

**Monitoring for Baseline Radiochemistry before Natural Gas
Development in the Delaware River Basin**

DELAWARE RIVER BASIN COMMISSION



Delaware River Basin Commission

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Acknowledgements

This report was prepared by the Delaware River Basin Commission staff: Steven J. Tambini, P.E., Executive Director. John Yagecic was the principal author of the report. Mr. Yagecic is the Supervisor of the Standards & Assessment Section in the Modeling, Monitoring, and Assessment Branch and a licensed professional engineer. Dr. A. Ronald MacGillivray was a contributing author and is the Commission's Environmental Toxicologist. Project support was provided by Dr. Thomas Fikslin, Elaine Panuccio, Eric Wentz, Victoria Trucksess, Jerrell Spotwood, and Jessica Sanko of the Delaware River Basin Commission, and Dr. Bahman Parsa and William Kirk Nemeth of the New Jersey Department of Health, Radioanalytical Services.

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This report describes the results of monitoring baseline radiochemistry before natural gas development in the Delaware River Basin, funded by the William Penn Foundation under Grant #56-13.

Project Description

From January 2014 through May 2015, the Delaware River Basin Commission (DRBC) collected surface water samples from a total of 32 Interstate Control Points (ICPs; mainstem Delaware River), Boundary Control Points (BCPs; tributaries to the Delaware) and other tributary monitoring points for radiochemistry analysis. This work was performed with financial support from the William Penn Foundation under Grant #56-13. Samples were analyzed by the New Jersey Department of Health Laboratory for the following parameters:

- Gross alpha & gross beta (evaporation), NJDHSS ECLS-R-GA & GB
- Radium -226 + Radium-228, NJDHSS ECLS-RA-RA226/228

This report documents the results of the sampling and analysis effort and its relevance toward documenting baseline radiochemistry conditions in the mainstem Delaware River and select tributaries. Details on sampling and analysis are contained in the project Quality Assurance Project Plan (QAPP) dated October 4, 2013.

