EVALUATION OF THE HYDROLOGIC EFFECTS OF STOCK PONDS ON A PRAIRIE WATERSHED

by

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INTRODUCTION

Background

The World Wildlife Fund (WWF) is interested in restoring prairie streams on the American Prairie Reserve in north central Montana. Prairie streams provide vital habitat and beneficial processes for several plant and animal species in the area and are critical to successful wildlife conservation. Interest in stream restoration has led the WWF to question the hydrologic effect of numerous stock ponds located throughout the reserve. The unknown influence of the stock ponds provides the motivation for this research.

The hydrology and ecology of the semi-arid landscape of north central Montana has been impacted by agricultural operations (Figure 1.1). While some grains and hay are grown in the region, the majority of the area is considered most suitable for cattle production. This has resulted in the visible alteration of the landscape by the construction of stock ponds to expand livestock grazing range. Because the region is prone to drought, many ephemeral channels have been dammed to store and utilize the limited available precipitation. These stock ponds are ubiquitous in the region and can occur at a density of one to two per square mile. Groundwater typically does not contribute to the water balance of the ponds, and most ponds retain water only on a seasonal basis depending on yearly precipitation amounts. However, a few of the larger ponds can consistently hold water throughout the year. These ponds have likely affected the natural hydrologic cycle of the watershed, but the extent of that change has not been previously investigated.

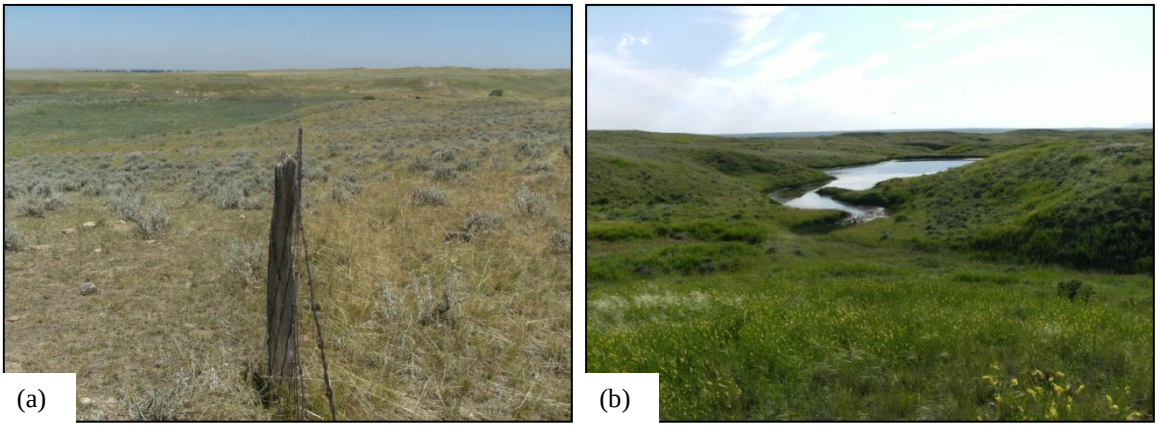

Figure 1.1: Box Elder Watershed; (a) a fence dividing grazed land and land unaffected by grazing and (b) a stock pond.

Few ephemeral watersheds greater than one square mile in the region, including the Box Elder Watershed, have been left in an unaltered condition. Therefore a direct comparison of watersheds with and without ponds is not practical, necessitating the need to model pond removal to determine the ponds' effects. Nevertheless, some general inferences on the influence of the ponds can be made. Stock ponds increase water storage within the watershed and alter the natural hydrologic response of these prairie streams by reducing runoff volume and attenuating peak flows. The magnitude of these changes as well as the impact of these changes on the hydrologic function of these streams remains uncertain, and this study aims to quantify the individual and cumulative effects of stock ponds on the hydrologic regime of the Box Elder Watershed specifically which can serve as a model for other prairie watershed systems.

The Box Elder Watershed was chosen as the study site for an investigation into stock pond effects partly because it has a large percentage of land set aside for wildlife management. Currently 81% of Box Elder is either deeded to the American Prairie

Foundation (APF) or managed by it through blocks leased from the Bureau of Land Management (BLM) or controlled by the CMR National Wildlife Refuge. This better allows for changes in water management to be readily implemented and for the establishment of an experimental watershed.

The WWF and APF, in particular, are motivated to restore this watershed to a more naturally functioning hydrologic state. Concerns over the current state of Box Elder's hydrology include the stock ponds' negative effect on riparian habitat. Stock pond inclusion could be impeding natural processes necessary for seed dispersal. Geomorphic stream changes due to lower flow rates and less sediment in the system may have resulted in new stream and floodplain interactions. Less scouring in the floodplain reduces the size and variability of the riparian zone. A more detailed discussion on the impacts of dams is included in the literature review.

A few projects in the region aim to restore in-stream flows and riparian areas. In-stream dams on two creeks neighboring the Box Elder Watershed have been removed, and native grasses have been re-planted in selected areas. There are plans to observe resultant changes over time, but to date little hydrologic monitoring or modeling has been completed for the area.

