Temporal and Spatial Analysis of Groundwater Quality and Unconventional Gas Well Density in Washington County, Pennsylvania

Brianne R. Duncan

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Science

University of Washington

2016

Committee:

Peter Rabinowitz

Gretchen Onstad

David Kalman

Program Authorized to Offer Degree:

Environmental & Occupational Health Sciences

University of Washington

Abstract

Temporal and Spatial Analysis of Groundwater Quality and Unconventional Gas Well Density in Washington County, Pennsylvania

Brianne R. Duncan

Chair of the Supervisory Committee:

Associate Professor Peter Rabinowitz

Environmental & Occupational Health Sciences

A total of 265 household water supply samples were collected from 154 houses in Washington County, Pennsylvania between 2012 and 2014. The inorganic and anion constituent concentrations were compared to active unconventional gas well density relative to each household. Cross-sectional, temporal, and spatial analytical techniques were employed to explore potential relationships between analyte concentrations or change in analyte concentrations and gas well density or change in gas well density. Overall, the groundwater in Washington County is of good quality and there was no evidence for systematic deterioration of water quality due to gas well density. Manganese and pH exceeded the United States Environmental Protection Agency (USEPA) and Pennsylvania Department of Environmental Protection (PADEP) secondary maximum contaminant levels (SMCLs) in ~12% of samples each, but these exceedances were expected due to the long history of acid mine drainage throughout the County. Eight analytes (Cr, Co, Li, Hg, Ni, K, Sn, and temperature) exhibited statistical significance when their initial and subsequent sample event medians were compared. There were seven analytes (Al, Cr, Fe, Pb, Li, Na, U) found to have significant relationships between the concentration or change in concentration and gas well density or change in gas well density. Lithium exhibited correlations in almost all statistical tests and had a median value (7.7 ppb) almost three times higher than the national median (2.8 ppb). Correlations for all analytes may be explained by various anthropogenic sources, both from unconventional gas extraction activities and from other unrelated activities. Further characterization of causal pathways is needed to clarify these relationships.

Table of Contents

List of Tables

List of Figures

Acknowledgements

I would like to take this opportunity to extend my thanks to several people, without whom this would not have been possible. I would like to thank the Chair of my Committee, Dr. Peter Rabinowitz who gave me the opportunity to work on an incredibly interesting and relevant scientific topic. His guidance on how to approach such a complex analysis proved invaluable in clarifying my objectives and keeping me on track. My other two Committee members, Dr. Gretchen Onstad and Dr. David Kalman graciously committed their time and energy into discussions that helped to shape my thought process. I thoroughly enjoyed all the opportunities I had to work with my Committee members and am grateful for their help.

To my co-workers, Ms. Melanie Edwards and Dr. Mihai Aldea who supplied invaluable advice regarding statistical approaches and interpretations. Dr. Laurie Benton whose insight always ensured that I got to the point. Dr. Mark Johns for his technical input and continued support throughout this experience.

I would like to acknowledge The Heinz Endowments for providing the funding that supported this research and analysis.

Also, a huge thanks to my family and friends for letting me ignore them for extended periods of time but still sending much needed motivational messages.

1. Introduction

Technological advances in unconventional natural gas extraction have become the driving force behind rising US gas production which has led to increasing availability and subsequently low prices (Ratner and Tiemann 2015). With this industry boom, proper environmental oversight and management are a necessity. The US Energy Information Administration (USEIA) defines conventional oil and gas production as "crude oil and natural gas that is produced by a well drilled into a geologic formation in which the reservoir and fluid characteristics permit the oil and natural gas to readily flow to the wellbore". To contrast this, unconventional oil and gas production is any oil and gas production that is not defined as conventional (USEIA 2016). A 2009 publication from the Groundwater Protection Council in cooperation with the US Department of Energy (USDOE) differentiated modern shale gas development from conventional gas development by the use of horizontal drilling techniques and high volume hydraulic fracturing (GWPC and ALLC 2009).

There are five basic stages to establishing an onshore unconventional gas extraction pad: 1) well pad setup; 2) drilling; 3) hydraulic fracturing; 4) extraction; and 5) closure (Prud'homme 2014). The well pad setup requires fencing off the work area and constructing a level site which has been cleared. Setup often includes building roads to the well pad and digging and lining a reserve pit for wastewater storage near the well pad (DOI-BLM 2007). Other equipment and worker facilities are brought to the site including portable offices, generators, slurry blenders, high-volume fracturing pumps, a monitoring unit, fracturing tanks, proppant (typically sand – props open fractures to promote production) storage and handling units, a chemical additive unit, low-pressure flexible hoses, gauges and meters, and the drill itself. The drill rig, which is up to four stories tall, is constructed on the well pad and once this and other setup is completed drilling can begin (Prud'homme 2014). Including the well pad itself and the supporting process areas, access roads, utility corridors, etc., conventional, vertical wells occupy an average of 4.8 acres/well. This same area can serve multiple wells utilizing horizontal drilling techniques reducing the occupied area per well (Arthur and Cornue 2010).

Drilling the wellbore may require vertical or horizontal techniques in order to reach the desired resources from the surface location. A vertical well is drilled directly downward while a horizontal well will make a turn at depth to penetrate into the reserves. The well is drilled in intervals of 300–1,200 meters, casings are placed in the wellbore, and cement is poured into the annulus (the space between the outside of the casing and the inside of the wellbore). This process is repeated until the gas or oil reservoir is reached typically at depths of 1,800–3,050 meters (FracFocus 2014). It is imperative that the well casing integrity is maintained since faulty well casings can permit extracted oil or gas to flow into surrounding formations.

The actual hydraulic fracturing of the well entails pumping large volumes of water with proppant and chemical additives from the surface to the end of the well and into the formation. Pumping these fluids into the formation causes cracks in the reservoir resulting in increased gas or oil production (FracFocus 2014). There are many types of chemical additives which are used for a variety of reasons and fracturing fluids are typically 99% water, 1% additives (FracFocus 2014). Table 1.1 below summarizes many of those additives and their purposes (FracFocus 2014; Prud'homme 2014). After pumping the water into the well, the water flows back to the surface and is called “flowback” or “produced water”. Flowback is transferred via pipes to the open air reserve pit or steel tanks if the well pad has a closed loop system which contains all fluids during production (Prud'homme 2014). A well may be hydraulically fractured multiple times during its production lifetime and a single pad may have 12 or more wells (Ladlee and Jacquet 2011).

Table 1.1 Additives in Hydraulic Fracturing Fluids

Function	Purpose	Example(s)
Acid	Helps dissolve minerals and initiate cracks in the rock	Hydrochloric acid (7647-01-0)
Biocide	Eliminates bacteria in the water than can cause corrosive byproducts	Glutaraldehyde (111-30-8); Quaternary Ammonium Chloride (12125-02-9)
Breaker	Allows a delayed breakdown of gels when gels are used	Ammonium Persulfate (7727-54-0); Magnesium Oxide (1309-48-4)
Corrosion Inhibitor	Protects casing from corrosion	Isopropanol (67-63-0); Methanol (67-56-1); Acetaldehyde (75-07-0)
Cross-Linker	Maintains viscosity as temperature increases	Petroleum Distillate (64741-85-1); Hydrotreated Light Petroleum Distillate (64742-47-8); Boric Acid (1333-73-9)
Friction Reducer	Reduces friction effects over base water in pipe	Polyacrylamide (9003-05-8)
Gel	Thickens the water in order to suspend the proppant	Guar Gum (9000-30-0); Polysaccharide Blend (68130-15-4); Diesel Fuel
Iron Control	Iron chelating agent that helps prevent precipitation of metal oxides	Citric Acid (77-92-9); Acetic Acid (64-19-7)
Non-Emulsifier	used to break or separate oil/water mixtures (emulsions)	Lauryl Sulfate (151-21-3); Isopropanol (67-63-0)
pH Adjusting Agent/Buffer	Maintains the effectiveness of other additives such as cross-linkers	Sodium Hydroxide (1310-73-2); Potassium Hydroxide (1310-58-3)

Function	Purpose	Example(s)
Proppant	Keeps fractures open allowing for oil or gas production	Silica Sand (112945-52-5); Ceramic Balls
Scale Inhibitor	Prevents scale in pipe and formation	Copolymer of Acrylamide and Sodium Acrylate (25987-30-8)
Stabilizer	Temporary or permanent clay stabilizer to lock down clays in the shale structure	Sodium Chloride (7647-14-5); Tetramethyl Ammonium Chloride (75-57-0)
Surfactant	Reduces surface tension of the treatment fluid in the formation and helps improve fluid recovery from the well after the fracturing is completed	Ethanol (64-17-5); Naphthalene (91-20-3); 2-Butoxyethanol (111-76-2)

During extraction, the oil or gas is collected topside and transferred in pipes to storage tanks and then further downstream for processing and/or separation (Prud'homme 2014). Well pad closure requires operators to cap the well(s), remove aboveground components and gravel, remove access roads not used for other purposes, re-contour the landscape, and re-vegetate disturbed areas (TEEIC 2014).

All stages of this process pose potential risks to humans and the environment from chemical releases and habitat alteration. Examples of releases include leaks or spills on the ground’s surface, leaks from improperly constructed wellbore casings, leaching from wastewater pits, volatilization of fluids, and emissions from equipment (e.g. trucks, compressors) (Adgate 2014; Boyer 2012; Brantley 2015; Burton 2014). The threat to surface and groundwater resources is of particular concern in rural areas where residents rely on private water wells.

There is an expanding body of research (government, academic, and private institution-led) focused on impacts to groundwater quality from unconventional oil and gas operations and so far the results are mixes. Osborn et al. reported that the methane carbon and hydrogen isotopes analyzed from household water samples indicated a thermogenic methane source such as the Marcellus Shale (Osborn 2011). A follow-up publication from Jackson et al. concluded that the methane carbon and hydrogen isotopic signatures of the same samples from Osborn’s publication were consistent with Marcellus-like thermogenic methane signatures and was therefore likely due to impacts from unconventional operations (Jackson 2013a). However, a rebuttal publication to the Osborn findings reported that the thermogenic methane carbon and hydrogen isotopic signature was more indicative of deposits overlying the Marcellus Shale (Molofsky 2011).

A 2004 report from USEPA found that hydraulic fracturing posed little or no threat to underground sources of drinking water (USEPA 2004). However, at the urging of Congress USEPA initiated another study into impacts to groundwater from hydraulic fracturing that was released for comment in June 2015 (USEPA 2015a). Although the conclusions regarding impact or potential impact vary, most publications recommend continued monitoring or further research.

One of the difficulties in assessing impacts to residential groundwater water supplies is the lack of historic data. For Washington County, this is compounded by the variety and lengthy history of industrial activities. Trace elements, ions, and physical water parameters are metrics for determining water quality and are indicators of anthropogenic impacts. Utilizing single time-point samples or measurements generates results that are less capable of supporting causal inferences. This research attempts to address the shortcomings of cross-sectional analyses by analyzing the change in water quality parameters between the 2012/2013 and 2014 repeat sampling events. The changes in water quality are surrogate measures for the ongoing chemical interactions and reactions that occur in the subsurface environment.

This research also utilized publically available spatial datasets and includes controlling variables into the statistical analysis. These analytical methods have not been widely used in previous research on groundwater quality as it relates to unconventional oil and gas extraction and strengthens conclusions drawn from the analytical results. By addressing known confounders or effect modifiers for groundwater quality we can reduce the risk of observing spurious associations (Sweet and Grace-Martin 2012).

The results of this research will help inform whether there is evidence of environmental impacts related to the density of active unconventional gas wells evidenced in household water resources. The analytical strategy is aimed to reduce confounding impacts from historic activities, anthropogenic activities besides unconventional gas production, and natural phenomena. Focusing on the paralleled change over time of gas well density and household water quality analytes will provide more objective measures of association.

2. Site Background

2.1 Location

Washington County covers 2,220 km^2 (PennDOT 2015) and is located in the southwest portion of Pennsylvania (Figure 2.1). The western border of Washington County is along the Pennsylvania-West Virginia border and the eastern edge is bounded by the Monongahela River. To the north are Beaver and Allegheny Counties and to the south is Greene County. In 2014 the US Census Bureau estimated that the population was 208,187 (US Census Bureau 2015). The two largest cities in the County are Monongahela and Washington (WC No date).

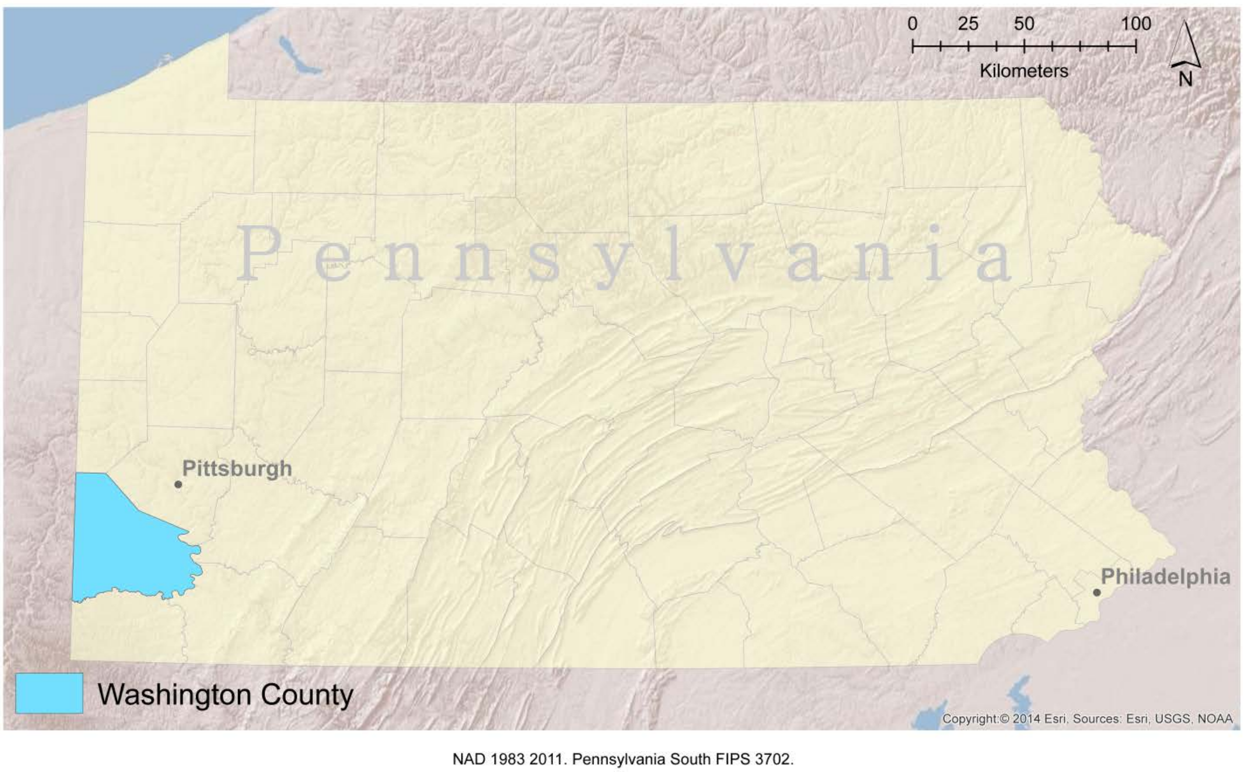


Figure 2.1 Washington County

2.2 Climate

The average summer temperature in Washington County is 27.8 °C and the average winter temperature is 2.8 °C (WC No date). The precipitation in Pennsylvania is slightly mineralized and acidic (pH 3.9-5.8 SU), acting as a mild solvent (Flint 1979; Newport and Socolow 1973; USGS 1995). From 1948 to 2014 the average annual precipitation was 38.7 inches with a range of 14.2 to 56.7 inches. Between 2012 and 2014 (the study period) the average annual precipitation was 41 inches (CDO 2015; NWS 2015).

2.3 Topography

The County has a rugged terrain with elevations between 229 meters above sea level in the stream valleys and 457 meters on the hilltop peaks. Erosion in the stream beds has resulted in elevation differences of up to 229 meters between valleys and hilltops. Hill slopes are much steeper in minor stream valleys than in the major tributary valleys (Newport and Socolow 1973).

2.4 Land Use

Washington County is primarily forest (55.44%) and pastures (19.77%). The remaining land cover is developed (14.63%), crops (7.23%), shrub/herbaceous (1.81%), water (0.6%), barren (0.47%), and wetlands (0.04%) (Figure 2.2). Since the mid-1900s, the amount of land dedicated to farming has decreased. In the 1940s 76% was farm acreage, in 1970 40% was farm acreage, and in the 2010s 27% was pasture or crop land (National Geospatial Center of Excellence 2011; Newport and Socolow 1973).

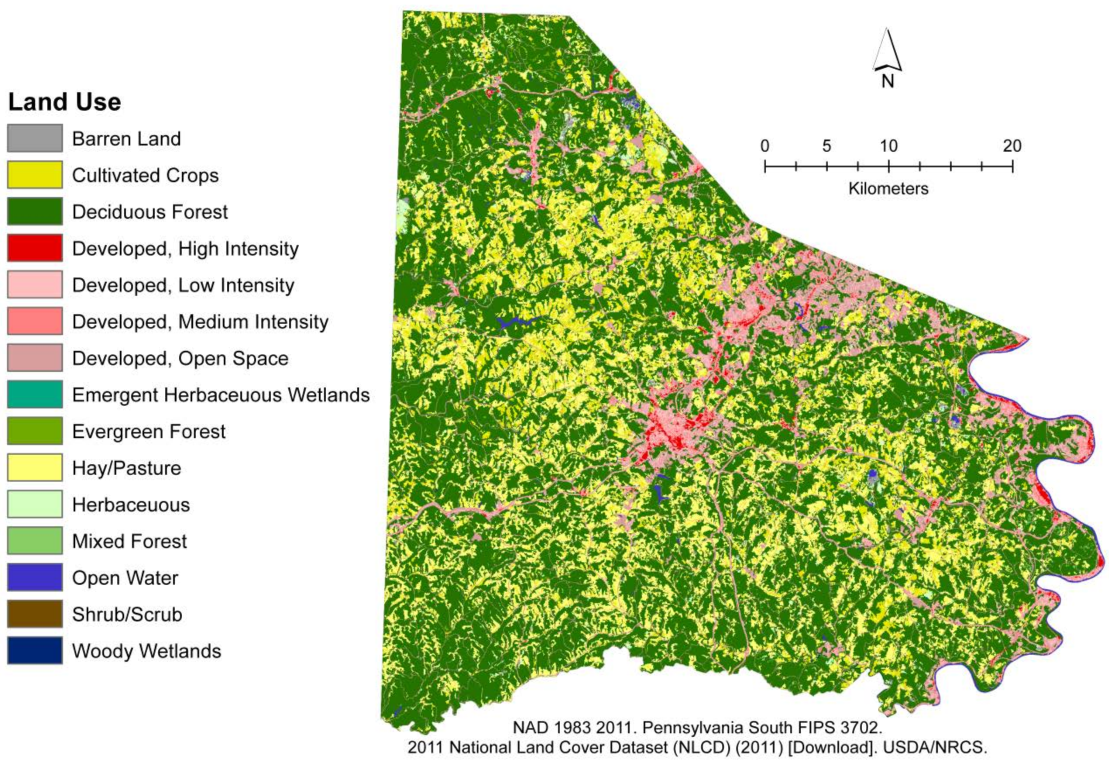


Figure 2.2 Land Use

2.5 Lithology and Hydrogeology

The County is situated in the Appalachian Plateau Physiographic Province and is comprised of two of the seven sections within the Province: Pittsburg Low Plateau Section and Waynesburg Hills Section. The uppermost stratigraphic units are sedimentary rocks of the Pennsylvanian and Permian age. The

Pennsylvanian age groups include the Conemaugh Group and Monongahela Group while the Permian age group is the Dunkard Group. There are also unconsolidated Quaternary alluvium deposits in the stream valleys which are primarily sand and gravel with some silt and clay. There are 17 coal beds underlying the County, but only two (Waynesburg and Pittsburg) are economically viable on a regional scale (Earth Sciences Consultants 2001; Newport and Socolow 1973).

Washington County is located in the Ohio River watershed. There are 15 sub-watersheds which can be further divided into 42 smaller watersheds that are shown below in Figure 2.3 (FracTrackerAlliance 2012). The aquifers in the County are recharged solely by precipitation and water moves freely between the surface and subsurface environment. These aquifers may be confined (artesian, under pressure) or unconfined (free, water table). In general, groundwater is more mineralized (i.e. higher concentrations of inorganic compounds) than surface water because it has more contact with mineral matter and moves more slowly. During extended periods without precipitation, groundwater seepage serves to maintain streamflow resulting in greater mineral concentrations (Earth Sciences Consultants 2001; Newport and Socolow 1973). Groundwater mean annual recharge rates are estimated between 8 and 12 inches (Reese and Risser 2010b).

The County relies on groundwater derived from bedrock which occurs largely in secondary openings (e.g. joint planes or solution openings). However, there are a few places where Quaternary alluvium overlies bedrock along the major stream valleys and yields moderate to large supplies of groundwater. Secondary permeability is related to the number, size, and extent of interconnected fractures. The geologic groups and formations in the County typically are poor to moderate water bearers because fractures are small and scarce. Groundwater yields range from <1 gallon per minute (gpm) to over 350 gpm (Battelle 2013; Earth Sciences Consultants 2001; Newport and Socolow 1973). Mean depth to bedrock throughout the county ranges from 0.78–1.35 m (PSU 1995).

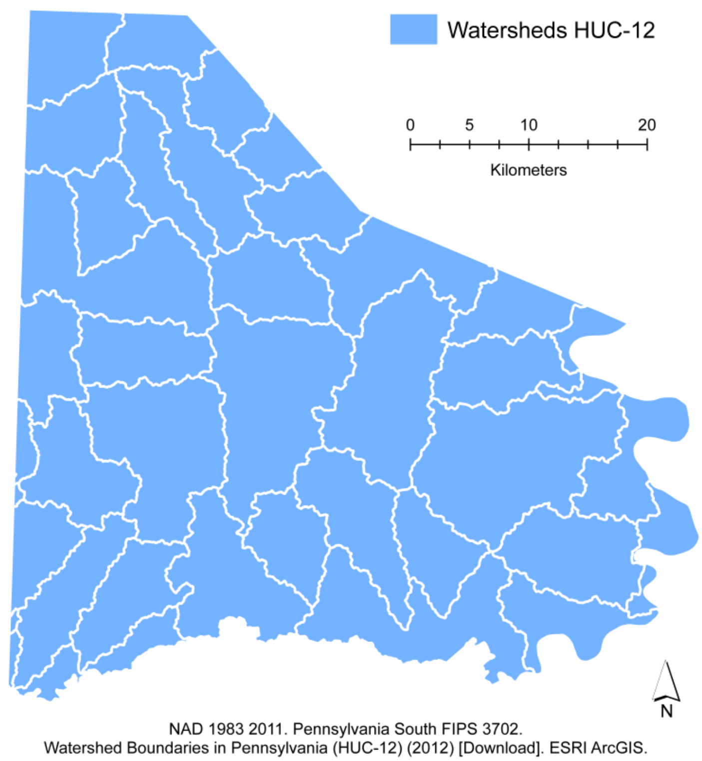


Figure 2.3 HUC-12 Watersheds

2.5.1 *Conemaugh Group*

The Conemaugh Group gradually thickens to the east and is dominated by claystone, siltstone, sandstone, and shale. It is subdivided into two formations: Glenshaw and Casselman. The primary lithology for the Glenshaw and Casselman Formations is shale (Earth Sciences Consultants 2001; Reese 2010a). Typical shale composition includes illite, kaolinite, smectite, quartz, chert, and feldspar. These clay minerals contain elements such as aluminum, calcium, iron, magnesium, potassium, sodium, and silicon (Brittanica 2016) Shale aquifers in this region commonly have high iron concentrations (Fleeger 1999).

2.5.2 *Monongahela Group*

The Monongahela Group overlies the Conemaugh Group and also thickens to the east. It is comprised of limestone, dolomitic limestone, calcareous mudstone, shale, and thin-bedded siltstone. This group is further divided into two formations: Pittsburg and Uniontown. The primary lithology for the Monongahela Group is Limestone (Earth Sciences Consultants 2001; Reese 2010a). With a substrate composed primarily of calcium carbonate (Brittanica 2016), limestone aquifers in this area have relatively high dissolved solids (>320 ppm) and tend to produce hard water (Fleeger 1999).

2.5.3 *Dunkard Group*

The Dunkard Group is subdivided into three formations: Waynesburg, Washington, and Greene. The Waynesburg Formation increases in thickness from the northwest to the south and is primarily sandstone and siltstone. The Washington Formation is comprised of shale, sandstone, limestone, and coal. The Greene Formation is comprised of coal, carbonaceous shale, sandstone, siltstone, mudstone, and clay. The primary lithology of the Waynesburg, Washington, and Greene Formations is sandstone (Earth Sciences Consultants 2001; Reese 2010a). The foundation for sandstone matrices is quartz, feldspar, and rock fragments containing aluminum, calcium, potassium, silicon, and sodium (Brittanica 2016). Similar to shale aquifers in the County, sandstone aquifers frequently exhibit high iron concentrations (Fleeger 1999). The physiographic sections and formations are shown below in Figure 2.4.

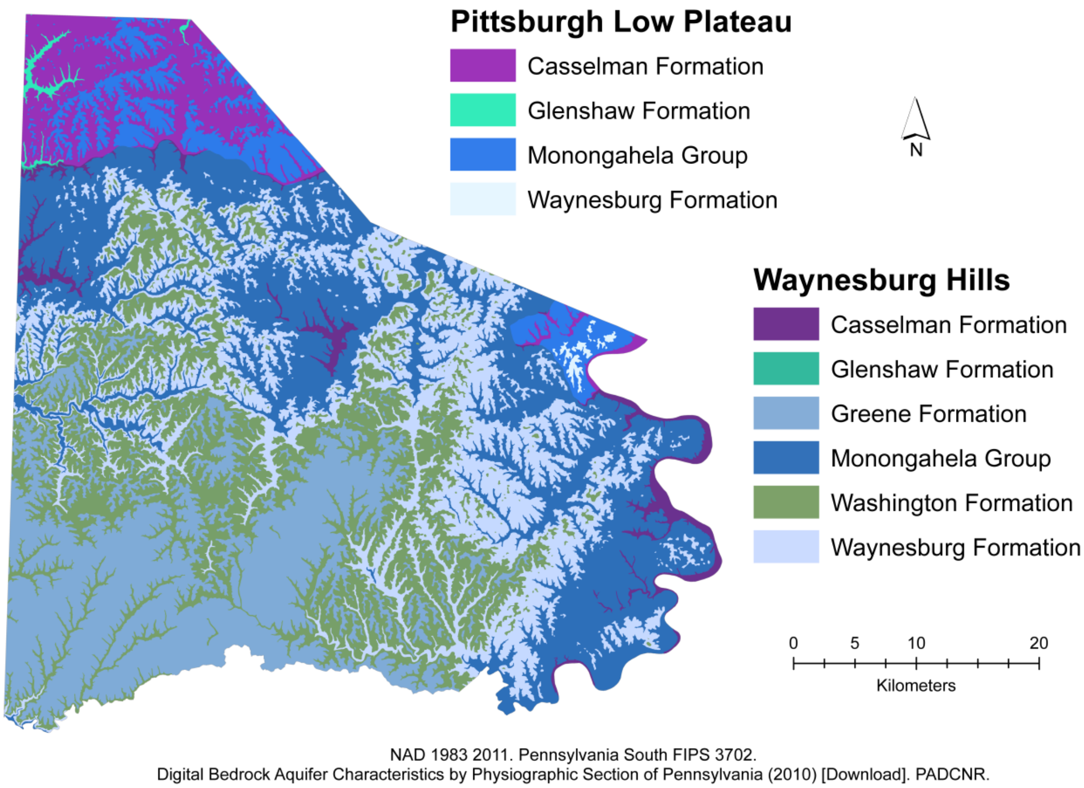


Figure 2.4 Washington County Formations

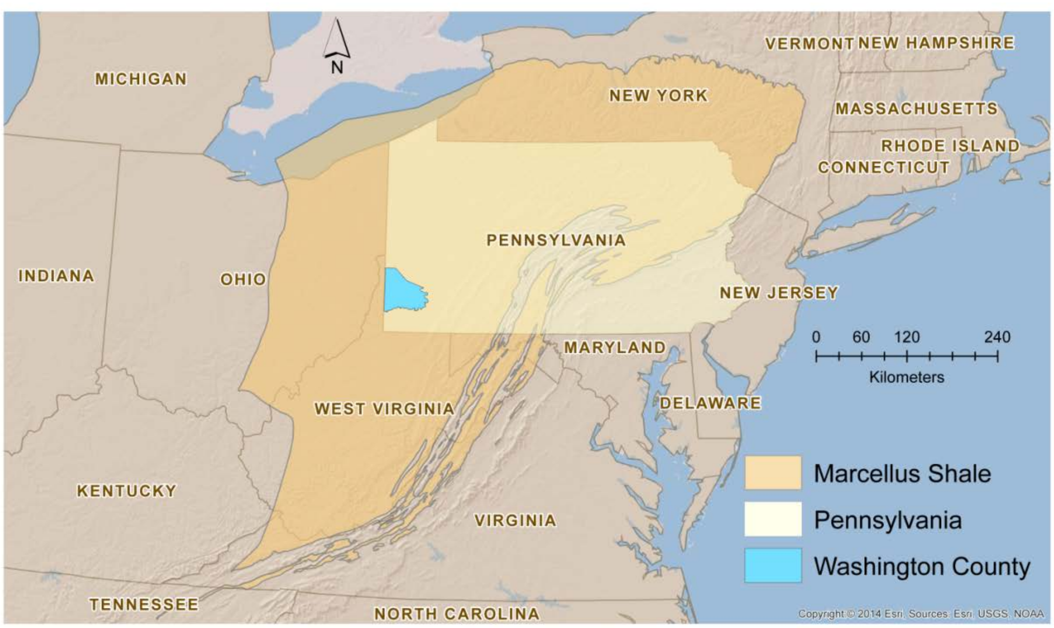
2.6 Historic Activities

The earliest industrial activities in the County were commercial coal mining and raising sheep, both of which began in the early 1800s. Coal mining revealed the availability of iron ore and iron fabrication began around the turn of the 19th century along with steel manufacturing. Washington County also experienced a short-lived oil and natural gas boom in the late 1800s and early 1900s. The first producing oil well in the County was drilled in 1882. Due to the presence of natural gas in the County, glass production also expanded quickly in the early 1900s. These historic industrial, manufacturing, and commercial activities have led to over 1,900 sites in Washington County with reported adverse environmental impacts (Battelle 2013; WC 2005).

2.7 Marcellus Shale

The ~246,050 km^2 Marcellus Shale underlies roughly two-thirds of Pennsylvania and portions of six other states in the Northeast US: New York, Ohio, West Virginia, Maryland, Kentucky, and Virginia (Figure 2.5) (Halliburton 2015; PADEP 2013b). The Marcellus is as deep as ~2,745 meters from the earth's surface and ranges in thickness from 2 to 76 meters (PSU 2015b). The depth range with the highest natural gas production rates is between 1,525 and 2,590 meters below ground surface (bgs) (PADEP 2013b). It is a black organic-rich Middle Devonian age shale between the Hamilton Group shale (above) and the Tristates limestone (below) (GWPC and ALLC 2009; PADCNR 2008).

Within Washington County, the Marcellus is as thick as 45.7 meters with the thickness generally increasing from the west to the east. Depth to the Shale ranges from roughly 1,524 meters to less than 2,439 meters with depth increasing from the northwest to the southeast (PSU 2015b).



NAD 1983 2011. Pennsylvania South FIPS 3702.
Extent of Marcellus Shale Formation (2013) [Download]. ESRI ArcGIS.

Figure 2.5 Extent of Marcellus Shale

2.8 Active Unconventional Gas Wells

Previous attempts to extract natural gas from the Marcellus utilized various foam and gel-based fluids but were not successful. In 2003, Range Resources brought Texas Barnett Shale-style high volume hydraulic fracturing to the Marcellus Shale and proved the technique in 2004 with the Renz #1 well (Darbonne 2014). Unconventional oil and gas operations began to flourish in the County beginning in 2005 (Battelle 2013) and as of January 2015 there were 1,117 active unconventional gas wells in Washington County (PADEP 2015a). Figure 2.6 displays the number of active unconventional gas wells by the year drilling began (spud date year) in Washington County (PADEP 2015a).

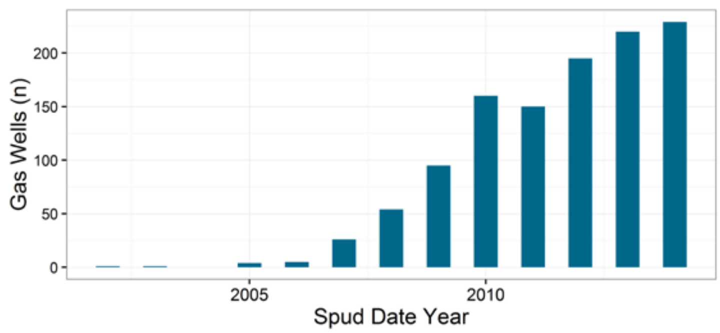


Figure 2.6 Washington County Active Gas Wells by Spud Date Year

The active unconventional gas well density in 2014 ranged from 0 gas wells/km^2 to 2.2 gas wells/km^2 and is shown in Figure 2.7. This map was generated in ArcGIS using PADEP-permitted well locations and a kernel density function with a search radius of 5 kilometers (PADEP 2015a).

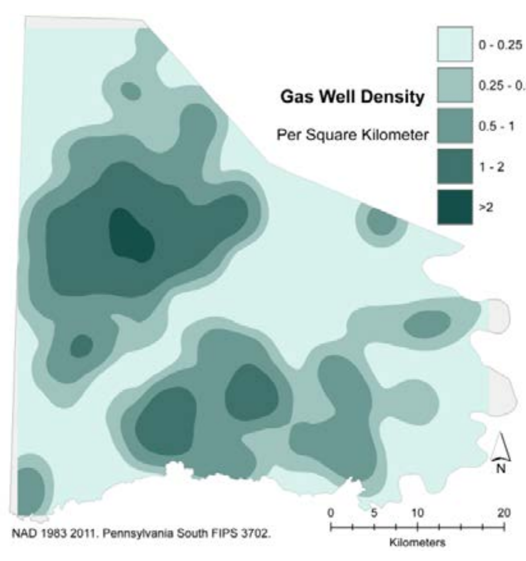


Figure 2.7 2014 Active Unconventional Gas Well Density

2.9 Baseline Groundwater Characterization

DeSimone et al. (2014) reviewed available data from 6,600 private wells across the US and found that 22% of wells had at least one chemical constituent at a concentration greater than a USEPA maximum contaminant level (MCL). Most exceedances (17%) were from constituents primarily equated to geologic sources (e.g. arsenic, manganese, radon, and uranium). The remaining 5% were from anthropogenic sources, and nitrate was the most frequent constituent in this group.

A study of trace elements and radon across the United States provided a subset analysis of groundwater in humid regions similar to Washington County (Ayotte 2011). The analytes with the greatest percentage of MCL exceedances were manganese (33.8%) and iron (23.5%). Arsenic, zinc, and aluminum had the next greatest MCL exceedances at 4.5%, 2.1%, and 1.6% respectively (Table 2.1).

Table 2.1 Median Groundwater Values & Exceedances – USA

Analyte	Units	Location		USA[a]	
		Source		Ayotte 2011	
		Years		1992-2003	
		Samples (n)		Varied: 485-3,425	
		Benchmark		Median	Exceedances (%)
		Type	Value		
Aluminum	ppb	SMCL	200	3.3	1.6
Antimony	ppb	MCL	6	<1	0
Arsenic	ppb	MCL	10	0.41	4.5
Barium	ppb	MCL	2000	47	0.2
Beryllium	ppb	MCL	4	<1	0.1
Cadmium	ppb	MCL	5	<1	0.2
Chromium	ppb	MCL	100	1.2	0
Cobalt	ppb	--	--	0.16	--
Copper	ppb	SMCL	1,000	1	0.05
Iron	ppb	SMCL	300	11	23.5
Lead	ppb	AL	15	0.12	0.3
Lithium	ppb	--	--	2.8	--
Manganese	ppb	SMCL	50	13	33.8
Molybdenum	ppb	HBSL	40	0.54	1.3
Nickel	ppb	HBSL	100	1	0.2
Selenium	ppb	MCL	50	<1	0.05
Silver	ppb	SMCL	100	<1	0
Strontium	ppb	HBSL	4,000	160	1
Thallium	ppb	MCL	2	<1	0
Uranium	ppb	MCL	30	0.17	2.1

Analyte	Units	Location		USA[a]	
		Source		Ayotte 2011	
		Years		1992-2003	
		Samples (n)		Varied: 485-3,425	
		Benchmark		Median	Exceedances (%)
		Type	Value		
Vanadium	ppb	--	--	0.4	--
Zinc	ppb	SMCL	5,000	4.1	0

Notes-
[a]Humid regions; AL = Action level; HBSL = Health-based screening level; MCL = Maximum contaminant level; SMCL = Secondary maximum contaminant level; -- = No limit or value

There is limited baseline water quality data for Washington County due to the fact that many residents draw water from private wells which were constructed prior to their occupancy and data collection on such resources was and continues to be largely uncommon or decentralized. Major causes of water quality impairment in the County are acid mine drainage (AMD) from coal mining activities, agriculture, urban and stormwater runoff, and human waste handling:

- AMD contains iron, nickel, copper, zinc, sulfate, lead, arsenic, aluminum, and manganese, and treatment of AMD may involve adding lime which contains calcium.
- Agricultural impacts are primarily from pesticides and fertilizers which may contain nitrogen, phosphorus, arsenic, selenium, and bromine.
- Urban and stormwater runoff contain a variety of organic and inorganic contaminants.
- Septic system discharges have high nitrate levels (Battelle 2013).

Regarding historic oil and gas wells, there were few, if any, construction, production, and abandonment procedures enforced prior to the Pennsylvania Oil and Gas Act of 1984 (Battelle 2013). Additionally, many casings from these historic wells were removed during World War II to support the US steel requirements as part of the war effort. These wells typically were not closed properly and likely serve as the source of migration pathways to shallow groundwater aquifers (Battelle 2013). In Pennsylvania alone, over 180,000 wells were drilled prior to establishing requirements to document their locations; some of these wells were likely improperly abandoned and may serve as conduits for groundwater contamination (Davies 2011).

Four publications that contained Washington County groundwater data from between the 1920s and 2002 were identified (Table 2.2) (Battelle 2013; Low 2008; Newport and Socolow 1973; Piper 1933). These data may provide baseline groundwater quality values since the samples were collected before the first unconventional gas well was operational. Antimony, beryllium, cadmium, lead, molybdenum, nickel, selenium, silver, and vanadium all had medium values of 1 ppb or less. Median iron ranged from 185 to 700 ppb and median manganese ranged from 20 and 40 ppb. The highest median values were recorded for calcium (73,500 ppb), sulfate (61,500 ppb), and sodium (33,000 ppb). The authors of the Battelle study noted that elevated chloride levels observed in samples (six exceeded the USEPA MCL of 250,000 ppb) were likely not due to inputs from oil and gas extraction activities.

Table 2.2 Historic Median Groundwater Values & Exceedances – Washington County

Analyte		Location	Washington County				
		Source	Piper 1933	Battelle 2013		Newport 1973	Low 2008
		Years	1920s-1930s	1926-2002		1971	1983-1997
		Samples (n)	14	Varied: 8-196		14	Varied: 1-88
	Benchmark						
	Type	Value	Units	Median	Median	Exceedances (%)	Median	Median
Aluminum	SMCL	200	ppb	--	21	4.9	--	10
Antimony	MCL	6	ppb	--	--	--	--	1
Arsenic	MCL	10	ppb	--	3	0	--	3
Barium	MCL	2,000	ppb	--	--	--	--	79
Beryllium	MCL	4	ppb	--	--	--	--	1
Cadmium	MCL	5	ppb	--	ND	0	--	1
Calcium	--	--	ppb	69,000	73,500	--	68,500	73,500
Chromium	MCL	100	ppb	--	0.5[a]	--	--	26.5
Cobalt	--	--	ppb	--	--	--	--	2
Copper	SMCL	1,000	ppb	--	--	--	--	10
Iron	SMCL	300	ppb	610	185	38.4	700	185
Lead	AL	15	ppb	--	0.5	12.5	--	1
Magnesium	--	--	ppb	18,000	11,000	--	18,000	16,000
Manganese	SMCL	50	ppb	--	20	32.9	40	20
Mercury	MCL	2	ppb	--	0.05	0	--	0.1
Molybdenum	HBSL	40	ppb	--	--	--	--	1
Nickel	HBSL	100	ppb	--	0.5	--	--	1
Potassium	--	--	ppb	3,600	1,700	--	3,600	1,500
Selenium	MCL	50	ppb	--	0.05	0	--	1
Silver	SMCL	100	ppb	--	--	--	--	1
Sodium	--	--	ppb	29,500	15,000	--	33,000	30,000
Strontium	HBSL	4,000	ppb	--	580	--	--	580
Uranium	MCL	30	ppb	--	0.217	0	--	--
Vanadium	--	--	ppb	--	0.05	--	--	--

Analyte	Location			Washington County				
	Source			Piper 1933	Battelle 2013		Newport 1973	Low 2008
	Years			1920s-1930s	1926-2002		1971	1983-1997
	Samples (n)			14	Varied: 8-196		14	Varied: 1-88
	Benchmark		Units	Median	Median	Exceedances (%)	Median	Median
	Type	Value						
Zinc	SMCL	5,000	ppb	--	30	0	--	30
Bromide	--	--	ppb	--	50.5	--	--	60
Chloride	MCL	250,000	ppb	14,000	16,600	3.68	17,000	--
Fluoride	MCL	4,000	ppb	--	200	1.27	600	--
Nitrate	MCL	10,000	ppb	965	150	7.69	950	865
Sulfate	SMCL	250,000	ppb	61,500	53,700	0.22	53,500	53,650
pH	SMCL	6.5–8.5	SU	--	7.3	5.73	8.2	7.6
Conductivity	--	--	u/s	--	640	--	520	690
Temperature	--	--	°C	11.1	16.7	--	11.1	17.75

Notes-
[a]Chromium(IV); AL = Action level; HBSL = Health-based screening level; MCL = Maximum contaminant level; SMCL = Secondary maximum contaminant level; -- = No limit or value

3. Previous Research

Research related to unconventional natural gas operations and groundwater quality has been conducted by various governmental, academic, and private institutions. In general, these publications agree that additional research or continued monitoring is needed to elucidate, clarify, or dispel possible environmental and human-health impacts related to unconventional natural gas extraction operations. Several studies have looked at water quality utilizing physical distance, temporal trends (pre- and post-drilling samples), or literature reviews to assess possible natural gas activity impacts.

3.1 Nationwide

In 2004, the United States Environmental Protection Agency (USEPA) published a report that reviewed the impacts to underground water resources from coalbed methane hydraulic fracturing (USEPA 2004). The three year effort found that,

> "…the injection of hydraulic fracturing fluids into [coalbed methane] wells poses little or no threat to [underground sources of drinking water] and does not justify additional study at this time."

This was a focused study which looked at impacts from the hydraulic fracturing stage of natural gas extraction only. It did not include an assessment of the pre- or post-fracking operations. At the urging of Congress, USEPA has prepared a follow up report which was released for comment in June 2015 (USEPA 2015a).

The 2015 report assessed hydraulic fracturing activities that involve water including: water acquisition, chemical mixing, injection, flowback and produced water, and wastewater treatment and waste disposal. The major findings in this study were summarized as follows-

> "From our assessment, we conclude there are above and below ground mechanisms by which hydraulic fracturing activities have the potential to impact drinking water resources…We did not find evidence that these mechanisms have led to widespread, systemic impacts on drinking water resources in the United States. Of the potential mechanisms identified in this report, we found specific instances where one or more mechanisms led to impacts on drinking water resources, including contamination of drinking water wells."

3.2 Non-Pennsylvania States

A study of groundwater in the San Juan Basin, La Plata County, Colorado prior to and after gas well drilling found that in the 39% of samples where methane was detected, 21% had higher pre-drilling concentrations, while 18% had higher post-drilling concentrations (Gorody 2005). Ultimately, the authors determined that short and long term changes in methane concentrations are the result of: sampling error, environmental variability, aquifer mixing dilution, mixed biogenic and migrated thermogenic gas sources, and bacterially-mediated methane oxidation.

In the Barnett Shale region in Texas, one study found elevated levels of arsenic, selenium, strontium, barium, and total dissolved solids (TDS) in samples from private wells located within 3 kilometers of natural gas wells (Fontenot 2013). The spatial distribution of the private wells with elevated concentrations suggested that the elevated levels may be due to a variety of factors including mobilization of natural constituents, hydrogeochemical changes from lowering of the water table, or industrial accidents such as faulty gas well casings.

Another study in the Fayetteville Shale Formation in Arkansas analyzed trace elements, ions, redox, and methane in groundwater from shallow aquifer systems in sites less than and greater than 2 miles from an active natural gas well (Kresse 2012). Major ions and trace metals had lower concentrations in samples collected post-drilling when compared to historic samples. This study determined that the groundwater quality was the result of natural processes.

In 1982 the private well of a homeowner in West Virginia became contaminated with a gelatinous substance and polycyclic aromatic hydrocarbons (PAHs). The American Petroleum Institute (API) indicated that the groundwater contamination resulted from “a malfunction in the fracturing process.” Laboratory analysis of the water found high levels of fluoride, alkalinity, sodium, and total dissolved solids. USEPA posited that this was evidence for direct contamination from hydraulic fracturing fluids, particularly because of the viscous nature of the water (USEPA 1987).

3.3 Pennsylvania

Boyer et al. (2012) assessed water quality across 20 counties in private water wells of rural Pennsylvania before and after Marcellus Shale gas wells were drilled nearby. Approximately 40% of the water wells failed at least one federal MCL standard for samples collected before gas well drilling. These exceedances included primarily coliform bacteria, turbidity and manganese (Table 3.1). Analysis of post- versus pre-drilling samples did not suggest gas well drilling or hydraulic fracturing influenced the water quality.

Although statistical analysis did not indicate effects on water quality from gas well drilling, there were three instances where residents perceived changes in the water quality which were confirmed by analysis of post-drilling samples. Manganese values for these three houses were near or below the MCL (0.05 mg/L) in pre-drilling samples and increased far above the MCL in post-drilling samples (from 400 to 2,600 ppb). Iron values also increased for these locations. One household well showed an increase in bromide in the post-drilling sample, but the well was sampled 10 months later and bromide had returned to non-detect at that time. The study asserted that bromide increases appeared to be primarily related to drilling operations and may serve as an indicator for small influences from natural brines or drilling waste fluids. This is because bromide is typically not detected in undisturbed groundwater. The authors further stated that changes to groundwater are expected with land disturbance or drilling activity and are frequently transient in nature (Boyer 2012).

Table 3.1. Median Groundwater Values & Exceedances – Pennsylvania

Analyte		Location		Pennsylvania[a]	
		Source		(Boyer 2012)	
		Years		2010-2011	
		Samples (n)		233	
	Benchmark		Units	Median	Exceedances (%)
	Type	Value			
Arsenic	MCL	10	ppb	2.5	4
Barium	MCL	2000	ppb	130	1
Cadmium	MCL	5	ppb	<1	0
Calcium	--	--	ppb	36,160	--
Chromium	MCL	100	ppb	<5	0
Copper	SMCL	1,000	ppb	--	--
Iron	SMCL	300	ppb	50	20
Lead	AL	15	ppb	2.5	7
Magnesium	--	--	ppb	6,980	--
Manganese	SMCL	50	ppb	10	27
Mercury	MCL	2	ppb	<0.2	0
Potassium	--	--	ppb	1,270	--
Selenium	MCL	50	ppb	<5	0
Silver	SMCL	100	ppb	<0.5	0
Sodium	--	--	ppb	10,890	--
Strontium	HBSL	4,000	ppb	280	--
Bromide	--	--	ppb	<100	--
Chloride	MCL	250,000	ppb	5,900	<1
Nitrate	MCL	10,000	ppb	<500	0
Sulfate	SMCL	250,000	ppb	14,000	<1
pH	SMCL	6.5–8.5	SU	7.44	17

Notes-
[a]Samples collected prior to nearby Marcellus gas well drilling; AL = Action level; HBSL = Health-based screening level; MCL = Maximum contaminant level; SMCL = Secondary maximum contaminant level; -- = No limit or value

A study of methane in household water wells in Pennsylvania and New York found that homes <1 km from gas wells had methane concentrations six times higher than those farther away (Jackson 2013a). Jackson et al. used methane isotopes to distinguish between biogenic methane (produced by bacteria and typically shallower sources) and thermogenic methane (produced by buried organic sedimentary matter and from deeper sources). Results of this analysis indicated that some of the methane in household water wells had isotopic signatures consistent with biogenic sources, and some had Marcellus-like thermogenic methane sources.

Per the Pennsylvania Oil and Gas Act of 1984 gas well operators are presumed responsible for water pollution that occurs within 1,000 feet (304.8 meters) of the gas well for six months after drilling has been completed if no pre-drill samples were collected from private water supplies (Boyer 2012). If pre-drill samples are collected and the water quality declines after initiation of unconventional activities within 2,500 feet (610 meters) the operator is also presumed responsible. In both of these instances no specific causal link is needed. In 2014 the Pennsylvania Department of Environmental Protection (PADEP) released a statement that identified households with private water supplies that were adversely impacted by conventional or unconventional oil and gas activities per the requirements of the PA Oil and Gas Act of 1984 (PADEP 2016). This list is dynamic and updated by PADEP as needed and as of February 16, 2016 included 272 households, three of which were in Washington County. The distribution of impact determination by county is shown in Figure 3.1 and relative to the East and Northwest counties those in the Southwest (including Washington County) have fewer households with impacted water sources.

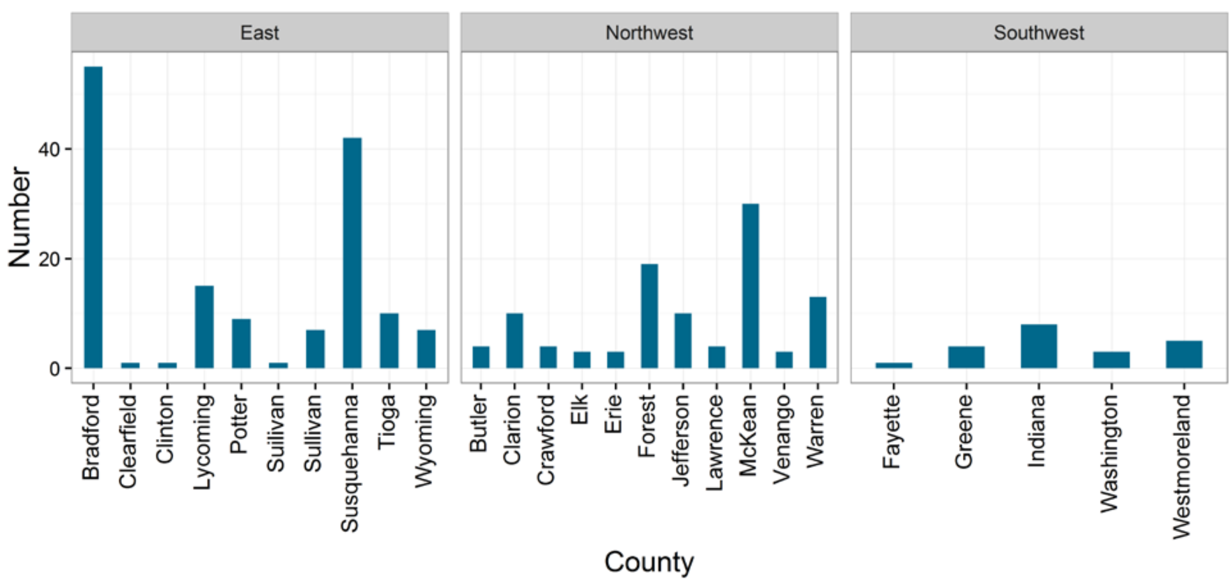


Figure 3.1 Number of Water Source Impact Determinations by County

PADEP does specify that the list does not necessarily represent ongoing impacts and many of the private wells on the list have returned to background conditions, been mitigated, or been addressed through the replacement of the original water supply.

From 2008 to 2012, PADEP received approximately 1,000 public complaints regarding groundwater quality. Of these complaints, 160 were credited to oil and gas operations (80 were to companies known to drill unconventional wells) and most of these were isolated in the NE portion of the state (Brantley 2015). Vidic et al. compiled information on violations issued by PADEP to oil and gas operators and found that between 2005 and 2013 3.4% (219/6,466) of unconventional gas wells received notices of violation for cement, casing, or well integrity problems (Vidic 2013). Other estimates of well integrity issues ranged between 1 and 6.2% (Ingraffea 2014; King 2012). Also during the 2005 to 2013 time period, 0.24% of all gas wells were cited for contaminating groundwater (Brantley 2015).

A study published in 2012 modeled the time it would take for hydraulic fracturing fluid injected into the Marcellus Shale at a depth of 1,500 m bgs to travel up to ground surface (Myers 2012). This study varied the conductivity, presence or absence of faults, and extent of faults in the shale and overlying sandstone matrices. The authors calculated that hydraulic fracturing fluid could be transported by advection to the surface in as little as ten years.

3.3.1 *Washington County*

In May 2015 USEPA published a retrospective case study regarding the potential impacts of hydraulic fracturing on drinking water resources in Washington County (USEPA 2015b). The study compared well and spring water sample data (22 locations, 46 samples) from 2011, 2012, and 2013 to historic groundwater quality data. Primarily, the conclusions indicated that the water quality data was consistent with historical observations, with the exception of chloride contamination in wells near a wastewater impoundment. Additionally, the county has naturally occurring methane in the groundwater with an isotopic signature that is distinct from the methane produced by Marcellus Shale gas wells. There was one MCL exceedance for nitrate and two for lead, and secondary maximum contaminant level (SMCL) exceedances were common for manganese and iron.

4. Research Objectives

The purpose of this study is to determine whether there is a correlation between: 1) household well water quality and unconventional natural gas well density; and 2) the change in household well water quality and the change in unconventional natural gas well density as a function of time in Washington County, Pennsylvania. To examine the relationship between unconventional gas activities and groundwater quality, chemical and physical measurements of water quality, source characteristics, PADEP-reported active unconventional gas well locations, precipitation data, and hydrogeological spatial data were evaluated in this study.

The primary research objectives were: to determine whether there is evidence of systematic impacts on groundwater quality from unconventional gas extraction activities; to employ potentially confounding variables in this relationship; to make use of publically available data to compensate for lacking baseline information; to use temporal and spatial analytical techniques to strengthen the conclusions regarding any identified associations; and to provide a methodological and analytical foundation for continued water quality monitoring at private households. This research was hypothesis generating, rather than hypothesis testing.

5. Methods

In order to accomplish my research objectives, I utilized household water supply samples that were previously collected and analyzed as part of a human health survey led by Dr. Peter Rabinowitz (Rabinowitz 2015). Additionally, I used publically available data for unconventional gas well locations and activity status, hydrogeological factors, and precipitation data.

5.1 Initial Research

In 2015 Rabinowitz et al. published a paper in Environmental Health Perspectives which found that residents living within 1 km of an active natural gas extraction well pad had a statistically greater ($p=0.02$) number of self-reported health symptoms compared with residents >2 km from the nearest gas well (Rabinowitz 2015). During this survey study (conducted in 2012), household well water samples were collected from the houses of survey participants with their permission. Additional water samples were collected in 2013. Follow-up water samples were collected in 2014 and several new households were also sampled at that time. The study site was comprised of 38 rural townships in Washington County. Using ArcGIS, households nearest to 20 randomly selected geographic points from each of the 38 townships were identified as potential survey and sample sites. Only houses with ground-fed water wells or springs were considered eligible. The analytical results from the household well water samples were the basis for the analysis herein.

5.2 Field Data Collection

Household water samples were collected in 2012, 2013, and 2014. The 2013 sampling event was focused on collecting water samples from houses that had not been sampled in 2012. Samples collected in 2014 were primarily collected from household locations that were previously sampled in 2012 or 2013 (paired samples; n=109), but some new households were also sampled. Table 5.1 below shows a summary of the samples collected for each year and the total number of unique household locations.

Table 5.1 Number of Houses Sampled

Sample Year	Total Households Sampled	New Households Sampled
2012	126	126
2013	13	11
2014	126	17

Total Samples	Total Houses
265	154

In 2012 household well water samples were collected in an effort led by Ms. Vanessa Lamers, a Master's student at Yale University. The 2013 and 2014 samples were collected using the same 2012 sampling methodology which is summarized below. A total of 154 households ("sites") were sampled and 109 sites have data for initial (2012 or 2013) and subsequent (2014) sample dates. The summary provided below is based on the descriptions in Vanessa Lamers' Master's Thesis (2013) from her research at Yale University.

Latitude-longitude coordinates (degrees) were recorded at each household sample location using a handheld global positioning system (GPS) device. Physical measurements (pH, conductivity, and temperature) were taken utilizing a probe and four separate samples were collected for laboratory analysis: 1) inorganics; 2) anions; 3) benzene, toluene, ethylbenzene, xylenes (BTEX); and 4) organics. The spigot nearest the household well head was preferentially sampled and all hoses or filters were removed prior to sample collection. Spigots were opened and run for approximately 3-5 minutes to purge the water, after which the water stream was reduced to ~1/8th of an inch for sample collection.

5.3 Sample Analysis

Physical measurements were collected in the field, while chemical analyses were conducted at Baron Consulting Co., Yale, and Connecticut Agricultural Experiment Station laboratories. For full details on sample analyses, see Appendix A.

5.4 Data Selection

5.4.1 *Exclusions*

The current study does not include analysis of any of the organic parameters in an effort to focus modeling design and separate analytes into two manageable groups. Analytical results for BTEX, antimony, beryllium, gadolinium, and thallium were all non-detects, results for cadmium, vanadium, and nitrite had only one detected value, and silver had four detected values near the detection limit. All of these analytes were excluded from the analyses because they lacked sufficient data points.

The 2013 and 2014 iron analyses had a detection limit (25 ppb) three orders of magnitude higher than 2012 detection limit (0.5 ppb) and there were no detected values in 2013 and only two detected values in 2014. This would artificially elevate average values for the cross-sectional analysis and incorrectly indicate an increase in most iron values for the temporal analysis. Therefore only 2012 iron values were included in the cross-sectional analysis and iron was not included in the temporal analysis. Silicon was not included in the temporal analyses because it was only analyzed in the 2012 samples. During data quality assurance/quality control (QA/QC) procedures, the 2012 anion data for bromide, chloride, fluoride, nitrate, phosphate, and sulfate had been flagged as circumspect due to negative reported values and so was not included in cross-sectional or temporal analyses.

There were 20 samples from 2012 and one sample from 2014 that were excluded from the cross-sectional analysis, and there were 61 households excluded from the temporal analysis. Reasons for these exclusions are detailed below in Table 5.2.

Table 5.2 Sample and Household Exclusions

<table>
<tr><td colspan="2">Reason for Exclusion</td><td colspan="3">Number Excluded</td></tr>
<tr><td rowspan="5">Samples</td><td>Cross-Sectional Analysis</td><td>2012</td><td>2013</td><td>2014</td></tr>
<tr><td>Collected after water received treatment</td><td>18</td><td>--</td><td>--</td></tr>
<tr><td>Water source is uncertain</td><td>1</td><td>--</td><td>3</td></tr>
<tr><td>Sample data was not from the location indicated</td><td>2</td><td>--</td><td>1</td></tr>
<tr><td>Total</td><td>21</td><td>0</td><td>4</td></tr>
<tr><td rowspan="7">Households</td><td colspan="4">Temporal Analysis</td></tr>
<tr><td>No initial or subsequent sample (one sample at household – unpaired)</td><td colspan="3">45</td></tr>
<tr><td>Initial sample unusable because it was collected after water received treatment</td><td colspan="3">12</td></tr>
<tr><td>Water source different between initial and subsequent sample events</td><td colspan="3">2</td></tr>
<tr><td>Water source is uncertain</td><td colspan="3">1</td></tr>
<tr><td>Sample data was not from the location indicated</td><td colspan="3">1</td></tr>
<tr><td>Total</td><td colspan="3">61</td></tr>
</table>

5.4.2 *Inclusions*

Analytes that were included in the cross-sectional analysis were: aluminum, arsenic, barium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, nickel, potassium, selenium, silicon, sodium, strontium, tin, uranium, zinc, bromide, chloride, fluoride, nitrate, phosphate, sulfate, pH, conductivity, and temperature.

Analytes included in the temporal analysis were: aluminum, arsenic, barium, calcium, chromium, cobalt, copper, lead, lithium, magnesium, manganese, mercury, nickel, potassium, selenium, sodium, strontium, tin, uranium, zinc, pH, conductivity, and temperature.

Of the 265 available samples, 240 were included in the cross-sectional analysis collected from 145 households. There were 186 samples (93 initial samples and 93 subsequent samples) and 93 households included in the temporal analysis.

5.5 Data Treatments

5.5.1 *Gas Well Density*

Gas well density was based on a 2 km radius around the household well location and calculated using a spatial join in ArcGIS. The 2 km cutoff distance was the distance determined in Rabinowitz et al. 2015 for dermal and respiratory effects. Determination of whether a gas well was active at the time of the household well water sample collection depended upon well spud dates (aka the date drilling began). The gas well density is represented by the count of gas wells within the 2 km radius. ArcGIS kernel density with a search radius of 5 km was selected to generate the gas well density coverage plot presented in the site background section.

5.5.2 *Precipitation*

Annual rainfall for each household was assigned according to the nearest grid measurement from the NOAA-NWS precipitation vector file (NWS 2015). Rainfall values for 2012, 2013, and 2014 were assigned to each household.

5.5.3 *Spatial Data Assignment*

Each household site was assigned a nominal or continuous variable from a spatial layer for: formation, watershed, and annual rainfall. This was performed in ArcGIS with a spatial join function. These and household elevation served as controlling variables in all the multiple regression analyses described below. Site elevation was calculated using an online tool based on the locational information (latitude-longitude) (Schneider 2015).

5.5.4 *Household Well Depth*

Household well depth was available for 72 of the 154 households and was expected to be an important factor in the water quality. Since it was not available for all households, the cross-sectional multiple linear regression analysis was performed both with and without household well depth as a controlling variable for all analytes.

5.5.5 *Confidentiality*

To protect the confidentiality of the household locations for participants in this study, any plots using the location of the household were provided without any reference layers (e.g. county boundaries, terrain, etc.) or descriptive axes. This effectively de-identifies the houses while still preserving the relational attributes of the water quality parameters between houses.

5.5.6 *Reference Groups*

For the multiple linear regression, categorical variables had differential representation within the dataset. To maximize the benefit of the comparison, the group with the largest number of households was selected as the comparison group. This was applicable for the water source, watershed, and formation. The reference groups used are:

- Household Water Source – Well.
- Watershed – Headwaters Buffalo Creek.
- Formation – Washington Formation.

5.5.7 *Detection Limit*

For sample analytes with results below the limit of detection, a value set to half the detection limit was assigned.

5.5.8 *Averages*

In order to prevent differential weighting of households with multiple sample measurements in the cross-sectional regression analysis, sample value averages were used for each location. Averages were also used for gas well density and precipitation at each household.

5.5.9 *Change Over Time*

To obtain the change over time, initial (2012 & 2013) sample values, gas well densities, and precipitation values were subtracted from subsequent (2014) sample values. Resulting values will be positive in instances where the 2014 value is higher (increase) and negative where the 2014 value is lower (decrease). Since the values for the temporal analysis were positive, zero and negative numbers, it was necessary to shift all values to positive non-zero numbers prior to executing the correlation matrix (further detailed in the Statistical Analysis section). This was accomplished by adding the absolute value of the minimum plus one for each analyte to all values for that analyte.

5.6 Qualitative Analysis

Several spatial variables were of interest in this analysis and the data for these was supplied by the study data collection itself, and from online geospatial information system (GIS) repositories such as the Pennsylvania Spatial Data Access (PASDA), ESRI ArcGIS, PADEP, and the National Oceanic and Atmospheric Administration – National Weather Service (NOAA – NWS). These variables are summarized in Table 5.3.

Table 5.3 Spatial Variables

Variable	Source	Reference
Unconventional gas wells	PADEP	(PADEP 2015a)
Household water source	Current study	(Rabinowitz 2015)
Geological formation	PASDA	(Reese 2010a)
HUC-12 watershed	ESRI	(FracTrackerAlliance 2012)
Elevation	GPS Visualizer	(Schneider 2015)
Precipitation	NOAA – NWS	(NWS 2015)

These data were used to generate informative maps in ArcGIS and were used as an exploratory tool for inductive research. Additional maps were created to show graduated symbol plots of each water quality analyte and plots showing locations with increases or decreases. These were generated in R (a statistical software suite) using ggplot2 (Wickham 2009) and include data from both the cross-sectional and temporal analysis. The sample data plots are devoid of locational identifiers to protect the privacy of the homeowners as described above.

5.7 Statistical Analysis

5.7.1 *Power Calculations*

Though the sample size has already been established, calculating required sample size by varying power and effect size gave us an indication of whether or not we would be able to detect a true difference. For this reason, the pwr package in R was used (Champley 2015) with an assumed normal data distribution. Although the data was not initially normally distributed, the Box-Cox power transformations detailed below was implemented to achieve normality.

5.7.2 *Summaries*

Data summaries were generated to determine the general water quality of the samples and whether there was sufficient data to include each analyte in further analysis. The data summaries are tabulated separately for the cross-sectional and temporal results. Analytes with sufficient data (more than four detected values) were included in additional analysis.

5.7.3 *Correlation Matrix*

Since there are a large number of analytes a correlation matrix was generated using the corrplot package (R Core Team 2014; Wei 2013) with all predictor, outcome, and controlling continuous variables. The correlation matrix allowed exploration of the dependencies between variables at one time (STHDA No Date).

5.7.4 *Principal Component Analysis (PCA)*

There are a large number of water quality variables (n=31) included in this analysis and PCA often allows researchers to reduce the dimensions of a dataset and observe the components which account for the greatest variability within a complex dataset (PSU 2016). Only households with data for all variables included in the analysis are eligible for PCA. Rows (i.e. households) with missing values for any one variable (i.e. column) are excluded because the model requires values for all included variables.

The dataset for this analysis has a limited number of samples or households for both cross-sectional and temporal analyses and PCA is less able to identify trends within complex, small datasets (UNT 2009). To minimize the variables included in the PCA, the results of the correlation matrix were used to identify analytes with minimal correlations and remove them from the PCA. These variables tended to be ones with primarily non-detect values in the cross-sectional analysis, and variables with primarily no change (i.e. zero values) in the temporal analysis. For the cross-sectional analysis aluminum, arsenic, calcium, cobalt, magnesium, mercury, selenium, silicon, strontium, tin, phosphate, pH, and temperature were removed. Arsenic, chromium, cobalt, lead, selenium, and uranium were removed from the temporal PCA.

5.7.5 *Wilcoxon Signed Rank Test*

There were 93 households which were sampled in 2012 or 2013 and 2014 that are included in this analysis. To determine whether there is a difference between the initial and subsequent sample results the Wilcoxon signed rank test was employed for each analyte using the stats package in R (R Core Team 2014). The null hypothesis is that the difference between the initial analyte median and subsequent analyte median is zero and I used a confidence level of 95%. This test was used instead of a t-test because the data is not normally distributed.

5.7.6 *Non-Parametric Correlation*

To test the association between the predictor of interest (gas well density) and each outcome of interest (water quality analyte) I used a non-parametric rank correlation test in Kendall's Tau (R Core Team 2014) because it does not assume linearity or normality. This correlation was selected because it was anticipated that there would be some outliers in the dataset and the sample size is small so Spearman's Rho was not appropriate (Statistics Solutions 2015). Kendall's Tau was calculated for both the cross-sectional and temporal analyses.

5.7.7 *Box-Cox Transformation*

As with many environmental datasets, there were non-detect values (Type 1 left censored (Millard 2013)) which resulted in an exponential distribution for many of the analytes in the cross-sectional dataset. The non-detect issue also resulted in many analytes with zero change values for the temporal analysis which created a Cauchy distribution. The EnvStats package in R was used since it has a Box-Cox function for censored variables[1] (Millard 2013) and the Mass package for variables that had no censored values[2] (Venables and Ripley 2002). Box-Cox power transformations use a normal probability plot to determine the optimal lambda (λ) value for the variable of interest. The optimal λ value is the power you raise the variable to and provides a data distribution most near to normal (NIST-ILT No Date).

5.7.8 *Multiple Linear Regression*

Prior to running each analyte through the multiple linear regression model, each response variable received a Box-Cox power transformation to normalize the data distribution and minimize heteroscedasticity. To verify that the transformation resulted in more appropriately scaled data for the regression analysis the transformed and non-transformed data were compared with the following:

- Histogram and box-plots of distributions,
- Skewness and Kurtosis,
- Regression object plots:
    - Residuals vs. Fitted,
    - Normal Q-Q,
    - Scale-Location,

[1] Aluminum, arsenic, barium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, nickel, potassium, selenium, silicon, strontium, tin, uranium, zinc, bromide, fluoride, nitrate, phosphate, and sulfate.
[2] Sodium, chloride, pH, conductivity at 25 °C, and temperature.

- Residuals vs. Leverage,
- Akaike's '*An Information Criterion*' (AIC) scores, and
- 95% confidence intervals for estimates.

Based on an assessment of the factors listed above, the original non-transformed or Box-Cox model was selected for each analyte. All diagnostic plots and regression summaries are provided in Appendix B.

A multiple regression model (generalized linear model (R Core Team 2014)) was used to test the relationship between the predictor of interest (gas well density) and the outcome of interest (water quality analyte), adjusting for several hydrogeological and climate variables of interest. The working null hypothesis is that there is no change in the water quality analyte value for each additional gas well located within 2 km of the household. Below, Equation 5.1 and Equation 5.2 show the non-transformed models (with and without household well depth respectively), and Equation 5.3 and Equation 5.4 show the Box-Cox transformed models (with and without household well depth respectively.

Equation 5.1. Non-Transformed Model with Well Depth

$$Y = \beta_0 + \beta_G x_G + \beta_A x_A + \beta_W x_W + \beta_F x_F + \beta_S x_S + \beta_P x_P$$

Equation 5.2. Non-Transformed Model with Well Depth

$$Y = \beta_0 + \beta_G x_G + \beta_A x_A + \beta_W x_W + \beta_F x_F + \beta_S x_S + \beta_P x_P + \beta_D x_D$$

Equation 5.3. Transformed Model

$$Y^\lambda = \beta_0 + \beta_G x_G + \beta_A x_A + \beta_W x_W + \beta_F x_F + \beta_S x_S + \beta_P x_P$$

Equation 5.4. Transformed Model with Well Depth

$$Y^\lambda = \beta_0 + \beta_G x_G + \beta_A x_A + \beta_W x_W + \beta_F x_F + \beta_S x_S + \beta_P x_P + \beta_D x_D$$

Where,

$Y = Analyte\ or\ physical\ parameter\ value$

$\lambda = Optimal\ lambda\ value$

$\beta_0 = Intercept\ coefficient$

$\beta_G = Gas\ well\ density\ coefficient$

$\beta_A = Altitude\ coefficient$

$\beta_W = Watershed\ coefficient$

$\beta_F = Formation\ coefficient$

$\beta_S = Source\ coefficient$

$\beta_P = Precipitation\ coefficient$

$\beta_D = Household\ well\ depth\ coefficient$

Six controlling variables were selected: elevation, watershed, formation, source, precipitation, and household well depth. The first five were available for all household locations, but due to data collection limitations well depth was not collected for all household locations. For the cross-sectional analysis there were 72 of the 145 households that had recorded well depth; for the temporal analysis there were 25 of the 48 households that had recorded well depth. Due to the small sample size of the temporal data subset, I did not run a separate regression model with well depth as a controlling variable.

Elevation

The elevation serves as a surrogate for peaks and stream valleys which may have alluvial deposits. The locations of these deposits were not available in the GIS datasets I compiled. Precipitation is able to more easily infiltrate through the alluvial deposits and water spends less time in contact with the surrounding soil/rock. This results in decreased mineralization of the available groundwater and subsequently lower analyte concentrations (Earth Sciences Consultants 2001).

Watershed

According to the United States Geological Survey (USGS), “a watershed is the area of land where all of the water that falls in it and drains off of it goes to a common outlet” (USGS 2015). Since surface runoff during rainfall events infiltrate through each identified catchment area, localized effects may alter groundwater quality.

Geology

The geology of the well location will have an effect on groundwater chemistry since chemicals associate with or dissociate between the soil/rock particles and water (Hoch 2008; Swistock 2009). The water chemistry can often be attributed to one or more natural processes unique to the aquifer geology (e.g. dissolution, precipitation, oxidation-reduction reactions, ion exchange, and biological activity (USGS

1986)). Since we do not have cores for each household well to characterize the specific geology, we will be using the formation as a surrogate measure. Geologic formations are unique and distinct from the neighboring formations (Earth Sciences Consultants 2001).

Precipitation

The amount of precipitation in a given area will have an effect on groundwater quality (Earth Sciences Consultants 2001). This is especially true in Washington County, PA because precipitation is solely responsible for groundwater recharge (Earth Sciences Consultants 2001).

Groundwater Source

Since samples were collected from both spring water sources and well water sources, we used source as a controlling variable. Spring water is typically representative of shallower aquifer resources and may be at higher risk for impacts from surface contamination (Berndt 2005).

Household Well Depth

I expect the depth of the household well to have an impact on water quality. Shallower wells/springs may be subject to land use impacts and deeper wells draw more saline water. Additionally, wells at different depths may tap into aquifer systems with different geology (Farrel-Poe and Pater 2011).

6. Results

6.1 Qualitative

In addition to the land use, formation, watershed and general reference maps presented as part of the site background, data maps were generated in R showing sample values and locations with increases or decreases in concentrations. While some of these maps are highlighted below, all are compiled in Appendix C (graduated symbols) and Appendix D (increases and decreases). In general, there were few spatial patterns observed within the data.

6.1.1 *Cross-Sectional*

Chromium and iron displayed the highest values in the southwestern portion of Washington County and the location of the highest values for these two analytes were generally the same. To the northwest and southeast lithium and magnesium exhibited relatively higher concentrations (Figure 6.1).

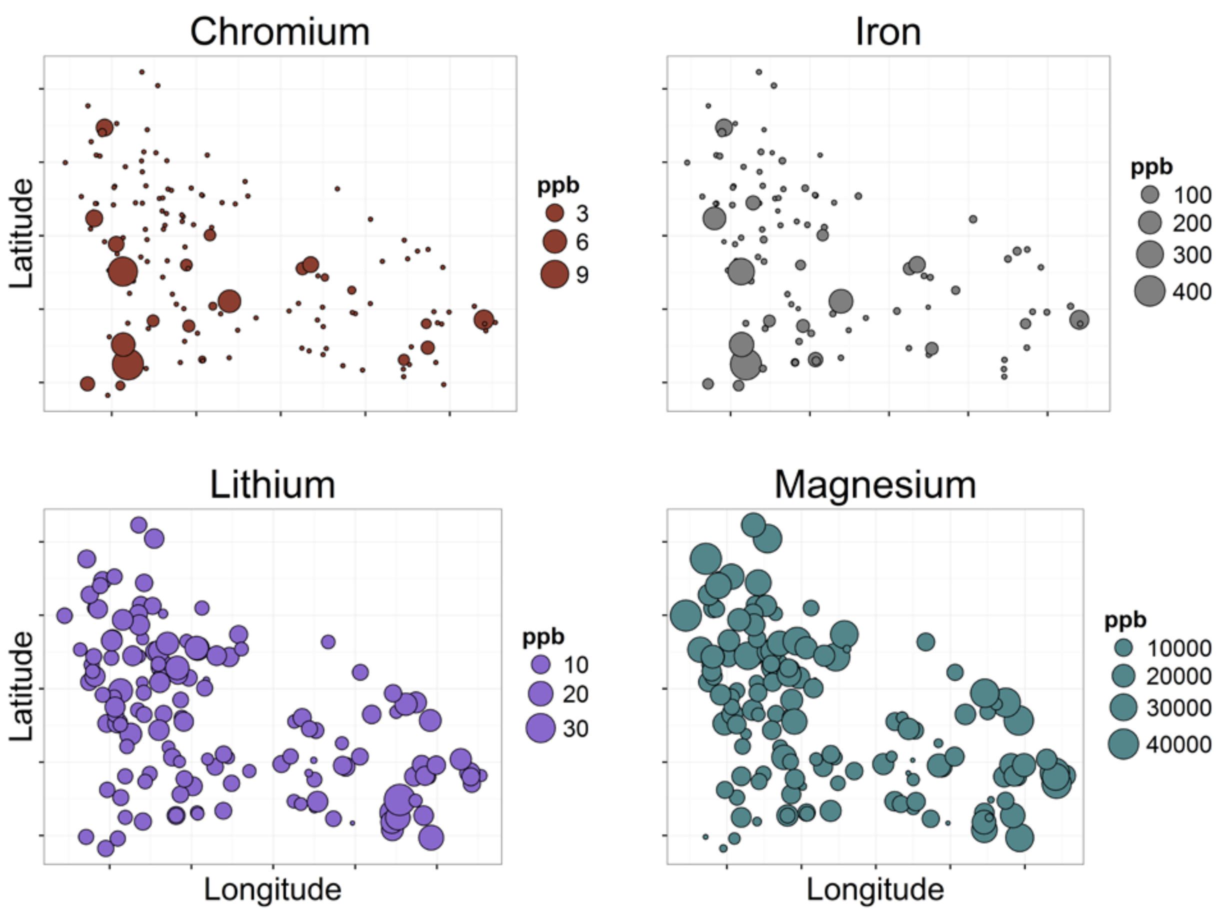


Figure 6.1 General Cross-Sectional Spatial Patterns

6.1.2 *Temporal*

A review of the temporal data plots did not yield obvious spatial patterns to the water quality variables with few exceptions. Increases in selenium concentrations occurred in the northwestern and southeastern corners of the county (Figure 6.2).

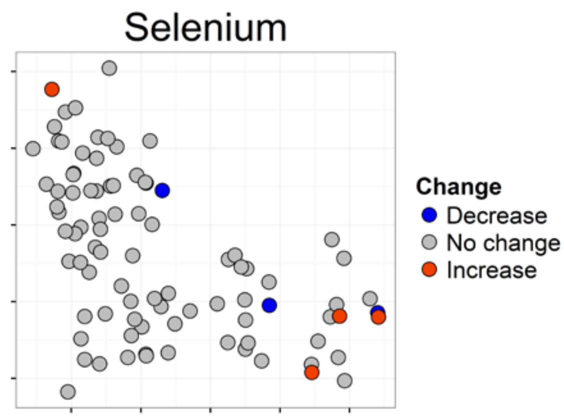


Figure 6.2 Distribution of Selenium Increases

Regarding decreases, lead showed concentration decreases in the northwest region of the county and tin concentrations decreased in households in the southeast (Figure 6.3).

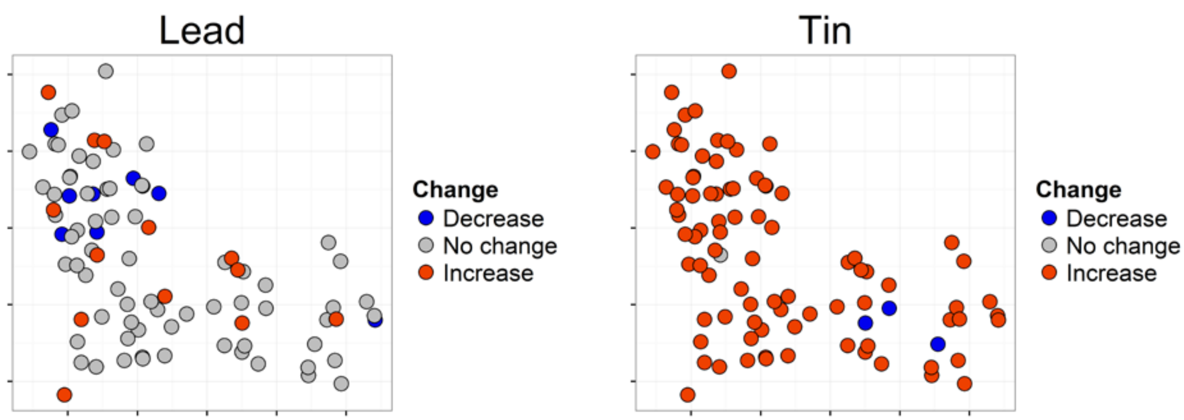


Figure 6.3 Distribution of Lead and Tin Decreases

6.2 Quantitative

6.2.1 *Power*

To determine the power of my analysis, varying effect size from 20 – 40% and using an alpha level of 0.05 for a two-tailed analysis revealed that the cross-sectional analysis (n=240) would have 87% power for a 20% effect size. Since the temporal dataset had fewer samples (n=186), the analysis would have 78% power for a 20% effect size. Figure 6.4 below shows the power distributions and sample sizes for the variable effect sizes (20%, 30%, and 40%).

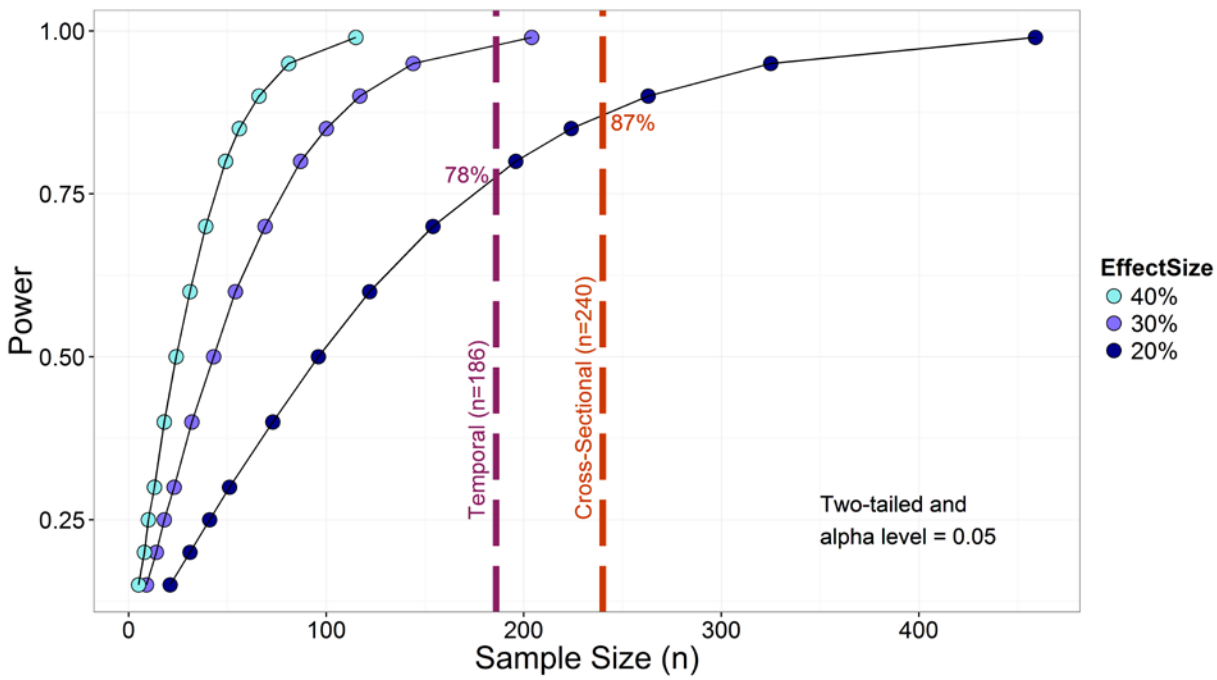


Figure 6.4 Power and Sample Size Varying Effect Size

6.2.2 *Summaries*

There were 28 chemical and three physical analytes included in the cross-sectional summary. Most of the 240 samples had values that were within the regulatory limits provided by Pennsylvania's maximum contaminant levels (MCLs), secondary maximum contaminant levels (SMCLs) (PADEP 2011), or the United States Geological Survey's health-based screening level (Toccalino 2014) standards (20 analytes – see Table 6.1). However, six analytes exceeded those standards: manganese, pH, aluminum, iron, lead, and mercury. Manganese and pH had the most exceedances at 30 and 29 samples respectively.

Aluminum, iron, and lead each had one sample with an exceedance while mercury had two samples with exceedances. There are no standards for the remaining eleven analytes[3].

Median values for magnesium, nickel, sodium, and pH were within the range of medians reported in the historic Washington County reports (see Table 2.2 for historic medians) (Battelle 2013; Low 2008; Newport and Socolow 1973; Piper 1933). Samples for these historic publications were collected prior to 2004 – the year the first unconventional gas well came online in the county. Four analytes had higher medians than the historic datasets: barium (104 versus 79 ppb), calcium (75,130 versus 68,500–73,500 ppb), conductivity (703 versus 520–690 u/s), and temperature (21.2 versus 11.1–17.8 °C).

Median iron was considerably lower (1.4 ppb) than the medians report in historic publications (185–700 ppb) and this was true also for chloride (10.1 versus 14,000–17,000 ppb), fluoride (0.21 versus 200–600 ppb), nitrate (0.295 versus 150-965 ppb), and sulfate (36.575 versus 53,650–61,500 ppb)[4]. Manganese was also lower with a median of 0.8 ppb in our samples versus 20–40 ppb in the historic data. Potassium was slightly lower (1,218 ppb) than the historic median range (1,500–3,600 ppb) as was strontium (416 versus 580 ppb) and zinc (18 versus 30 ppb). Median comparisons are plotted below in .

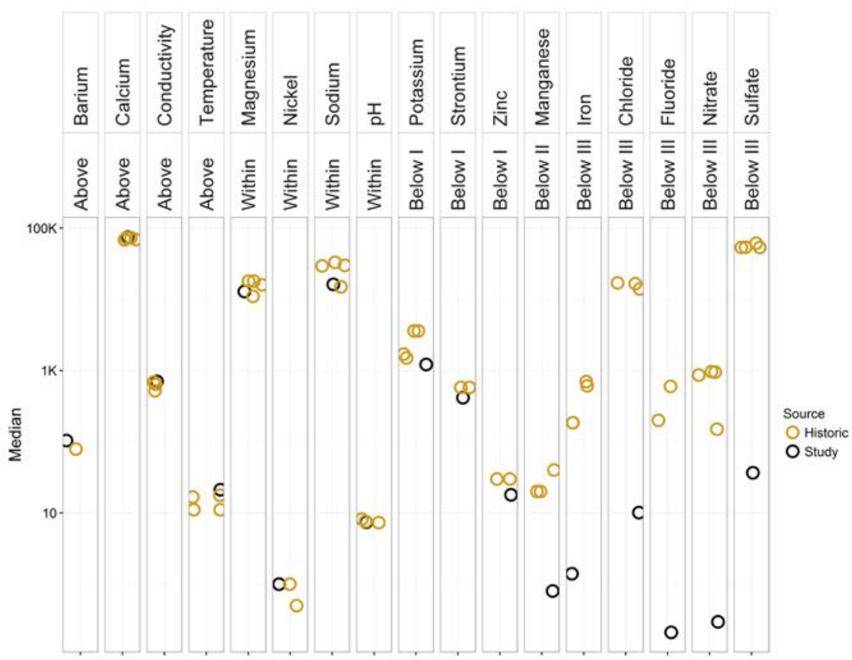


Figure 6.5 Current Study and Historic Median Comparisons

---

[3] Calcium, cobalt, lithium, magnesium, potassium, silicon, sodium, bromide, phosphate, conductivity, and temperature.
[4] When compared to historic data, all anions in this study dataset are ~1,000-time smaller. It is likely that the anion results were in ppm, not ppb. Original laboratory reports need to be reviewed, but at the time of this report confirmation had not been received regarding this issue.

Table 6.1 Cross Sectional Data Summary

Analyte	Units	Limit	Samples (n)	Min	Median	Max	Outside Limit (n)
Aluminum	ppb	200	237	0.25	0.25	329	1
Arsenic	ppb	10	237	0.25	0.25	4.4	0
Barium	ppb	2,000	237	0.25	104	1,211	0
Calcium	ppb	--	237	50	75,130	213,416	--
Chromium	ppb	100	237	0.25	0.25	23	0
Cobalt	ppb	--	237	0.25	0.25	1.8	--
Copper	ppb	1,000	237	0.25	9.6	389	0
Iron	ppb	300	104	0.25	1.4	424	1
Lead	ppb	5	237	0.25	0.25	7.923	1
Lithium	ppb	--	237	0.25	7.684	39	--
Magnesium	ppb	--	237	10	12,910	45,773	--
Manganese	ppb	50	237	0.25	0.8	365	30
Mercury	ppb	2	237	0.25	0.25	3.2	2
Nickel	ppb	100	237	0.25	1	6	0
Potassium	ppb	--	237	25	1,218	24,130	--
Selenium	ppb	50	237	0.25	0.25	2.6	0
Silicon	ppb	--	104	0.25	5,229	11,820	--
Sodium	ppb	--	237	2517	16,246	468,900	--
Strontium	ppb	4,000	237	0.25	416	2,931	0
Tin	ppb	22,000	237	0.25	1	94	0
Uranium	ppb	30	237	0.25	0.25	2	0
Zinc	ppb	2,000	237	0.25	18	1,714	0
Bromide	ppb	--	134	0.025	0.025	2	--
Chloride	ppb	250,000	134	0.43	10.115	332	0
Fluoride	ppb	2,000	134	0.025	0.21	4	0
Nitrate	ppb	10,000	134	0.025	0.295	5.6	0
Phosphate	ppb	--	134	0.05	0.05	1.81	--
Sulfate	ppb	250,000	134	0.25	36.575	362.5	0
pH	SU	6.5-8.5	233	4.35	7.39	9.45	29
Conductivity (at 25 °C)	u/s	--	237	185	703	2319	--
Temperature	°C	--	237	13.1	21.2	34.1	--

Notes-
-- No limit or value

Arsenic, barium, manganese, nickel, potassium, sodium, strontium, bromide, chloride, fluoride, and nitrate had the highest values in well source water versus spring or mix sources (black plots in Figure 6.6). Selenium, on the other hand, was highest in spring source water in households in the east. These high selenium values were located in the Waynesburg Formation and Monongahela Group (blue plot in Figure 6.6).

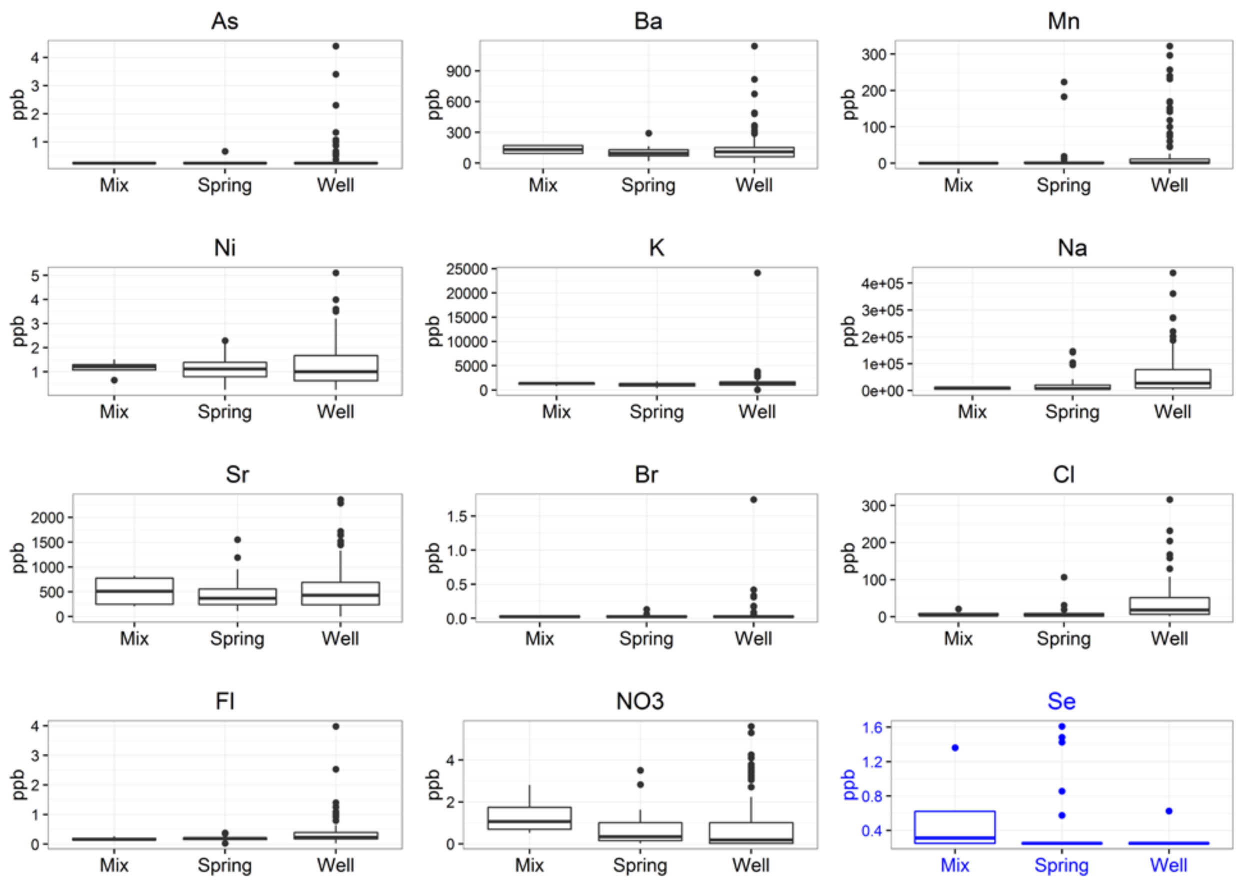


Figure 6.6 Analytes with Highest Values by Source

The Casselman Formation (limestone) and Monongahela Group (shale) had relatively higher magnesium values than the sandstone formations (Washington, Waynesburg, and Greene). Whereas the highest iron, mercury, nickel, and aluminum concentrations were found in the Waynesburg, Greene, and Washington Formations (primary lithology is sandstone for all three) (Figure 6.7).

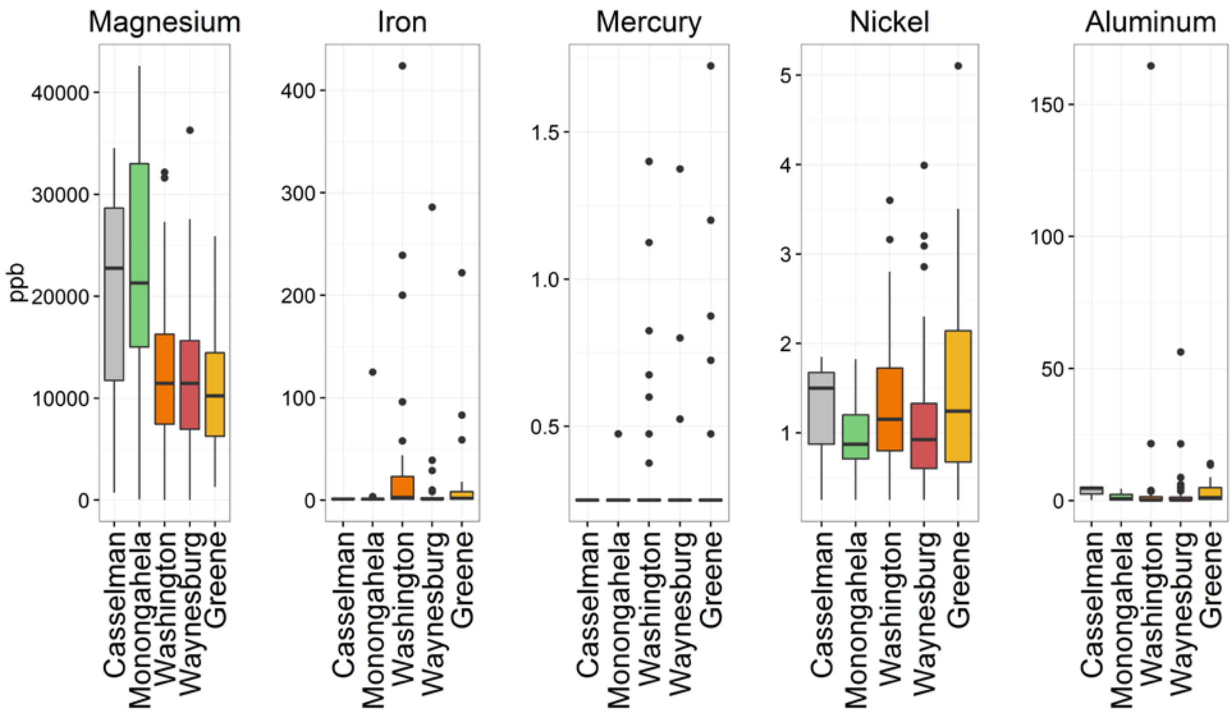


Figure 6.7 Cross-Sectional Highest Concentrations by Formation

Of the 23 analytes in the temporal analysis, nine had median change values of zero and another nine had median change values within -1 and 1. Two analytes, cobalt and mercury, did not have any concentration increases. Barium, potassium, sodium and strontium had negative medians and magnesium and conductivity were the only analytes with substantial positive medians. All changes in gas well density were positive with the greatest value being an increase of 21 gas wells within 2 km of one household (Table 6.2).

Table 6.2 Temporal Data Summary

Analyte or Measure Name	Units	Households (n)	Min	Median	Max
Aluminum	ppb	91	-329	0	37.2
Arsenic	ppb	91	-1.25	0	0.052
Barium	ppb	91	-621	-4.52	183
Calcium	ppb	91	-91,353	1	97,700
Chromium	ppb	91	-22.8	0	0.41
Cobalt	ppb	91	-0.79	0	0
Copper	ppb	91	-295	0.37	196
Lead	ppb	91	-1.25	0	1.17
Lithium	ppb	91	-19.5	1.02	12.2
Magnesium	ppb	91	-17,500	703	21,381
Manganese	ppb	91	-365	0	152
Mercury	ppb	91	-2.95	0	0
Nickel	ppb	91	-3.15	-0.25	2.81
Potassium	ppb	91	-4931	-129	1152
Selenium	ppb	91	-2.35	0	1.22
Sodium	ppb	91	-222,920	-1,000	111,770
Strontium	ppb	91	-1288	-12.9	1995
Tin	ppb	91	-1.42	0.78	3.63
Uranium	ppb	91	-0.55	0	0.70
Zinc	ppb	91	-169	-0.91	203
pH	SU	91	-1.41	0.11	2.87
Conductivity (at 25 °C)	u/s	91	-479	30	764
Temperature	°C	93	-14.6	-1.1	9.8
Change in Precipitation	Inches	93	-20.4	-9.24	8.46
Change in Gas Wells (2 km)	Count	93	0	1	21

Aluminum, calcium, and strontium had approximately an equitable number of households that experienced increases and decreases. Arsenic, chromium, cobalt, lead, mercury, selenium and uranium were dominated by no change. Almost all households had an increase in tin concentration (87/91) and the majority of households showed a decrease in nickel (60/91). Lithium concentrations that experienced an increase often corresponded with an increase in gas well density (37 households). Precipitation values typically decreased between the initial and subsequent sampling events (Table 6.3).

Table 6.3 Change in Values Relative to Change in Gas Well Density

Analyte or Measure Name	Decrease (n)	No Change (n)	Increase (n)	Decrease in Analyte, Increase in Gas Wells (n)	Increase in Analyte, Increase in Gas Wells (n)
Aluminum	28	36	27	14	13
Arsenic	8	82	1	5	0
Barium	57	1	33	31	16
Calcium	45	0	46	26	22
Chromium	17	72	2	5	1
Cobalt	7	84	0	3	0
Copper	39	4	48	18	28
Lead	8	70	13	4	5
Lithium	21	1	69	11	37
Magnesium	36	1	54	21	26
Manganese	40	24	27	21	12
Mercury	12	79	0	5	0
Nickel	60	9	22	34	9
Potassium	63	0	28	38	10
Selenium	3	84	4	0	2
Sodium	66	0	25	37	11
Strontium	49	1	41	27	20
Tin	3	1	87	0	47
Uranium	29	53	9	11	6
Zinc	51	0	40	24	24
pH	35	1	55	20	27
Conductivity (at 25 °C)	36	0	55	20	27
Temperature	52	1	38	26	21
Change in Precipitation	82	0	11	--	--
Change in Gas Wells (2 km)	0	45	48	--	--

6.2.3 *Correlation Matrix*

Generally speaking, there was very little correlation among variables for the cross-sectional or temporal data. Within the cross-sectional correlation matrix, the strongest positive correlations were between chromium/iron (0.56), calcium/nickel (0.49), magnesium/strontium (0.48), chloride/conductivity (0.44), and nickel/sulfate (0.40). The strongest negative correlations were between calcium/sodium (-0.41) and manganese/nitrate (-0.42). Figure 6.8 below provides the full mixed model correlation matrix for the cross-sectional analysis. Larger boxes with more color intensity indicate greater correlation coefficients (Kendall's Tau). Blue boxes are positive correlations while red are negative correlations.

