Significance of Uncertainty in Water Resources Decisions for Western Pennsylvania’s Marcellus Shale

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A DROP OUT OF THE BUCKET...

- Total volume of approved water withdrawals in Pennsylvania’s Ohio River Basin ~100 MGD as of July 1st 2010

- July 2010 Average daily discharge of the Ohio River at Sewickley ~9,200 MGD

Source: http://www.marcellus-shale.us/impoundments.htm
APPROVED WATER SOURCES FOR HYDRAULIC FRACTURING
PaDEP REQUIRES WATER MANAGEMENT PLANS FOR ALL HYDRAULIC FRACTURING SOURCES

- Withdrawal impact assessments are necessary for the approval of surface water sources
- Water allocations based on discharge statistics
Q$_{7-10}$
- 10 percent or less of the natural or continuously augmented 7-day, 10-year low flow of the stream or river. (SRBC)

Passby flow
- Prescribed quantity of flow that must be allowed to pass a prescribed point downstream from a water supply intake at any time during which a withdrawal is occurring. (SRBC)
- Monitored using provisional daily discharge data
GAGED AND UNGAGED DISCHARGE STATISTICS

Gaged streams

- Rating Curve
- Stage-discharge field measurements
- Provisional Daily Discharge
- Daily stage measurements
- Approved Discharge Record
- $Q_{7-10}$ Discharge & Average daily flow

Ungaged streams

- Regional Regressions and Gage Correlations
UNCERTAINTY OF THE RATING CURVE

Gaged streams

- Rating Curve
- Stage-discharge field measurements
- Provisional Daily Discharge
  - Daily stage measurements
- Approved Discharge Record
  - $Q_{7-10}$ Discharge & Average daily flow

Ungaged streams

- Regional Regressions and Gage Correlations
FIELD MEASUREMENTS

- Measurement device and operator error
  - ‘Good’ measurement 3–6% error (Sauer and Meyer, 1992)
- Variable environmental conditions

Source: USGS OSW

Source: USGS Basic Training Materials
Gaged streams

Rating Curve
Stage-discharge field measurements

Provisional Daily Discharge
Daily stage measurements

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Q7–10 Discharge & Average daily flow

Ungaged streams

Regional Regressions and Gage Correlations
PREDICTIVE CAPABILITY OF STATISTICAL MODELS

- Log-linear rating curve
- Log-Pearson Type III

Source: Bayesian Power Law Regression, Reitan 2008
ERROR IN DAILY DISCHARGE

Gaged streams

Rating Curve
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Q_{7-10} Discharge & Average Daily Flow

Ungaged streams
Regional Regressions and Gage Correlations
UNSTEADY STAGE–DISCHARGE RELATIONSHIP

- Provisional daily discharge includes the effects of environmental variability on rating curves
  - Three months to one year before provisional data is accepted

Source: USGS Basic Training Materials
EXTRAPOLATION ERROR

Gaged streams

Ungaged streams

Rating Curve

Stage-discharge field measurements

Provisional Daily Discharge

Daily stage measurements

Approved Discharge Record

Q_{7-10} Discharge & Average Daily Flow

Regional Regressions and Gage Correlations
Predicted $Q_{7-10} = -3.81524 + 1.23338 \times \log(\text{Drainage Area}) + 0.56179 \times \log(\text{Mean Elevation})$
COONS CREEK in REGION 3

Predicted $Q_{7-10} = -10.1337 + 1.07462 \times \log(\text{Drainage Area}) + 0.82334 \times \log(\text{Mean Elevation}) + 3.7325 \times \log(\text{Mean An. Precip.})$

Source: Stuckey, Marla. Low-Flow, Base-Flow, and Mean-Flow Regression Equations for Pennsylvania Streams, USGS

Histogram of Predicted $Q_{7-10}$ at Coon’s Creek

95% confidence intervals

Pennsylvania General Energy Approved Withdrawal
VIOLATIONS OF REGIONAL REGRESSION ASSUMPTIONS

- Unknown water diversions and consumption
- Streams impacted by mining

Surface Withdrawals and mining operations in Southwestern Pennsylvania
Under current system, streams have been “sucked” dry
Low flow raises water temperature which decreases dissolved oxygen
Protect existing uses
- Public water supplies
- Power plant and industrial cooling
- NPDES permitted dischargers
WHAT THE PaDEP CAN DO IN THE SHORT-TERM

- USGS StreamStats
  - Use given confidence intervals for $Q_{7-10}$ extrapolation
  - Uphold assumptions on which the regression is based
- Establish margin of error when using reference gages for passby flows
- Long-term solution involves more gaging
Taking too much water, especially during low-flow, negatively impacts local ecology and downstream users.

Discharge statistics are uncertain at gaged and ungaged sites.
- Extrapolation to ungaged sites must be done with care.

Provisional gage data includes natural variability.
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