While hydrologic restoration is a main priority on the American Prairie Reserve (APR), it is imperative that the watershed still maintain its suitability for a bison herd and other wildlife. Currently, a herd of about 200 bison reside on the reserve and use the ponds as water sources. The herd does not have its historic grazing range to search for water and must have access to water sources year round. The ponds preferred by wildlife

and the ponds having the greatest effect on hydrologic function may or may not be the same, and a compromise between competing objectives may be required regarding which ponds to remove. A developed hydrologic model will provide an immediate tool for ranking the significance of each pond based on its effects on flow rate and runoff volume.

Goals and Objectives

The primary goal of this research was to quantify the cumulative effect of Box Elder Watershed's stock ponds on peak flow rates and runoff volumes through a mathematical model created within the United States Army Corps of Engineers' (USACE) Hydraulic Engineering Center's Hydrologic Modeling System (HEC-HMS). Additionally, determining the effects of individual ponds was a desired outcome of the project so that recommendations could be made regarding their potential removal. These goals were obtained through the following objectives:

1. Field work. Physical characteristics of the ponds and streams were measured for input into the model. Pond measurements were used to develop storage functions and describe the outflow of the ponds. The site was monitored for rain and runoff events for model calibration.

2. Model setup. A geographic information system (GIS) was used to quickly abstract parameters and delineate the watershed. The appropriate files were also created in a GIS for the HEC-HMS model.

3. Model calibration. A rating curve was developed to transform measured stage data into flow rates for calibration. Parameters not related to physical characteristics were then manually adjusted to match observed responses of the watershed.

4. Pond analysis. The HEC-HMS model was run for several scenarios using developed frequency storms. The model was run with all of the ponds in and all of the ponds out to determine the cumulative effects of the ponds. The watershed

was also simulated with only one pond in at a time to determine what, if any, parameters related to the pond could predict their subsequent influence.

5. Pond removal. The model was run with all ponds in except one to determine which individual ponds had the greatest effect on the flow regimes. A list ranking the impact of the ponds was compiled for each of the frequency storms.

SUMMARY AND CONCLUSIONS

The hydrology of Box Elder Creek was modeled to explore the effects of 28 stock ponds currently on the watershed. Stock ponds have received little attention in regards to their influence on flow regimes, and this research helped to quantify their impact for water management decisions on the American Prairie Reserve. Limited research on farm dams had previously been completed for watersheds in Austrailia [e.g. Callow and Smetten 2009; Schreider et al 2002; Verstraeten and Prosser, 2008], but no work was found on stock ponds and their watershed-scale effects in the Northern Great Plains. This work is meant to help guide efforts in restoring prairie streams.

Modeling Box Elder Watershed involved a combination of field and computer work. The ponds were identified from aerial photos and verified during field investigations. Each pond's volume was described through a stage-area function fitted to field measurements and then entered into the HEC-HMS model to account for the model's stage and storage requirements. Additional field measurements included those to describe the shapes and roughness parameters of the channel reaches. Physical parameters not measured in the field were abstracted through a GIS using HEC-GeoHMS. HEC-GeoHMS was also used to set up the HEC-HMS model and transform the precipitation point data into an appropriate form.

After the model was constructed, the model was refined by the calibration of specific parameters using measured flow data. Because only water height had been recorded, calibration was preceded by the development of a rating curve for the outlet's culverts to convert stage data to flow rates. A HEC-RAS model was built to describe the

hydraulics at the outlet. Once the model was calibrated, the watershed was simulated with all of the ponds left in and all of the ponds taken out for synthesized frequency storms. This served to quantify the cumulative effect of the ponds.

Results showed that the ponds are having a noticeable effect on the flow regimes of Box Elder Watershed and indicate that some pond removal will be necessary to mitigate peak flow and volume reductions caused by the inclusion of the ponds. Model simulations with only one pond out at a time showed that most ponds have a negligible individual effect. This means multiple ponds will have to be removed to achieve significant changes. Unfortunately, no simple relationships between a pond's parameters and its influence on flows could be discerned from the data, making pond removal predictions without the aid of a model more difficult for areas outside of Box Elder Watershed. The following list summarizes key findings from the analysis of the hydrologic model for Box Elder Watershed:

- A simulated Box Elder Watershed with no stock ponds demonstrated that the stock ponds are reducing peak flow rates by 12.7% to 24.1% and reducing runoff volumes by 10.1% to 16.8% depending on the return interval of the design storm modeled.

- An analysis of pond parameters and the ponds' corresponding influence on peak flow rate and runoff volume was unsuccessful in finding a simple relationship that could predict a pond's impact and be used for other watersheds.

- A ranking system that combined all the results from runoff volume and peak discharge provided an ordered list of the relative influence of the ponds on Box Elder Watershed.

- The results showed that making watershed management decisions based on runoff volume may be acceptable when there are limited resources. The curve number equation can be applied inexpensively to other watersheds to determine which ponds should take priority for removal.

This project highlights the need for further investigations into stock ponds and their influence on the hydrology of prairie systems. Pond removal is a likely outcome in efforts to restore portions of the Northern Great Plains to a more unaltered condition, and careful planning will be required to maintain suitability for animals living on limited ranges.