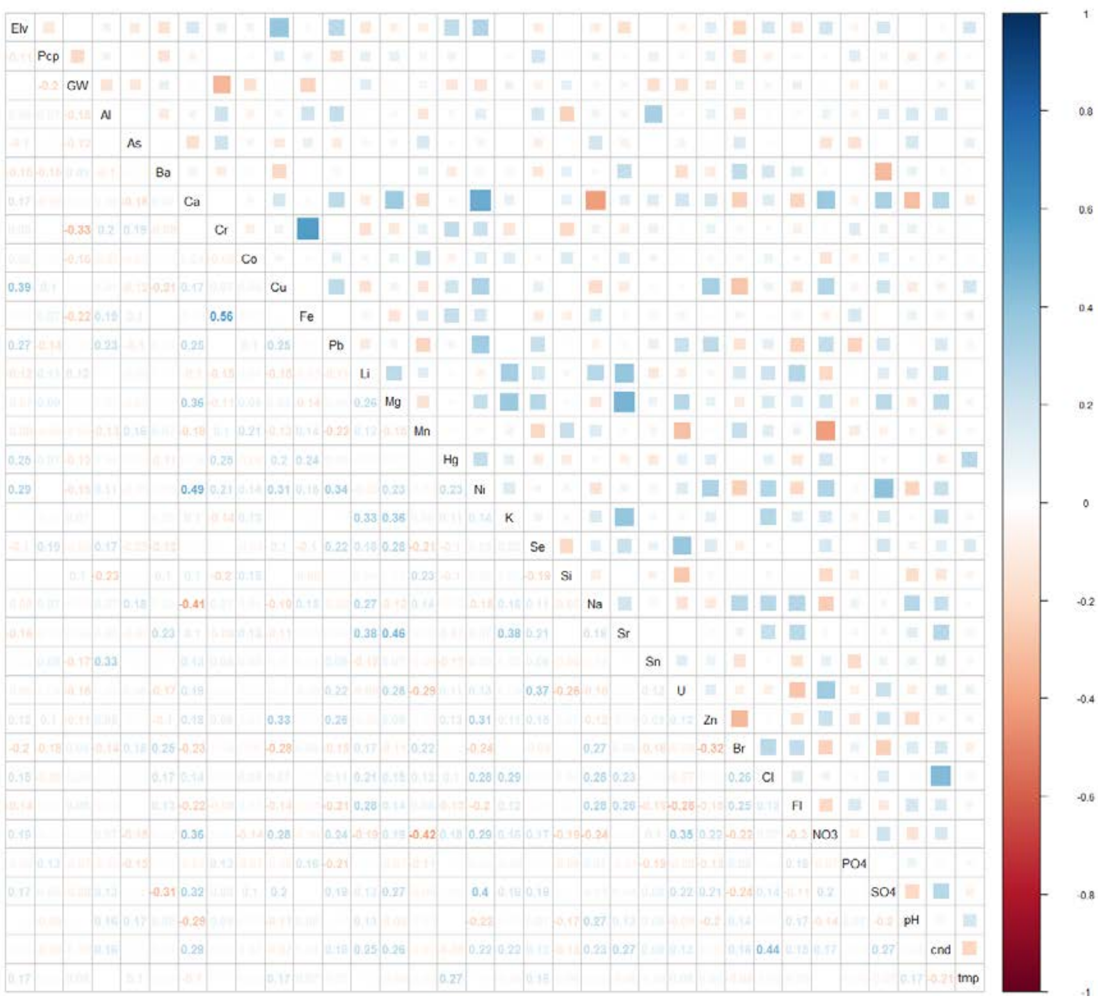


Figure 6.8 Cross-Sectional Correlation Matrix

The temporal correlation matrix (Figure 6.9) had the strongest positive correlations between calcium/magnesium (0.54), chromium/nickel (0.37), and magnesium/potassium (0.33) while the strongest negative correlation was between conductivity/temperature (-0.29).

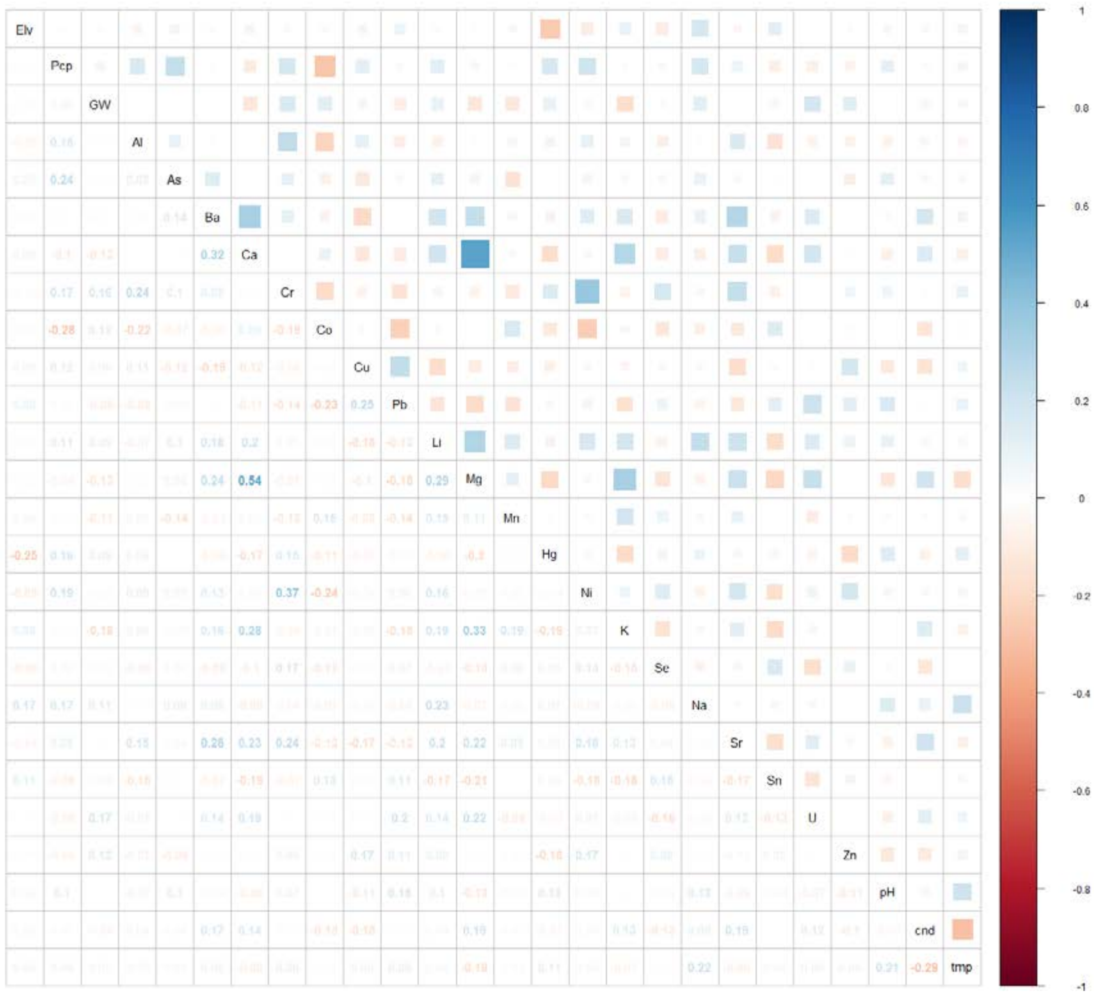


Figure 6.9 Temporal Correlation Matrix

6.2.4 *PCA*

One of the underlying assumptions of PCA is that there is correlation among the variables included in the analysis. If the variables are primarily uncorrelated, it is unlikely that PCA will yield meaningful results (UNT 2009). For both the cross-sectional and temporal PCA there was limited correlation among all water quality variables (see above section). See Appendix E for PCA output including hierarchical cluster tree, bar chart for component variability, first two factor distributions, and optimal grouping selection.

The first two principal components of the cross-sectional analysis were able to account for 38% of the variability in the data. In Figure 6.10 is a red radial plot which has a distribution of components at regular intervals and comparable magnitudes indicating that the variability is distributed among many of the variables. There are also no obvious groupings in the component loading plots further revealing the homogeneity in data variability between components. Hierarchical cluster analysis (HCA) identified two groups as the optimum number which is illustrated by the two point colors (yellow and blue).

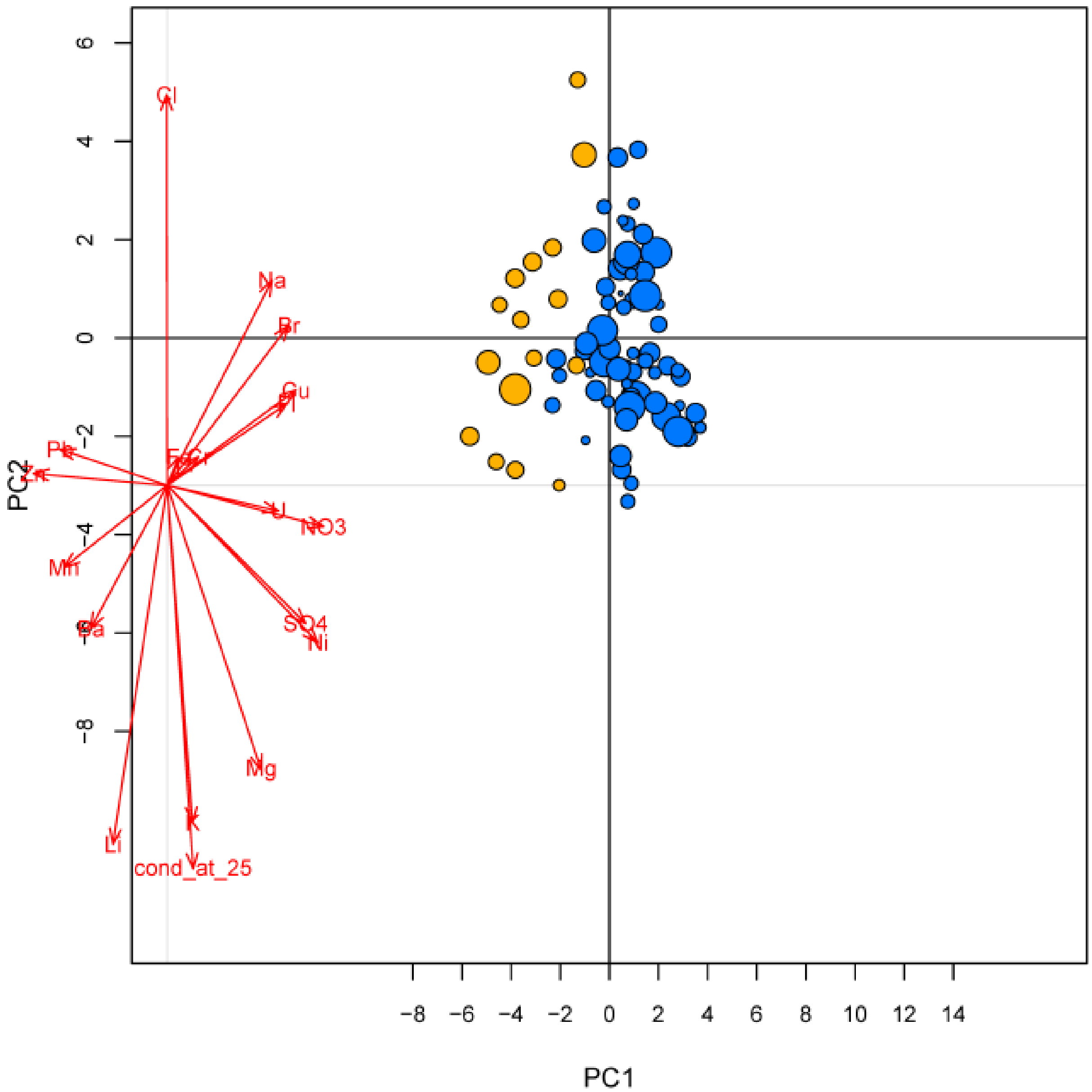


Figure 6.10 Cross-Sectional PCA Radial Plot and Component Loading

The HCA was supplemental to the PCA and identified an optimum group number using Hubert's gamma. The cluster group number with the highest Hubert's gamma is the optimum grouping number. The point and line plot on the left of Figure 6.11 is a plot of the group on the y-axis (which has a range of two to nine groups) and Hubert's gamma on the x-axis. The cross-sectional analysis was split into two groups using the Hubert's gamma. The cluster tree based on this grouping is also shown in Figure 6.11.

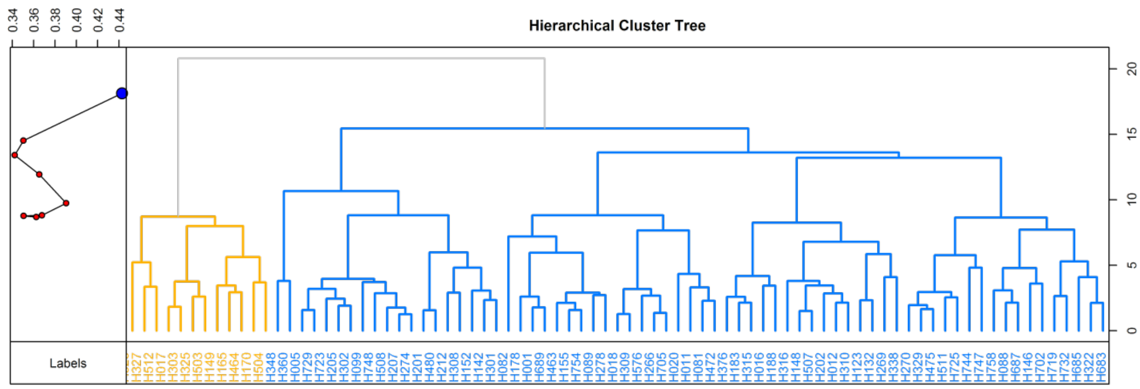


Figure 6.11 Cross-Sectional Hierarchical Cluster Analysis

The largest Hubert's gamma in the HCA for the temporal analysis was nine and the optimum grouping plot and cluster tree is shown below in Figure 6.12.

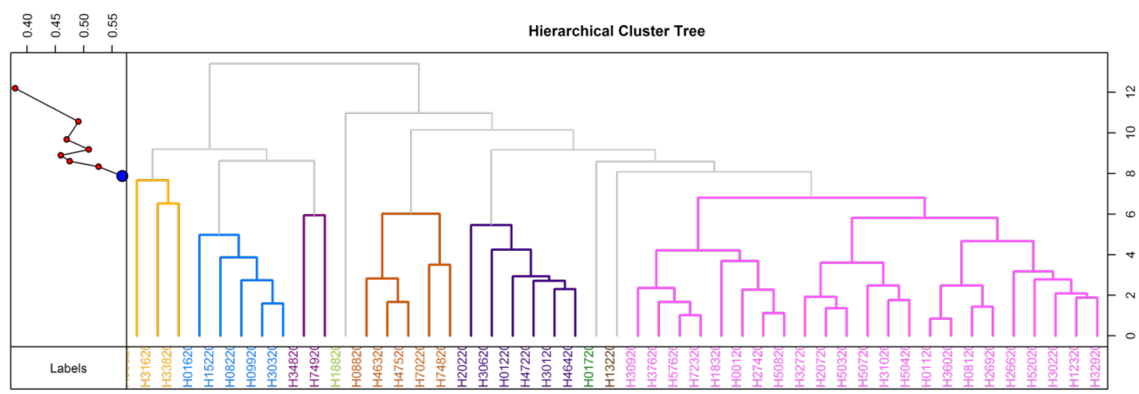


Figure 6.12 Temporal Hierarchical Cluster Analysis

Similar to the cross-sectional PCA there are no identifiable groupings or pattern to the components. The radial plot in red shows distribution all the way around in regular intervals and the points on the loading plot are distributed in the same area (Figure 6.13). The first two components for this analysis only accounted for 30% of the variability in the data.

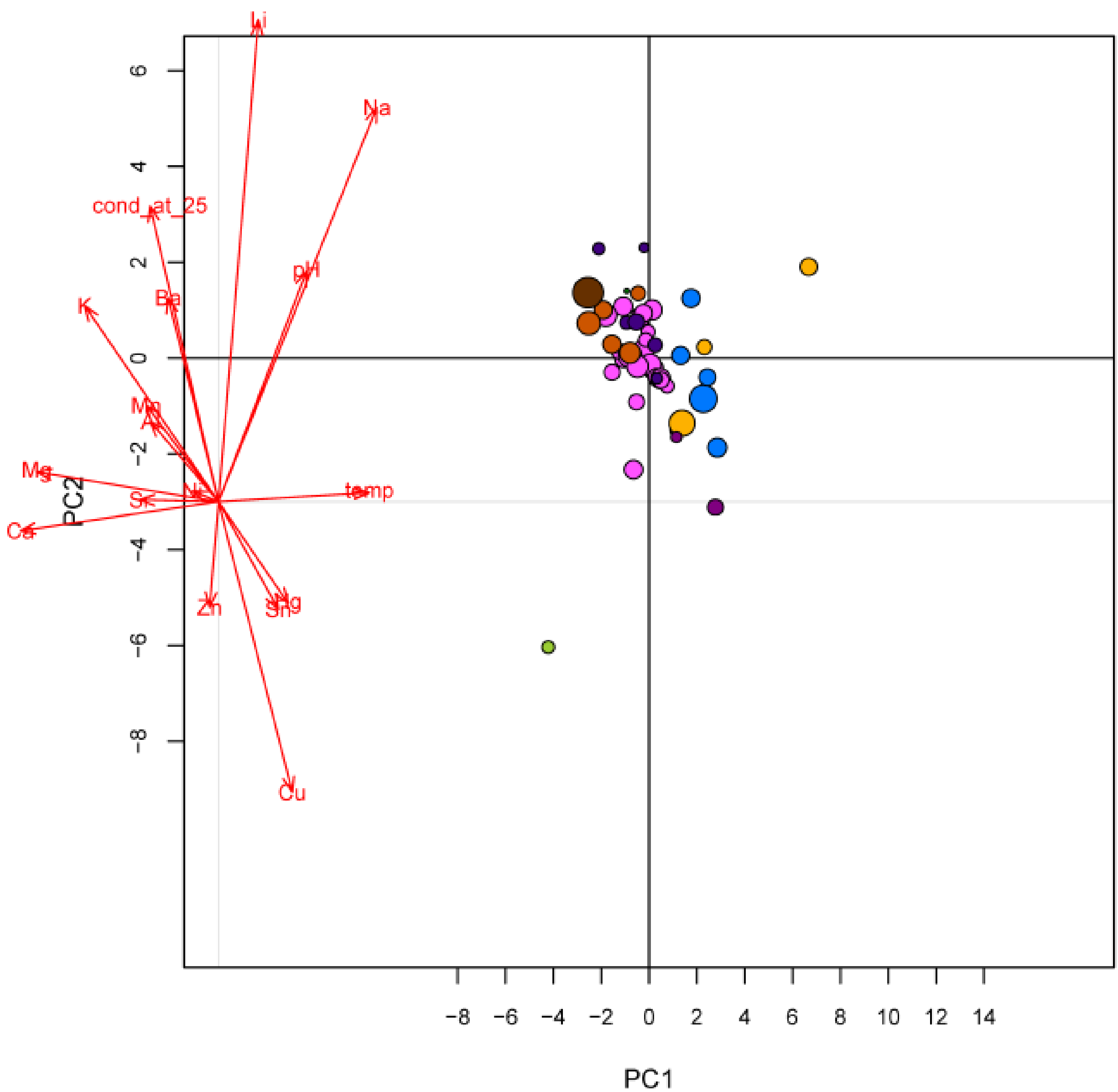


Figure 6.13 Temporal PCA Radial Plot and Component Loading

6.2.5 *Wilcoxon Signed Rank Test*

A comparison of the median values for initial and subsequent sample events with a Wilcoxon Signed Rank Test for each analyte identified eight with very strong correlations ($p \leq 0.05$): chromium, cobalt, lithium, mercury, nickel, potassium, tin, and temperature. We would reject the null hypothesis that the difference in medians is zero at an alpha level of 0.1 or 0.05. Cobalt and mercury did not have identifiable confidence intervals (zero for upper and lower interval) and this was likely due to the large number of non-detect values.

Table 6.4 Wilcoxon Results and Median Values

Analyte or Measure Name	Units	House-holds (n)	Median				95% CI	p-value
			Initial		Subsequent			
Aluminum	ppb	91	0.25	⇔	0.25	⇔	-0.00003 to 0.00004	0.9
Arsenic	ppb	91	0.25	⇔	0.25	⇔	-0.00008 to 0.00006	0.41
Barium	ppb	91	112	↑	102	↓	-11 to 24.9	0.46
Calcium	ppb	91	76,600	↓	79,750	↑	-11150 to 10460	0.98
Chromium	ppb	91	0.25	⇔	0.25	⇔	0.00001 to 0.00002	0.0001**
Cobalt	ppb	91	0.25	⇔	0.25	⇔	0 to 0	0.007**
Copper	ppb	91	9.5	↓	10.27	↑	-4.9 to 1.6	0.4
Lead	ppb	91	0.25	⇔	0.25	⇔	-0.00008 to 0.00005	0.81
Lithium	ppb	91	6.8	↓	8.42	↑	-2.4 to 0.01003	0.053*
Magnesium	ppb	91	12,545	↓	13,580	↑	-3390 to 1816	0.54
Manganese	ppb	91	0.9	↑	0.662	↓	-0.00001 to 0.35	0.35
Mercury	ppb	91	0.25	⇔	0.25	⇔	0 to 0	0.0003**
Nickel	ppb	91	1.3	↑	0.945	↓	0.011 to 0.51	0.008**
Potassium	ppb	91	1,246	↑	1,176	↓	14.4 to 276	0.032**
Selenium	ppb	91	0.25	⇔	0.25	⇔	-0.00007 to 0.00001	0.74
Sodium	ppb	91	15,666	↑	15,220	↓	-2573 to 5312	0.47
Strontium	ppb	91	417	↑	416	↓	-105 to 79	0.79
Tin	ppb	91	0.25	↓	1.84	↑	-1.64 to -0.67	3.042E-26**
Uranium	ppb	91	0.25	⇔	0.25	⇔	-0.00003 to 0.00005	0.17
Zinc	ppb	91	17	↓	18.15	↑	-4.51 to 5.02	0.7
pH	SU	92	7.29	↓	7.42	↑	-0.22 to 0.05	0.18
Conductivity (at 25 °C)	u/s	92	683	⇔	683	⇔	-85 to 52	0.67
Temperature	°C	92	21.85	↑	20.8	↓	0.1 to 2.1	0.033**
Change in Precipitation	Inches	93	40.9	↑	37.5	↓	NA	NA
Change in Gas Wells (2 km)	Count	93	8	↓	10	↑	NA	NA

Notes-
↑ = Higher value; ↓ = Lower value; ⇔ = Same value for initial and subsequent; * < 0.1; ** < 0.05;
NA = Not applicable

6.2.6 *Kendall's Tau*

The non-parametric Kendall's Tau rank correlation between water quality analytes and gas well density, or change in water quality analytes and change in gas well density, detected several statistically significant relationships. The cross-sectional analysis indicated that aluminum, chromium, iron, sodium, uranium ($p<0.05$), arsenic and manganese ($p<0.1$) had negative correlations with gas well density while barium and lithium had positive correlations at an alpha level of 0.1. For the temporal analysis lithium ($p< 0.05$), cobalt, and pH ($p<0.1$) were positively correlated with change in gas well density. Results for all Kendall's Tau analyses are presented in Table 6.5.

Table 6.5 Kendall's Tau Summary

Analyte	Cross-Sectional		Temporal	
	Tau	p-value	Tau	p-value
Aluminum	-0.17	0.0062**	-0.058	0.6
Arsenic	-0.12	0.074*	0.18	0.14
Barium	0.099	0.085*	0.018	0.87
Calcium	0.089	0.12	-0.13	0.22
Chromium	-0.21	0.0018**	-0.0096	0.94
Cobalt	-0.11	0.11	0.21	0.09*
Copper	0.022	0.7	-0.013	0.9
Iron	-0.24	0.00052**	NA	
Lead	0.043	0.52	-0.024	0.84
Lithium	0.1	0.074*	0.27	0.0091**
Magnesium	0.045	0.43	-0.072	0.49
Manganese	-0.045	0.1*	-0.062	0.57
Mercury	-0.05	0.46	0.01	0.93
Nickel	-0.034	0.56	0.02	0.85
Potassium	0.037	0.52	-0.083	0.43
Selenium	-0.1	0.15	-0.19	0.13
Silicon	0.11	0.11	NA	
Sodium	-0.13	0.026**	0.16	0.12
Strontium	0.11	0.065*	-0.021	0.84
Tin	-0.062	0.28	-0.11	0.29
Uranium	-0.13	0.048**	0.11	0.33
Zinc	-0.028	0.63	-0.018	0.87
Bromide	-0.029	0.69	NA	
Chloride	-0.017	0.78	NA	
Fluoride	0.04	0.53	NA	
Nitrate	0.0041	0.95	NA	
Phosphate	-0.033	0.65	NA	

Analyte	Cross-Sectional		Temporal	
	Tau	p-value	Tau	p-value
Sulfate	0.011	0.87	NA	
pH	-0.015	0.79	0.2	0.059*
Conductivity (at 25 °C)	-0.069	0.23	0.14	0.17
Temperature	0.0086	0.88	0.013	0.9

Notes-
* ≤ 0.1; ** ≤ 0.05; NA = Analyte not included in temporal analysis (not applicable)

6.2.7 *Multiple Regression*

For the cross-sectional analysis a non-transformed model was preferentially fit to five analytes: cobalt, mercury, selenium, fluoride, and temperature. The remaining 26 analytes received a Box-Cox power transformation and the optimal λ values used in each transformation are included in Table 6.6 below.

Since well depth was not available for all households, the subset where well depth was available (n=72 households) was re-analyzed including well depth as a controlling variable. The p-values for this subset analysis are included in Table 6.6 along with the regression results from the full dataset analysis. When adjusting for elevation, watershed, formation, and precipitation aluminum and nickel were associated with gas well density (p-value<0.05). At an alpha level of 0.1 lead and lithium were associated with gas well density.

When including depth as a controlling variable lithium was associated with gas well density at an alpha level of 0.05 while calcium was associated with gas well density at an alpha level of 0.1. The regression output also indicated that depth was significant in predicting silicon, tin, bromide, and fluoride (p<0.1) as well as aluminum (p<0.05).

Table 6.6 Cross-Sectional Multiple Regression Summary

Analyte	Model Selected	Optimal λ	Est.	95% CI	p-value	p-value (w/ depth)
Aluminum	Box-Cox	-0.0558	+	-0.0003 to 0.004	0.087*	0.11††
Arsenic	Box-Cox	0.0306	+	-0.0004 to 0.0005	0.76	0.36
Barium	Box-Cox	0.2206	-	-0.021 to 0.019	0.89	0.98
Calcium	Box-Cox	0.9413	-	-682 to 466	0.71	0.094*
Chromium	Box-Cox	0.3233	-	-0.02 to 0.002	0.11	0.17
Cobalt	Original	NA	-	-0.006 to 0.004	0.77	0.96
Copper	Box-Cox	0.1423	+	-0.006 to 0.014	0.45	0.35
Iron	Box-Cox	-0.3715	+	-0.014 to 0.019	0.77	1
Lead	Box-Cox	-0.5014	-	-0.025 to -0.001	0.032**	0.13
Lithium	Box-Cox	0.4392	+	0.007 to 0.051	0.0071**	0.024**
Magnesium	Box-Cox	0.6261	+	-5 to 5.2	0.97	0.72
Manganese	Box-Cox	0.0351	-	-0.003 to 0.002	0.6	0.42
Mercury	Original	NA	-	-0.008 to 0.007	0.87	0.71
Nickel	Box-Cox	0.1977	-	-0.008 to 0.001	0.097*	0.17
Potassium	Box-Cox	0.05004	+	-0.0012 to 0.002	0.58	0.9
Selenium	Original	NA	+	-0.005 to 0.006	0.93	0.91
Silicon	Box-Cox	0.5212	+	-0.652 to 0.668	0.98	0.76†
Sodium	Box-Cox	-0.18	-	-0.001 to 0.001	0.75	0.66
Strontium	Box-Cox	0.4368	+	-0.1 to 0.28	0.35	0.5
Tin	Box-Cox	-0.3516	-	-0.014 to 0.006	0.44	0.79†
Uranium	Box-Cox	0.601	-	-0.009 to 0.002	0.22	0.19
Zinc	Box-Cox	-0.007335	+	-0.0003 to 0.0003	0.9	0.58
Bromide	Box-Cox	-0.01979	+	-0.0005 to 0.001	0.92	0.67†
Chloride	Box-Cox	-0.08	+	-0.002 to 0.004	0.69	0.77
Fluoride	Original	NA	+	-0.004 to 0.03	0.15	0.29†
Nitrate	Box-Cox	0.3194	-	-0.02 to 0.008	0.4	0.11
Phosphate	Box-Cox	0.2537	+	-0.004 to 0.005	0.83	0.18
Sulfate	Box-Cox	0.1604	+	-0.006 to 0.009	0.73	0.42
pH	Box-Cox	-0.4	-	-0.0004 to 0.0004	0.98	0.39
Conductivity (at 25 °C)	Box-Cox	0.14	-	-0.005 to 0.003	0.54	0.87
Temperature	Original	NA	+	-0.027 to 0.161	0.16	0.22

Notes-
*p-value < 0.1; **p-value < 0.05; †Well depth was significant in predicting the outcome variable (p-value<0.1); ††Well depth was significant in predicting the outcome variable (p-value<0.05); NA = Optimal lambda not applicable since original model was selected; Est. = Coefficient estimate (+ = positive, - = negative).

The majority (16/23) of the analytes in the temporal analysis were original non-transformed variables and 7 received a Box-Cox power transformation: aluminum, magnesium, selenium, tin, uranium, zinc, and temperature. When adjusting for elevation, watershed, formation, and precipitation, only lead and gas well density were associated at a $p < 0.1$.

Table 6.7 Temporal Multiple Regression Summary

Analyte	Model Selected	Optimal λ	Est.	95% CI	p-value
Aluminum	Box-Cox	0.5	-	-0.089 to 0.039	0.44
Arsenic	Original	NA	+	-0.019 to 0.025	0.81
Barium	Original	NA	-	-21.25 to 2.71	0.13
Calcium	Original	NA	-	-2934 to 1802	0.64
Chromium	Original	NA	+	-0.374 to 0.466	0.83
Cobalt	Original	NA	-	-0.015 to 0.013	0.86
Copper	Original	NA	+	-7.22 to 8.58	0.86
Lead	Original	NA	+	-0.004 to 0.056	0.089*
Lithium	Original	NA	-	-0.431 to 0.369	0.88
Magnesium	Box-Cox	0.94	-	-328 to 304	0.94
Manganese	Original	NA	-	-9.54 to 6.14	0.67
Mercury	Original	NA	+	-0.028 to 0.032	0.89
Nickel	Original	NA	+	-0.078 to 0.086	0.92
Potassium	Original	NA	-	-114 to 38	0.32
Selenium	Box-Cox	-35.42	-	-0.029 to 0.015	0.55
Sodium	Original	NA	+	-3590 to 4102	0.9
Strontium	Original	NA	-	-46 to 22	0.48
Tin	Box-Cox	0.12	-	-0.009 to 0.005	0.52
Uranium	Box-Cox	-0.9	-	-0.016 to 0.002	0.14
Zinc	Box-Cox	0.22	-	-0.096 to 0.02	0.2
pH	Original	NA	+	-0.046 to 0.058	0.83
Conductivity (at 25 °C)	Original	NA	+	-8.92 to 28.92	0.3
Temperature	Box-Cox	0.86	-	-0.286 to 0.234	0.85

Notes-
*p-value < 0.1; **p-value < 0.05; NA = Optimal lambda not applicable since original model was selected; Est. = Coefficient estimate (+ = positive, - = negative).

The strongest associations ($p<0.05$) for the test of medians, unadjusted regression, and adjusted regression are summarized below in Table 6.8.

Table 6.8 Very Strong Statistical Association Summary ($p<0.05$)

Analyte	Medians	Unadjusted Correlation		Adjusted Correlation	
	Wilcoxon	Kendall's Tau		Multiple Regression	
	Temporal	Cross-Sectional	Temporal	Cross-Sectional	Temporal
Aluminum		✓			
Chromium	✓	✓			
Cobalt	✓				
Iron		✓			
Lead				✓	
Lithium	✓		✓	✓	
Mercury	✓				
Nickel	✓				
Potassium	✓				
Sodium		✓			
Tin	✓				
Uranium		✓			
Temperature	✓				

7. Discussion

The quality of the groundwater in Washington County is generally good and systematic deterioration from unconventional gas production activities was not evident. There were SMCL exceedances for manganese and pH but this occurred in fewer samples than expected based on nationwide or statewide datasets. Additionally, these exceedances were expected based on the lengthy history of coal mining in the County. Eight analytes exhibited statistical significance when their initial and subsequent sample event medians were compared. There were also seven analytes with significant relationships between the concentration and gas well density or change in concentration and change in gas well density. Lithium exhibited correlations in almost all statistical tests and had a median value almost three times higher than the national median. Associations between analytes and active conventional gas well density may be explained by anthropogenic sources like unconventional gas extraction activities, other industrial, agricultural, and urban inputs or may be part of the normal hydrogeochemical fluctuations. Further research emphasizing specific causal pathways is needed to clarify these relationships.

There were a large number of non-detect values in the dataset (2,181/6,459 or 34%) which may be attributable to the geology in the area. The aquifers in this region generally have low metals concentrations because the sedimentary rock they are located in does not readily dissolve and the water is a calcium sodium bicarbonate type (USGS 1997). There was more homogeneity in water quality between the aquifer systems than expected. This could be the result of the complicated hydrogeological system in the county and households are tapping into aquifers that have different geology than is assumed based on the formation. Without additional information on the individual household wells the results of this analysis may be confounded.

The median analyte values for the data in this study were generally within the range of historic median values. Additionally there were fewer exceedances than national and statewide data suggested. Concentrations for a number of analytes in wells were higher than those for spring or mixed sources. These differences could be the result of reduced residence time for the groundwater in shallow aquifers that produce spring water. Few spatial patterns emerged, but the qualitative analysis showed highest values of chromium and iron in areas of lowest gas well density, while the highest lithium and magnesium concentrations tended to be located in areas with the highest gas well densities.

The power analysis (two-tailed; $\alpha = 0.05$) provided support in conducting this hypothesis-generating research since the cross-sectional analysis had 87% power in detecting a 20% effect size and the temporal analysis had 78% power in detecting a 20% effect size.

The correlation matrices for both the cross-sectional and temporal datasets yielded relatively weak correlations among all predictor and outcome variables. Some correlations were weaker than expected such as ions and conductivity. Though chloride and conductivity had one of the higher correlations (0.44) greater correlation was anticipated since conductivity is directly related to ion concentrations (USGS 2016). The greatest correlation was in the cross-sectional analysis between chromium and iron (0.56). The PCA accounted for little of the variability in the data: 38% in the cross-sectional, 30% in the temporal. Radial plot distributions supported the conclusion that the data was homogenous with each component accounting for slightly less variability than the one before.

The statistical analyses that compared the initial and subsequent median values provided a gross estimation of differences in the medians. This test is simple and helpful in determining which analytes experienced changes that were likely not due to chance. Chromium, cobalt, lithium, mercury, nickel, potassium, tin, and temperature displayed very strong associations ($p<0.05$) between median values for the initial and subsequent sampling events.

The unadjusted test (Kendall's Tau) for correlation between the predictor (gas well density) and outcomes (analyte variables) provides a basis for comparing the potential effect gas well density has or does not have on water quality parameters. This analysis builds upon the comparison between analyte medians. In comparing gas well density/change in gas well density to analyte values/change in analyte values several very strong associations ($p<0.05$) emerged: aluminum, chromium, iron, sodium, and uranium in the cross-sectional analysis; and lithium in the temporal analysis.

The potentially strongest argument for a connection between gas well density and analyte values was from the adjusted multiple linear regression. Here, potentially confounding variables were included to reduce Type 1 errors. Lead and lithium were very strongly correlated ($p<0.05$) with gas well density in the adjusted model for the cross-sectional analysis. When depth was added to the cross-sectional model, only lithium showed a very strong association ($p<0.05$) with gas well density. In the temporal analysis, only lead demonstrated a strong association with an alpha level below 0.1 ($p=0.089$).

Analytes identified as having strong or very strong statistical associations (Table 6.8) were not limited to constituents that were characteristic of one particular source. There are several potential sources (some related to unconventional activities, some related to historic activities) which may account for concentration increases: drilling mud, hydraulic fracturing fluids, flowback or produced water, brines, plumbing lines and corrosive water, acid mine drainage, and agriculture. The specific constituents for these activities are summarized below in Table 7.1.

Table 7.1 Potential Sources of Statistically Significant Analytes

Analyte	Drilling Mud	Hydraulic Fracturing Fluids	Flowback or Produced Water	Brines	Plumbing/ Corrosive Water	AMD	Agriculture
Aluminum	X				X	X	
Chromium	X		X				
Cobalt					X		
Iron	X		X	X		X	
Lead				X	X	X	
Lithium				X			
Mercury			X				
Nickel	X				X	X	
Potassium	X		X	X			
Sodium		X	X	X			
Tin			X				
Uranium							
Temperature							

Sources: (Battelle 2013; Boyer 2012; Dresel and Rose 2010; Kresse 2012; Maguire-Boyle and Barron 2014; Ziemkiewicz 2014)

For almost all correlative analyses, lithium displayed strong ($p<0.1$) or very strong ($p<0.05$) associations with gas well density. Lithium is typically highest in marine shale deposits and relatively immobile because its fluoride, phosphate, and carbonate compounds have low solubility. However, dissolved lithium concentrations may increase when pH is lowered (FOREGS 2006). For the dataset in this analysis, the Monongahela (carbonate) locations had the highest median value (~10 ppb). Lithium concentrations in natural waters are generally low (between 1 and10 ppb) (FOREGS 2006) but can be very high in some brines – up to 315,000 ppb in one study of brines from oil and gas wells in Western Pennsylvania (Dresel and Rose 2010).

Lithium in this study had a median of 7.7 ppb, which is approximately three times the reported national median for groundwater in humid regions (2.8 ppb) (Ayotte 2011). Lithium increased in the majority of household water supplies in this study (69/91) and over half of those that increased (37/69) also saw an increase in gas well density. There is currently no USEPA MCL or PADEP MCL for lithium, though a Virginia Department of Health fact sheet recommended that potable water not exceed 700 ppb (VDOH 2011). The lithium concentrations observed in Washington County were not of health concern, but the pattern of increases and the statistical associations with gas well density are interesting. These changes could be indicative of shifts in groundwater chemistry from anthropogenic activities, or may be part of the natural fluctuations in the hydrogeochemical system. Longer term datasets and additional analyses are needed to establish which of these scenarios (or possibly a third undefined scenario) is occurring.

Natural processes like cation exchange were evident in plots showing sodium, calcium, iron, and magnesium (Figure 7.1). As water travels through the ground cation exchange occurs and dissolved calcium, magnesium, and iron ions exchange for sodium ions (Alberta Canada 2015). As sodium concentrations increased, Ca, Mg, and Fe concentrations generally decreased.

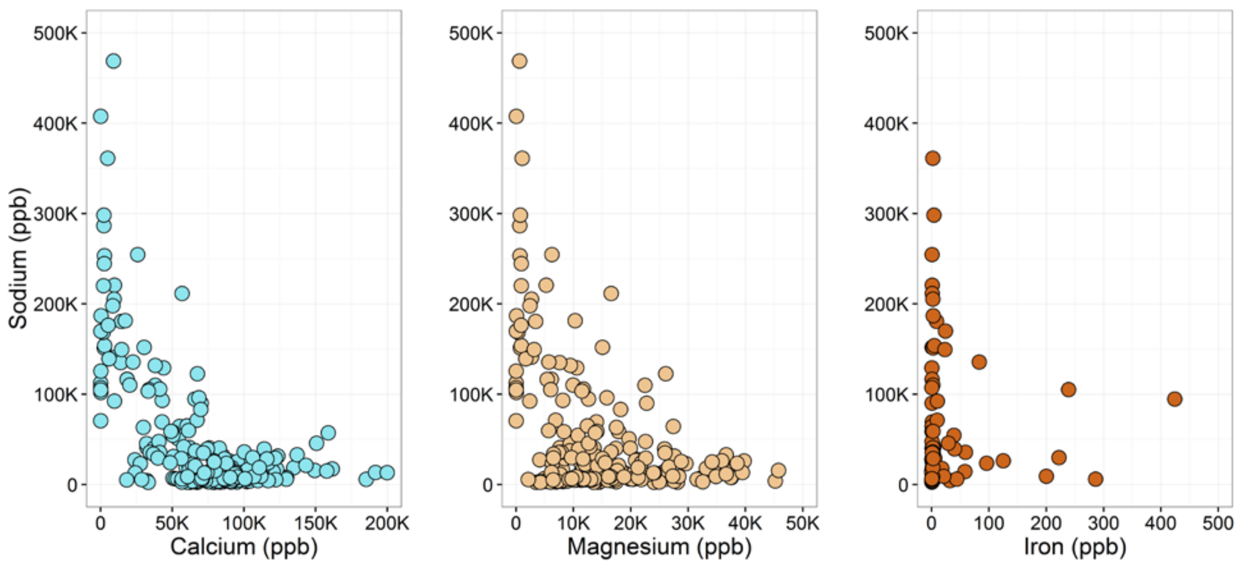


Figure 7.1 Cation Exchange - Na, Ca, Fe, Mg

7.1 Limitations

Household well information is limited and different well characteristics are expected to impact the water quality. Varying subsurface depths have varying bio-geo-chemical processes which will affect the characteristics of the water. Since only half of the household wells had depth data, the strength of the conclusions for analyses including this variable is reduced. The materials, age, depth, and integrity of the casing may also provide a route of impacts to water quality. Poorly constructed, deteriorating, or metal-based casings will also affect the quality of household well water.

Analytical results for elemental analytes are a gross quantities; species composition for each elemental analyte is unknown. Some species are more bioavailable while others are more toxic, and without speciation data the specific hazards of extreme analyte values cannot be appropriately evaluated.

Specific historic operations around or near each household site have not been characterized. Multiple reports and studies have indicated Washington County has a well-defined history of acid mine drainage and it has impacted water quality for decades or centuries. Specific areas where these operations occurred have not been specifically identified in the study area and are a source of confounding. Other sources of potential anthropogenic impacts are not quantified. As with the historic mining, other ongoing industrial, agricultural, or private practices which can adversely affect water quality are not considered here.

Sample sites are not evenly distributed throughout the county, and are located in areas with greater gas well density. Also regarding site locations, household inclusion was dependent upon resident participation so houses which may have excellent water quality may have been excluded because the residents who refused to participate in a health survey were of good health with high quality water. Finally, samples were only collected in the summer and therefore results likely do not represent year round conditions.

8. Conclusions

Overall, the quality of groundwater in Washington County is good in regards to inorganic and anion concentrations. Exceedances for contaminants regulated by USEPA and PADEP were below national and statewide percentages. The observed manganese and pH exceedances (both ~12% of samples) are expected in this area from acid mine drainage effects due to the long history of coal mining in the County. Most data in this analysis supports that groundwater chemistry is the result of natural processes. This analysis did not find evidence for systematic deterioration of water quality from unconventional gas activities.

However, significant statistical relationships between several water quality analytes and gas well density were identified. For these analytes changes could be explained by anthropogenic sources besides unconventional gas extraction such as acid mine drainage, plumbing systems with corrosive water, or agricultural activities. But, they may also be explained by influences from drilling mud, flowback or produced water, or formation brines. The changes in water quality represented by the statistical associations require further characterization to appropriately assess a causal pathway if one exists.

For most correlation analyses between gas well density and lithium, strong ($p<0.1$) or very strong ($p<0.05$) associations were observed. Most household water lithium levels increased from 2012 or 2013 to 2014 but not near levels of health concern. This pattern of increase and correlation with gas well density is unique and additional research would help clarify if there is a causal connection or if these variations are normal for the area.

Unconventional gas extraction activities started in Washington County, Pennsylvania exactly ten years prior to the second year of sample collection for this study (2014). If in fact there is migration of fluids from Marcellus Shale depth we are at the time when it is theoretically possible to start observing changes in groundwater chemistry according to Myers et al. (2012). This dataset may serve as a baseline groundwater quality databank for unconventional gas activities. Additional groundwater quality monitoring in this area could provide evidence for or against this migration. Further monitoring would also offer private residents continued information on the quality of their water supplies. At a time when the effects or postulated effects of unconventional oil and gas activities are so hotly debated, a little reassurance could go a long way.

References

Adgate, J. L., B. D. Goldstein and L. M. McKenzie (2014). Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development. Environ Sci Technol. **48**(15): 8307-20.

Alberta Canada. (2015). "Understanding Groundwater." Retrieved June 4, 2015, from http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/wwg406.

Arthur, D. and D. Cornue (2010). Technologies Reduce Pad Size, Waste. The American Oil & Gas Reporter.

Ayotte, J. D., J. M. Gronberg and L. E. Apodaca (2011). Trace Elements and Radon in Groundwater across the United States, 1992-2003. USDOI

Battelle (2013). Washington County, Pennsylvania Retrospective Case Study Characterization Report.92

Berndt, M. P., B. G. Katz, B. d. Lindsey, et al. (2005). Comparison of Water Chemistry in Spring and Well Samples from Selected Carbonate Aquifers in the United States. USGS Sci Invest Rpt. **5160**: 74-81.

Boyer, E. W., B. R. Swistock, J. Clark, et al. (2012). The Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies.28

Brantley, S. L. (2015). Drinking Water While Fracking: Now and in the Future. Ground Water. **53**(1): 21-3.

Brittanica, E. (2016). "Encyclopedia." Retrieved March 8, 2016, from http://www.britannica.com.

Burton, G. A., Jr., N. Basu, B. R. Ellis, et al. (2014). Hydraulic "Fracking": Are Surface Water Impacts an Ecological Concern? Environ Toxicol Chem. **33**(8): 1679-89.

CDO (2015). Annual Climatological Summary for Washington County, Pa. NOAA Climatic Data Center. http://www.ncdc.noaa.gov/cdo-web/.

Champley, S. (2015). Pwr: Basic Functions for Power Analysis.

Darbonne, N. (2014). The American Shales: From Rich Rock, Unconventional Ideas and Unwavering Determination to a Renewed World Energy Future. North Charleston, SC, CreateSpace Independent Publishing Platform.

Davies, R. J. (2011). Methane Contamination of Drinking Water Caused by Hydraulic Fracturing Remains Unproven. Proc Natl Acad Sci U S A. **108**(43): E871; author reply E2.

DOI-BLM (2007). Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development: The Gold Book, Department of the Interior - Bureau of Land Management and United States Department of Agriculture - Forest Service.

Dresel, P. E. and A. W. Rose (2010). Chemistry and Origin of Oil and Gas Well Brines in Western Pennsylvania. P. G. Survey

Earth Sciences Consultants (2001). Study of the Effects of Longwall Mining on Streams, Wetlands and Riparian Areas: Robinson Fork, South Washington County, Pennsylvania. PADEP - Bureau of Mining and Reclamation.29

Farrel-Poe, K. and S. Pater (2011). Do Deeper Wells Mean Better Water? University of Arizona, Arizona Cooperative Extension.

Fleeger, G. M. (1999). The Geology of Pennsylvania's Groundwater. Pennsylvania Geologial Survey

Flint, N. K. (1979). Pennsylvania Baseline - Geology, Climatology and Soils. USEPA

Fontenot, B. E., L. R. Hunt, Z. L. Hildenbrand, et al. (2013). An Evaluation of Water Quality in Private Drinking Water Wells near Natural Gas Extraction Sites in the Barnett Shale Formation. Environ Sci Technol. **47**(17): 10032-40.

FOREGS (2006). Geochemical Atlas of Europe, Forum of European Geological Surveys,.

FracFocus. (2014). "Hydraulic Fracturing." Retrieved November 11, 2014, from http://fracfocus.org/hydraulic-fracturing-how-it-works/hydraulic-fracturing-process.

FracTrackerAlliance (2012). Watershed Boundaries in Pennsylvania (Huc-12). ESRI ArcGIS. www.arcgis.com/home/item.html?id=7ae85d1915f54ba0a7d95fc8003cdd78.

Gorody, A. W., D. Baldwin and C. Scott (2005). Dissolved Methane in Groundwater, San Juan Basin, La Plata County Colorado: Analysis of Data Submitted in Response to Cogcc Orders 112-156 & 112-157. Annual International Petroleum Environmental Conference. Houston, TX**:** 14.

GWPC and ALLC (2009). Modern Shale Gas Development in the United States: A Primer.

Halliburton. (2015). "Marcellus Shale." Retrieved October 22, 2015, from http://www.halliburton.com/en-US/ps/solutions/unconventional-resources/shale-gas-oil/shale-plays/marcellus-shale.page?node-id=hgjyd46z.

Hoch, T. (2008). How Geology Affects Your Well Water Quality. University of Wyoming.

Ingraffea, A., M. T. Wells, R. L. Santoro, et al. (2014). Assessment and Risk Analysis of Casing and Cement Impairment in Oil and Gas Wells in Pennsylvania, 2000-2012. Proc Natl Acad Sci U S A. **111**(30): 10955-60.

Jackson, R. B., A. Vengosh, T. H. Darrah, et al. (2013a). Increased Stray Gas Abundance in a Subset of Drinking Water Wells near Marcellus Shale Gas Extraction. Proc Natl Acad Sci U S A. **110**(28): 11250-5.

King, G. E. (2012). Hydraulic Fracturing 101: What Every Representative, Environmentalist, Regulator, Report, Investor, University Researcher, Neighbor and Engineer Should Know About Estimating Frac Risk and Improving Frac Performance in Unconventional Gas and Oil Wells, Society of Petroleum Engineers.

Kresse, T. M., N. R. Warner, P. D. Hays, et al. (2012). Shallow Groundwater Quality and Geochemistry in the Fayetteville Shale Gas-Production Area, North Central Arkansas, 2011.42

Ladlee, J. and J. Jacquet (2011). The Implications of Multi-Well Pads in the Marcellus Shale. Research & Policy Brief Series. (43).

Low, D. J., D. C. Chichester and L. F. Zarr (2008). Selected Ground-Water Quality Data in Pennsylvania - 1979-2006. USGS

Maguire-Boyle, S. J. and A. R. Barron (2014). Organic Compounds in Produced Waters from Shale Gas Wells. Environ Sci Process Impacts. **16**(2237-48).

Millard, S. P. (2013). Envstats: An R Package for Environmental Statistics. New York, NY, Springer Science + Business Media.

Molofsky, L. J., J. A. Connor, S. K. Farhat, et al. (2011). Methane in Pennsylvania Water Wells Unrelated to Marcellus Shale Fracturing. Oil & Gas J. **109**(49): 54-67.

Myers, T. (2012). Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers. Ground Water. **50**(6): 872-82.

National Geospatial Center of Excellence (2011). 2011 National Land Cover Dataset (Nlcd). USDA/NRCS. https://gdg.sc.egov.usda.gov/.

Newport, T. G. and A. A. Socolow (1973). Summary Ground-Water Resources of Washington County, Pennsylvania. Department of Environmental Resources - Bureau of Topographic and Geologic Survey

NIST-ILT. (No Date). "Box-Cox Normality Plot." Retrieved March 11, 2016, from http://www.itl.nist.gov/div898/handbook/eda/section3/boxcoxno.htm.

NWS (2015). Annual Us Precipitation. NOAA-NWS. Advanced Hydrologic Prediction Service,. http://water.weather.gov/precip/download.php.

Osborn, S. G., A. Vengosh, N. R. Warner, et al. (2011). Methane Contamination of Drinking Water Accompanying Gas-Well Drilling and Hydraulic Fracturing. Proc Natl Acad Sci U S A. **108**(20): 8172-6.

PADCNR (2008). Pennsylvania Geology. Department of Natural Resources

PADEP (2011). Statewide Health Standards - Revised Mcls and Hals. Pennsylvania Department of Environmental Protection,.

PADEP (2013b). Marcellus Shale Development Fact Sheet. Department of Environmental Protection

PADEP (2015a). Unconventional Oil and Gas Well Production - January 2015. https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/DataExports/DataExports.aspx.

PADEP (2016). Water Supply Determination Letters. Department of Environmental Protection
PennDOT (2015). Pennsylvania County Boundaries. Pennsylvania Department of Transportation. PASDA. http://www.pasda.psu.edu/uci/MetadataDisplay.aspx?entry=PASDA&file=PaCounty2015_01.xml&dataset=24.
Piper, A. M. (1933). Ground Water in Southwestern Pennsylvania. D. o. I. Affairs
Prud'homme, A. (2014). Hydrofracking: What Everyone Needs to Know. New York, NY, Oxford University Press.
PSU (1995). Conus Soil Texture Classes in Pennsylvania. Soil Information for Environmental Modeling and Ecosystem Management. Pennsylvania State University. http://www.soilinfo.psu.edu/index.cgi?soil_data&conus&data_cov&texture&datasets&alb.
PSU. (2015b). "Marcellus Center for Outreach & Research (Mcor)." Retrieved October 22, 2015, from http://www.marcellus.psu.edu/resources/maps.php.
PSU. (2016). "Principal Components Analysis (Pca)." Stat 505 Applied Multivariate Statistical Analysis Retrieved February 15, 2016, from https://onlinecourses.science.psu.edu/stat505/node/49.
R Core Team (2014). R: A Language and Environment for Statistical Computing. Vienna, Austria, R Foundation for Statistical Computing.
Rabinowitz, P. M., I. B. Slizovskiy, V. Lamers, et al. (2015). Proximity to Natural Gas Wells and Reported Health Status: Results of a Household Survey in Washington County, Pennsylvania. Environ Health Perspect. **123**(1): 21-6.
Ratner, M. and M. Tiemann (2015). An Overview of Unconventional Oil and Natural Gas: Resources and Federal Action.34
Reese, S. O. (2010a). Digital Bedrock Aquifer Characteristics by Physiographic Section of Pennsylvania. Bureau of Topographic and Geologic Survey. PADCNR. http://www.dcnr.state.pa.us/topogeo/groundwater/gw_data/dac_data/index.htm.
Reese, S. O. and D. W. Risser (2010b). Summary of Groundwater-Recharge Estimates for Pennsylvania. Pennsylvania Geological Survey
Schneider, A. (2015). "Gps Visualizer: Add Dem Elevation Data." Retrieved May 23, 2015, from http://www.gpsvisualizer.com/elevation.
Statistics Solutions. (2015). "Kendall's Tau and Spearman's Rank Correlation Coefficient." Retrieved February 15, 2016, from https://www.statisticssolutions.com/kendalls-tau-and-spearmans-rank-correlation-coefficient/.
STHDA. (No Date). "Correlation Matrix : A Quick Start Guide to Analyze, Format and Visualize a Correlation Matrix Using R Software." Retrieved February 16, 2016, from http://www.sthda.com/english/wiki/correlation-matrix-a-quick-start-guide-to-analyze-format-and-visualize-a-correlation-matrix-using-r-software.
Sweet, S. A. and K. A. Grace-Martin (2012). Modeling Relationships of Multiple Variables with Linear Regression. Data Analysis with Spss: A First Course in Applied Statistics. S. A. Sweet and K. A. Grace-Martin, Pearson**:** 161-88.
Swistock, B. R., S. Clemens and W. E. Sharpe (2009). Drinking Water Quality in Rural Pennsylvania and Effect of Management Practices.
TEEIC. (2014). "Oil and Gas Decommissioning/Reclamation Impacts." Retrieved November 12, 2014, from http://teeic.indianaffairs.gov/er/oilgas/impact/decom/index.htm.
Toccalino, P. L., J. E. Norman and K. M. Schoephoester. (2014). "Health-Based Screening Levels for Evaluating Water Quality Data." Retrieved August 9, 2015, from http://water.usgs.gov/nawqa/HBSL.
UNT (2009). Principal Component Analysis. University of North Texas.
US Census Bureau (2015). Annual Estimates of the Resident Population, Pennsylvania Counties. US Department of Commerce
USEIA. (2016). "Glossary Terms." Retrieved March 7, 2016, from https://www.eia.gov/tools/glossary/.

USEPA (1987). Report to Congress - Management of Wastes from the Exploration, Development, and Production of Crude Oil, Natural Gas and Geothermal Energy. Office of Solid Waste an Emergency Response

USEPA (2004). Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs: Final.

USEPA (2015a). Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources (External Review Draft).

USEPA (2015b). Retrospective Case Study in Southwestern Pennsylvania - Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources.

USGS (1986). National Water Summary 1986 - Hydrologic Events and Ground-Water Quality. Department of the Interior

USGS (1995). National Water-Quality Assessment Program - the Allegheny-Monongahela River Basin (Nawqa Fact Sheet). USDOI

USGS (1997). Ground Water Atlas of the United States: Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia. U. S. G. Survey

USGS. (2015, 12/9/2015). "What Is a Watershed?" Retrieved February 15, 2016, from http://water.usgs.gov/edu/watershed.html.

USGS. (2016). "Electrical Conductivity and Water." Retrieved March 14, 2016, from http://water.usgs.gov/edu/electrical-conductivity.html.

VDOH (2011). Lithium. Virginia Department of Health

Venables, W. N. and B. D. Ripley (2002). Modern Applied Statistics with S. New York, NY, Springer.

Vidic, R. D., S. L. Brantley, J. M. Vandenbossche, et al. (2013). Impact of Shale Gas Development on Regional Water Quality. Science. **340**(6134): 1235009.

WC (2005). Washington County Comprehensive Plan.

WC (No date). Washington County Key Statistics. Washington County

Wei, T. (2013). Corrplot: Visualization of a Correlation Matrix.

Wickham, H. (2009). Ggplot2: Elegant Graphics for Data Analysis. New York, NY, Springer-Verlag.

Ziemkiewicz, P. F., J. D. Quaranta, A. Darnell, et al. (2014). Exposure Pathways Related to Shale Gas Development and Procedures for Reducing Environmental and Public Risk. J Nat Gas Sci Engineer. **16**: 77-84.

Appendices

Appendix A

Sample Collection and Analysis

Appendix A
Description of Household Well Water Sample Collection and Analysis

Physical			
Device	**Calibration**	**Analytical Method**	**Analytes**
Oakton Waterproof Hand-held pH/Conductivity/Temperature Meter Kit	Calibrated daily before sampling with pH buffer solutions and conductivity standards per instruction manual (Oakton 2006)	The probe was rinsed with de-ionized (DI) water and placed in a cup (also rinsed with DI water) which was positioned under the water stream. Measurements were recorded on a data collection sheet after values equilibrated.	pH, Conductivity, Temperature

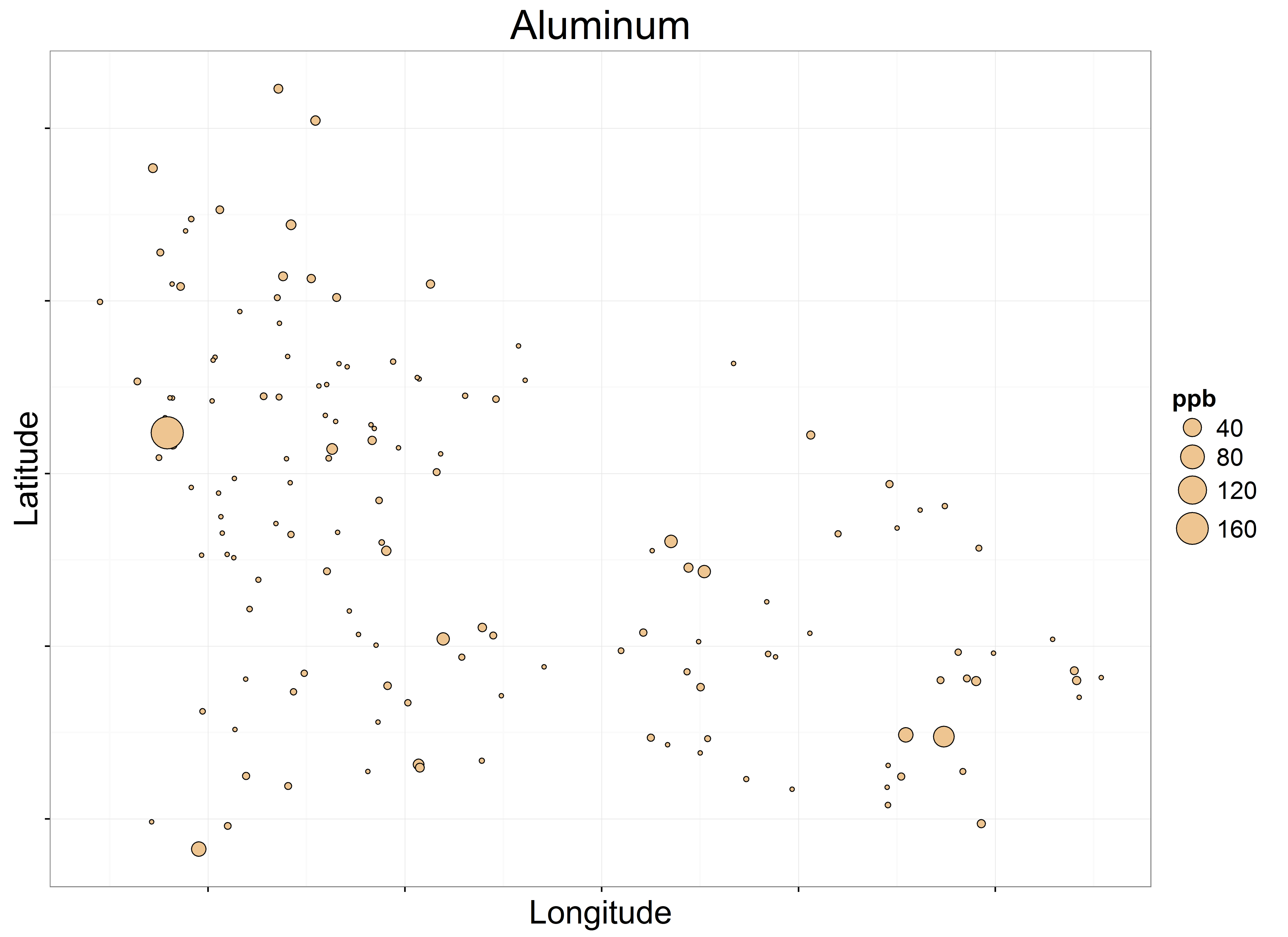
Chemical								
Parameter	**Container**	**Sample Volume**	**Collection Method**	**Storage**	**Shipment**	**Lab**	**Analytical Method**	**Analytes**
Anions	Small plastic bottles, various sizes.	Minimum 50 mL.	Filled from spigot.	Samples were placed on ice in a cooler in the field. Prior to shipping, samples were kept in a refrigerator to maintain chilled temperature, but were never frozen.	Samples were shipped in a cooler with dry ice within 7 days of collection with COC documentation.	2012: Yale Laboratory (analyzed by Vanessa Lamers) 2013 & 2014: Baron Consulting Co. in Milford, CT.	2012: Ion chromatography 2013 & 2014: EPA 300.1 – Ion chromatography	Bromide, Chloride, Fluoride, Nitrate, Nitrite, Phosphate, Sulfate
Elemental (Metals/ Nutrients)	250 mL low density polyethylene (LPDE) plastic bottles.	Filled up to ¼ of an inch of the rim.	Filled from spigot.	Samples were placed on ice in a cooler in the field. Prior to shipping, samples were kept in a refrigerator to maintain chilled temperature, but were never frozen.	Samples were shipped in a cooler with dry ice within 7 days of collection with COC documentation.	Connecticut Agricultural Experiment Station (CAES) in New Haven, CT.	ICP-MS after acid digestion	Calcium, Chromium, Cobalt, Copper, Gadolinium ,Iron, Lead, Lithium, Magnesium, Manganese, Mercury, Nickel, Potassium, Selenium, Silicon, Silver, Sodium, Strontium, Thallium, Tin, Uranium, Vanadium, Zinc
BTEX	Clear glass VOA vials (40 mL) with hydrochloric acid preservative.	Filled until there was a convex meniscus at the top of the vial (~40 mL).	Filled with care not to avoid overfilling and flush out preservative; also air bubbles were removed via capping, inversion, and top off re-filling. After vial was full it was capped and agitated to mix preservative with sample.	Samples were wrapped in bubble wrap and placed on ice in a cooler in the field. Prior to shipping, samples were kept in a refrigerator to maintain chilled temperature, but were never frozen.	Samples were shipped in a cooler with dry ice within 7 days of collection with chain of custody (COC) documentation.	Baron Consulting Co. in Milford, CT.	EPA 524.2 – GC/MS	Benzene, Toluene, Ethylbenzene, Xylene

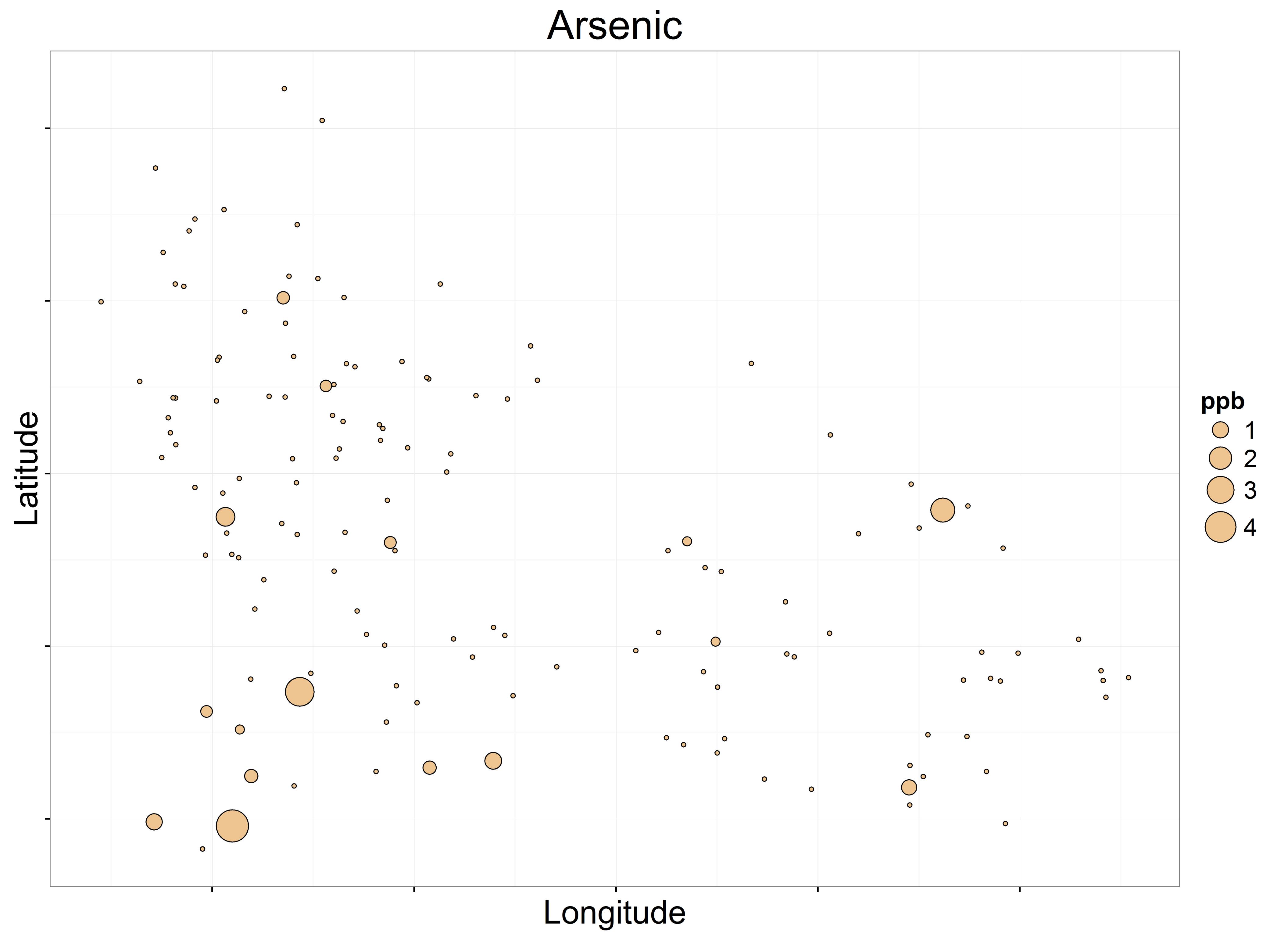
Appendix A
Description of Household Well Water Sample Collection and Analysis

Chemical								
Parameter	**Container**	**Sample Volume**	**Collection Method**	**Storage**	**Shipment**	**Lab**	**Analytical Method**	**Analytes**
Organics	250 mL amber glass bottles.	Filled up to ¼ of an inch of the rim.	Filled from spigot.	Samples were wrapped in bubble wrap and placed on ice in a cooler in the field. Prior to shipping samples were kept in a refrigerator to maintain chilled temperature, but were never frozen.	Samples were shipped in a cooler with dry ice within 7 days of collection with COC documentation.	Connecticut Agricultural Experiment Station (CAES) in New Haven, CT.	GC/MS with solid phase extraction (SPE)	Atrazine, Azoxystrobin, Bisphenol A, Bisphthalates, Bromodichloromethane, Bromoform, Chloroform, DDE, Dibromochloromethane, Diethyltoluene, Fenhexamid, Fenuron, Fipronil, Flurprimidol, Flutolanil, Hydramethylnon, Malathion, Metolachlor, Metsulfuron, Metsulfuron-Methyl, MTBE, Naphthalene, N-Butylbenzene, Pendimethalin, Permethrin, Piperonyl Butoxide, Propiconazole, Rotenone, Sulfometuron, Sulfometuron-Methyl, Sulfur (S8), Thiamethoxam, Trifluralin, Tris(2-Chloroethyl) Phosphate, V4-Isopropyltoluene

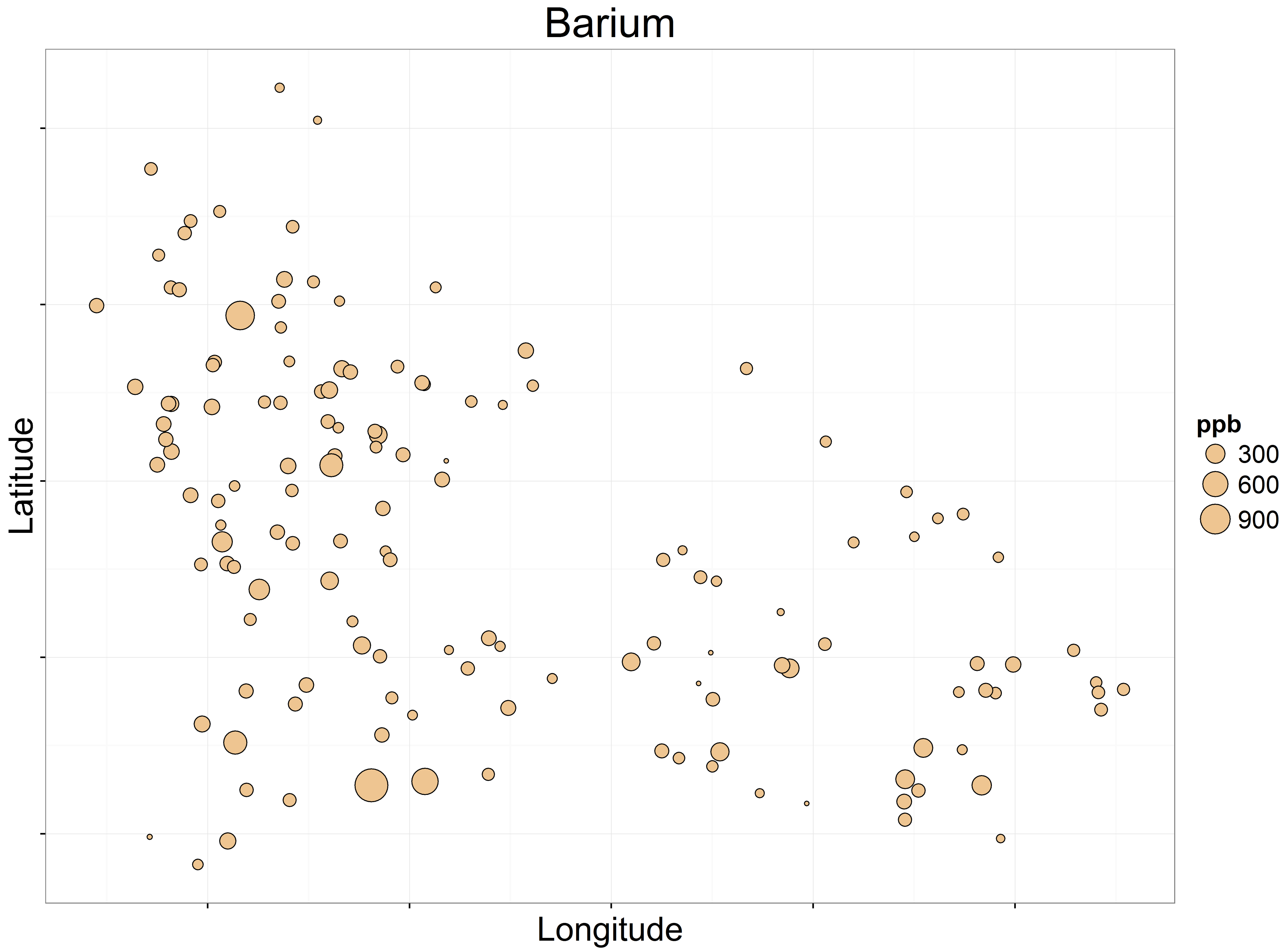
Appendix B

Model Comparison and Multiple Regression

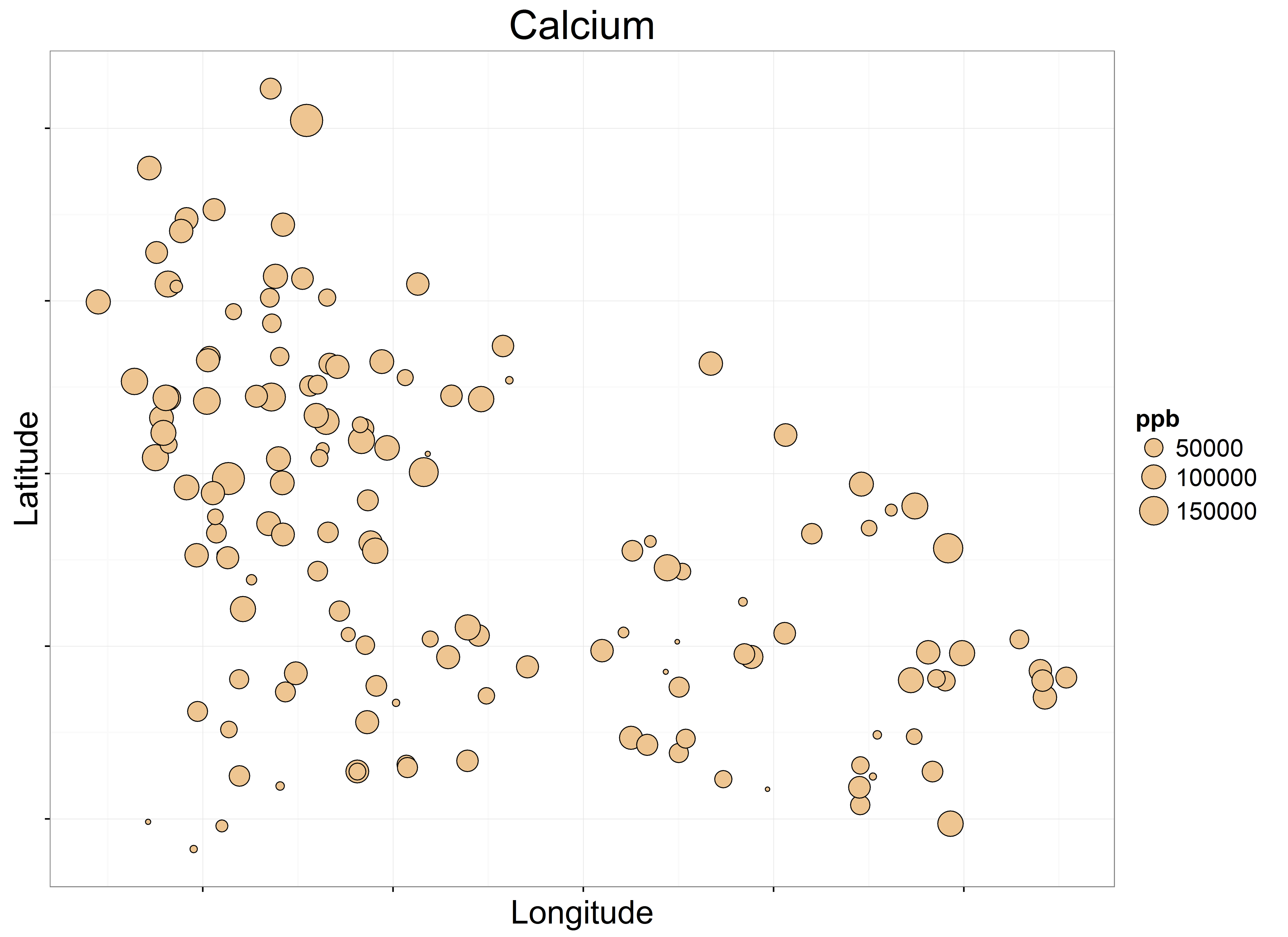

Aluminum
Latitude
Longitude
ppb
40
80
120
160



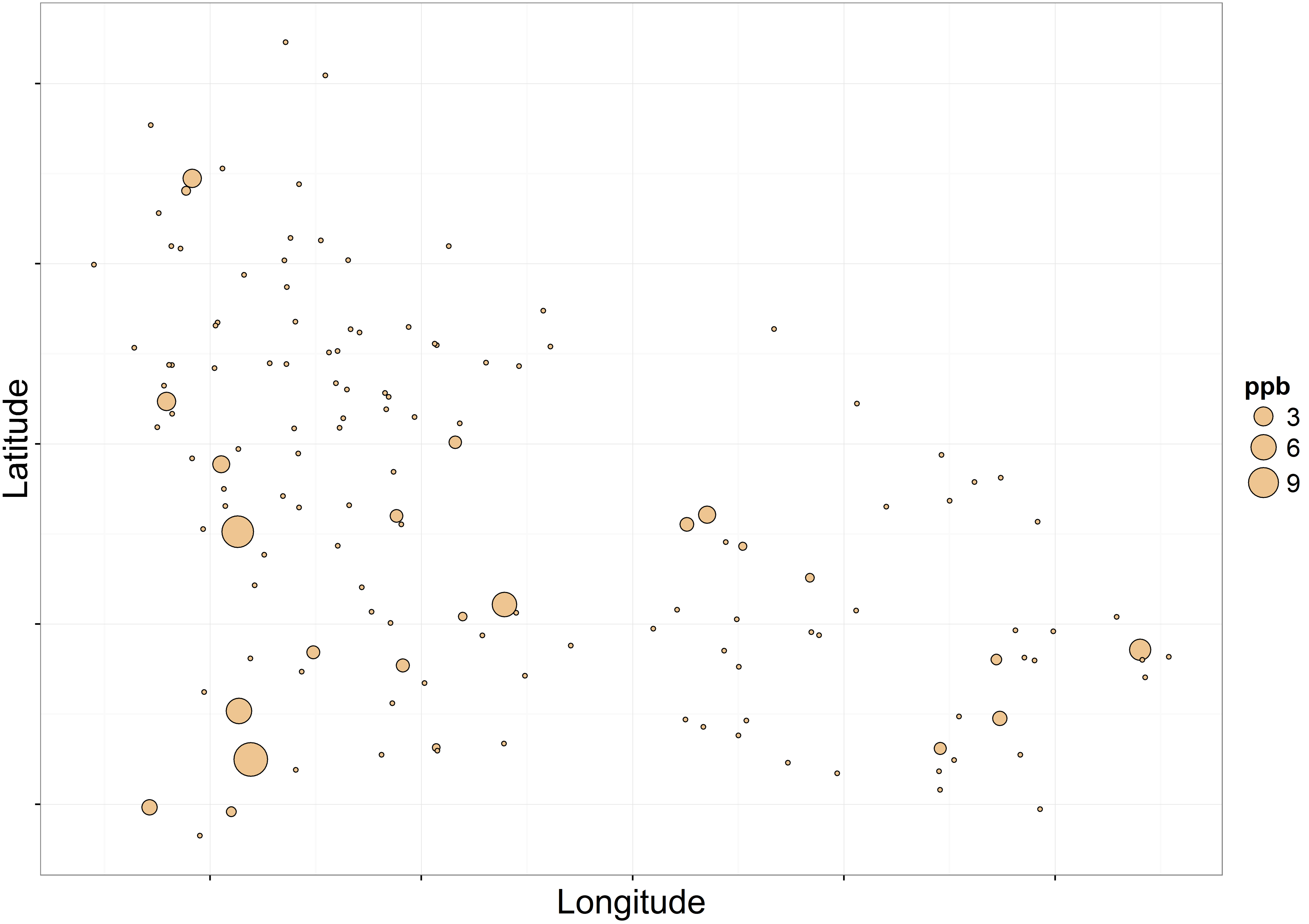
Arsenic
Latitude
Longitude
ppb
1
2
3
4

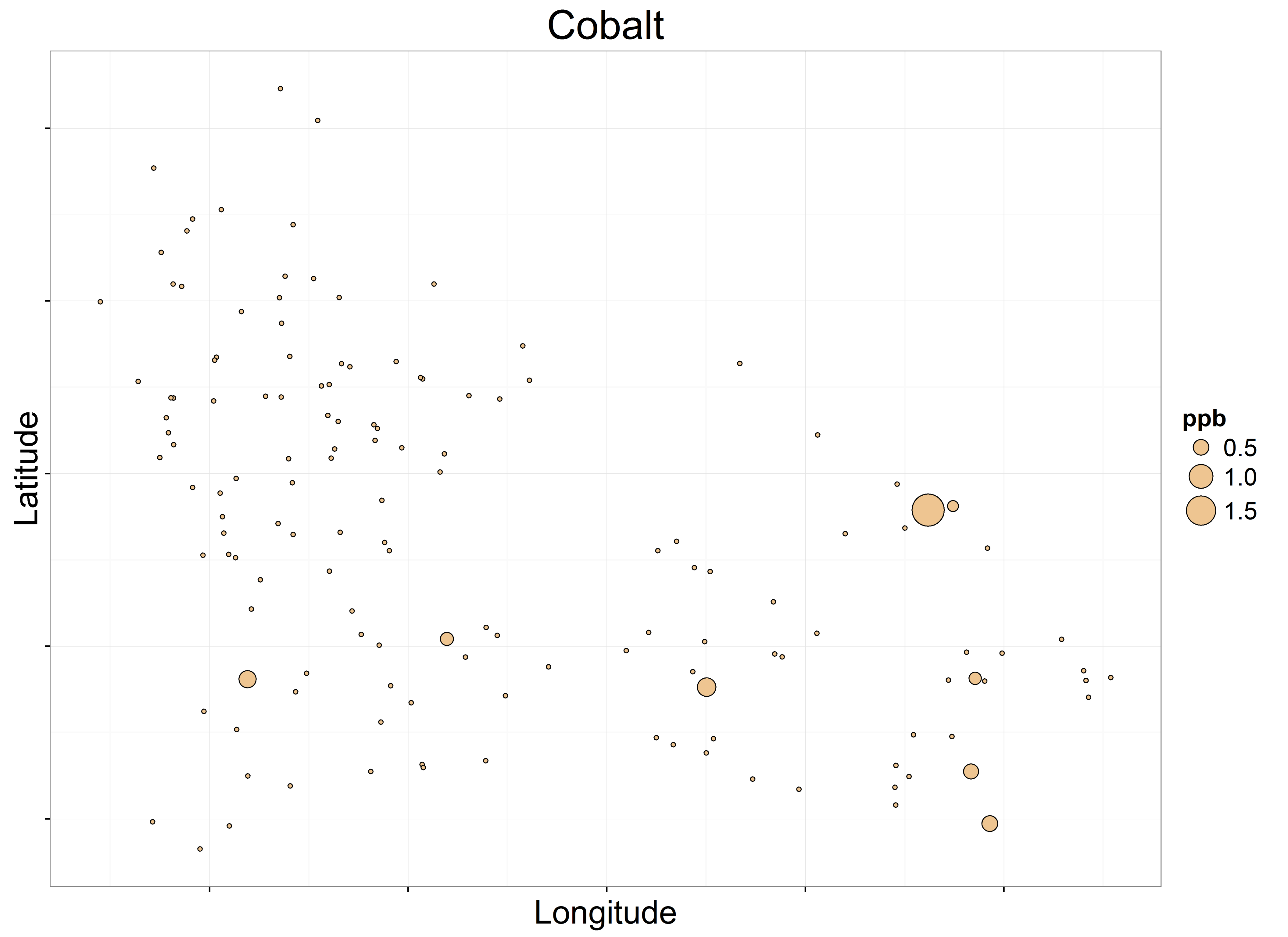


Barium
Latitude
Longitude
ppb
300
600
900

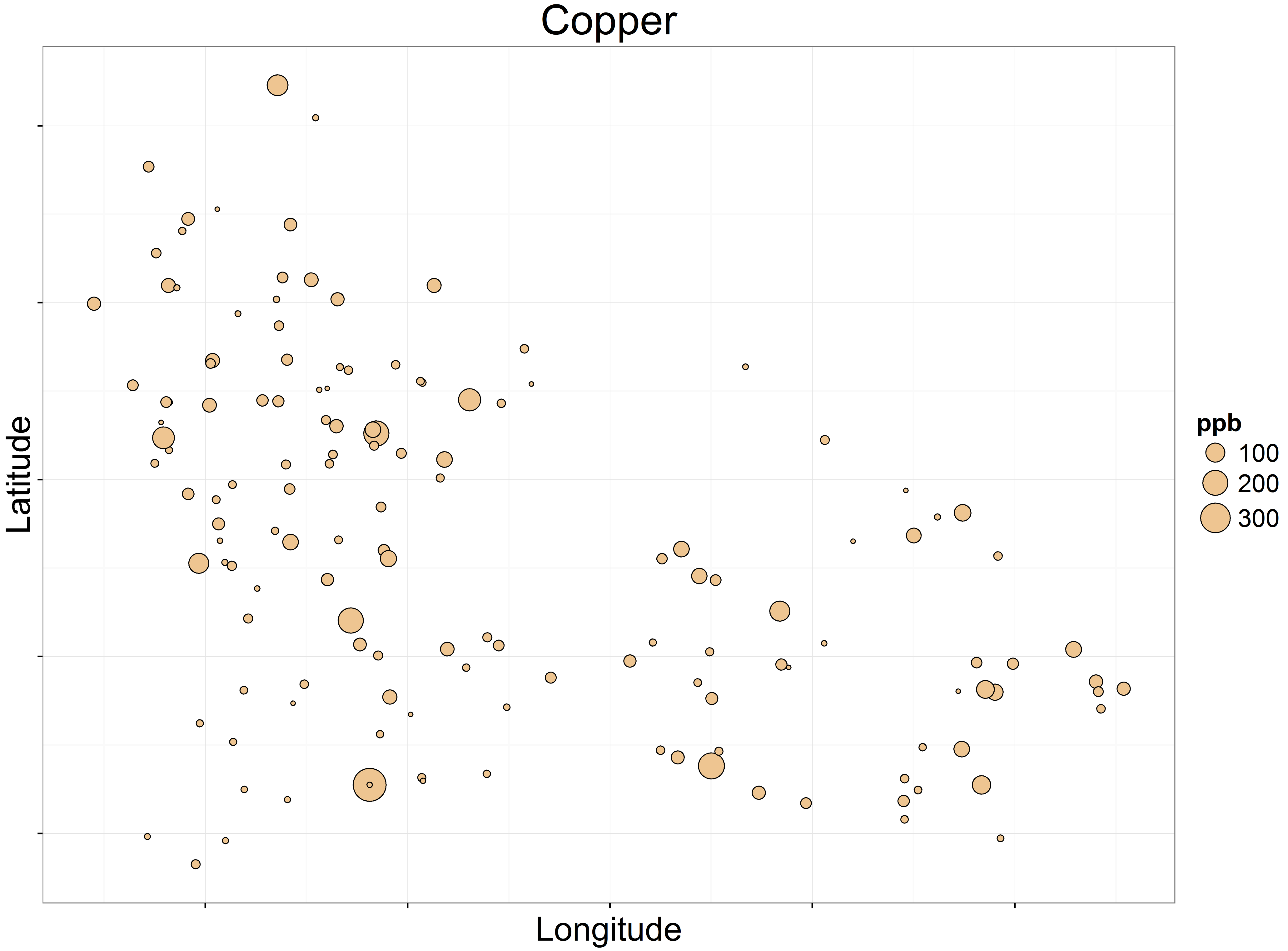

Calcium
Latitude
Longitude
ppb
50000
100000
150000

Chromium

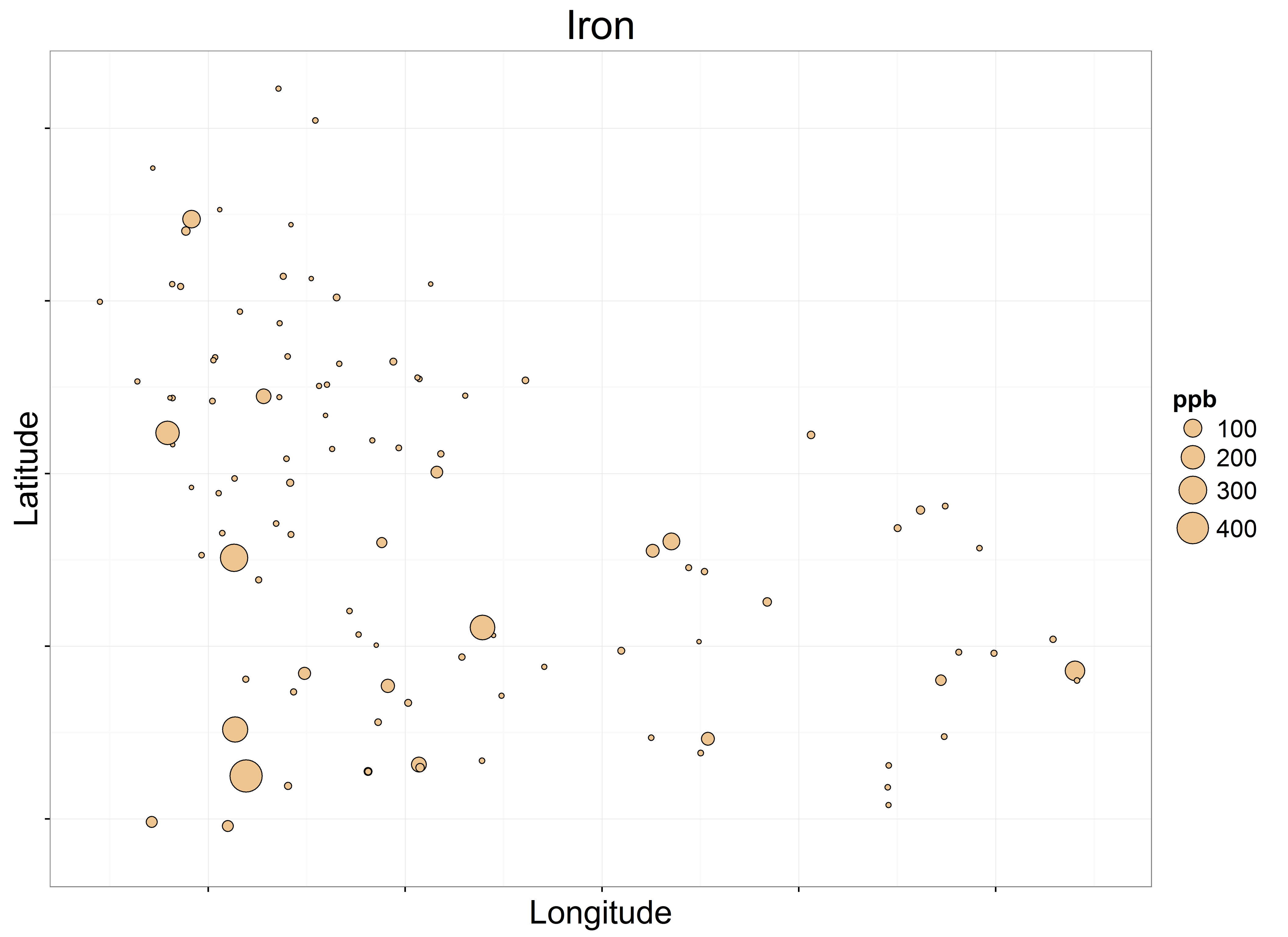


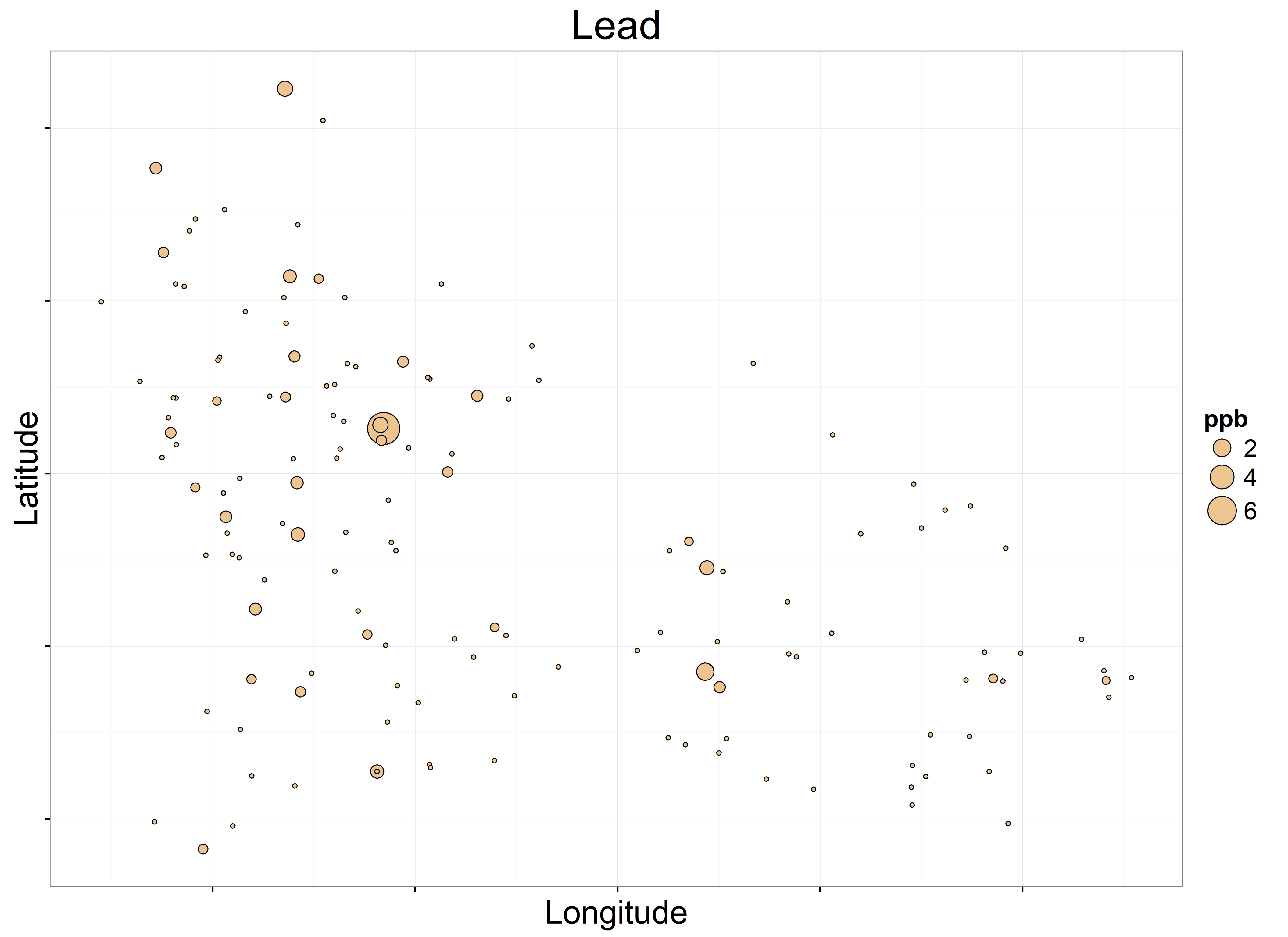


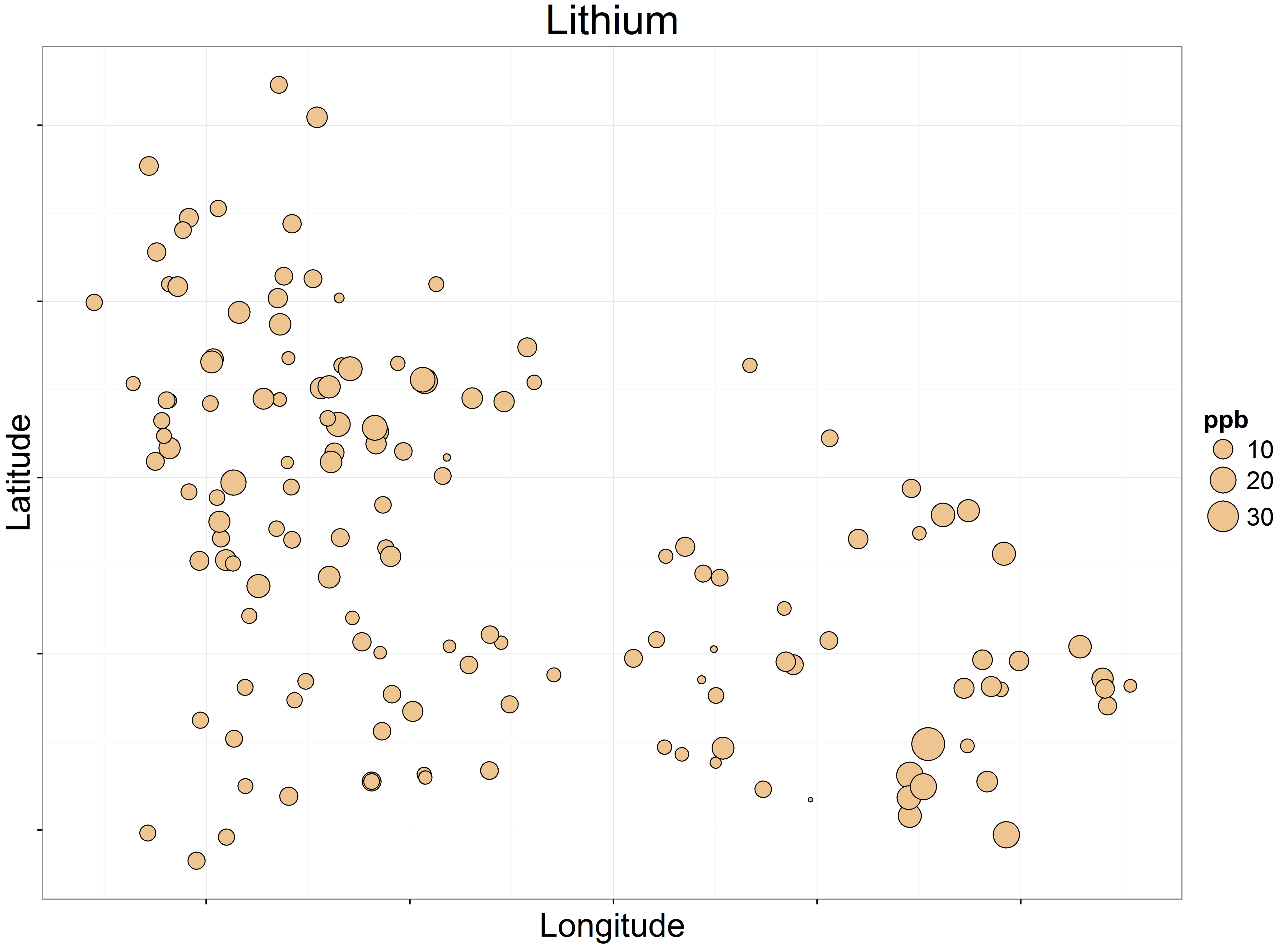
Cobalt
Latitude
Longitude
ppb
0.5
1.0
1.5



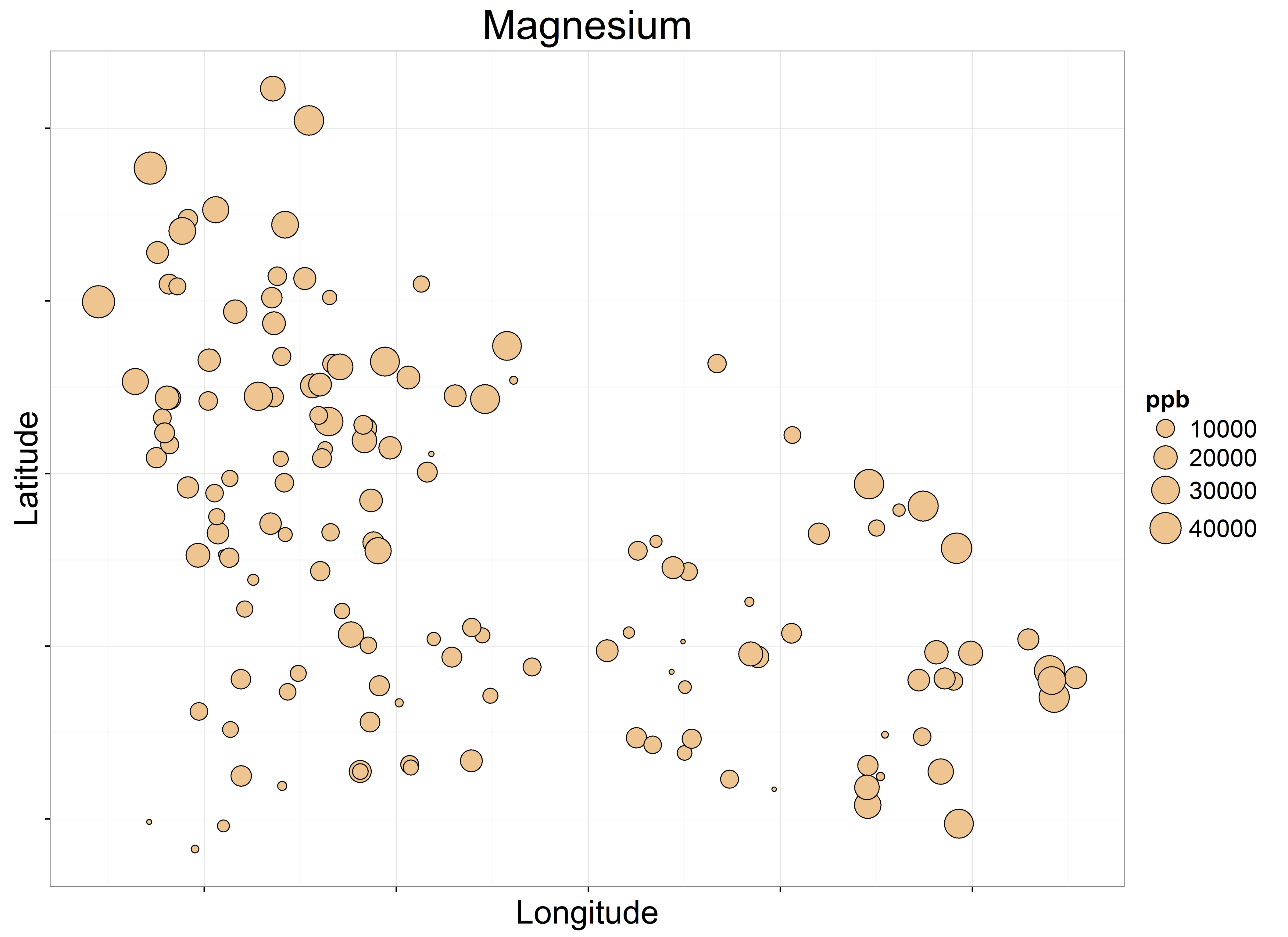
Copper
Latitude
Longitude
ppb
100
200
300