Figure 1. Baseline Radiochemistry Sampling Locations

Radiochemistry Sites

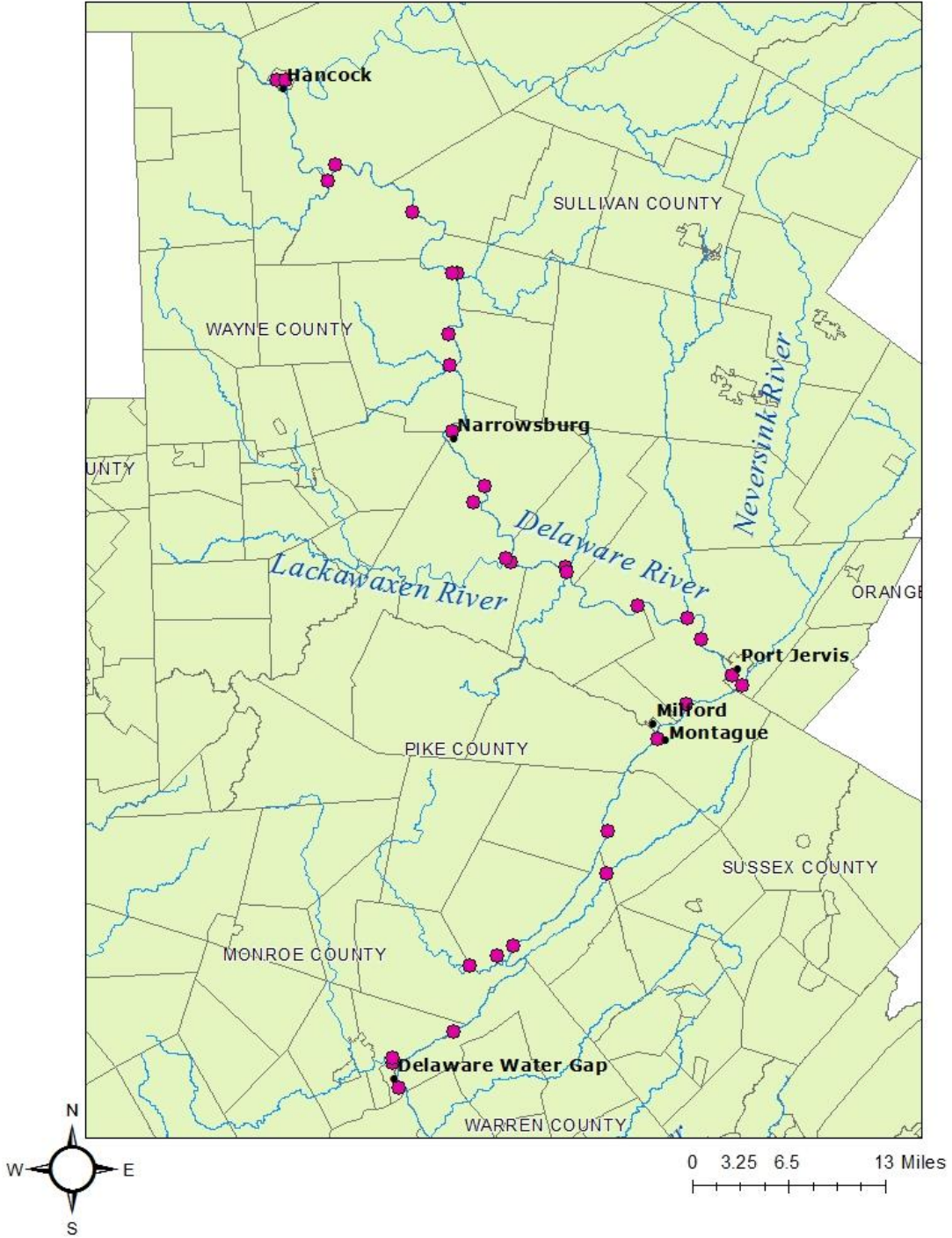


Table 1. Sampling Locations and Coordinates

Sample Location Name	Latitude	Longitude
West Branch Delaware River	41.9525	-75.29121
East Branch Delaware River	41.95199	-75.28016
Delaware River at Lordville	41.86917	-75.21444
Equinunk Creek	41.85333	-75.22528
Delaware River at Kellems Bridge	41.82333	-75.11417
Delaware River at Callicoon	41.76472	-75.06167
Callicoon Creek	41.76418	-75.05563
Delaware River at Damascus	41.705	-75.0675
Calkins Creek	41.67361	-75.06528
Delaware River at Narrowsburg	41.60944	-75.06222
Ten Mile River	41.55606	-75.019541
Masthope Creek	41.5401	-75.03384
Lackawaxen River	41.48639	-74.99222
Delaware River at Roebling Bridge	41.48196	-74.98566
Delaware River at Barryville	41.47694	-74.91389
Shahola Creek	41.47222	-74.91319
Delaware River at Pond Eddy	41.43944	-74.82028
Mongaup River	41.42694	-74.75611
Delaware River at Millrift	41.40639	-74.73917
Delaware River at Port Jervis	41.37167	-74.69778
Neversink River at Port Jervis	41.36111	-74.68556
Delaware River at DEWA Boundary	41.34361	-74.75778
Delaware River at Montague	41.30917	-74.79556
Delaware River at Dingmans	41.219691	-74.860184
Flatbrook Creek	41.17871	-74.86159
Delaware River at Bushkill Access	41.10833	-74.98194
Little Bushkill Creek	41.09778	-75.00417
Bushkill Creek	41.08861	-75.03833
Delaware River at Smithfield Beach	41.02444	-75.05972
Marshalls Creek	40.99861	-75.13833
Brodhead Creek	40.993385	-75.137787
Delaware River at Kittatinny Access	40.96951	-75.12939

