ESTIMATION OF GROUNDWATER RECHARGE IN THE POWDER RIVER BASIN[1]

Fred L. Ogden,[2] and Kerri Puckett[2]

Abstract. This paper evaluates the uncertainty associated with a water budget model developed to predict the recharge rate to deep aquifers in the Power River Basin (Northeastern Wyoming). The controlling factors in this model are springtime snowmelt, streambed infiltration, infrequent convective rainfall, and evapotranspiration. The dominant recharge mechanism for the deeper aquifer units was assumed to be infiltrated water at the aquifer margins, where the formations daylight at the edges of the basin. Historical records were used to model infiltration along the formations and gaps in spatial and temporal data were filled using radar-rainfall estimates and climate model reanalysis. Model estimates were compared to field measured values. The uncertainty associated with each component of the water budget model is quantified using a Monte Carlo analysis and error bounds were established for each input parameter, ultimately trying to develop a new methodology to estimate groundwater recharge in semi-arid areas using recent advances in instrumentation and remote sensing.

Additional Key Words: evapotranspiration, infiltration, soil moisture, precipitation, measurements, modeling, development, research, methodology.

---

[1] Paper was presented at the 2007 National Meeting of the American Society of Mining and Reclamation, Gillette, WY, 30 Years of SMCRA and Beyond June 2-7, 2007. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

[2] Fred L. Ogden, Professor and Cline Distinguished Chair of Engineering, Environment and Natural Resources, and Kerri Puckett, Graduate Student, Department of Civil and Architectural Engineering, University of Wyoming, Laramie, WY 82071 USA

Proceedings America Society of Mining and Reclamation, 2007 pp 557-560
DOI: 10.21000/JASMR07010557
http://dx.doi.org/10.21000/JASMR07010557

Introduction

The semi-arid environment of Wyoming makes water of utmost importance and therefore the ability to accurately predict the movement of water is of high importance as well. Recently, waters related to Coal Bed Natural Gas (CBGN) production have been of concern, both in quality and quantity. Groundwater quantity in the Powder River Basin (PRB) is of concern here.

Groundwater is produced in the as a by-product of CBGN extraction in the PRB. Depending on the water quality, it is placed in infiltration/evaporation ponds or discharged into the surface flow. It is predicted that over the life of the CBGN project over 3,000,000 acre-feet will be removed from the groundwater storage in the Wasatch and Fort Union Formations (BLM, 2003). This equates to approximately 800 feet maximum drawdown in the Fort Union Formation. As part of the Environmental Impact Statement (EIS) for the PRB, the Bureau of Land Management (BLM) predicted:

> "Recovery to within 50 to 100 feet of pre-development water levels occurs by 2030. By 2060, water levels in the coal would recover to within 10 to 50 feet of preoperational levels, exception in very localized areas of the basin. Recovery of more than 50 percent in the deep Wasatch Sands would occur by 2030."

However, the PRB EIS (BLM, 2003) contains critical assumptions about the recharge rates across the basin that are not fully justified and further research is necessary to verify or contradict the recovery time.

<u>Geology and Groundwater Recharge in the Powder River Basin</u>

Structurally, the Powder River Basin is part of a broad syncline bounded by the Bighorn Mountains to the west, the Black Hills to the east, and the Casper Arch, Laramie Mountains, and the Hartville uplift to the south. The PRB geology is defined by two major formations, the Wasatch and Fort Union, and alluvium veins. The Fort Union formation is further classified into four members: Undifferentiated Fort Union, Lebo Member, Tongue River Member, and the Tullock Member. Heffern and Coates (1999) found recharge to confined units occurred primarily at basin margins, primary in the highly permeable clinker deposits. The eastern PRB is the primary recharge area for the Wasatch formation (Davis, 1976) and the western boundary is the primary recharge zone for the Fort Union formation (Bartos and Ogle, 2002). Throughout the majority of the basin, the Fort Union formation lies below the Wasatch formation, sometimes over 1400 ft below (WRDS online document). Until the Fort Union daylights from underneath the Wasatch, negligible recharge is expected. The Fort Union daylights at the base of the Bighorn Mountains on the western edge of the basin and again on the western boundary, near the Black Hills.

Model Description and Work in Progress

Having identified the major recharge zones, we propose to estimate the groundwater recharge to the deep aquifers using a water balance equation:

[illegible] (1)

Where P is rainfall, SM is snow melt, ET is evpotranspiration from the land surface, including sublimation of snow, RO is the volume of surface runoff leaving the study area, and ΔGW_{DEEP} and $\Delta GW_{SHALLOW}$ are the changes of volume in the deep and shallow aquifers, respectively.