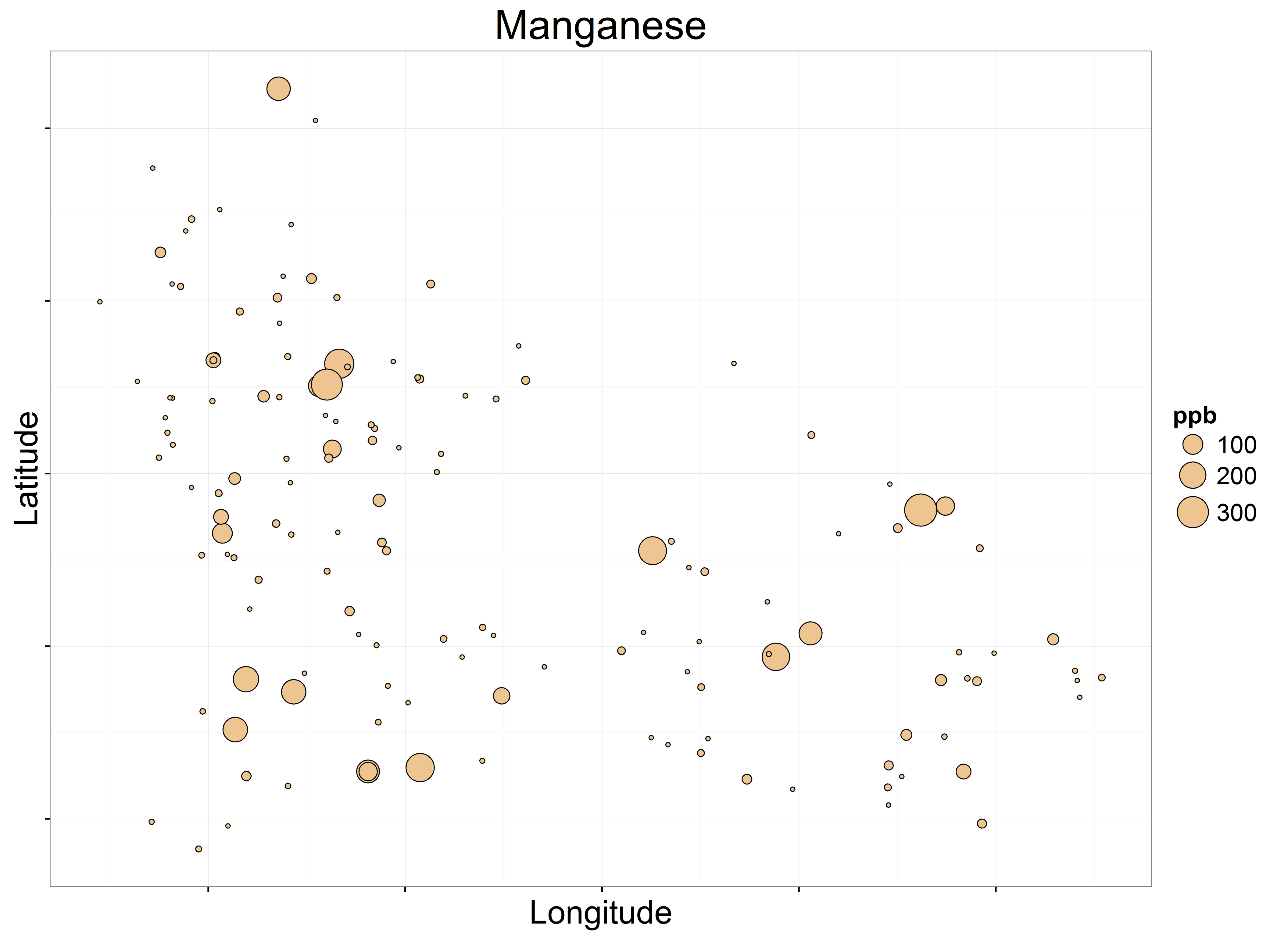

Iron
Latitude
Longitude
ppb
100
200
300
400

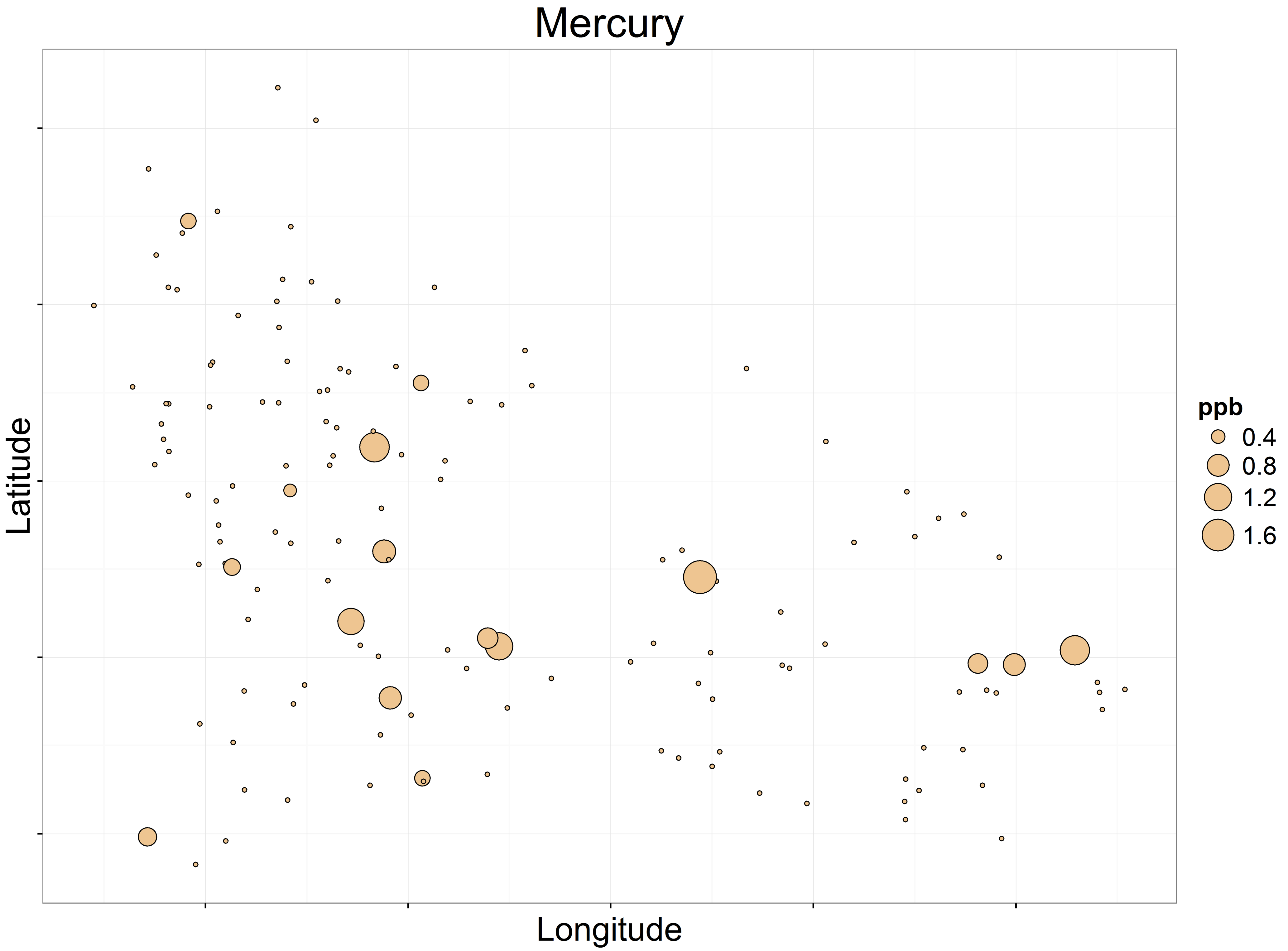

Lead
Latitude
Longitude
ppb
2
4
6

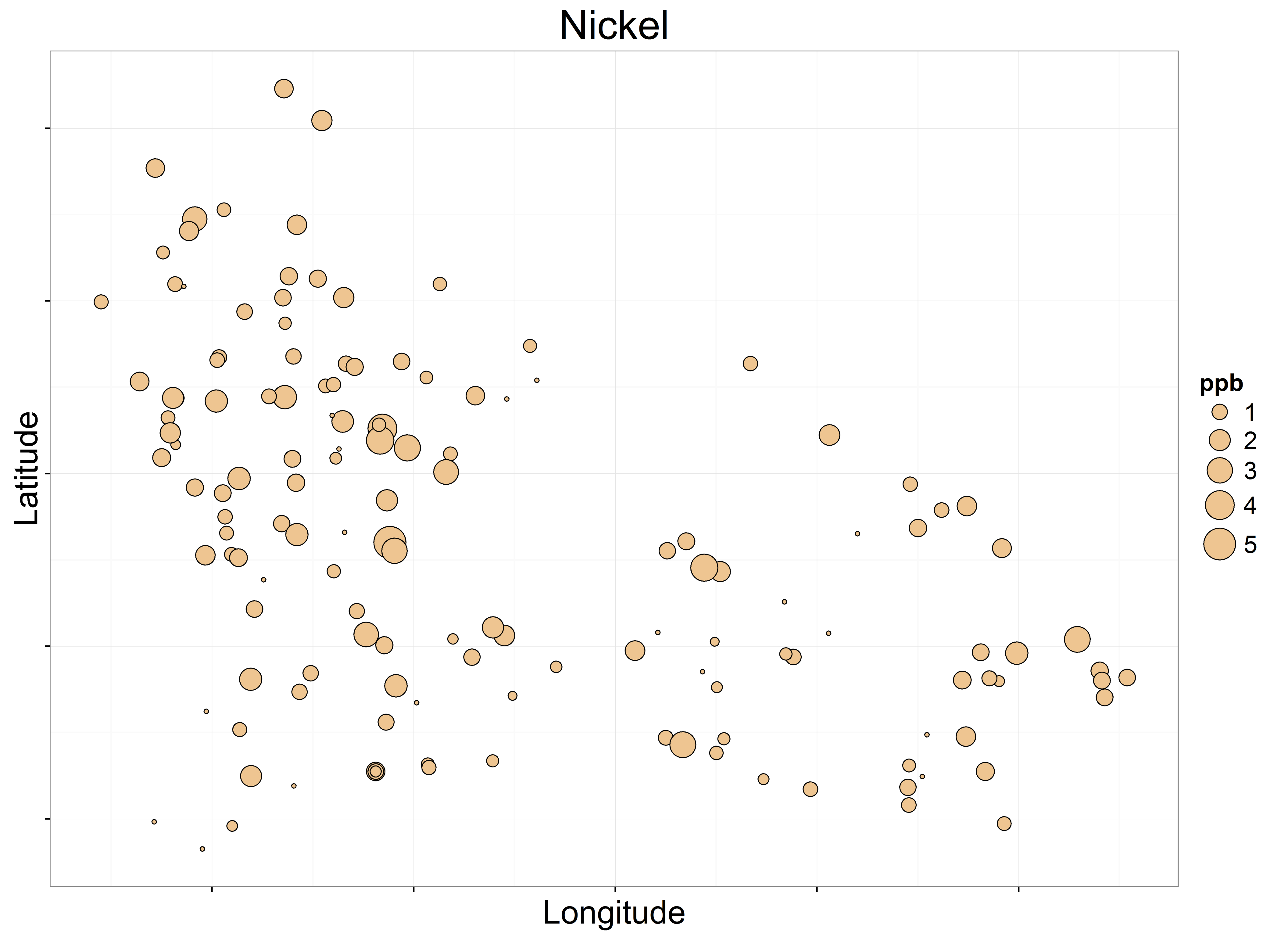


Lithium
Latitude
Longitude
ppb
10
20
30

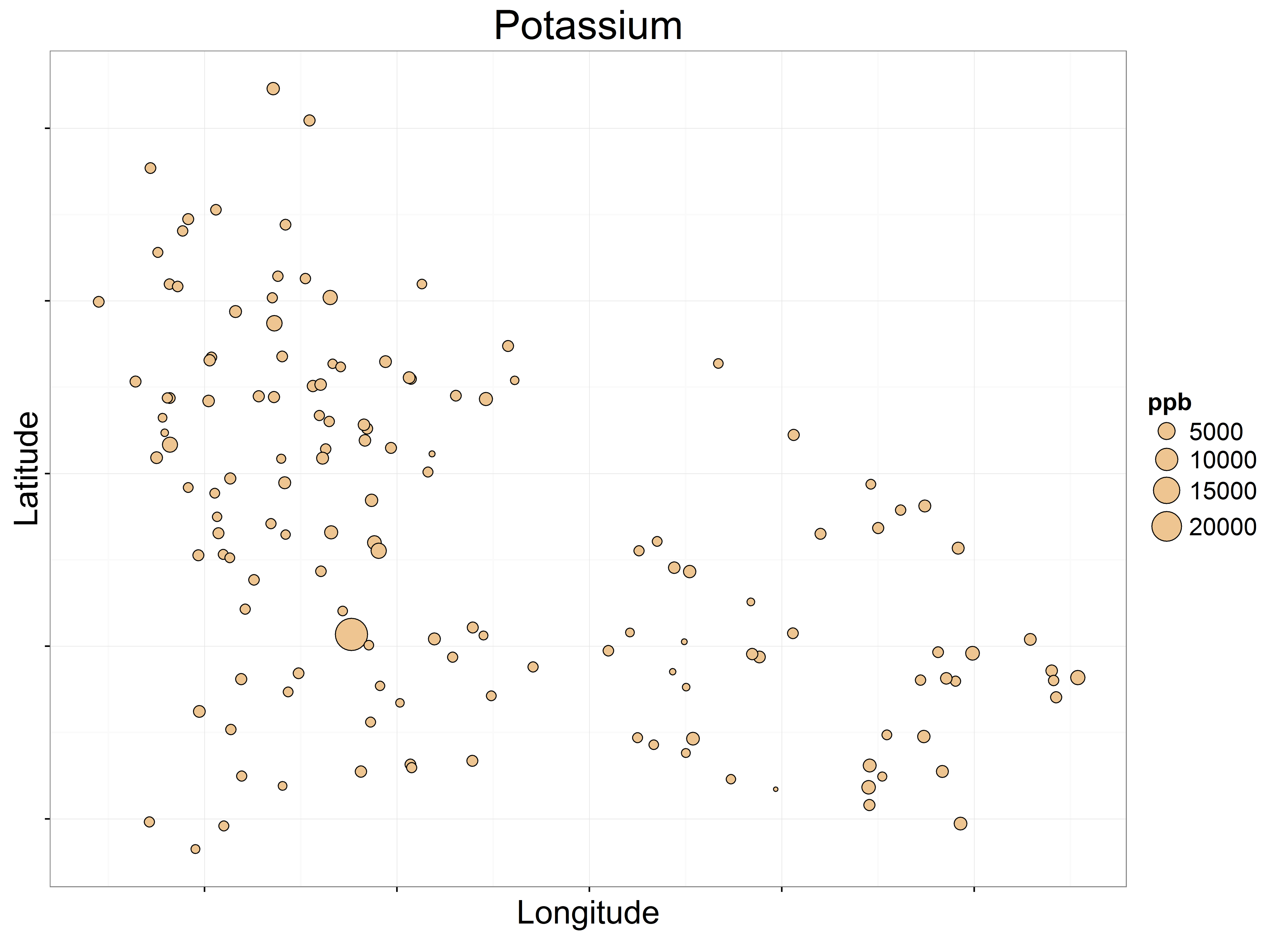

Magnesium
Latitude
Longitude
ppb
10000
20000
30000
40000

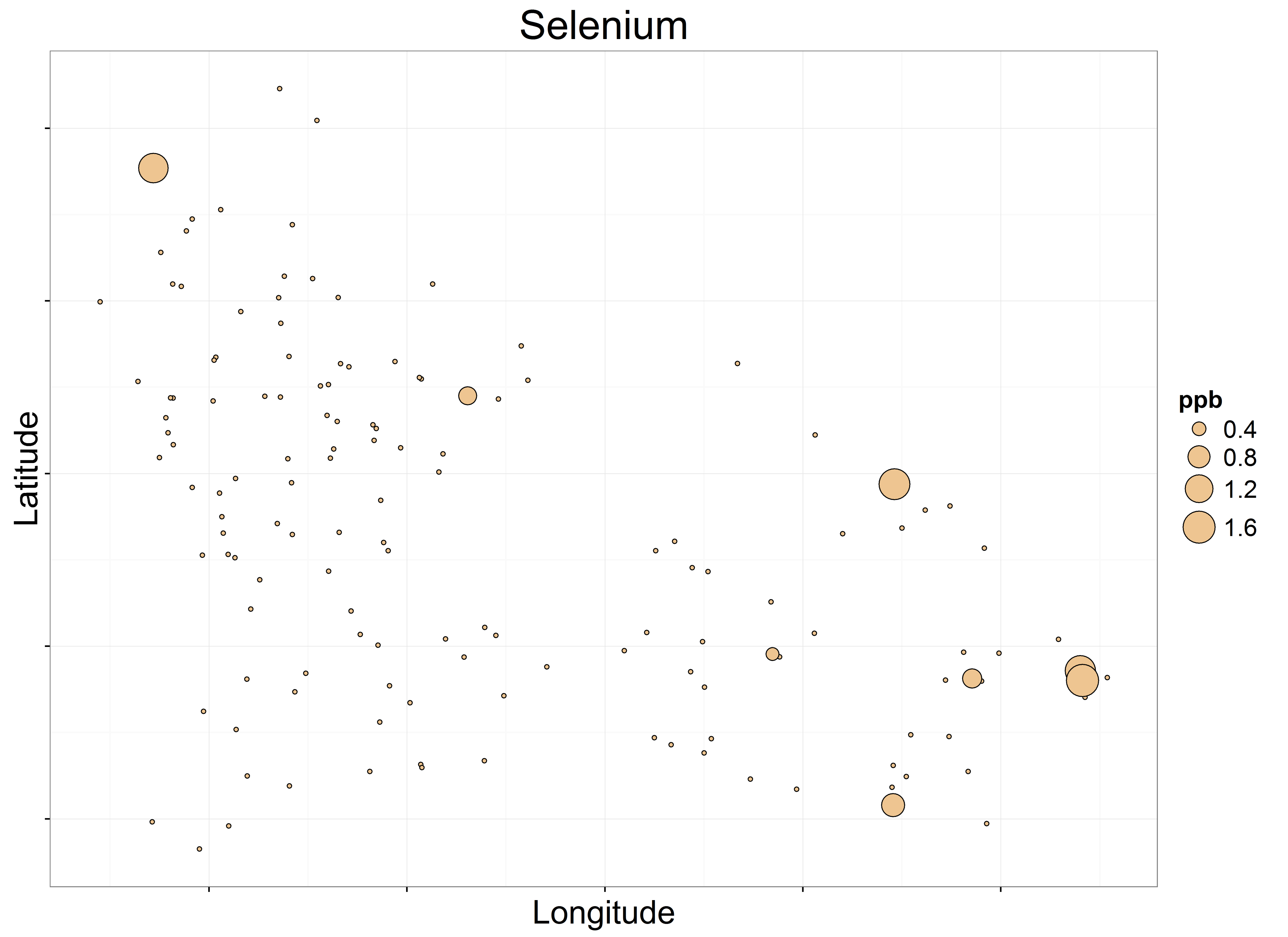

Manganese
Latitude
Longitude
ppb
100
200
300


Mercury
Latitude
Longitude
ppb
0.4
0.8
1.2
1.6

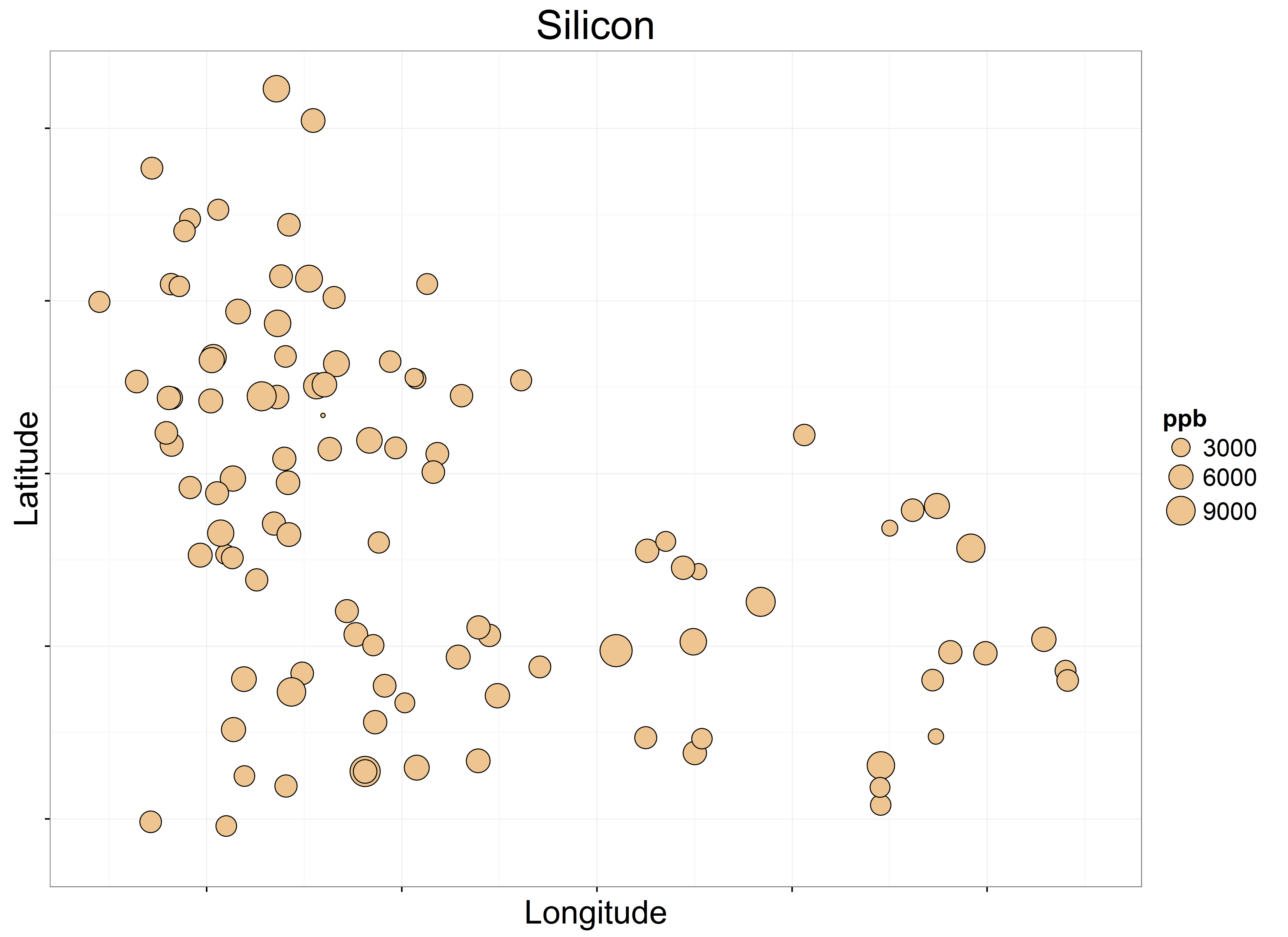


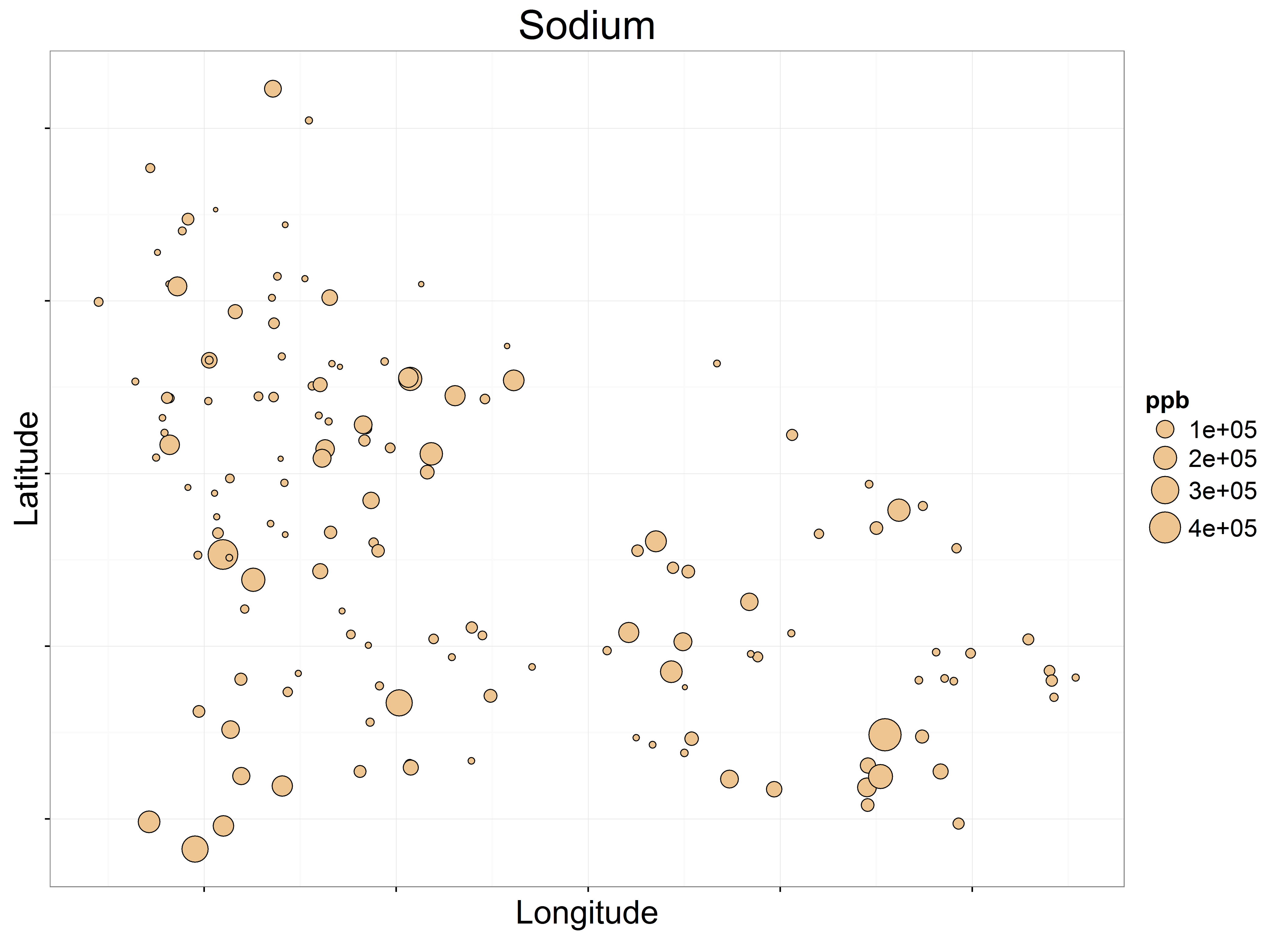
Nickel
Latitude
Longitude
ppb
1
2
3
4
5


Potassium
Latitude
Longitude
ppb
5000
10000
15000
20000

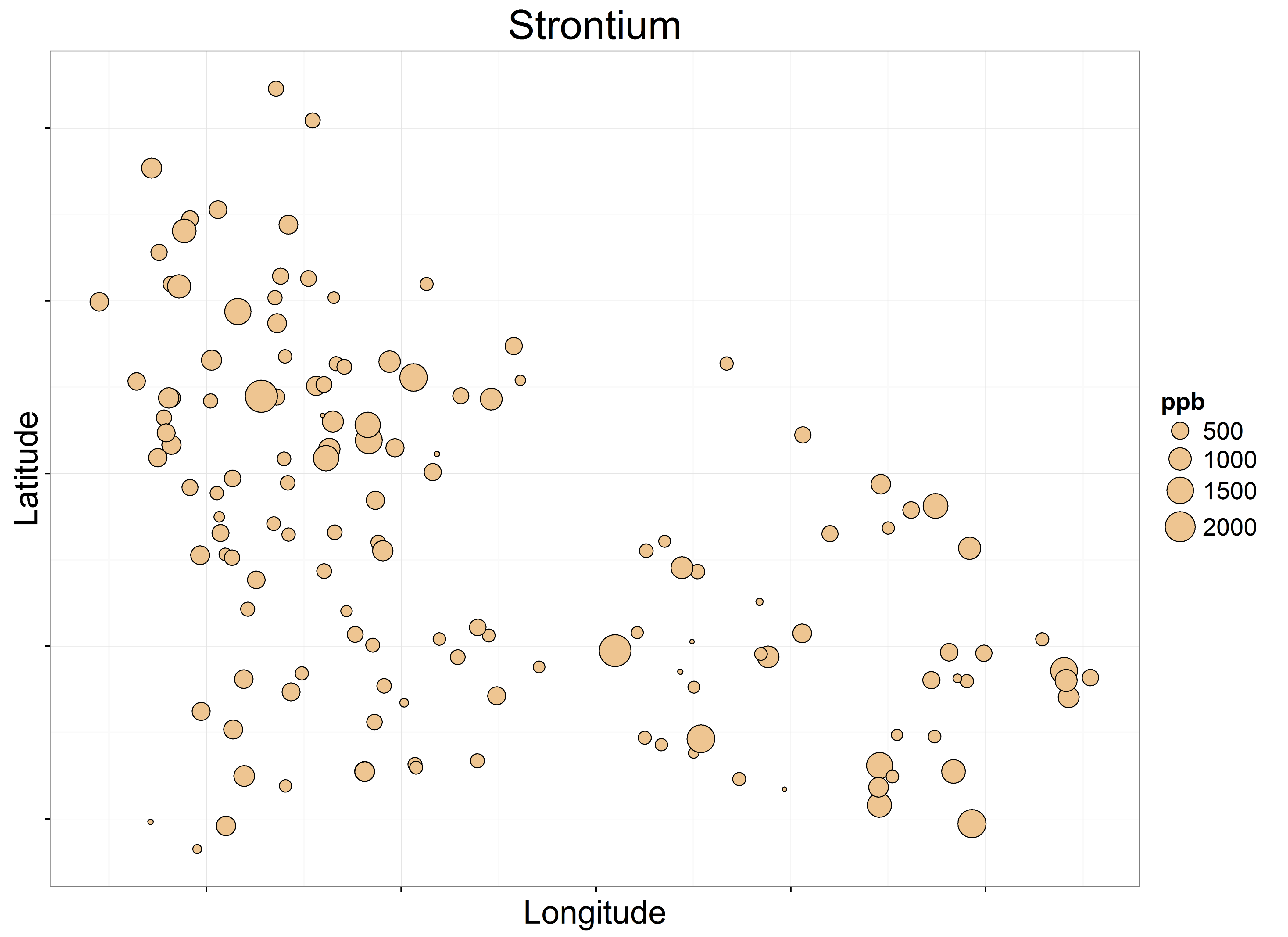


Selenium
Latitude
Longitude
ppb
0.4
0.8
1.2
1.6

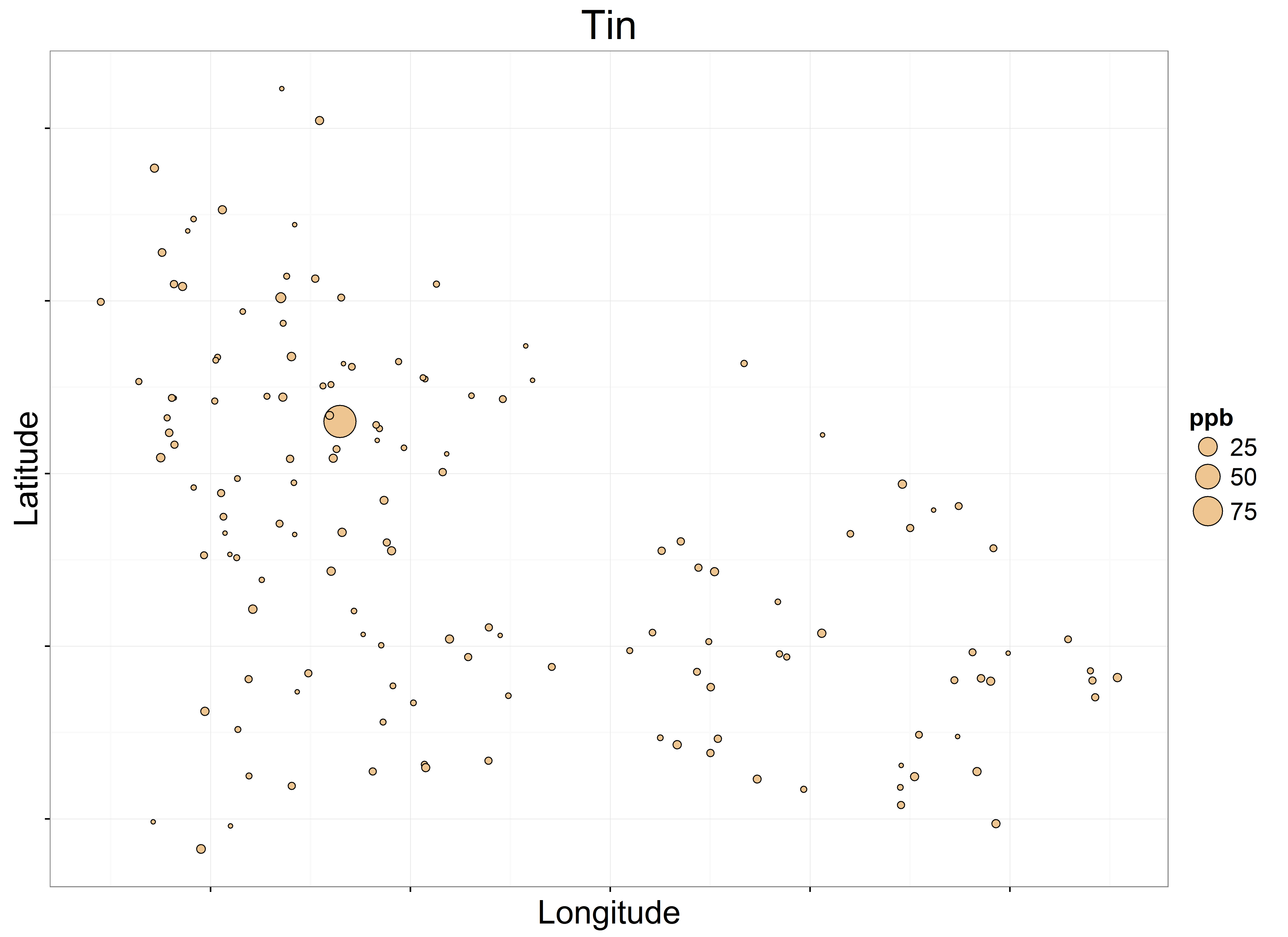

Silicon
Latitude
Longitude
ppb
3000
6000
9000



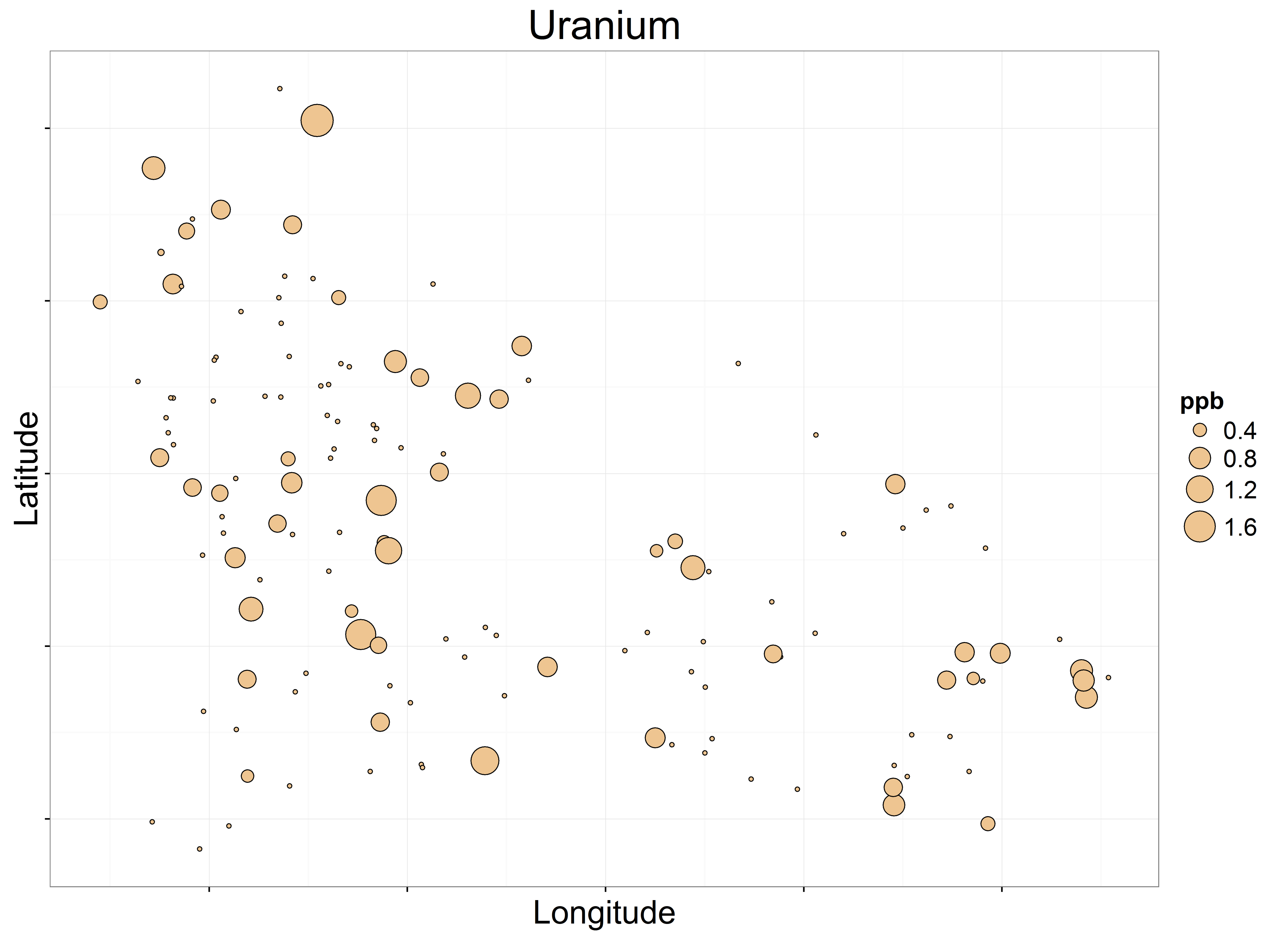
Sodium
Latitude
Longitude
ppb
1e+05
2e+05
3e+05
4e+05



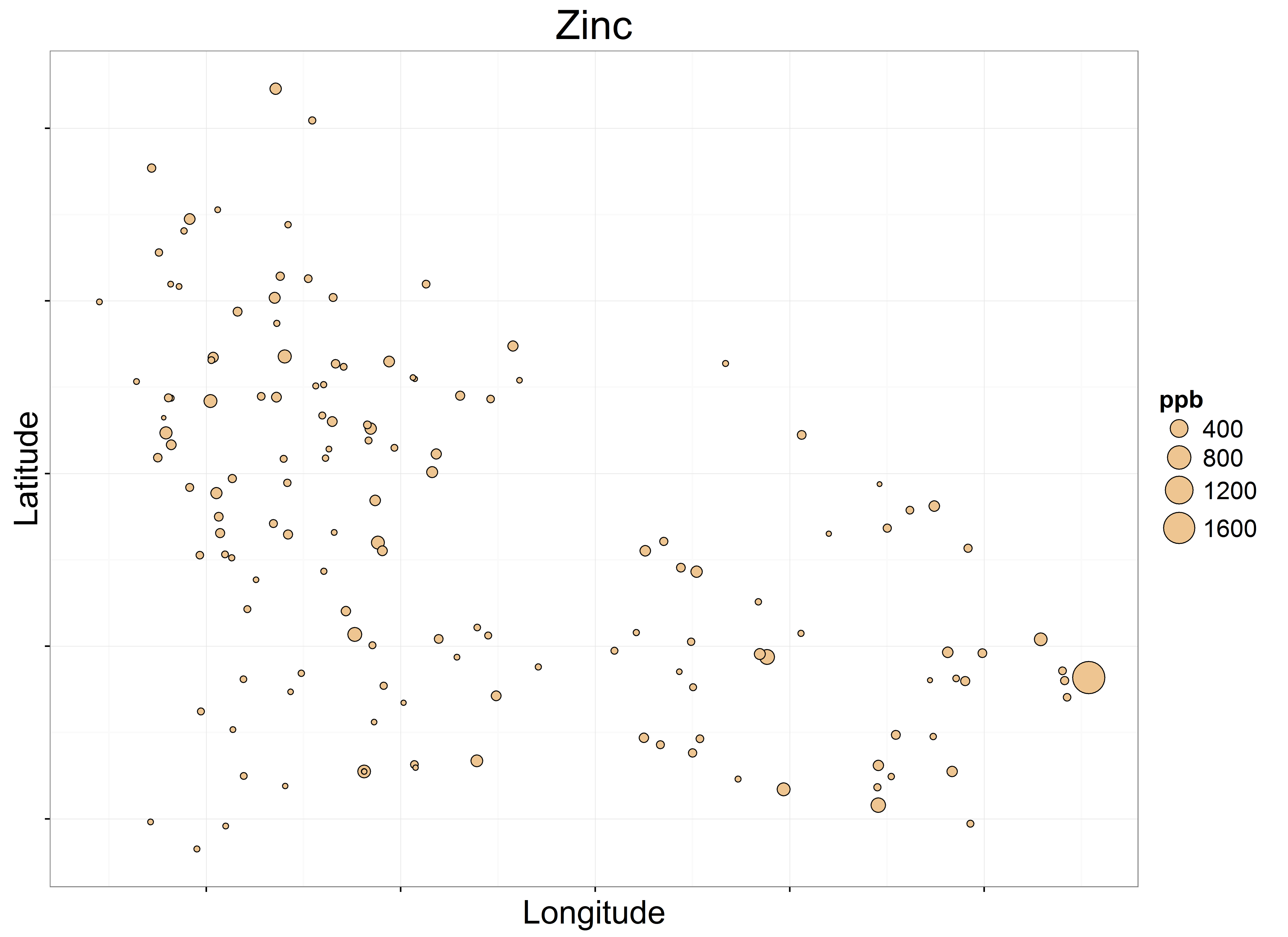
Strontium
Latitude
Longitude
ppb
500
1000
1500
2000

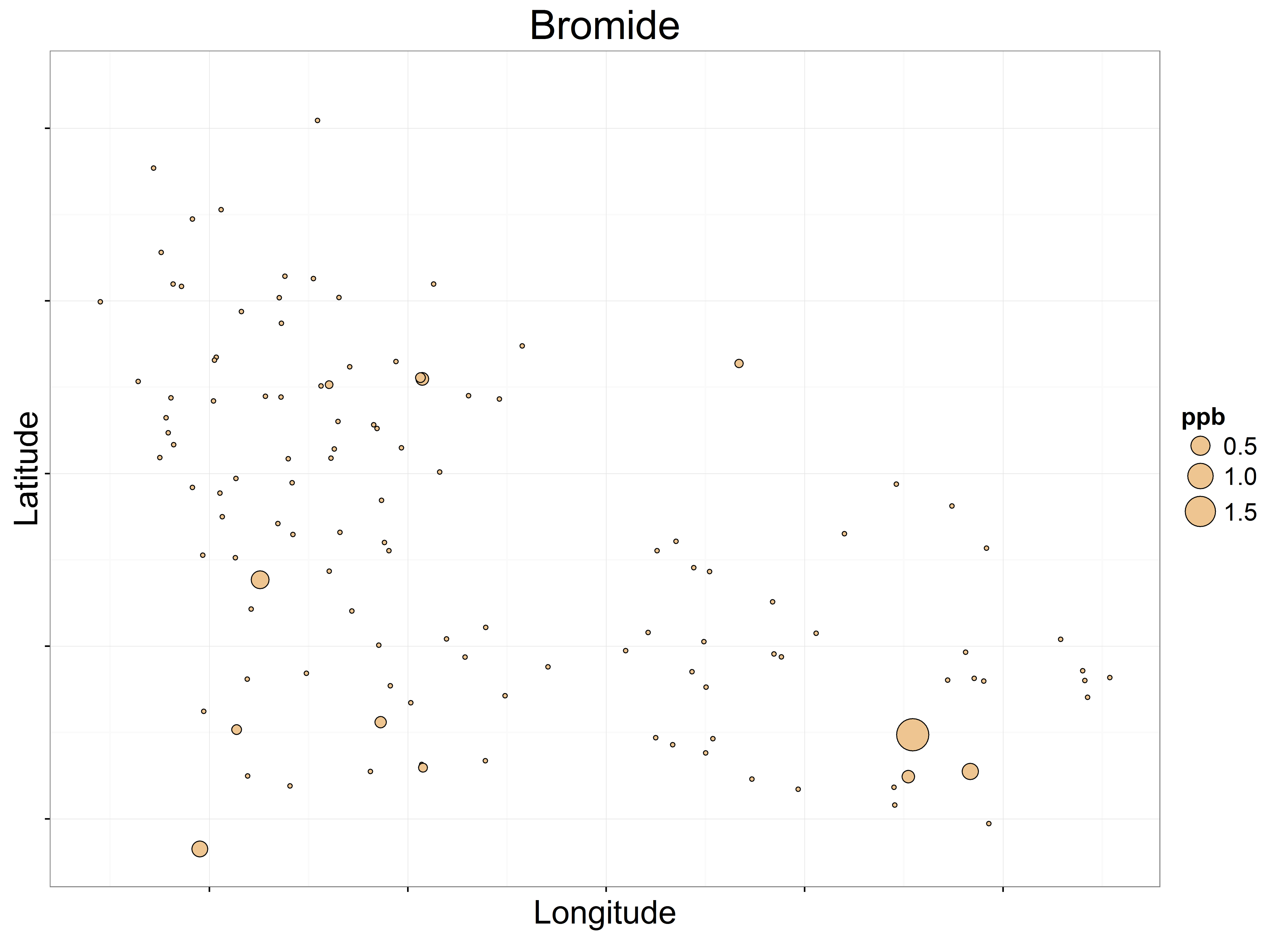


Tin
Latitude
Longitude
ppb
25
50
75

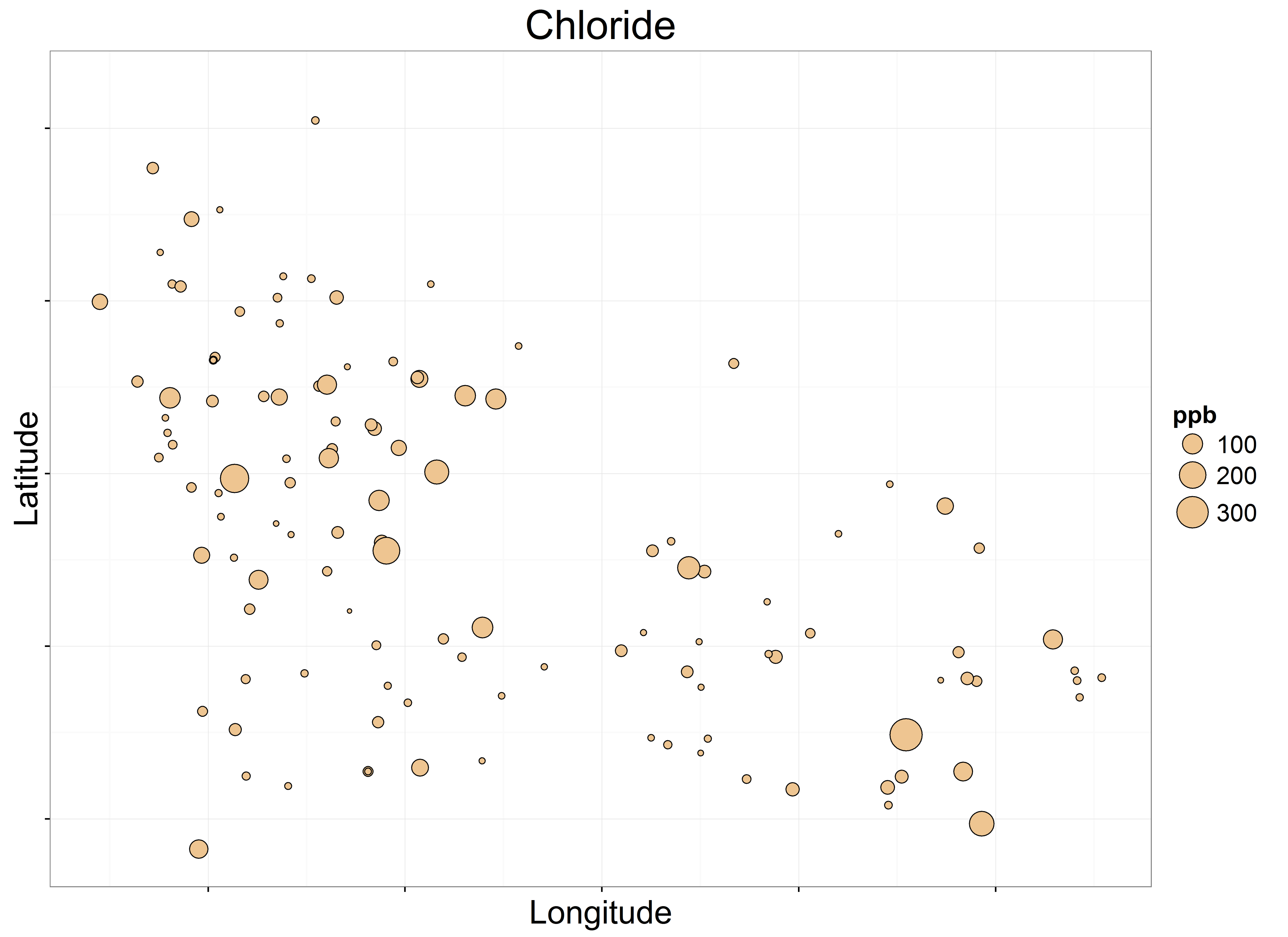


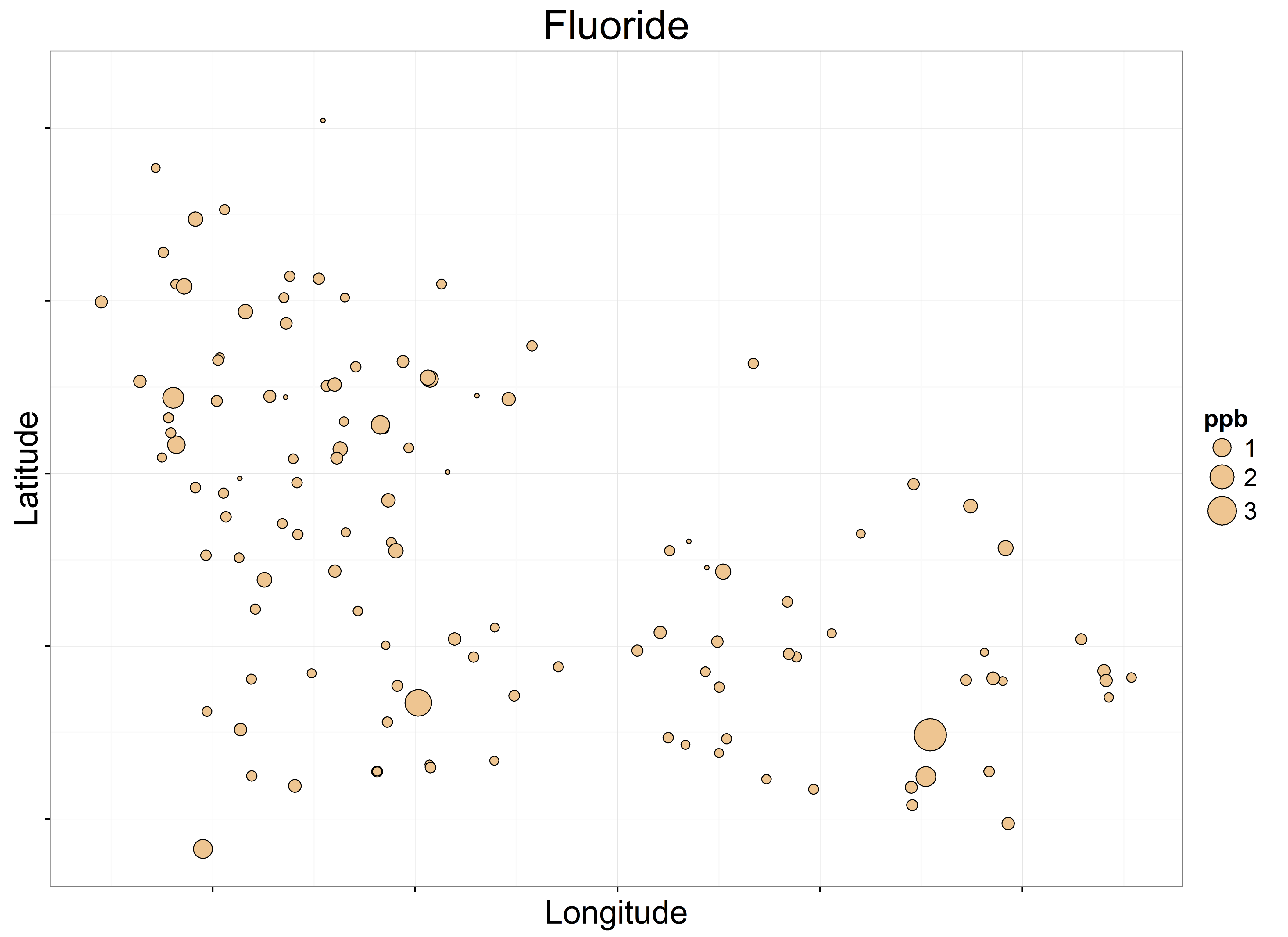
Uranium
Latitude
Longitude
ppb
0.4
0.8
1.2
1.6

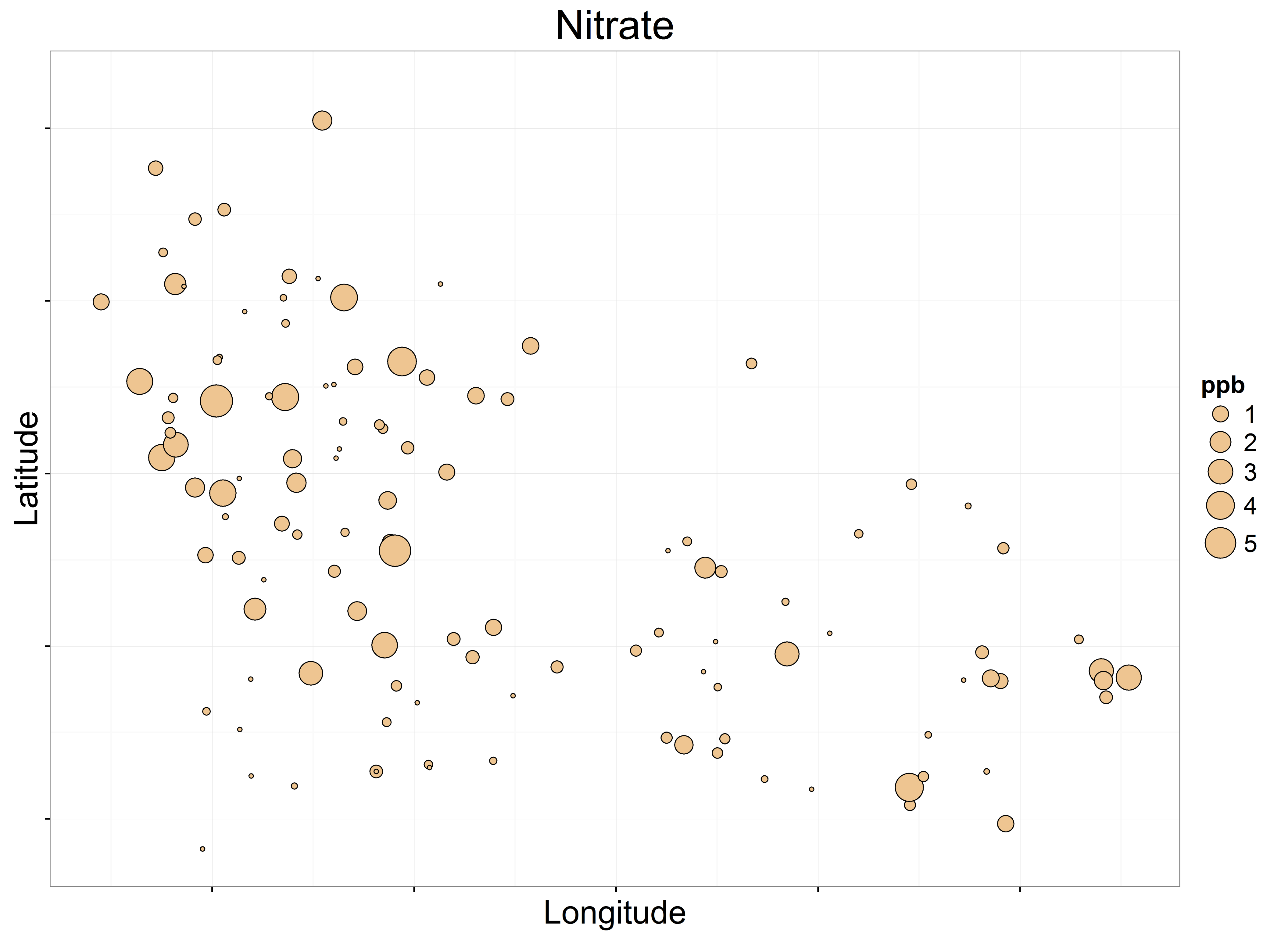

Zinc
Latitude
Longitude
ppb
400
800
1200
1600



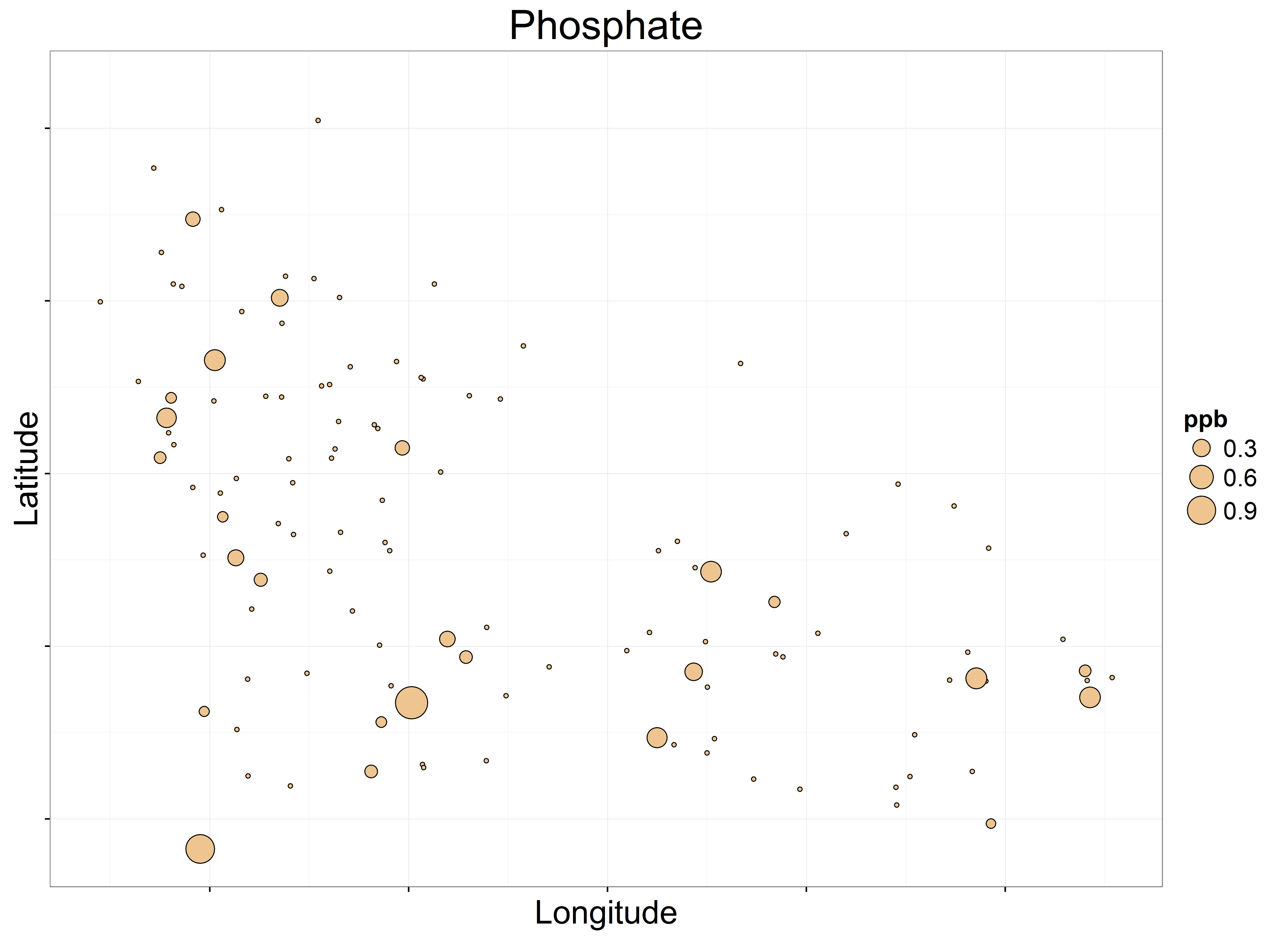
Bromide
Latitude
Longitude
ppb
0.5
1.0
1.5

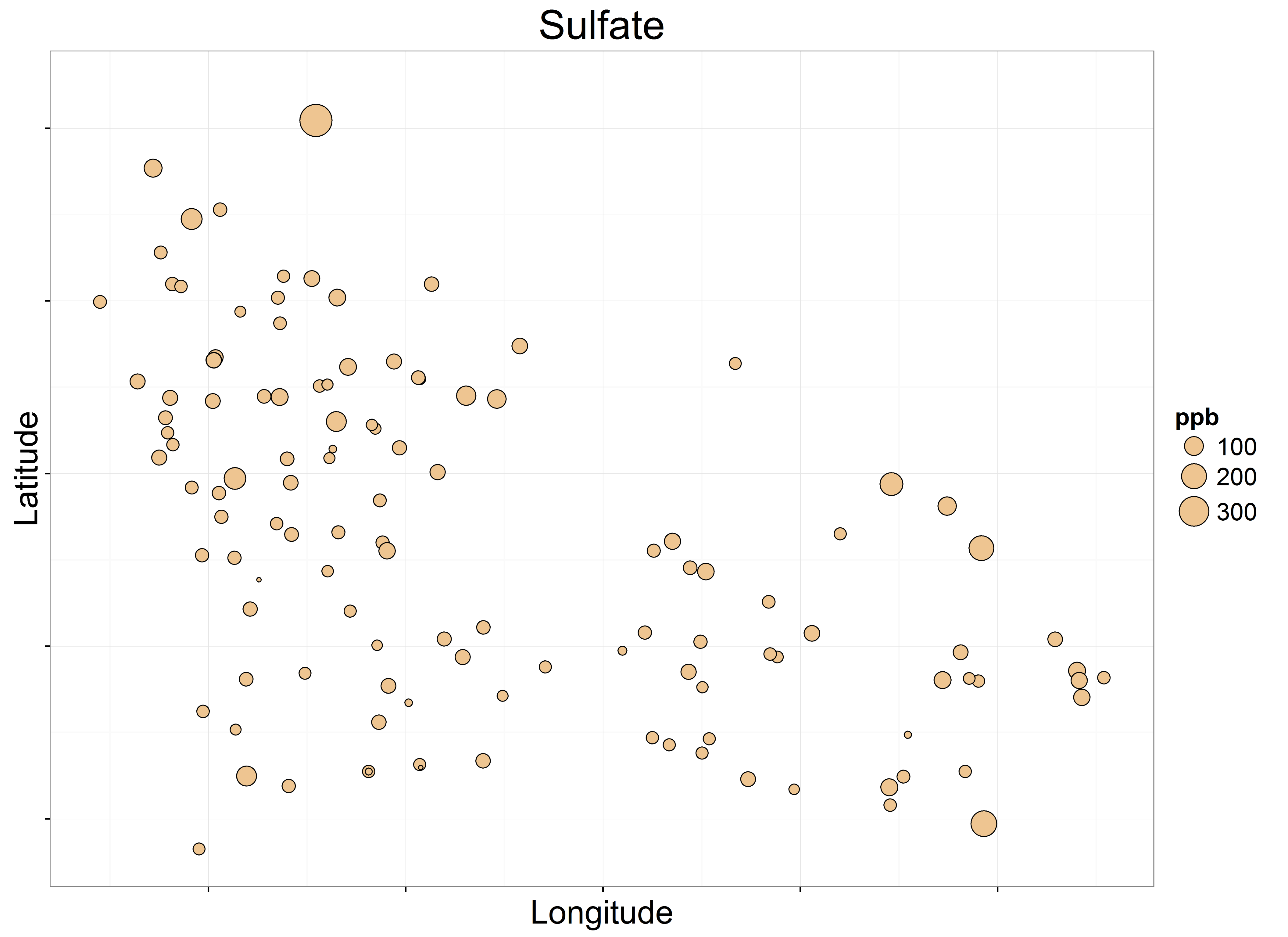

Chloride
Latitude
Longitude
ppb
100
200
300

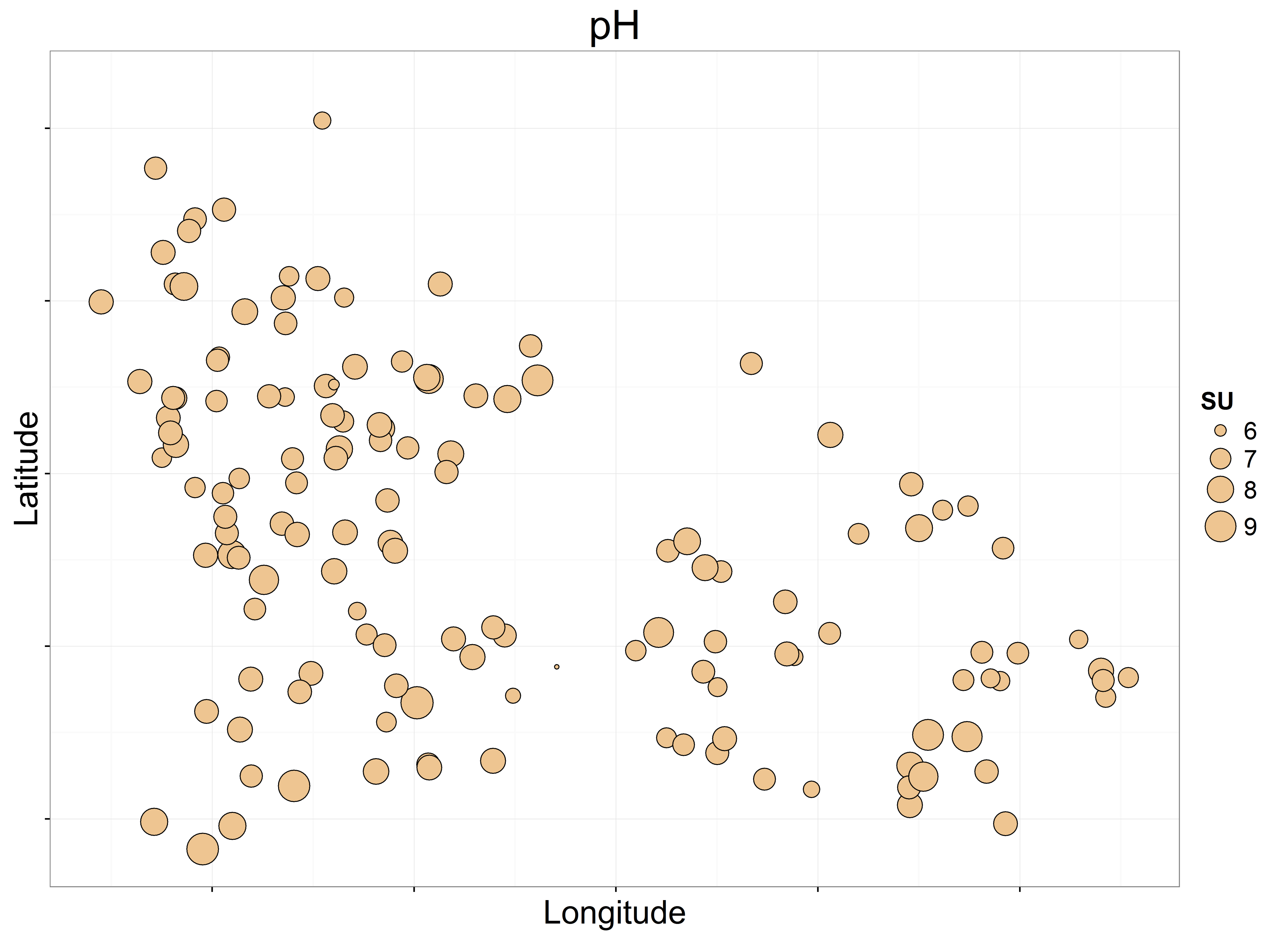

Fluoride
Latitude
Longitude
ppb
1
2
3

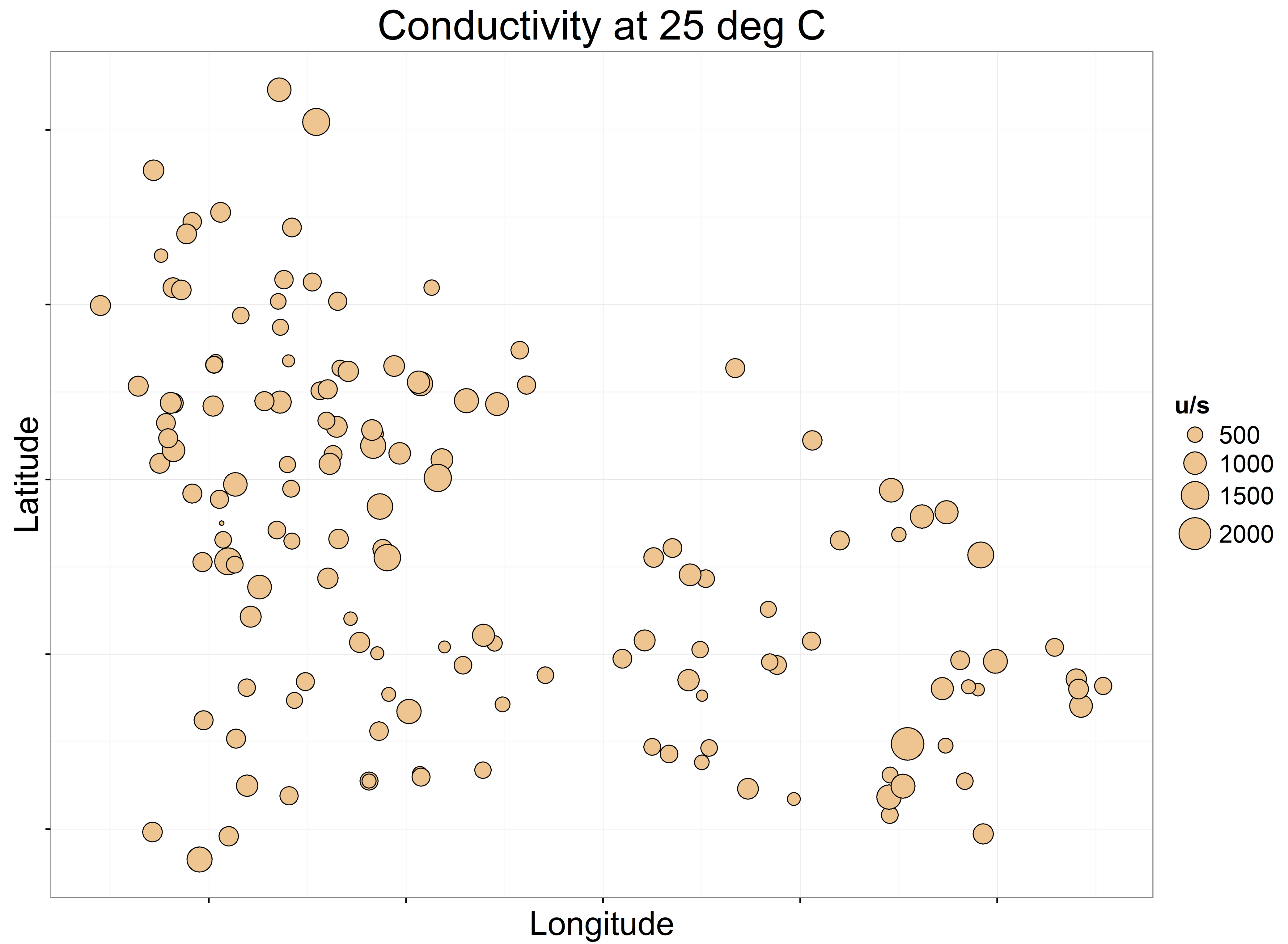


Nitrate
Latitude
Longitude
ppb
1
2
3
4
5

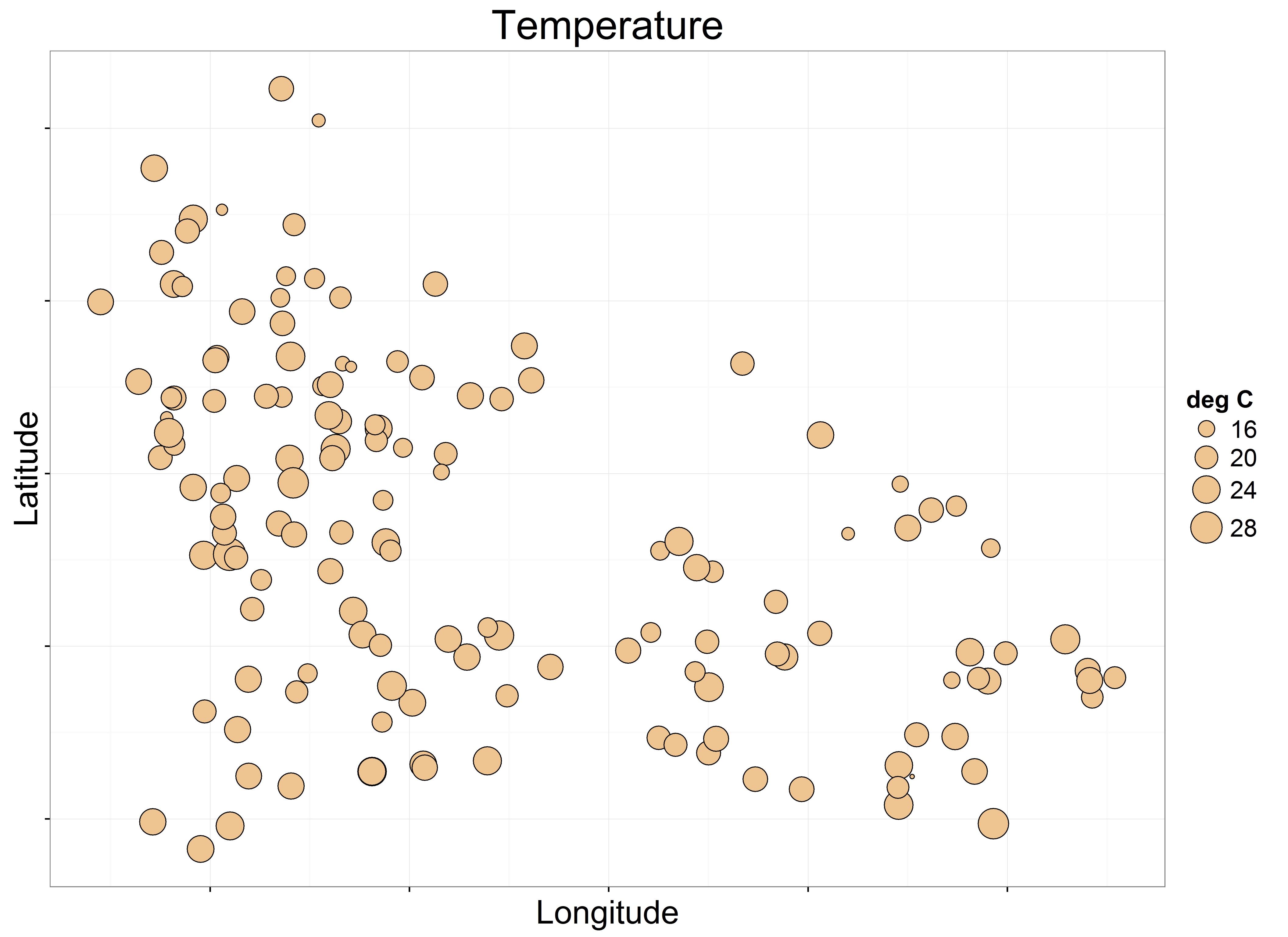

Phosphate
Latitude
Longitude
ppb
0.3
0.6
0.9


Sulfate
Latitude
Longitude
ppb
100
200
300


pH
Latitude
Longitude
SU
6
7
8
9

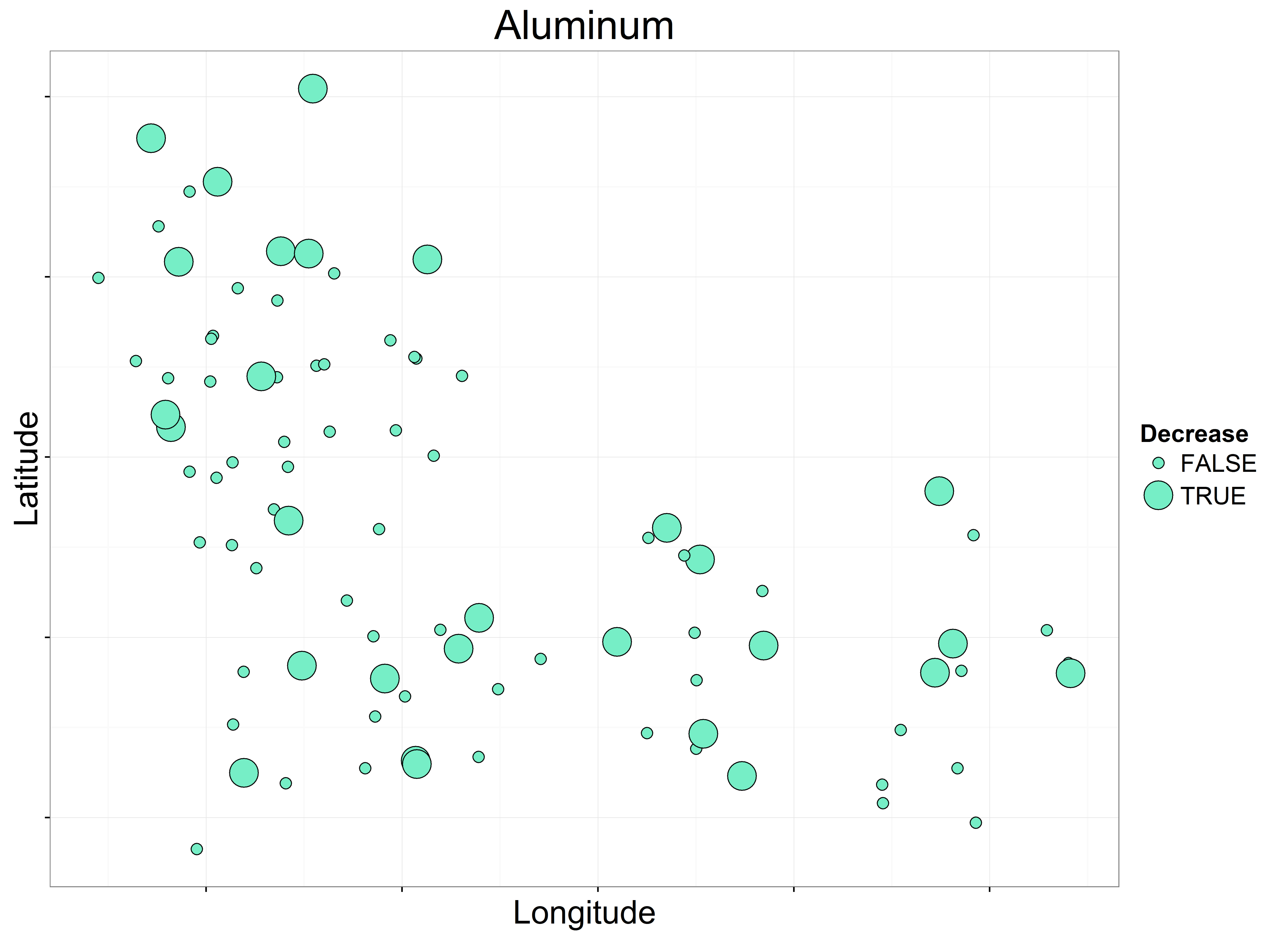


Conductivity at 25 deg C
Latitude
Longitude
u/s
500
1000
1500
2000

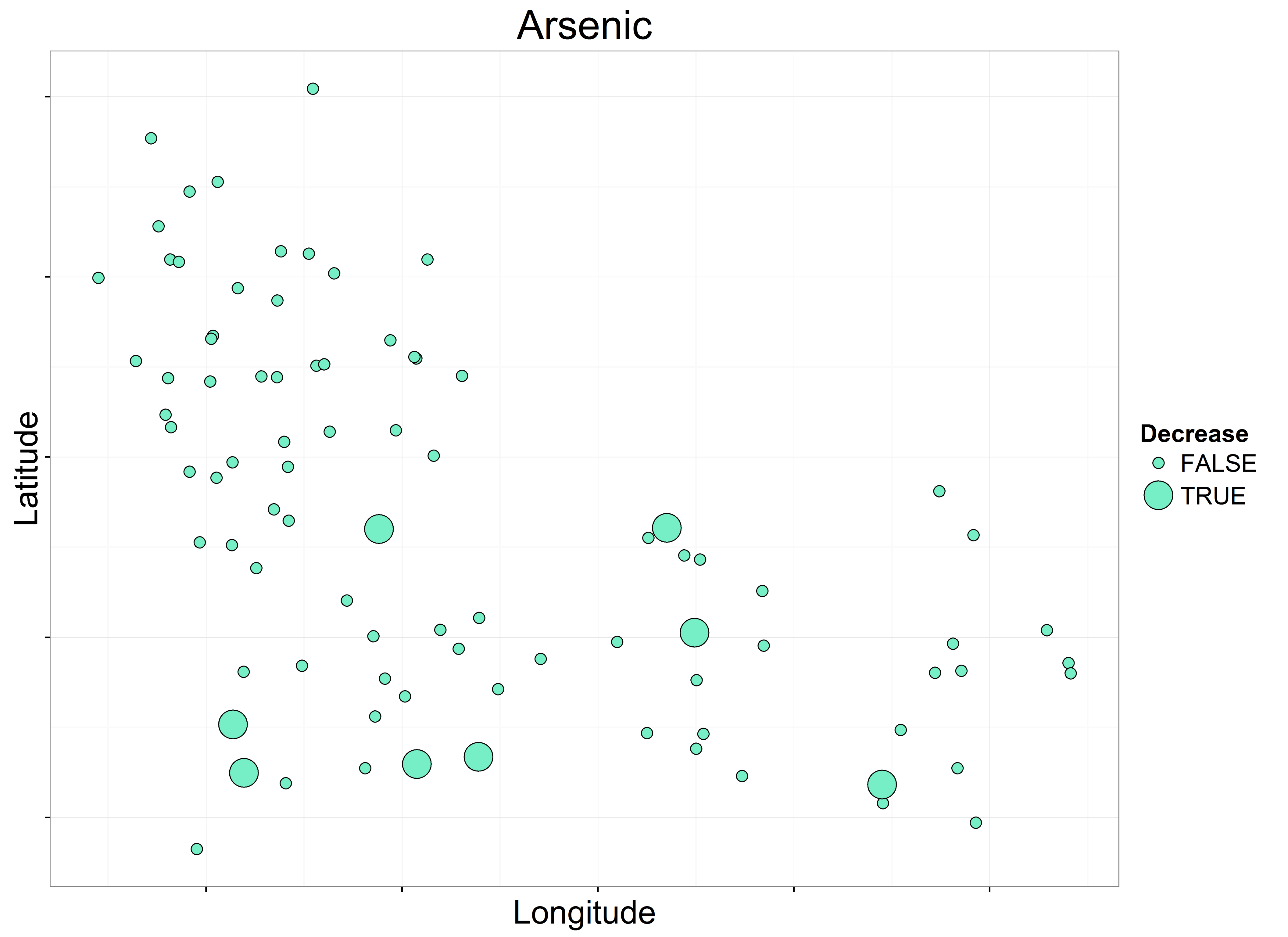

Temperature
Latitude
Longitude
deg C
16
20
24
28

Appendix C

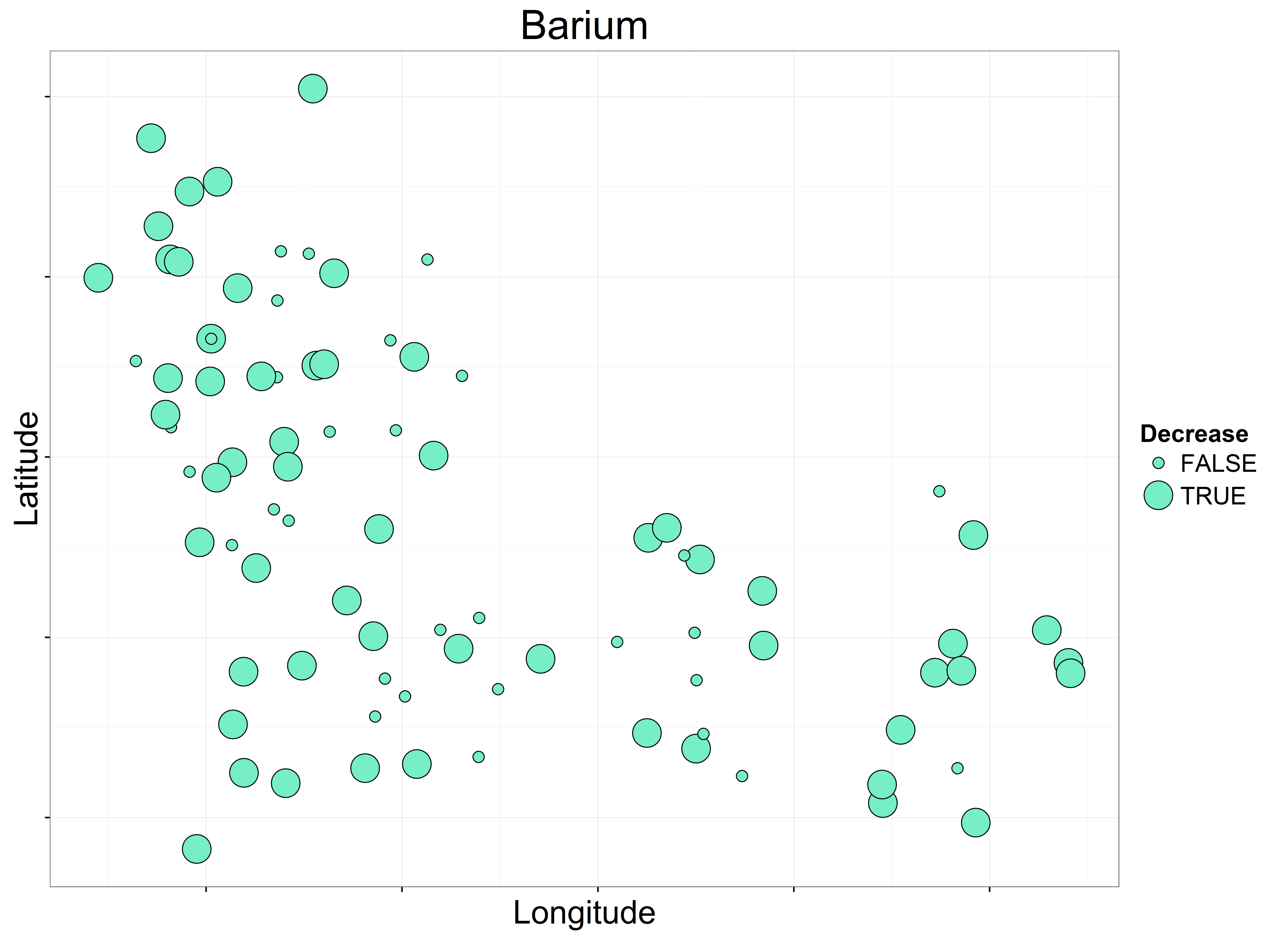
Graduated Symbol Plots



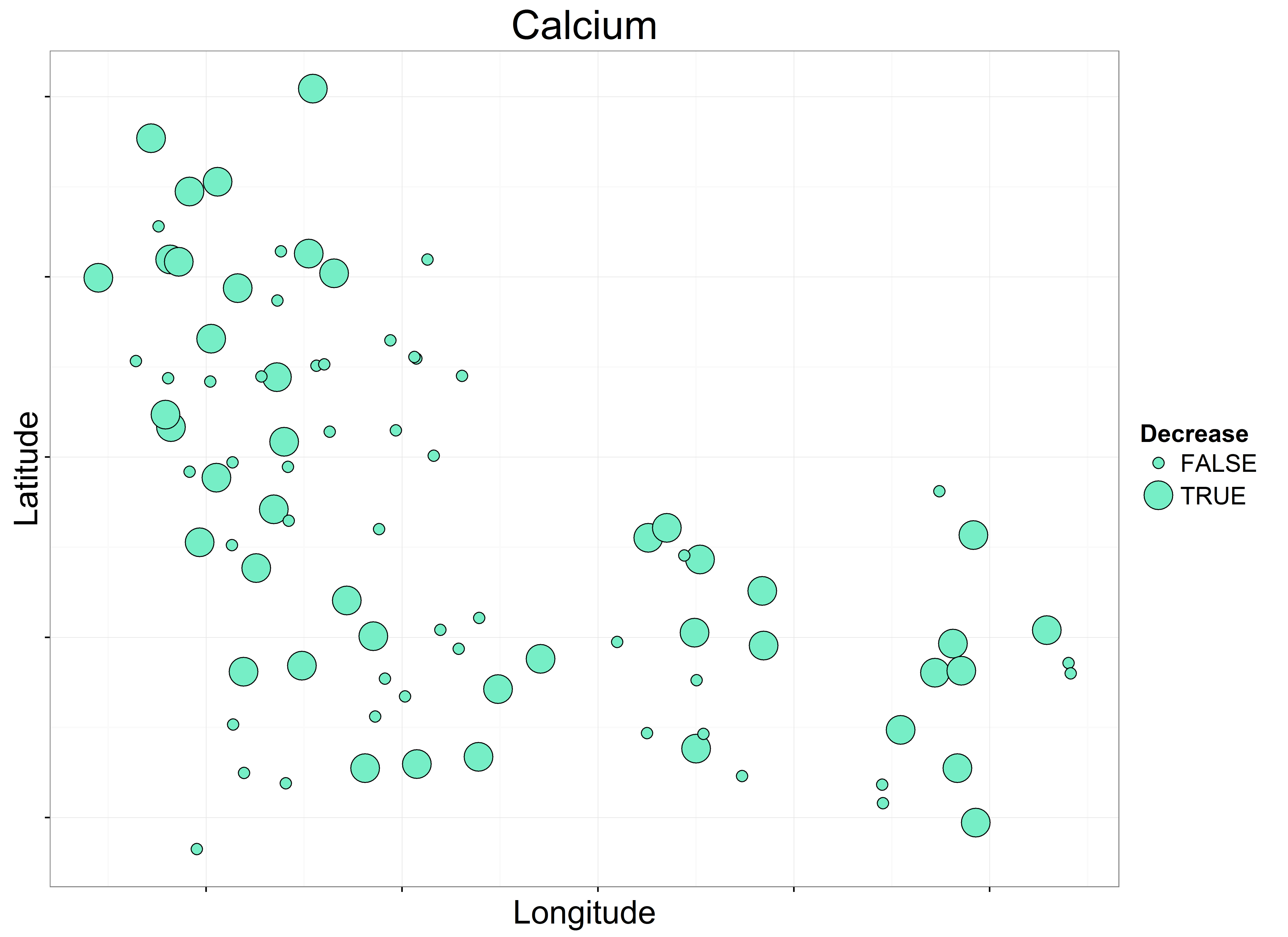
Aluminum
Latitude
Longitude
Decrease
FALSE
TRUE

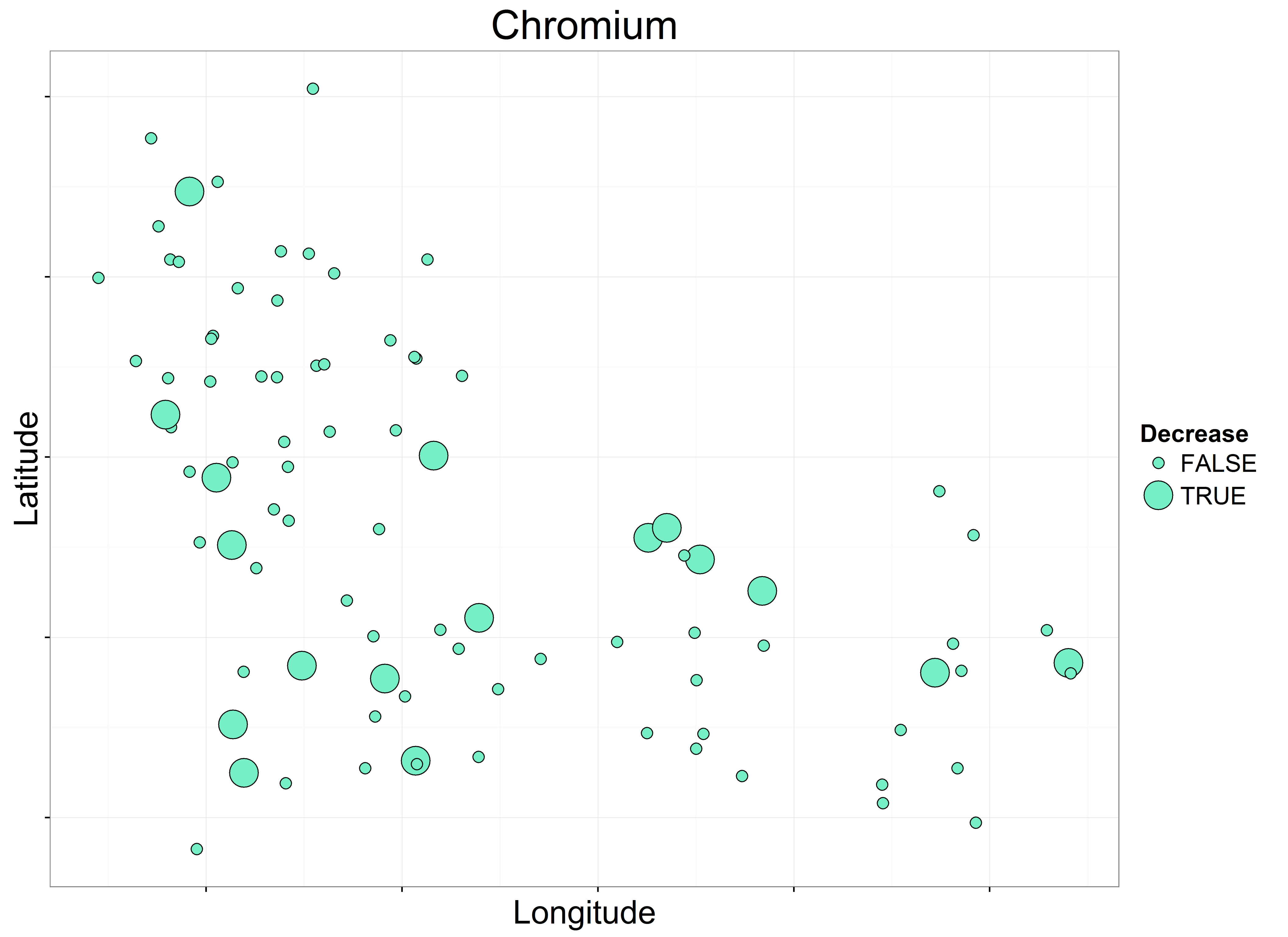


Arsenic
Latitude
Longitude
Decrease
FALSE
TRUE

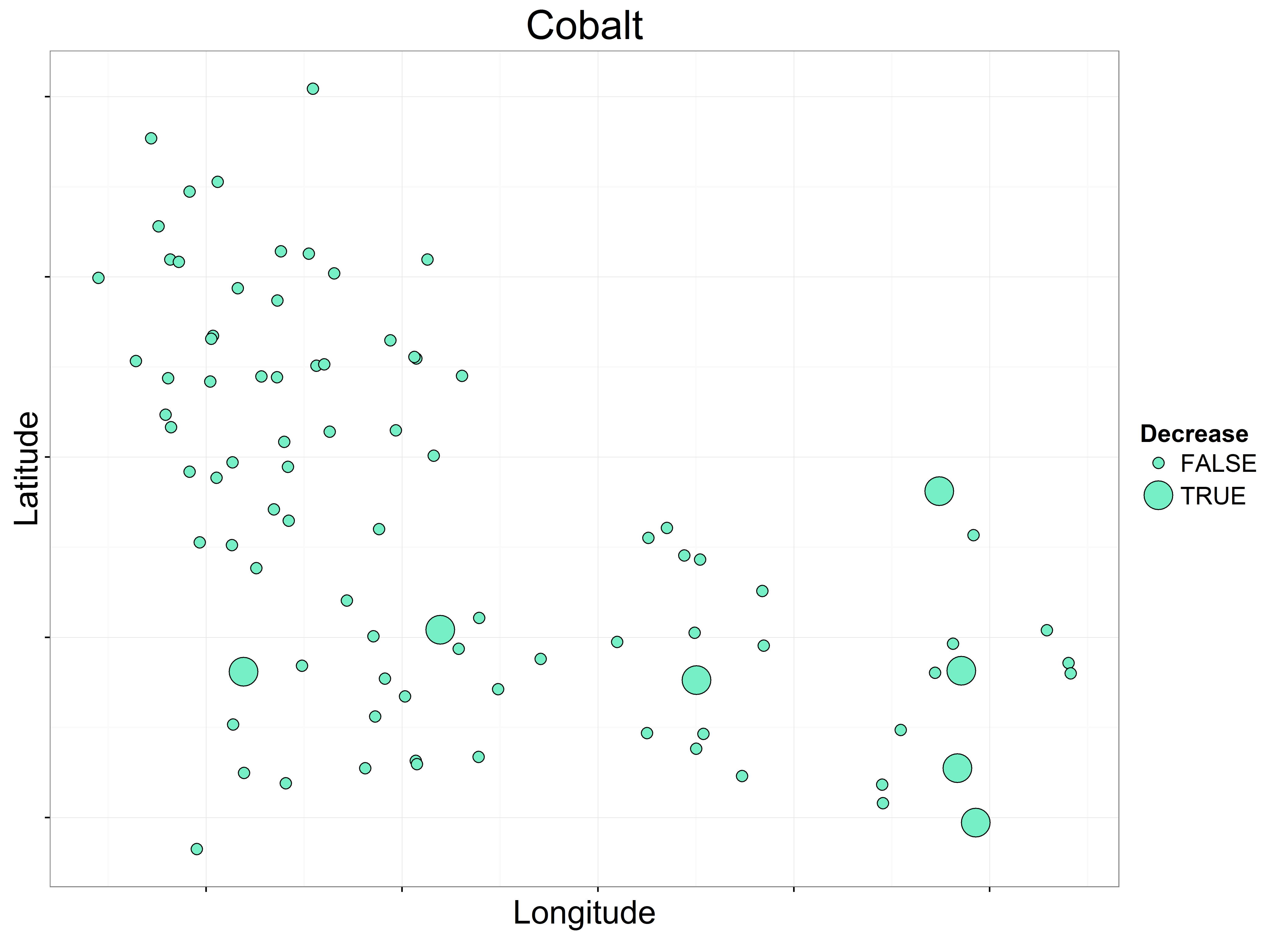


Barium
Latitude
Longitude
Decrease
FALSE
TRUE

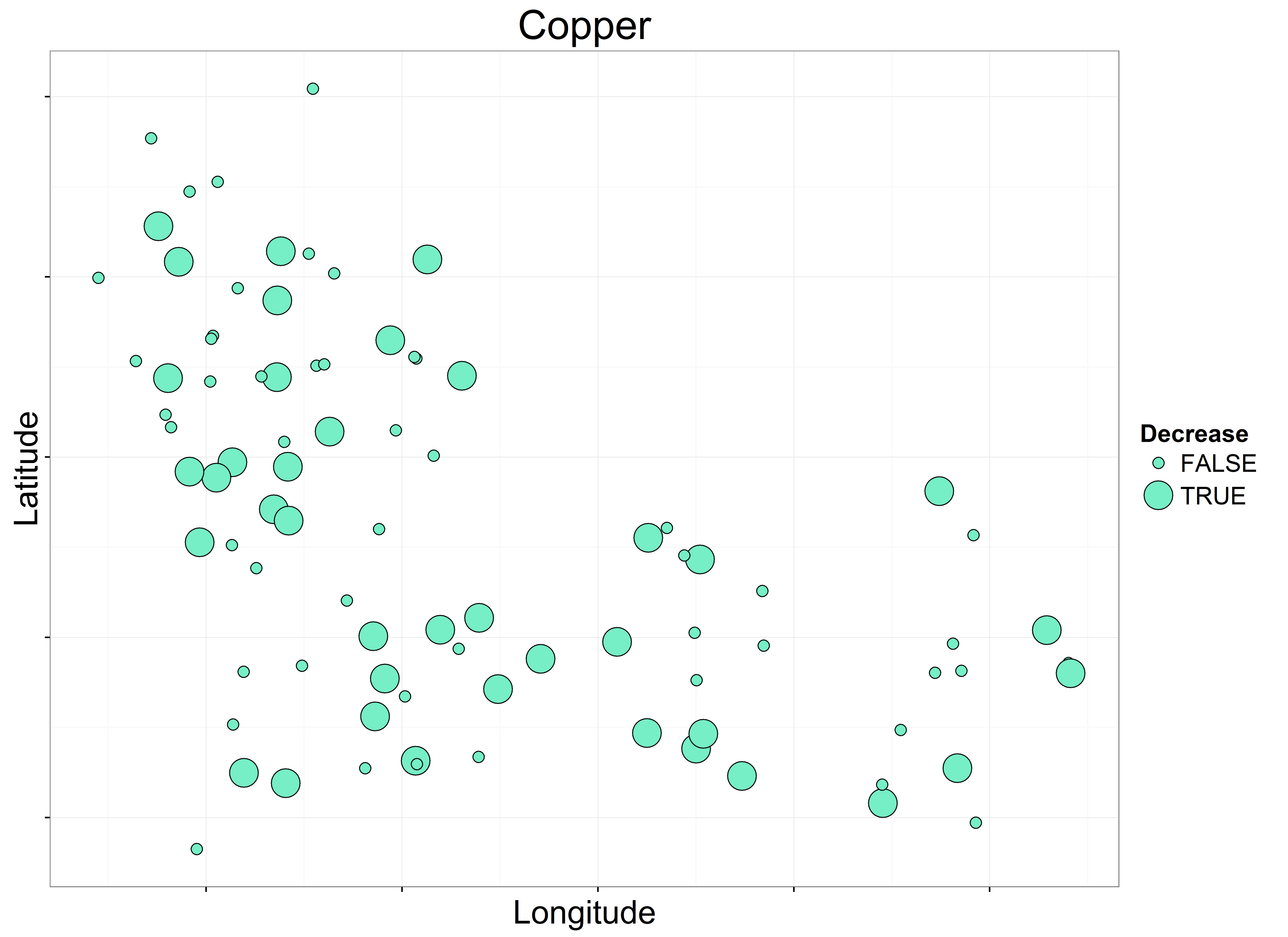

Calcium
Latitude
Longitude
Decrease
FALSE
TRUE



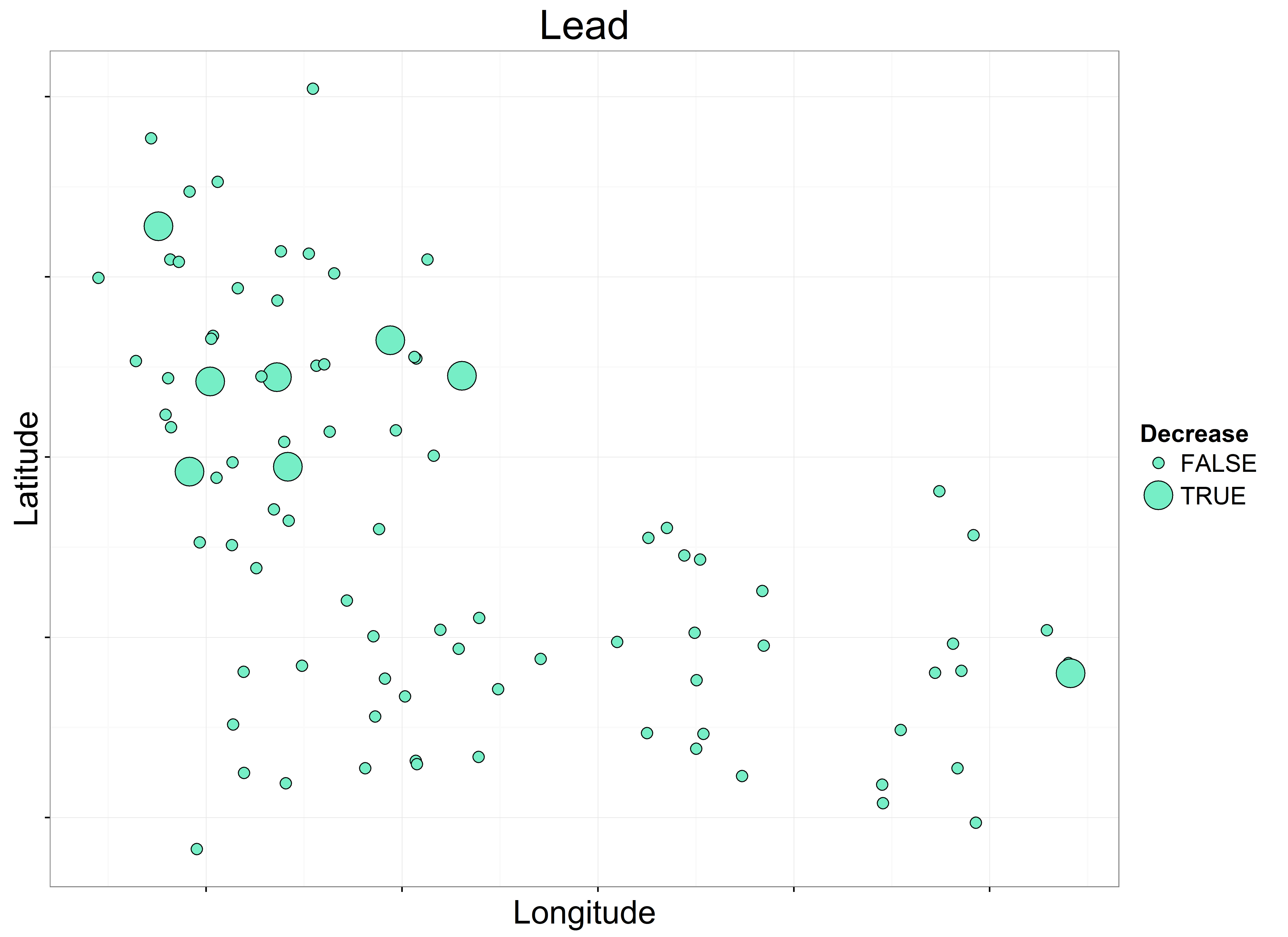
Chromium
Latitude
Longitude
Decrease
FALSE
TRUE