Project Outputs and Outcomes

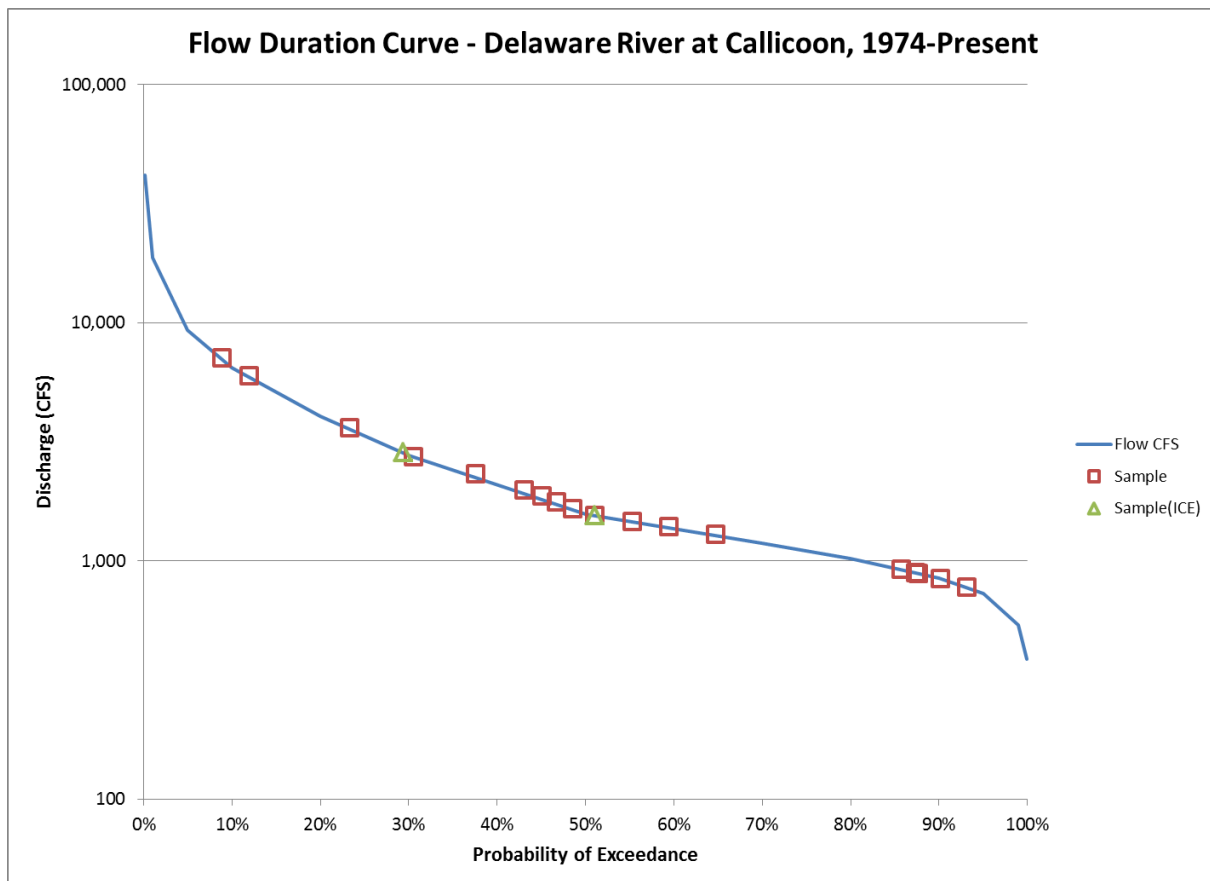
Under this project, DRBC characterized baseline radiochemistry at water quality control points, before the potential introduction of technologically-enhanced naturally occurring radioactive materials (TENORMs) associated with gas extraction using hydraulic fracturing techniques. In all 163 water samples (including field blanks and replicates) were collected and analyzed for alpha emitters, beta emitters, radium-226,

and radium-228. A link to the analytical results are provided in **Appendix A** of this report. This effort will provide a baseline for water quality protection over the long term.

Monitoring over the Flow Regime

Prior to initiation of this project, we did not know if radiochemistry activity measurements would vary with flow condition. As such we sought to sample over a range of flow conditions, so as not to limit sampling to either high or low flow conditions. Figure 2, below, shows flow conditions reported by the US Geological Survey (USGS) at gage 01427510 on Delaware River at Callicoon, NY (a representative site for the overall monitoring region) on each sample collection day plotted against the probability of exceedance curve for this site for the period from 1974 through the present. This graph demonstrates that monitoring spanned the majority of the flow range, from 90% probability of exceedance at low flow to 10% probability of exceedance at high flow, with relatively even distribution of monitoring events within that range. This figure also shows the estimated flow on sampling days when the presence of ice made exact determination of flow impossible.

