P,,	P ₂₅	
II		P ₂₅	P ₅₀	
111	P ₂₅	P ₁₀₀	.3 PMP	
IV	P ₅₀	.3 PMP	.5 PMP	
V	P.00	.4 PMP	PMP	

- 1 Precipitation amounts by return period in years.
- ² PMP = Probable Maximum Precipitation.
- ³ Each dam will have to be carefully evaluated to determine potential impact of dam failure. If the design engineer can show that damages and loss of life would not be significant as a result of failure, the State Engineer may allow a smaller event as the acceptable criteria.
 - 4 See Table 4-1, page 3.
- 5 The requirement of the principal spillway event is to pass the flows without use of a non-structural emergency spillway.
- The requirement of the velocity hydrograph is to pass the flows within acceptable velocity limits (See Table 5-2, page 6).
- ⁷ The requirement of the freeboard hydrograph is to pass the flows without overtopping the dam.

Figure 2 - "Table 5-1, Suggested Precipitation Criteria For Spillway Design," *North Dakota Dam Design Handbook*, North Dakota State Engineer, June 1985.



When using the Study results for dam design, the goal is to develop the Inflow Design Flood (IDF) for the dam. The IDF is the flood that is used to design a dam and its appurtenances. Once the most severe rainfall event has been found using the PMP Tool, rainfall-runoff modeling is needed to develop the IDF. Multiple potential design storms will likely need to be analyzed with hydrologic modeling to identify the controlling storm event to be used for the IDF. The controlling storm may not be readily apparent from the precipitation results alone.

For the purposes of obtaining a construction permit to construct or modify a dam, holding pond, lagoon, or dugout in accordance with N.D.C.C. § 61-16.1-38, the interim spillway design criteria options outlined below provide guidance on the options available to construction permit applicants. The DWR must review and approve the PMP and the associated IDF as part of the process to obtain a construction permit, based upon the path selected by the applicant. For either PMP selection path chosen, applicants must provide documentation of their rationale to justify selection of the PMP and resulting design decisions.



For any dam meeting the definition of a high hazard dam under North Dakota Administrative Code (N.D.A.C.) ch. 89-08-01, including both new dams and modifications to existing dams, there is flexibility to use either of the two options below.

- PMP data from the HMRs, in conjunction with the existing freeboard and velocity criteria in Figure 2. The principal spillway criteria given in Figure 2 still apply.
- 2. The Study results. If using the Study results for design, the following design requirements apply:
 - a. The IDF for the dam must equal the probable maximum flood (PMF). The PMF is the flood that results from the PMP. The requirement is for the dam to pass the PMF without overtopping the dam.
 - b. The principal spillway criteria given in Figure 2 still apply.
 - c. Any auxiliary spillway must be adequately designed to prevent excessive erosion, without specific reference to the velocity requirements in Figure 2. Justification for the spillway design, showing that excessive erosion will not occur, must be included in the construction permit application materials.

For any dam meeting the definition of a medium hazard dam under N.D.A.C. ch. 89-08-01, including both new dams and modifications to existing dams, the same two options outlined above for high hazard dams apply. In order to use the Study results for the design of a medium hazard dam, the dam must be designed to accommodate the full PMF as described in option 2(a) above for a high hazard dam.

The Study results are not applicable to the design of low hazard dams. Low hazard dams should continue to be designed to the criteria given in Figure 2, unless the dam owner or designer wishes to voluntarily design design the dam to a higher standard.



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