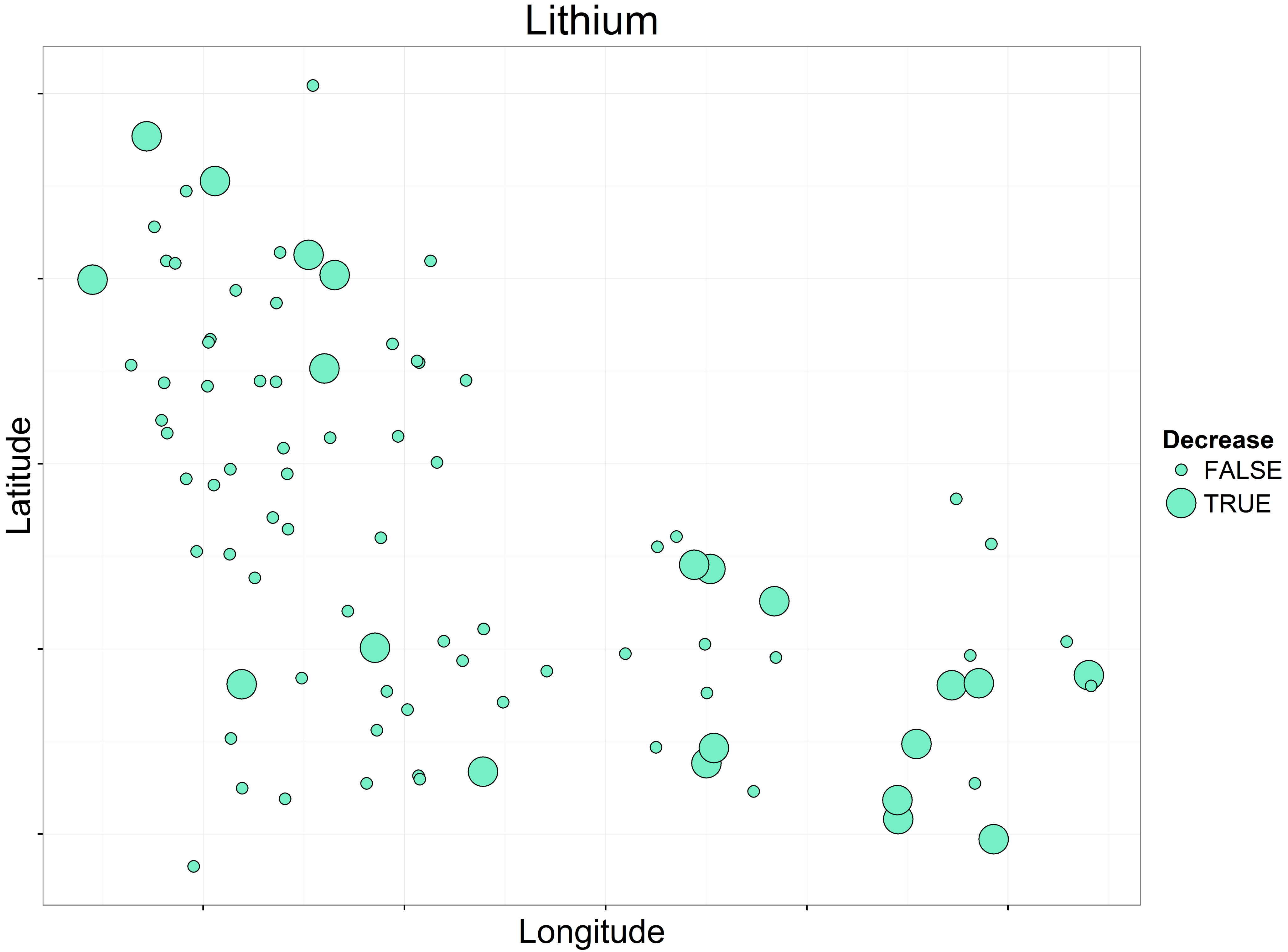
Cobalt
Latitude
Longitude
Decrease
FALSE
TRUE



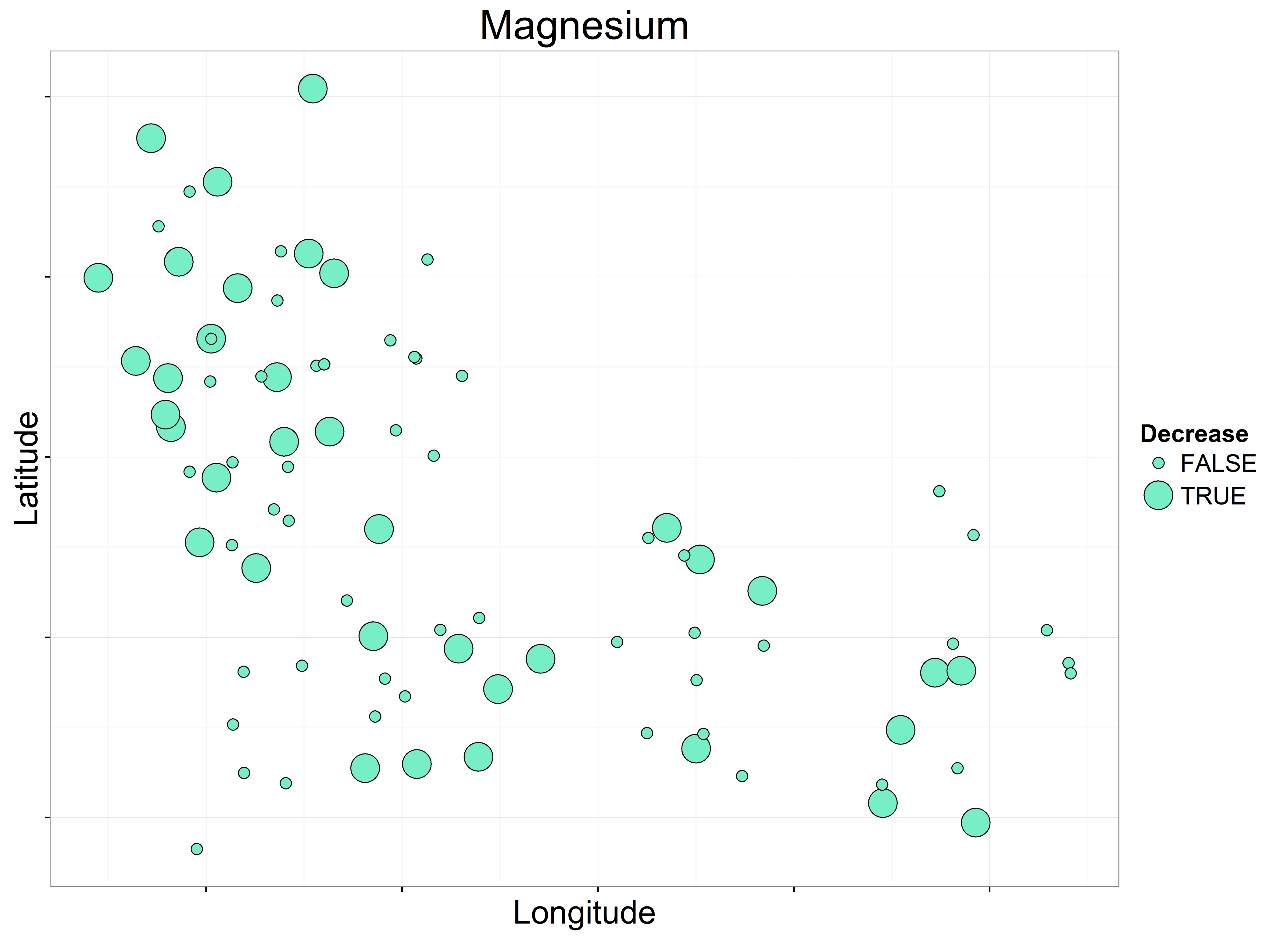
Copper
Latitude
Longitude
Decrease
FALSE
TRUE



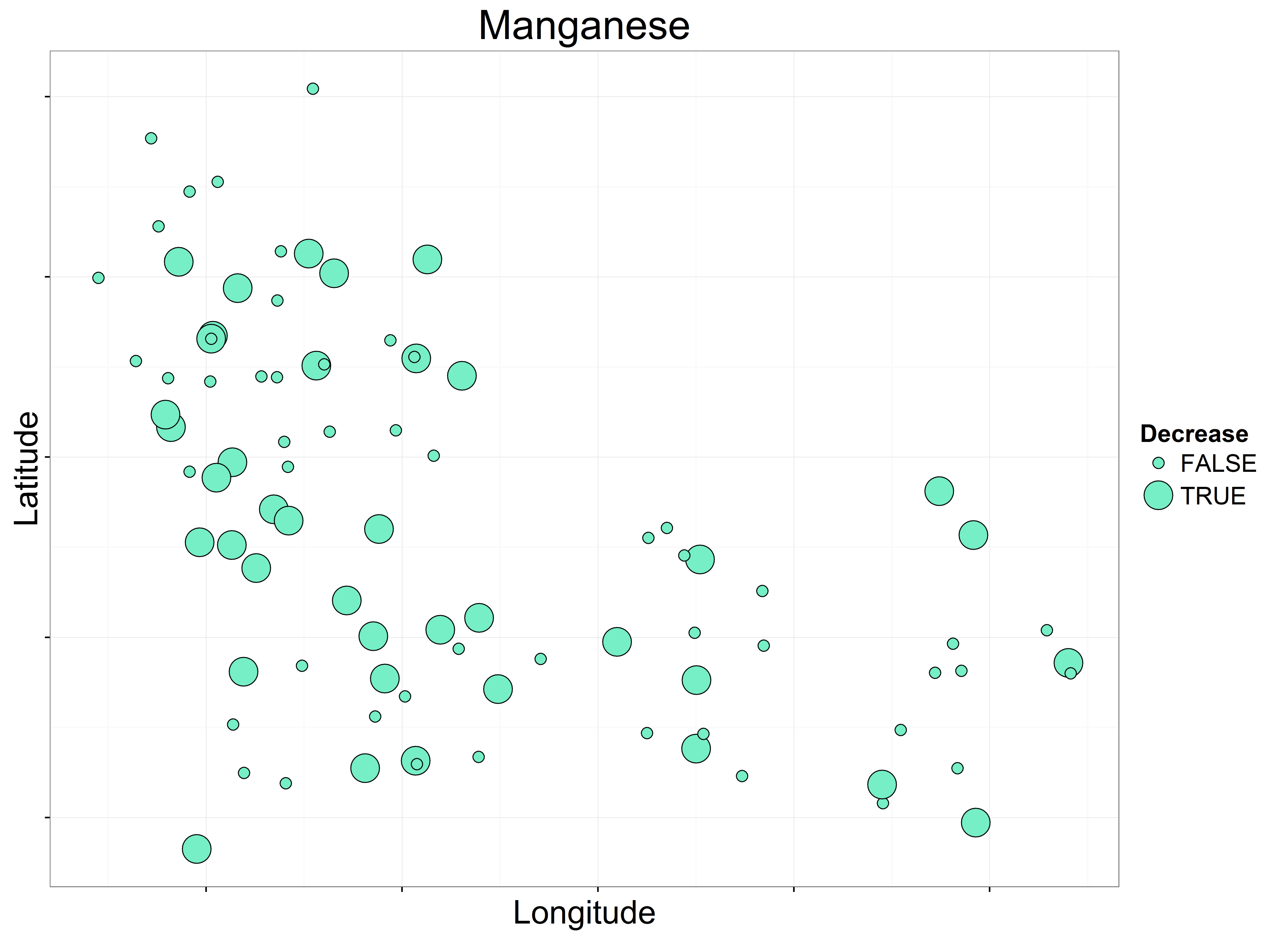
Lead
Latitude
Longitude
Decrease
FALSE
TRUE

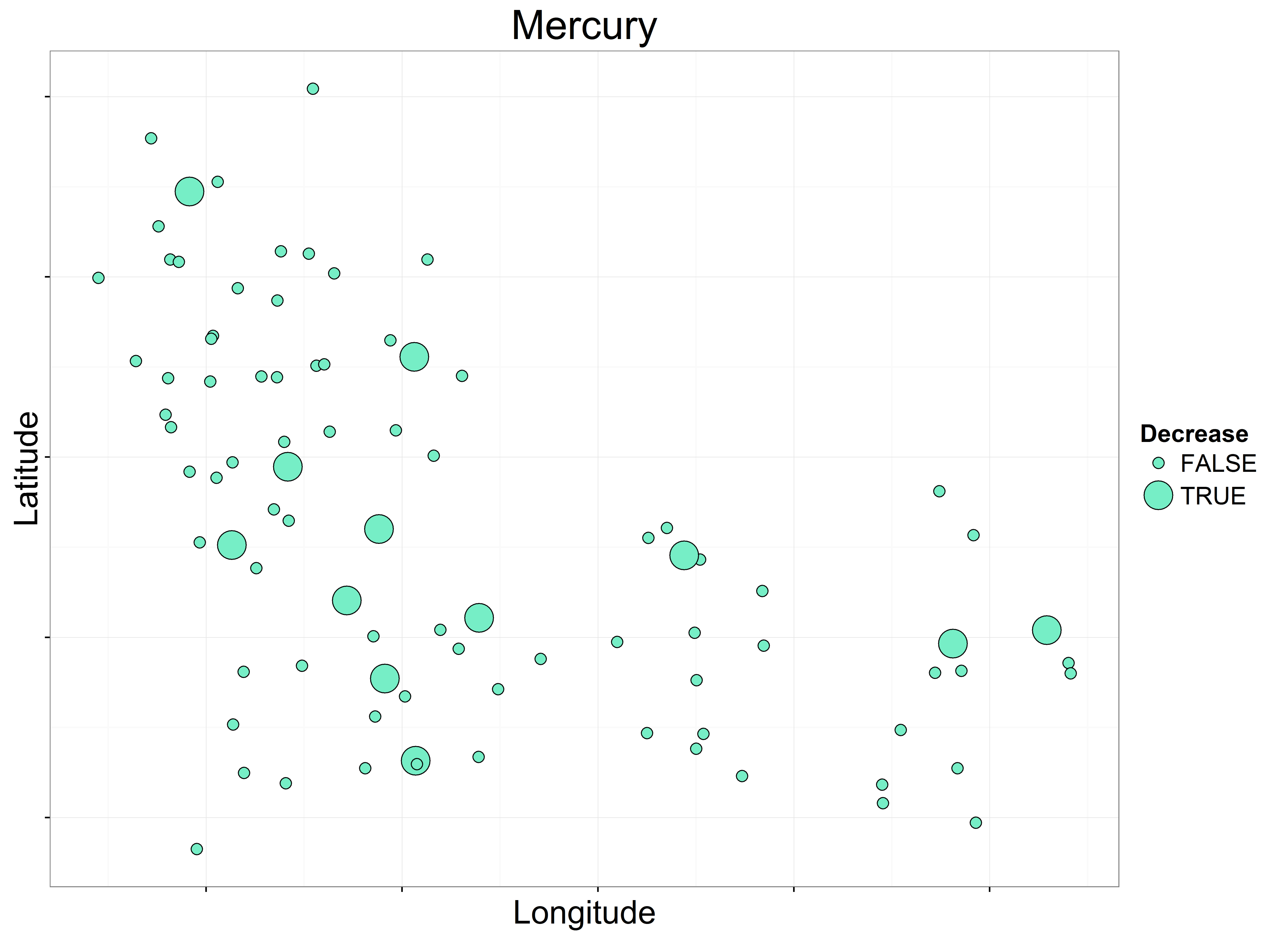


Lithium
Latitude
Longitude
Decrease
FALSE
TRUE

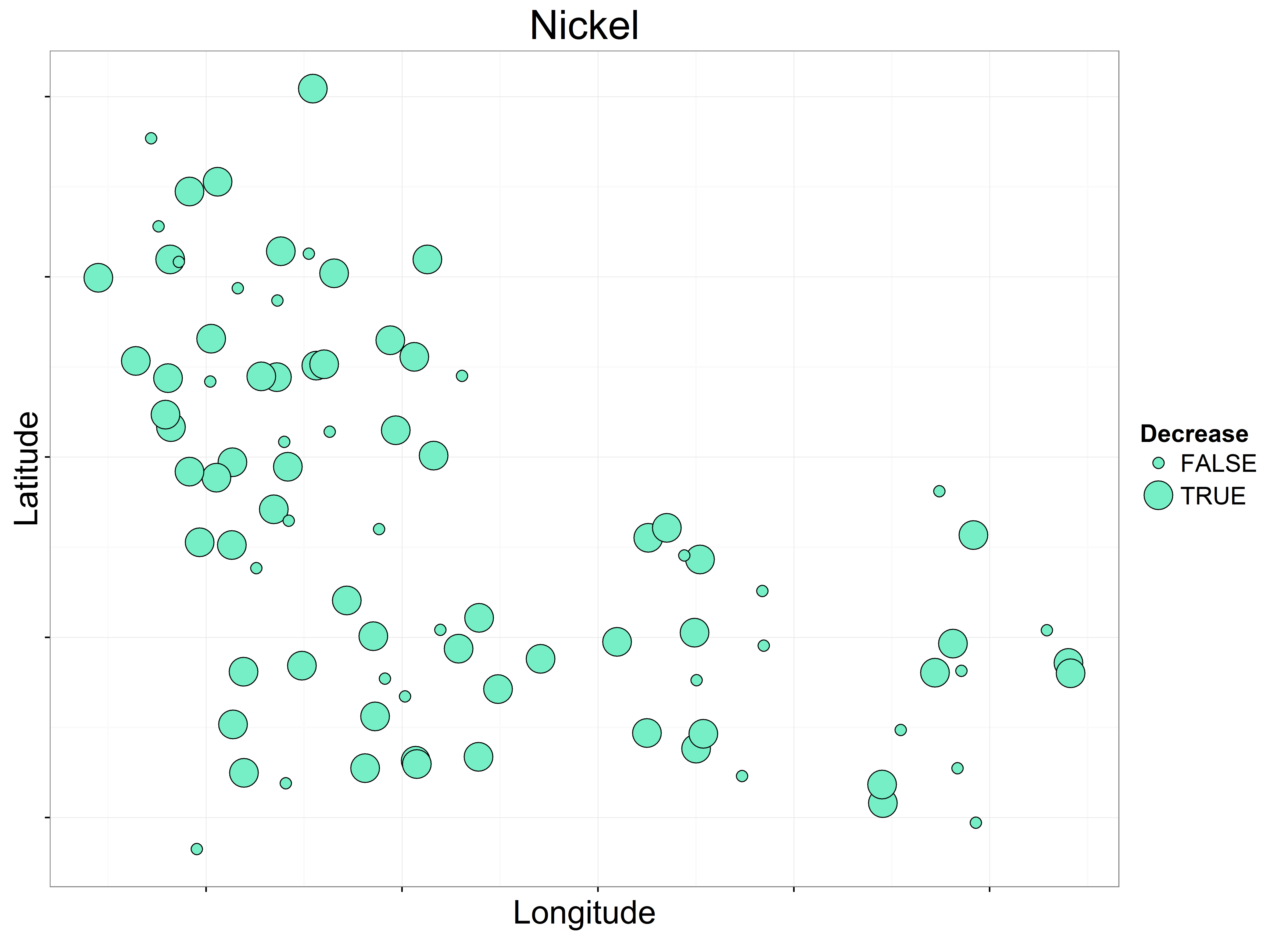


Magnesium
Latitude
Longitude
Decrease
FALSE
TRUE

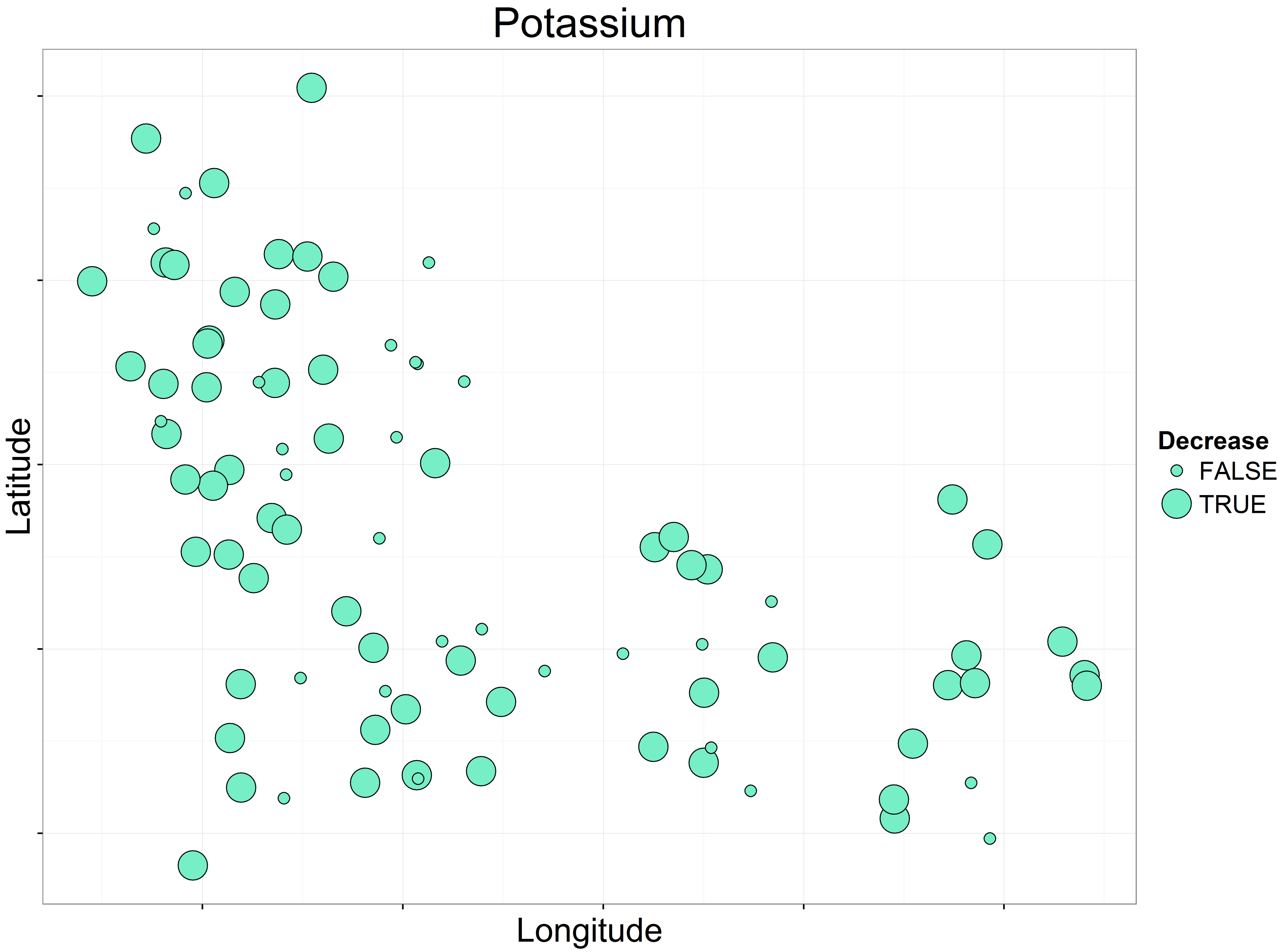

Manganese
Latitude
Longitude
Decrease
FALSE
TRUE



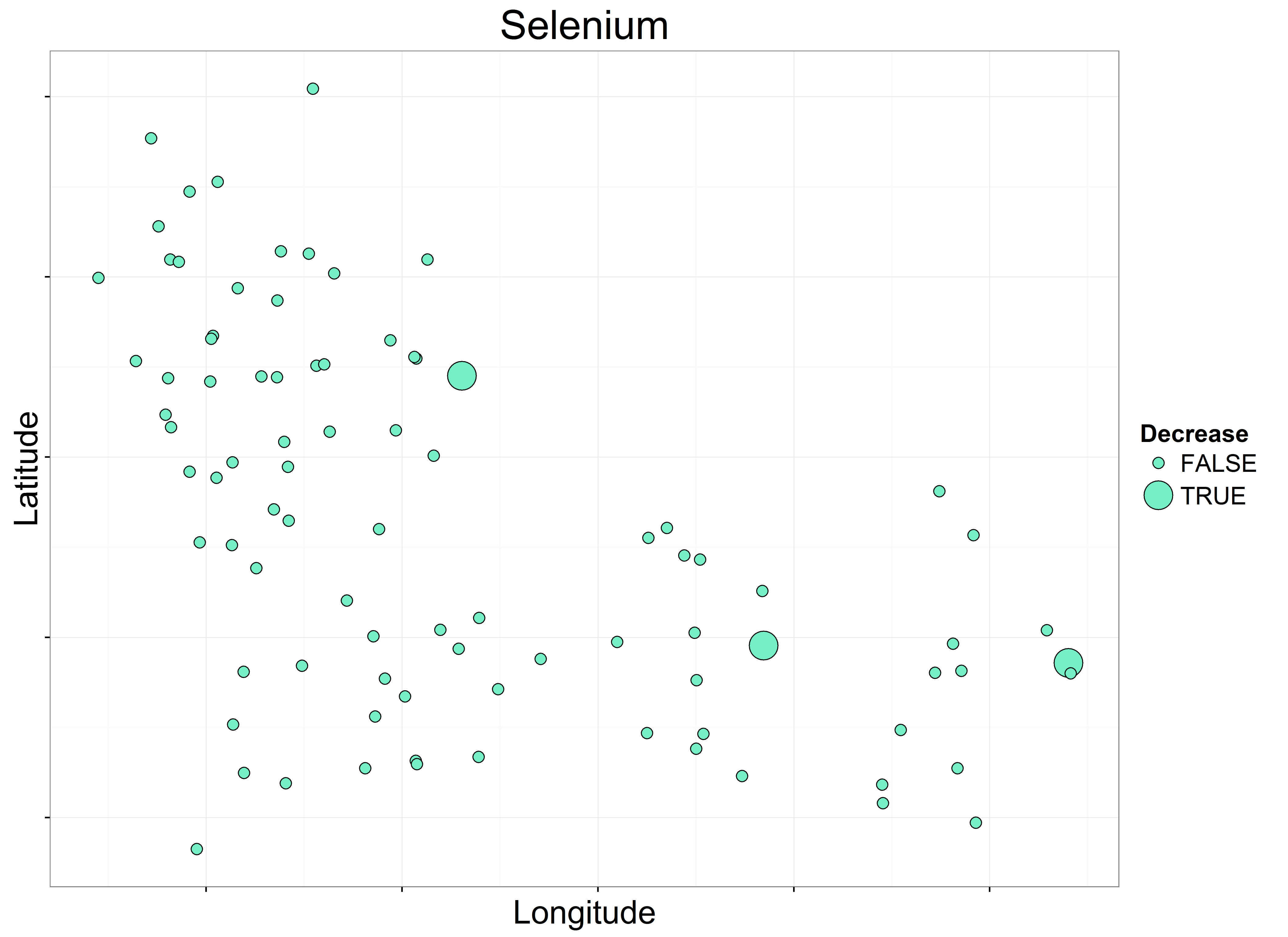
Mercury
Latitude
Longitude
Decrease
FALSE
TRUE

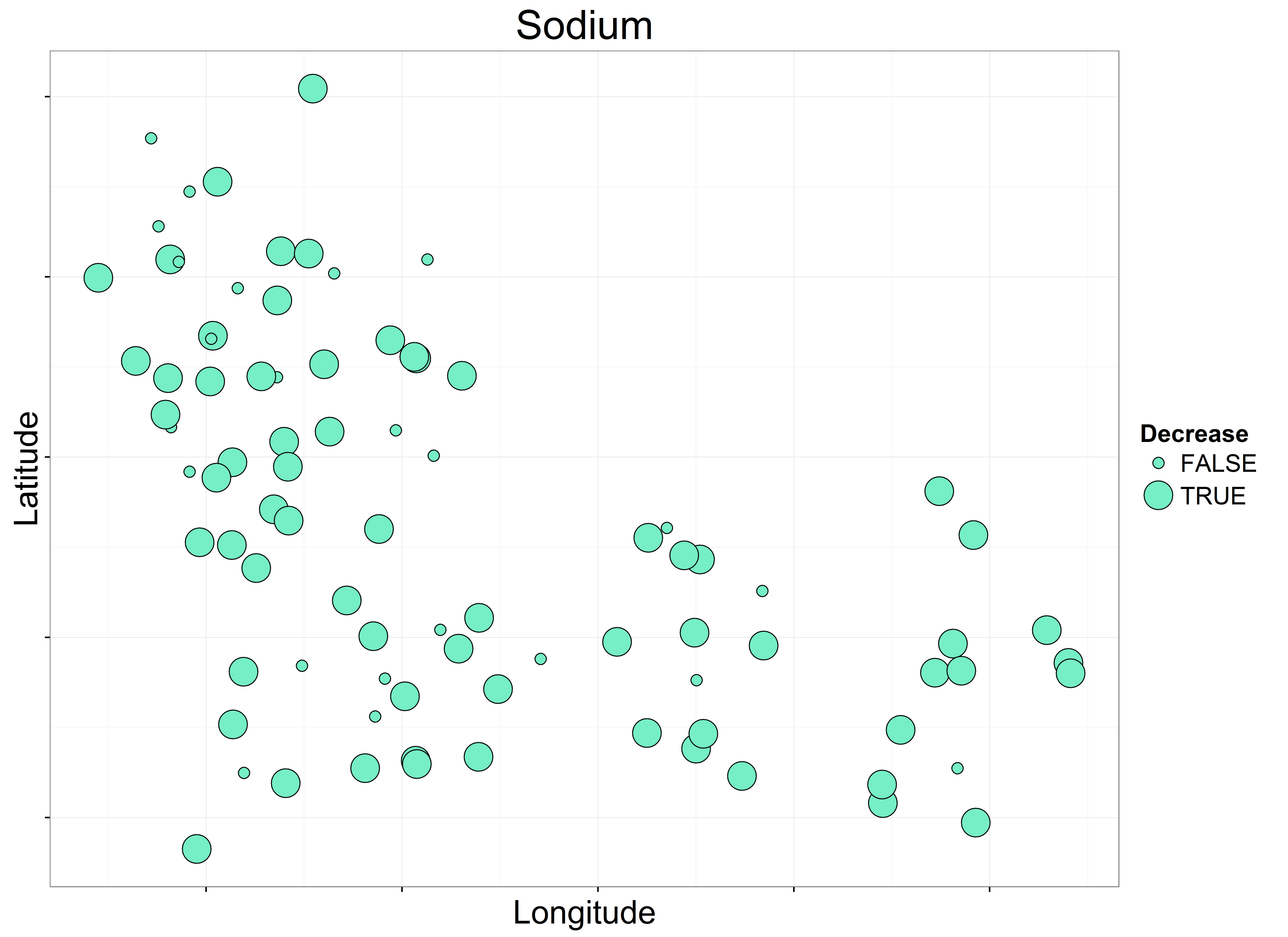


Nickel
Latitude
Longitude
Decrease
FALSE
TRUE

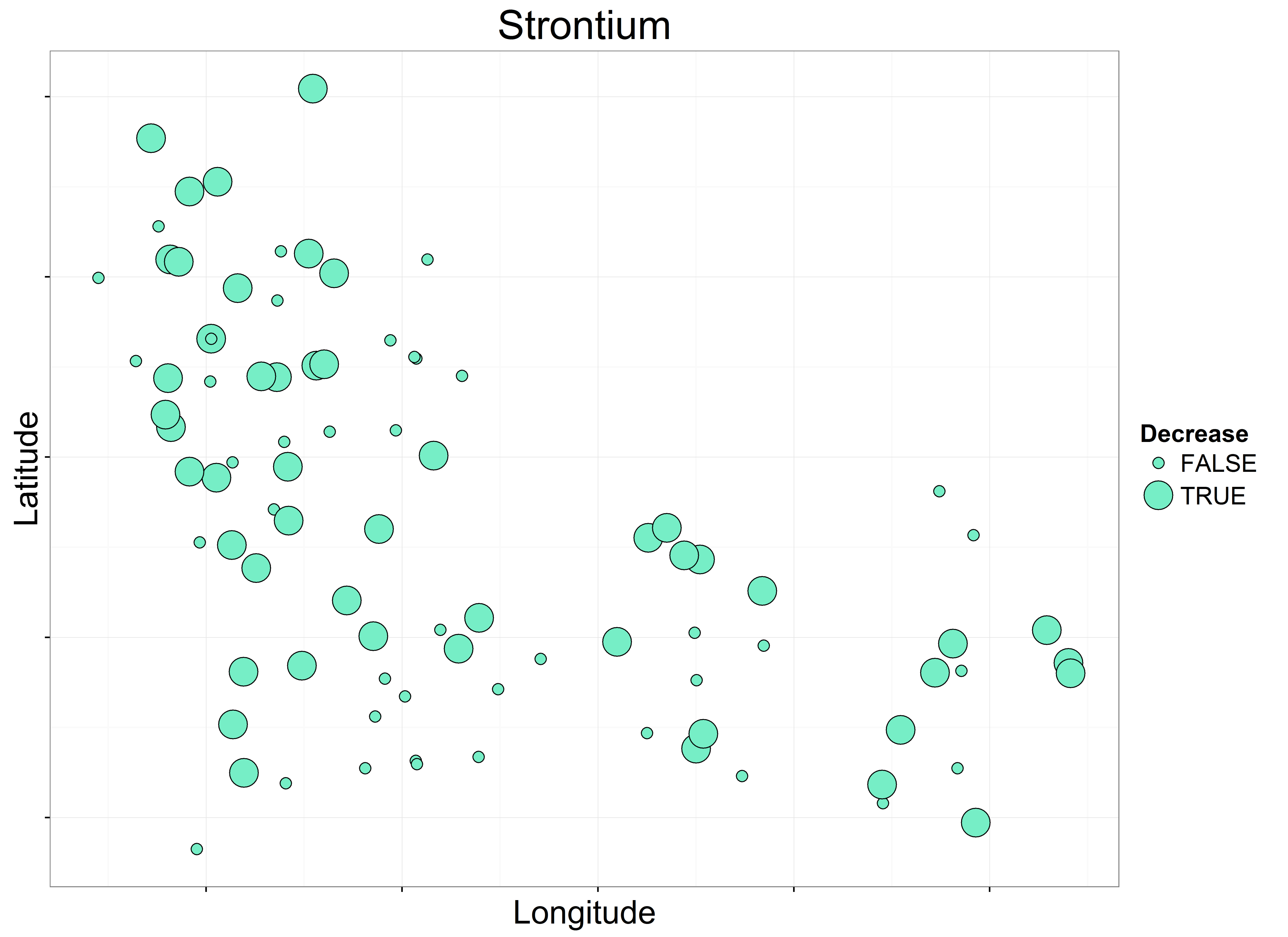


Potassium
Latitude
Longitude
Decrease
FALSE
TRUE

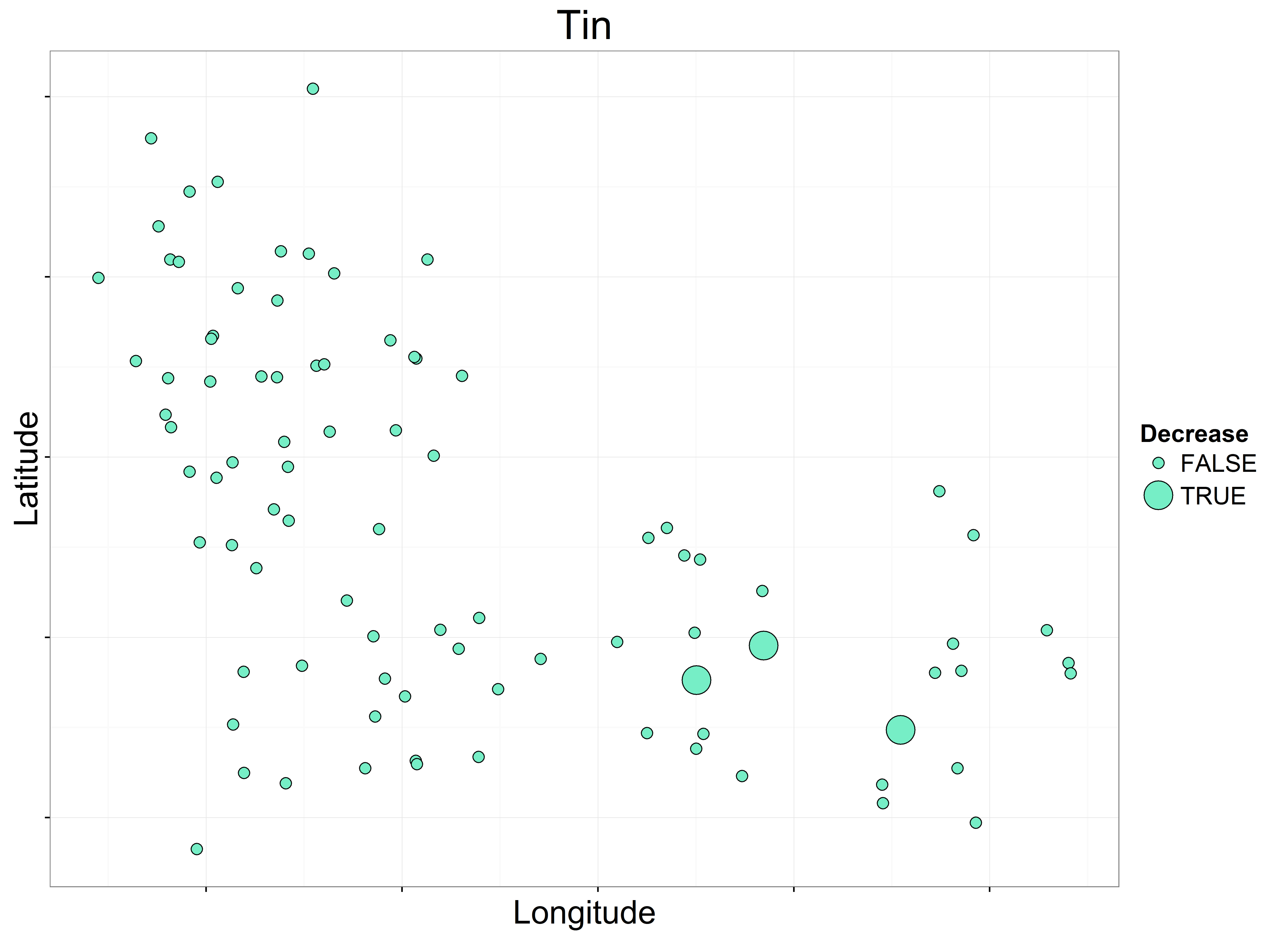

Selenium
Latitude
Longitude
Decrease
FALSE
TRUE



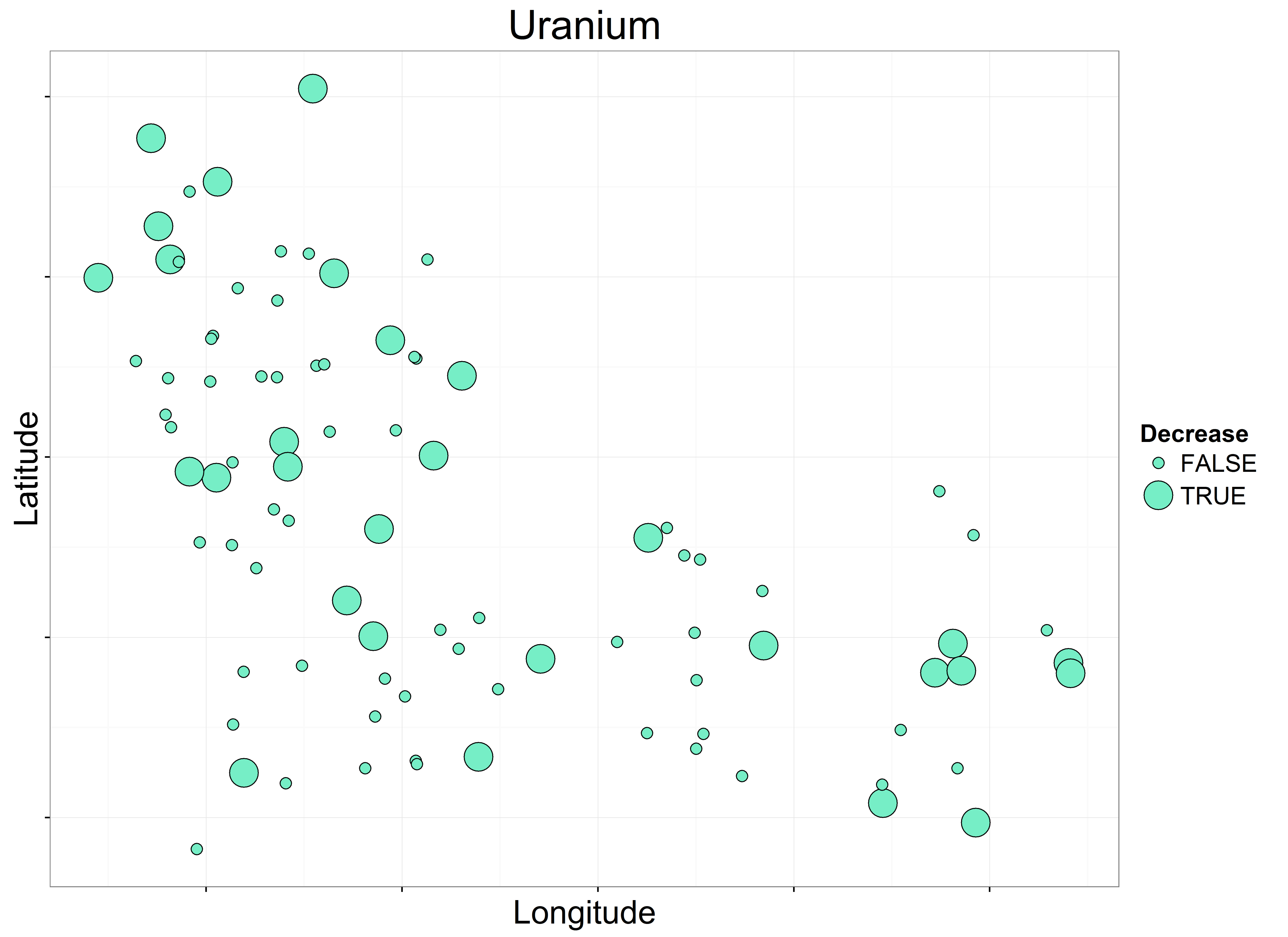
Sodium
Latitude
Longitude
Decrease
FALSE
TRUE



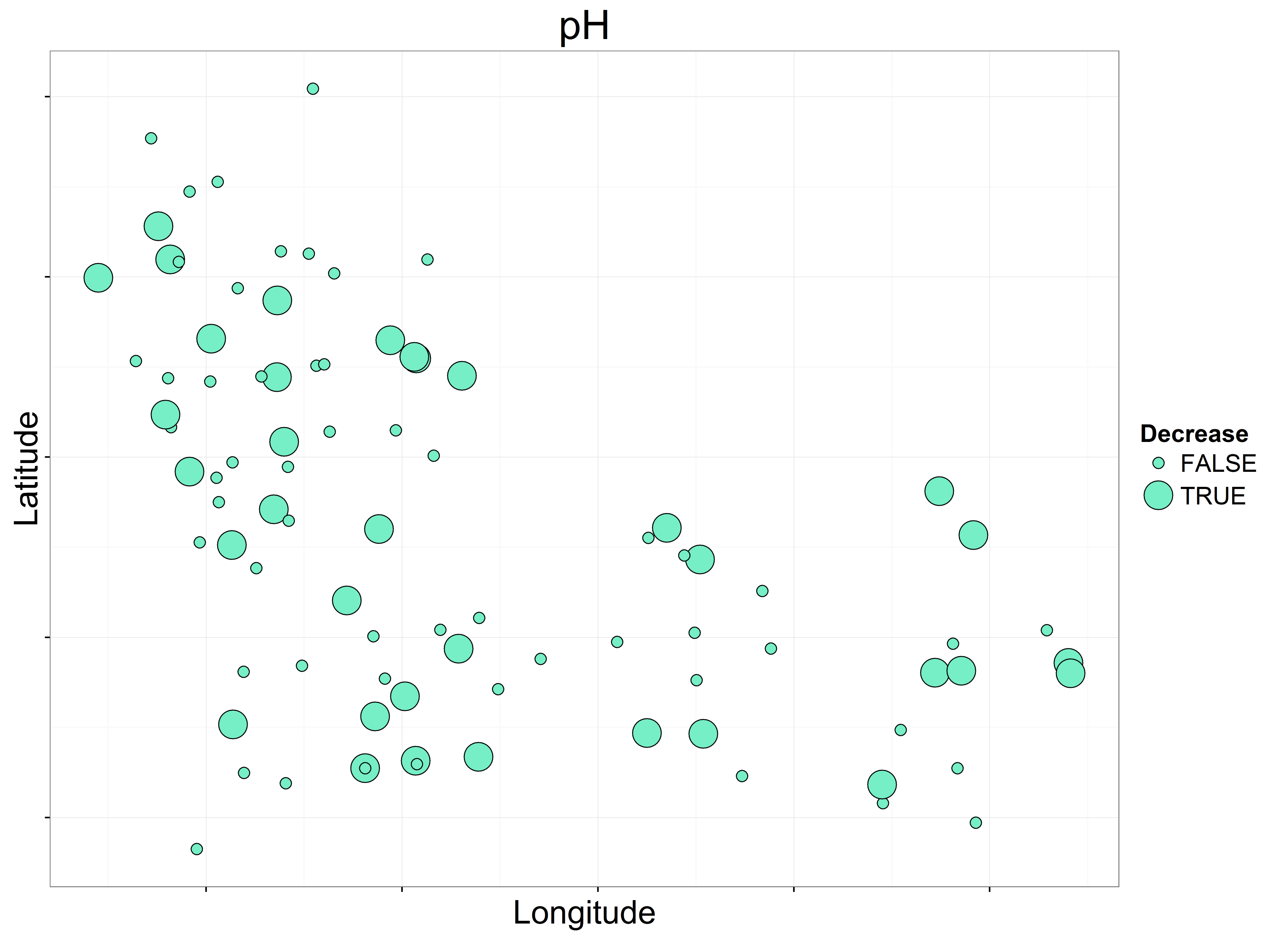
Strontium
Latitude
Longitude
Decrease
FALSE
TRUE

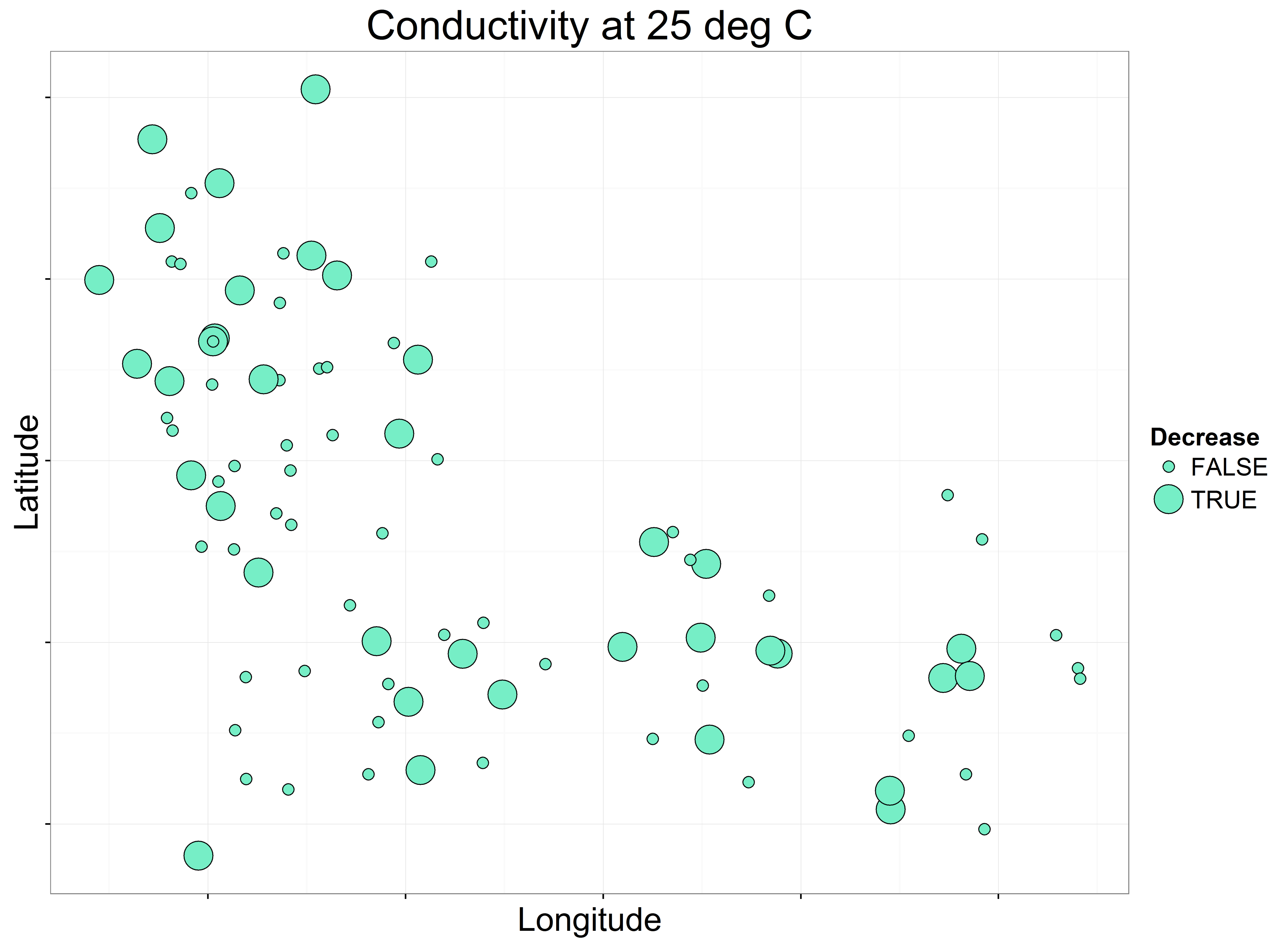


Tin
Latitude
Longitude
Decrease
FALSE
TRUE

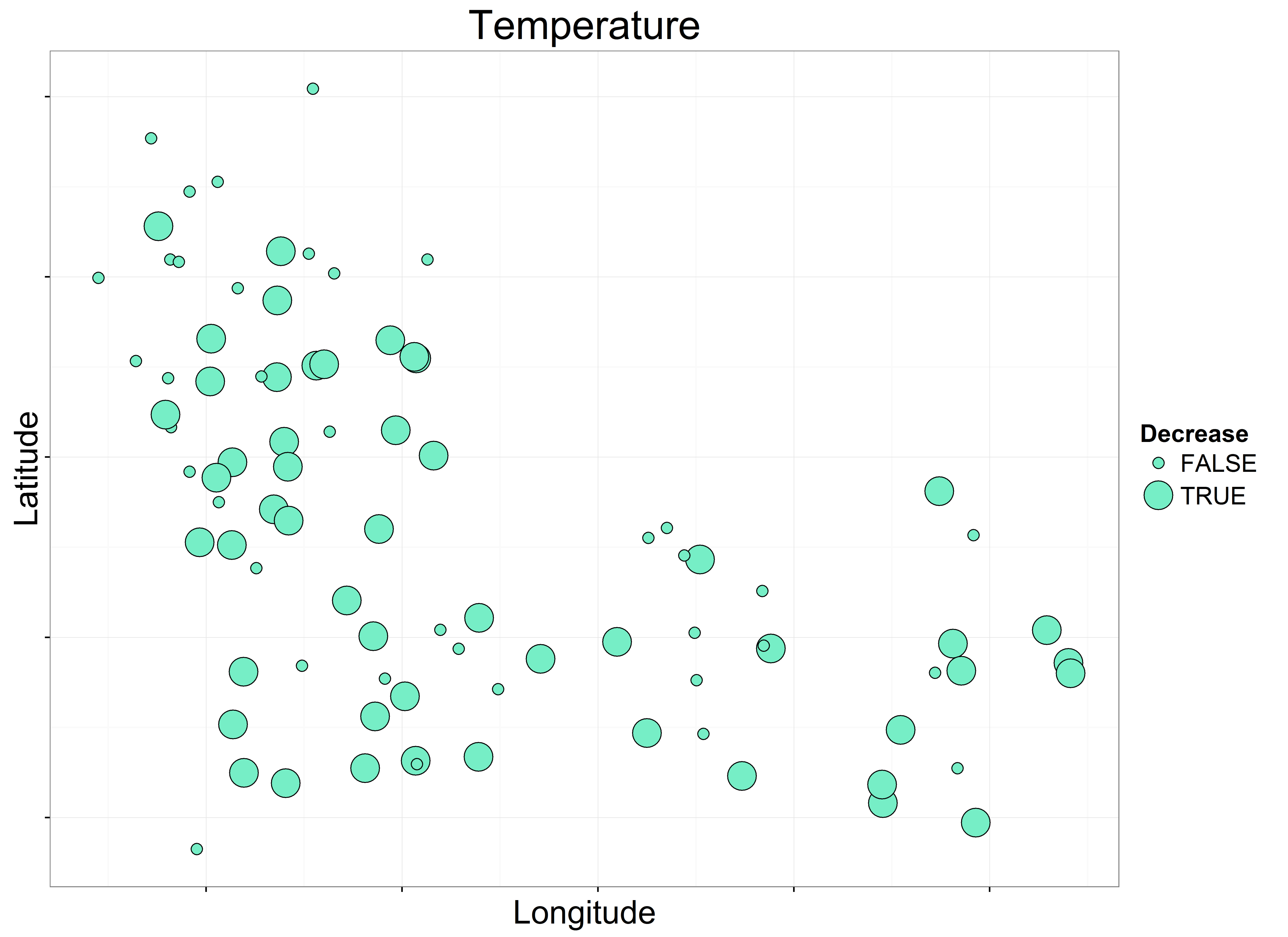

Uranium
Latitude
Longitude
Decrease
FALSE
TRUE

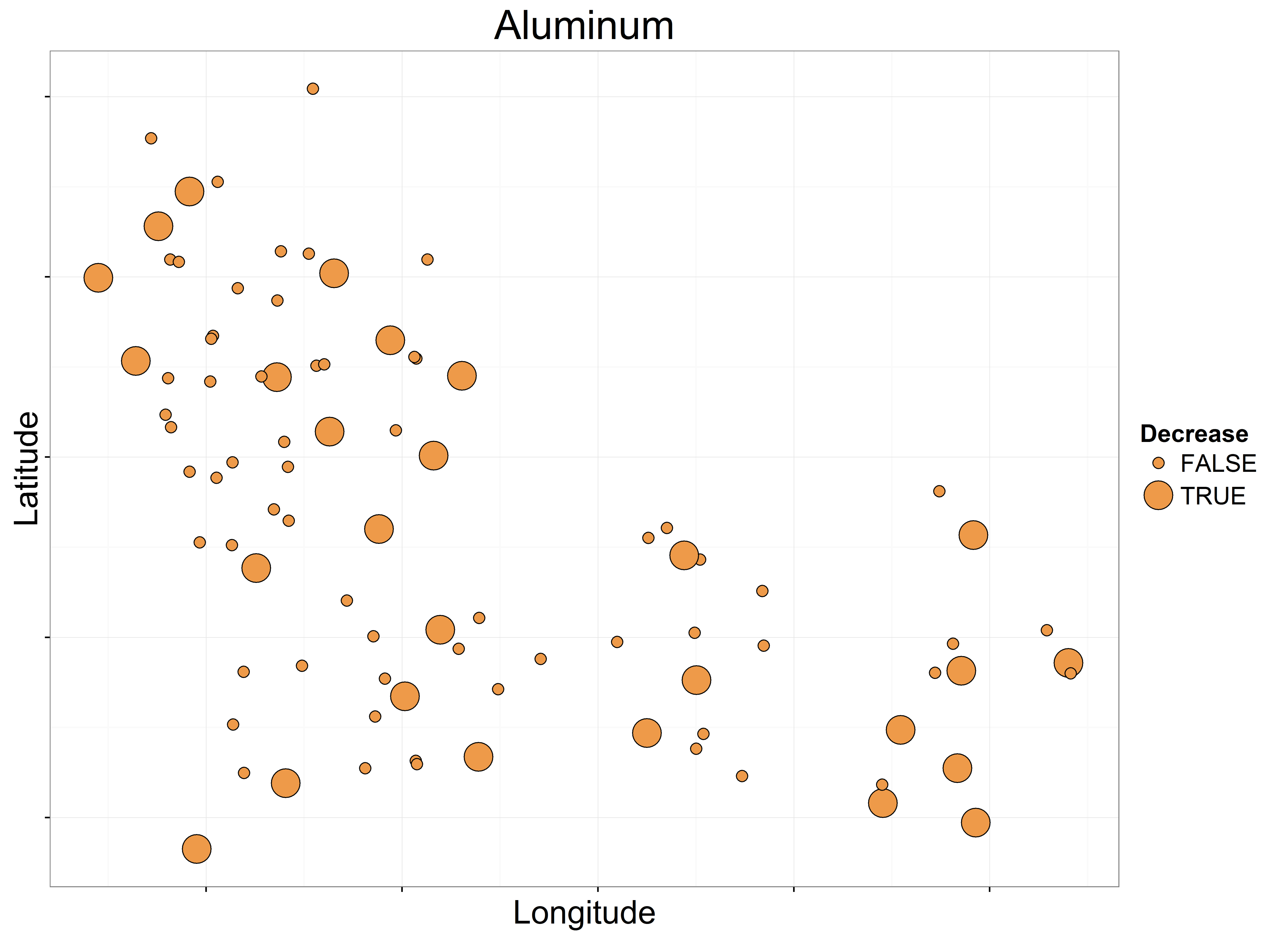
Zinc
Latitude
Longitude
Decrease
FALSE
TRUE


pH
Latitude
Longitude
Decrease
FALSE
TRUE

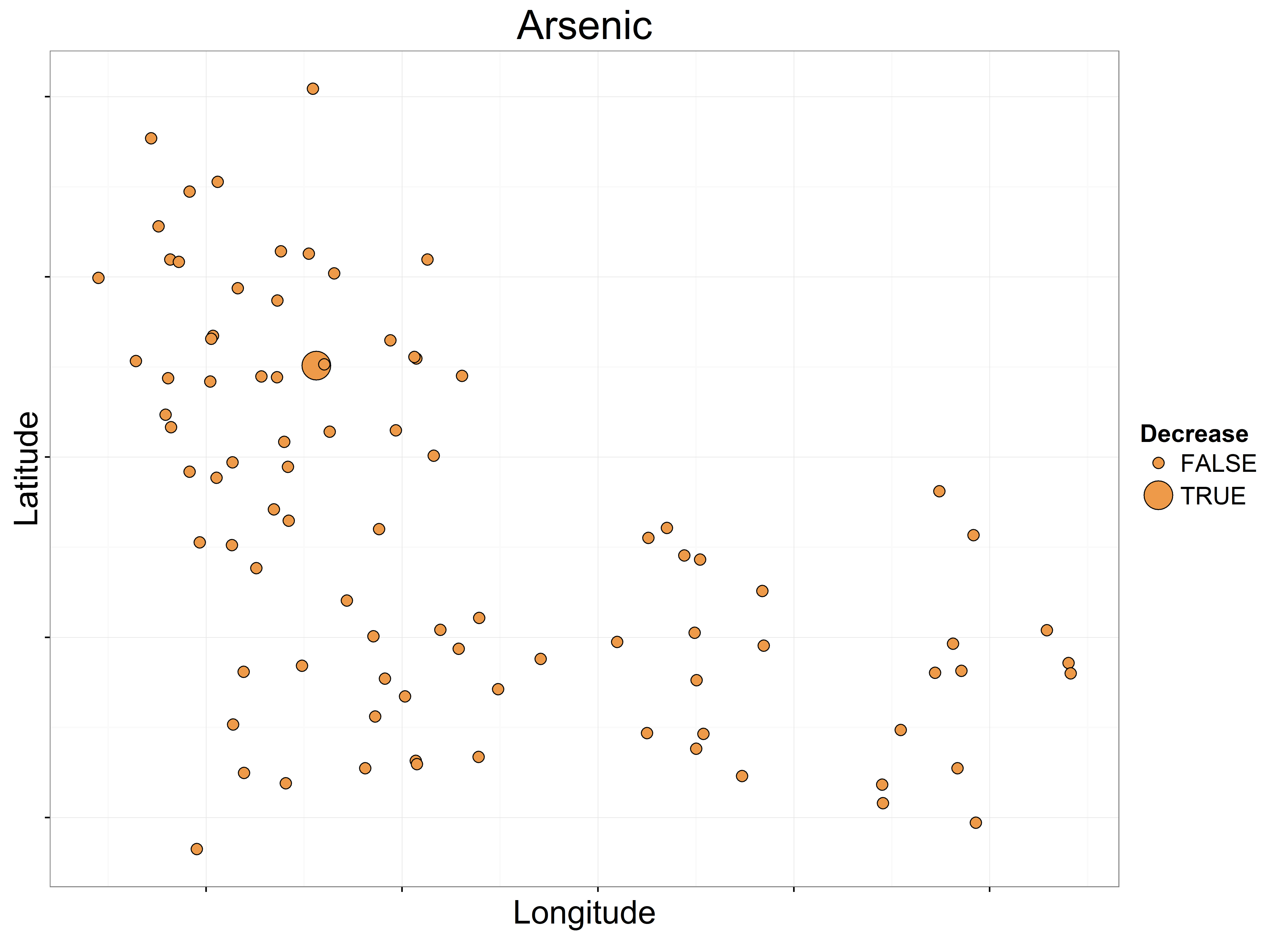


Conductivity at 25 deg C
Latitude
Longitude
Decrease
FALSE
TRUE

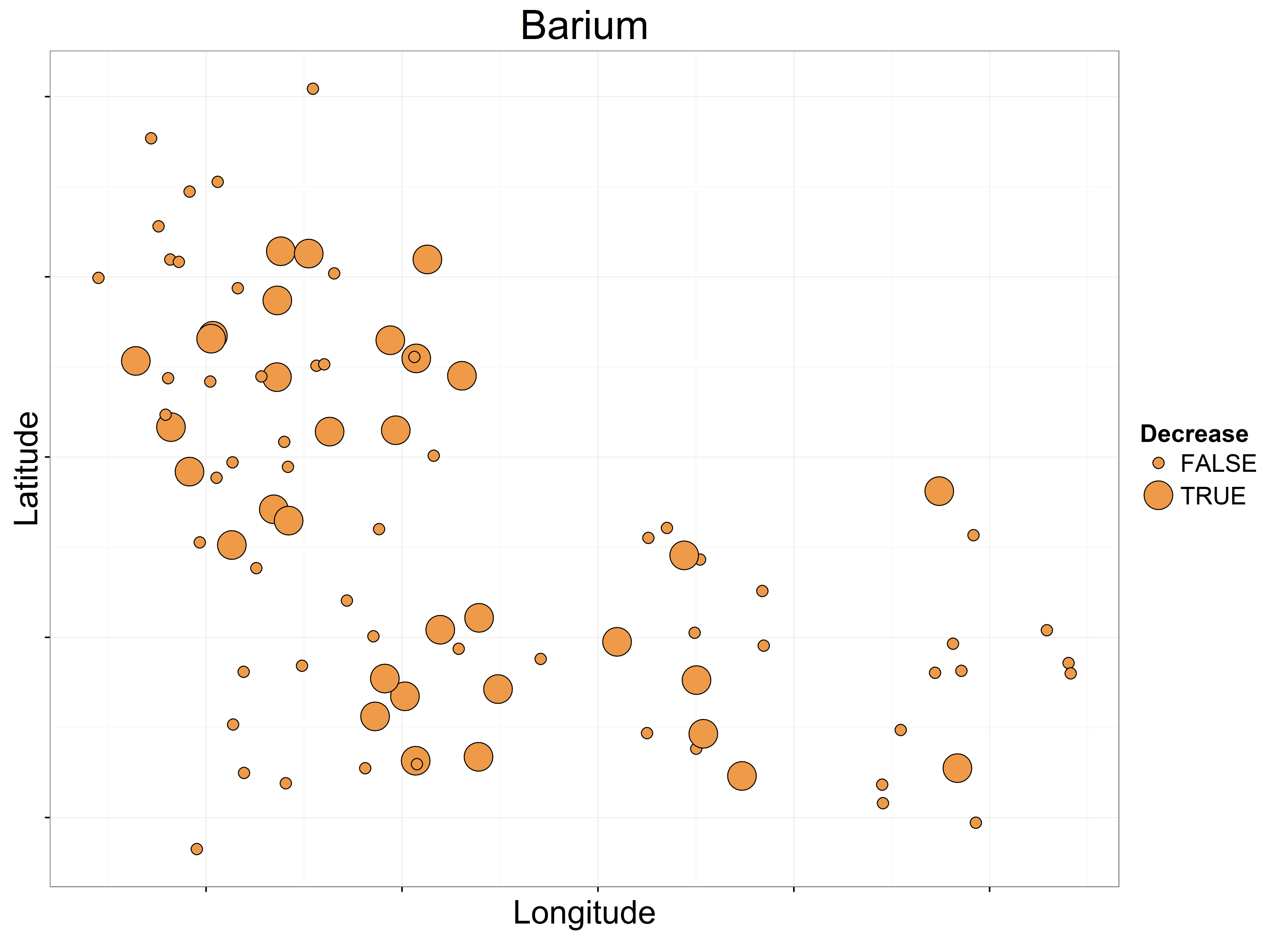

Temperature
Latitude
Longitude
Decrease
FALSE
TRUE

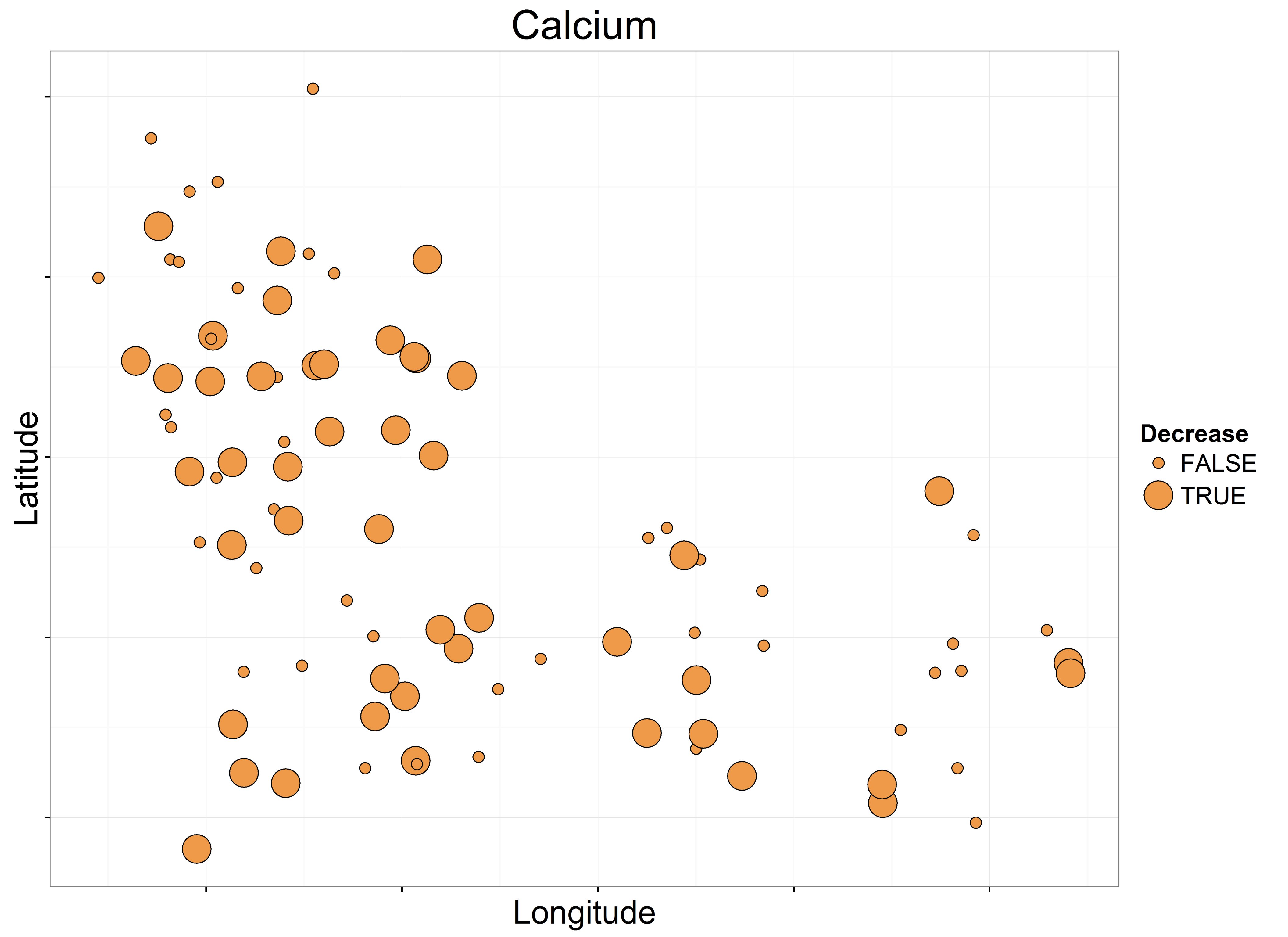


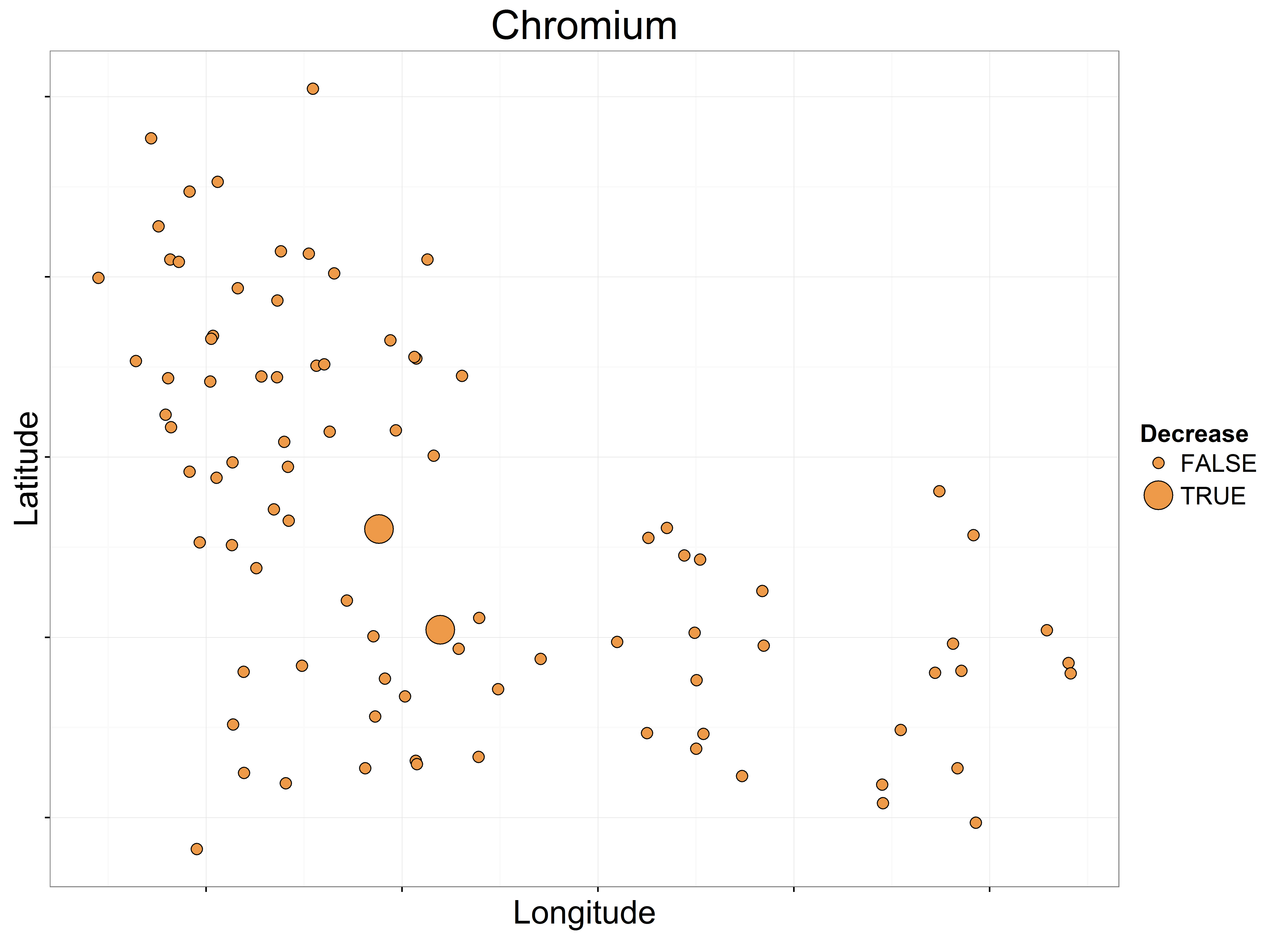
Aluminum
Latitude
Longitude
Decrease
FALSE
TRUE



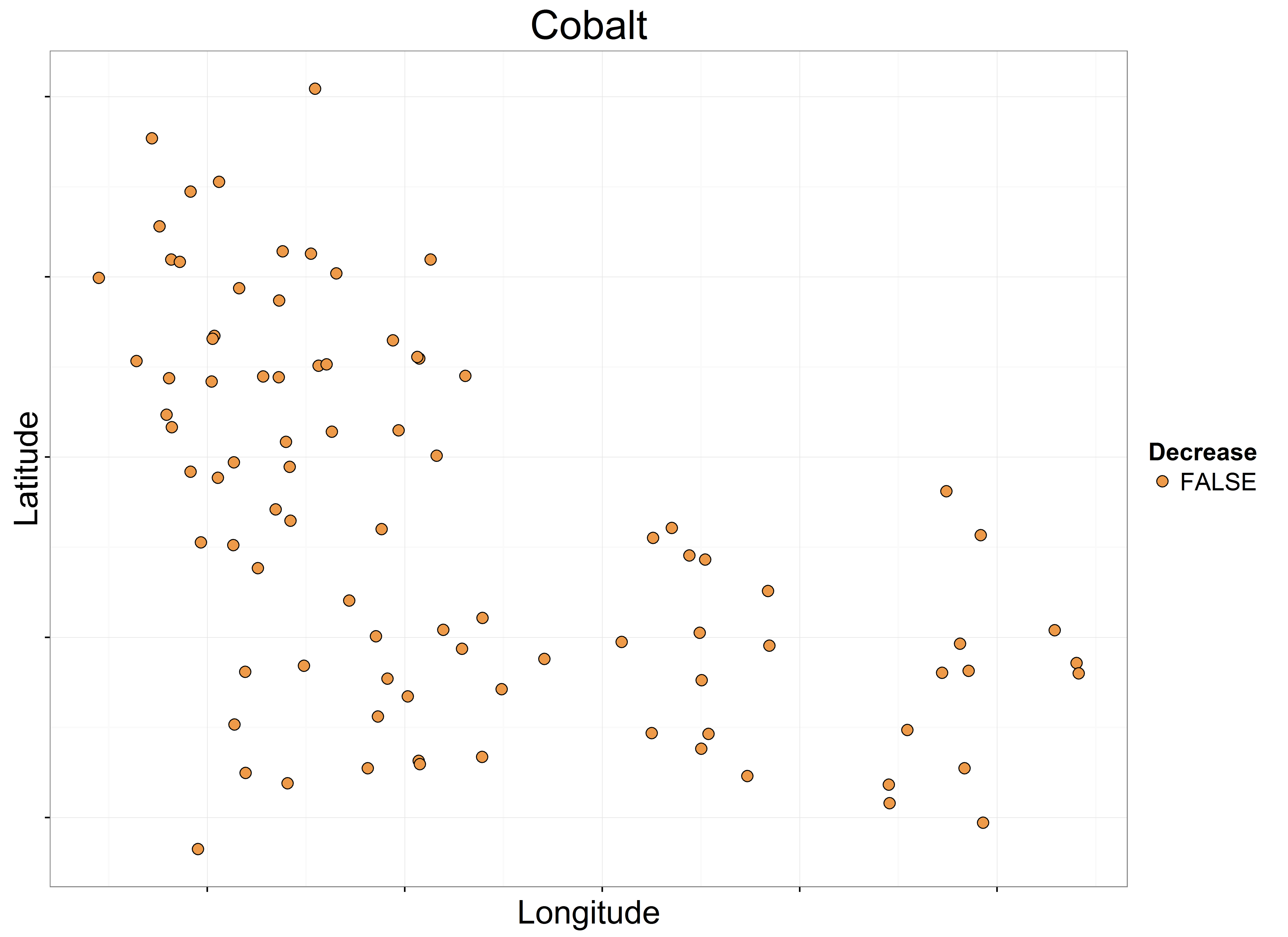
Arsenic
Latitude
Longitude
Decrease
FALSE
TRUE


Barium
Latitude
Longitude
Decrease
FALSE
TRUE

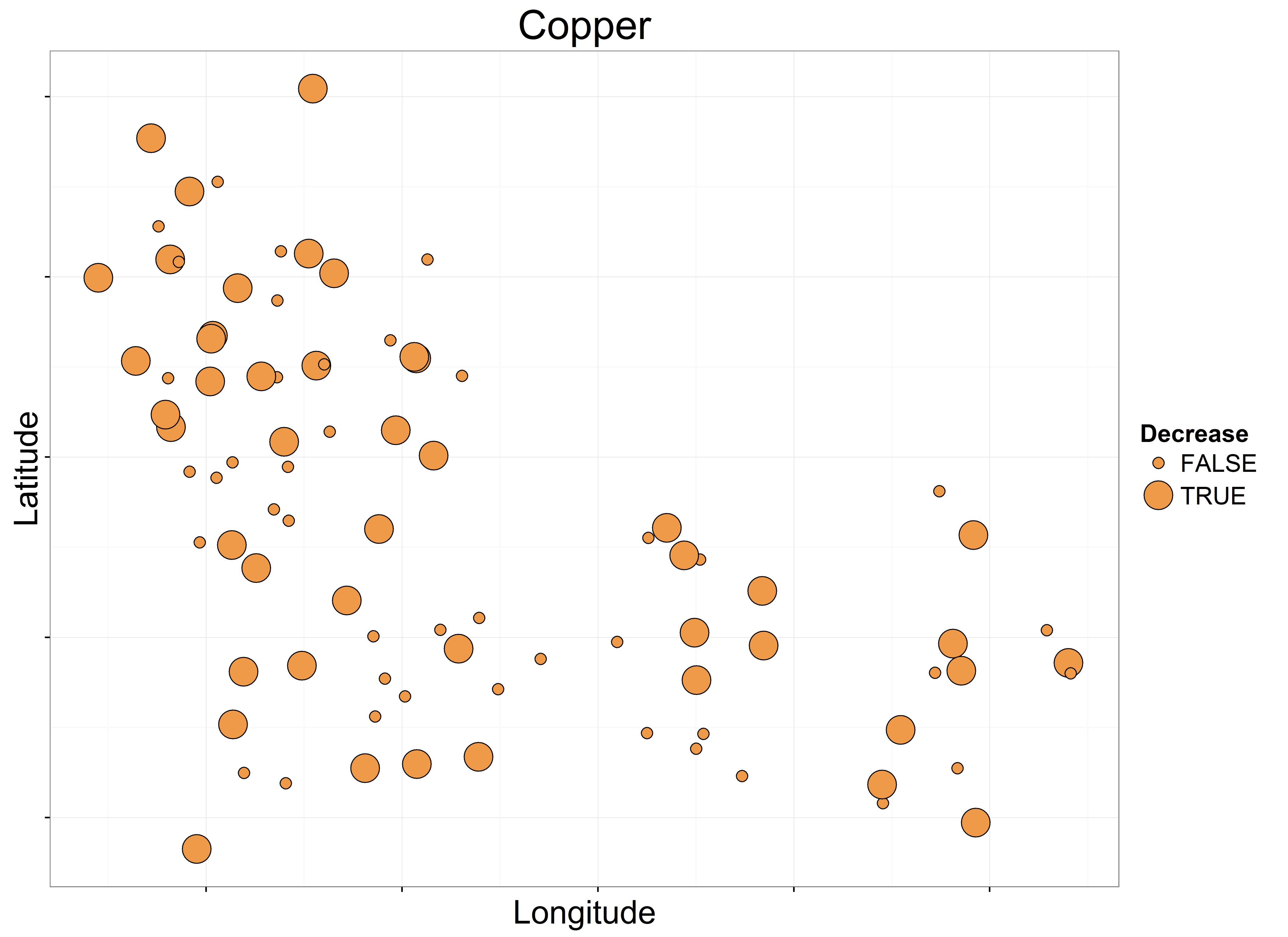

Calcium
Latitude
Longitude
Decrease
FALSE
TRUE



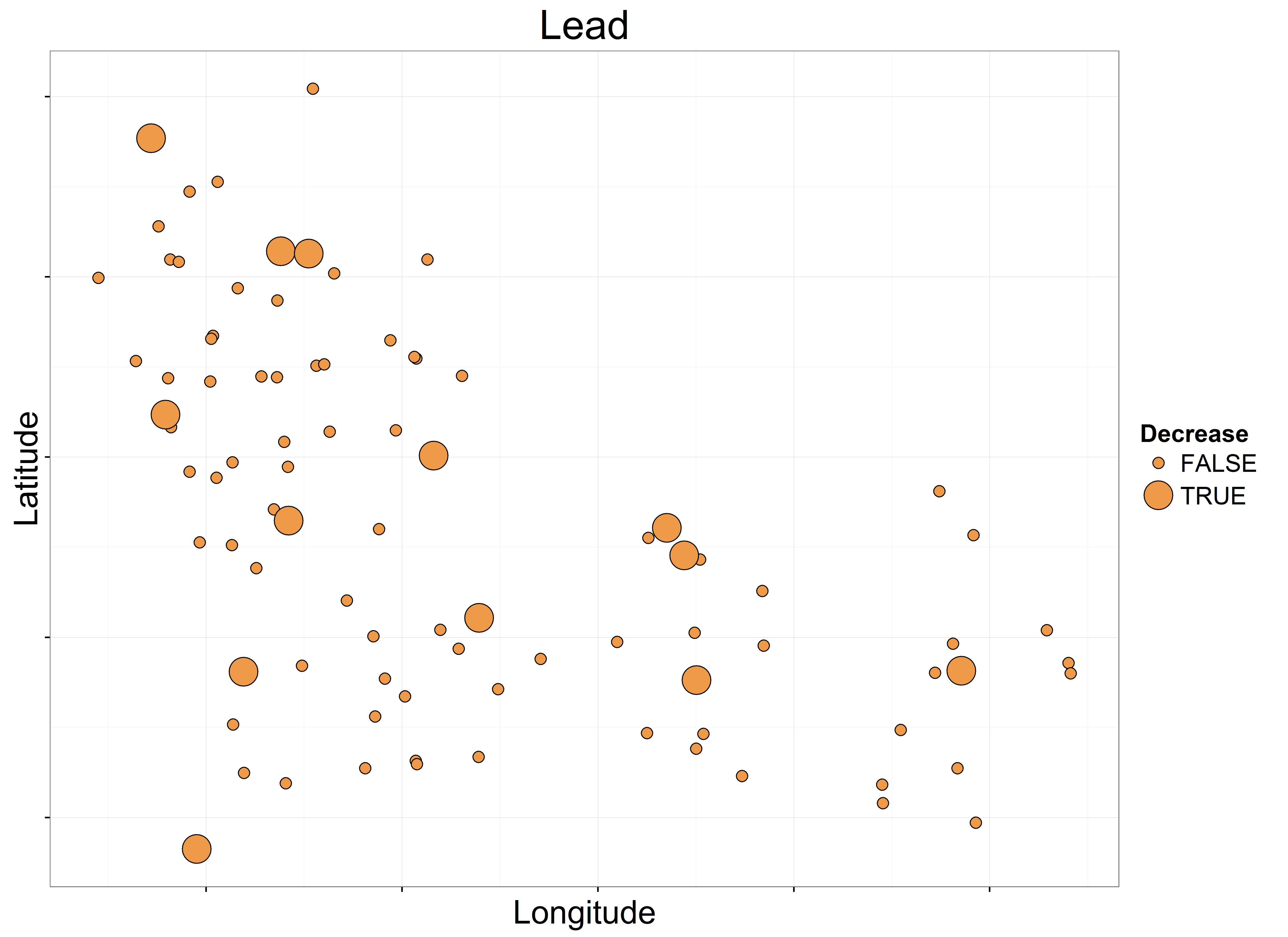
Chromium
Latitude
Longitude
Decrease
FALSE
TRUE



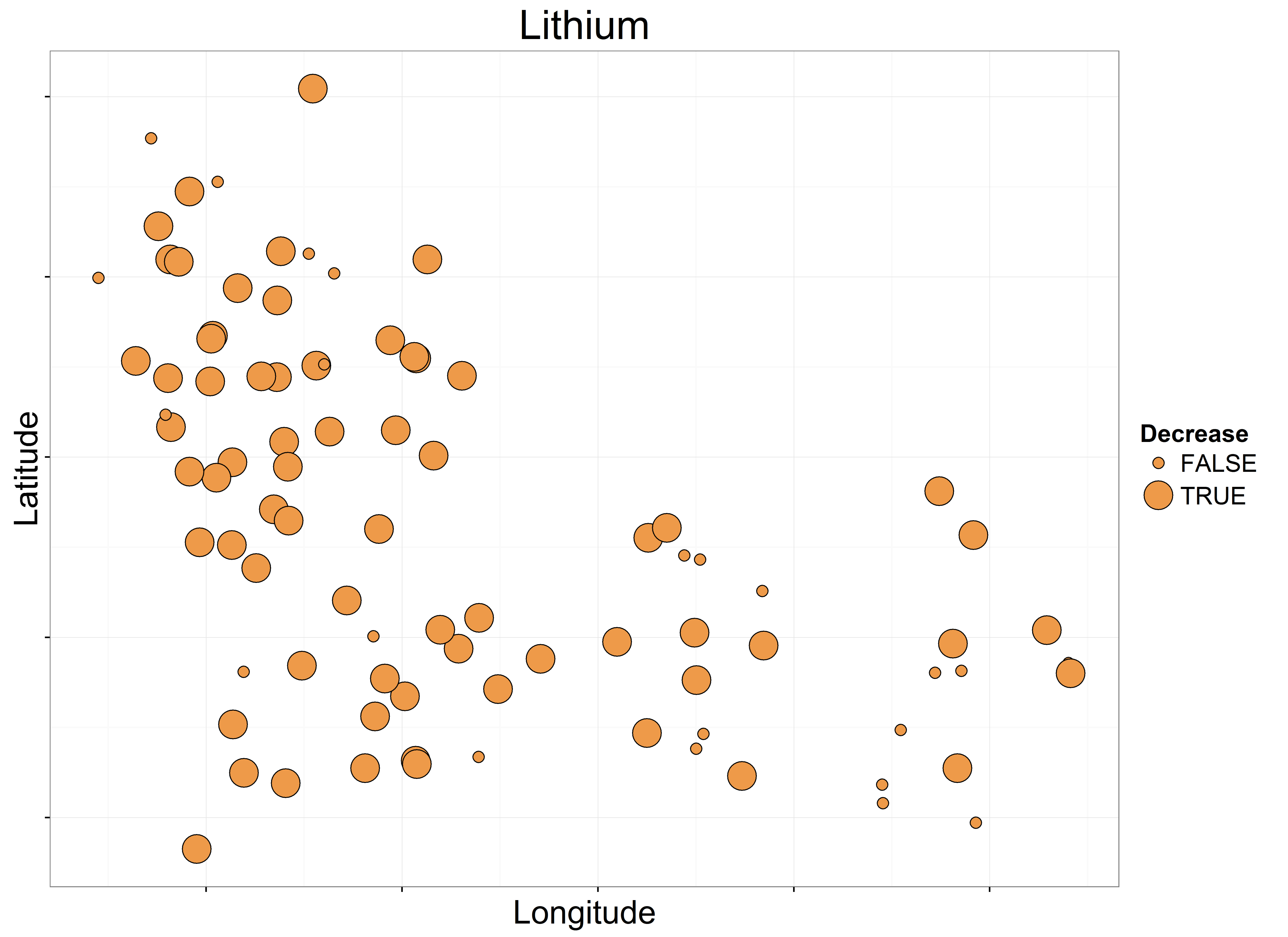
Cobalt
Latitude
Longitude
Decrease
FALSE



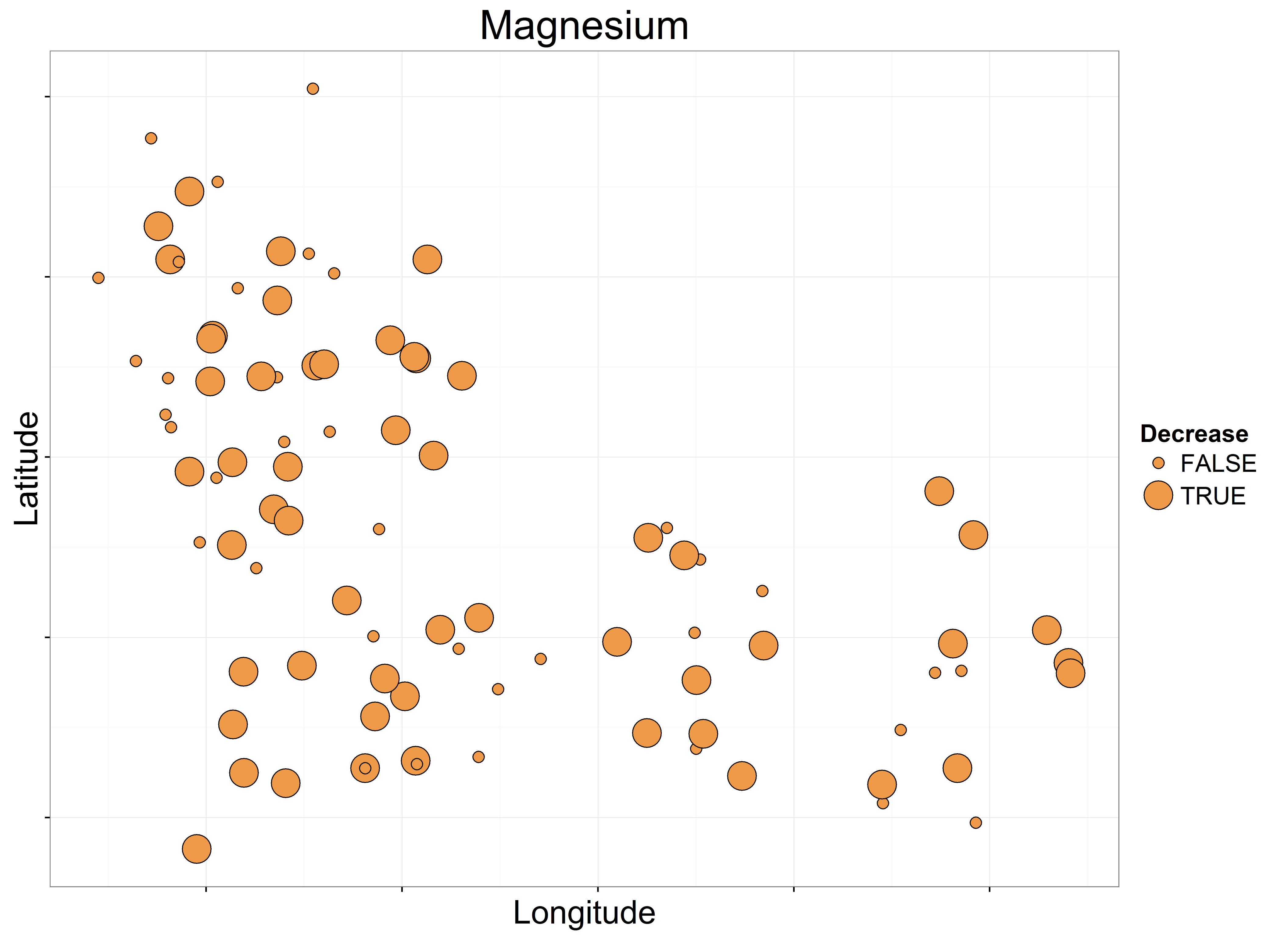
Copper
Latitude
Longitude
Decrease
FALSE
TRUE



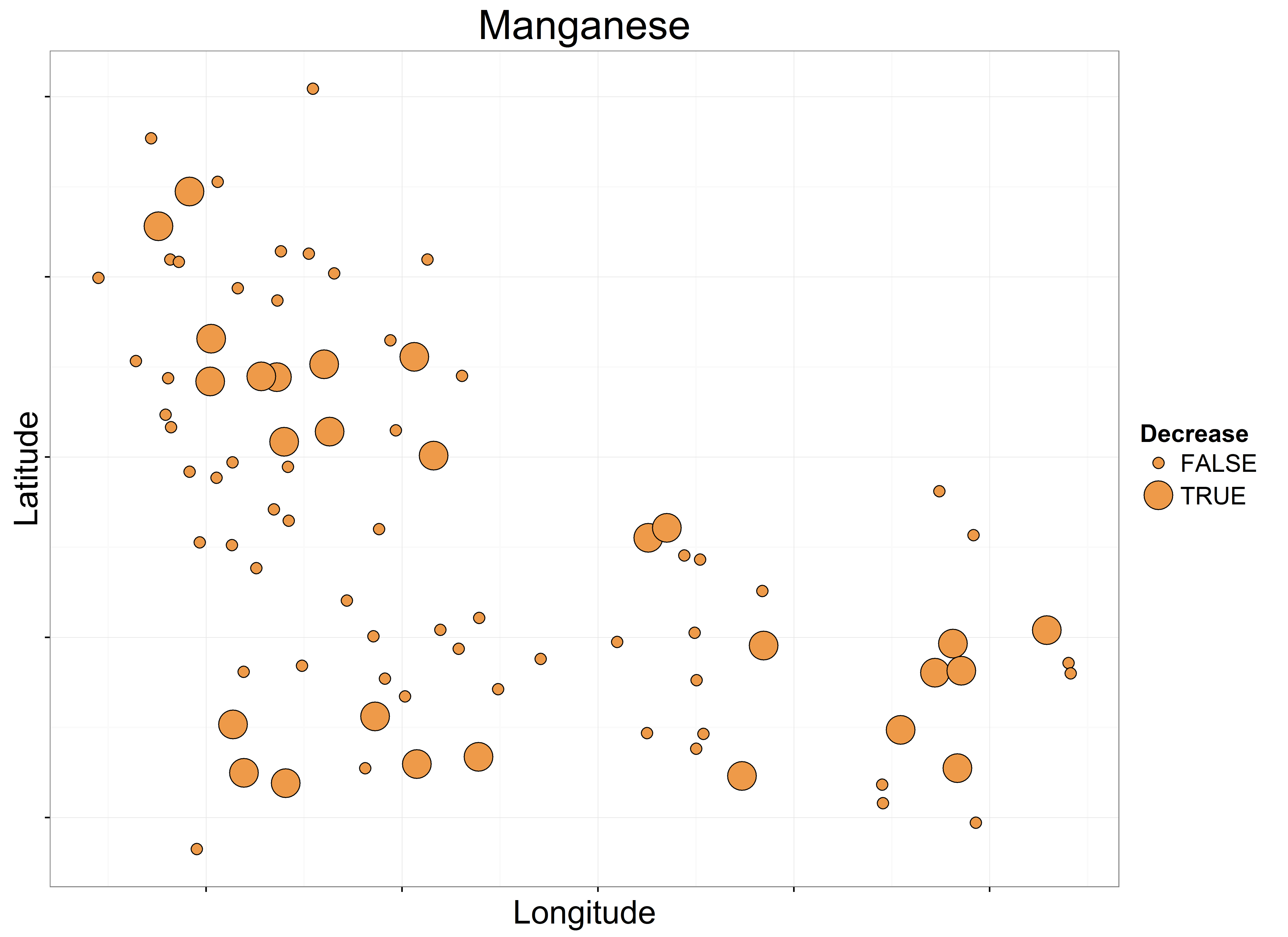
Lead
Latitude
Longitude
Decrease
FALSE
TRUE