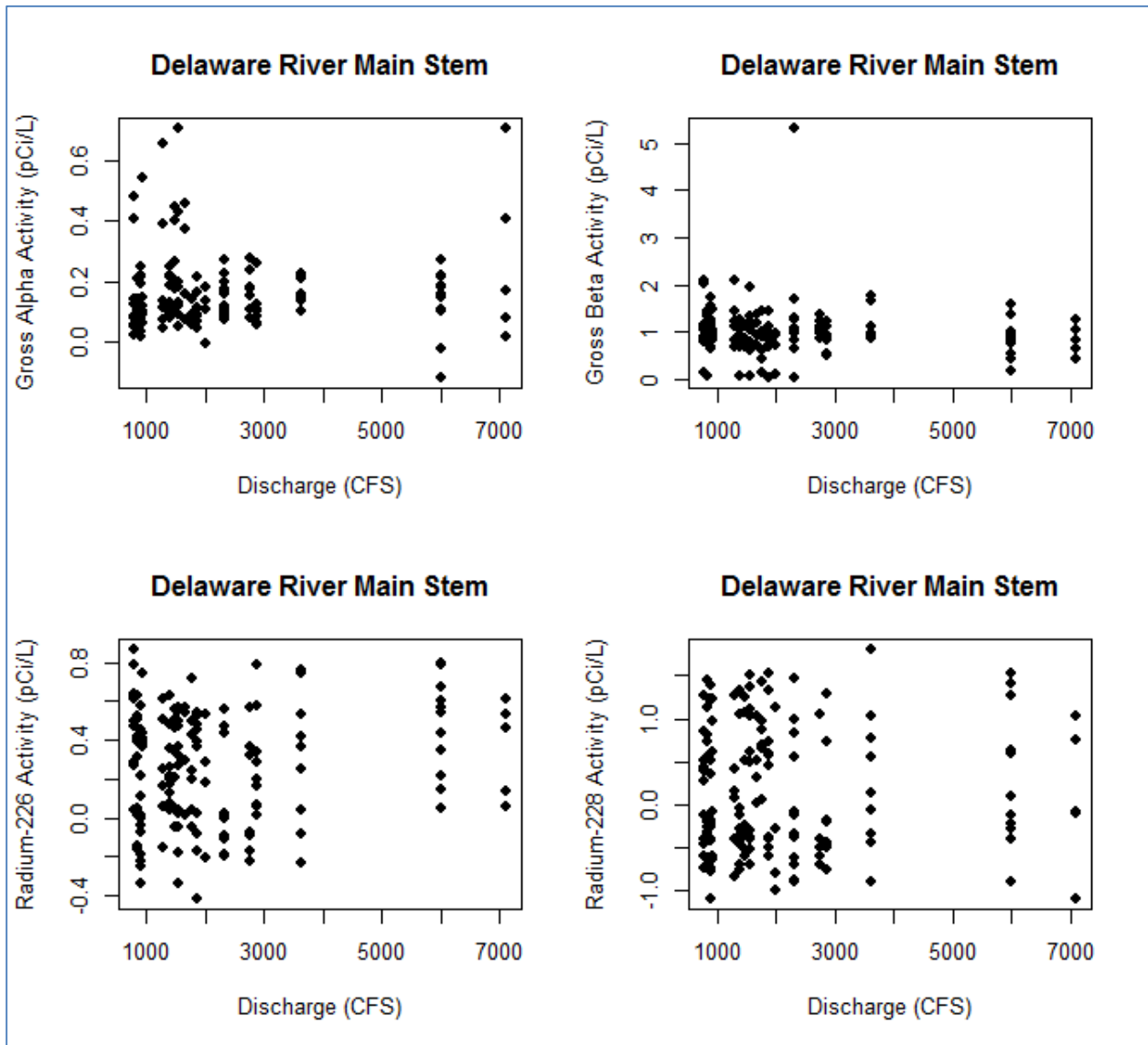
Figure 2. Flow on radiochemistry monitoring Days at the USGS Delaware River at Callicoon Gage 01427510 plotted against the probability of exceedance curve for this location.