We are in the process of collecting our own data on evapotranspiration, rainfall, net radiation, and soil moisture at two locations in the Tongue and Powder River Basins in far northern Wyoming. An example of one of our instrumentation sites is shown in Fig. 1. We are also collecting existing data sets to develop a stochastic basin-average precipitation estimate, including March 1 snowfall, and summertime convective rainfall. These data will be used to drive a land-surface model such as the Variable Infiltration Capacity (VIC) model. Model predictions within a Monte-Carlo framework will allow us to estimate basin average recharge rates to the deeper confined units, including confidence limits. The end result of this research will be an improved methodology for estimating groundwater recharge rates in semi-arid regions in the northern Rocky Mountains.

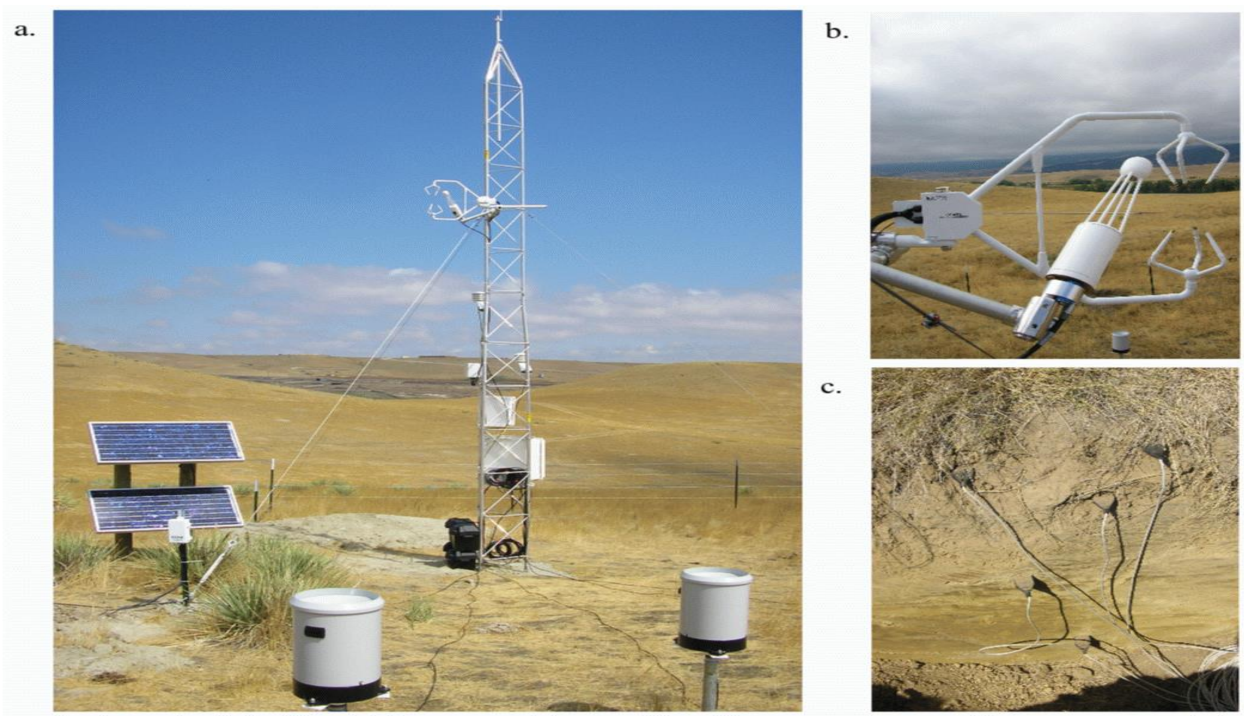

Figure 1. Instrumentation installed in the Powder and Tongue River Basins: a) Eddy-covariance flux tower; b) Infrared Gas Analyzer and 3-D Sonic Anemometer; c) Soil Moisture Probes

Cited Literature

Bartos, T.T. and K.M. Ogle. 2002. Water quality and environmental isotopic analyses of ground-water samples collected from the Wasatch and Fort Union formations in areas of coalbed methane development – implications to recharge and ground-water flow, eastern Powder River Basin, Wyoming. U.S.G.S. Water-Resources Investigations Report 02–4045, 88 pp.

BLM, Bureau of Land Management. 2003. Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project, Wyoming State Office, WY-070-02-065.

Davis, R.W. 1976. Hydrologic factors related to coal development in the eastern Powder River Basin. Geological Association 28th Annual Field Conference Guidebook. p. 203–207. *In* R.B. Laudon (ed.) Geology and Energy Resources of the Powder River. Wyoming Geological Association 28th Annual Field Conference Guidebook.

Heffern, E.L. and D.A. Coates. 1997. Clinker - Its occurrence, uses, and effects on coal mining in the Powder River Basin. p. 151–166. *In* R.W. Jones and R.E. Harris (eds.) Proceedings of the 32nd Annual Forum on the Geology of Industrial Minerals. Wyoming State Geological Survey Public Information Circular 38.

Monks, J. "Comments on Draft Environmental Impact Statement and Draft Planning Amendment for the Powder River Basin Oil and Gas Project." Powder River Basin.org. 23 May 2002. Powder River Basin Resource Council. Accessed 4 Dec 2006. http://www.powderriverbasin.org/cbm/expert_monk.shtml.