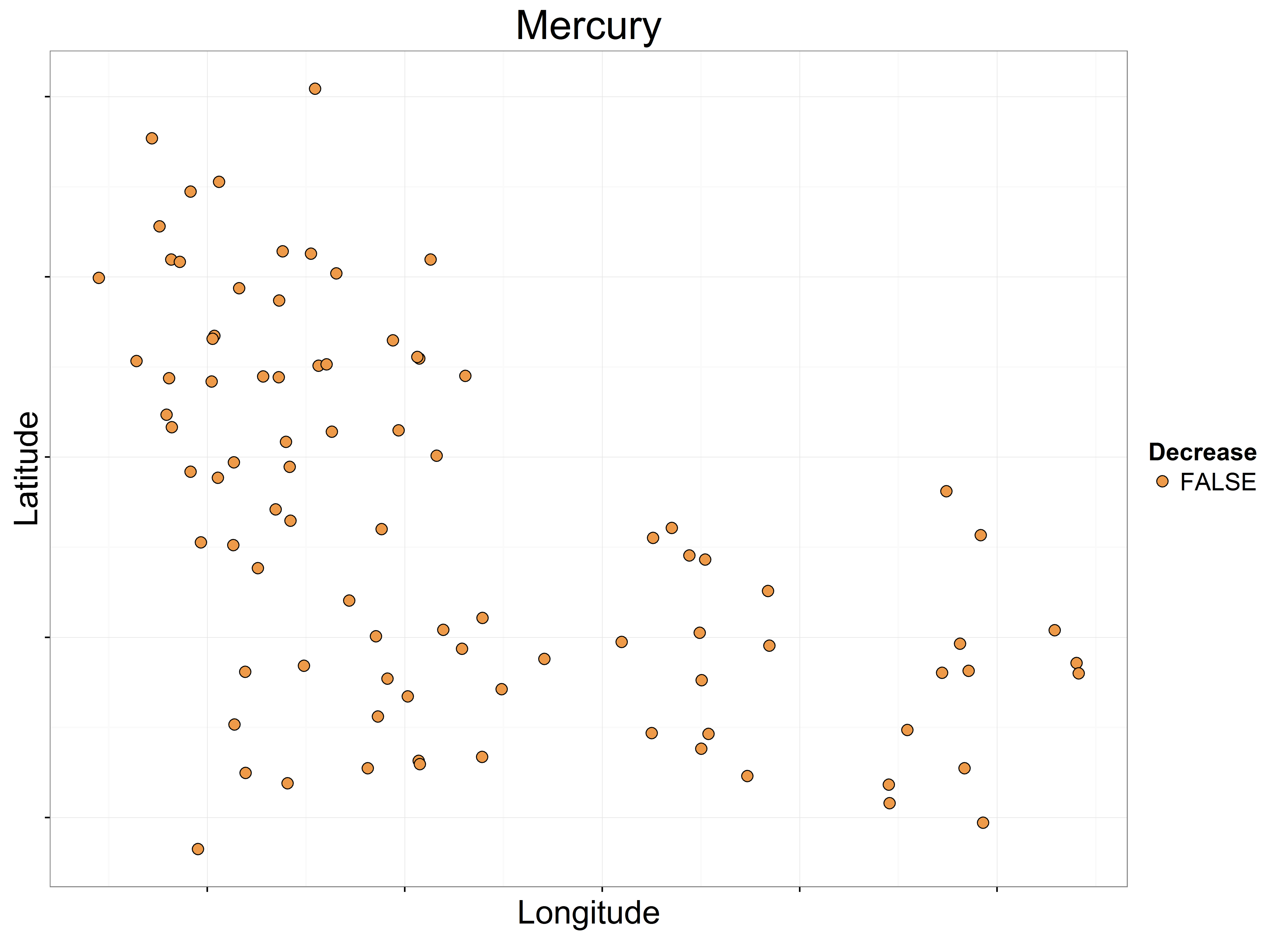


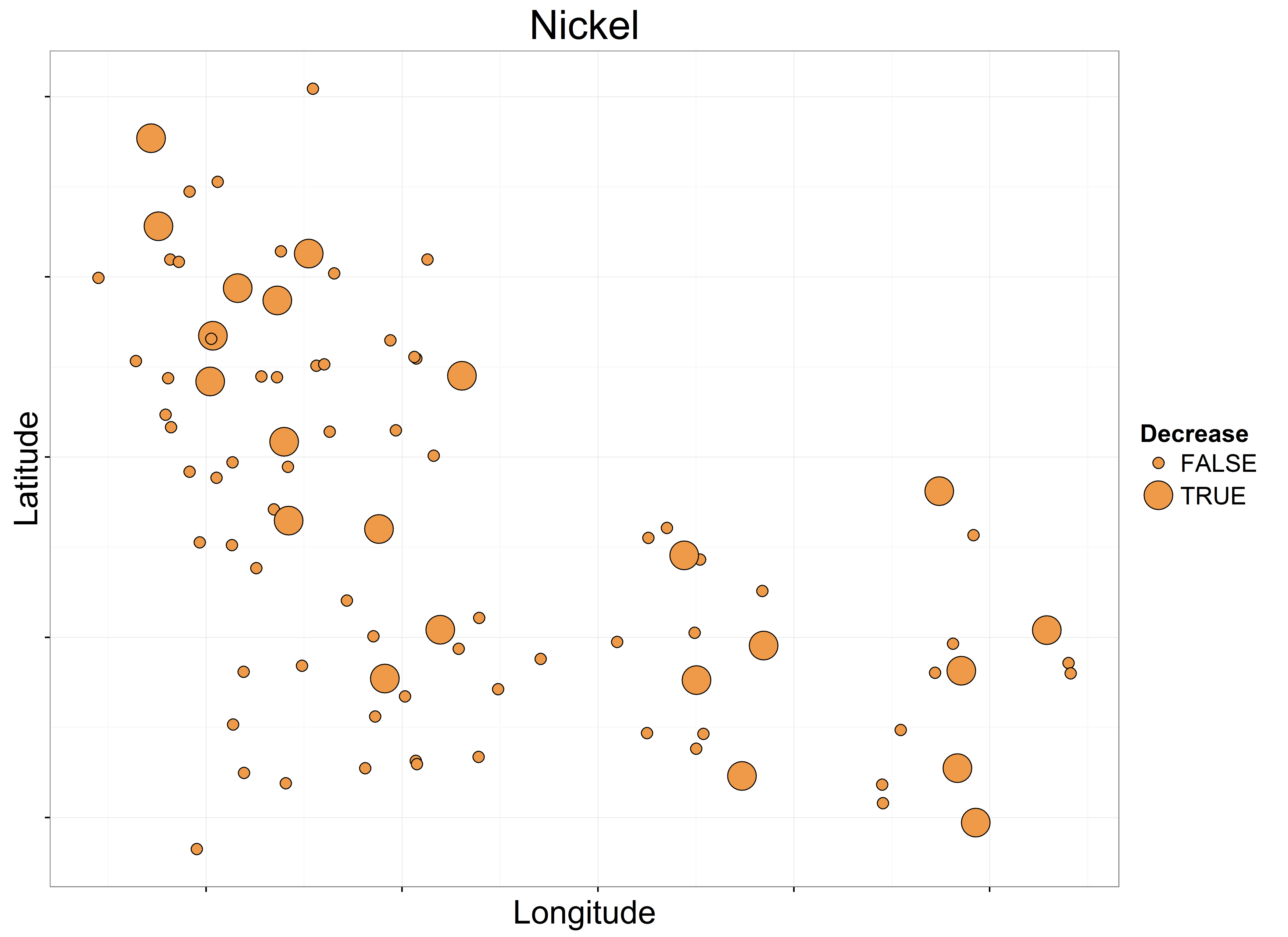
Lithium
Latitude
Longitude
Decrease
FALSE
TRUE



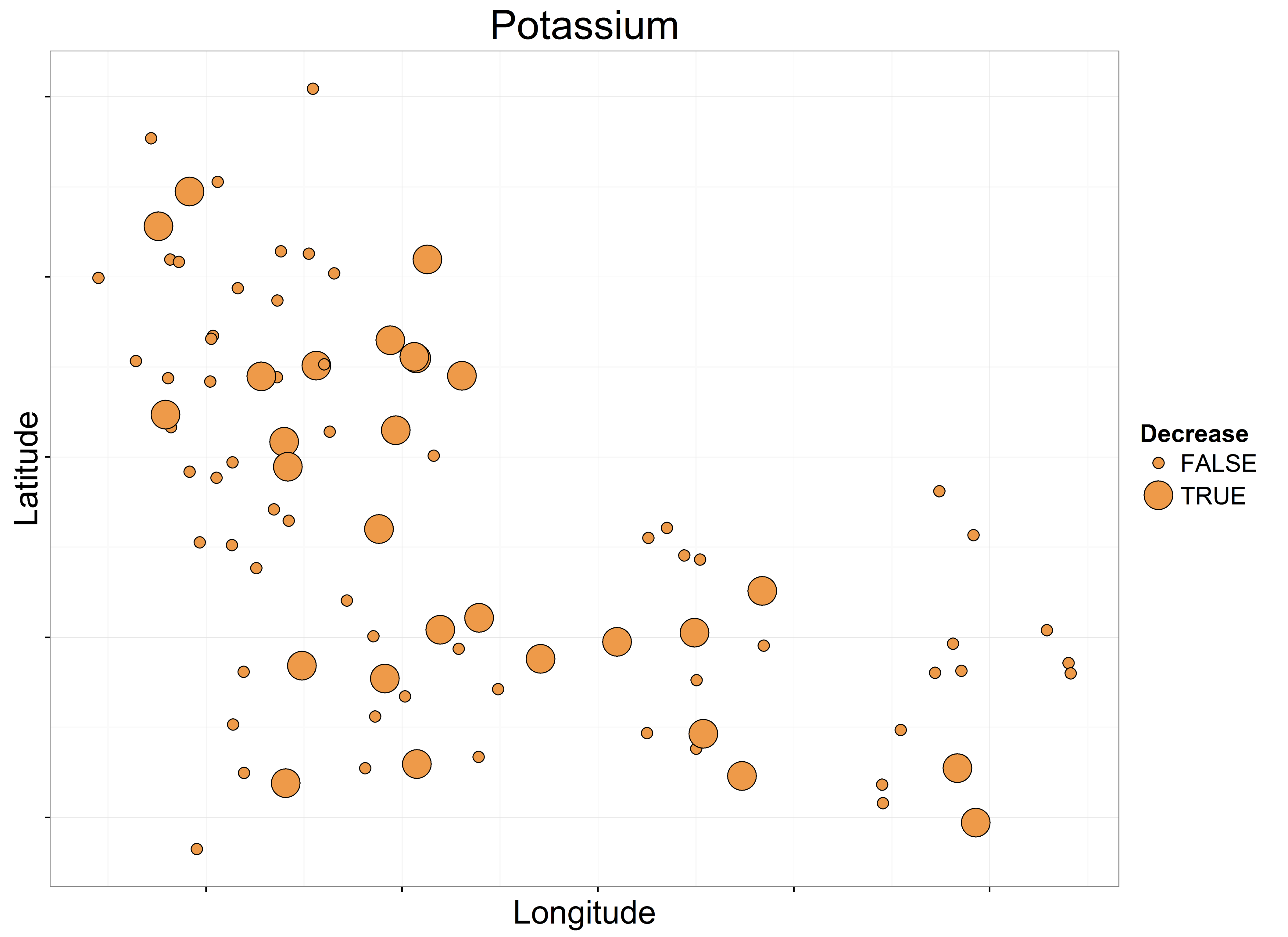
Magnesium
Latitude
Longitude
Decrease
FALSE
TRUE


Manganese
Latitude
Longitude
Decrease
FALSE
TRUE

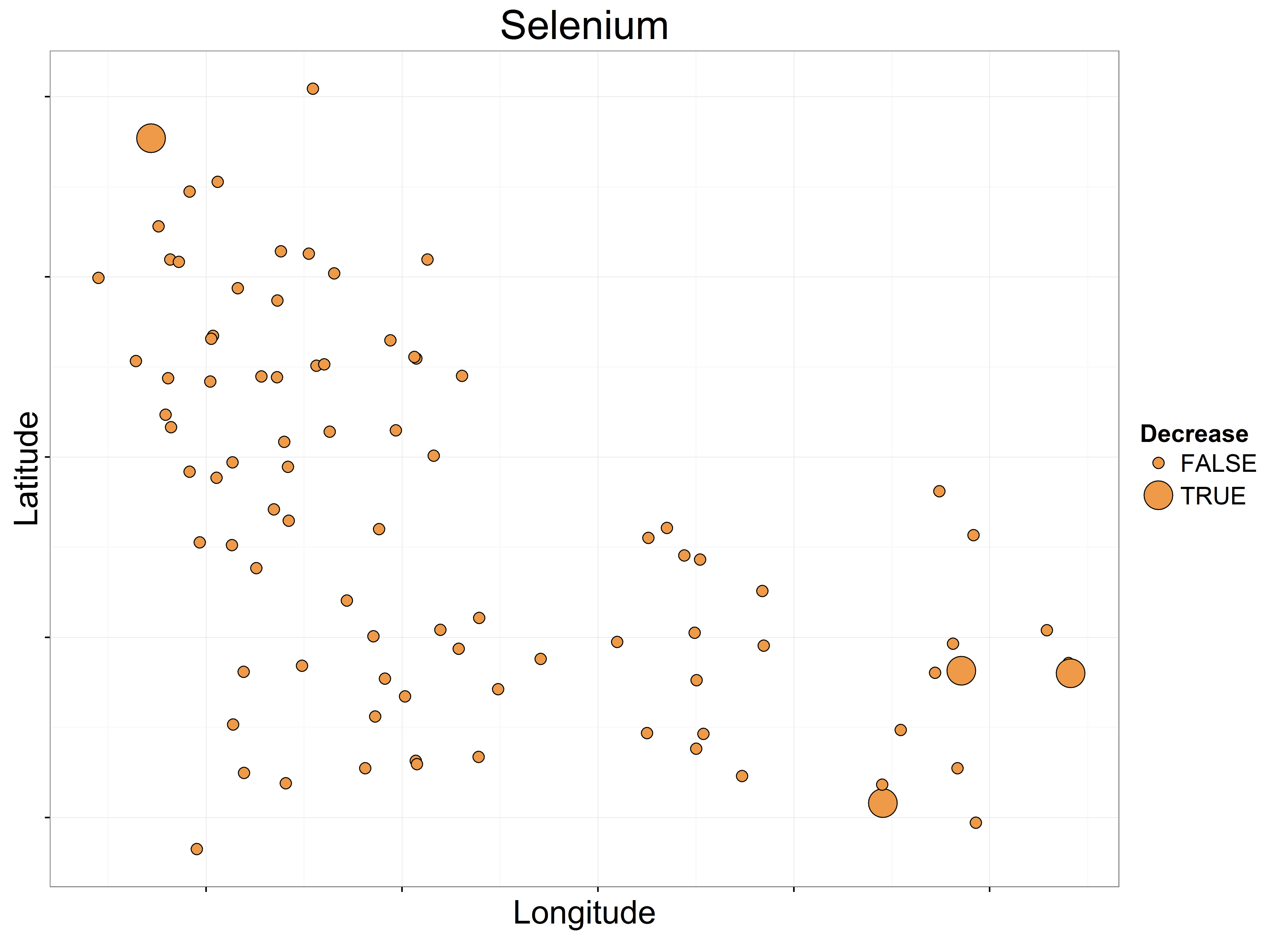

Mercury
Latitude
Longitude
Decrease
FALSE



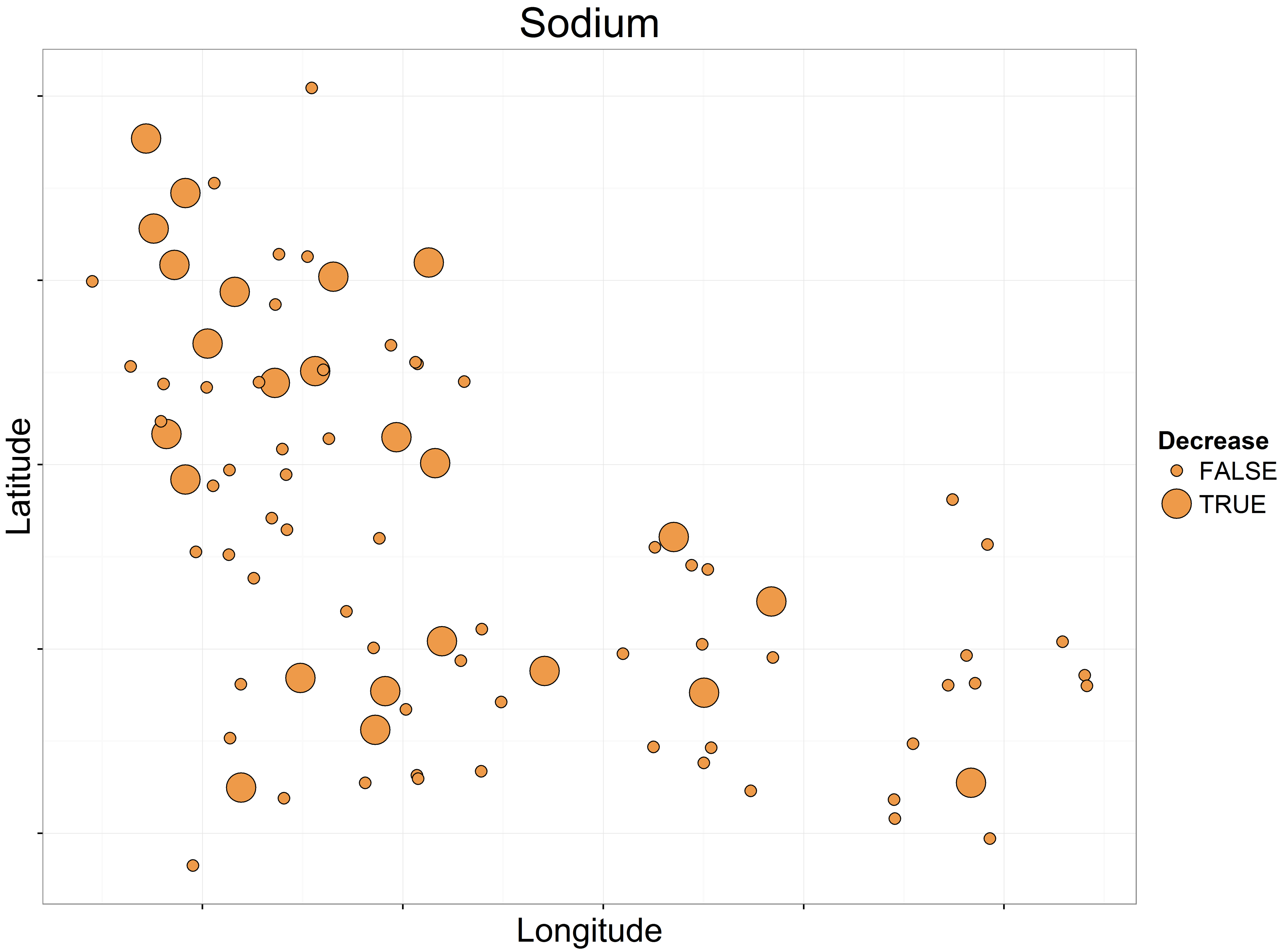
Nickel
Latitude
Longitude
Decrease
FALSE
TRUE

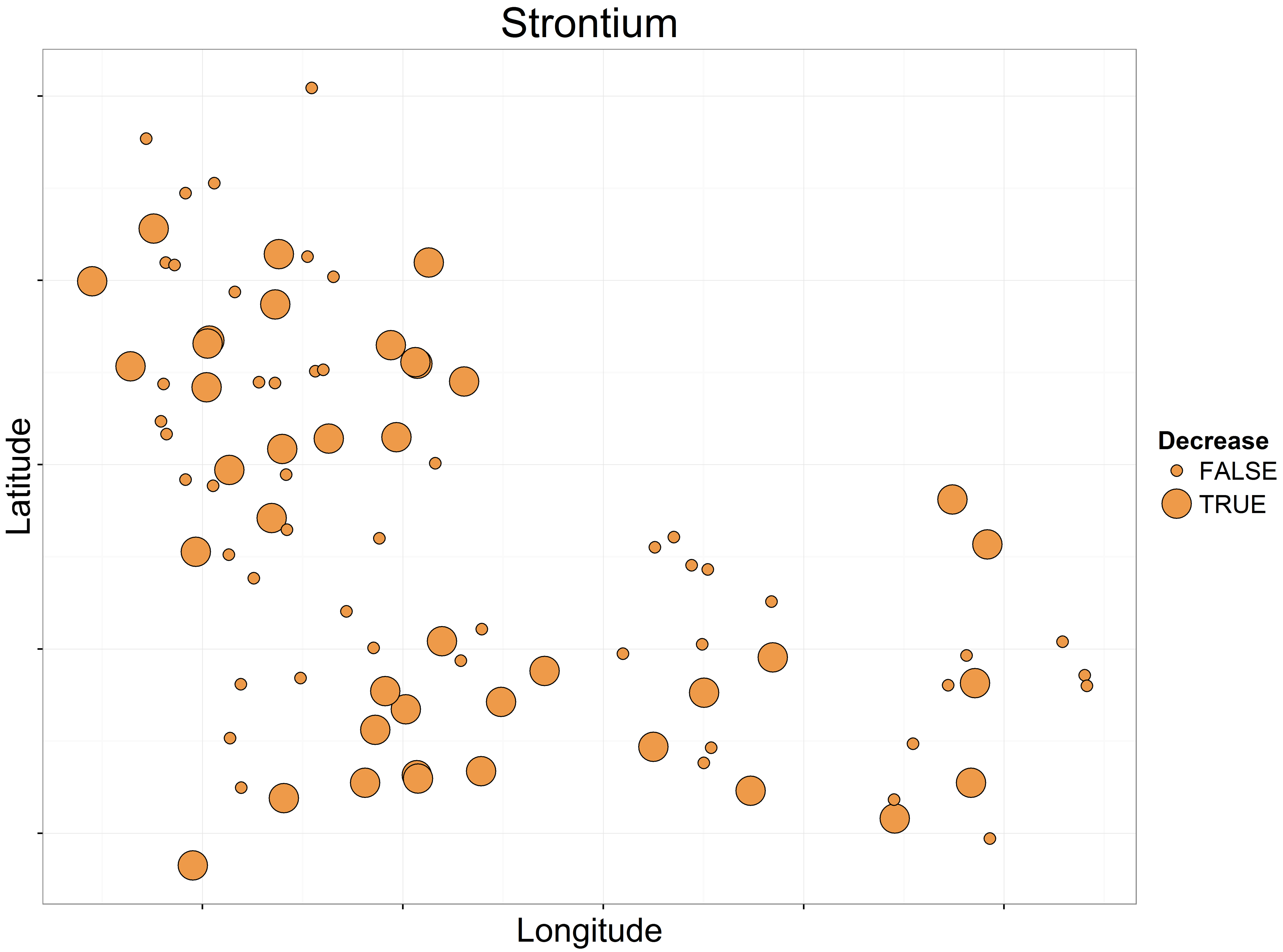


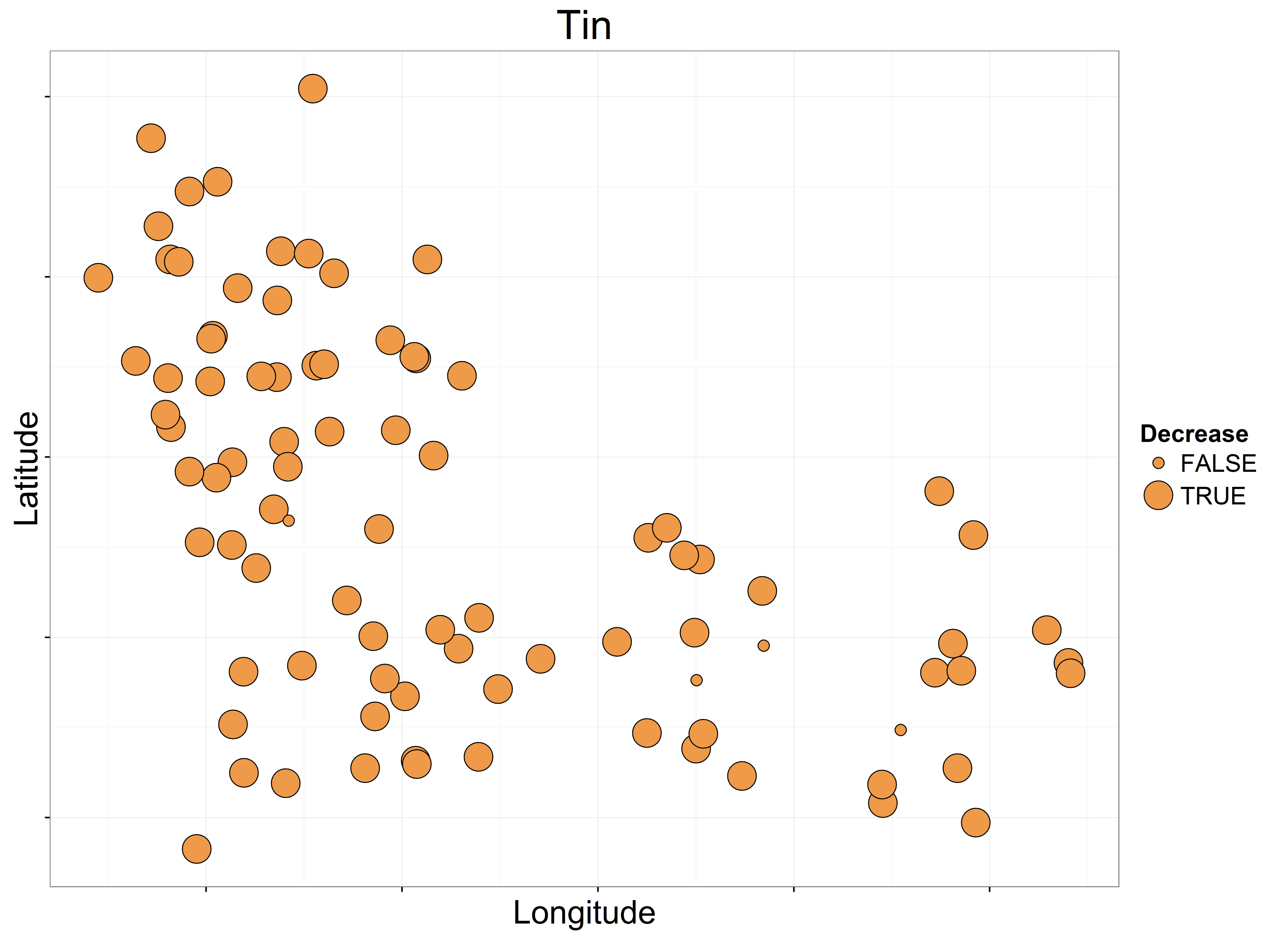
Potassium
Latitude
Longitude
Decrease
FALSE
TRUE



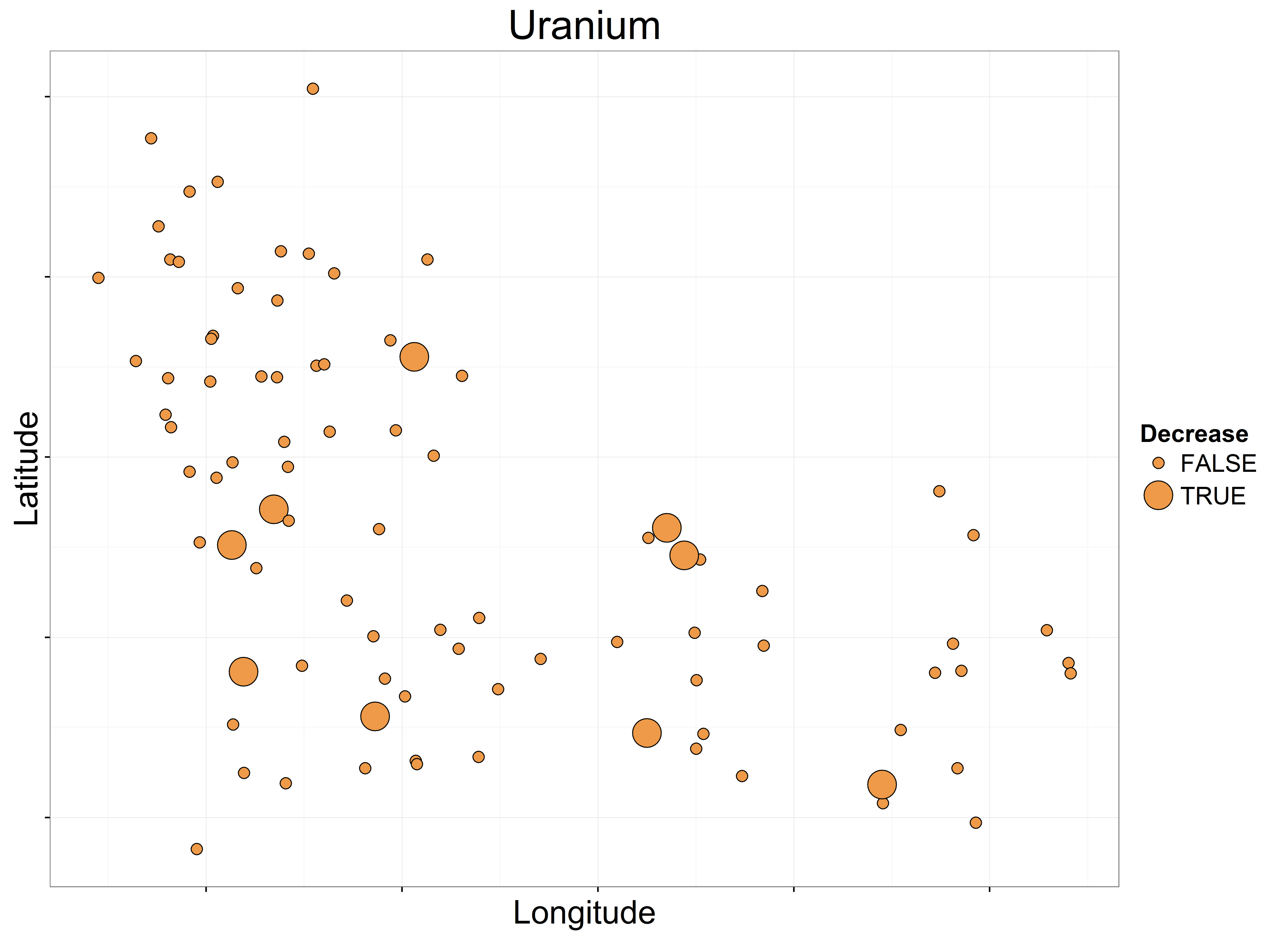
Selenium
Latitude
Longitude
Decrease
FALSE
TRUE

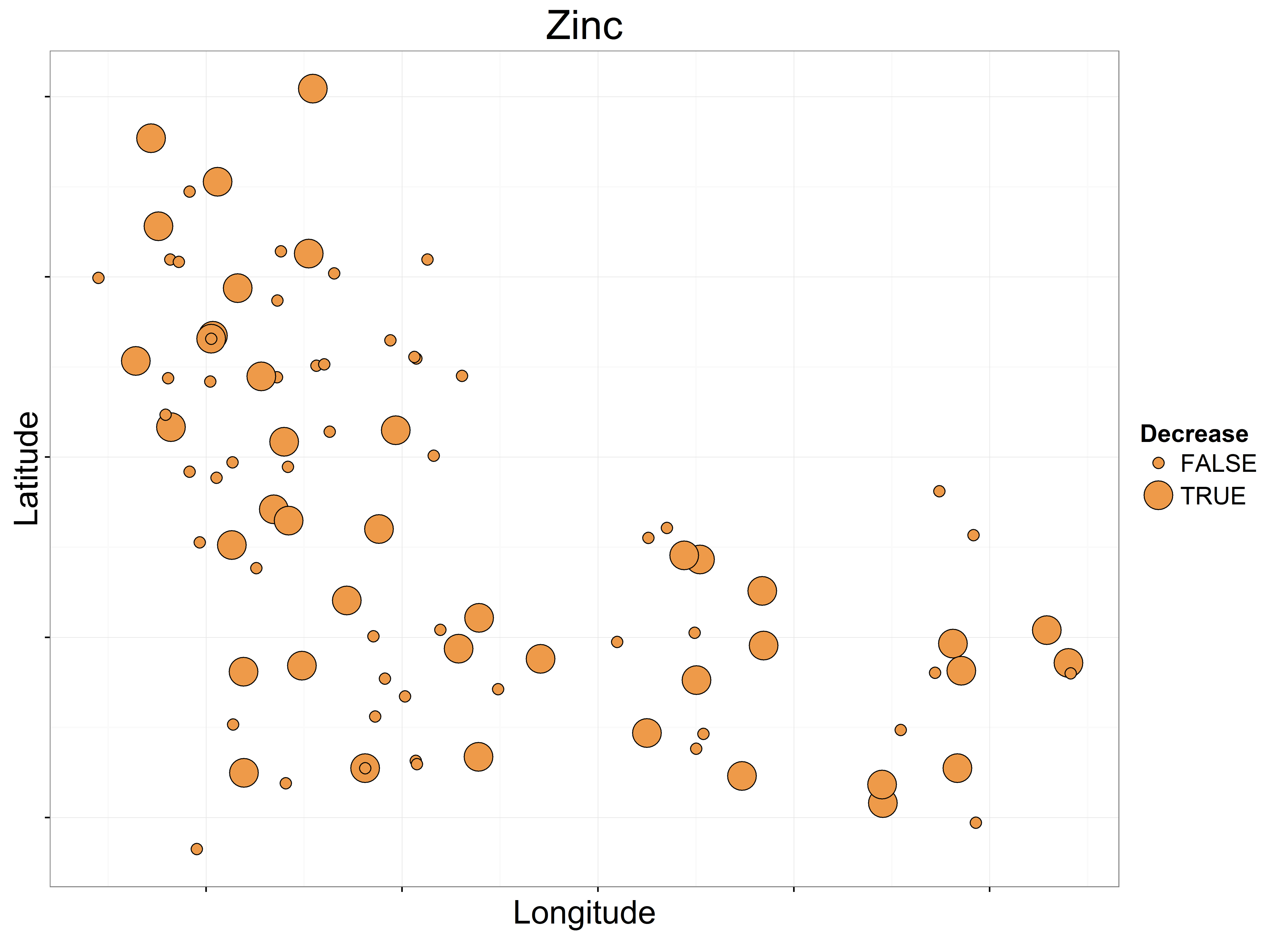

Sodium
Latitude
Longitude
Decrease
FALSE
TRUE

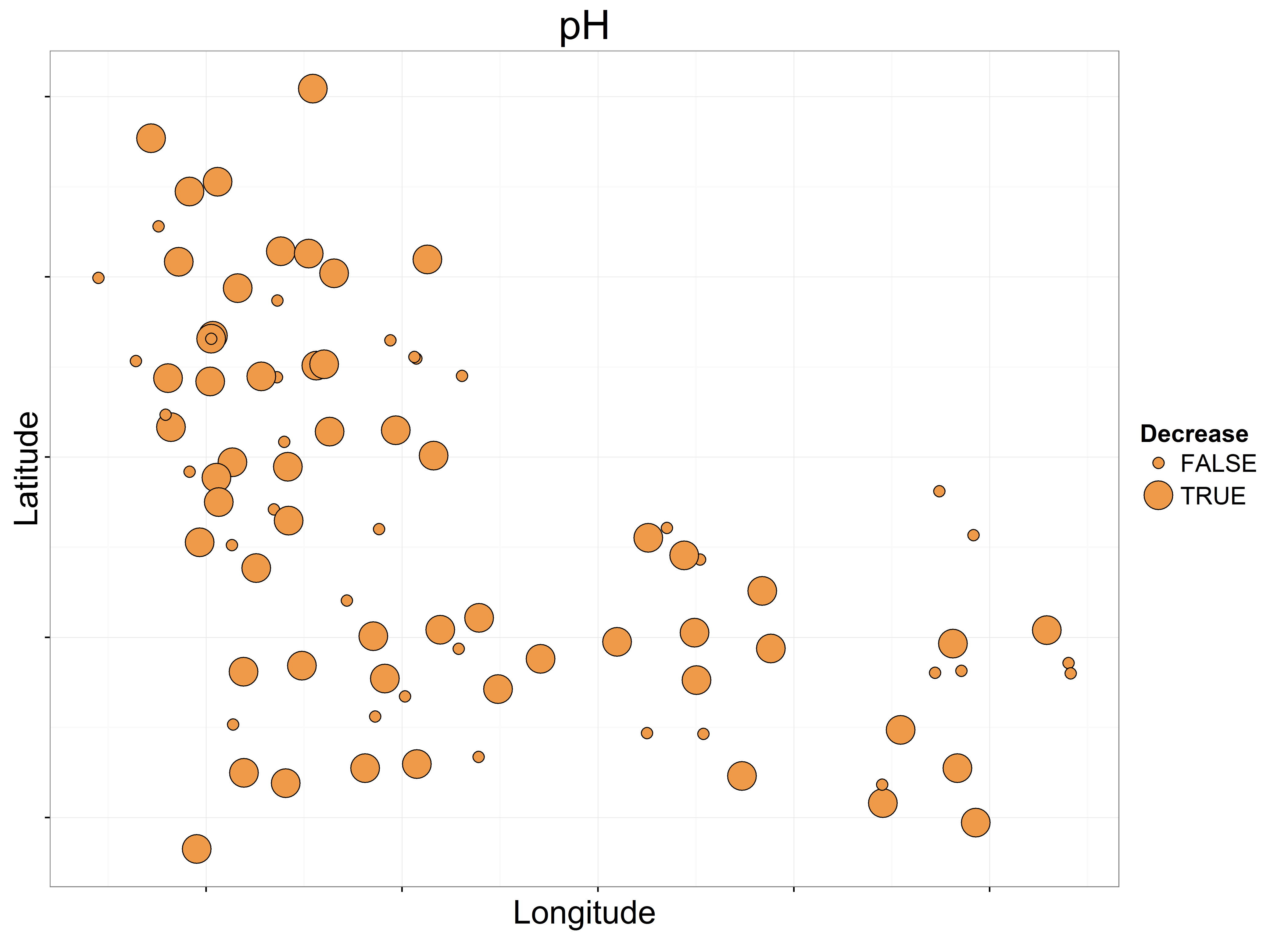

Strontium
Latitude
Longitude
Decrease
FALSE
TRUE



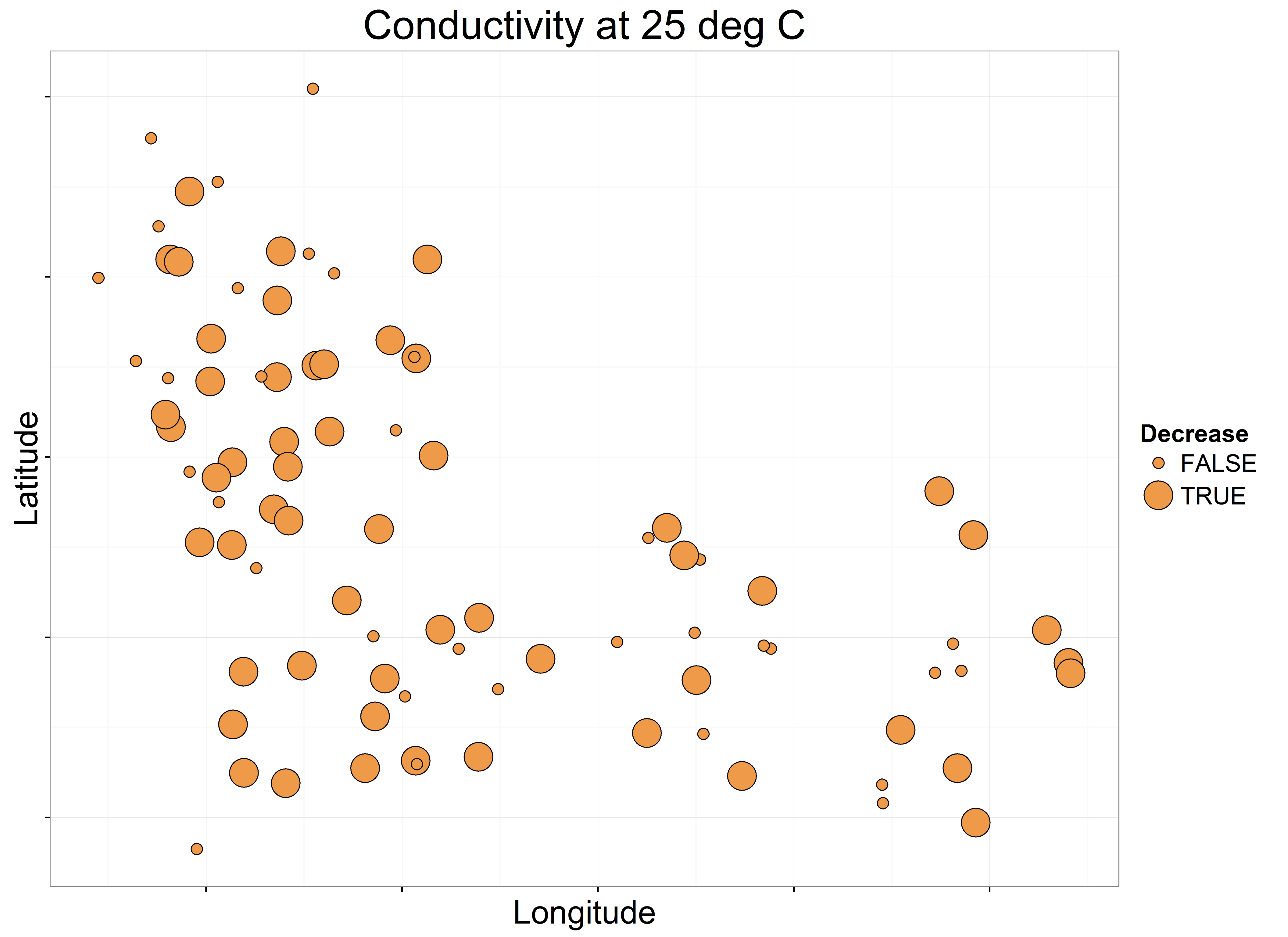
Tin
Latitude
Longitude
Decrease
FALSE
TRUE

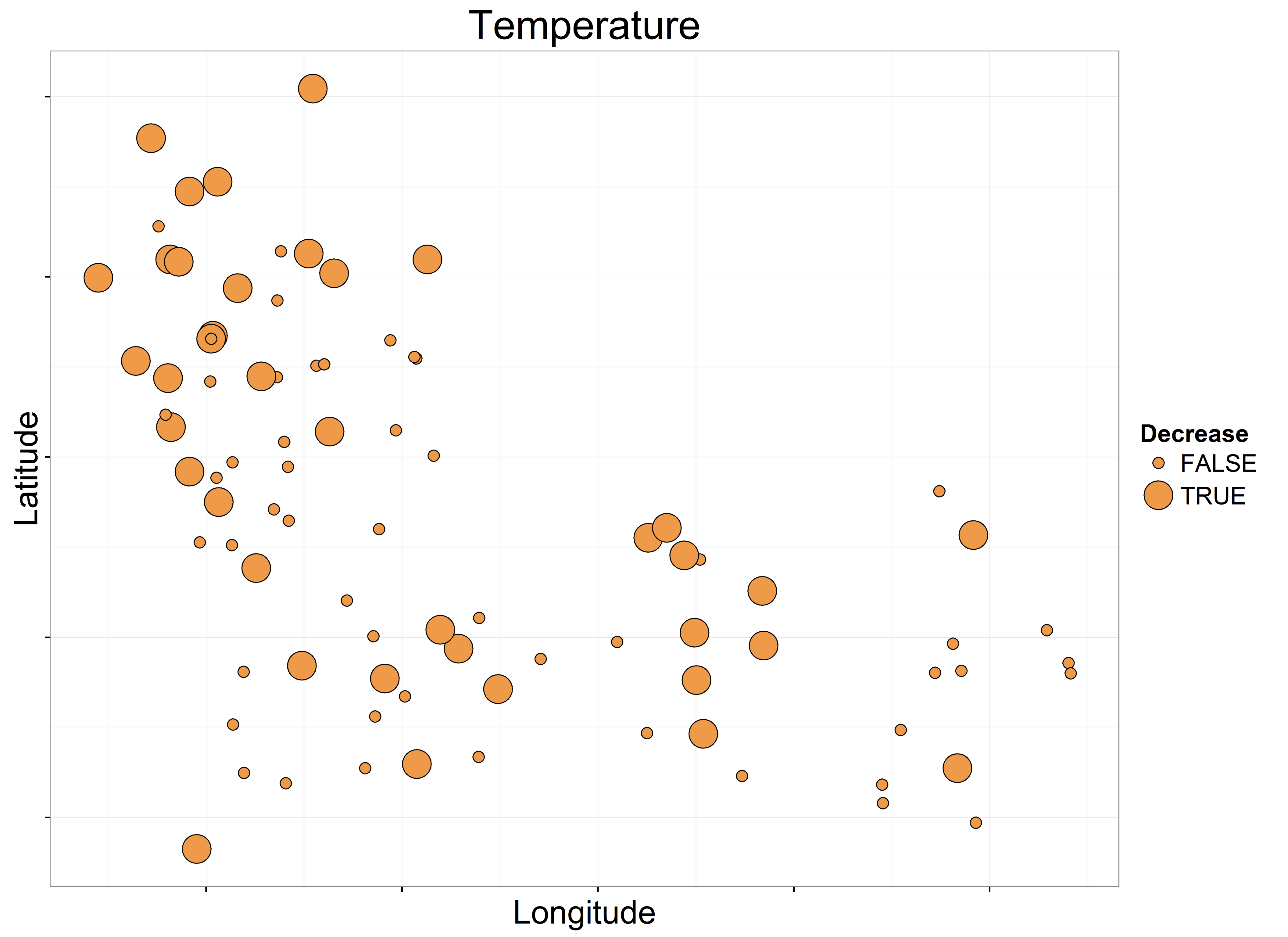

Uranium
Latitude
Longitude
Decrease
FALSE
TRUE


Zinc
Latitude
Longitude
Decrease
FALSE
TRUE



pH
Latitude
Longitude
Decrease
FALSE
TRUE


Conductivity at 25 deg C
Latitude
Longitude
Decrease
FALSE
TRUE



Temperature
Latitude
Longitude
Decrease
FALSE
TRUE

Appendix D

Decrease and Increase Plots

Aluminum

Skewness: 9.7202

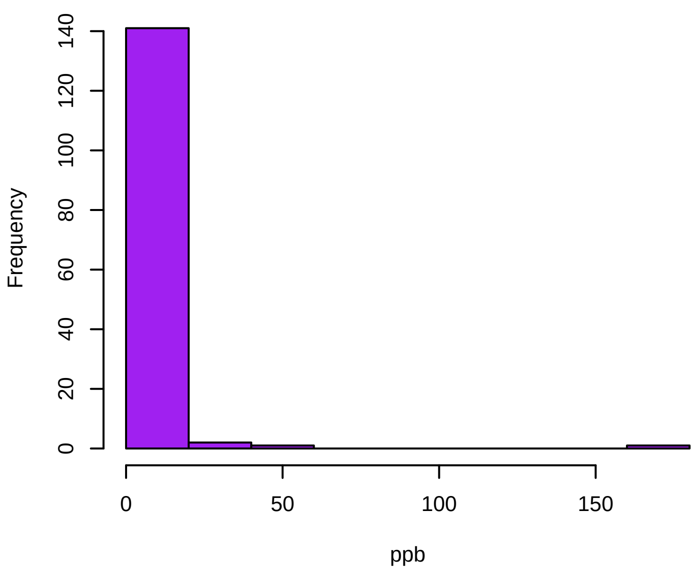
Kurtosis: 104.8571

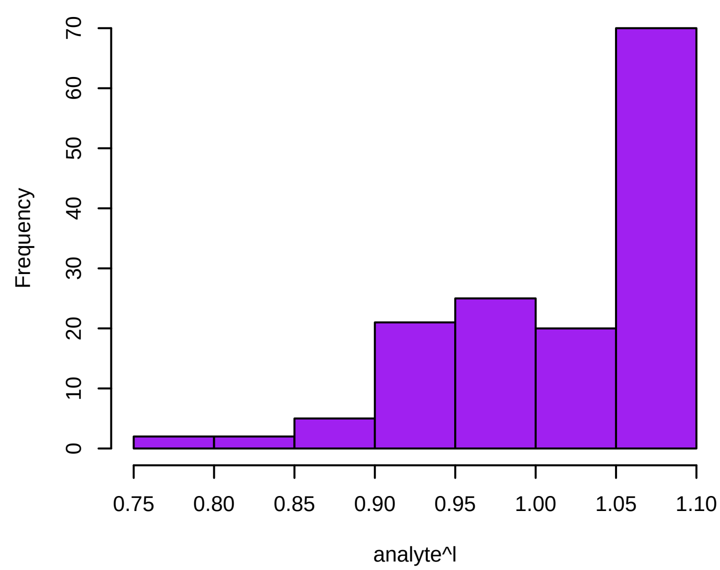
Aluminum Box−Cox

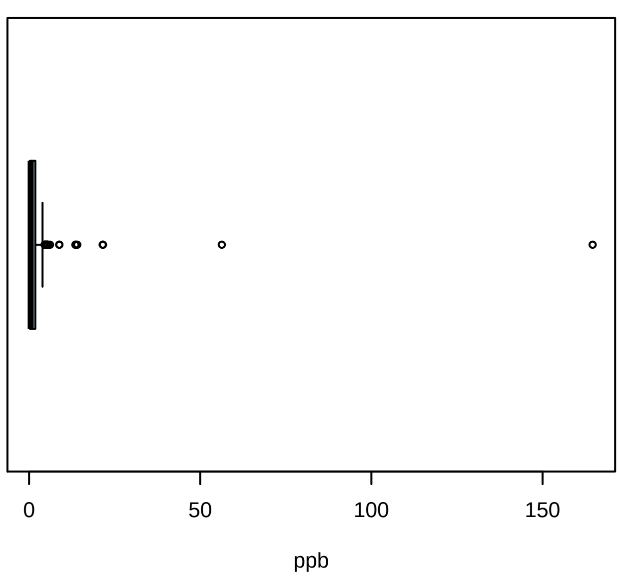
Skewness: −0.9831

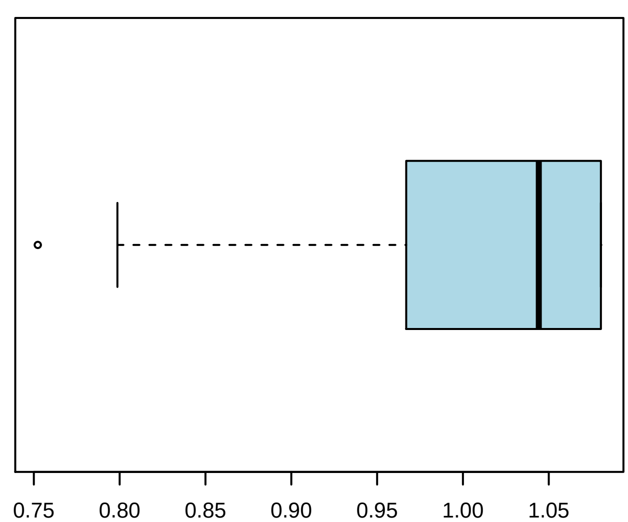
Kurtosis: 3.3174

Optimal lambda: −0.05577



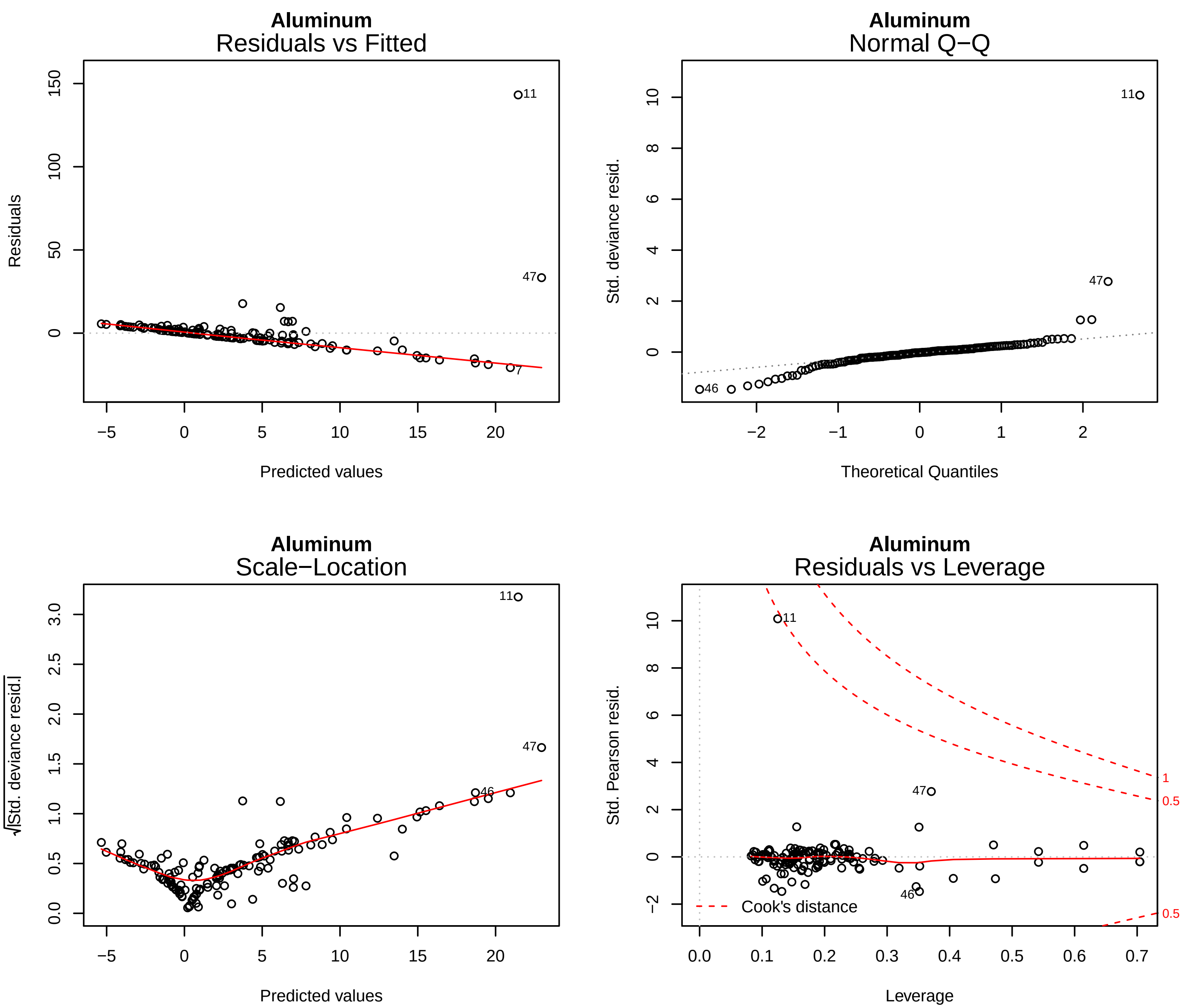






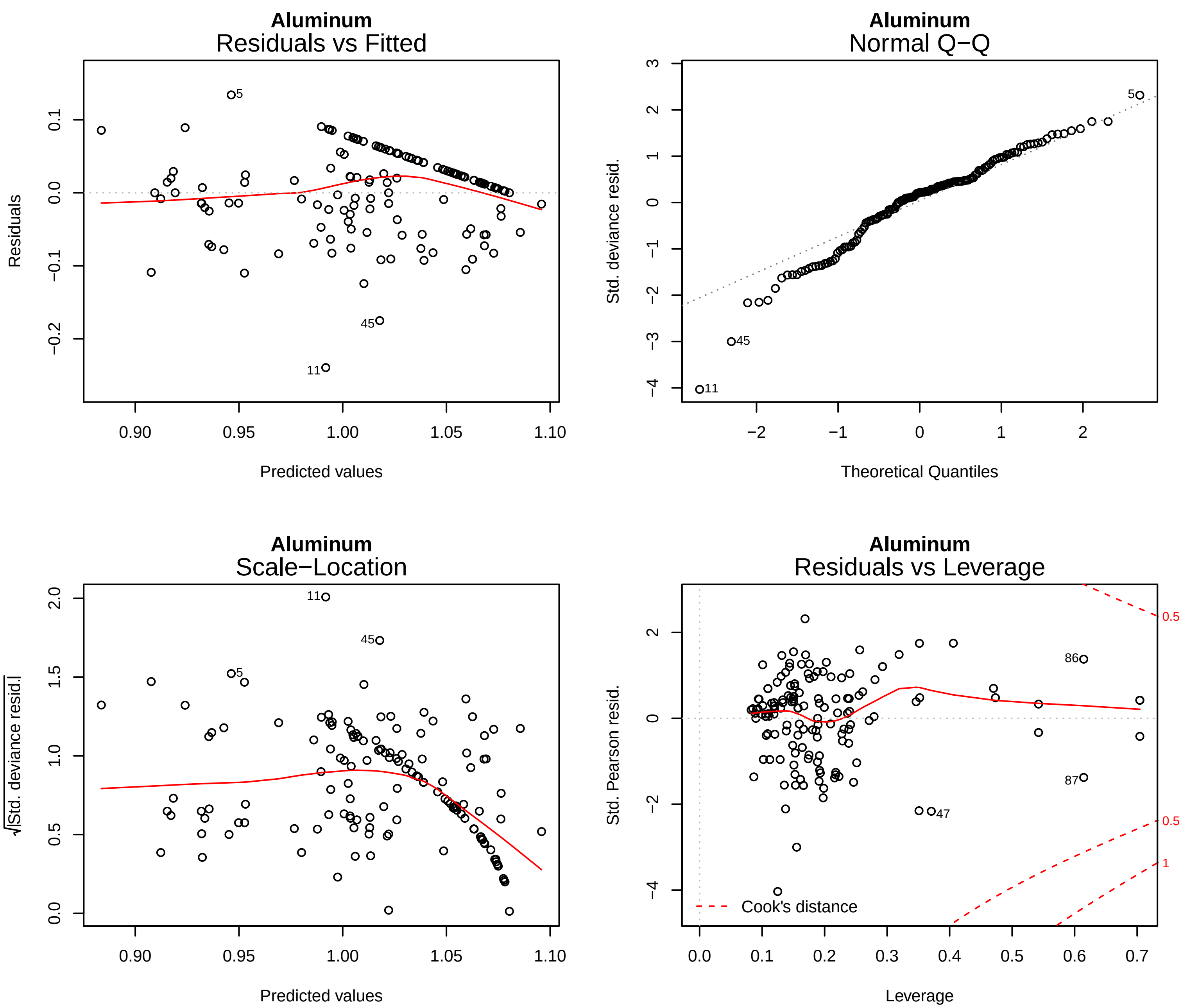
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

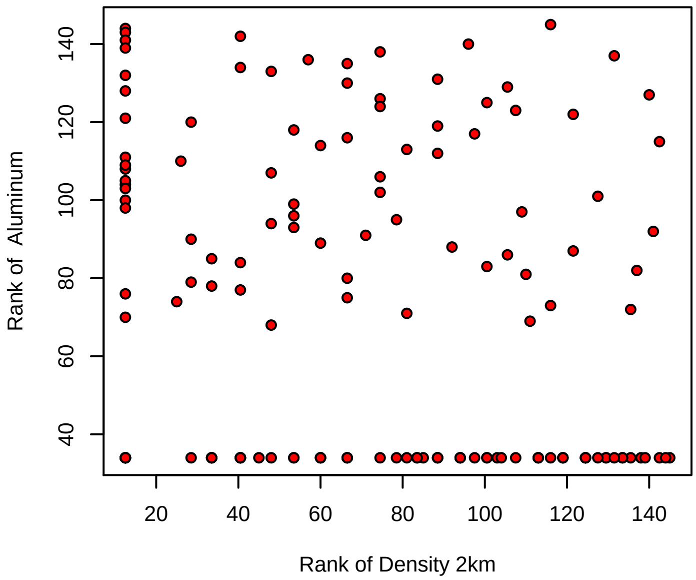
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



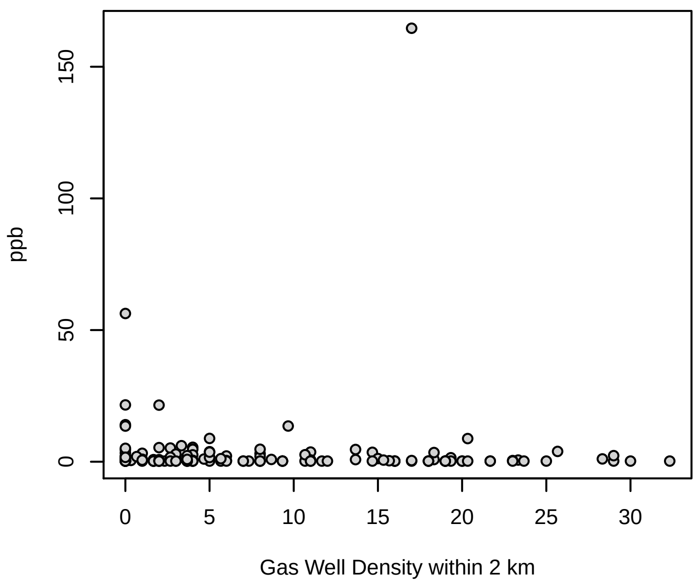


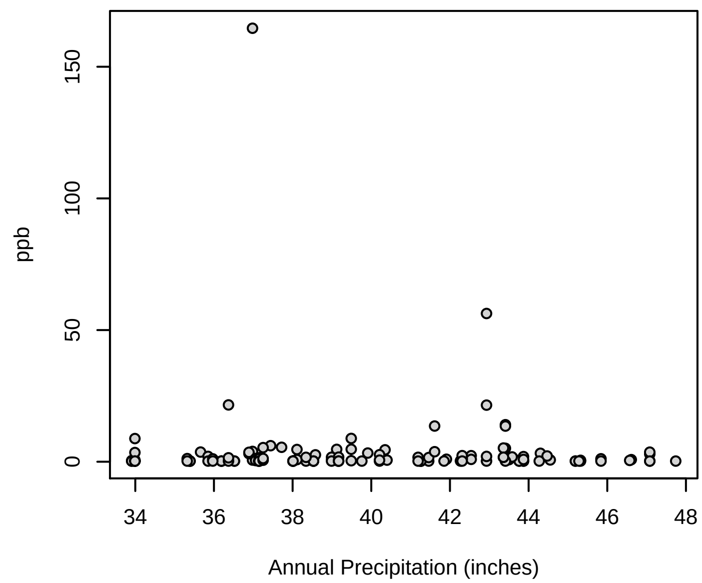
Aluminum

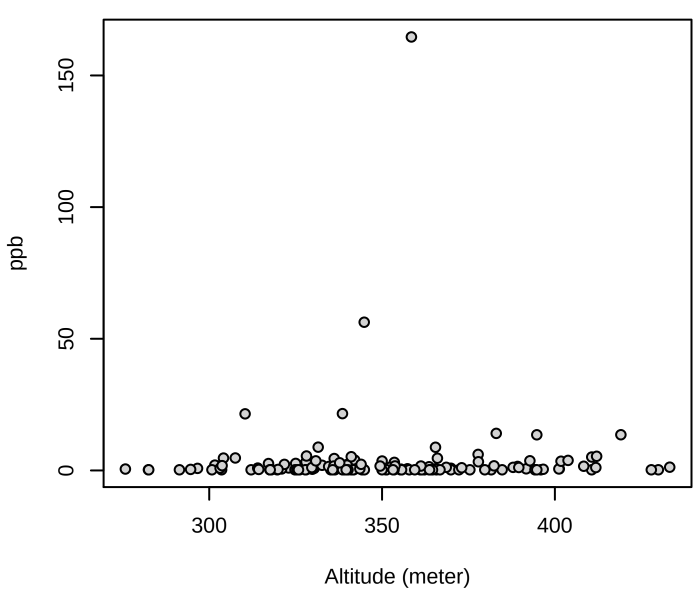
Kendalls Tau Rank Correlation

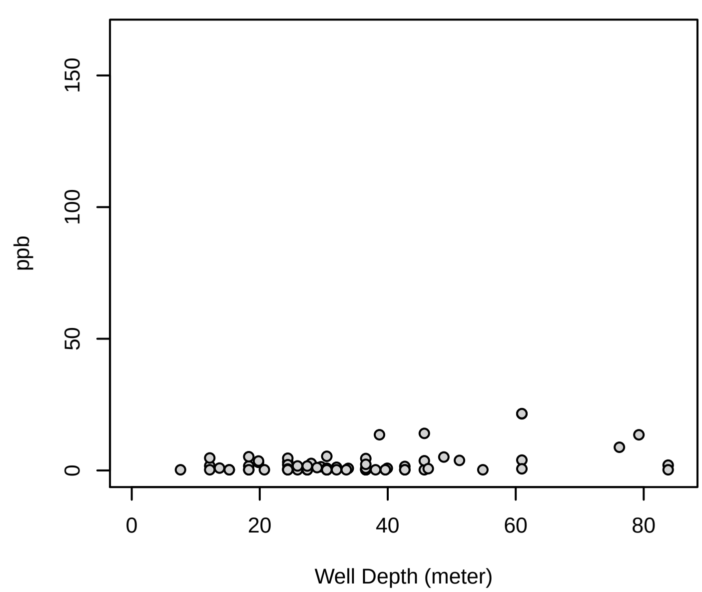
p−value: 0.00623

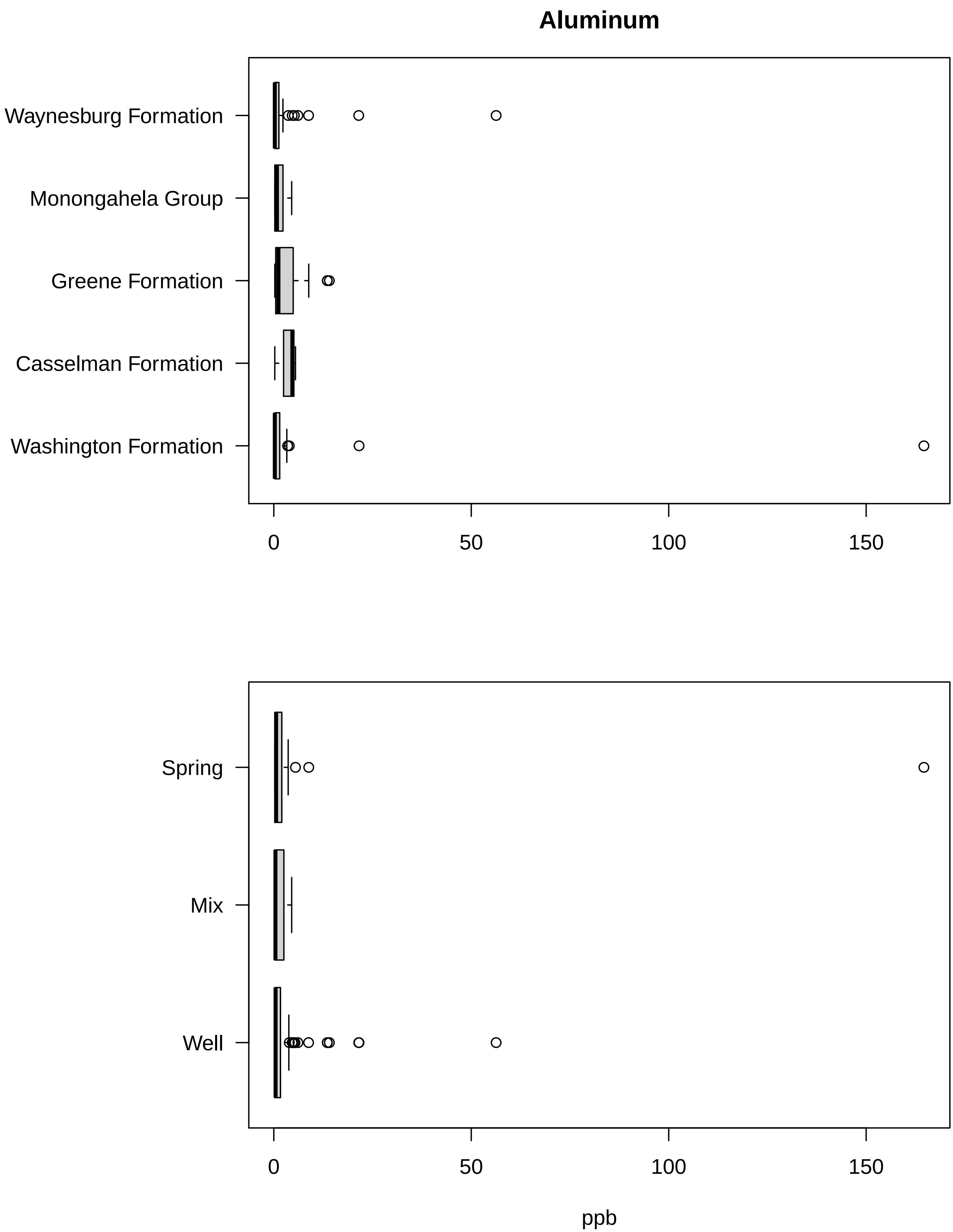
Tau: −0.167



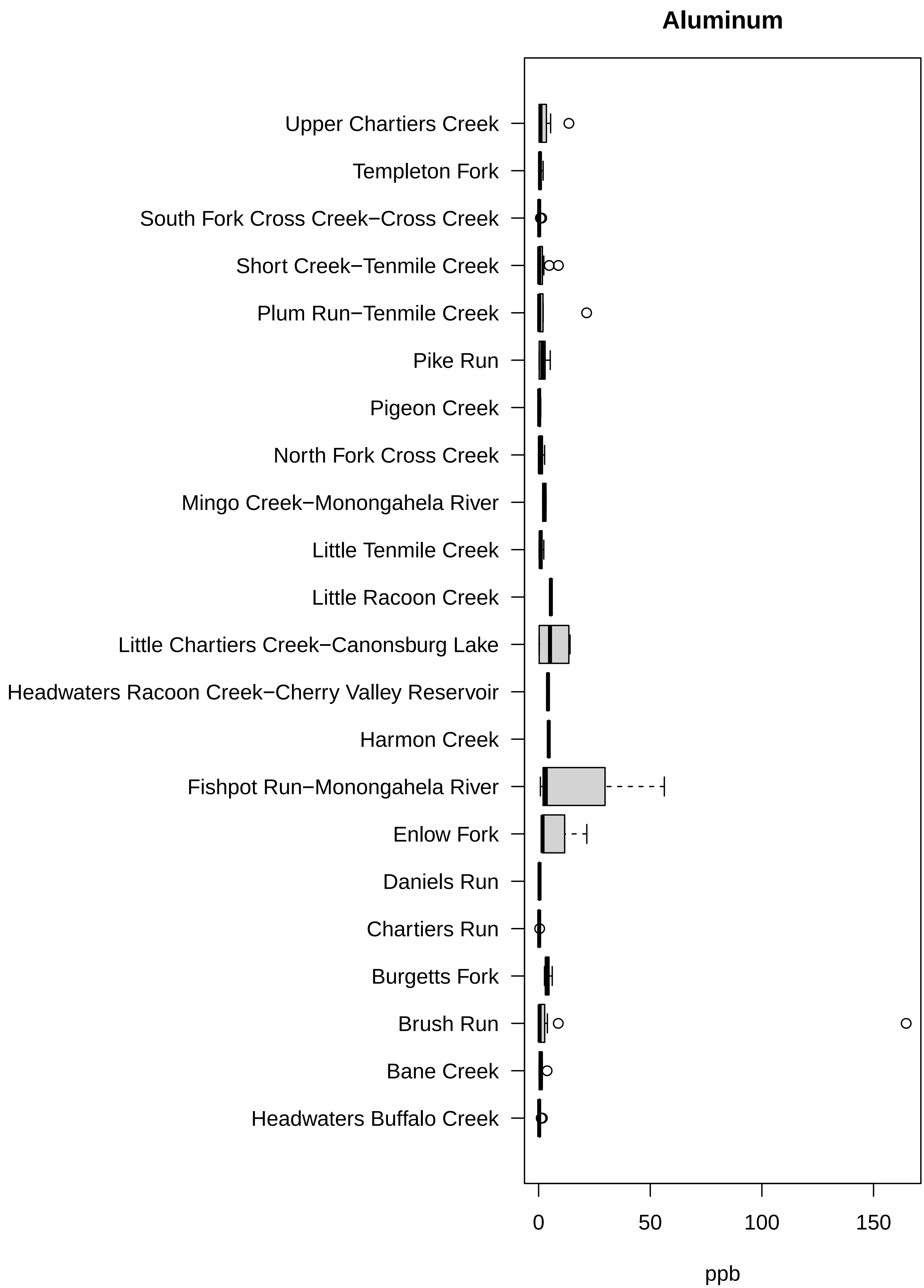








Aluminum
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
50
100
150
Spring
Mix
Well
0
50
100
150
ppb



Aluminum
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
50
100
150
ppb

```
[1] "ORIGINAL MODEL - Aluminum"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-20.701   -2.893   -0.241    1.796  143.173

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  -8.29113   41.73833  -0.199  0.84289
dat$GWellDensity_2kmAvg                                      -0.30763    0.25795  -1.193  0.23550
dat$Altitude_meter                                           -0.02314    0.07080  -0.327  0.74435
dat$WatershedBane Creek                                       0.85314    8.84510   0.096  0.92333
dat$WatershedBrush Run                                       21.76065    7.26929   2.994  0.00338 **
dat$WatershedBurgetts Fork                                    8.80858    8.50470   1.036  0.30252
dat$WatershedChartiers Run                                   10.44838    9.93038   1.052  0.29495
dat$WatershedDaniels Run                                     -3.54869   14.09257  -0.252  0.80164
dat$WatershedEnlow Fork                                       6.21034    9.60494   0.647  0.51921
dat$WatershedFishpot Run-Monongahela River                   20.55031   11.63231   1.767  0.07996 .
dat$WatershedHarmon Creek                                    11.86073   19.01041   0.624  0.53394
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir 10.67791   13.84654   0.771  0.44221
dat$WatershedLittle Chartiers Creek-Canonsburg Lake           4.04128    8.95896   0.451  0.65278
dat$WatershedLittle Racoon Creek                              9.18013   21.41783   0.429  0.66901
dat$WatershedLittle Tenmile Creek                            -2.03971    9.16255  -0.223  0.82423
dat$WatershedMingo Creek-Monongahela River                    0.35852   12.27641   0.029  0.97675
dat$WatershedNorth Fork Cross Creek                           5.14199    8.23726   0.624  0.53372
dat$WatershedPigeon Creek                                    -1.41112   10.31435  -0.137  0.89142
dat$WatershedPike Run                                        -0.60583   10.07604  -0.060  0.95216
dat$WatershedPlum Run-Tenmile Creek                           1.15707    8.93566   0.129  0.89720
dat$WatershedShort Creek-Tenmile Creek                        1.83648    7.41709   0.248  0.80489
dat$WatershedSouth Fork Cross Creek-Cross Creek               6.10244    6.64356   0.919  0.36027
dat$WatershedTempleton Fork                                   0.03811    7.85483   0.005  0.99614
dat$WatershedUpper Chartiers Creek                            8.12797    6.78031   1.199  0.23311
dat$FormationCasselman Formation                             -8.41098   15.46247  -0.544  0.58753
dat$FormationGreene Formation                                 0.86244    5.25154   0.164  0.86984
dat$FormationMonongahela Group                               -5.30805    5.49700  -0.966  0.33627
dat$FormationWaynesburg Formation                            -0.30501    4.25428  -0.072  0.94297
dat$HHWSourceMix                                             -3.79679   10.26946  -0.370  0.71228
dat$HHWSourceSpring                                           5.15797    3.36475   1.533  0.12806
dat$Precip_inchAvg                                            0.44217    0.86114   0.513  0.60862
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 230.4164)

    Null deviance: 30785  on 144  degrees of freedom
Residual deviance: 26267  on 114  degrees of freedom
AIC: 1229.4

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Aluminum"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.23952  -0.02511   0.01216   0.03105   0.13412

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              1.1631595  0.1745717   6.663 9.95e-10 ***
dat$GWellDensity_2kmAvg                                  0.0018635  0.0010789   1.727  0.08683 .
dat$Altitude_meter                                      -0.0001207  0.0002961  -0.408  0.68436
dat$WatershedBane Creek                                 -0.0079919  0.0369948  -0.216  0.82935
dat$WatershedBrush Run                                  -0.0973897  0.0304040  -3.203  0.00176 **
dat$WatershedBurgetts Fork                              -0.1570901  0.0355711  -4.416 2.30e-05 ***
dat$WatershedChartiers Run                              -0.0370397  0.0415341  -0.892  0.37438
dat$WatershedDaniels Run                                -0.0258132  0.0589425  -0.438  0.66226
dat$WatershedEnlow Fork                                 -0.1166560  0.0401729  -2.904  0.00443 **
dat$WatershedFishpot Run-Monongahela River              -0.1514680  0.0486525  -3.113  0.00234 **
dat$WatershedHarmon Creek                               -0.2029365  0.0795115  -2.552  0.01202 *
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.1690760  0.0579135  -2.919  0.00423 **
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     -0.0656492  0.0374711  -1.752  0.08246 .
dat$WatershedLittle Racoon Creek                        -0.1821868  0.0895806  -2.034  0.04430 *
dat$WatershedLittle Tenmile Creek                       -0.0568176  0.0383226  -1.483  0.14094
dat$WatershedMingo Creek-Monongahela River              -0.1095877  0.0513464  -2.134  0.03496 *
dat$WatershedNorth Fork Cross Creek                     -0.0538303  0.0344525  -1.562  0.12095
dat$WatershedPigeon Creek                               -0.0045286  0.0431400  -0.105  0.91658
dat$WatershedPike Run                                   -0.0691707  0.0421433  -1.641  0.10349
dat$WatershedPlum Run-Tenmile Creek                     -0.0492114  0.0373736  -1.317  0.19057
dat$WatershedShort Creek-Tenmile Creek                  -0.0461777  0.0310222  -1.489  0.13937
dat$WatershedSouth Fork Cross Creek-Cross Creek         -0.0303945  0.0277869  -1.094  0.27633
dat$WatershedTempleton Fork                             -0.0178933  0.0328530  -0.545  0.58706
dat$WatershedUpper Chartiers Creek                      -0.0760946  0.0283588  -2.683  0.00838 **
dat$FormationCasselman Formation                         0.0240156  0.0646722   0.371  0.71107
dat$FormationGreene Formation                           -0.0511567  0.0219647  -2.329  0.02162 *
dat$FormationMonongahela Group                           0.0077990  0.0229913   0.339  0.73507
dat$FormationWaynesburg Formation                        0.0001933  0.0177936   0.011  0.99135
dat$HHWSourceMix                                         0.0505985  0.0429523   1.178  0.24124
dat$HHWSourceSpring                                     -0.0084632  0.0140732  -0.601  0.54879
dat$Precip_inchAvg                                      -0.0014575  0.0036018  -0.405  0.68648
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.004030794)

    Null deviance: 0.78500  on 144  degrees of freedom
Residual deviance: 0.45951  on 114  degrees of freedom
AIC: -358.89

Number of Fisher Scoring iterations: 2
```

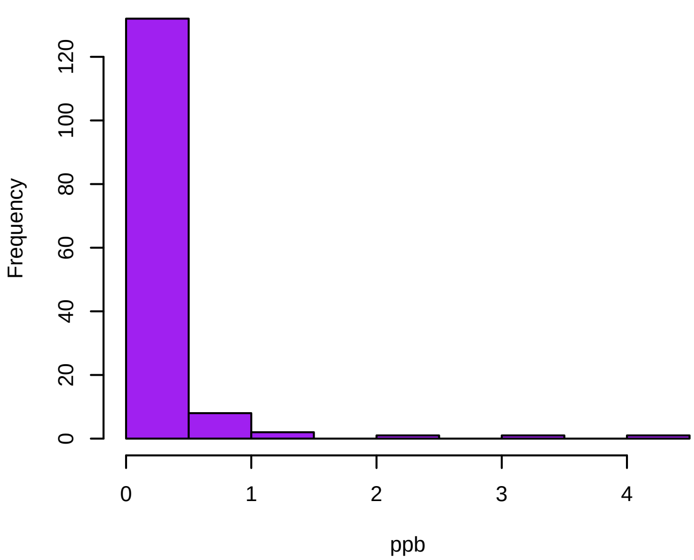
Arsenic

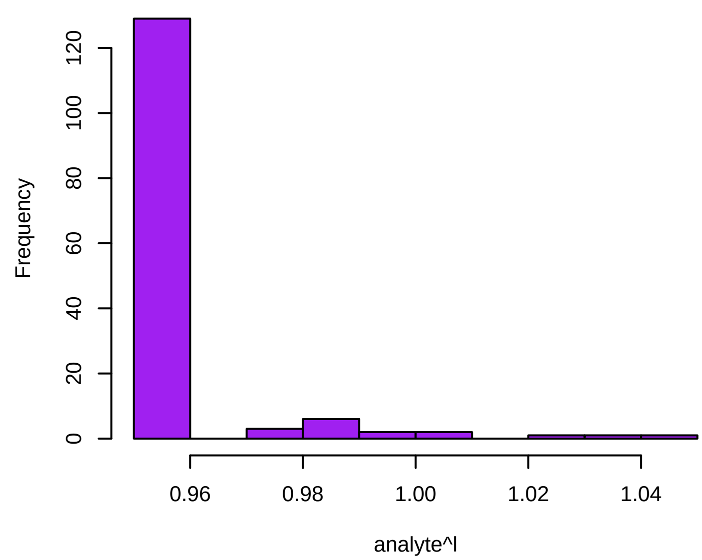
Skewness: 6.4713
Kurtosis: 48.1911

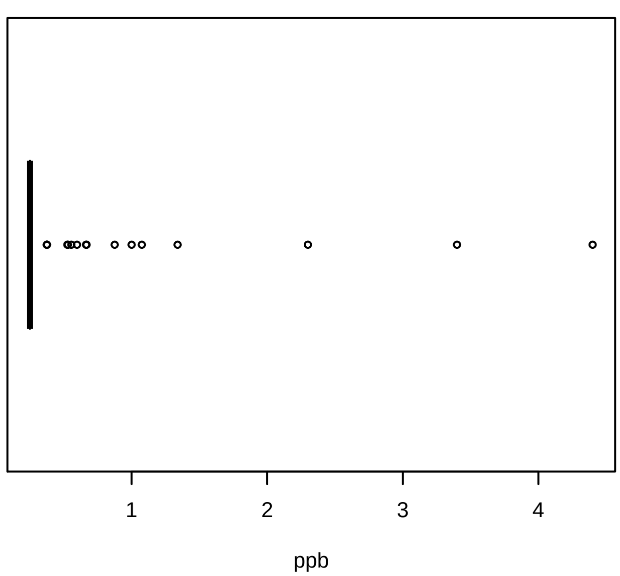
Arsenic Box−Cox

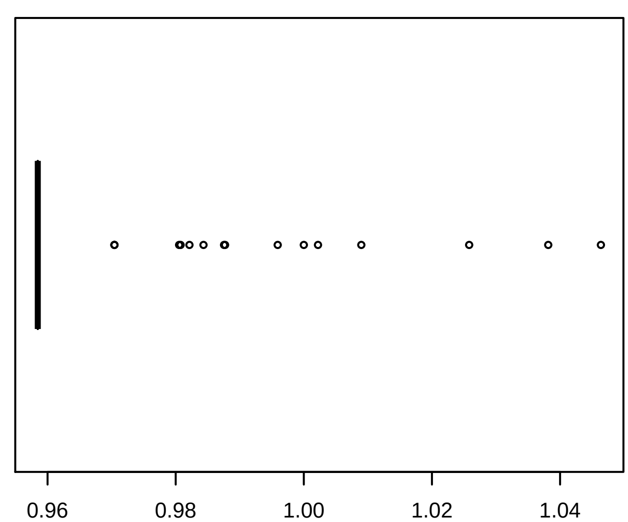
Skewness: 4.0344
Kurtosis: 20.1362

Optimal lambda: 0.0306



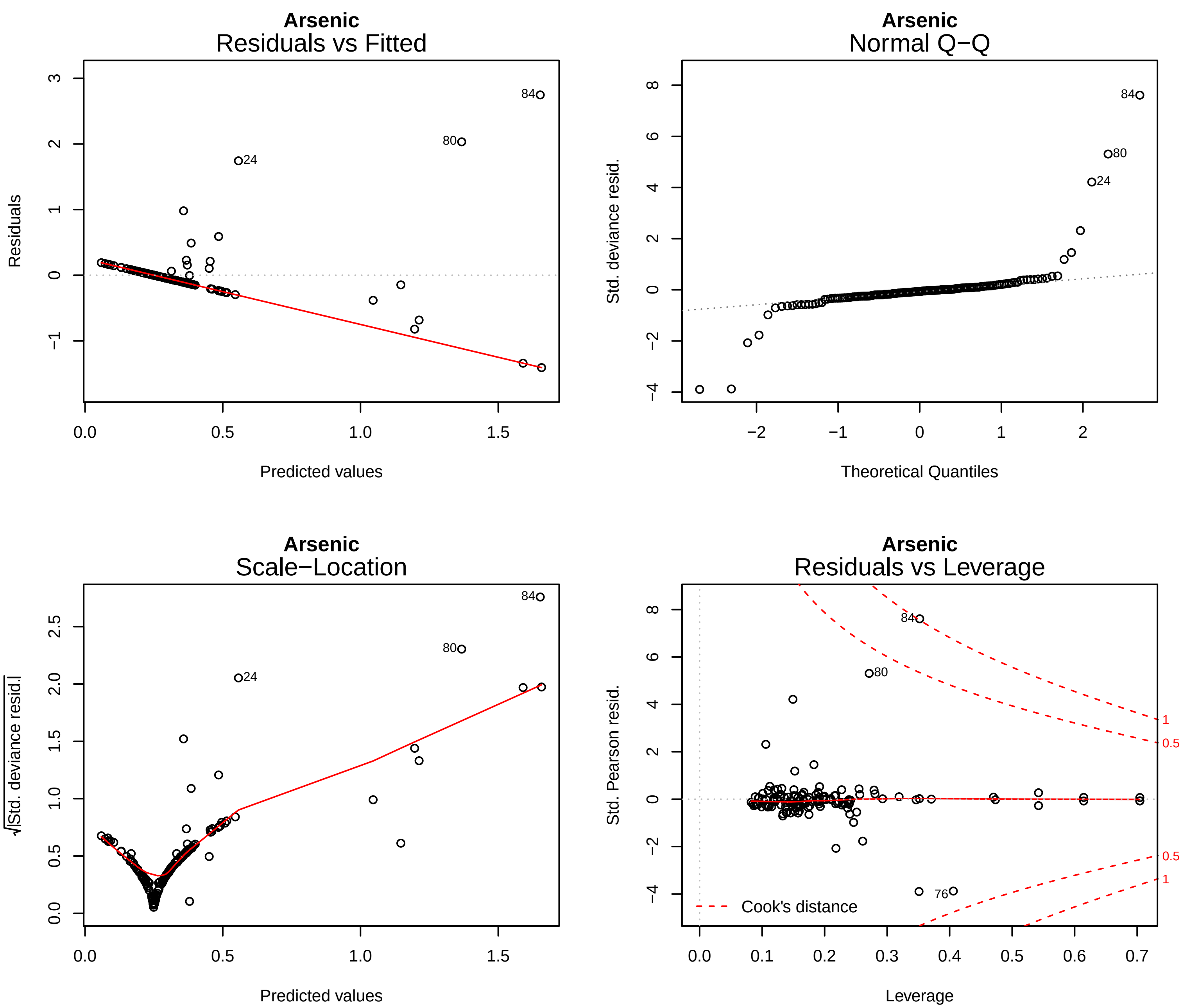






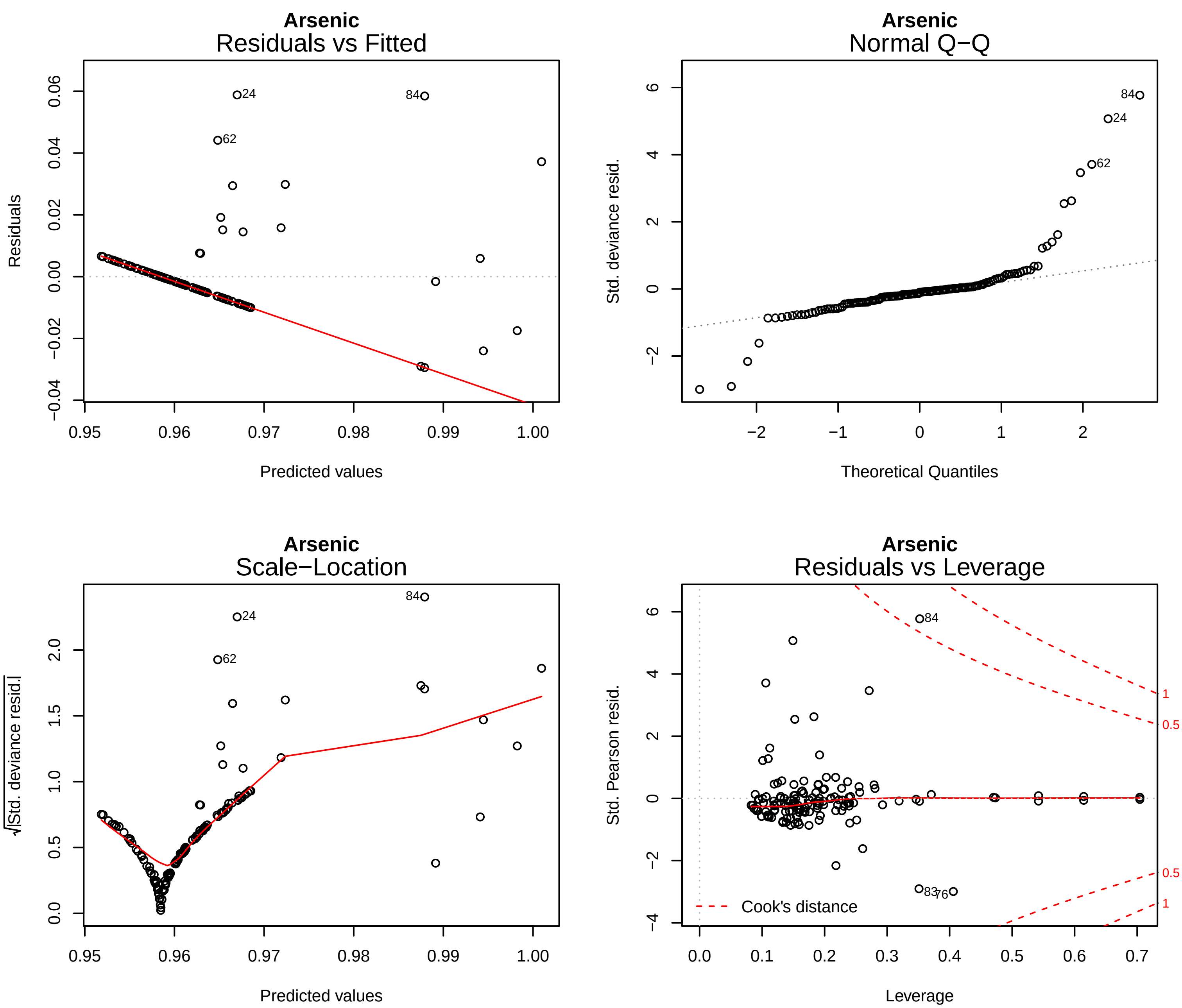
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

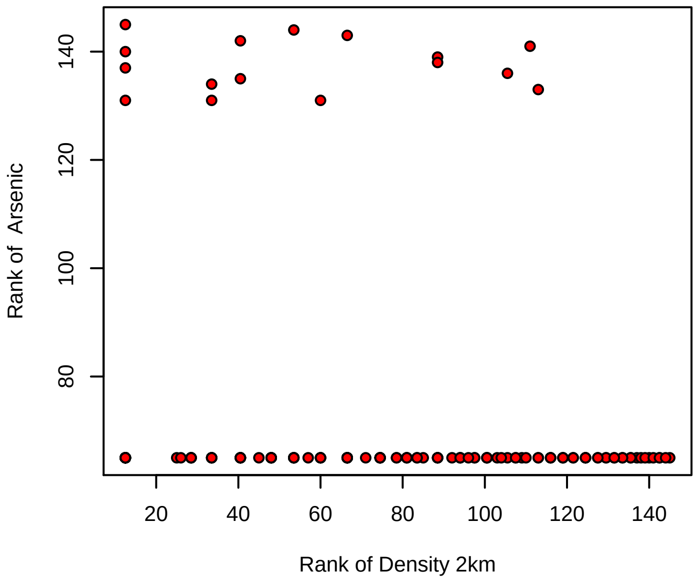
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



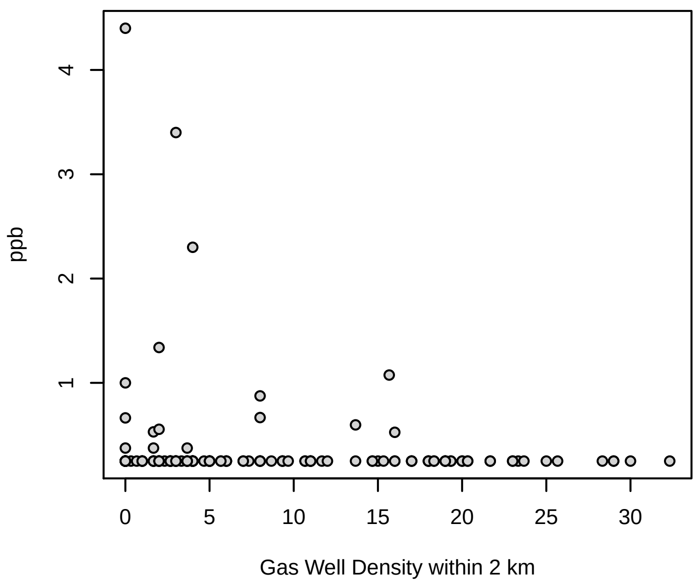


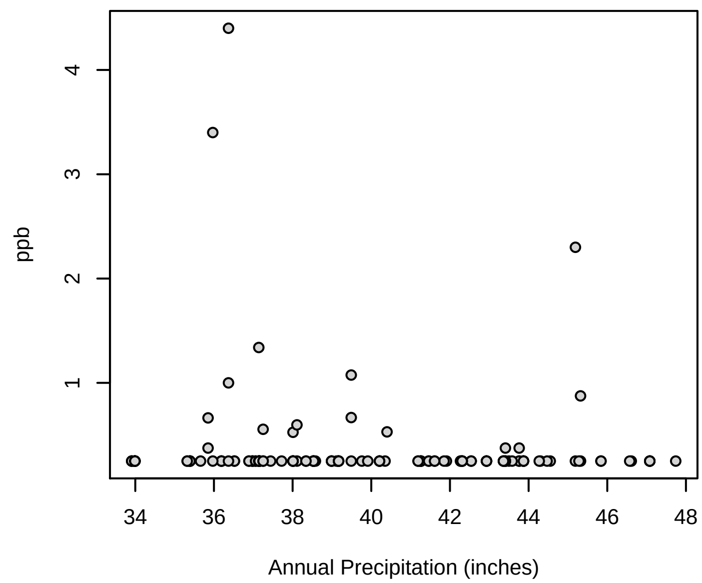
Arsenic

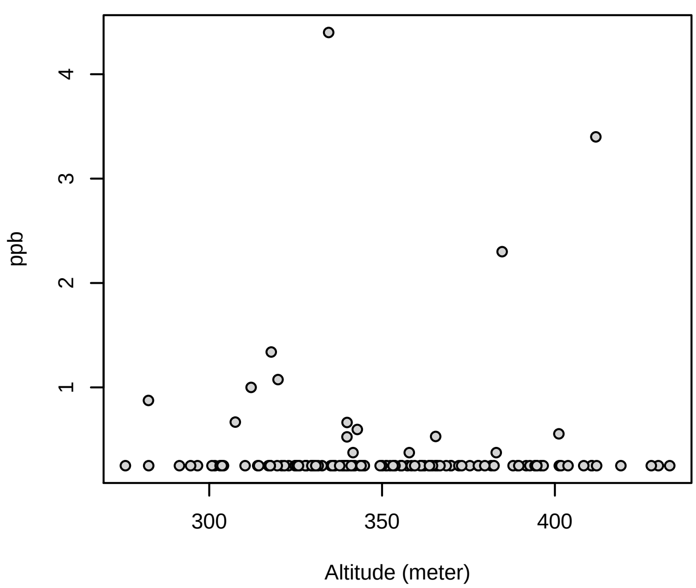
Kendalls Tau Rank Correlation

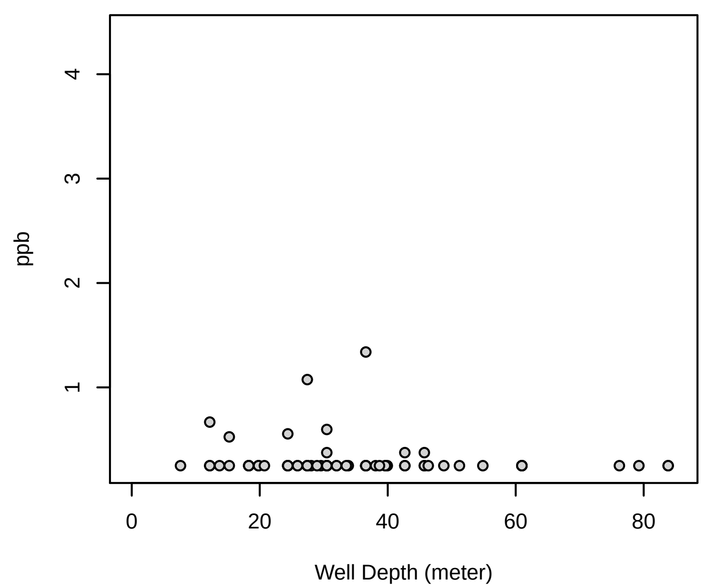
p−value: 0.0735

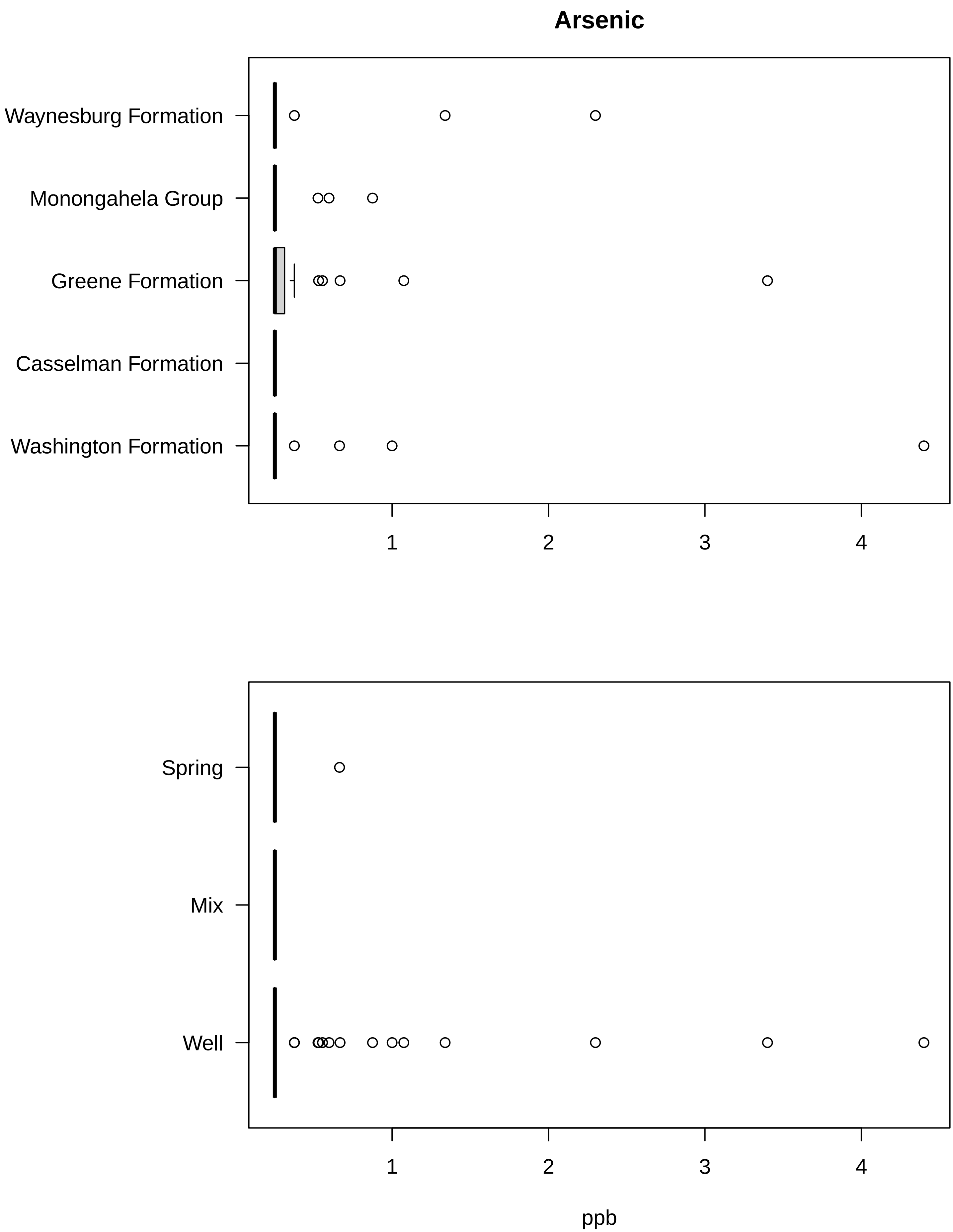
Tau: −0.122



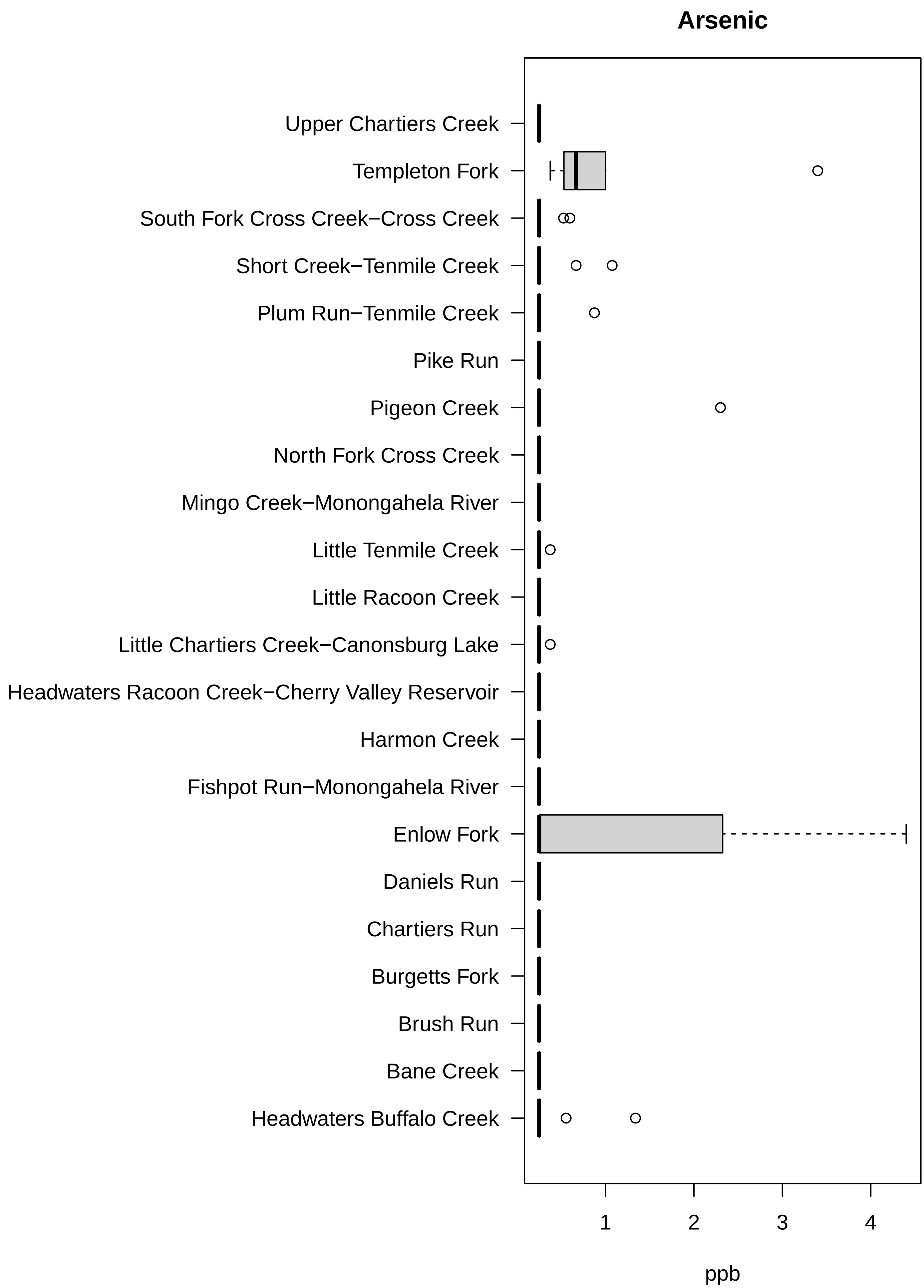








Arsenic
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
1
2
3
4
Spring
Mix
Well
1
2
3
4
ppb