Summary of Analytical Results

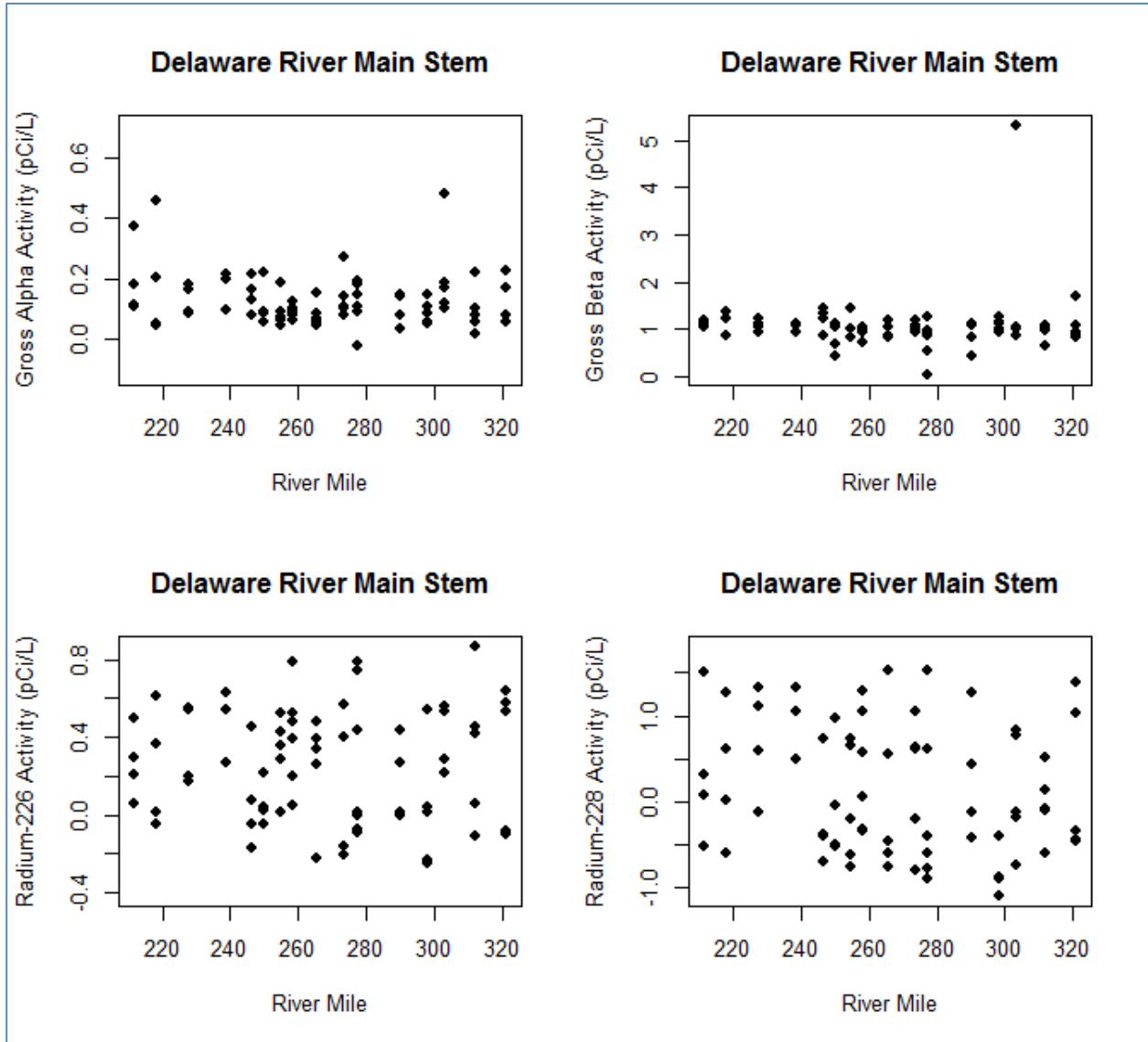
We compared activity measurements for the four radiochemistry parameters collected on the mainstem Delaware River to the flow at Callicoon NY on the sampling day to see if any relationship with flow was apparent. Figure 3 shows no apparent relationship with flow for any of four radiochemistry analytes suggesting that values within the observed ranges are similarly likely during high or low flow. It is noteworthy that at low ambient levels, activity measurement results below zero are possible. This is especially evident with Radium-226 and Radium-228.

Figure 3. Activity measurements for four radiochemistry parameters collected on the mainstem Delaware River compared to discharge at the USGS Callicoon, NY Gage on the monitoring day.