Arsenic
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
1
2
3
4
ppb

```
[1] "ORIGINAL MODEL - Arsenic"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.40730  -0.10289  -0.01728   0.03806   2.74746

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               0.693732   1.233133   0.563 0.574828
dat$GWellDensity_2kmAvg                                   0.002096   0.007621   0.275 0.783773
dat$Altitude_meter                                        0.001193   0.002092   0.570 0.569666
dat$WatershedBane Creek                                  -0.069815   0.261323  -0.267 0.789830
dat$WatershedBrush Run                                   -0.132018   0.214766  -0.615 0.539975
dat$WatershedBurgetts Fork                               -0.159789   0.251266  -0.636 0.526092
dat$WatershedChartiers Run                               -0.250206   0.293387  -0.853 0.395547
dat$WatershedDaniels Run                                  0.157140   0.416356   0.377 0.706565
dat$WatershedEnlow Fork                                   1.353129   0.283772   4.768 5.53e-06 ***
dat$WatershedFishpot Run-Monongahela River               -0.010255   0.343669  -0.030 0.976246
dat$WatershedHarmon Creek                                -0.014472   0.561650  -0.026 0.979488
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.230796   0.409087  -0.564 0.573744
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       0.022992   0.264687   0.087 0.930932
dat$WatershedLittle Racoon Creek                         -0.127467   0.632776  -0.201 0.840712
dat$WatershedLittle Tenmile Creek                         0.114933   0.270702   0.425 0.671947
dat$WatershedMingo Creek-Monongahela River                0.058510   0.362699   0.161 0.872129
dat$WatershedNorth Fork Cross Creek                      -0.118963   0.243364  -0.489 0.625904
dat$WatershedPigeon Creek                                 0.290952   0.304731   0.955 0.341708
dat$WatershedPike Run                                     0.111984   0.297690   0.376 0.707484
dat$WatershedPlum Run-Tenmile Creek                       0.177514   0.263998   0.672 0.502686
dat$WatershedShort Creek-Tenmile Creek                    0.151348   0.219133   0.691 0.491179
dat$WatershedSouth Fork Cross Creek-Cross Creek          -0.081274   0.196280  -0.414 0.679599
dat$WatershedTempleton Fork                               0.873908   0.232066   3.766 0.000264 ***
dat$WatershedUpper Chartiers Creek                       -0.201365   0.200320  -1.005 0.316922
dat$FormationCasselman Formation                          0.252004   0.456829   0.552 0.582277
dat$FormationGreene Formation                             0.086871   0.155153   0.560 0.576641
dat$FormationMonongahela Group                            0.148985   0.162405   0.917 0.360888
dat$FormationWaynesburg Formation                         0.090690   0.125690   0.722 0.472057
dat$HHWSourceMix                                         -0.099014   0.303405  -0.326 0.744762
dat$HHWSourceSpring                                      -0.145221   0.099409  -1.461 0.146810
dat$Precip_inchAvg                                       -0.021813   0.025442  -0.857 0.393040
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.2011234)

    Null deviance: 33.365  on 144  degrees of freedom
Residual deviance: 22.928  on 114  degrees of freedom
AIC: 208.06

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Arsenic"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
      Min         1Q     Median         3Q        Max  
-0.029434  -0.004408  -0.001059   0.000736   0.058817  

Coefficients:
                                                            Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                                9.850e-01  3.459e-02  28.477  < 2e-16 ***
dat$GWellDensity_2kmAvg                                    6.463e-05  2.138e-04   0.302  0.76293    
dat$Altitude_meter                                        -2.563e-06  5.867e-05  -0.044  0.96523    
dat$WatershedBane Creek                                   -6.164e-03  7.330e-03  -0.841  0.40213    
dat$WatershedBrush Run                                    -4.380e-03  6.024e-03  -0.727  0.46865    
dat$WatershedBurgetts Fork                                -6.755e-03  7.048e-03  -0.959  0.33983    
dat$WatershedChartiers Run                                -9.889e-03  8.229e-03  -1.202  0.23199    
dat$WatershedDaniels Run                                   2.638e-03  1.168e-02   0.226  0.82171    
dat$WatershedEnlow Fork                                    2.633e-02  7.960e-03   3.308  0.00126 ** 
dat$WatershedFishpot Run-Monongahela River                -3.813e-03  9.640e-03  -0.396  0.69319    
dat$WatershedHarmon Creek                                 -2.193e-03  1.575e-02  -0.139  0.88952    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -7.891e-03  1.147e-02  -0.688  0.49303    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       -8.463e-04  7.424e-03  -0.114  0.90944    
dat$WatershedLittle Racoon Creek                          -3.700e-03  1.775e-02  -0.208  0.83525    
dat$WatershedLittle Tenmile Creek                          2.066e-03  7.593e-03   0.272  0.78608    
dat$WatershedMingo Creek-Monongahela River                -7.063e-05  1.017e-02  -0.007  0.99447    
dat$WatershedNorth Fork Cross Creek                       -5.014e-03  6.826e-03  -0.735  0.46412    
dat$WatershedPigeon Creek                                  7.194e-03  8.547e-03   0.842  0.40174    
dat$WatershedPike Run                                      1.520e-03  8.350e-03   0.182  0.85585    
dat$WatershedPlum Run-Tenmile Creek                        3.971e-03  7.405e-03   0.536  0.59280    
dat$WatershedShort Creek-Tenmile Creek                     5.001e-03  6.146e-03   0.814  0.41757    
dat$WatershedSouth Fork Cross Creek-Cross Creek           -2.033e-03  5.505e-03  -0.369  0.71262    
dat$WatershedTempleton Fork                                3.247e-02  6.509e-03   4.988 2.21e-06 ***
dat$WatershedUpper Chartiers Creek                        -7.495e-03  5.619e-03  -1.334  0.18487    
dat$FormationCasselman Formation                           6.371e-03  1.281e-02   0.497  0.61998    
dat$FormationGreene Formation                              6.660e-03  4.352e-03   1.530  0.12870    
dat$FormationMonongahela Group                             5.834e-03  4.555e-03   1.281  0.20290    
dat$FormationWaynesburg Formation                          3.553e-03  3.525e-03   1.008  0.31574    
dat$HHWSourceMix                                          -4.282e-03  8.510e-03  -0.503  0.61583    
dat$HHWSourceSpring                                       -5.222e-03  2.788e-03  -1.873  0.06365 .  
dat$Precip_inchAvg                                        -6.198e-04  7.136e-04  -0.869  0.38691    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.0001582338)

    Null deviance: 0.028092  on 144  degrees of freedom
Residual deviance: 0.018039  on 114  degrees of freedom
AIC: -828.34

Number of Fisher Scoring iterations: 2
```

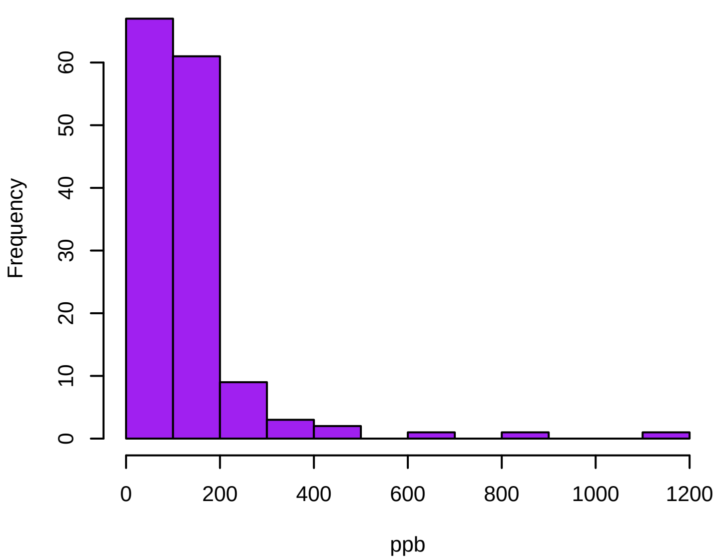
Barium

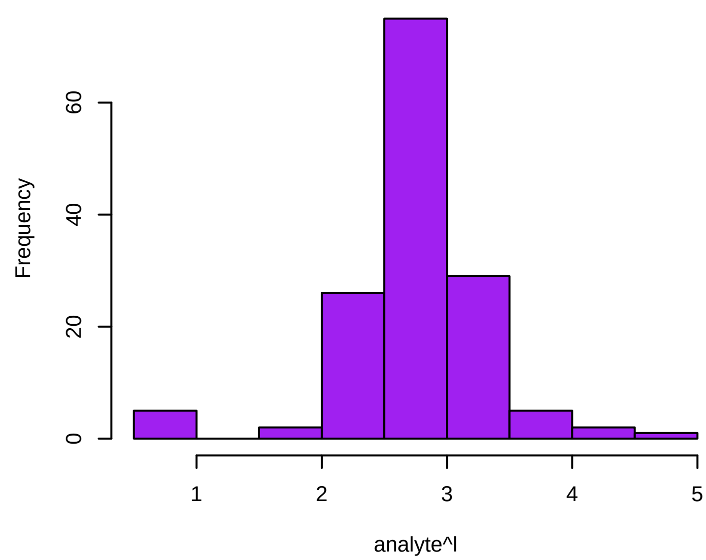
Skewness: 4.2177
Kurtosis: 26.3823

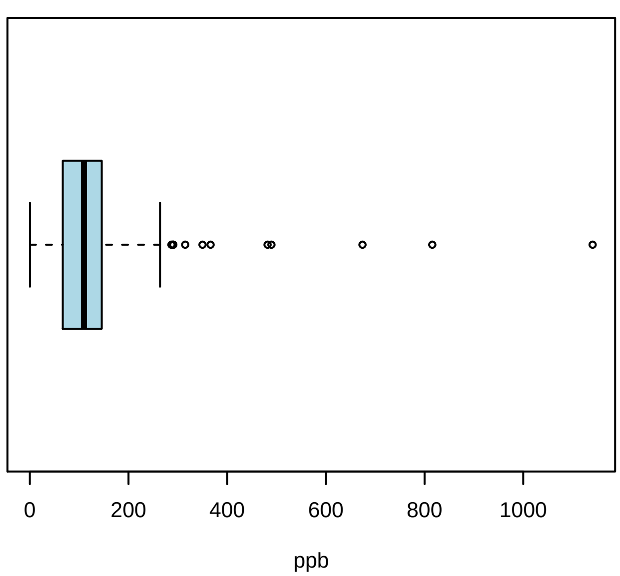
Barium Box−Cox

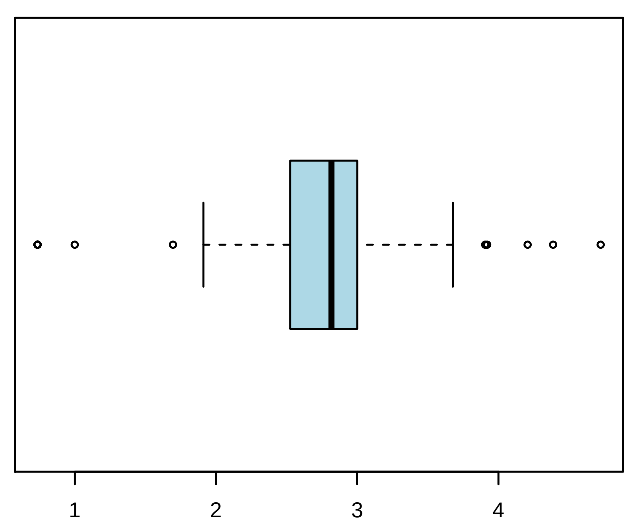
Skewness: −0.7065
Kurtosis: 7.0711

Optimal lambda: 0.2206



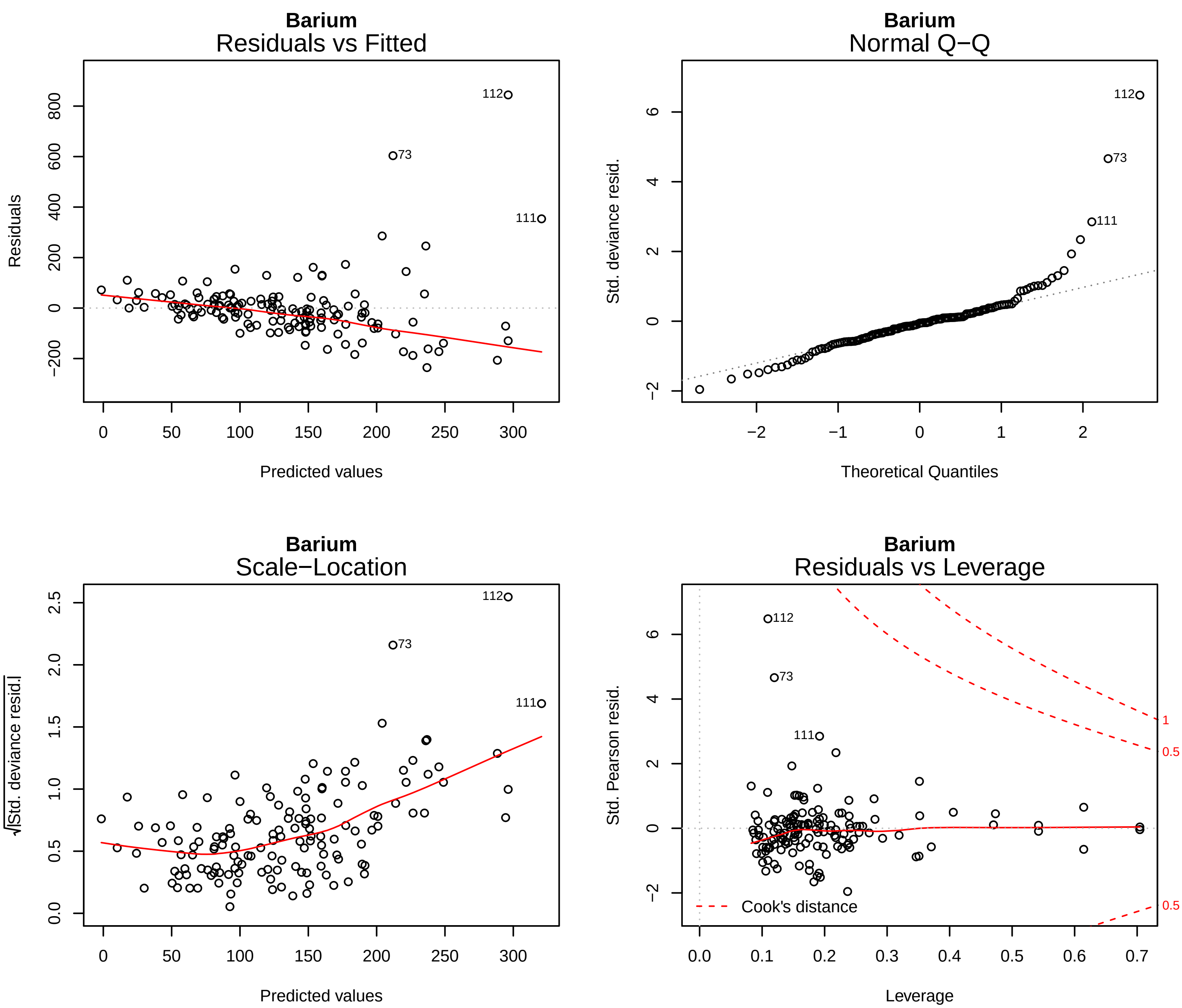






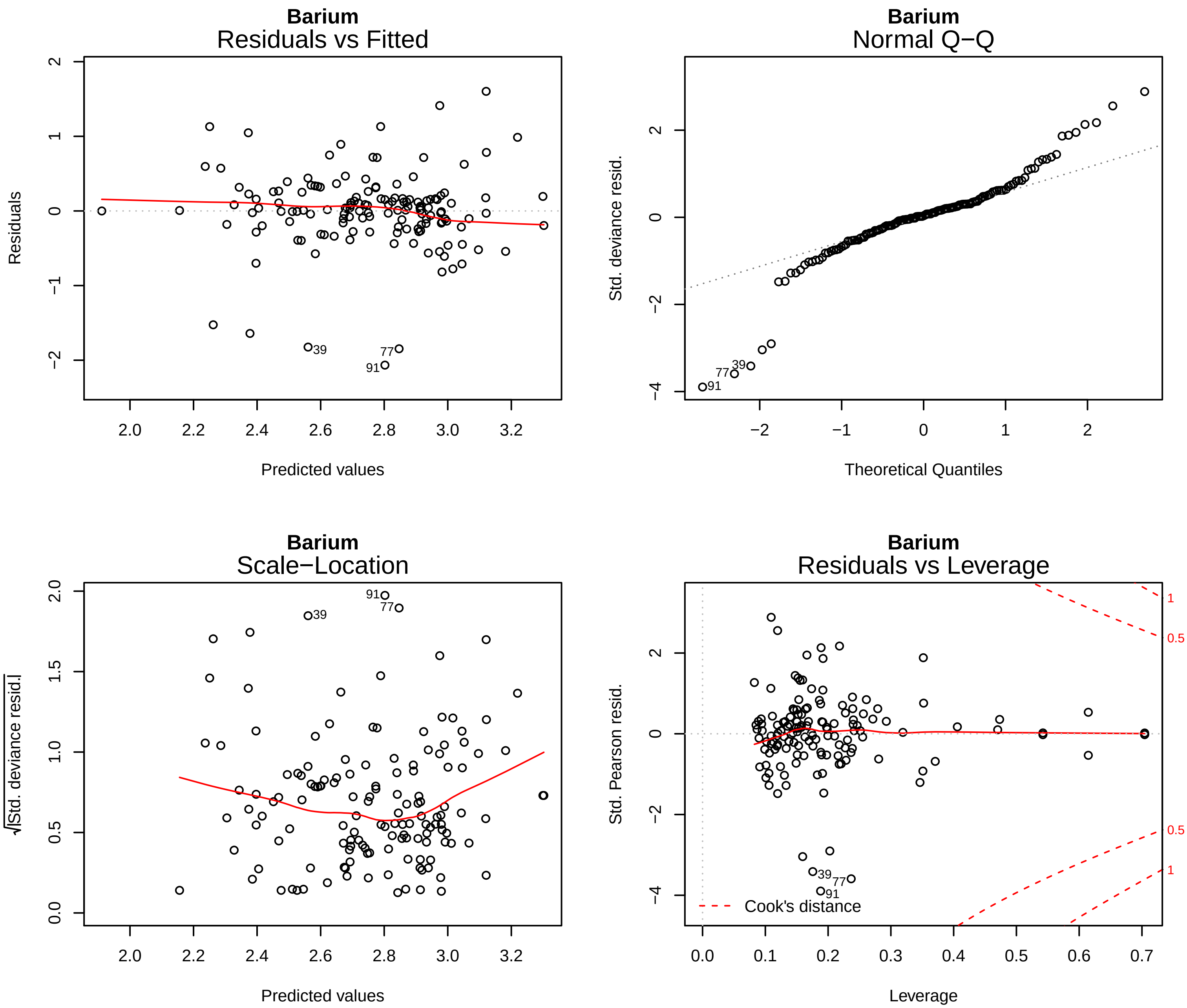
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

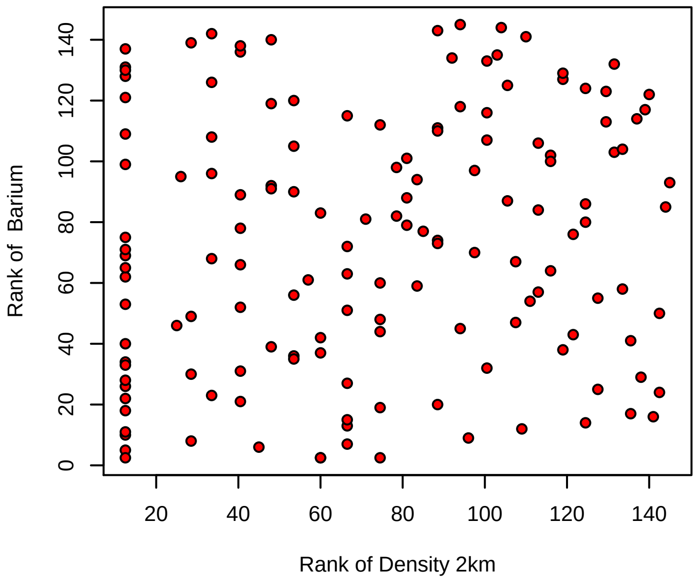
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



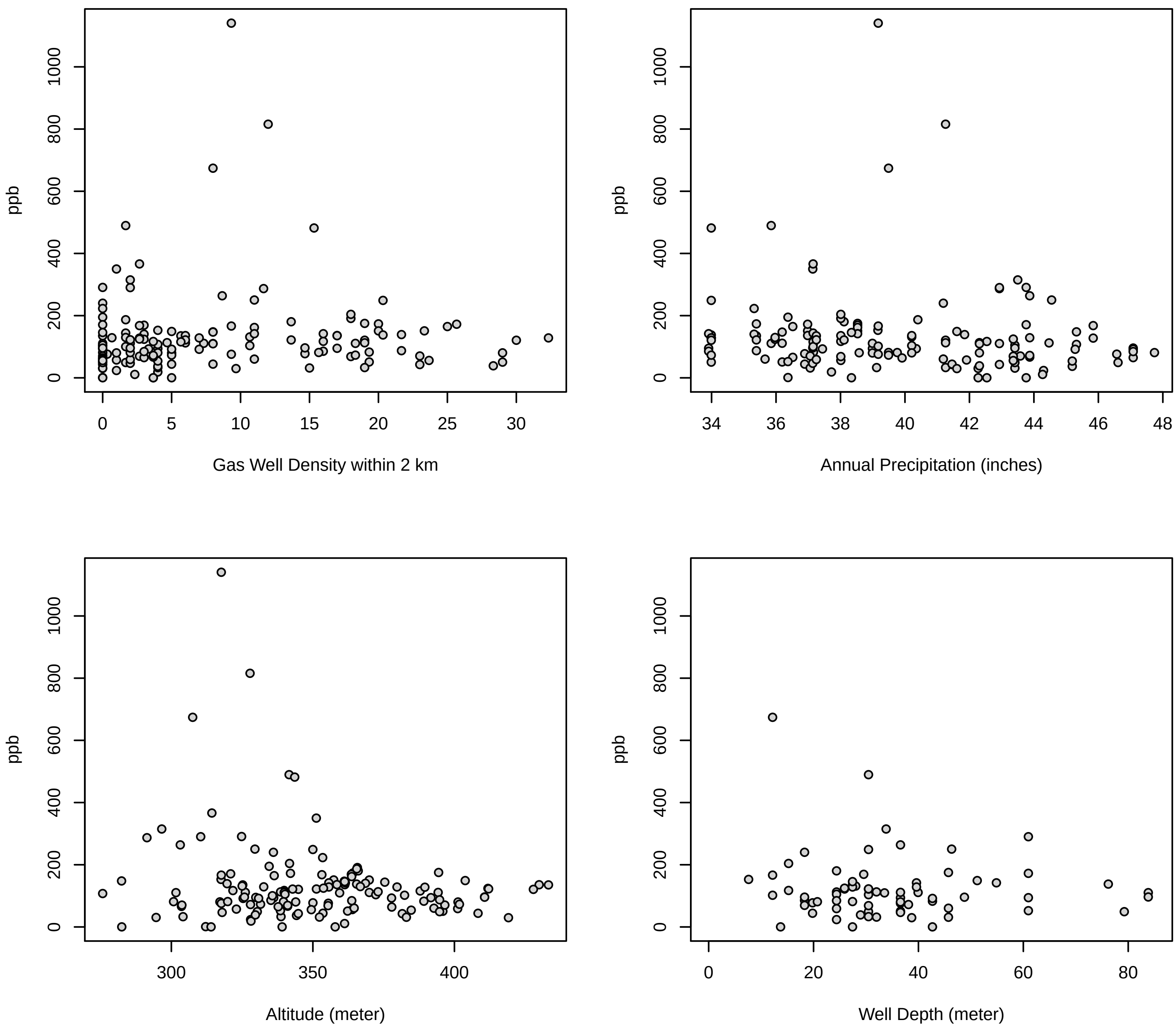


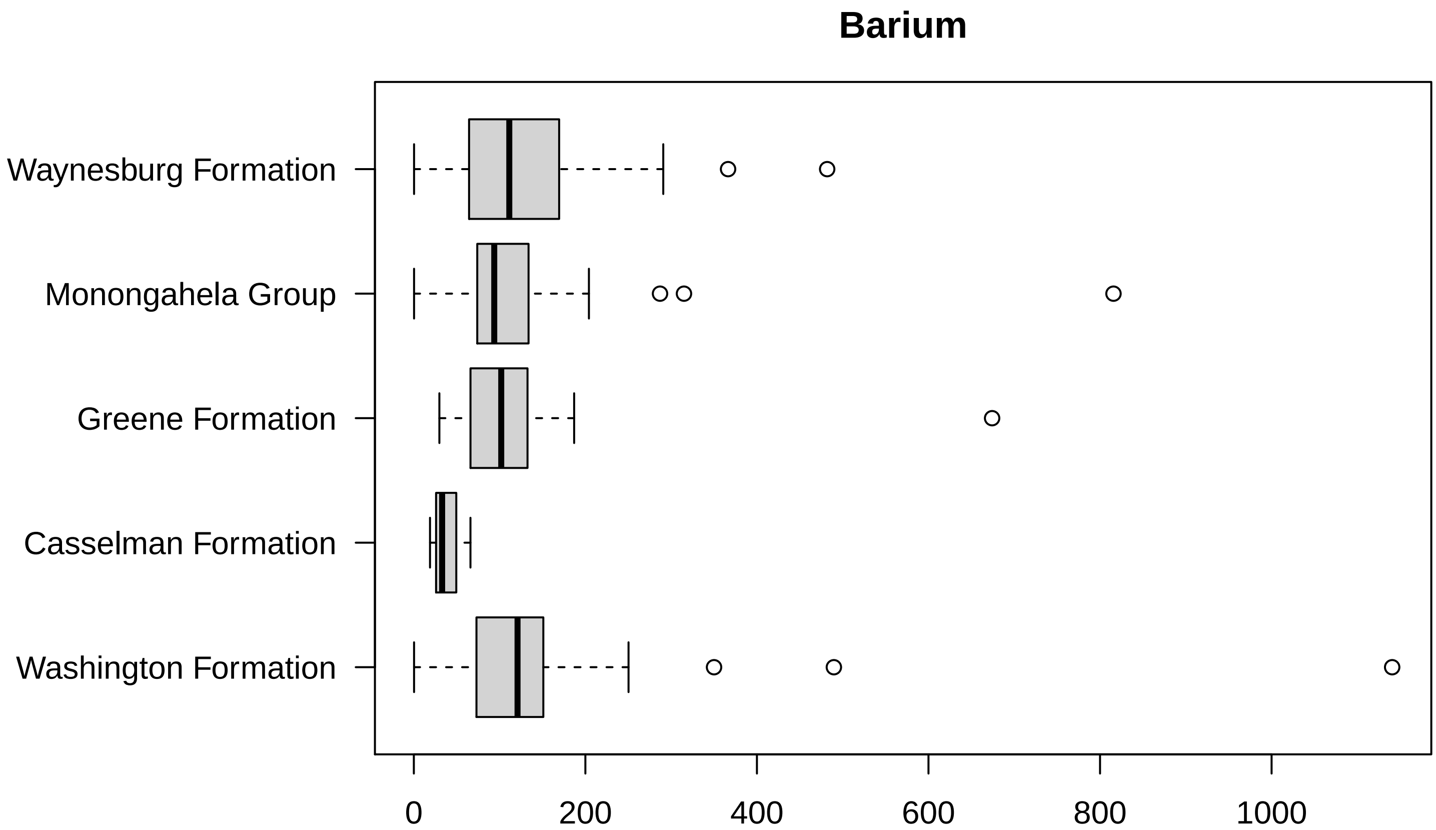
Barium

Kendalls Tau Rank Correlation

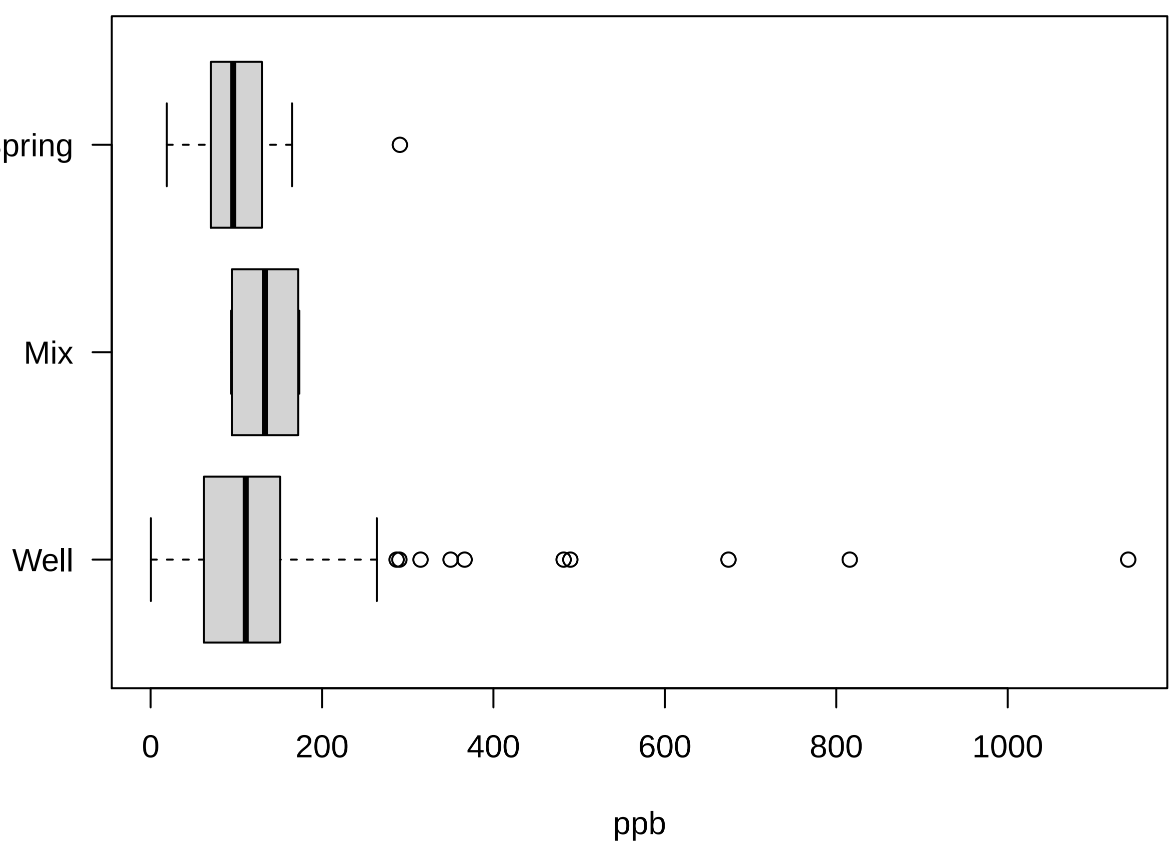
p−value: 0.0846

Tau: 0.0986

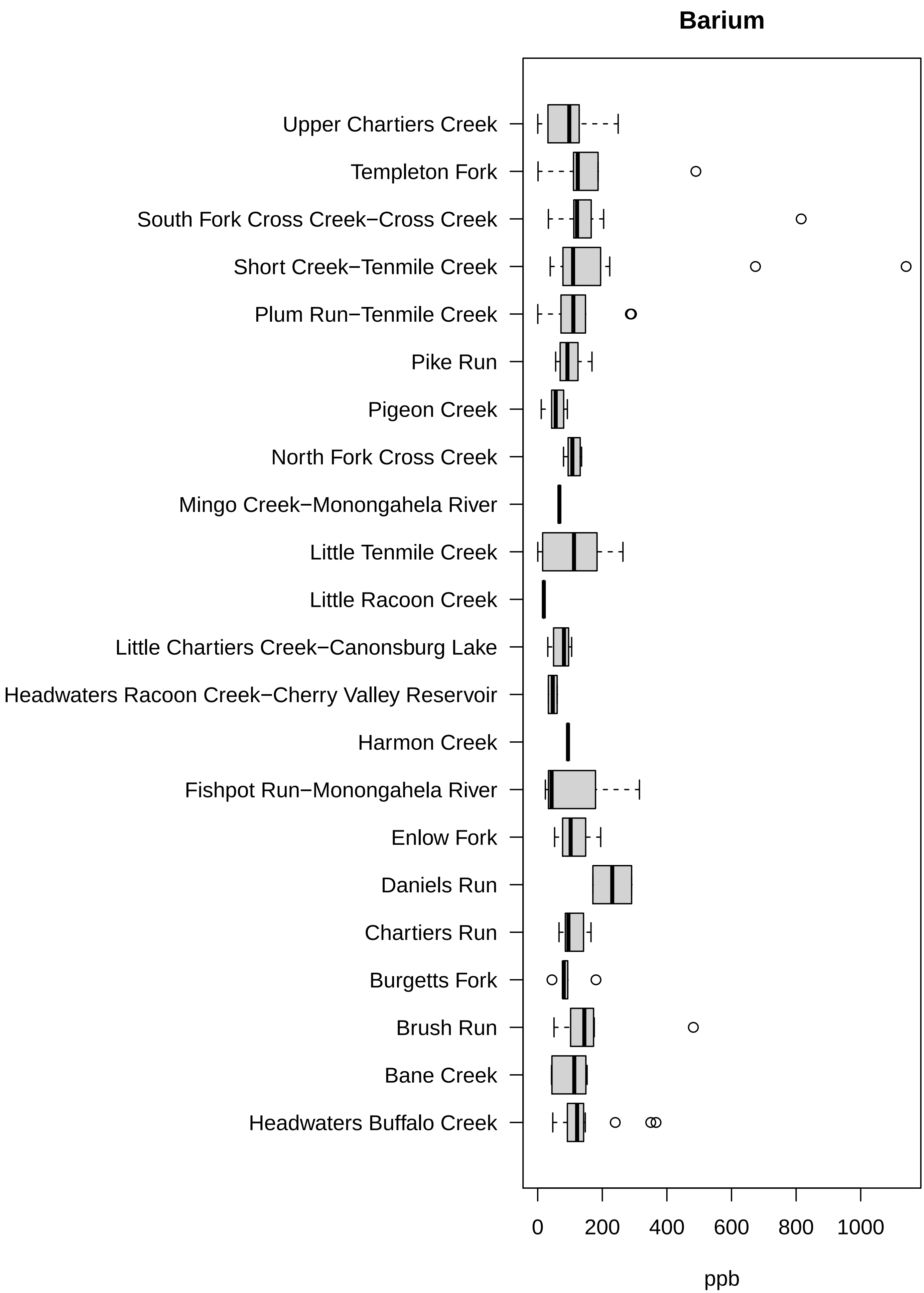




Barium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
200
400
600
800
1000



Spring
Mix
Well
0
200
400
600
800
1000
ppb


Barium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
200
400
600
800
1000
ppb

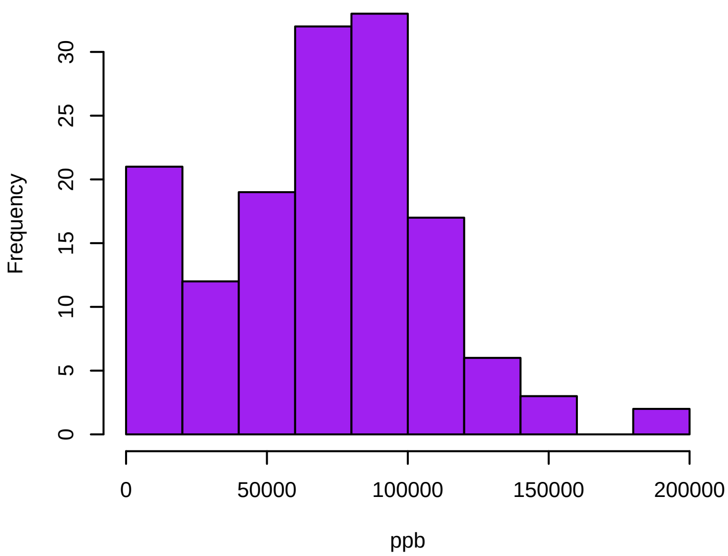
```
[1] "ORIGINAL MODEL - Barium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-235.82   -57.38    -6.63    29.78   844.36

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  635.2239   379.4534   1.674   0.0969 .
dat$GWellDensity_2kmAvg                                       -2.5831     2.3451  -1.101   0.2730
dat$Altitude_meter                                            -1.0129     0.6437  -1.574   0.1183
dat$WatershedBane Creek                                      -20.8995    80.4129  -0.260   0.7954
dat$WatershedBrush Run                                        68.3100    66.0868   1.034   0.3035
dat$WatershedBurgetts Fork                                   -62.1140    77.3183  -0.803   0.4234
dat$WatershedChartiers Run                                   -32.1907    90.2796  -0.357   0.7221
dat$WatershedDaniels Run                                      93.5082   128.1190   0.730   0.4670
dat$WatershedEnlow Fork                                      -46.6770    87.3209  -0.535   0.5940
dat$WatershedFishpot Run-Monongahela River                   -76.1752   105.7522  -0.720   0.4728
dat$WatershedHarmon Creek                                    -38.7172   172.8282  -0.224   0.8231
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -61.2381   125.8823  -0.486   0.6276
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          -76.2081    81.4481  -0.936   0.3514
dat$WatershedLittle Racoon Creek                               6.8418   194.7147   0.035   0.9720
dat$WatershedLittle Tenmile Creek                            -57.0695    83.2990  -0.685   0.4947
dat$WatershedMingo Creek-Monongahela River                   -89.9962   111.6078  -0.806   0.4217
dat$WatershedNorth Fork Cross Creek                          -42.3612    74.8869  -0.566   0.5727
dat$WatershedPigeon Creek                                   -100.9390    93.7703  -1.076   0.2840
dat$WatershedPike Run                                        -34.5896    91.6037  -0.378   0.7064
dat$WatershedPlum Run-Tenmile Creek                          -51.6205    81.2363  -0.635   0.5264
dat$WatershedShort Creek-Tenmile Creek                       111.9853    67.4306   1.661   0.0995 .
dat$WatershedSouth Fork Cross Creek-Cross Creek               33.6303    60.3983   0.557   0.5787
dat$WatershedTempleton Fork                                   15.3675    71.4102   0.215   0.8300
dat$WatershedUpper Chartiers Creek                           -28.7681    61.6414  -0.467   0.6416
dat$FormationCasselman Formation                            -120.6793   140.5731  -0.858   0.3924
dat$FormationGreene Formation                                 11.6346    47.7430   0.244   0.8079
dat$FormationMonongahela Group                                16.8872    49.9745   0.338   0.7360
dat$FormationWaynesburg Formation                             11.3149    38.6767   0.293   0.7704
dat$HHWSourceMix                                             -70.8542    93.3622  -0.759   0.4495
dat$HHWSourceSpring                                          -58.5833    30.5898  -1.915   0.0580 .
dat$Precip_inchAvg                                            -2.6842     7.8289  -0.343   0.7323
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 19044.08)

    Null deviance: 2754705  on 144  degrees of freedom
Residual deviance: 2171025  on 114  degrees of freedom
AIC: 1869.5

Number of Fisher Scoring iterations: 2
```

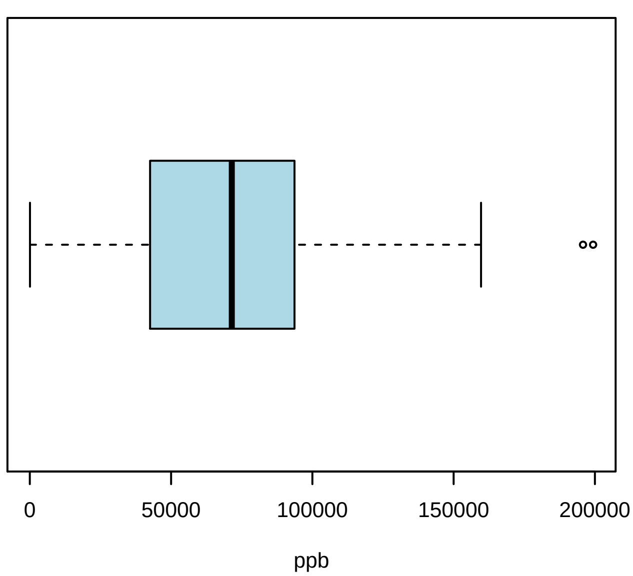
```
[1] "BOX-COX MODEL - Barium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-2.06570  -0.19484   0.01166   0.19484   1.60271

Coefficients:
                                                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                 4.304014   1.618149   2.660  0.00894 **
dat$GWellDensity_2kmAvg                                    -0.001398   0.010000  -0.140  0.88905
dat$Altitude_meter                                         -0.002178   0.002745  -0.794  0.42906
dat$WatershedBane Creek                                    -0.160354   0.342915  -0.468  0.64095
dat$WatershedBrush Run                                      0.099128   0.281822   0.352  0.72568
dat$WatershedBurgetts Fork                                 -0.230035   0.329718  -0.698  0.48680
dat$WatershedChartiers Run                                 -0.093785   0.384990  -0.244  0.80798
dat$WatershedDaniels Run                                    0.451133   0.546353   0.826  0.41069
dat$WatershedEnlow Fork                                    -0.134648   0.372373  -0.362  0.71833
dat$WatershedFishpot Run-Monongahela River                 -0.282004   0.450972  -0.625  0.53301
dat$WatershedHarmon Creek                                  -0.111412   0.737012  -0.151  0.88011
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.418060   0.536815  -0.779  0.43772
dat$WatershedLittle Chartiers Creek-Canonsburg Lake        -0.304772   0.347329  -0.877  0.38207
dat$WatershedLittle Racoon Creek                           -0.558628   0.830345  -0.673  0.50246
dat$WatershedLittle Tenmile Creek                          -0.584197   0.355222  -1.645  0.10281
dat$WatershedMingo Creek-Monongahela River                 -0.310575   0.475943  -0.653  0.51536
dat$WatershedNorth Fork Cross Creek                        -0.051127   0.319349  -0.160  0.87309
dat$WatershedPigeon Creek                                  -0.435808   0.399876  -1.090  0.27807
dat$WatershedPike Run                                      -0.049618   0.390637  -0.127  0.89915
dat$WatershedPlum Run-Tenmile Creek                        -0.188202   0.346426  -0.543  0.58801
dat$WatershedShort Creek-Tenmile Creek                      0.168737   0.287552   0.587  0.55850
dat$WatershedSouth Fork Cross Creek-Cross Creek             0.074223   0.257564   0.288  0.77374
dat$WatershedTempleton Fork                                -0.176589   0.304523  -0.580  0.56314
dat$WatershedUpper Chartiers Creek                         -0.373406   0.262865  -1.421  0.15818
dat$FormationCasselman Formation                           -0.415726   0.599463  -0.693  0.48941
dat$FormationGreene Formation                               0.080227   0.203596   0.394  0.69428
dat$FormationMonongahela Group                              0.008879   0.213112   0.042  0.96684
dat$FormationWaynesburg Formation                           0.049669   0.164934   0.301  0.76385
dat$HHWSourceMix                                           -0.080558   0.398136  -0.202  0.84001
dat$HHWSourceSpring                                        -0.075016   0.130448  -0.575  0.56638
dat$Precip_inchAvg                                         -0.016518   0.033386  -0.495  0.62172
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.3463221)

    Null deviance: 48.169  on 144  degrees of freedom
Residual deviance: 39.481  on 114  degrees of freedom
AIC: 286.86

Number of Fisher Scoring iterations: 2
```

Calcium

Skewness: 0.2329

Kurtosis: 3.4356



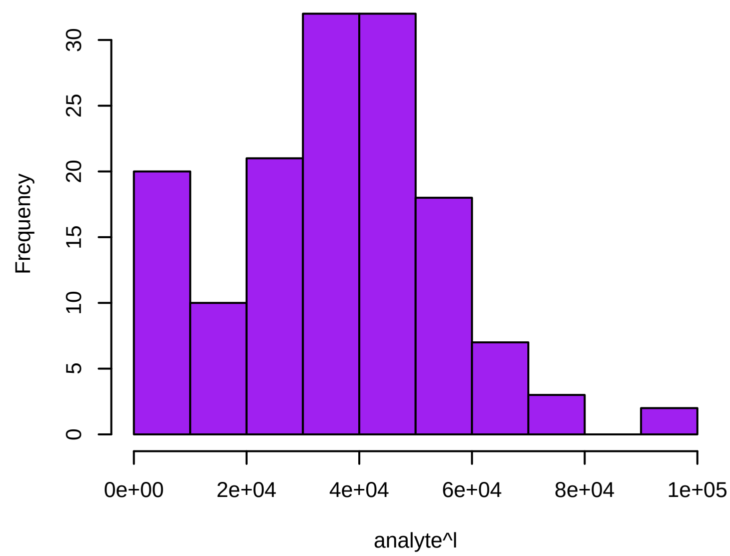


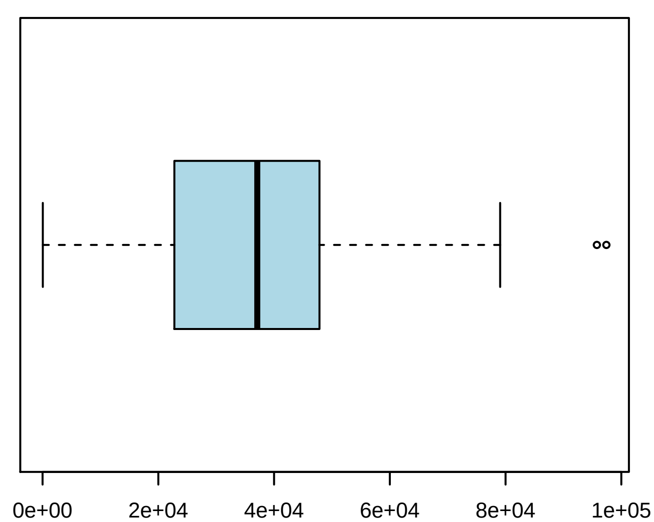
Calcium Box−Cox

Skewness: 0.1086

Kurtosis: 3.2783

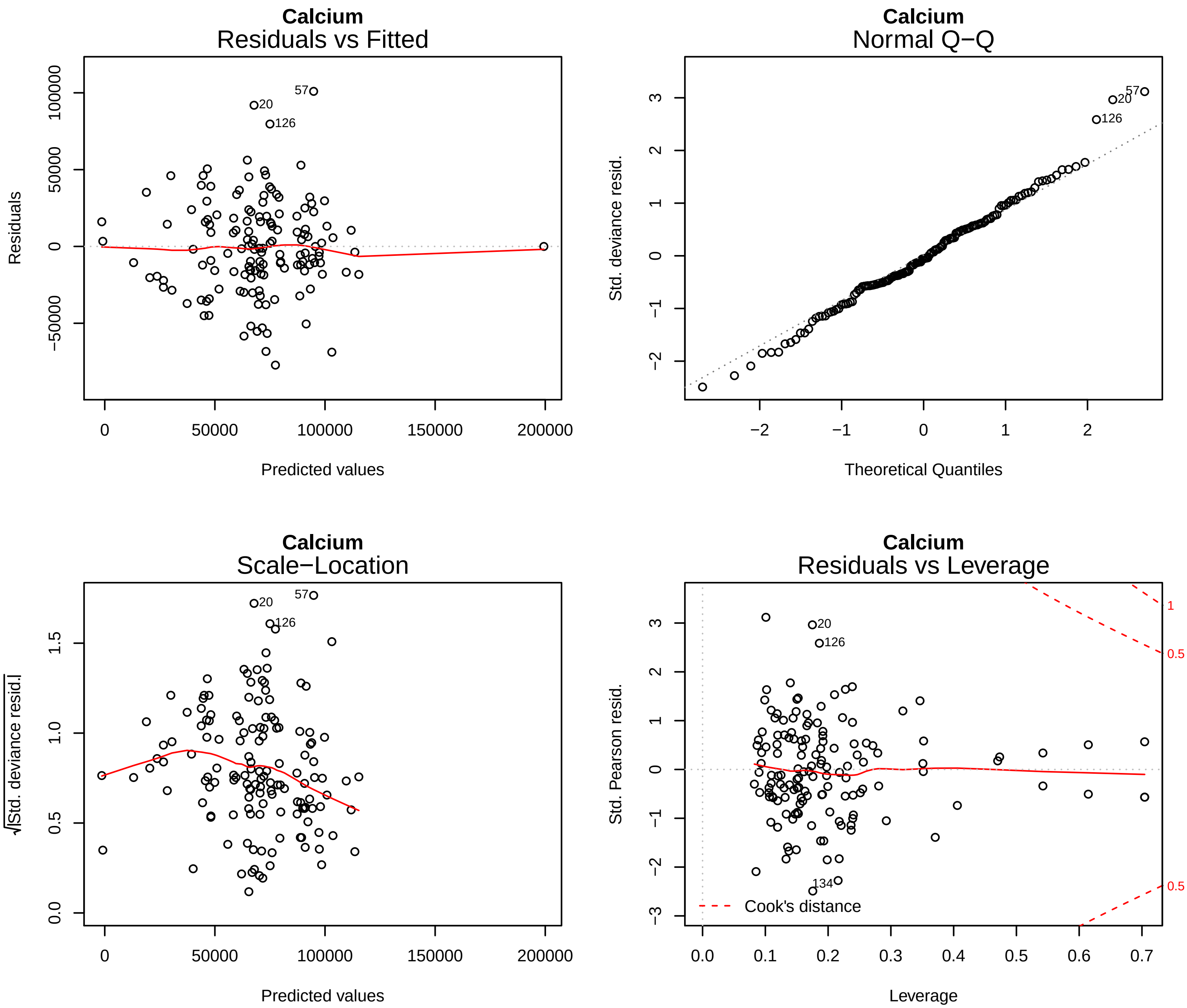
Optimal lambda: 0.9413





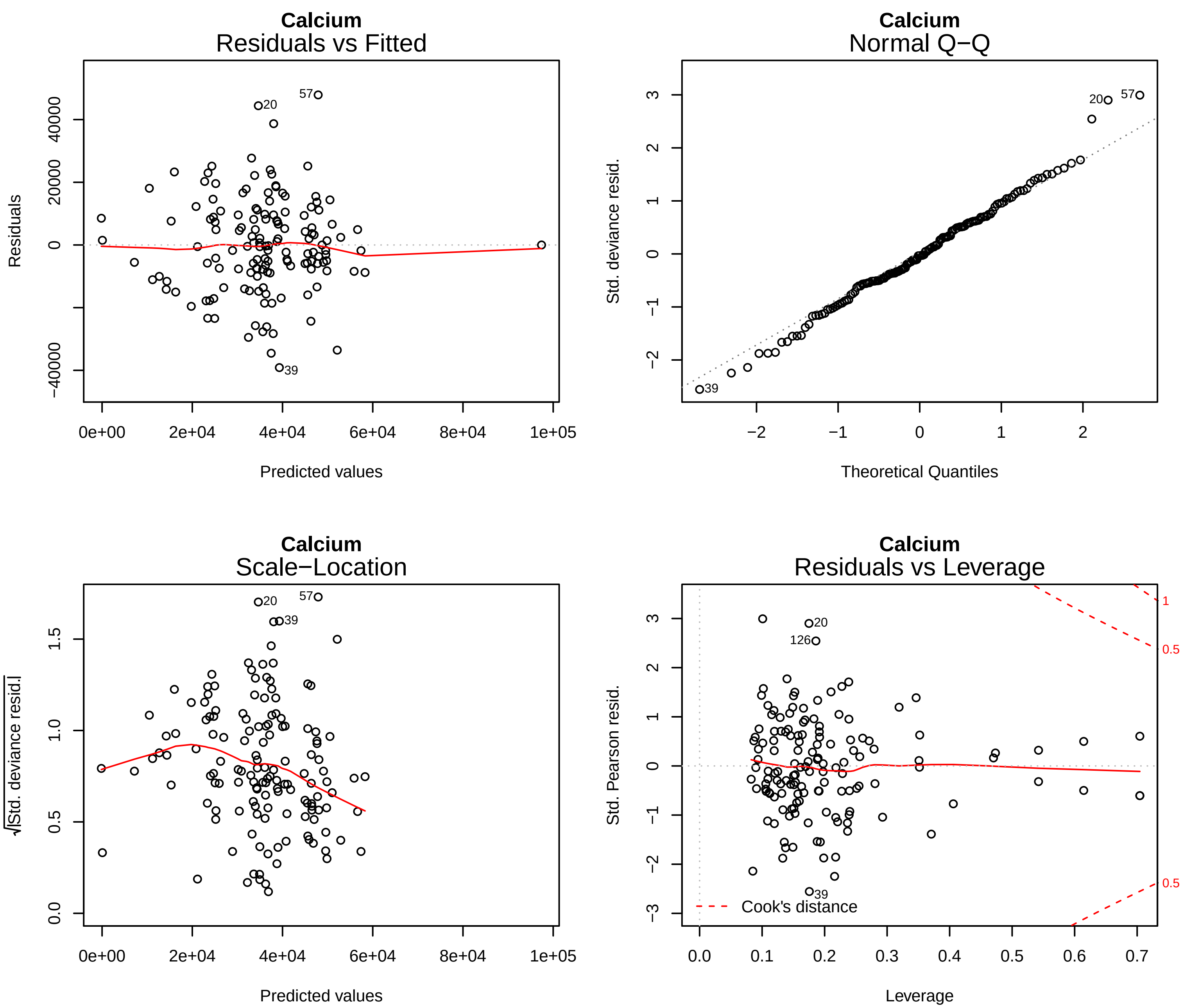
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

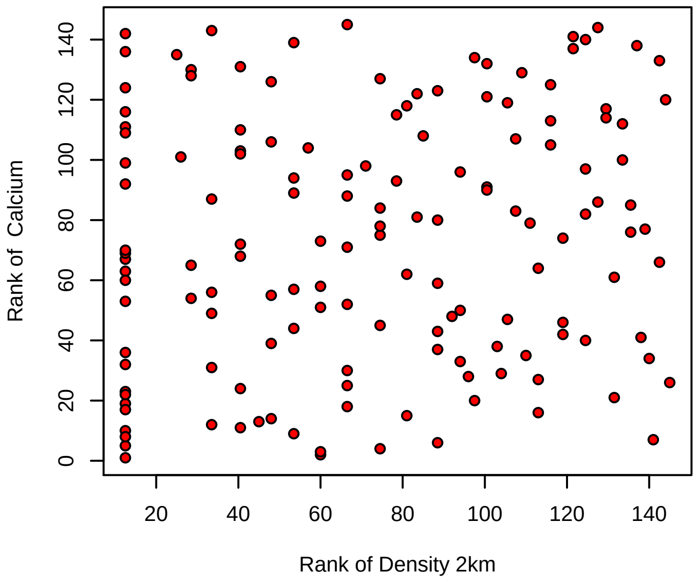
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



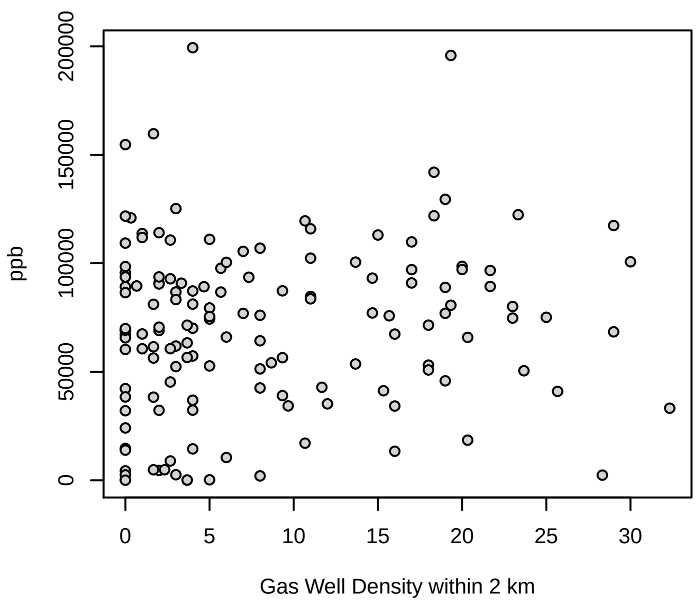


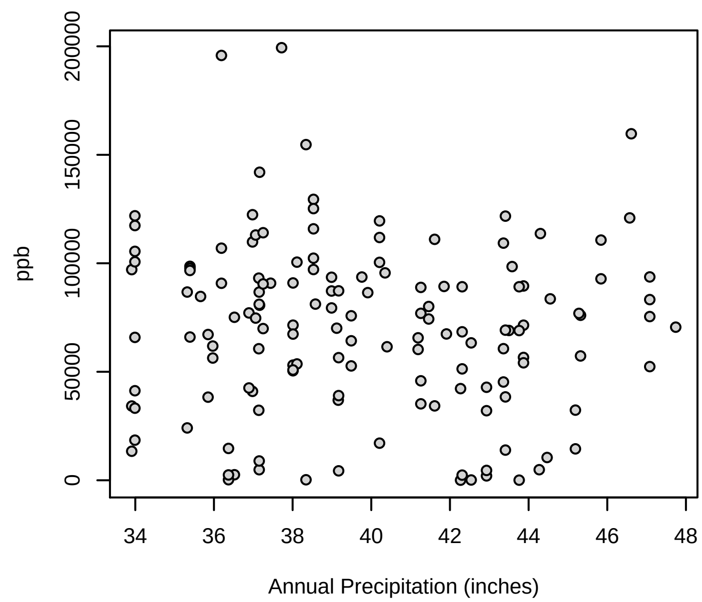
Calcium

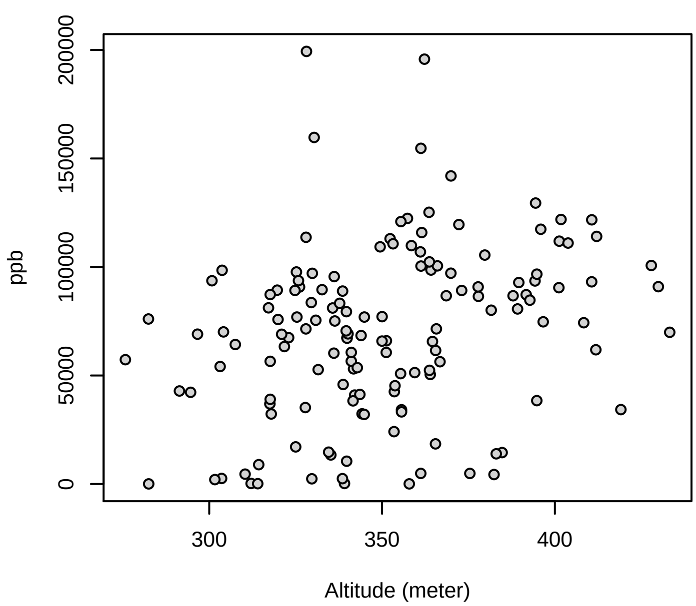
Kendalls Tau Rank Correlation

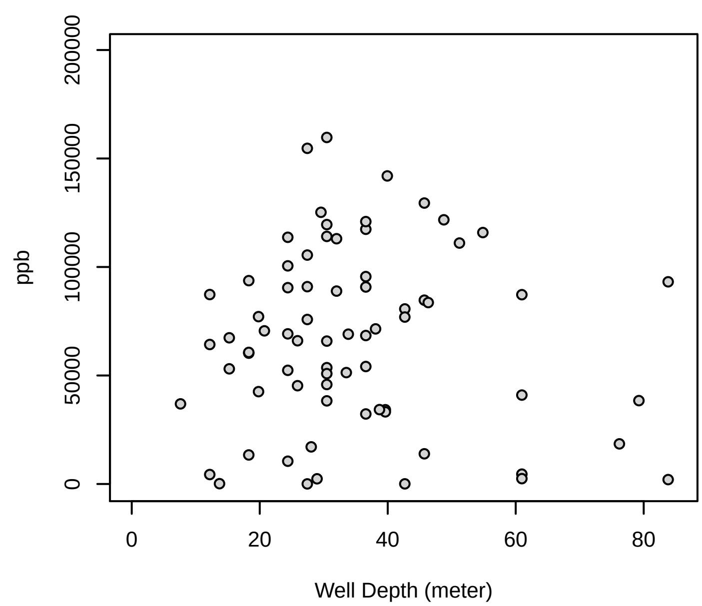
p−value: 0.119

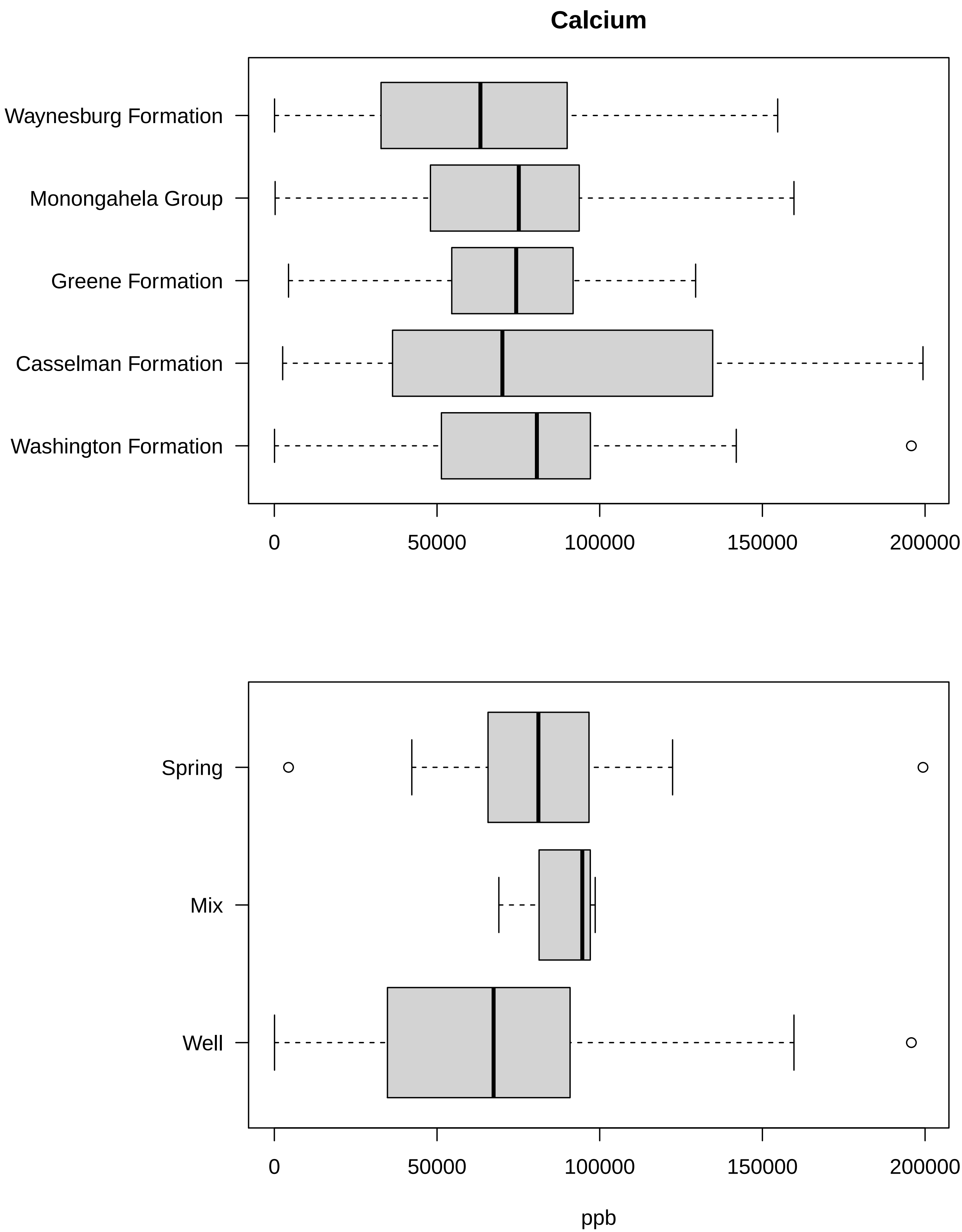
Tau: 0.089

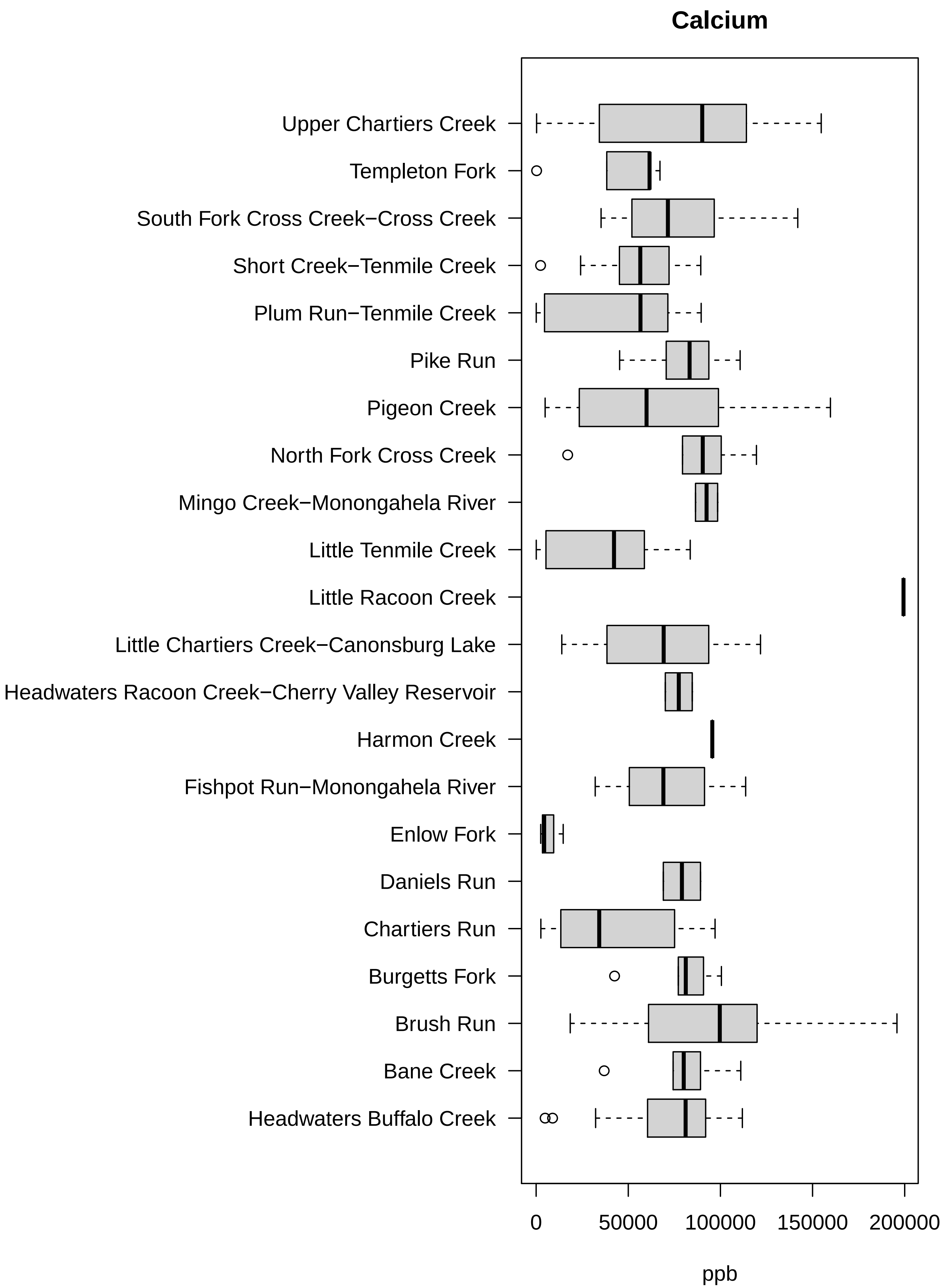









Calcium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
50000
100000
150000
200000
Spring
Mix
Well
0
50000
100000
150000
200000
ppb


Calcium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
50000
100000
150000
200000
ppb

```
[1] "ORIGINAL MODEL - Calcium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-77242  -17866   -1470   18410  100962

Coefficients:
                                                       Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               670.0    93903.6   0.007 0.994320
dat$GWellDensity_2kmAvg                                  -244.8      580.3  -0.422 0.673944
dat$Altitude_meter                                        120.3      159.3   0.756 0.451493
dat$WatershedBane Creek                                   686.2    19899.8   0.034 0.972554
dat$WatershedBrush Run                                  28240.2    16354.6   1.727 0.086921 .
dat$WatershedBurgetts Fork                              23743.7    19134.0   1.241 0.217184
dat$WatershedChartiers Run                                464.5    22341.6   0.021 0.983448
dat$WatershedDaniels Run                                 9780.0    31705.7   0.308 0.758295
dat$WatershedEnlow Fork                                -69481.8    21609.4  -3.215 0.001695 **
dat$WatershedFishpot Run-Monongahela River              17281.8    26170.6   0.660 0.510359
dat$WatershedHarmon Creek                               19984.3    42769.9   0.467 0.641211
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  45164.8    31152.2   1.450 0.149857
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     -9276.0    20156.0  -0.460 0.646241
dat$WatershedLittle Racoon Creek                       165098.5    48186.2   3.426 0.000852 ***
dat$WatershedLittle Tenmile Creek                      -27110.0    20614.1  -1.315 0.191109
dat$WatershedMingo Creek-Monongahela River              18307.4    27619.7   0.663 0.508772
dat$WatershedNorth Fork Cross Creek                     21949.3    18532.3   1.184 0.238727
dat$WatershedPigeon Creek                                8370.9    23205.4   0.361 0.718968
dat$WatershedPike Run                                   10453.1    22669.2   0.461 0.645595
dat$WatershedPlum Run-Tenmile Creek                    -21138.4    20103.6  -1.051 0.295266
dat$WatershedShort Creek-Tenmile Creek                 -17739.6    16687.1  -1.063 0.289996
dat$WatershedSouth Fork Cross Creek-Cross Creek         20586.5    14946.8   1.377 0.171113
dat$WatershedTempleton Fork                            -28027.3    17671.9  -1.586 0.115514
dat$WatershedUpper Chartiers Creek                      24011.4    15254.5   1.574 0.118245
dat$FormationCasselman Formation                       -51141.4    34787.7  -1.470 0.144290
dat$FormationGreene Formation                            -757.0    11815.0  -0.064 0.949027
dat$FormationMonongahela Group                         -15447.9    12367.2  -1.249 0.214188
dat$FormationWaynesburg Formation                      -21812.3     9571.3  -2.279 0.024534 *
dat$HHWSourceMix                                        19762.1    23104.4   0.855 0.394156
dat$HHWSourceSpring                                     18023.4     7570.1   2.381 0.018929 *
dat$Precip_inchAvg                                        747.6     1937.4   0.386 0.700321
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1166293433)

    Null deviance: 2.2134e+11  on 144  degrees of freedom
Residual deviance: 1.3296e+11  on 114  degrees of freedom
AIC: 3467.8

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Calcium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
   Min      1Q  Median      3Q     Max  
-39125   -8413    -439    9411   47877  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                                2306.39   46366.97   0.050  0.96041   
dat$GWellDensity_2kmAvg                                    -108.27     286.55  -0.378  0.70624   
dat$Altitude_meter                                           59.20      78.65   0.753  0.45319   
dat$WatershedBane Creek                                     339.96    9825.99   0.035  0.97246   
dat$WatershedBrush Run                                    13439.39    8075.42   1.664  0.09881 . 
dat$WatershedBurgetts Fork                                11873.57    9447.84   1.257  0.21141   
dat$WatershedChartiers Run                                  -53.29   11031.63  -0.005  0.99615   
dat$WatershedDaniels Run                                   4984.16   15655.39   0.318  0.75079   
dat$WatershedEnlow Fork                                  -35142.83   10670.10  -3.294  0.00132 **
dat$WatershedFishpot Run-Monongahela River                 8816.04   12922.30   0.682  0.49647   
dat$WatershedHarmon Creek                                  9833.24   21118.60   0.466  0.64238   
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  22811.62   15382.08   1.483  0.14083   
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       -4547.43    9952.47  -0.457  0.64860   
dat$WatershedLittle Racoon Creek                          79246.26   23792.99   3.331  0.00117 **
dat$WatershedLittle Tenmile Creek                        -13645.54   10178.65  -1.341  0.18271   
dat$WatershedMingo Creek-Monongahela River                 9229.28   13637.82   0.677  0.49994   
dat$WatershedNorth Fork Cross Creek                       10919.18    9150.74   1.193  0.23525   
dat$WatershedPigeon Creek                                  4062.96   11458.18   0.355  0.72355   
dat$WatershedPike Run                                      5386.24   11193.43   0.481  0.63130   
dat$WatershedPlum Run-Tenmile Creek                      -10570.13    9926.60  -1.065  0.28920   
dat$WatershedShort Creek-Tenmile Creek                    -8764.98    8239.62  -1.064  0.28969   
dat$WatershedSouth Fork Cross Creek-Cross Creek           10231.11    7380.31   1.386  0.16837   
dat$WatershedTempleton Fork                              -13877.68    8725.91  -1.590  0.11451   
dat$WatershedUpper Chartiers Creek                        11492.74    7532.22   1.526  0.12983   
dat$FormationCasselman Formation                         -25655.10   17177.21  -1.494  0.13805   
dat$FormationGreene Formation                              -155.04    5833.91  -0.027  0.97885   
dat$FormationMonongahela Group                            -7595.54    6106.60  -1.244  0.21612   
dat$FormationWaynesburg Formation                        -10712.96    4726.06  -2.267  0.02529 * 
dat$HHWSourceMix                                          10051.95   11408.31   0.881  0.38011   
dat$HHWSourceSpring                                        9186.48    3737.89   2.458  0.01549 * 
dat$Precip_inchAvg                                          353.71     956.64   0.370  0.71226   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 284354853)

    Null deviance: 5.4038e+10  on 144  degrees of freedom
Residual deviance: 3.2416e+10  on 114  degrees of freedom
AIC: 3263.1

Number of Fisher Scoring iterations: 2
```

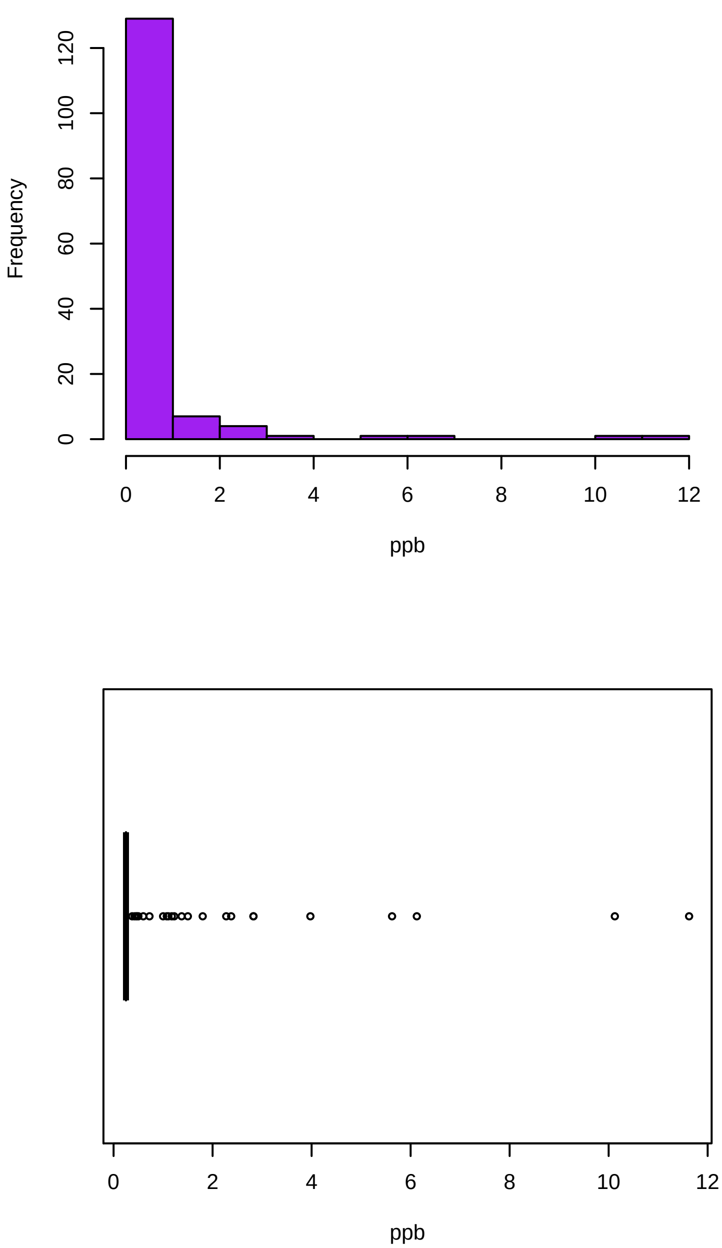
Chromium

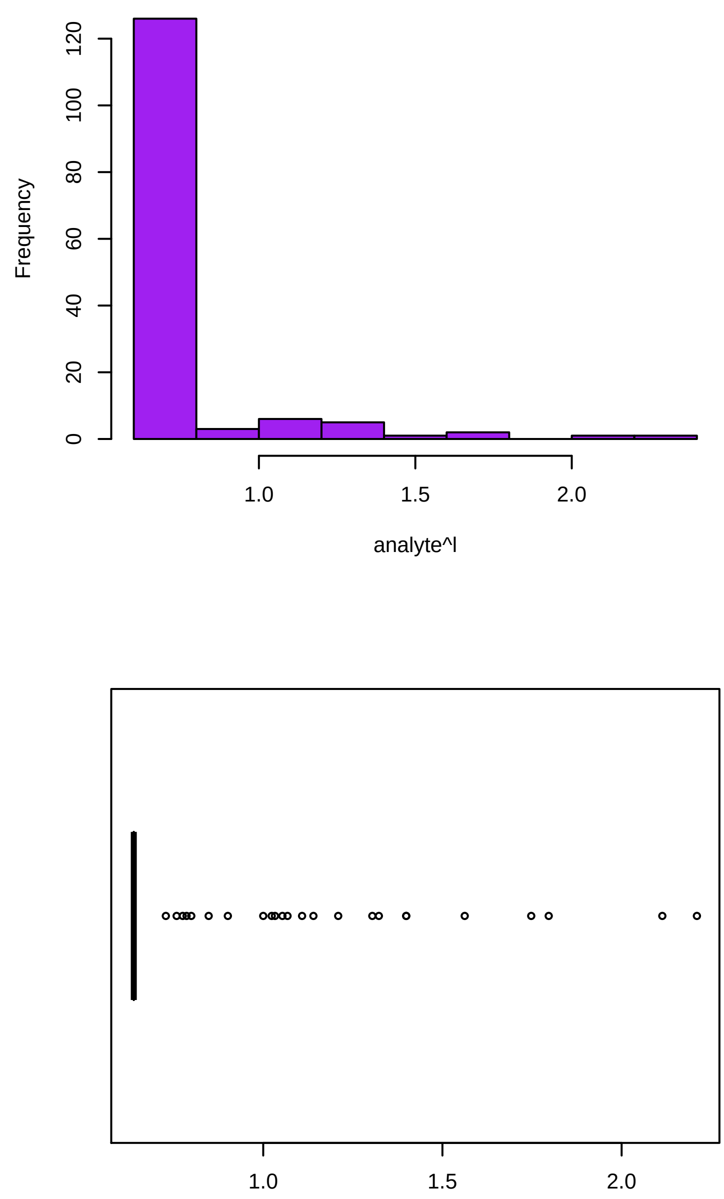
Skewness: 5.4834
Kurtosis: 35.8647

Chromium Box−Cox

Skewness: 3.4493
Kurtosis: 15.3782

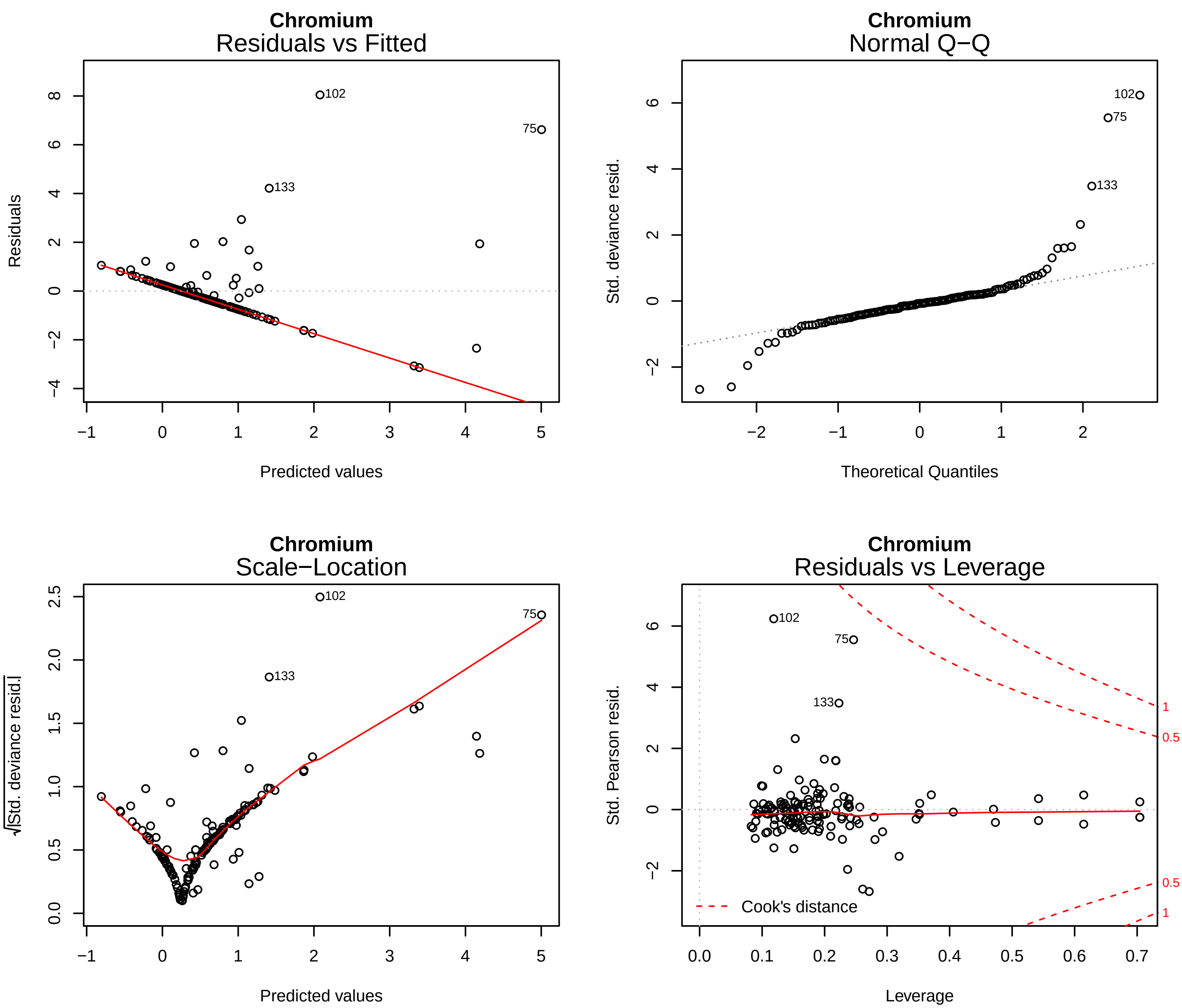
Optimal lambda: 0.3233





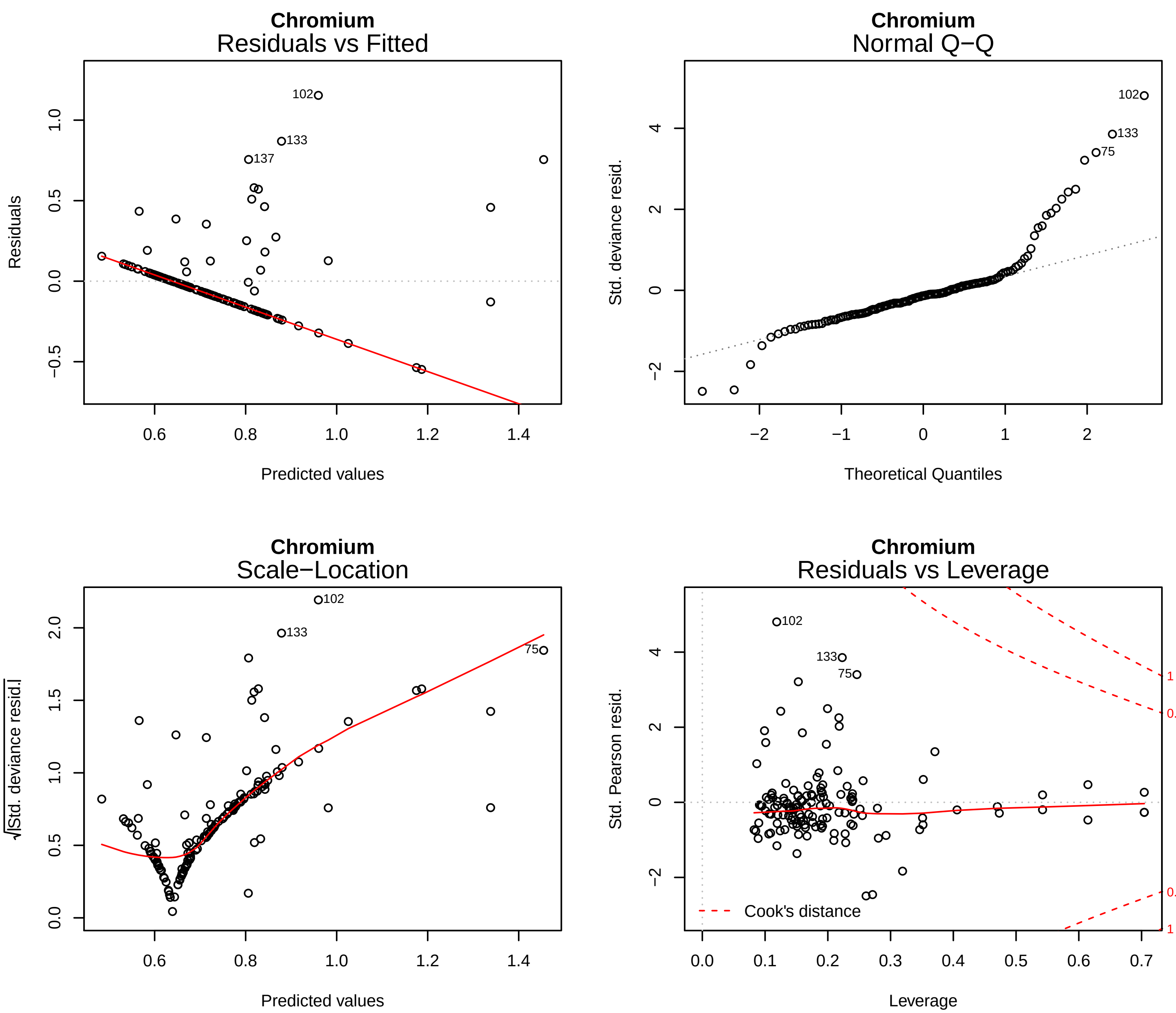
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

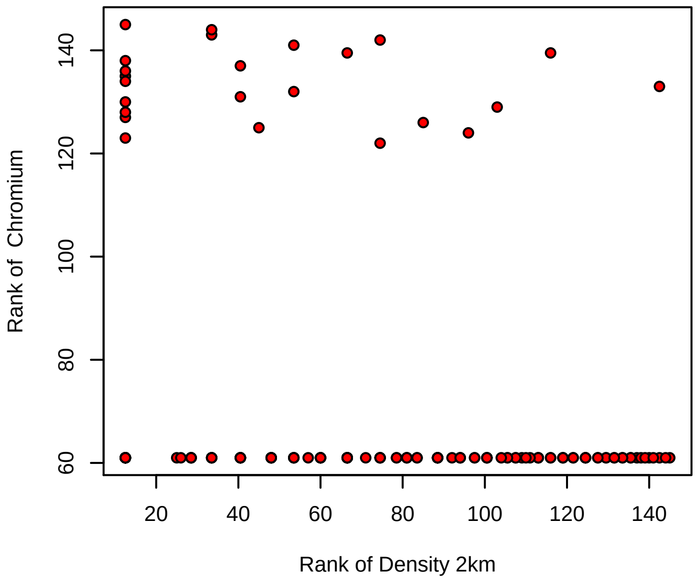
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



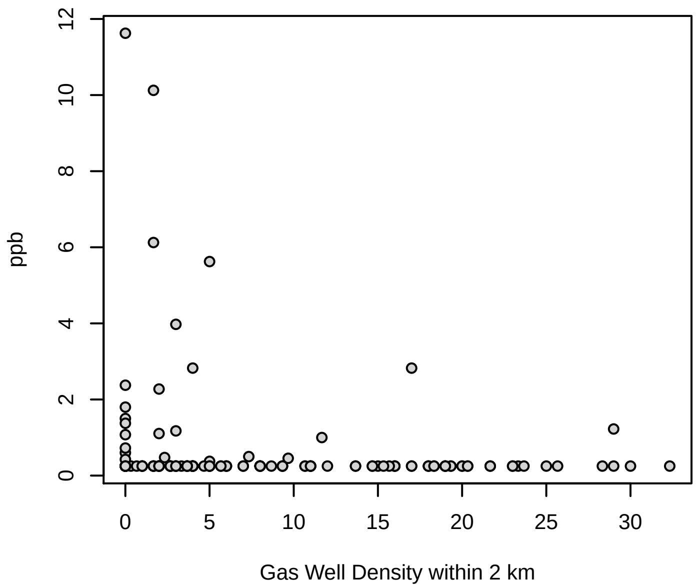


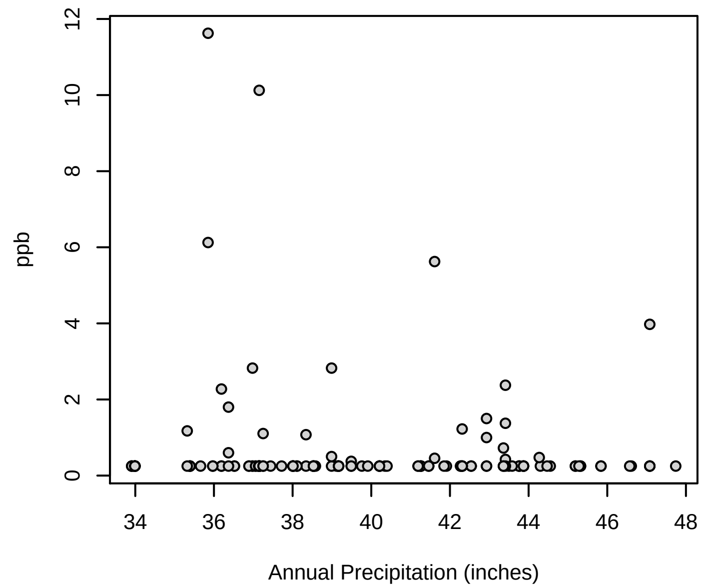
Chromium

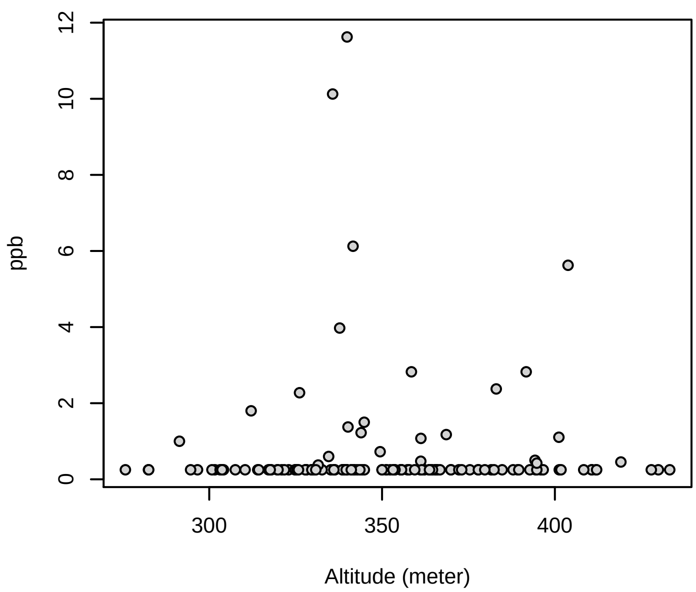
Kendalls Tau Rank Correlation

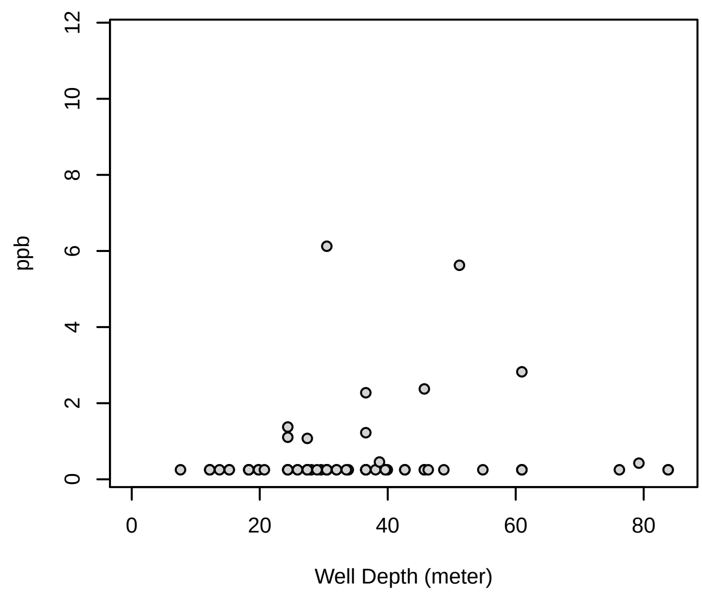
p−value: 0.00178

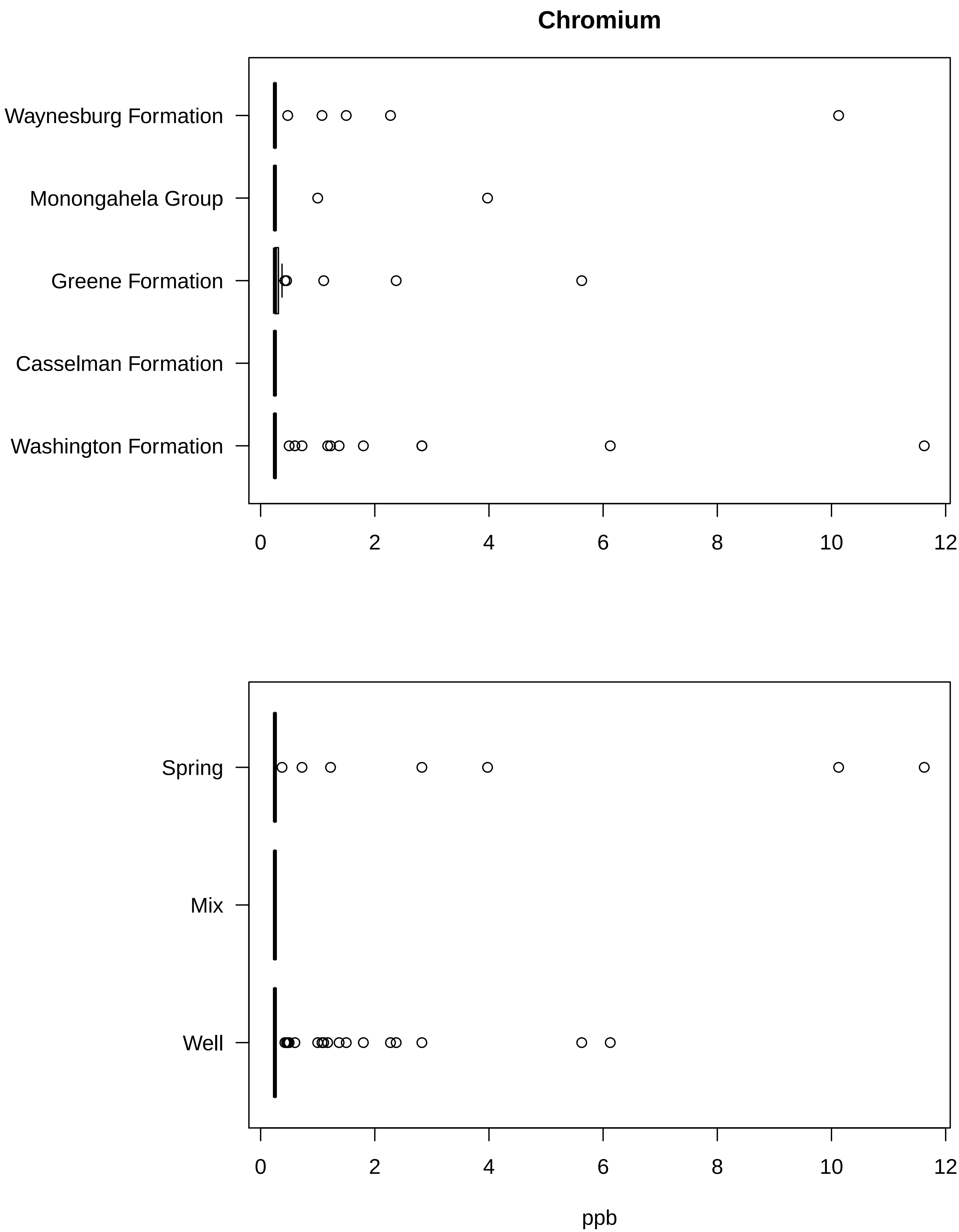
Tau: −0.209



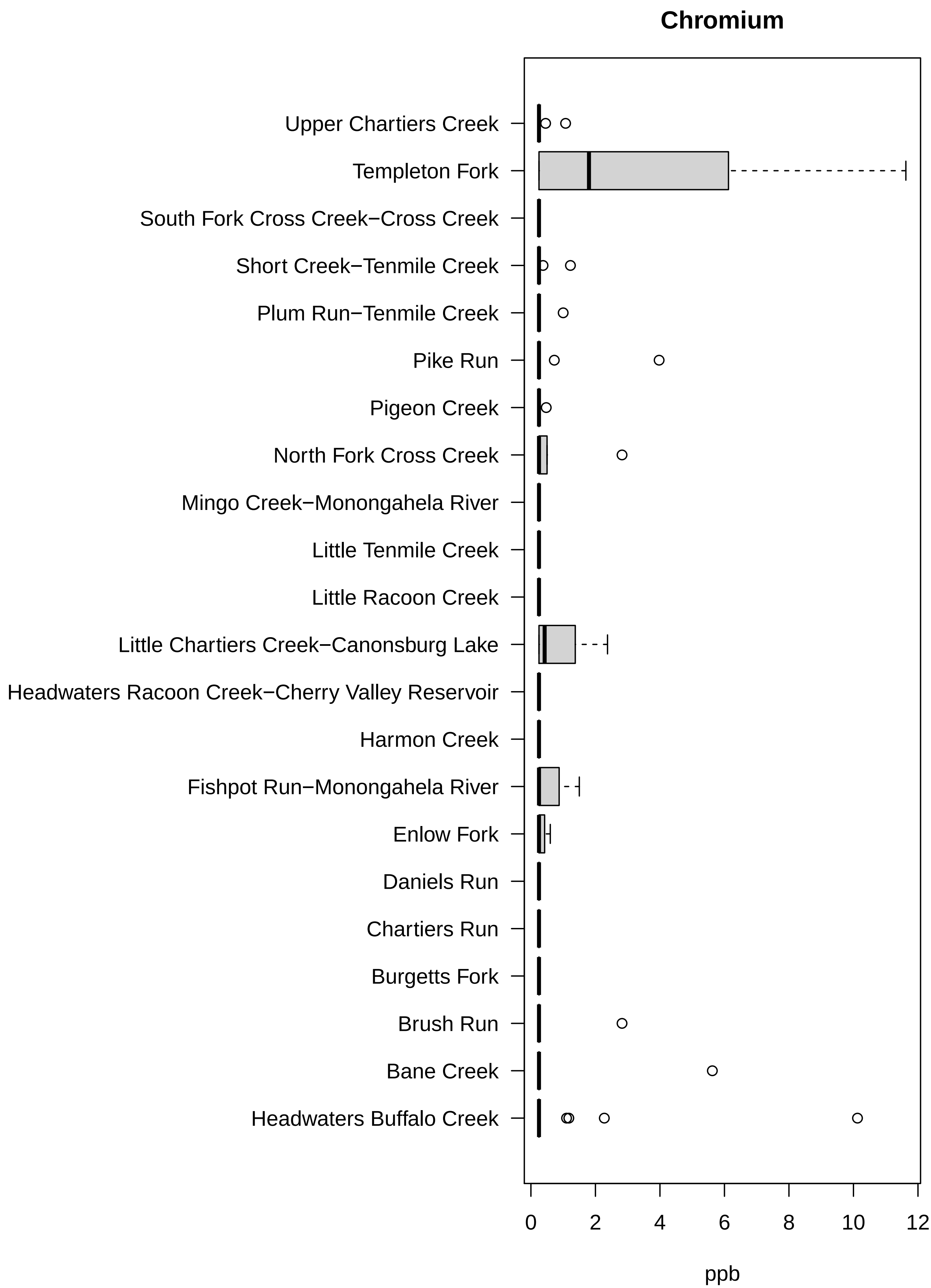








Chromium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
2
4
6
8
10
12
Spring
Mix
Well
0
2
4
6
8
10
12
ppb


Chromium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
2
4
6
8
10
12
ppb

```
[1] "ORIGINAL MODEL - Chromium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-3.1405  -0.4569  -0.0878   0.2255   8.0447  

Coefficients:
                                                      Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                          -0.808960   3.778360  -0.214   0.8308    
dat$GWellDensity_2kmAvg                              -0.038382   0.023351  -1.644   0.1030    
dat$Altitude_meter                                    0.003818   0.006409   0.596   0.5525    
dat$WatershedBane Creek                               1.351869   0.800702   1.688   0.0941 .  
dat$WatershedBrush Run                                0.004665   0.658052   0.007   0.9944    
dat$WatershedBurgetts Fork                           -0.847625   0.769888  -1.101   0.2732    
dat$WatershedChartiers Run                           -0.349918   0.898948  -0.389   0.6978    
dat$WatershedDaniels Run                             -1.530896   1.275729  -1.200   0.2326    
dat$WatershedEnlow Fork                              -0.559479   0.869487  -0.643   0.5212    
dat$WatershedFishpot Run-Monongahela River           -0.519647   1.053015  -0.493   0.6226    
dat$WatershedHarmon Creek                            -0.846067   1.720916  -0.492   0.6239    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.723703   1.253458  -0.577   0.5648    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake   0.229643   0.811009   0.283   0.7776    
dat$WatershedLittle Racoon Creek                     -1.367908   1.938847  -0.706   0.4819    
dat$WatershedLittle Tenmile Creek                     -0.995569   0.829439  -1.200   0.2325    
dat$WatershedMingo Creek-Monongahela River           -1.228282   1.111321  -1.105   0.2714    
dat$WatershedNorth Fork Cross Creek                  -0.232730   0.745677  -0.312   0.7555    
dat$WatershedPigeon Creek                            -1.169854   0.933706  -1.253   0.2128    
dat$WatershedPike Run                                -0.828723   0.912133  -0.909   0.3655    
dat$WatershedPlum Run-Tenmile Creek                  -0.769925   0.808900  -0.952   0.3432    
dat$WatershedShort Creek-Tenmile Creek               -0.106586   0.671432  -0.159   0.8742    
dat$WatershedSouth Fork Cross Creek-Cross Creek      -0.379346   0.601408  -0.631   0.5295    
dat$WatershedTempleton Fork                           3.297750   0.711058   4.638 9.45e-06 ***
dat$WatershedUpper Chartiers Creek                   -0.355539   0.613787  -0.579   0.5636    
dat$FormationCasselman Formation                      0.085814   1.399739   0.061   0.9512    
dat$FormationGreene Formation                        -1.016150   0.475395  -2.137   0.0347 *  
dat$FormationMonongahela Group                        0.144415   0.497615   0.290   0.7722    
dat$FormationWaynesburg Formation                     0.437132   0.385118   1.135   0.2587    
dat$HHWSourceMix                                     -0.039408   0.929642  -0.042   0.9663    
dat$HHWSourceSpring                                   0.758866   0.304594   2.491   0.0142 *  
dat$Precip_inchAvg                                    0.012802   0.077955   0.164   0.8699    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1.888208)

    Null deviance: 314.32  on 144  degrees of freedom
Residual deviance: 215.26  on 114  degrees of freedom
AIC: 532.78

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Chromium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.54799  -0.12058  -0.03018   0.03783   1.15378

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                 0.4352390  0.7031281   0.619   0.5371
dat$GWellDensity_2kmAvg                                    -0.0070263  0.0043454  -1.617   0.1087
dat$Altitude_meter                                          0.0005023  0.0011927   0.421   0.6744
dat$WatershedBane Creek                                     0.2266214  0.1490054   1.521   0.1311
dat$WatershedBrush Run                                      0.0047064  0.1224591   0.038   0.9694
dat$WatershedBurgetts Fork                                 -0.1562118  0.1432710  -1.090   0.2779
dat$WatershedChartiers Run                                 -0.0501458  0.1672883  -0.300   0.7649
dat$WatershedDaniels Run                                   -0.2904452  0.2374049  -1.223   0.2237
dat$WatershedEnlow Fork                                    -0.0896616  0.1618058  -0.554   0.5806
dat$WatershedFishpot Run-Monongahela River                 -0.0371862  0.1959591  -0.190   0.8498
dat$WatershedHarmon Creek                                  -0.1342175  0.3202512  -0.419   0.6759
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.1327032  0.2332603  -0.569   0.5705
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         0.1261813  0.1509235   0.836   0.4049
dat$WatershedLittle Racoon Creek                           -0.2051440  0.3608068  -0.569   0.5708
dat$WatershedLittle Tenmile Creek                          -0.2292017  0.1543532  -1.485   0.1403
dat$WatershedMingo Creek-Monongahela River                 -0.2496827  0.2068096  -1.207   0.2298
dat$WatershedNorth Fork Cross Creek                         0.0002222  0.1387656   0.002   0.9987
dat$WatershedPigeon Creek                                  -0.2369916  0.1737566  -1.364   0.1753
dat$WatershedPike Run                                      -0.1324440  0.1697419  -0.780   0.4369
dat$WatershedPlum Run-Tenmile Creek                        -0.1592699  0.1505310  -1.058   0.2923
dat$WatershedShort Creek-Tenmile Creek                     -0.0391348  0.1249490  -0.313   0.7547
dat$WatershedSouth Fork Cross Creek-Cross Creek            -0.0988683  0.1119181  -0.883   0.3789
dat$WatershedTempleton Fork                                 0.5374143  0.1323233   4.061 8.99e-05 ***
dat$WatershedUpper Chartiers Creek                         -0.0430811  0.1142218  -0.377   0.7067
dat$FormationCasselman Formation                           -0.0501915  0.2604823  -0.193   0.8475
dat$FormationGreene Formation                              -0.1896816  0.0884679  -2.144   0.0342 *
dat$FormationMonongahela Group                             -0.0208501  0.0926030  -0.225   0.8223
dat$FormationWaynesburg Formation                           0.0487133  0.0716680   0.680   0.4981
dat$HHWSourceMix                                           -0.0418935  0.1730003  -0.242   0.8091
dat$HHWSourceSpring                                         0.1056110  0.0566829   1.863   0.0650 .
dat$Precip_inchAvg                                          0.0057418  0.0145069   0.396   0.6930
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.06539011)

    Null deviance: 10.6159  on 144  degrees of freedom
Residual deviance:  7.4545  on 114  degrees of freedom
AIC: 45.144

Number of Fisher Scoring iterations: 2
```

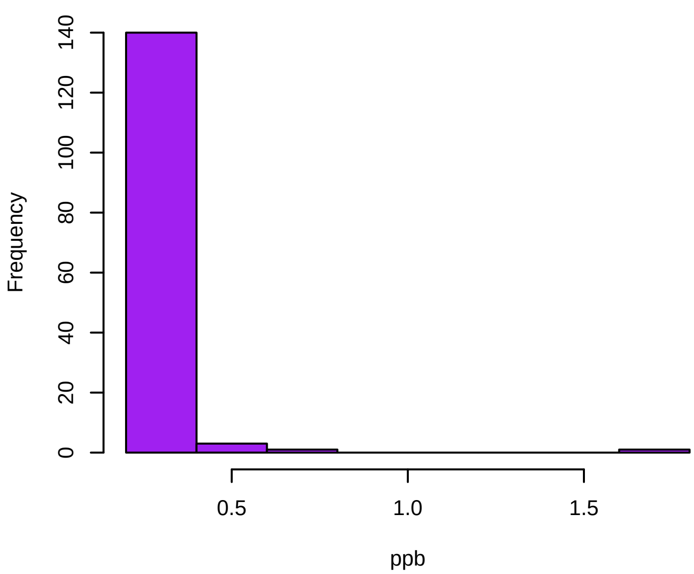
Cobalt

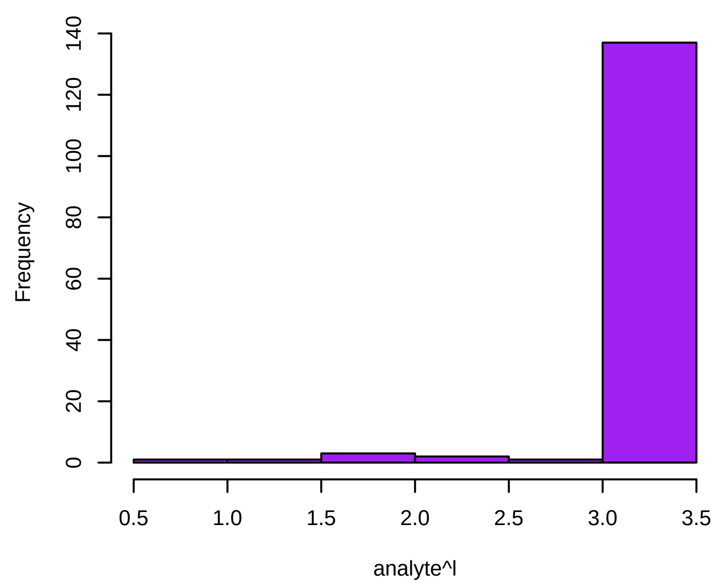
Skewness: 9.6494
Kurtosis: 104.4947

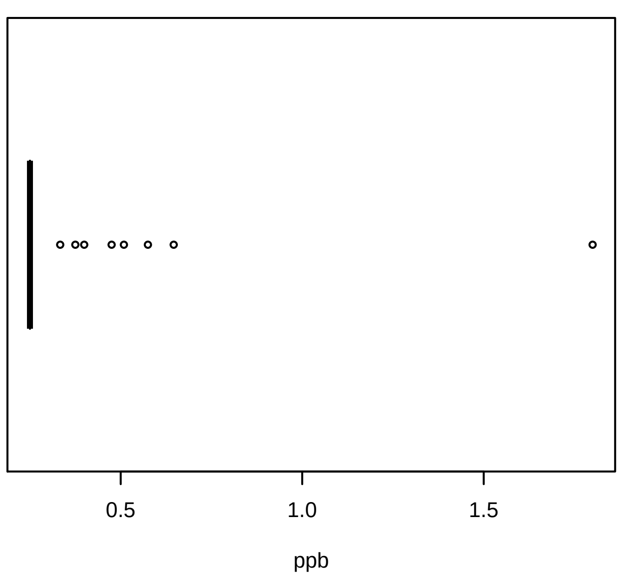
Cobalt Box−Cox

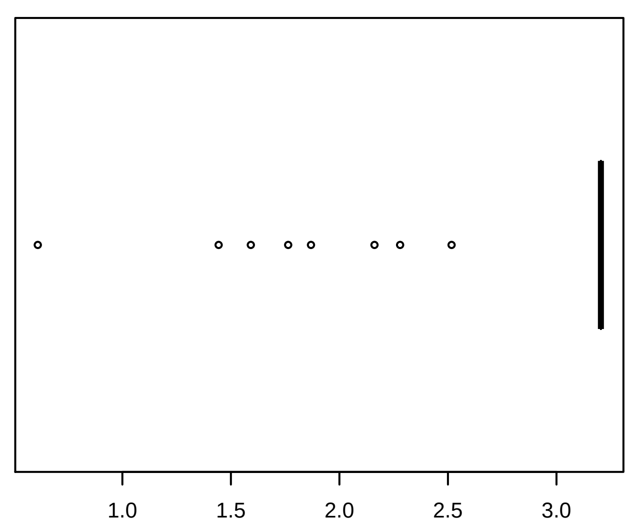
Skewness: −4.8803
Kurtosis: 27.9041

Optimal lambda: −0.8401



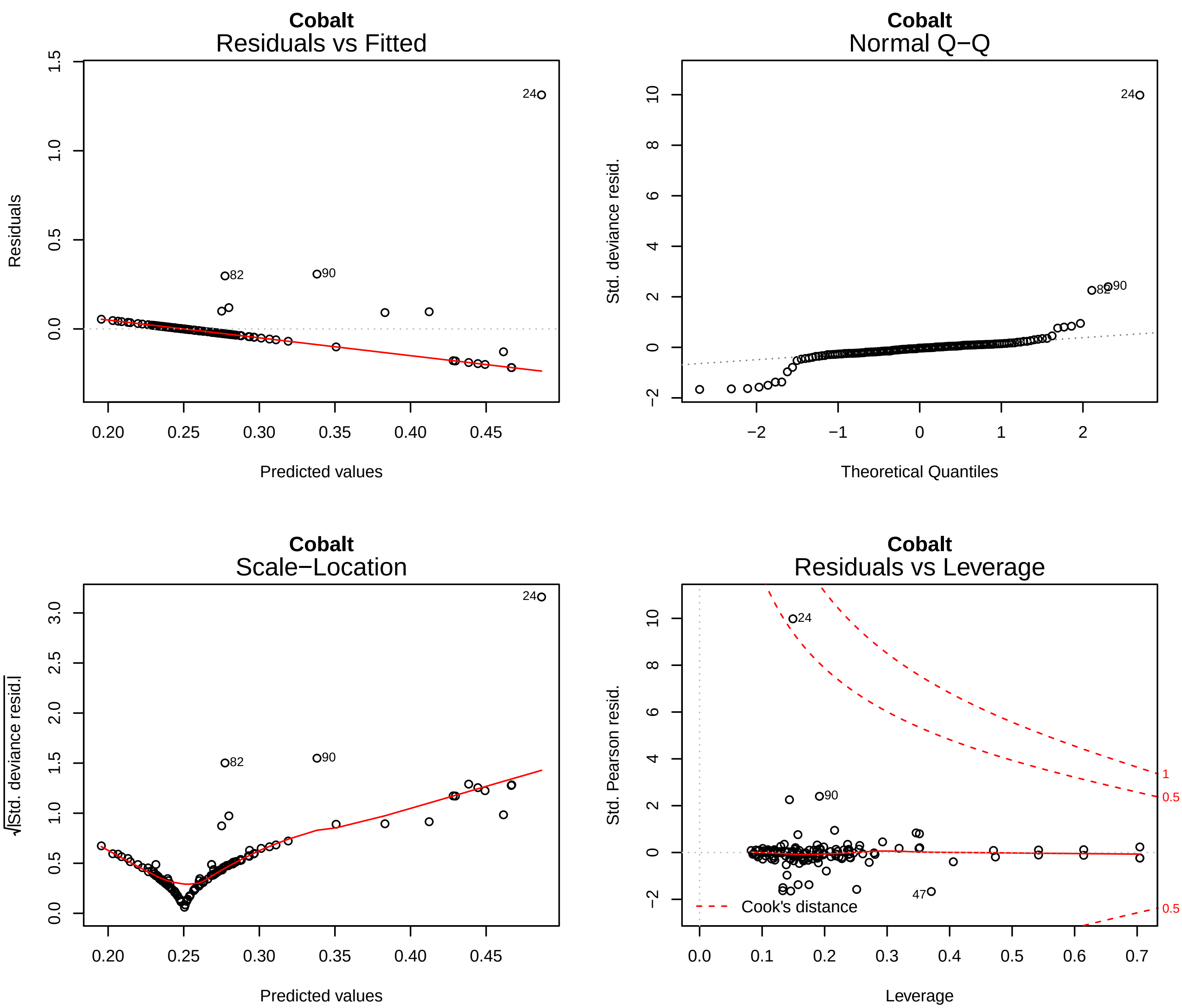






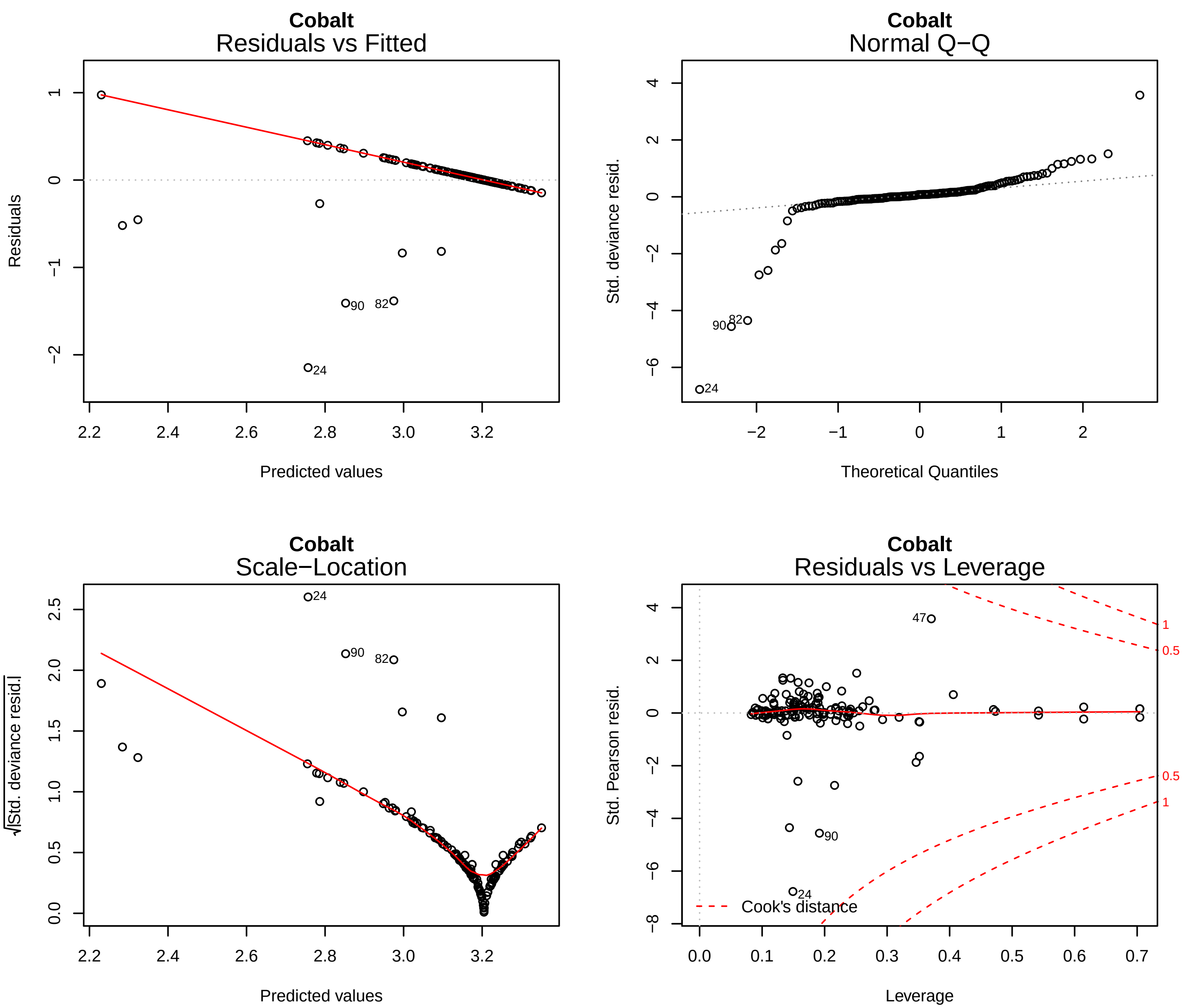
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

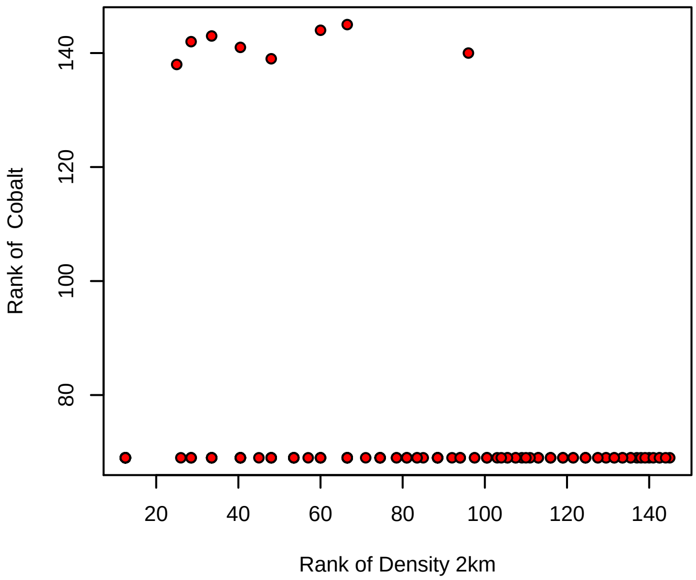
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



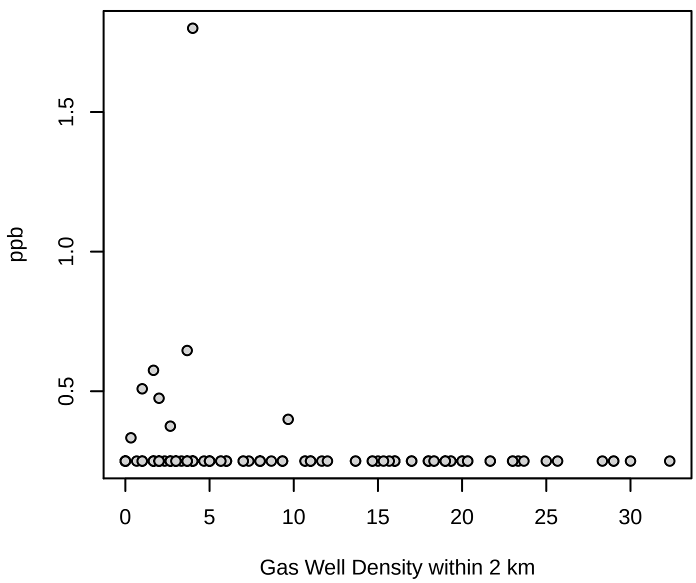


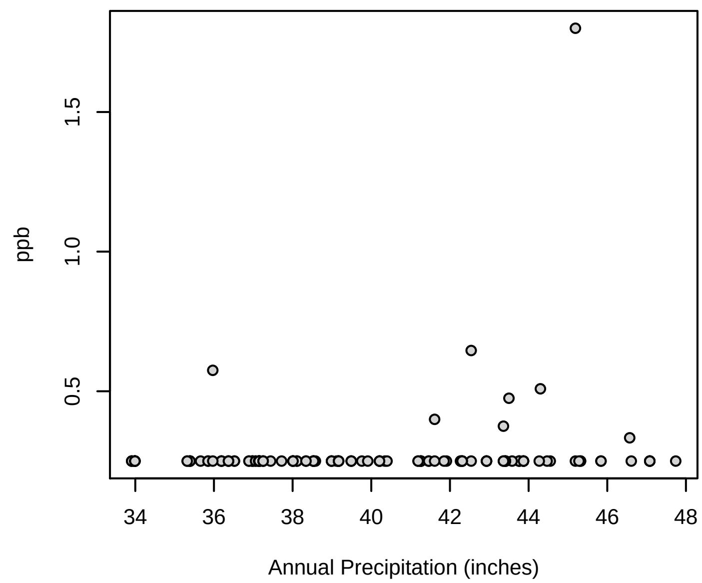
Cobalt

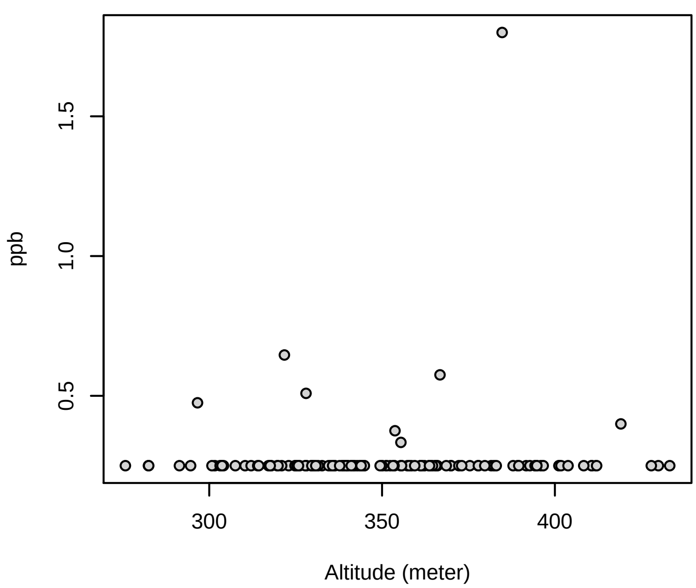
Kendalls Tau Rank Correlation

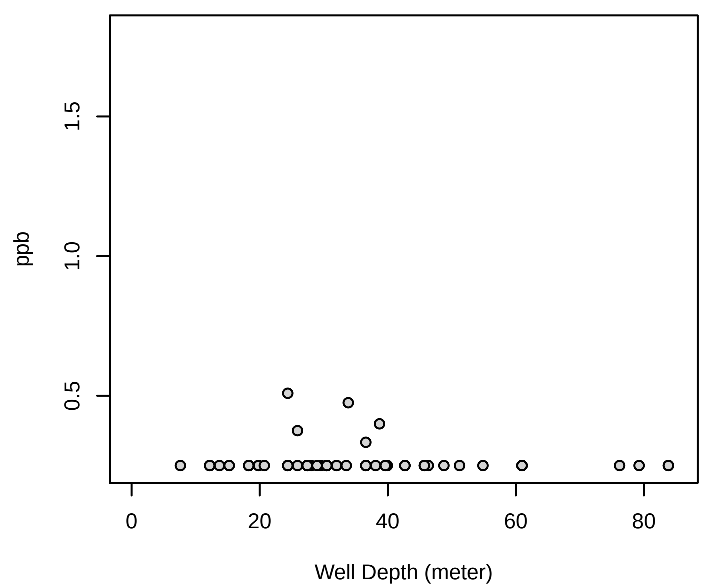
p−value: 0.114

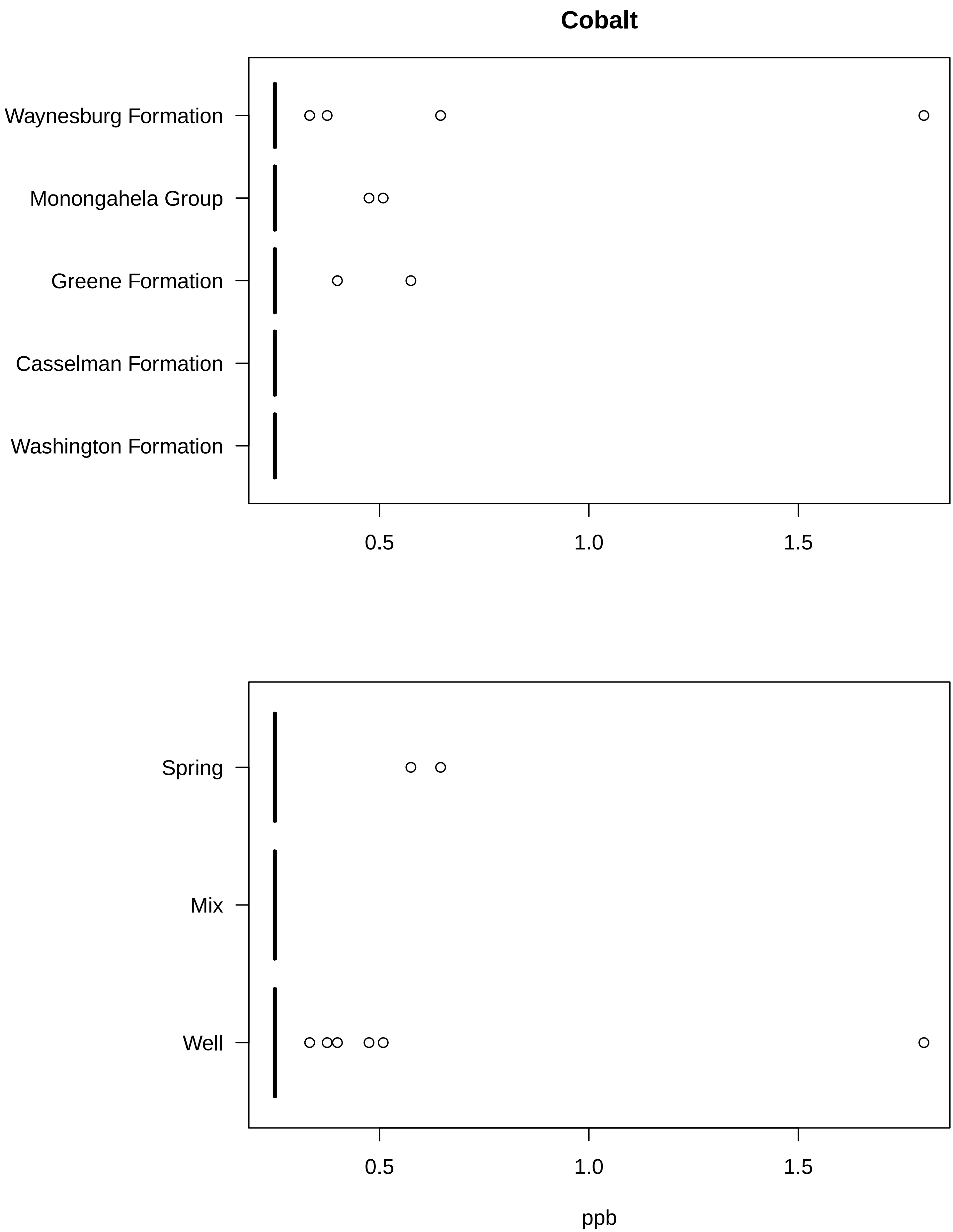
Tau: −0.109



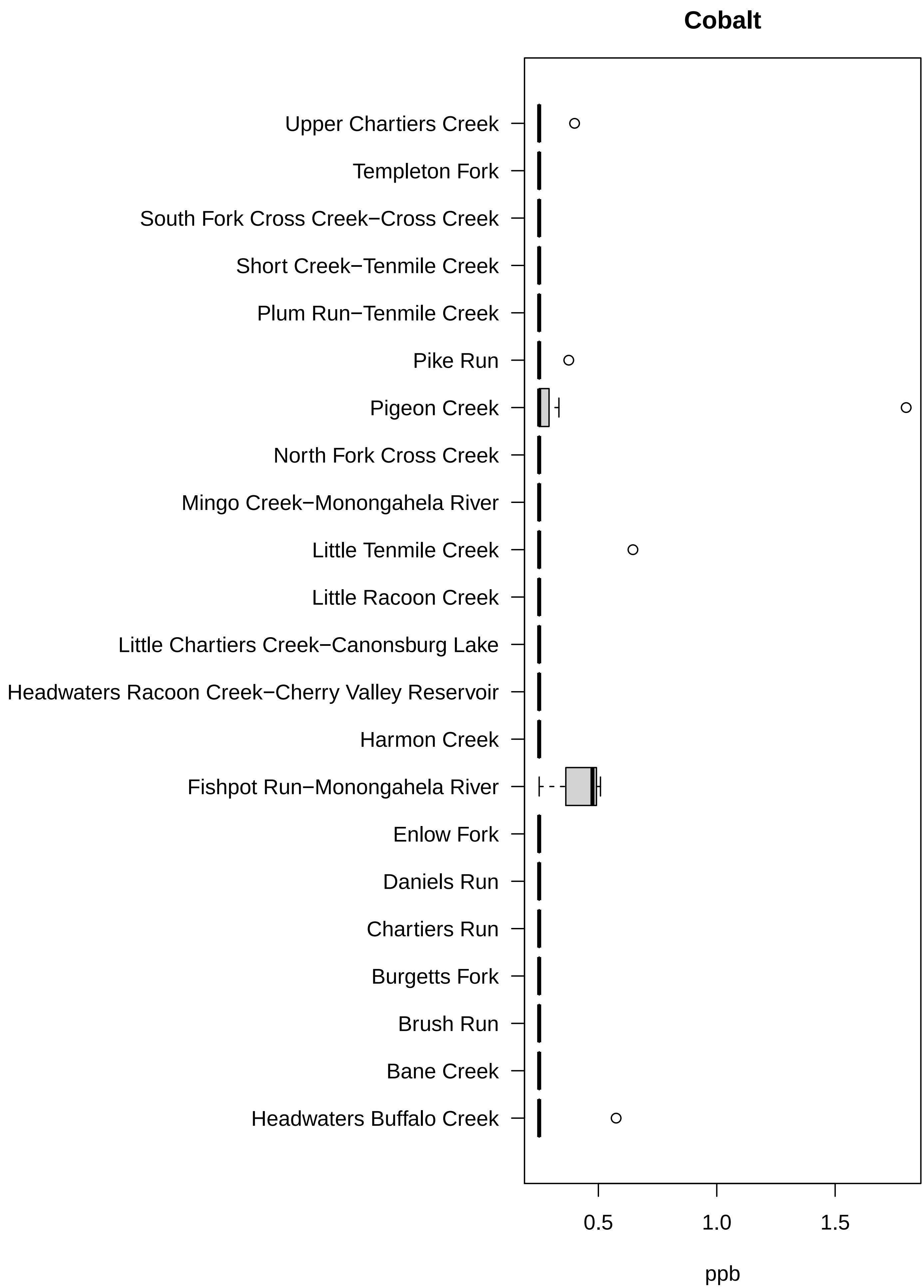








Cobalt
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0.5
1.0
1.5
Spring
Mix
Well
0.5
1.0
1.5
ppb


Cobalt
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0.5
1.0
1.5
ppb

```
[1] "ORIGINAL MODEL - Cobalt"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.21692  -0.02382  -0.00391   0.01158   1.31335

Coefficients:
                                                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              -0.0643364  0.3922344  -0.164   0.8700
dat$GWellDensity_2kmAvg                                  -0.0007124  0.0024241  -0.294   0.7694
dat$Altitude_meter                                        0.0009225  0.0006653   1.387   0.1683
dat$WatershedBane Creek                                  -0.0129433  0.0831214  -0.156   0.8765
dat$WatershedBrush Run                                   -0.0092130  0.0683128  -0.135   0.8930
dat$WatershedBurgetts Fork                               -0.0216223  0.0799226  -0.271   0.7872
dat$WatershedChartiers Run                               -0.0057033  0.0933204  -0.061   0.9514
dat$WatershedDaniels Run                                 -0.0093217  0.1324344  -0.070   0.9440
dat$WatershedEnlow Fork                                   0.0024288  0.0902621   0.027   0.9786
dat$WatershedFishpot Run-Monongahela River                0.1695628  0.1093142   1.551   0.1236
dat$WatershedHarmon Creek                                -0.0054795  0.1786496  -0.031   0.9756
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0409038  0.1301224  -0.314   0.7538
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -0.0120806  0.0841914  -0.143   0.8862
dat$WatershedLittle Racoon Creek                         -0.0654073  0.2012732  -0.325   0.7458
dat$WatershedLittle Tenmile Creek                         0.0729215  0.0861047   0.847   0.3988
dat$WatershedMingo Creek-Monongahela River               -0.0017055  0.1153671  -0.015   0.9882
dat$WatershedNorth Fork Cross Creek                      -0.0156610  0.0774093  -0.202   0.8400
dat$WatershedPigeon Creek                                 0.1850561  0.0969287   1.909   0.0588 .
dat$WatershedPike Run                                     0.0001189  0.0946892   0.001   0.9990
dat$WatershedPlum Run-Tenmile Creek                       0.0362918  0.0839725   0.432   0.6664
dat$WatershedShort Creek-Tenmile Creek                    0.0340516  0.0697018   0.489   0.6261
dat$WatershedSouth Fork Cross Creek-Cross Creek          -0.0026014  0.0624326  -0.042   0.9668
dat$WatershedTempleton Fork                               0.0032832  0.0738155   0.044   0.9646
dat$WatershedUpper Chartiers Creek                       -0.0168589  0.0637177  -0.265   0.7918
dat$FormationCasselman Formation                          0.0809715  0.1453080   0.557   0.5785
dat$FormationGreene Formation                             0.0045862  0.0493511   0.093   0.9261
dat$FormationMonongahela Group                            0.0299785  0.0516578   0.580   0.5628
dat$FormationWaynesburg Formation                         0.0391133  0.0399794   0.978   0.3300
dat$HHWSourceMix                                          0.0022899  0.0965068   0.024   0.9811
dat$HHWSourceSpring                                       0.0200062  0.0316201   0.633   0.5282
dat$Precip_inchAvg                                       -0.0005590  0.0080926  -0.069   0.9451
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.02034859)

    Null deviance: 2.7607  on 144  degrees of freedom
Residual deviance: 2.3197  on 114  degrees of freedom
AIC: -124.12

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Cobalt"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-2.14641  -0.02485   0.01831   0.07273   0.97442  

Coefficients:
                                                            Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                                 3.550560   0.944418   3.760 0.000270 ***
dat$GWellDensity_2kmAvg                                     0.002798   0.005837   0.479 0.632626    
dat$Altitude_meter                                         -0.001233   0.001602  -0.770 0.442961    
dat$WatershedBane Creek                                     0.139612   0.200139   0.698 0.486863    
dat$WatershedBrush Run                                      0.005016   0.164483   0.030 0.975723    
dat$WatershedBurgetts Fork                                  0.039376   0.192437   0.205 0.838237    
dat$WatershedChartiers Run                                  0.004959   0.224696   0.022 0.982431    
dat$WatershedDaniels Run                                    0.048365   0.318874   0.152 0.879712    
dat$WatershedEnlow Fork                                     0.059861   0.217332   0.275 0.783481    
dat$WatershedFishpot Run-Monongahela River                 -0.937002   0.263206  -3.560 0.000542 ***
dat$WatershedHarmon Creek                                   0.001561   0.430151   0.004 0.997111    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.055922   0.313308   0.178 0.858656    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         0.098796   0.202715   0.487 0.626936    
dat$WatershedLittle Racoon Creek                            0.145903   0.484624   0.301 0.763914    
dat$WatershedLittle Tenmile Creek                          -0.265936   0.207322  -1.283 0.202192    
dat$WatershedMingo Creek-Monongahela River                  0.026800   0.277780   0.096 0.923310    
dat$WatershedNorth Fork Cross Creek                         0.010786   0.186385   0.058 0.953952    
dat$WatershedPigeon Creek                                  -0.378807   0.233384  -1.623 0.107329    
dat$WatershedPike Run                                      -0.068854   0.227992  -0.302 0.763200    
dat$WatershedPlum Run-Tenmile Creek                        -0.044314   0.202188  -0.219 0.826908    
dat$WatershedShort Creek-Tenmile Creek                     -0.018477   0.167827  -0.110 0.912528    
dat$WatershedSouth Fork Cross Creek-Cross Creek            -0.019392   0.150325  -0.129 0.897584    
dat$WatershedTempleton Fork                                 0.058300   0.177732   0.328 0.743496    
dat$WatershedUpper Chartiers Creek                         -0.038480   0.153419  -0.251 0.802408    
dat$FormationCasselman Formation                           -0.117189   0.349871  -0.335 0.738280    
dat$FormationGreene Formation                              -0.141959   0.118827  -1.195 0.234697    
dat$FormationMonongahela Group                             -0.051705   0.124381  -0.416 0.678414    
dat$FormationWaynesburg Formation                          -0.078126   0.096262  -0.812 0.418717    
dat$HHWSourceMix                                            0.005951   0.232368   0.026 0.979613    
dat$HHWSourceSpring                                        -0.086636   0.076135  -1.138 0.257532    
dat$Precip_inchAvg                                          0.002798   0.019485   0.144 0.886091    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.1179701)

    Null deviance: 17.814  on 144  degrees of freedom
Residual deviance: 13.449  on 114  degrees of freedom
AIC: 130.7

Number of Fisher Scoring iterations: 2
```

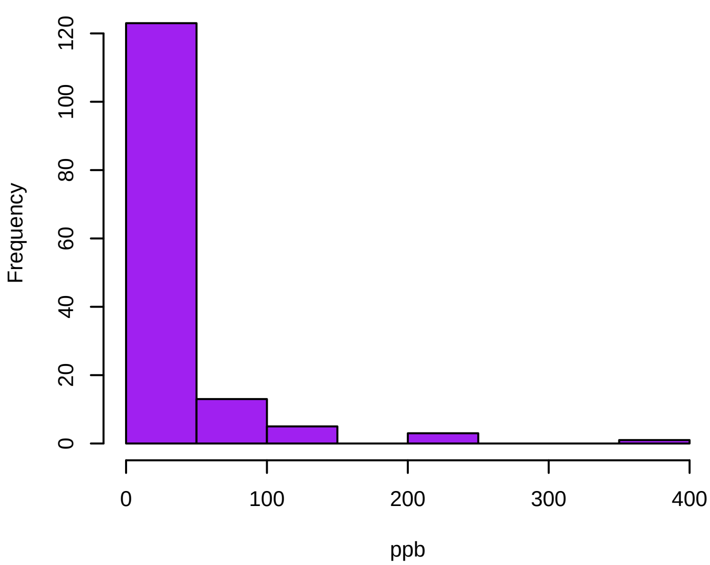
Copper

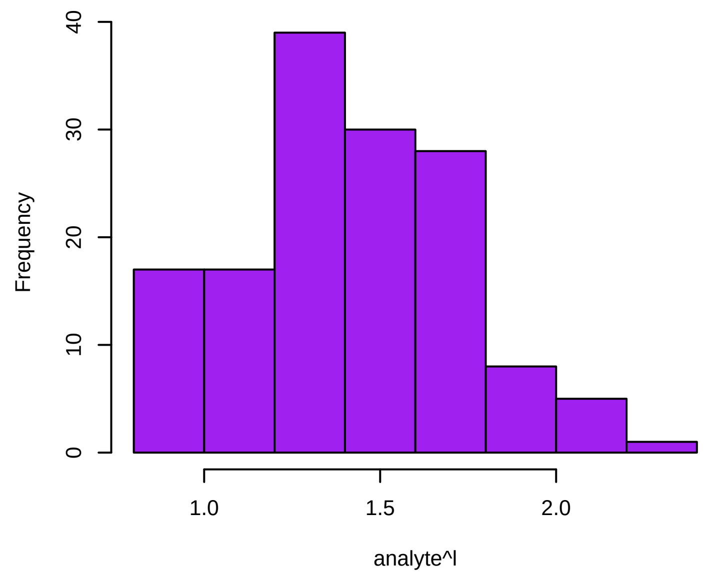
Skewness: 4.1072
Kurtosis: 24.8358

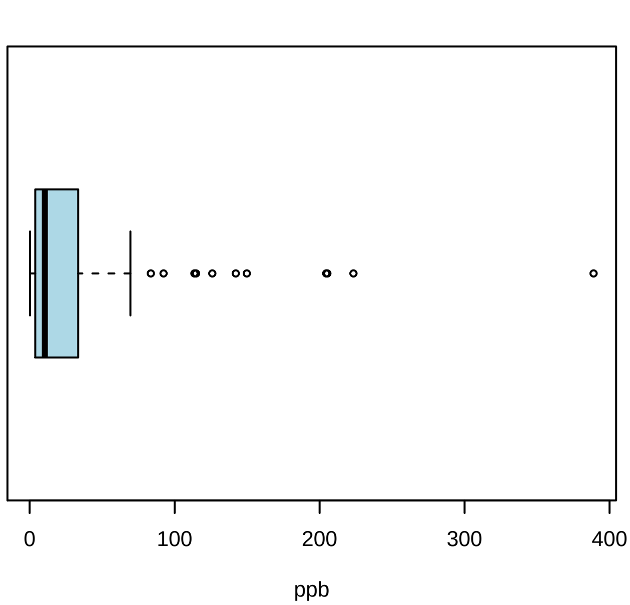
Copper Box−Cox

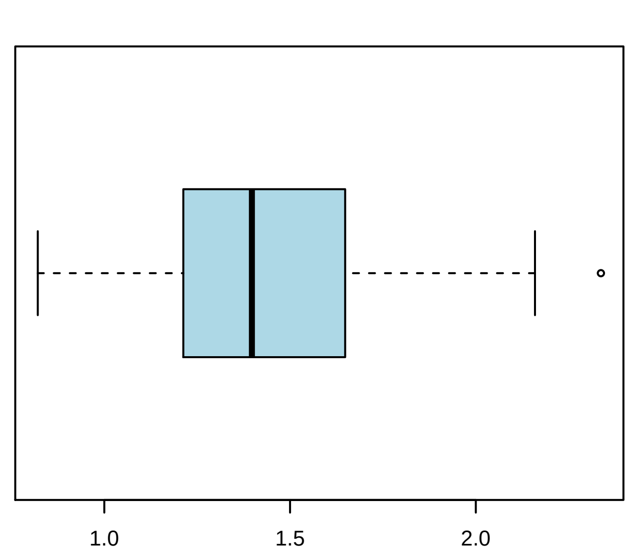
Skewness: 0.1399
Kurtosis: 2.7312

Optimal lambda: 0.1423



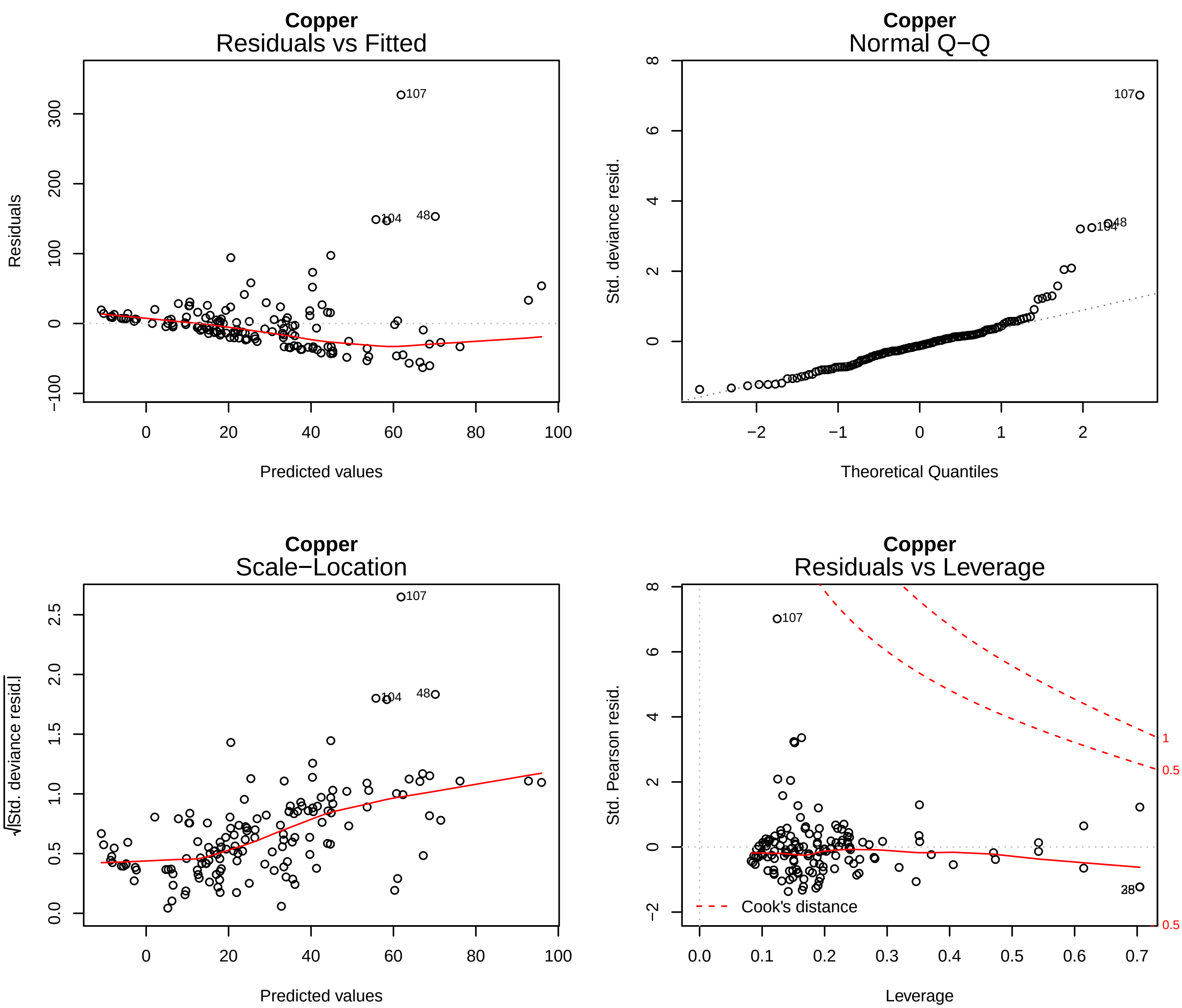






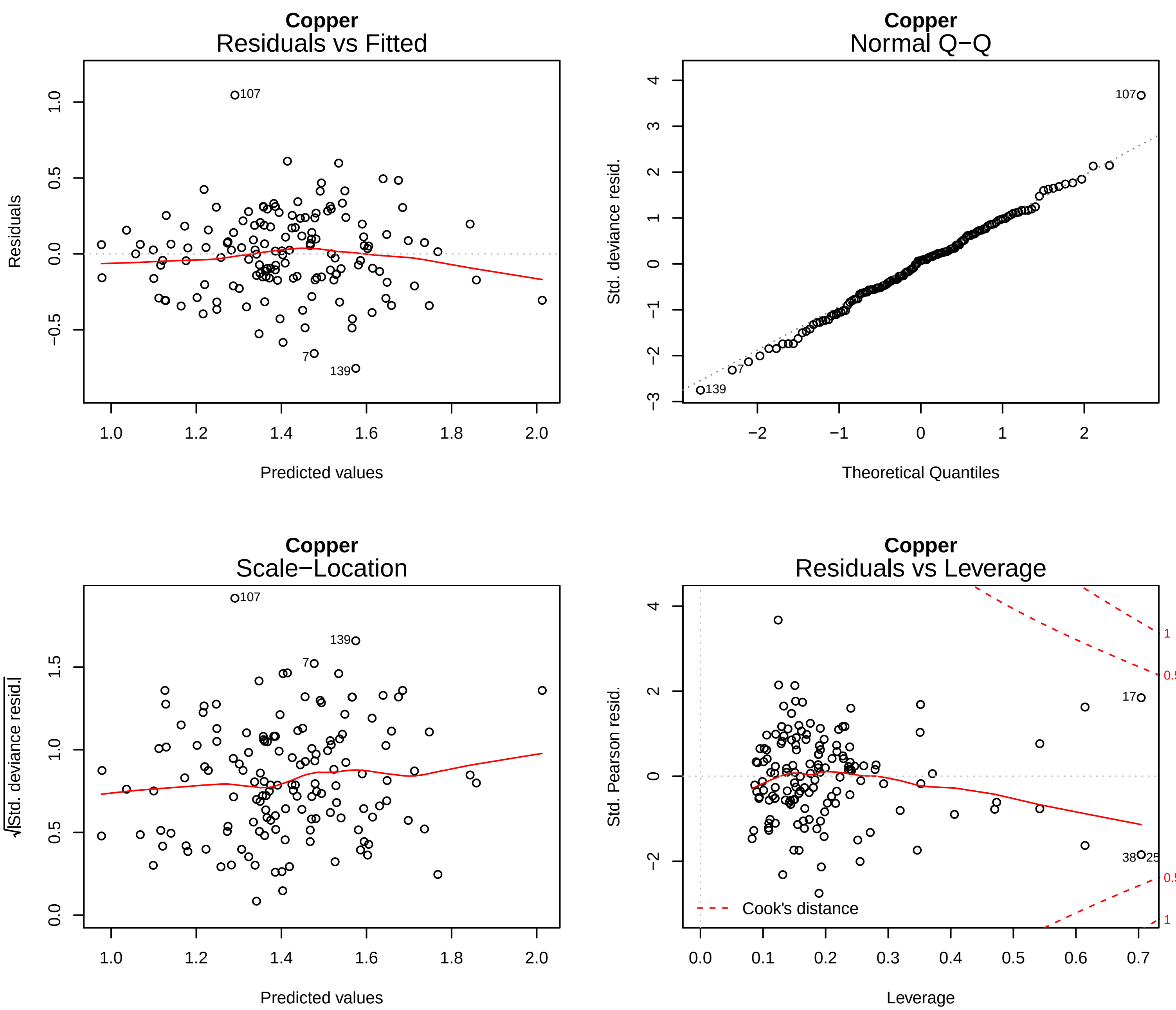
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

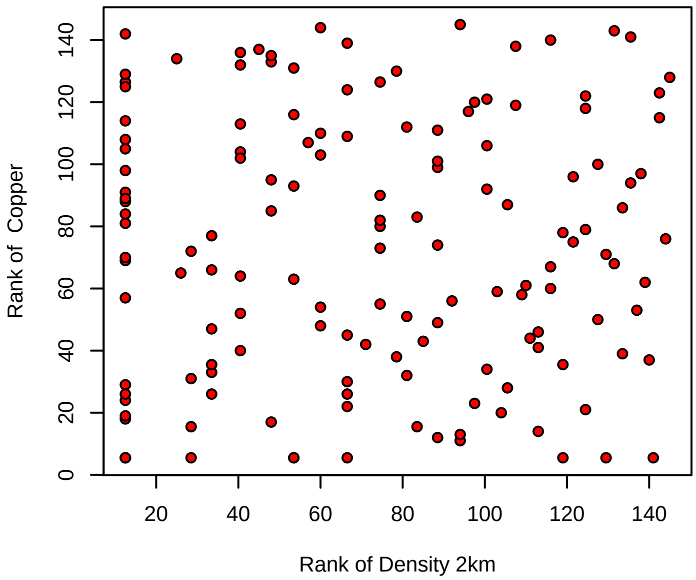
Original
Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



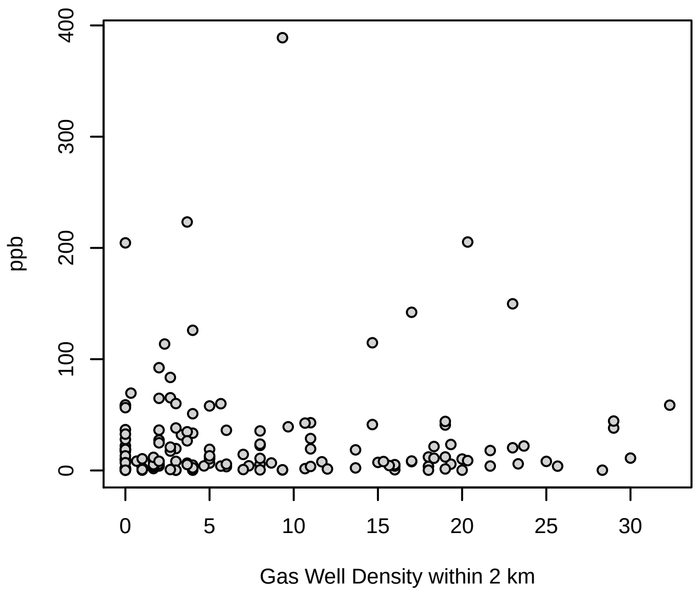


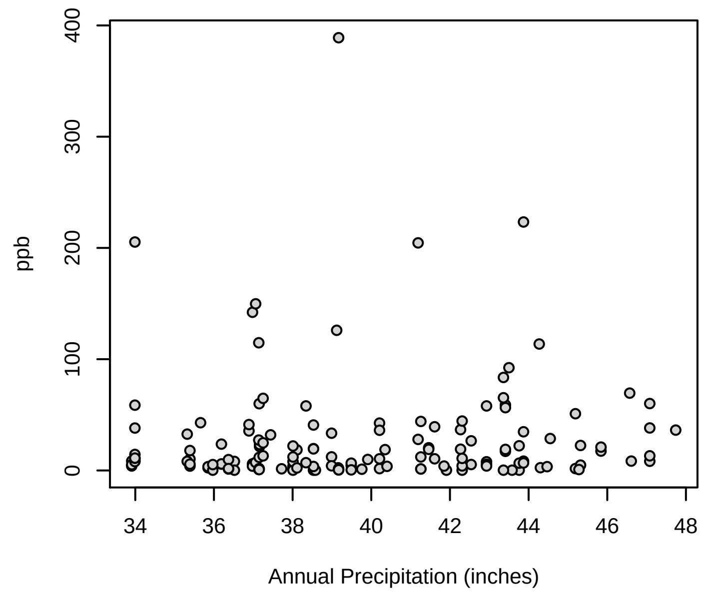
Copper

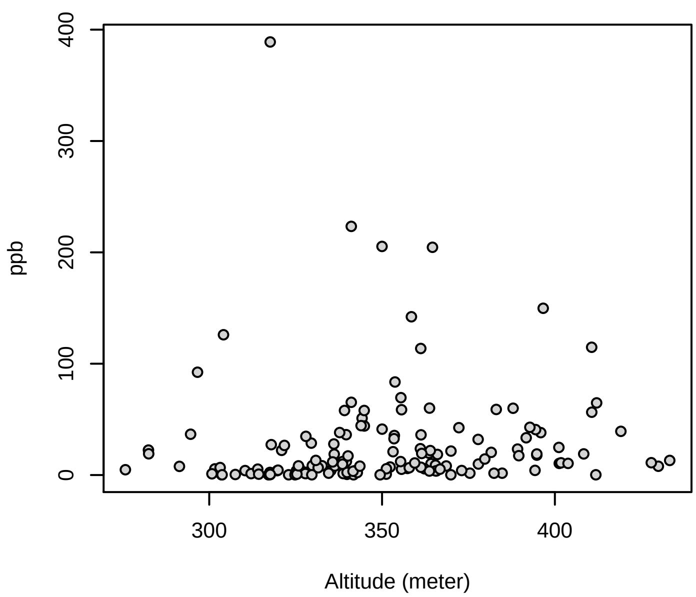
Kendalls Tau Rank Correlation

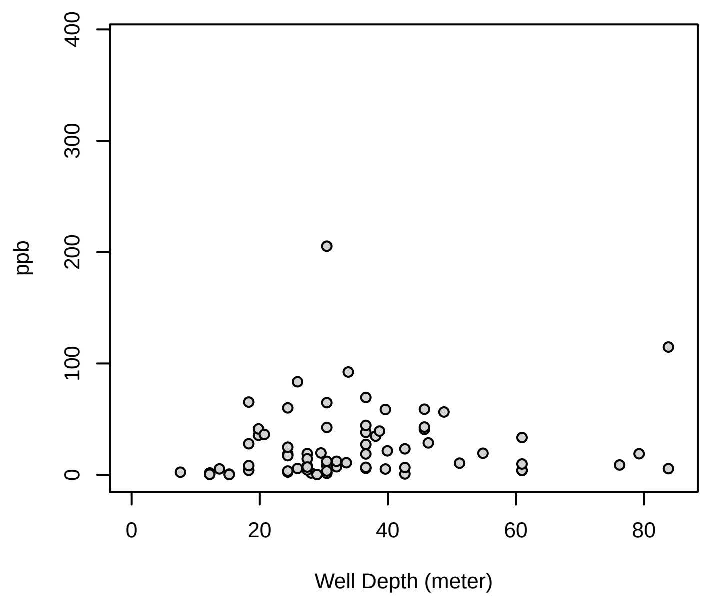
p−value: 0.698

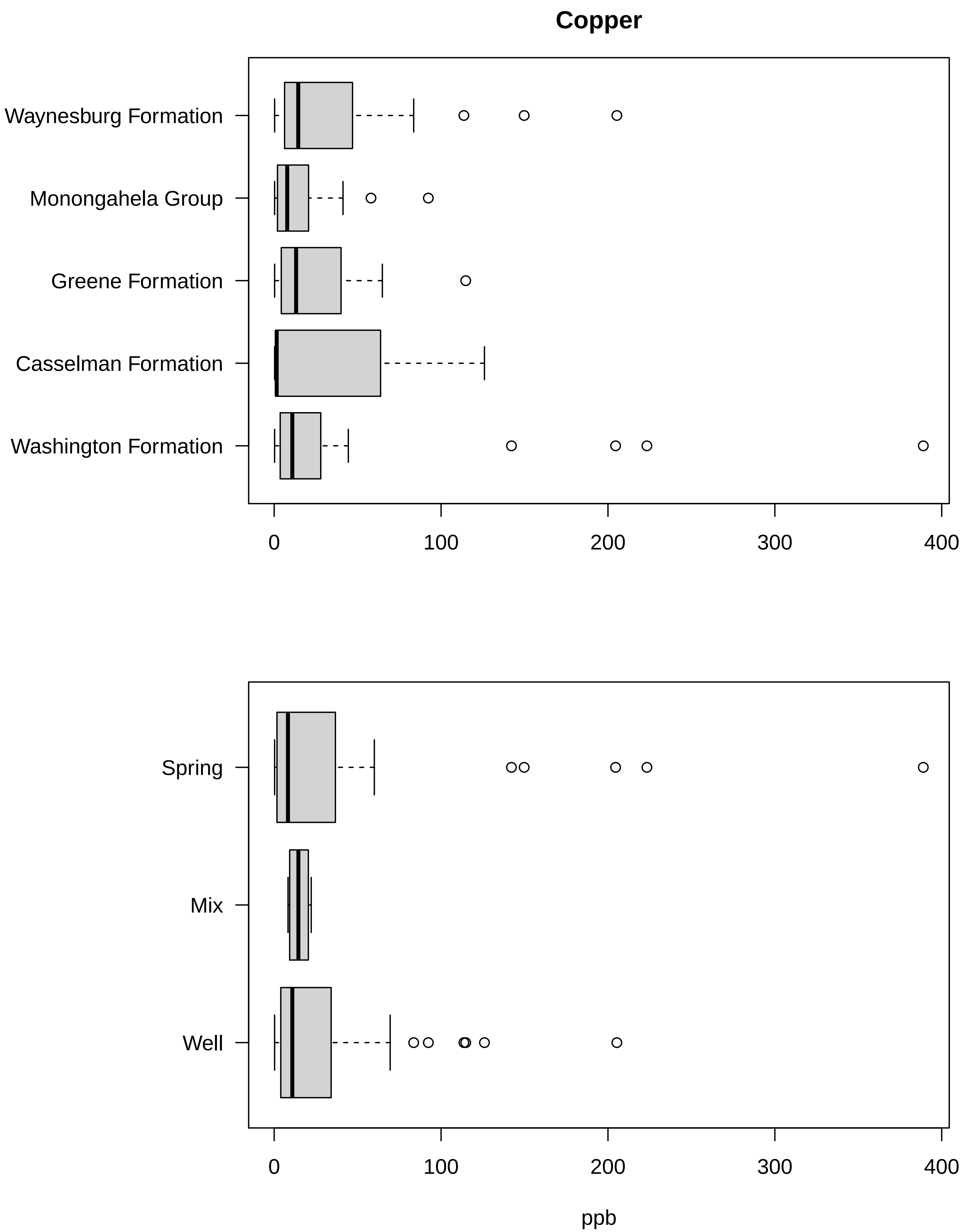
Tau: 0.0222

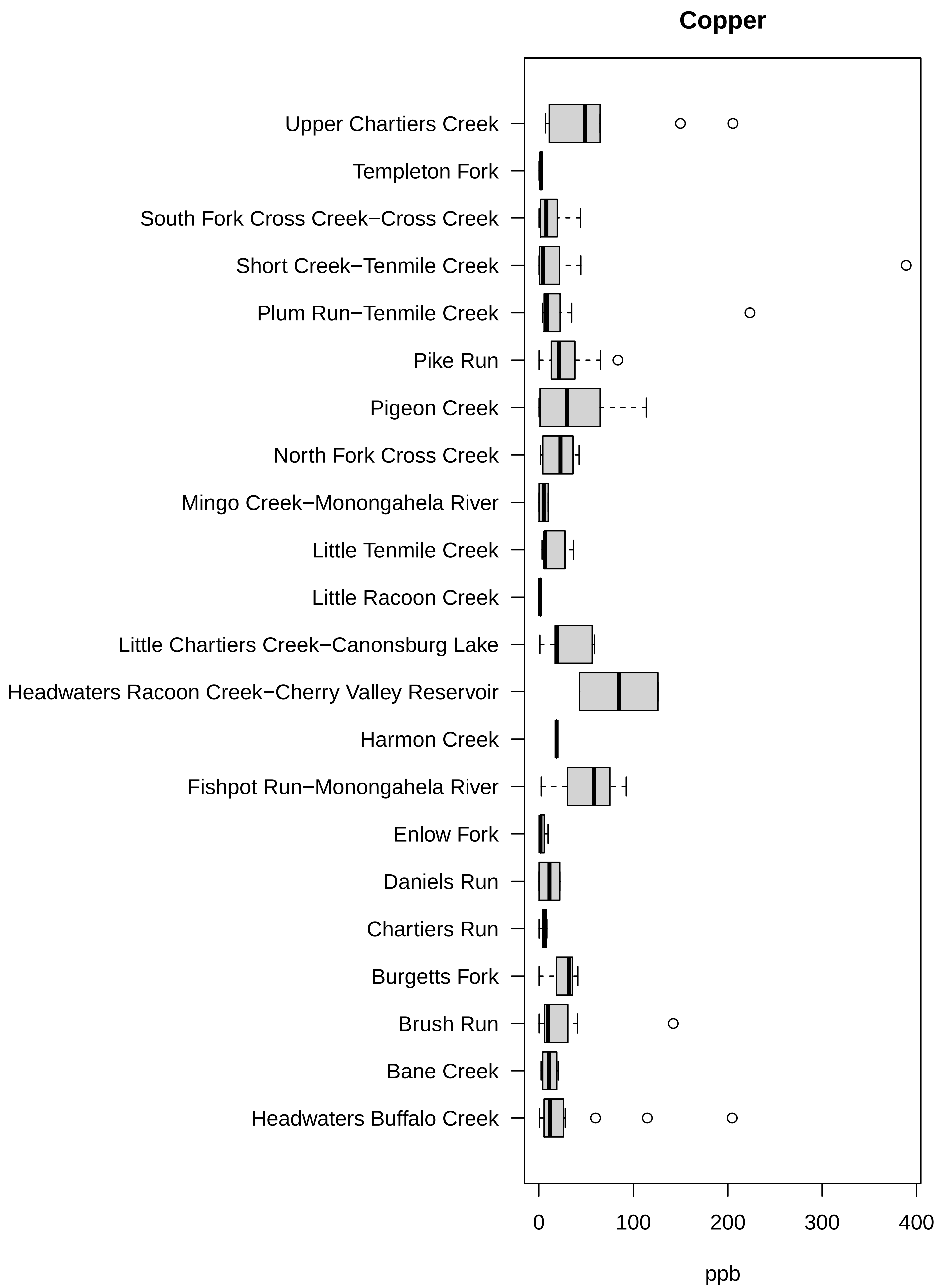









Copper
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
100
200
300
400
Spring
Mix
Well
0
100
200
300
400
ppb


Copper
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
100
200
300
400
ppb

```
[1] "ORIGINAL MODEL - Copper"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-63.11  -22.04   -4.81    8.44  327.12

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               -74.3369   136.9907  -0.543   0.5884
dat$GWellDensity_2kmAvg                                     0.1009     0.8466   0.119   0.9054
dat$Altitude_meter                                          0.1246     0.2324   0.536   0.5927
dat$WatershedBane Creek                                   -15.5290    29.0308  -0.535   0.5938
dat$WatershedBrush Run                                     -6.0404    23.8588  -0.253   0.8006
dat$WatershedBurgetts Fork                                 12.0233    27.9136   0.431   0.6675
dat$WatershedChartiers Run                                 -3.0131    32.5928  -0.092   0.9265
dat$WatershedDaniels Run                                  -32.2584    46.2537  -0.697   0.4870
dat$WatershedEnlow Fork                                   -23.0508    31.5247  -0.731   0.4662
dat$WatershedFishpot Run-Monongahela River                 40.4873    38.1788   1.060   0.2912
dat$WatershedHarmon Creek                                   9.1203    62.3947   0.146   0.8840
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  52.4596    45.4462   1.154   0.2508
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         4.7632    29.4045   0.162   0.8716
dat$WatershedLittle Racoon Creek                          -67.0444    70.2961  -0.954   0.3422
dat$WatershedLittle Tenmile Creek                         -17.4813    30.0727  -0.581   0.5622
dat$WatershedMingo Creek-Monongahela River                -23.0680    40.2928  -0.573   0.5681
dat$WatershedNorth Fork Cross Creek                         6.8241    27.0358   0.252   0.8012
dat$WatershedPigeon Creek                                   9.4996    33.8531   0.281   0.7795
dat$WatershedPike Run                                      -3.3260    33.0709  -0.101   0.9201
dat$WatershedPlum Run-Tenmile Creek                        13.2201    29.3280   0.451   0.6530
dat$WatershedShort Creek-Tenmile Creek                     13.8178    24.3439   0.568   0.5714
dat$WatershedSouth Fork Cross Creek-Cross Creek            -7.6359    21.8051  -0.350   0.7268
dat$WatershedTempleton Fork                               -20.7877    25.7806  -0.806   0.4217
dat$WatershedUpper Chartiers Creek                         41.4126    22.2539   1.861   0.0653 .
dat$FormationCasselman Formation                           21.7517    50.7499   0.429   0.6690
dat$FormationGreene Formation                              -9.5923    17.2362  -0.557   0.5789
dat$FormationMonongahela Group                            -23.6562    18.0419  -1.311   0.1924
dat$FormationWaynesburg Formation                          -1.7853    13.9631  -0.128   0.8985
dat$HHWSourceMix                                            9.4261    33.7057   0.280   0.7802
dat$HHWSourceSpring                                        27.1874    11.0436   2.462   0.0153 *
dat$Precip_inchAvg                                          1.3950     2.8264   0.494   0.6226
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 2482.136)

    Null deviance: 350379  on 144  degrees of freedom
Residual deviance: 282964  on 114  degrees of freedom
AIC: 1574.1

Number of Fisher Scoring iterations: 2
```

[1] "BOX-COX MODEL - Copper"

```
Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.75386  -0.16026   0.01859   0.18297   1.04596

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               0.005436   0.836639   0.006   0.9948
dat$GWellDensity_2kmAvg                                   0.003951   0.005171   0.764   0.4463
dat$Altitude_meter                                        0.002086   0.001419   1.470   0.1444
dat$WatershedBane Creek                                  -0.172345   0.177299  -0.972   0.3331
dat$WatershedBrush Run                                   -0.100669   0.145712  -0.691   0.4910
dat$WatershedBurgetts Fork                                0.144385   0.170476   0.847   0.3988
dat$WatershedChartiers Run                                0.016826   0.199053   0.085   0.9328
dat$WatershedDaniels Run                                 -0.360158   0.282484  -1.275   0.2049
dat$WatershedEnlow Fork                                  -0.223498   0.192530  -1.161   0.2481
dat$WatershedFishpot Run-Monongahela River                0.294529   0.233168   1.263   0.2091
dat$WatershedHarmon Creek                                 0.132677   0.381061   0.348   0.7283
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.524462   0.277552   1.890   0.0614 .
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       0.045842   0.179581   0.255   0.7990
dat$WatershedLittle Racoon Creek                         -0.170753   0.429317  -0.398   0.6916
dat$WatershedLittle Tenmile Creek                        -0.050316   0.183662  -0.274   0.7846
dat$WatershedMingo Creek-Monongahela River               -0.269009   0.246079  -1.093   0.2766
dat$WatershedNorth Fork Cross Creek                       0.068904   0.165115   0.417   0.6772
dat$WatershedPigeon Creek                                -0.046055   0.206750  -0.223   0.8241
dat$WatershedPike Run                                     0.033490   0.201973   0.166   0.8686
dat$WatershedPlum Run-Tenmile Creek                       0.127680   0.179114   0.713   0.4774
dat$WatershedShort Creek-Tenmile Creek                   -0.147197   0.148675  -0.990   0.3242
dat$WatershedSouth Fork Cross Creek-Cross Creek          -0.145196   0.133169  -1.090   0.2779
dat$WatershedTempleton Fork                              -0.320541   0.157449  -2.036   0.0441 *
dat$WatershedUpper Chartiers Creek                        0.232361   0.135910   1.710   0.0900 .
dat$FormationCasselman Formation                         -0.184885   0.309943  -0.597   0.5520
dat$FormationGreene Formation                            -0.025697   0.105266  -0.244   0.8076
dat$FormationMonongahela Group                           -0.202375   0.110187  -1.837   0.0689 .
dat$FormationWaynesburg Formation                        -0.008481   0.085276  -0.099   0.9210
dat$HHWSourceMix                                          0.169235   0.205850   0.822   0.4127
dat$HHWSourceSpring                                       0.042466   0.067446   0.630   0.5302
dat$Precip_inchAvg                                        0.017631   0.017261   1.021   0.3092
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.0925805)

    Null deviance: 15.287  on 144  degrees of freedom
Residual deviance: 10.554  on 114  degrees of freedom
AIC: 95.561

Number of Fisher Scoring iterations: 2
```

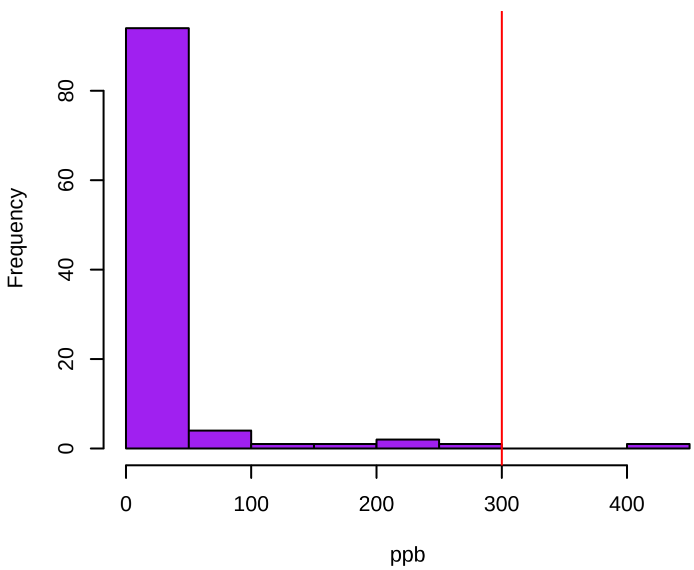
Iron

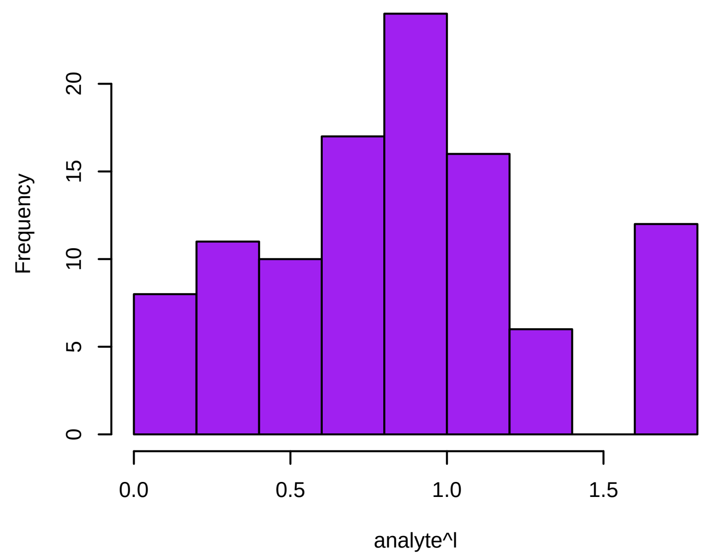
Skewness: 4.2620
Kurtosis: 22.5851

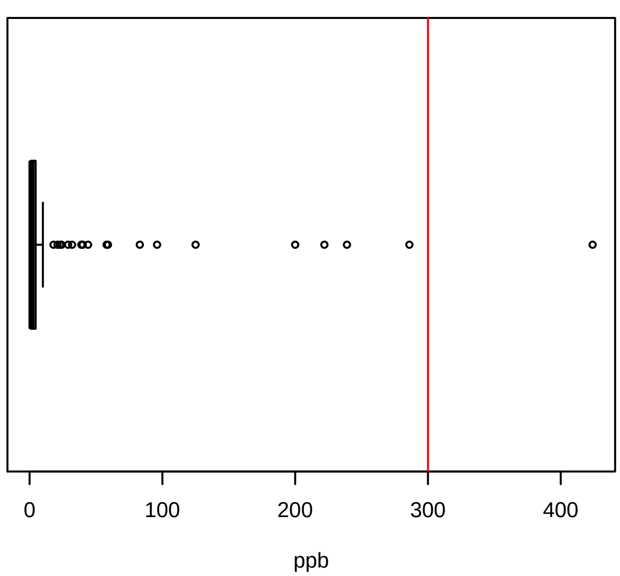
Iron Box−Cox

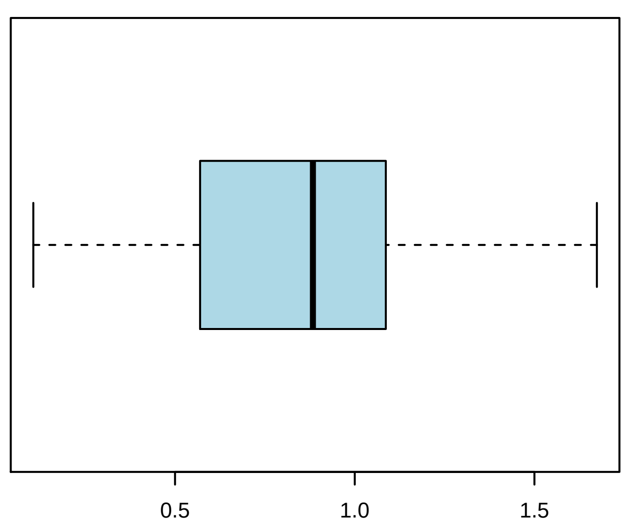
Skewness: 0.2169
Kurtosis: 2.5210

Optimal lambda: −0.3715



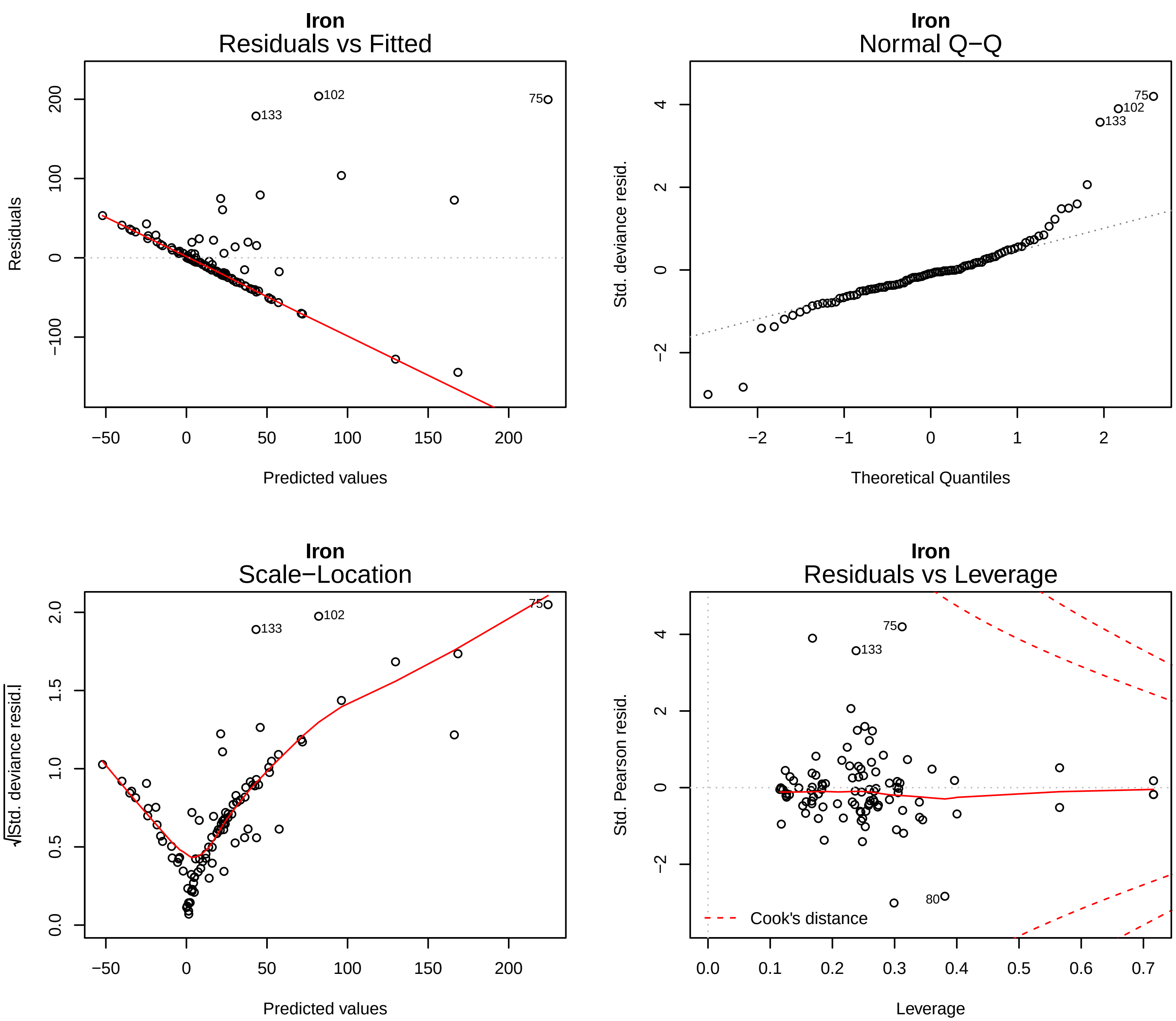






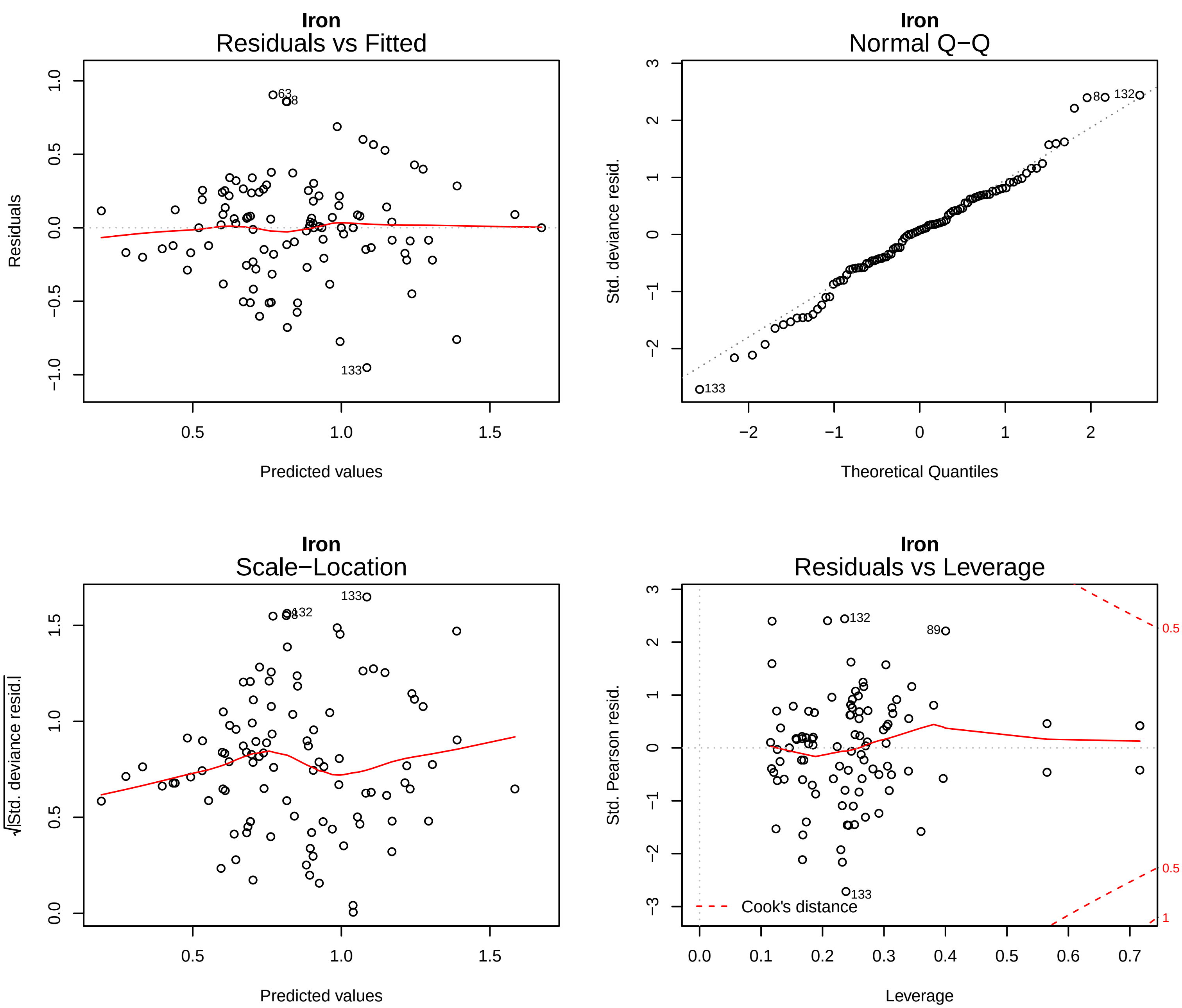
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

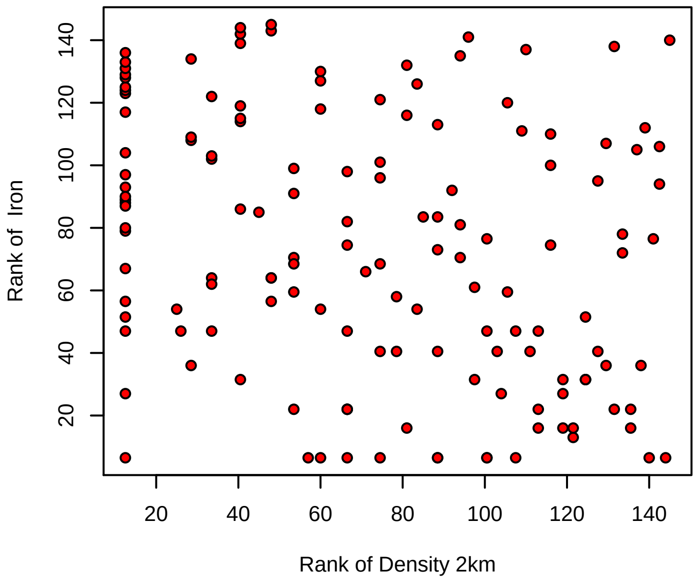
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



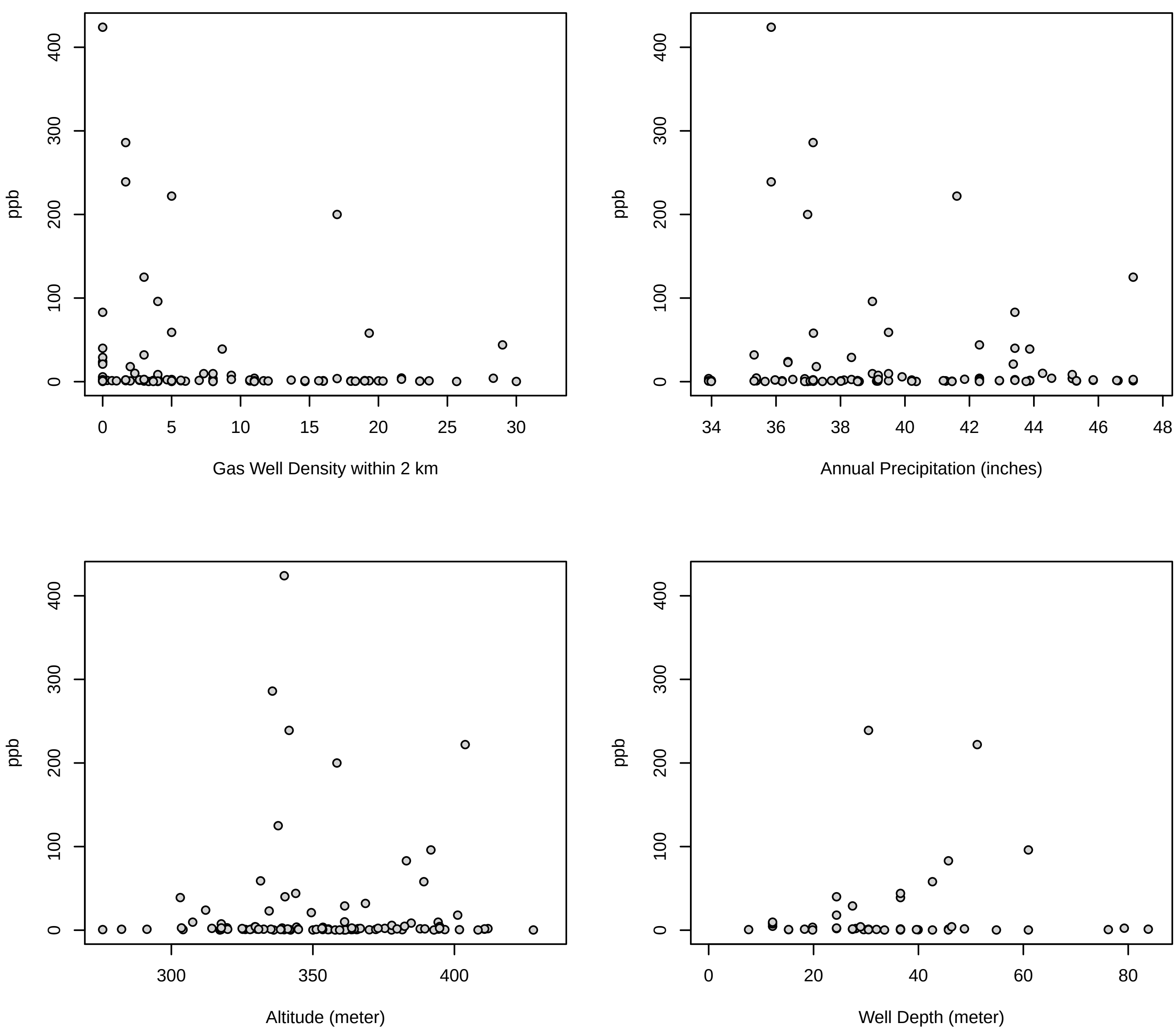


Iron

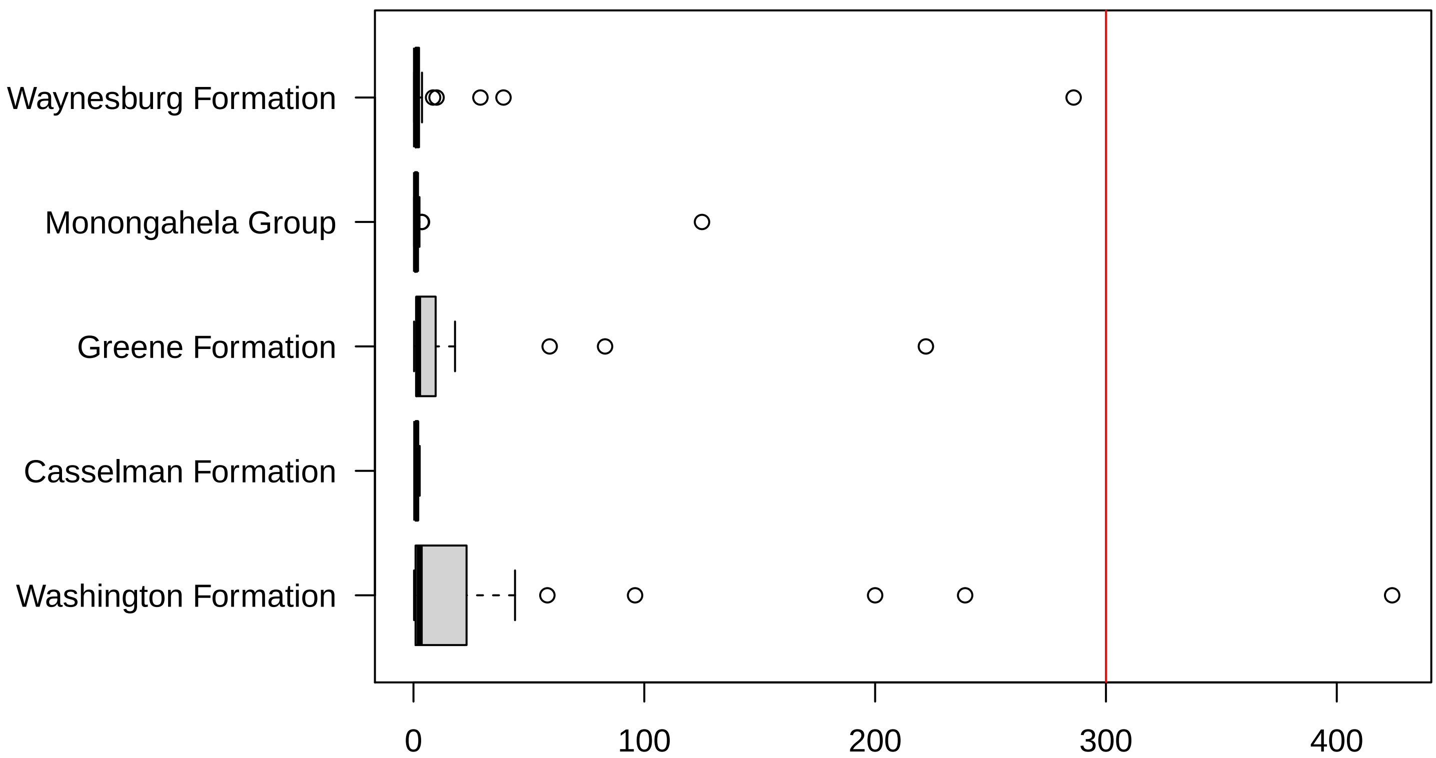
Kendalls Tau Rank Correlation

p−value: 0.000518

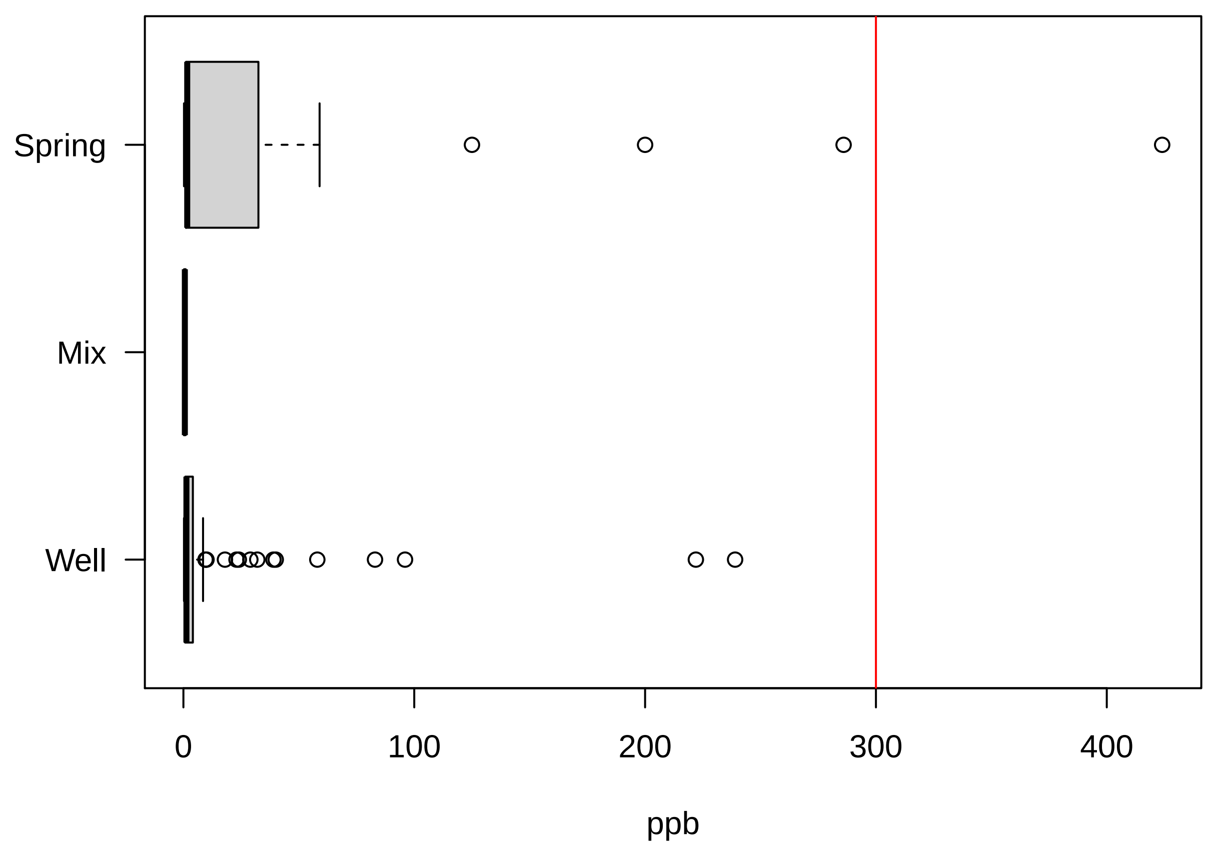
Tau: −0.238



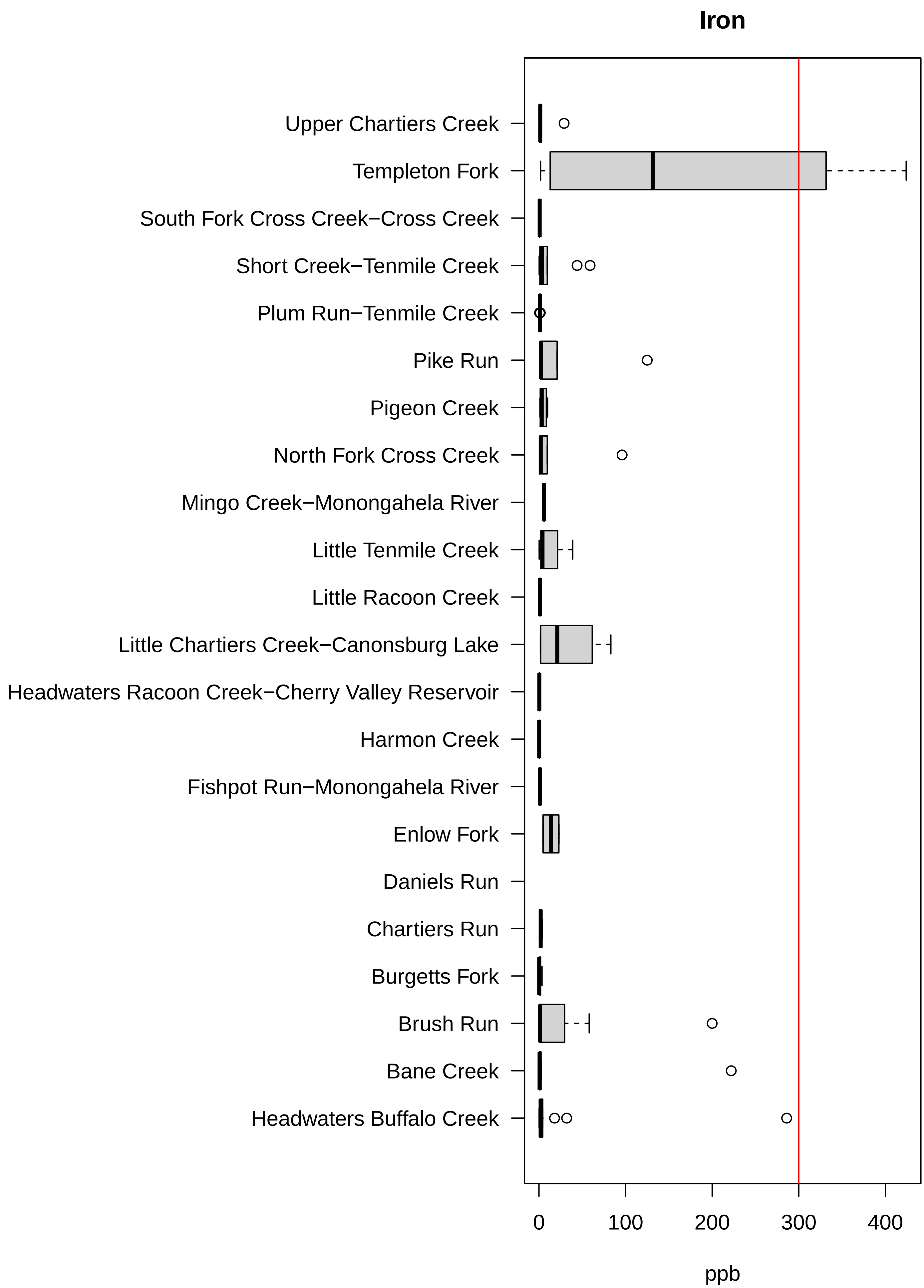
Iron



Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
100
200
300
400



Spring
Mix
Well
0
100
200
300
400
ppb



Iron
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
100
200
300
400
ppb

```
[1] "ORIGINAL MODEL - Iron"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-144.485   -21.968    -2.671    12.987   203.941

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  -19.88688  214.44682  -0.093   0.9264
dat$GWellDensity_2kmAvg                                       -2.19024    1.15289  -1.900   0.0614 .
dat$Altitude_meter                                             0.05497    0.32977   0.167   0.8681
dat$WatershedBane Creek                                       72.65112   39.76593   1.827   0.0717 .
dat$WatershedBrush Run                                        64.18044   33.78278   1.900   0.0614 .
dat$WatershedBurgetts Fork                                   -21.43765   34.73278  -0.617   0.5390
dat$WatershedChartiers Run                                     8.00764   45.21573   0.177   0.8599
dat$WatershedEnlow Fork                                       -9.65669   44.47408  -0.217   0.8287
dat$WatershedFishpot Run-Monongahela River                   -32.62359   68.32384  -0.477   0.6344
dat$WatershedHarmon Creek                                     21.43158   90.63758   0.236   0.8137
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -3.82811   54.58819  -0.070   0.9443
dat$WatershedLittle Chartiers Creek-Canonsburg Lake           41.35602   47.46626   0.871   0.3864
dat$WatershedLittle Racoon Creek                             -53.21849   83.52723  -0.637   0.5260
dat$WatershedLittle Tenmile Creek                              3.80901   51.53308   0.074   0.9413
dat$WatershedMingo Creek-Monongahela River                   -11.06153   63.38827  -0.175   0.8619
dat$WatershedNorth Fork Cross Creek                           12.76591   36.58211   0.349   0.7281
dat$WatershedPigeon Creek                                    -25.17287   53.53855  -0.470   0.6396
dat$WatershedPike Run                                        -35.18574   51.47803  -0.684   0.4964
dat$WatershedPlum Run-Tenmile Creek                          -43.20478   45.84414  -0.942   0.3490
dat$WatershedShort Creek-Tenmile Creek                        23.18061   33.68150   0.688   0.4935
dat$WatershedSouth Fork Cross Creek-Cross Creek               10.02814   29.67737   0.338   0.7364
dat$WatershedTempleton Fork                                  156.65499   33.90339   4.621 1.58e-05 ***
dat$WatershedUpper Chartiers Creek                            -9.68033   33.83924  -0.286   0.7756
dat$FormationCasselman Formation                              -4.67973   63.48003  -0.074   0.9414
dat$FormationGreene Formation                                -37.47200   22.62219  -1.656   0.1019
dat$FormationMonongahela Group                                15.41773   26.59607   0.580   0.5639
dat$FormationWaynesburg Formation                             17.66938   19.75156   0.895   0.3739
dat$HHWSourceMix                                             -51.34362   63.47577  -0.809   0.4212
dat$HHWSourceSpring                                           54.60874   17.12697   3.188   0.0021 **
dat$Precip_inchAvg                                             0.40031    4.57258   0.088   0.9305
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 3286.55)

    Null deviance: 408511  on 103  degrees of freedom
Residual deviance: 243205  on  74  degrees of freedom
  (41 observations deleted due to missingness)
AIC: 1163.9

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Iron"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.95158  -0.17557   0.01112   0.21706   0.90391

Coefficients:
                                                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                -0.044826   1.501873  -0.030   0.9763
dat$GWellDensity_2kmAvg                                     0.002419   0.008074   0.300   0.7653
dat$Altitude_meter                                          0.004241   0.002310   1.836   0.0704 .
dat$WatershedBane Creek                                     0.297839   0.278500   1.069   0.2883
dat$WatershedBrush Run                                      0.052675   0.236597   0.223   0.8244
dat$WatershedBurgetts Fork                                  0.328255   0.243250   1.349   0.1813
dat$WatershedChartiers Run                                 -0.153489   0.316667  -0.485   0.6293
dat$WatershedEnlow Fork                                    -0.245809   0.311473  -0.789   0.4325
dat$WatershedFishpot Run-Monongahela River                  0.212924   0.478504   0.445   0.6576
dat$WatershedHarmon Creek                                   0.794125   0.634778   1.251   0.2149
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.521177   0.382307   1.363   0.1769
dat$WatershedLittle Chartiers Creek-Canonsburg Lake        -0.171680   0.332429  -0.516   0.6071
dat$WatershedLittle Racoon Creek                            0.140770   0.584981   0.241   0.8105
dat$WatershedLittle Tenmile Creek                           0.243453   0.360911   0.675   0.5021
dat$WatershedMingo Creek-Monongahela River                 -0.275300   0.443938  -0.620   0.5371
dat$WatershedNorth Fork Cross Creek                        -0.187957   0.256202  -0.734   0.4655
dat$WatershedPigeon Creek                                  -0.063000   0.374956  -0.168   0.8670
dat$WatershedPike Run                                      -0.071258   0.360525  -0.198   0.8439
dat$WatershedPlum Run-Tenmile Creek                         0.410457   0.321068   1.278   0.2051
dat$WatershedShort Creek-Tenmile Creek                      0.125692   0.235888   0.533   0.5957
dat$WatershedSouth Fork Cross Creek-Cross Creek             0.293743   0.207845   1.413   0.1618
dat$WatershedTempleton Fork                                -0.392179   0.237442  -1.652   0.1028
dat$WatershedUpper Chartiers Creek                         -0.147550   0.236992  -0.623   0.5355
dat$FormationCasselman Formation                            0.202531   0.444581   0.456   0.6500
dat$FormationGreene Formation                              -0.097276   0.158434  -0.614   0.5411
dat$FormationMonongahela Group                              0.290418   0.186265   1.559   0.1232
dat$FormationWaynesburg Formation                           0.096246   0.138330   0.696   0.4888
dat$HHWSourceMix                                           -0.021172   0.444551  -0.048   0.9621
dat$HHWSourceSpring                                        -0.045053   0.119948  -0.376   0.7083
dat$Precip_inchAvg                                         -0.019090   0.032024  -0.596   0.5529
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.1612009)

    Null deviance: 19.366  on 103  degrees of freedom
Residual deviance: 11.929  on  74  degrees of freedom
  (41 observations deleted due to missingness)
AIC: 131.93

Number of Fisher Scoring iterations: 2
```