Similarly, we plotted mainstem Delaware River activity measurements against the River Mile (miles upstream from the mouth of Delaware Bay) to determine if any increase or decrease in activity measurements was apparent longitudinally along the river, associated either with localized loading or dilution. Results shown in Figure 4 suggested comparable activity measurements for all four radiochemistry parameters along the length of the monitored portion of the Delaware River.

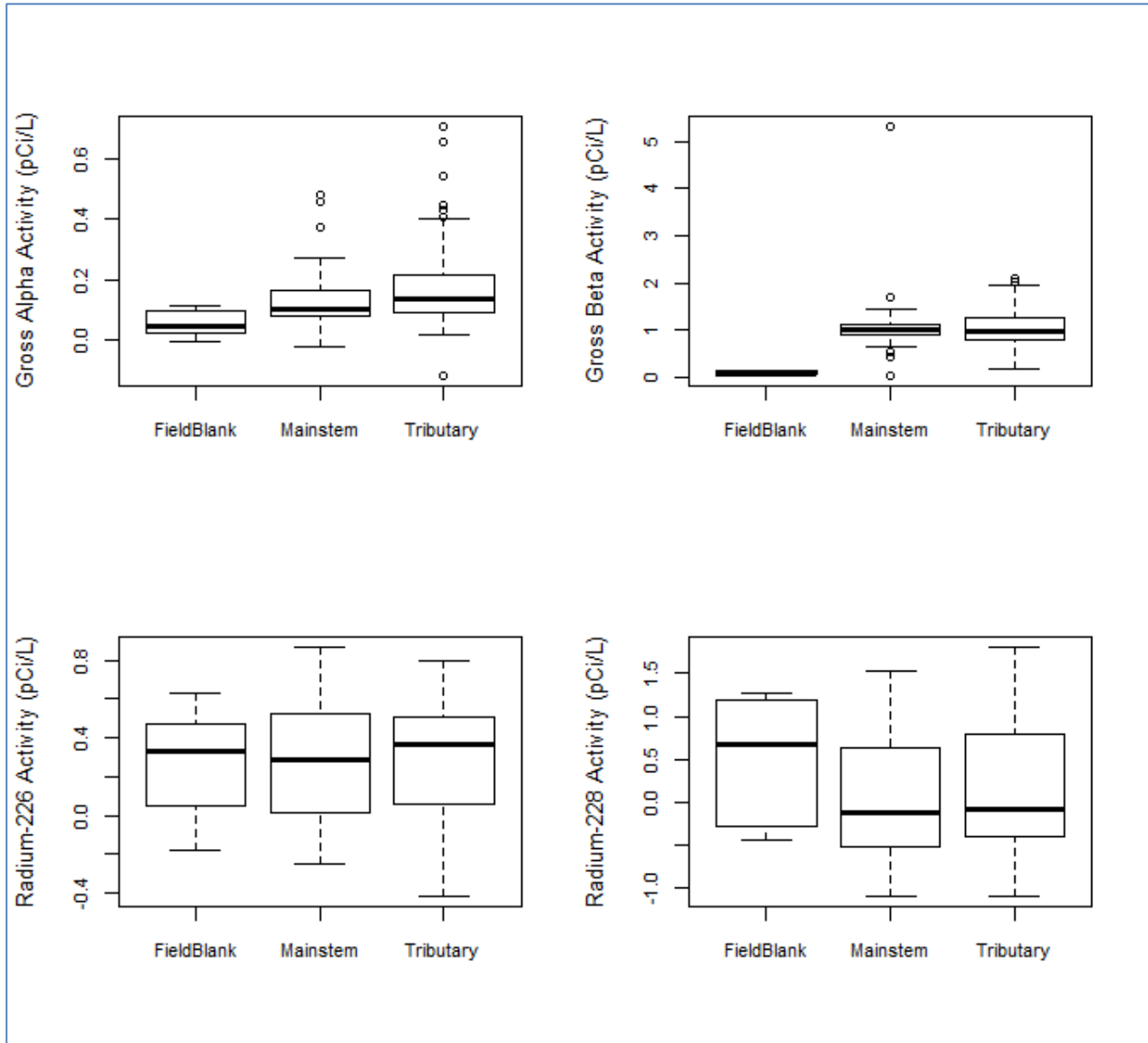
Figure 4. Activity Measurements for four radiochemistry parameters collected on the mainstem Delaware River compared to the river mile of the monitoring location.



We developed box and whisker plots of the activity measurement of the four radiochemistry parameters for tributary, mainstem Delaware, and field blank samples. Field blanks consist of clean laboratory water rinsed over all sample collection equipment and bottles which would come into direct contact with analytical samples. For this project, field blanks were blinded (provided a sample ID which would not allow identification as a blank by the laboratory) and submitted as routine analytical samples. This process is used to assess whether cross-contamination from field sampling equipment is evident and to compare differences between surface water and blank samples. Figure 5 below shows no appreciable difference between samples collected from mainstem Delaware River or Tributary sample locations for any of the four radiochemistry parameters. For Gross Beta, the results show that surface water samples are elevated

above field blank results. For other radiochemistry results, however, the field blanks are either comparable to surface water samples or actually exceed surface water samples in the case of Radium-228.

Figure 5. Box and whisker plots of activity measurements for four radiochemistry parameters for field blanks, tributary, and mainstem Delaware River surface water samples.



Interpretation of Low Activity Level Measurements

Reporting of ambient radiochemistry activity measurements in surface water is inherently different than traditional wet chemistry measurement. The typical heuristics used to assess the quality of traditional wet chemistry monitoring are a poor fit for interpreting radiochemistry monitoring quality. Reporting of negative activity values and field blanks results comparable to surface water results required interpretation from the analytical laboratory. We conferred with radiochemistry lab staff in January 2015 to better understand the results up to that point.

For each of the four radiochemistry parameters reported by the lab, results were reported as the measure activity level (in pCi/L) plus or minus an uncertainty range. Based on the methods documented in ECLS-R-Ra226/Ra228, negative activity counts are possible when sample activity is very low. As per consultation with the lab, the likeliest interpretation of both low (including negative) activity levels and similarity between blanks and surface water samples is that all samples are reflecting background ambient radiation. Localized inputs of additional radiation therefore are not evident in surface water results.

Comparison of Results to DRBC Surface Water Quality Standards

DRBC adopted surface water quality standards in the mainstem Delaware River, published as Water Quality Regulations in our Administrative Manual –Part III and as part of the Code of Federal Regulations at 18 CFR PART 410 (DRBC 2013). In water quality management Zones 1A, 1B, and 1C (corresponding to the monitoring region for this project) alpha emitters are not to exceed 3 pCi/L and beta emitters are not to exceed 1000 pCi/L. A review of the reported results shows that all results in all locations are well below the DRBC water quality standards. DRBC has not adopted any standards for Radium-226 or Radium-228.

Photographic Documentation of Monitoring Effort

A full set of photos documenting radiochemistry sample collection can be found on the DRBC flickr page. Many photos include recorded coordinates to facilitate mapping. The radiochemistry monitoring album is available at:

<https://www.flickr.com/photos/drbc1961/sets/72157639883618534/>

Two representative photos are shown below.



Photo 1. Field preservation of Radiochemistry samples collected in January 2014.



Photo 2. Bridge sampling for Radiochemistry in May 2014.

Conclusions

Monitoring results acquired under this program have allowed DRBC to establish a solid radiochemistry baseline for comparison with future radiochemistry levels, including levels occurring after commencement of natural gas extraction. With the funding provided under this grant, we've identified and selected appropriate analytical methods and field protocols, performed monitoring and analysis, and interpreted results. Monitoring was performed through the portions of the Delaware River basin likely to see impacts of natural gas development should that activity commence.

References

Administrative Manual –Part III Water Quality Regulations with Amendments through December 4, 2013. Delaware River Basin Commission. <http://www.nj.gov/drbc/library/documents/WQregs.pdf> Accessed July 15, 2015.

Radioanalytical Services Laboratory Quality Manual (**RSLQM**). Radioanalytical Services. New Jersey Department of Health and Senior Services. Effective July 1, 2013.

Standard Operating Procedure for Ra-226 and Ra-228 in Water Gamma-Ray Spectroscopy Method. ECLS-R-Ra226/Ra228. Radioanalytical Services. New Jersey Department of Health and Senior Services. Revised 5/16/2011.

Appendix A

Link to Analytical Results

Analytical results from this project are posted on the DRBC web site and may be downloaded using the link below:

<http://www.nj.gov/drbc/library/documents/BaselineRadiochemResultsAll.xlsx>