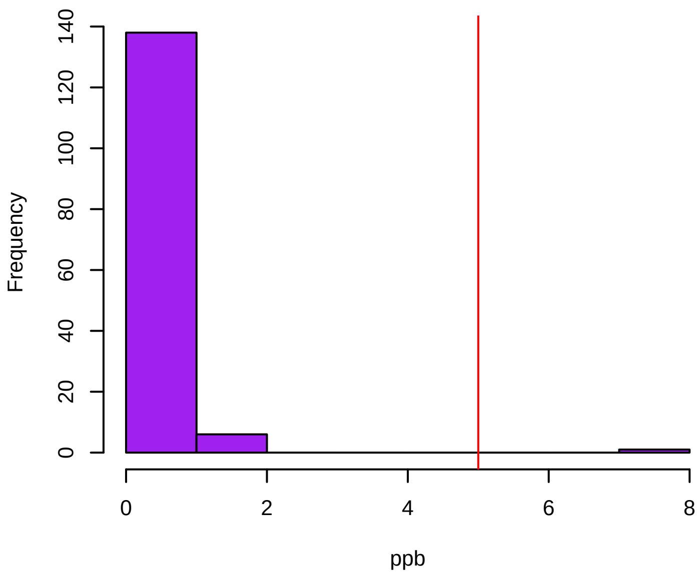
Lead

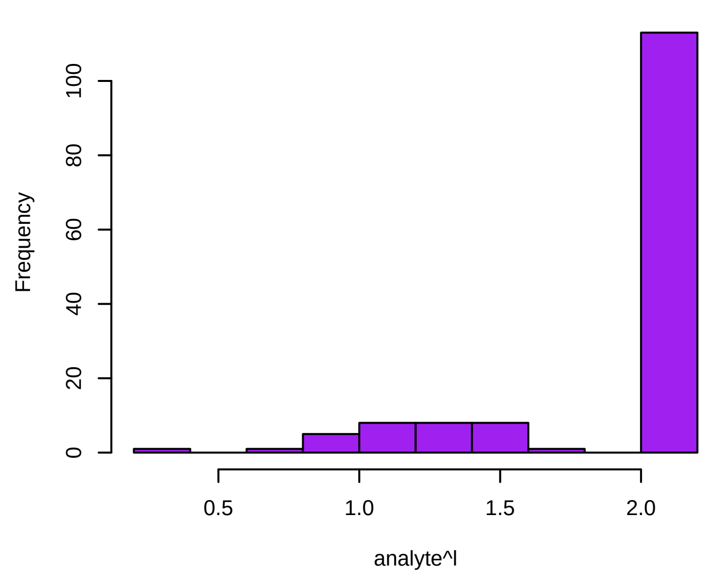
Skewness: 9.5659
Kurtosis: 104.8627

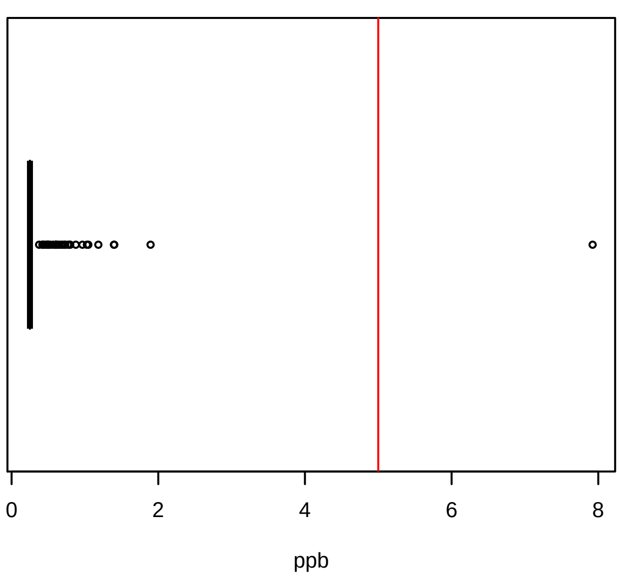
Lead Box−Cox

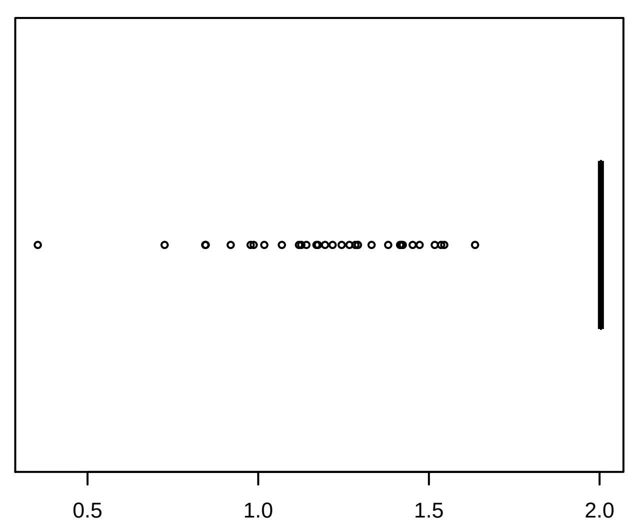
Skewness: −1.8521
Kurtosis: 5.3974

Optimal lambda: −0.5014



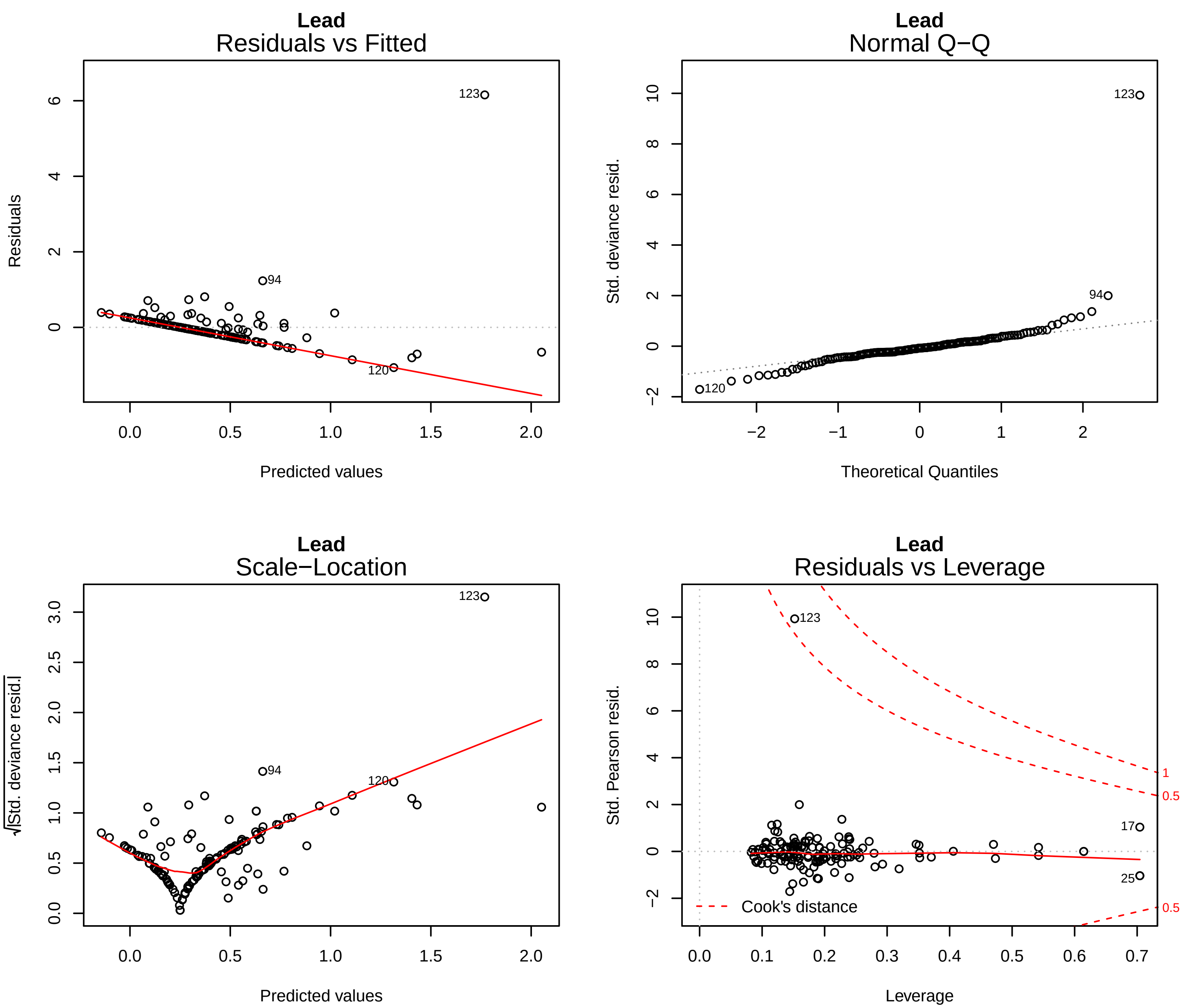






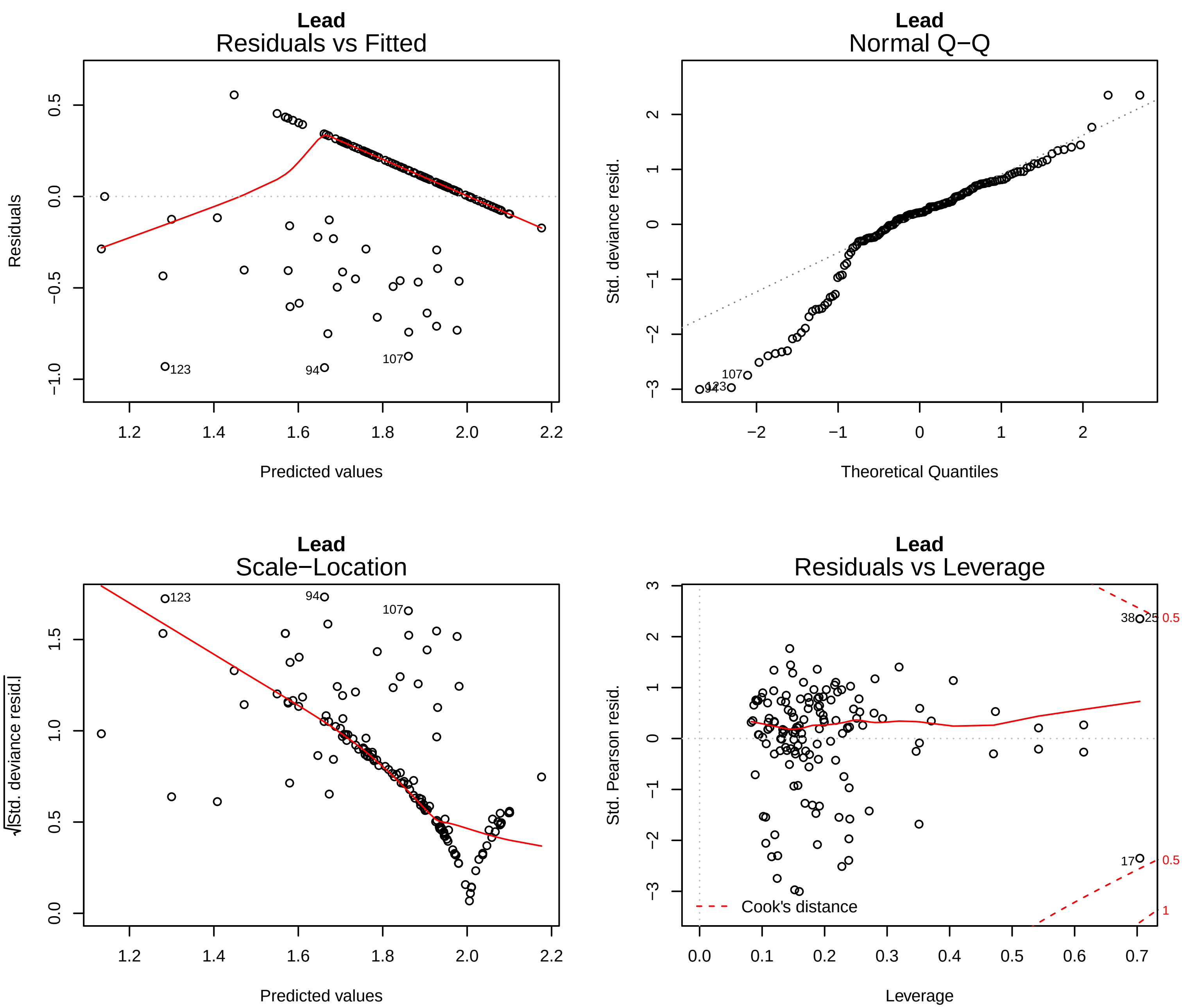
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

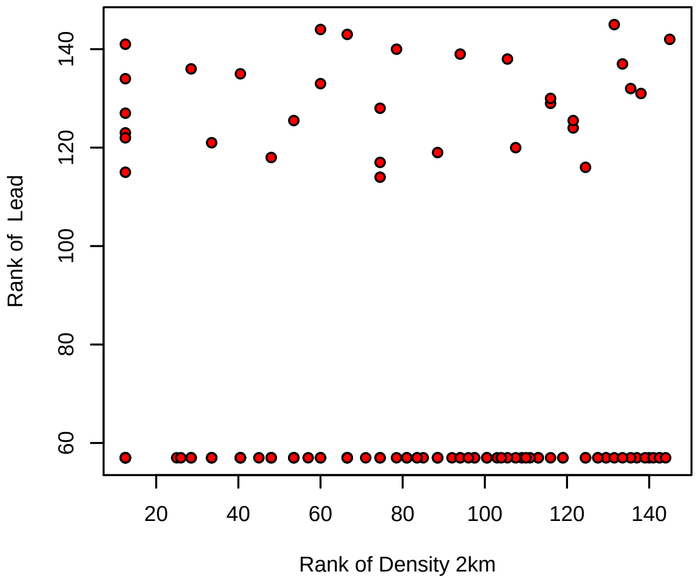
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



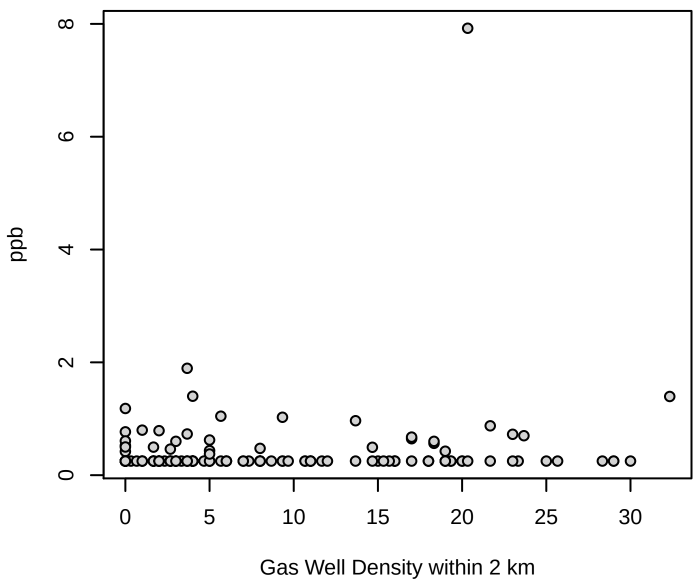


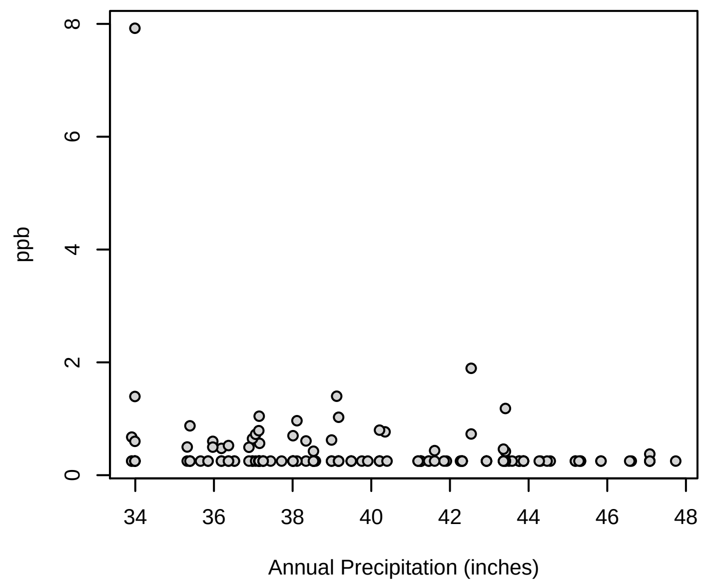
Lead

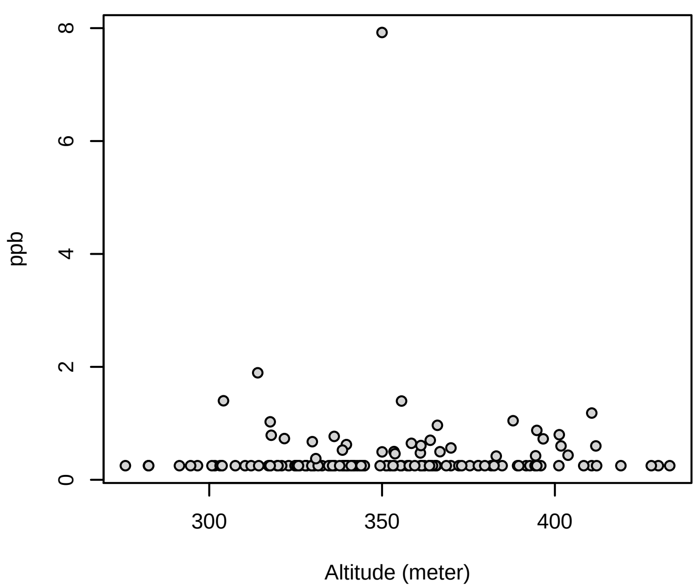
Kendalls Tau Rank Correlation

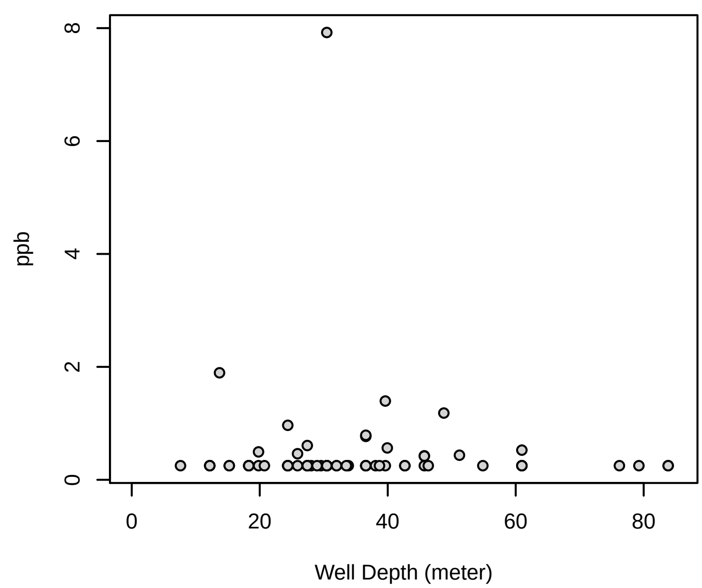
p−value: 0.52

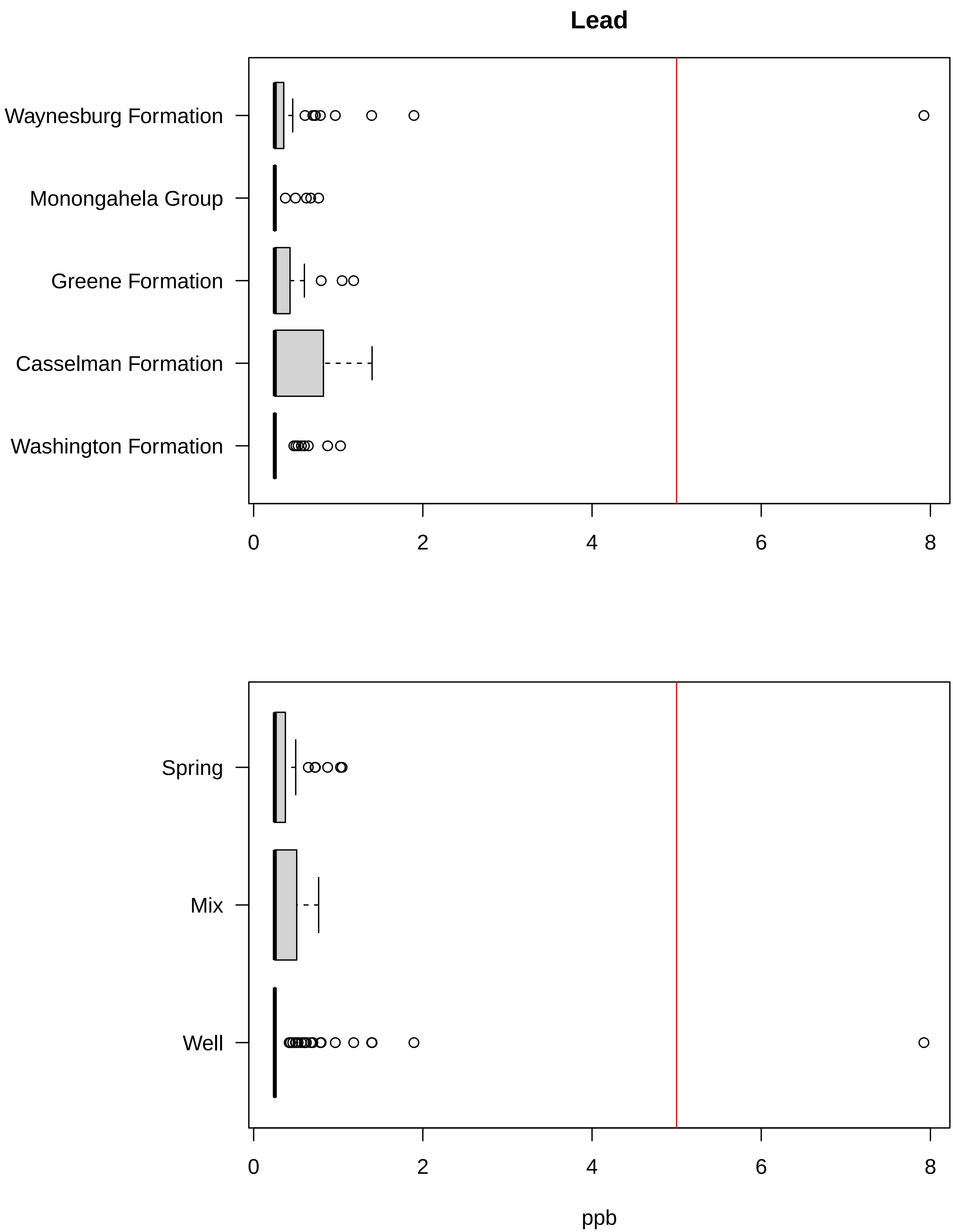
Tau: 0.0425

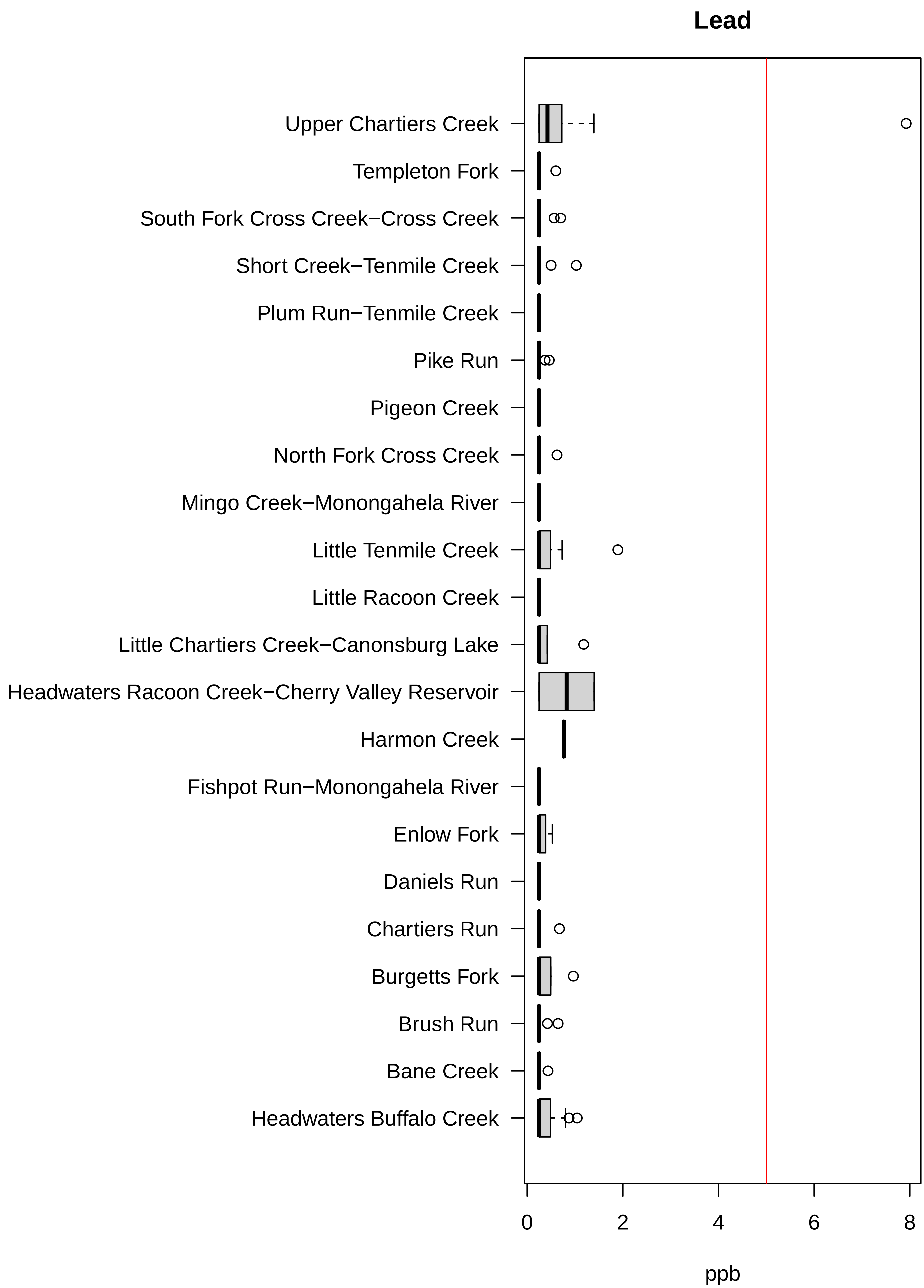









Lead
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
2
4
6
8
Spring
Mix
Well
0
2
4
6
8
ppb


Lead
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
2
4
6
8
ppb

```
[1] "ORIGINAL MODEL - Lead"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.0651  -0.1795  -0.0446   0.1199   6.1545

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  4.389464   1.851020   2.371   0.0194 *
dat$GWellDensity_2kmAvg                                      0.025421   0.011440   2.222   0.0282 *
dat$Altitude_meter                                          -0.003851   0.003140  -1.226   0.2226
dat$WatershedBane Creek                                     -0.009266   0.392264  -0.024   0.9812
dat$WatershedBrush Run                                      -0.545390   0.322380  -1.692   0.0934 .
dat$WatershedBurgetts Fork                                   0.068870   0.377168   0.183   0.8554
dat$WatershedChartiers Run                                  -0.525386   0.440395  -1.193   0.2354
dat$WatershedDaniels Run                                     0.278818   0.624980   0.446   0.6564
dat$WatershedEnlow Fork                                      0.027025   0.425962   0.063   0.9495
dat$WatershedFishpot Run-Monongahela River                   0.429103   0.515872   0.832   0.4073
dat$WatershedHarmon Creek                                    0.884992   0.843077   1.050   0.2961
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.037584   0.614069   0.061   0.9513
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          0.584970   0.397314   1.472   0.1437
dat$WatershedLittle Racoon Creek                            -0.750714   0.949842  -0.790   0.4310
dat$WatershedLittle Tenmile Creek                            0.469729   0.406343   1.156   0.2501
dat$WatershedMingo Creek-Monongahela River                   0.391343   0.544437   0.719   0.4737
dat$WatershedNorth Fork Cross Creek                          0.180639   0.365308   0.494   0.6219
dat$WatershedPigeon Creek                                    0.484993   0.457423   1.060   0.2913
dat$WatershedPike Run                                        0.634089   0.446854   1.419   0.1586
dat$WatershedPlum Run-Tenmile Creek                          0.261655   0.396281   0.660   0.5104
dat$WatershedShort Creek-Tenmile Creek                      -0.174289   0.328935  -0.530   0.5972
dat$WatershedSouth Fork Cross Creek-Cross Creek             -0.184897   0.294630  -0.628   0.5316
dat$WatershedTempleton Fork                                 -0.064399   0.348348  -0.185   0.8537
dat$WatershedUpper Chartiers Creek                           0.649320   0.300695   2.159   0.0329 *
dat$FormationCasselman Formation                             0.600561   0.685733   0.876   0.3830
dat$FormationGreene Formation                                0.239110   0.232896   1.027   0.3067
dat$FormationMonongahela Group                              -0.172490   0.243782  -0.708   0.4807
dat$FormationWaynesburg Formation                            0.113098   0.188670   0.599   0.5501
dat$HHWSourceMix                                            -0.008987   0.455432  -0.020   0.9843
dat$HHWSourceSpring                                          0.005090   0.149221   0.034   0.9728
dat$Precip_inchAvg                                          -0.075093   0.038190  -1.966   0.0517 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.4531746)

    Null deviance: 66.462  on 144  degrees of freedom
Residual deviance: 51.662  on 114  degrees of freedom
AIC: 325.85

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Lead"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.93627  -0.07587   0.05911   0.21313   0.55584

Coefficients:
                                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                                             0.2670310  0.9348859   0.286   0.7757
dat$GWellDensity_2kmAvg                                -0.0125340  0.0057777  -2.169   0.0321 *
dat$Altitude_meter                                     -0.0001156  0.0015858  -0.073   0.9420
dat$WatershedBane Creek                                 0.1061250  0.1981190   0.536   0.5932
dat$WatershedBrush Run                                  0.3695870  0.1628228   2.270   0.0251 *
dat$WatershedBurgetts Fork                             -0.0773477  0.1904946  -0.406   0.6855
dat$WatershedChartiers Run                              0.3661351  0.2224281   1.646   0.1025
dat$WatershedDaniels Run                               -0.0791892  0.3156558  -0.251   0.8024
dat$WatershedEnlow Fork                                -0.0382909  0.2151385  -0.178   0.8591
dat$WatershedFishpot Run-Monongahela River             -0.1610447  0.2605491  -0.618   0.5377
dat$WatershedHarmon Creek                              -0.9520647  0.4258091  -2.236   0.0273 *
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0291648  0.3101451  -0.094   0.9252
dat$WatershedLittle Chartiers Creek-Canonsburg Lake    -0.3482975  0.2006693  -1.736   0.0853 .
dat$WatershedLittle Racoon Creek                        0.8468492  0.4797322   1.765   0.0802 .
dat$WatershedLittle Tenmile Creek                      -0.3497399  0.2052296  -1.704   0.0911 .
dat$WatershedMingo Creek-Monongahela River             -0.0797179  0.2749761  -0.290   0.7724
dat$WatershedNorth Fork Cross Creek                    -0.0363185  0.1845041  -0.197   0.8443
dat$WatershedPigeon Creek                              -0.1539822  0.2310284  -0.667   0.5064
dat$WatershedPike Run                                  -0.2966865  0.2256905  -1.315   0.1913
dat$WatershedPlum Run-Tenmile Creek                    -0.1168746  0.2001475  -0.584   0.5604
dat$WatershedShort Creek-Tenmile Creek                  0.0538624  0.1661334   0.324   0.7464
dat$WatershedSouth Fork Cross Creek-Cross Creek         0.1426526  0.1488074   0.959   0.3398
dat$WatershedTempleton Fork                             0.0622063  0.1759383   0.354   0.7243
dat$WatershedUpper Chartiers Creek                     -0.1261675  0.1518704  -0.831   0.4078
dat$FormationCasselman Formation                       -0.6496569  0.3463398  -1.876   0.0632 .
dat$FormationGreene Formation                          -0.1725189  0.1176278  -1.467   0.1452
dat$FormationMonongahela Group                          0.0057255  0.1231258   0.047   0.9630
dat$FormationWaynesburg Formation                      -0.1047222  0.0952905  -1.099   0.2741
dat$HHWSourceMix                                        0.0269642  0.2300229   0.117   0.9069
dat$HHWSourceSpring                                    -0.0851920  0.0753661  -1.130   0.2607
dat$Precip_inchAvg                                      0.0454111  0.0192885   2.354   0.0203 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.1156007)

    Null deviance: 18.437  on 144  degrees of freedom
Residual deviance: 13.178  on 114  degrees of freedom
AIC: 127.76

Number of Fisher Scoring iterations: 2
```

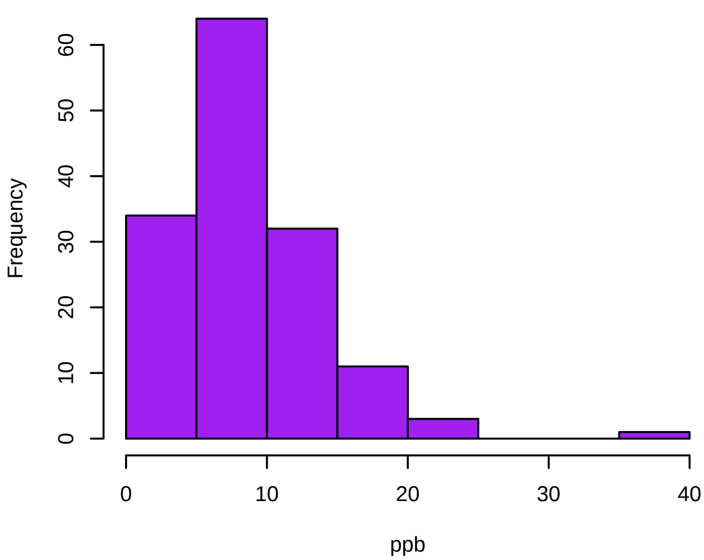
Lithium

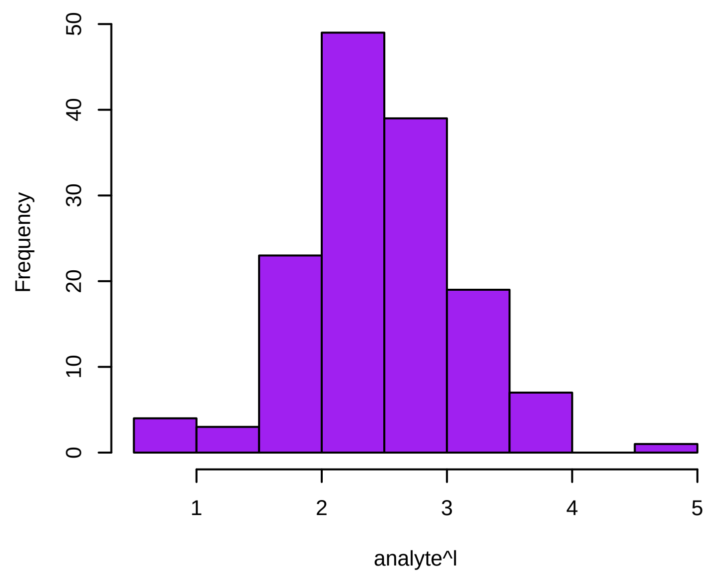
Skewness: 1.5250
Kurtosis: 7.8325

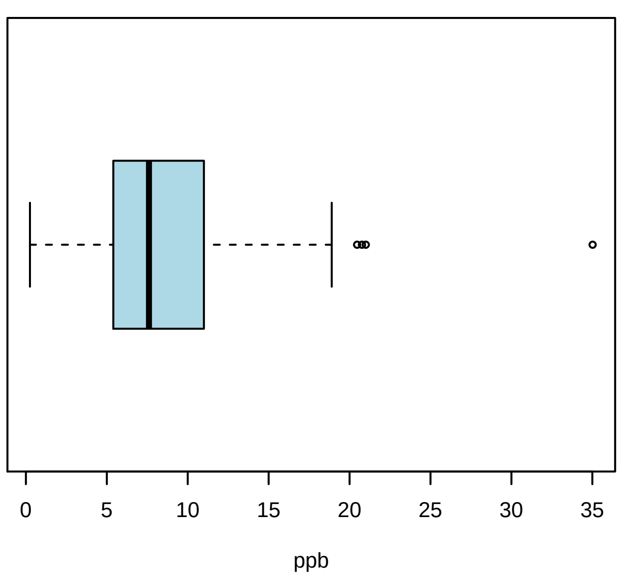
Lithium Box−Cox

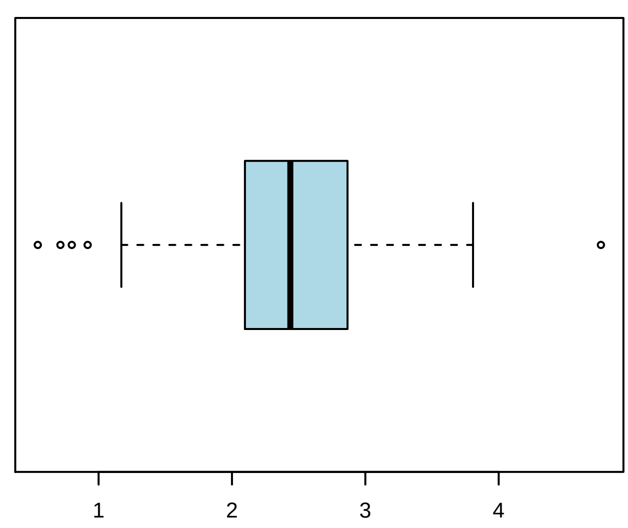
Skewness: 0.0415
Kurtosis: 4.0414

Optimal lambda: 0.4392



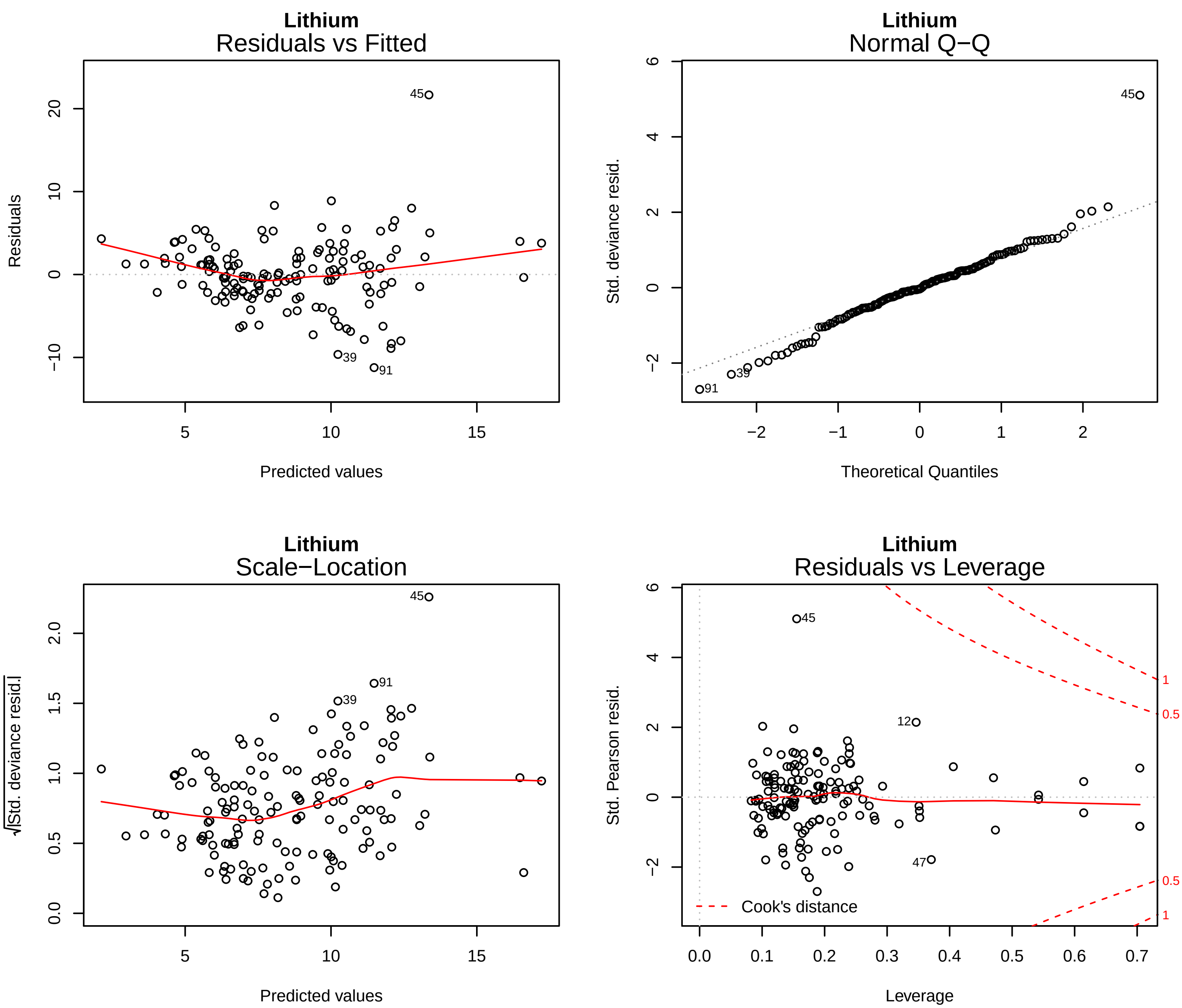






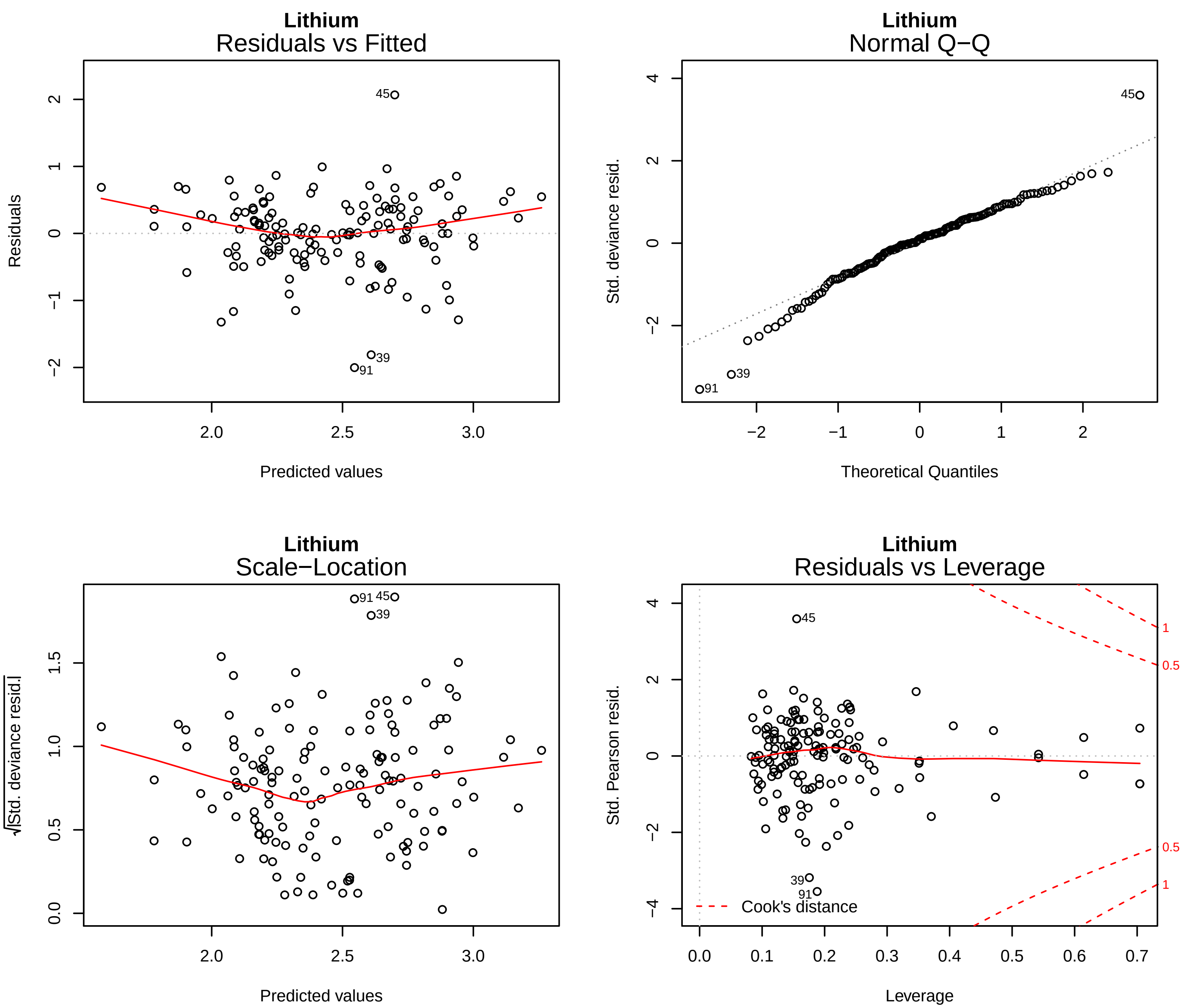
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

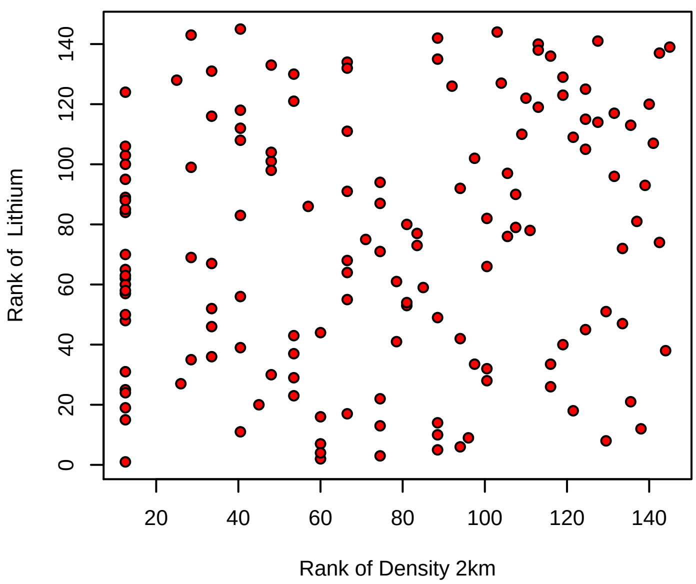
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



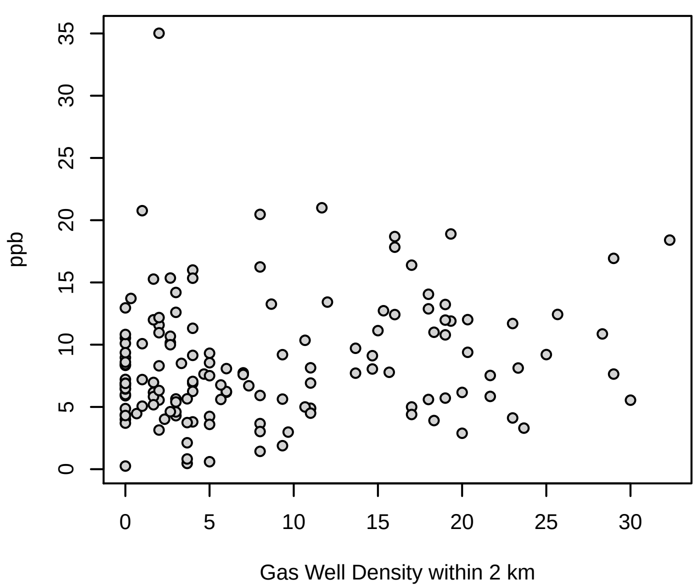


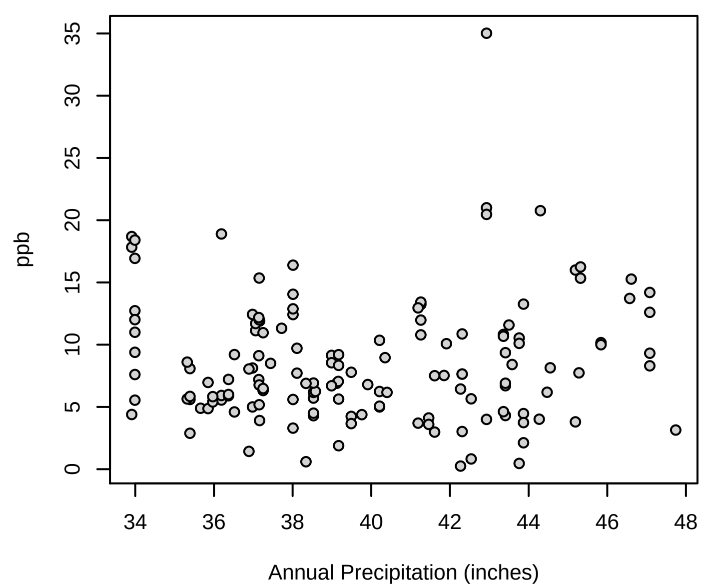
Lithium

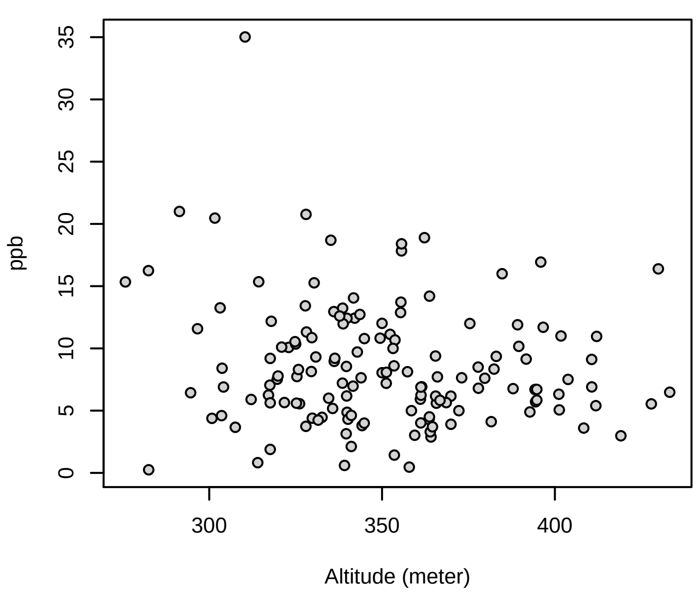
Kendalls Tau Rank Correlation

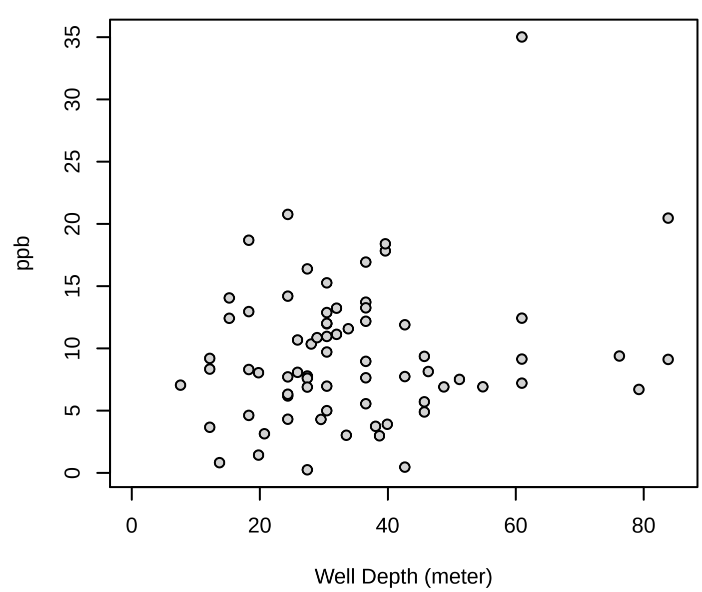
p−value: 0.0735

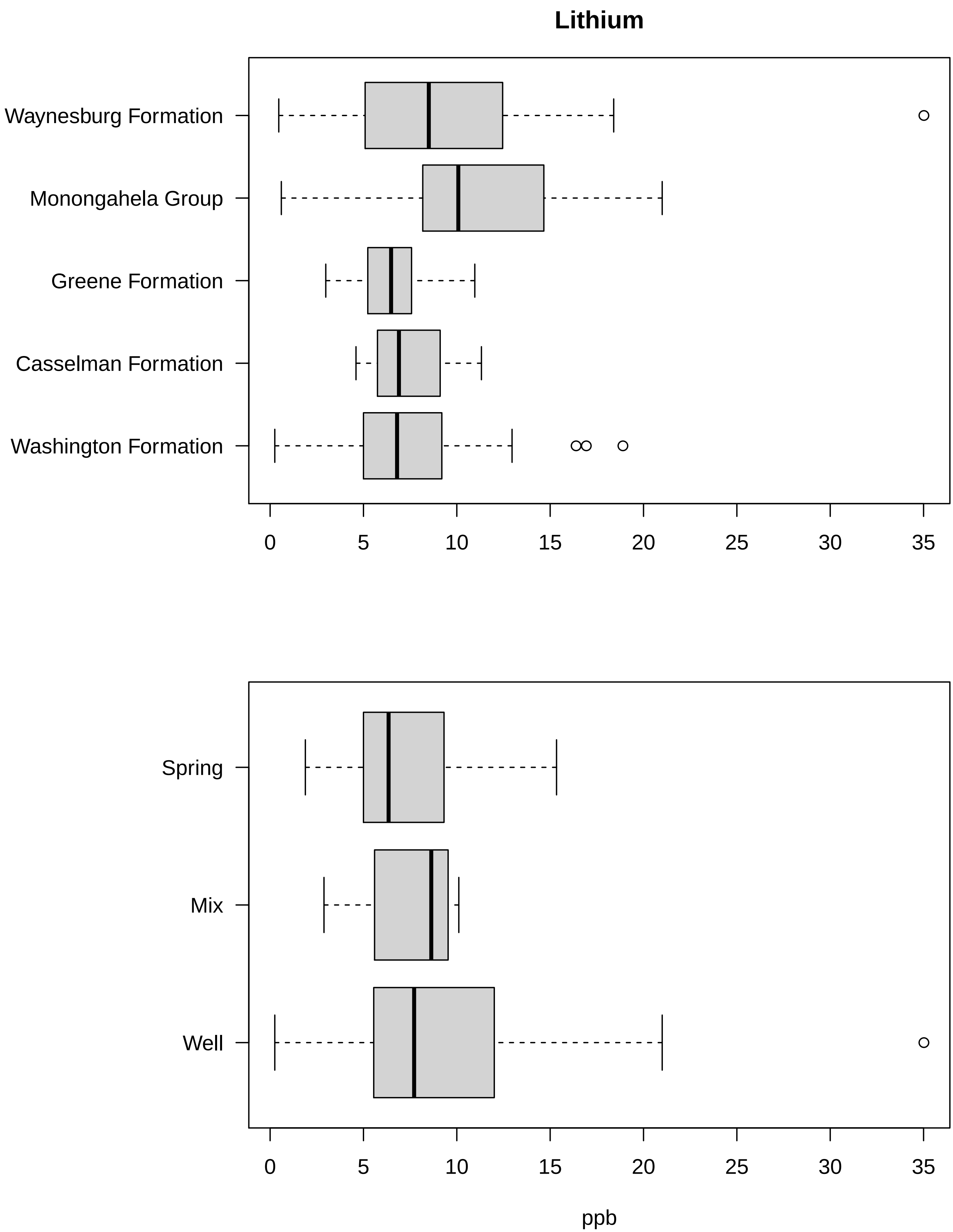
Tau: 0.102



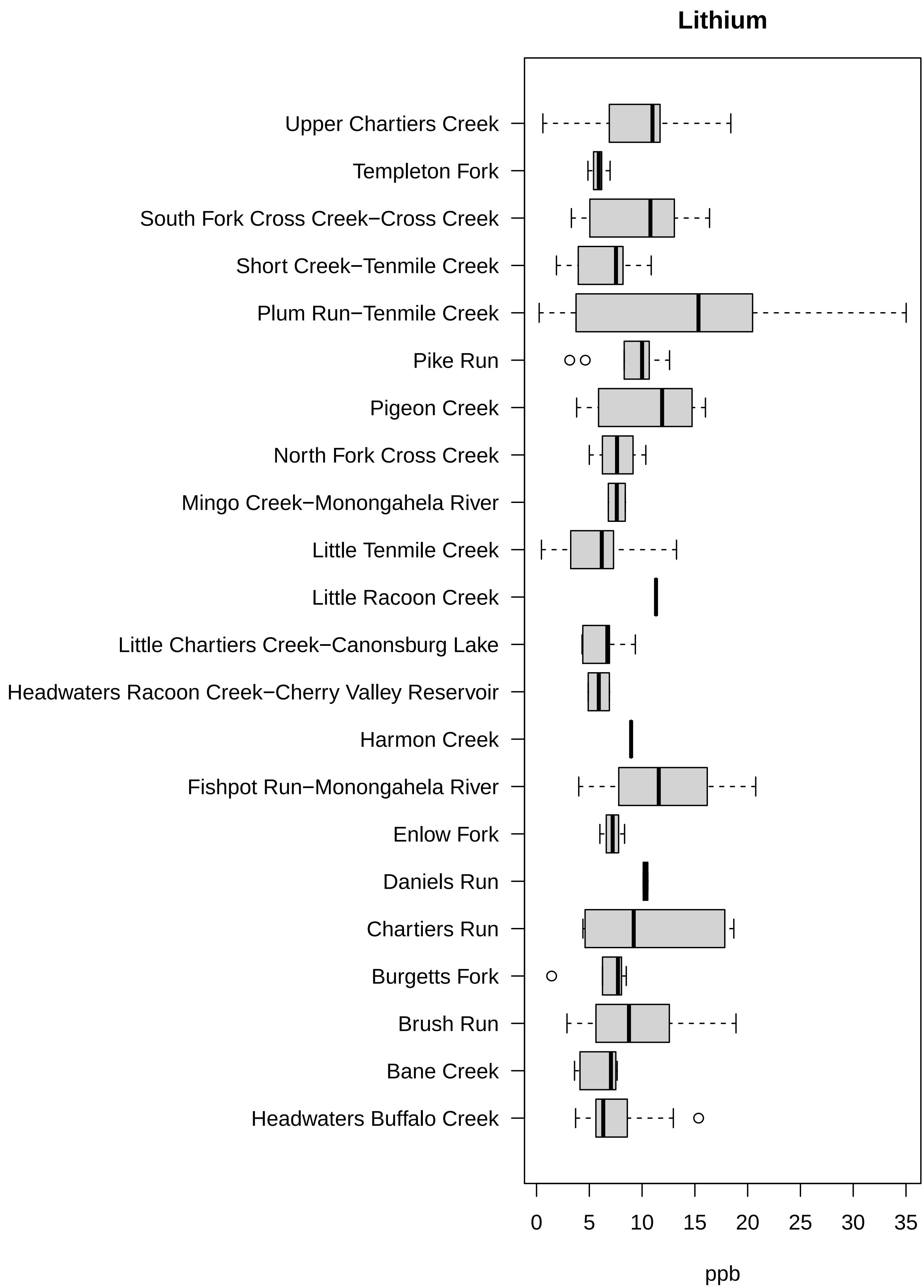








Lithium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
5
10
15
20
25
30
35
Spring
Mix
Well
0
5
10
15
20
25
30
35
ppb



Lithium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0 5 10 15 20 25 30 35
ppb

```
[1] "ORIGINAL MODEL - Lithium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-11.2276   -2.1559   -0.0542    2.0351   21.6613  

Coefficients:
                                                         Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                              7.678432  12.693063   0.605   0.5464  
dat$GWellDensity_2kmAvg                                  0.192368   0.078445   2.452   0.0157 *
dat$Altitude_meter                                      -0.003409   0.021531  -0.158   0.8745  
dat$WatershedBane Creek                                 -2.385747   2.689886  -0.887   0.3770  
dat$WatershedBrush Run                                  -1.114477   2.210666  -0.504   0.6151  
dat$WatershedBurgetts Fork                              -4.975086   2.586368  -1.924   0.0569 .
dat$WatershedChartiers Run                              -1.843698   3.019934  -0.611   0.5427  
dat$WatershedDaniels Run                                 5.151021   4.285698   1.202   0.2319  
dat$WatershedEnlow Fork                                  0.655393   2.920963   0.224   0.8229  
dat$WatershedFishpot Run-Monongahela River               1.320940   3.537508   0.373   0.7095  
dat$WatershedHarmon Creek                                3.492370   5.781263   0.604   0.5470  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -3.990077   4.210879  -0.948   0.3454  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     -1.290824   2.724512  -0.474   0.6366  
dat$WatershedLittle Racoon Creek                         5.278996   6.513384   0.810   0.4194  
dat$WatershedLittle Tenmile Creek                       -3.035875   2.786427  -1.090   0.2782  
dat$WatershedMingo Creek-Monongahela River              -0.461196   3.733384  -0.124   0.9019  
dat$WatershedNorth Fork Cross Creek                     -3.245461   2.505035  -1.296   0.1977  
dat$WatershedPigeon Creek                                0.617376   3.136701   0.197   0.8443  
dat$WatershedPike Run                                    0.368924   3.064228   0.120   0.9044  
dat$WatershedPlum Run-Tenmile Creek                      3.634843   2.717428   1.338   0.1837  
dat$WatershedShort Creek-Tenmile Creek                  -2.753415   2.255614  -1.221   0.2247  
dat$WatershedSouth Fork Cross Creek-Cross Creek         -2.435993   2.020377  -1.206   0.2304  
dat$WatershedTempleton Fork                             -1.229884   2.388737  -0.515   0.6076  
dat$WatershedUpper Chartiers Creek                      -1.776313   2.061963  -0.861   0.3908  
dat$FormationCasselman Formation                         0.342430   4.702299   0.073   0.9421  
dat$FormationGreene Formation                           -0.199000   1.597047  -0.125   0.9011  
dat$FormationMonongahela Group                           3.508230   1.671694   2.099   0.0381 *
dat$FormationWaynesburg Formation                        1.571884   1.293770   1.215   0.2269  
dat$HHWSourceMix                                        -5.649612   3.123050  -1.809   0.0731 .
dat$HHWSourceSpring                                     -2.638623   1.023256  -2.579   0.0112 *
dat$Precip_inchAvg                                       0.026671   0.261883   0.102   0.9191  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 21.30963)

    Null deviance: 3497.8  on 144  degrees of freedom
Residual deviance: 2429.3  on 114  degrees of freedom
AIC: 884.19

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Lithium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-2.00172  -0.28541   0.04636   0.35191   2.06682  

Coefficients:
                                                                 Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                                      2.641201   1.721067   1.535   0.1276   
dat$GWellDensity_2kmAvg                                          0.029160   0.010636   2.741   0.0071 **
dat$Altitude_meter                                              -0.001161   0.002919  -0.398   0.6917   
dat$WatershedBane Creek                                         -0.373808   0.364725  -1.025   0.3076   
dat$WatershedBrush Run                                          -0.235490   0.299747  -0.786   0.4337   
dat$WatershedBurgetts Fork                                      -0.649545   0.350689  -1.852   0.0666 . 
dat$WatershedChartiers Run                                      -0.341772   0.409476  -0.835   0.4057   
dat$WatershedDaniels Run                                         0.759110   0.581103   1.306   0.1941   
dat$WatershedEnlow Fork                                          0.106926   0.396057   0.270   0.7877   
dat$WatershedFishpot Run-Monongahela River                       0.114877   0.479655   0.239   0.8111   
dat$WatershedHarmon Creek                                        0.577008   0.783888   0.736   0.4632   
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.494247   0.570958  -0.866   0.3885   
dat$WatershedLittle Chartiers Creek-Canonsburg Lake             -0.161497   0.369420  -0.437   0.6628   
dat$WatershedLittle Racoon Creek                                 0.647292   0.883157   0.733   0.4651   
dat$WatershedLittle Tenmile Creek                               -0.568520   0.377815  -1.505   0.1352   
dat$WatershedMingo Creek-Monongahela River                       0.004213   0.506214   0.008   0.9934   
dat$WatershedNorth Fork Cross Creek                             -0.347752   0.339661  -1.024   0.3081   
dat$WatershedPigeon Creek                                        0.112031   0.425309   0.263   0.7927   
dat$WatershedPike Run                                            0.095093   0.415482   0.229   0.8194   
dat$WatershedPlum Run-Tenmile Creek                              0.090990   0.368459   0.247   0.8054   
dat$WatershedShort Creek-Tenmile Creek                          -0.476763   0.305841  -1.559   0.1218   
dat$WatershedSouth Fork Cross Creek-Cross Creek                 -0.342873   0.273945  -1.252   0.2133   
dat$WatershedTempleton Fork                                     -0.167972   0.323892  -0.519   0.6050   
dat$WatershedUpper Chartiers Creek                              -0.294854   0.279584  -1.055   0.2938   
dat$FormationCasselman Formation                                 0.045971   0.637590   0.072   0.9426   
dat$FormationGreene Formation                                    0.016098   0.216545   0.074   0.9409   
dat$FormationMonongahela Group                                   0.382743   0.226667   1.689   0.0940 . 
dat$FormationWaynesburg Formation                                0.125656   0.175424   0.716   0.4753   
dat$HHWSourceMix                                                -0.726359   0.423458  -1.715   0.0890 . 
dat$HHWSourceSpring                                             -0.293939   0.138744  -2.119   0.0363 * 
dat$Precip_inchAvg                                               0.003345   0.035509   0.094   0.9251   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.3917768)

    Null deviance: 59.628  on 144  degrees of freedom
Residual deviance: 44.663  on 114  degrees of freedom
AIC: 304.74

Number of Fisher Scoring iterations: 2
```

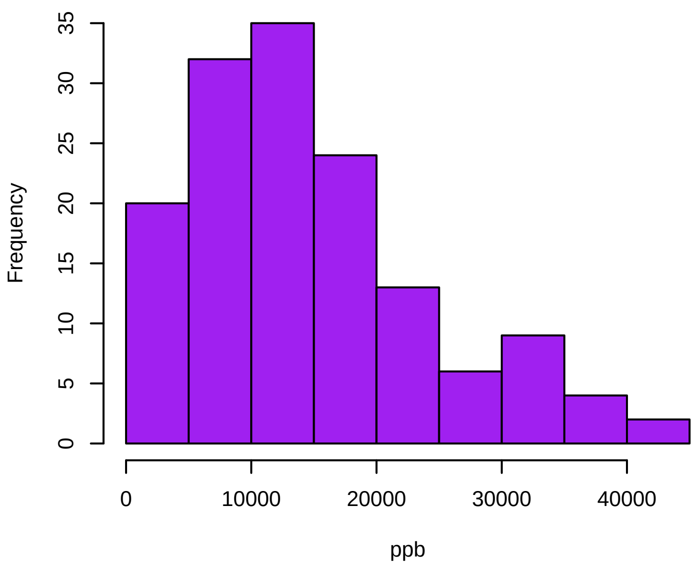
Magnesium

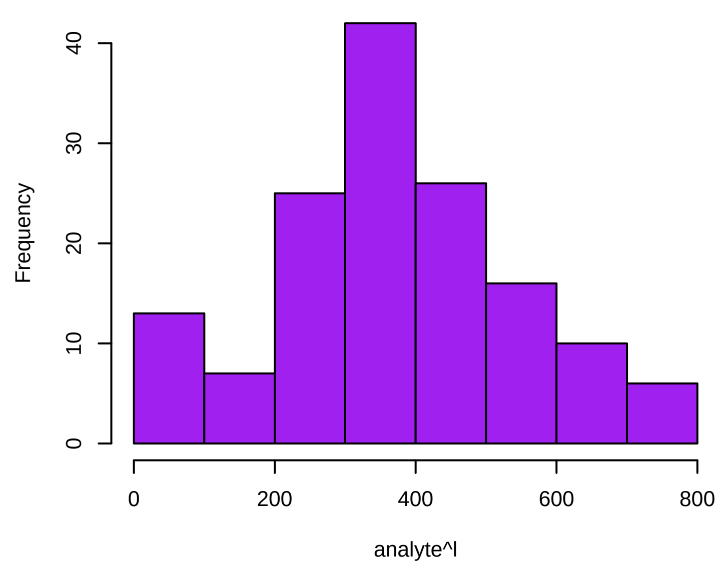
Skewness: 0.8362
Kurtosis: 3.2687

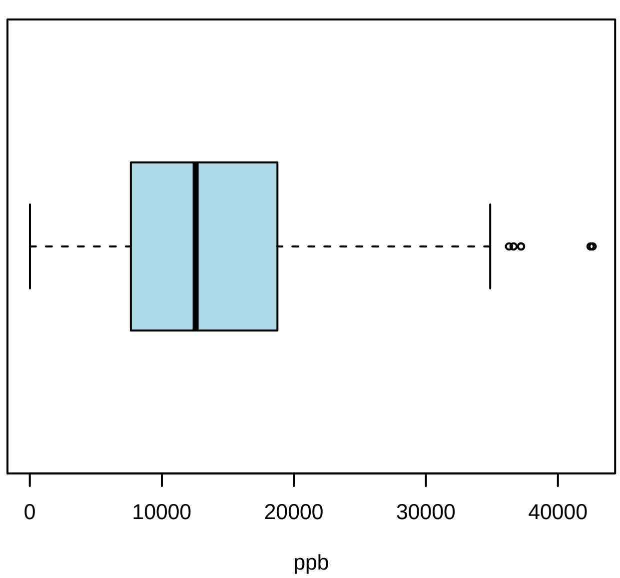
Magnesium Box−Cox

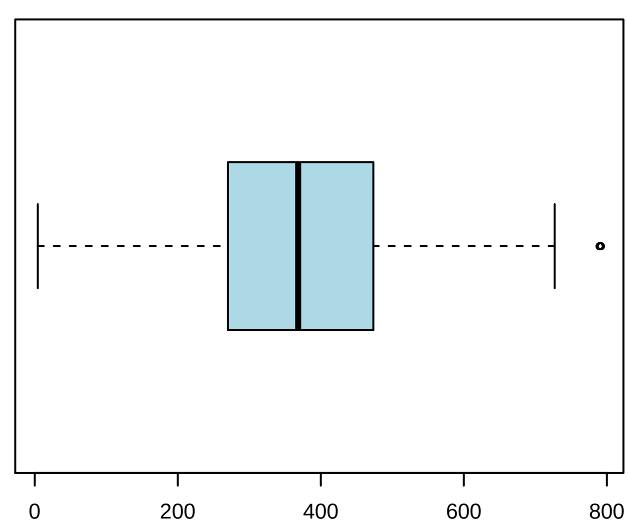
Skewness: 0.0808
Kurtosis: 2.8148

Optimal lambda: 0.6261



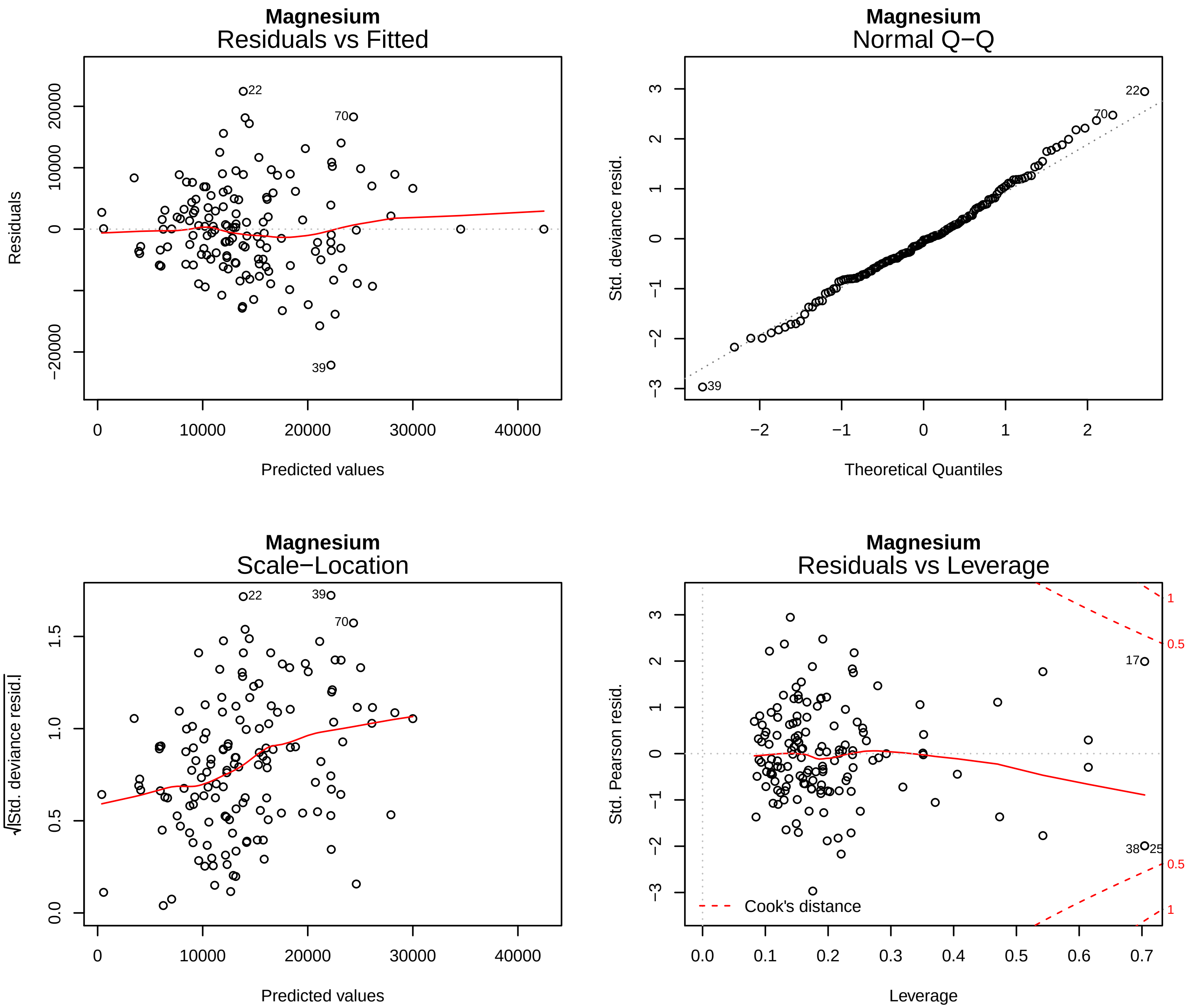






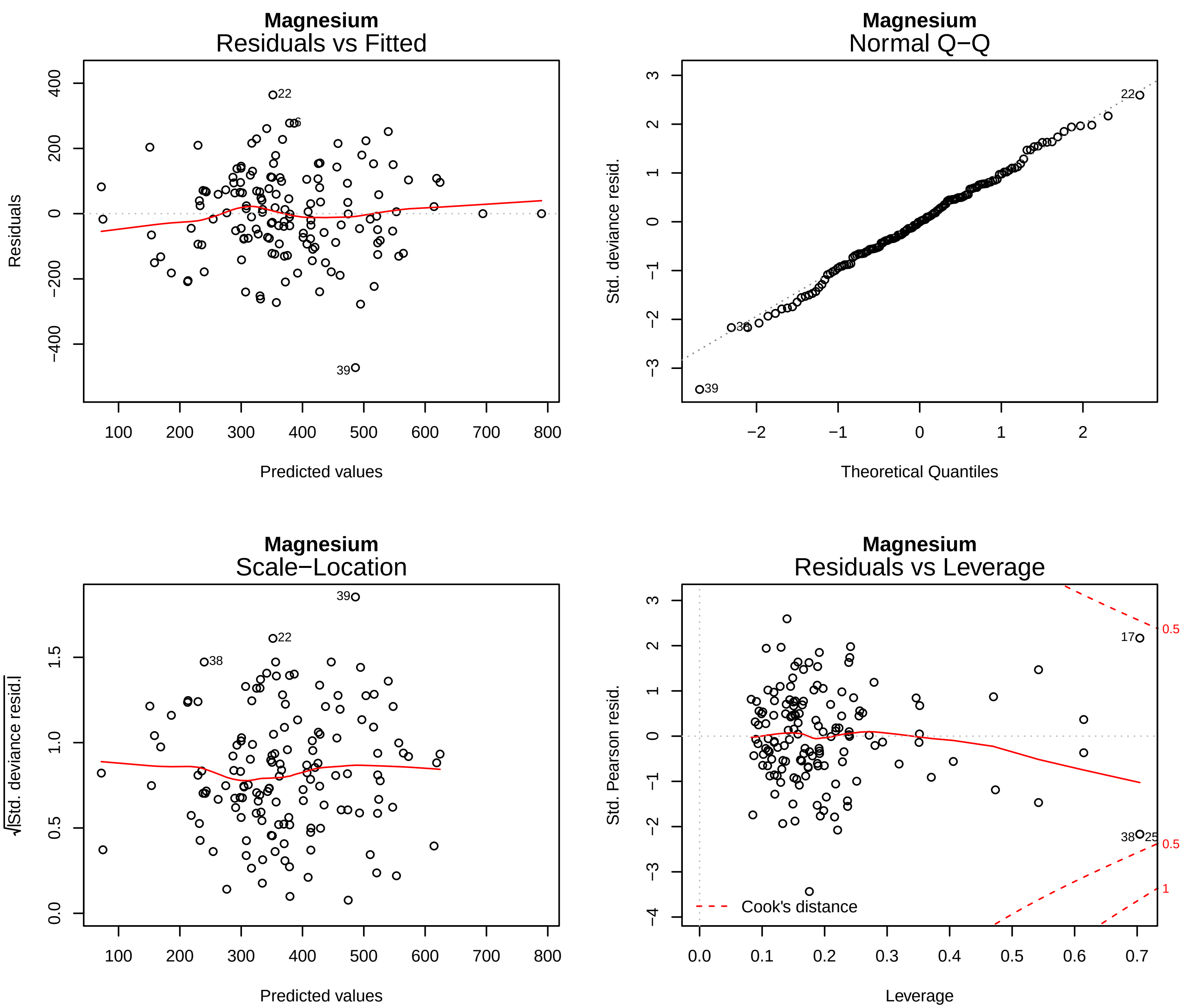
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

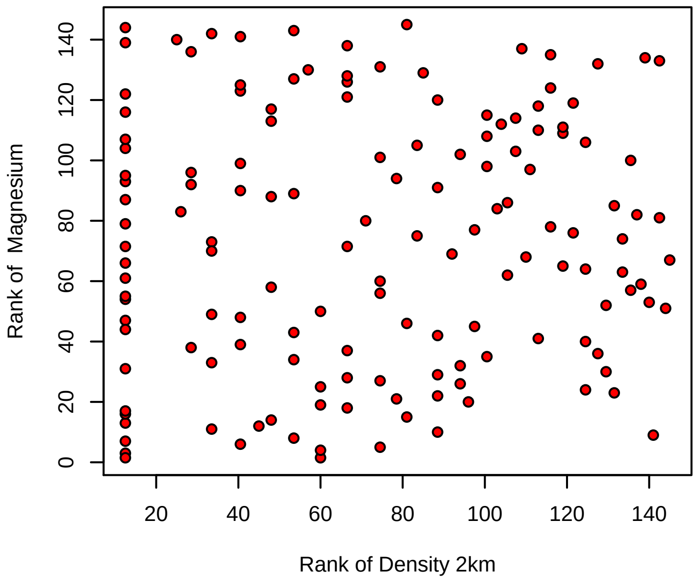
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



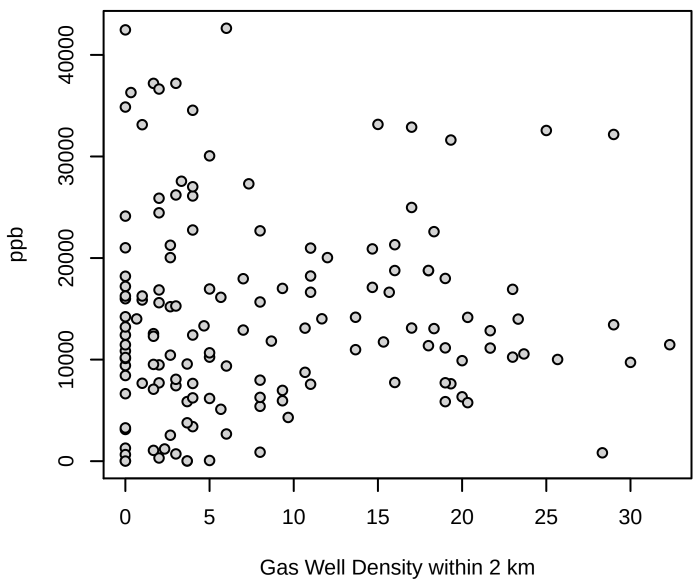


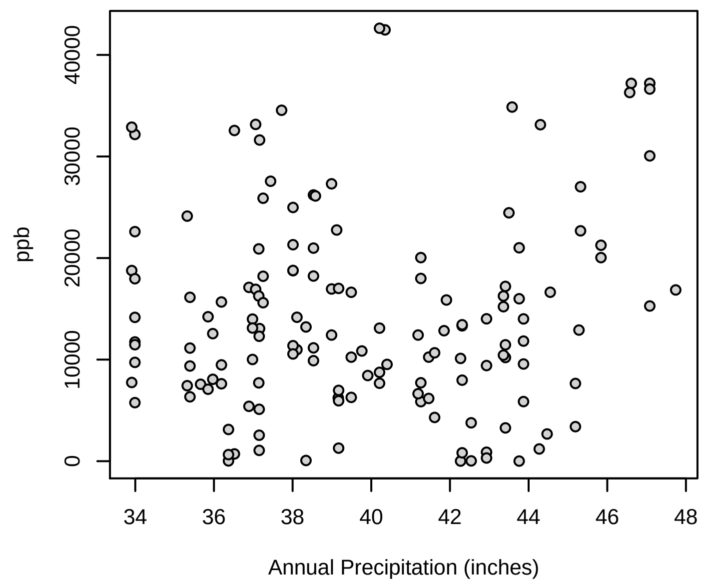
Magnesium

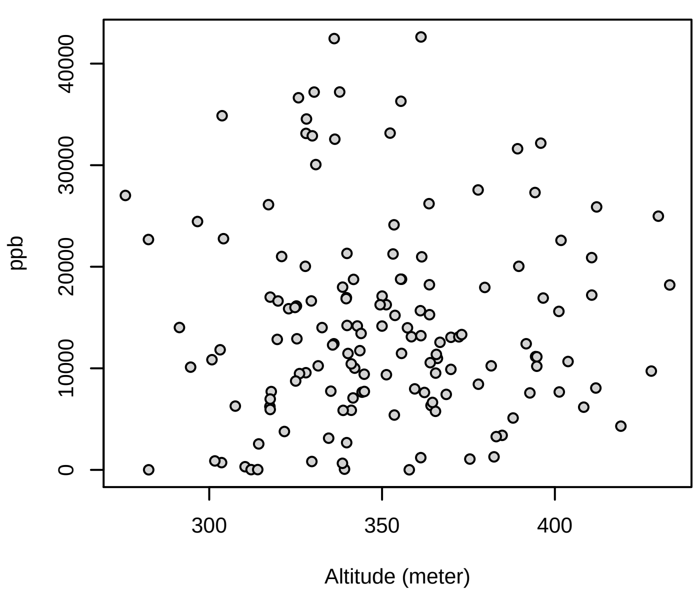
Kendalls Tau Rank Correlation

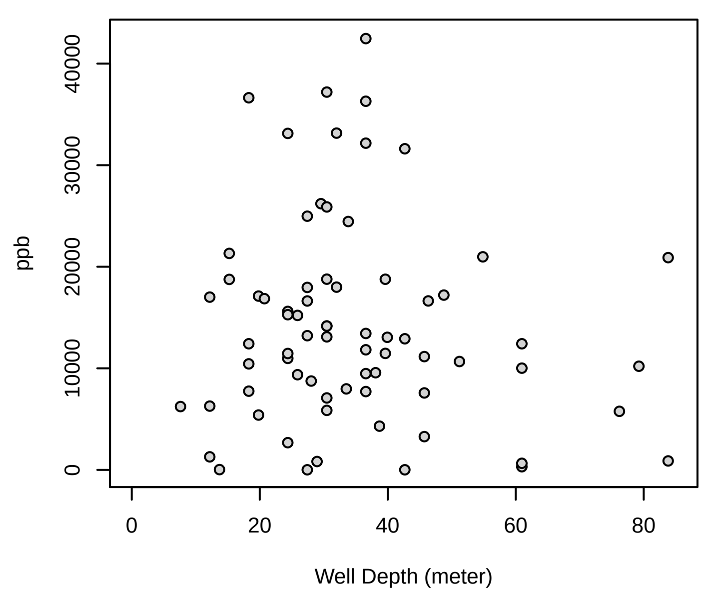
p−value: 0.427

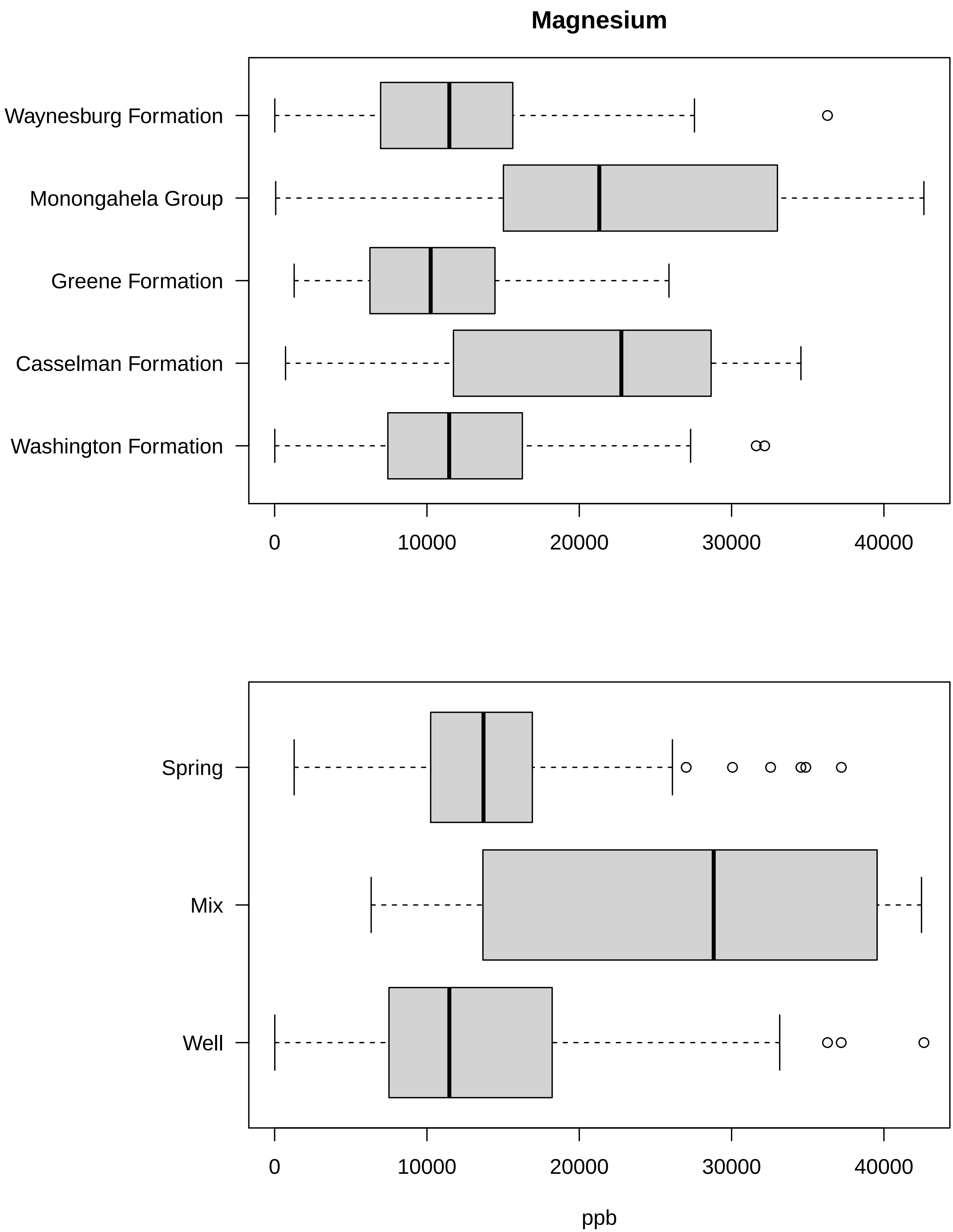
Tau: 0.0454



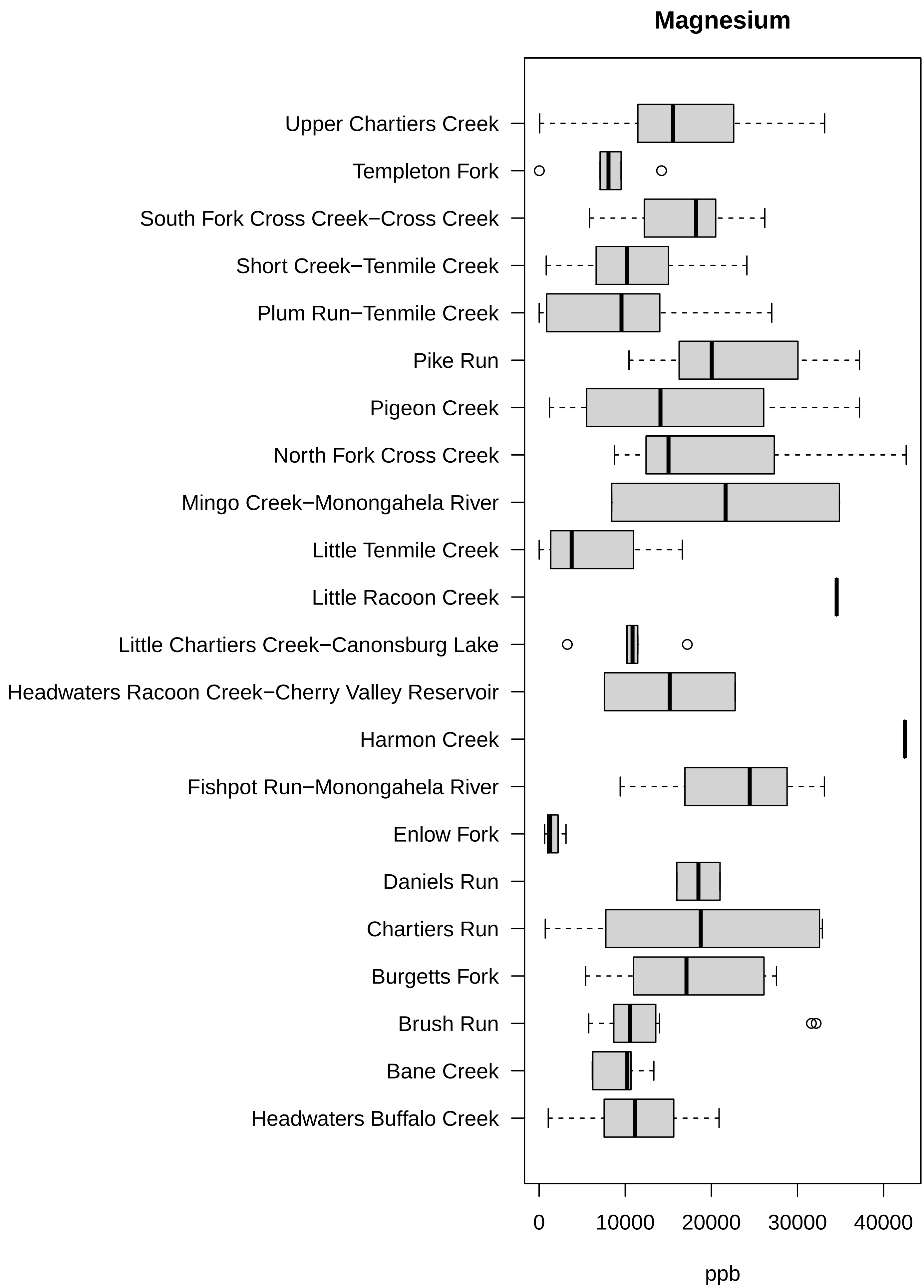








Magnesium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
10000
20000
30000
40000
Spring
Mix
Well
0
10000
20000
30000
40000
ppb


Magnesium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
10000
20000
30000
40000
ppb

```
[1] "ORIGINAL MODEL - Magnesium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-22136.3   -4891.3    -161.5    4785.3   22438.9

Coefficients:
                                                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                     -8215.04   22583.13  -0.364   0.7167
dat$GWellDensity_2kmAvg                                           -37.74     139.57  -0.270   0.7873
dat$Altitude_meter                                                 43.43      38.31   1.134   0.2593
dat$WatershedBane Creek                                         -2198.83    4785.77  -0.459   0.6468
dat$WatershedBrush Run                                           2680.73    3933.15   0.682   0.4969
dat$WatershedBurgetts Fork                                       3249.96    4601.59   0.706   0.4815
dat$WatershedChartiers Run                                       3560.45    5372.98   0.663   0.5089
dat$WatershedDaniels Run                                         7979.60    7624.99   1.047   0.2975
dat$WatershedEnlow Fork                                         -9634.30    5196.89  -1.854   0.0663 .
dat$WatershedFishpot Run-Monongahela River                       8305.10    6293.83   1.320   0.1896
dat$WatershedHarmon Creek                                       20177.19   10285.85   1.962   0.0522 .
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir     7568.33    7491.87   1.010   0.3145
dat$WatershedLittle Chartiers Creek-Canonsburg Lake             -2764.47    4847.37  -0.570   0.5696
dat$WatershedLittle Racoon Creek                                25033.24   11588.42   2.160   0.0329 *
dat$WatershedLittle Tenmile Creek                               -2460.74    4957.53  -0.496   0.6206
dat$WatershedMingo Creek-Monongahela River                       6006.14    6642.33   0.904   0.3678
dat$WatershedNorth Fork Cross Creek                              5718.38    4456.89   1.283   0.2021
dat$WatershedPigeon Creek                                        5059.62    5580.73   0.907   0.3665
dat$WatershedPike Run                                            7543.58    5451.78   1.384   0.1692
dat$WatershedPlum Run-Tenmile Creek                             -2492.00    4834.77  -0.515   0.6072
dat$WatershedShort Creek-Tenmile Creek                            881.52    4013.12   0.220   0.8265
dat$WatershedSouth Fork Cross Creek-Cross Creek                  5133.75    3594.60   1.428   0.1560
dat$WatershedTempleton Fork                                     -3173.58    4249.97  -0.747   0.4568
dat$WatershedUpper Chartiers Creek                               4686.58    3668.58   1.277   0.2040
dat$FormationCasselman Formation                                -2534.43    8366.19  -0.303   0.7625
dat$FormationGreene Formation                                    -977.18    2841.42  -0.344   0.7316
dat$FormationMonongahela Group                                   7281.34    2974.23   2.448   0.0159 *
dat$FormationWaynesburg Formation                               -3165.00    2301.84  -1.375   0.1718
dat$HHWSourceMix                                                 4506.71    5556.44   0.811   0.4190
dat$HHWSourceSpring                                              2317.85    1820.55   1.273   0.2056
dat$Precip_inchAvg                                                102.10     465.93   0.219   0.8269
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 67454554)

    Null deviance: 1.3729e+10  on 144  degrees of freedom
Residual deviance: 7.6898e+09  on 114  degrees of freedom
AIC: 3054.5

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Magnesium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-472.04   -82.17     0.00    94.30   364.17  

Coefficients:
                                                         Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                             114.85234  416.14159   0.276   0.7831  
dat$GWellDensity_2kmAvg                                   0.09621    2.57181   0.037   0.9702  
dat$Altitude_meter                                        0.64806    0.70589   0.918   0.3605  
dat$WatershedBane Creek                                 -35.58524   88.18781  -0.404   0.6873  
dat$WatershedBrush Run                                   37.53346   72.47659   0.518   0.6056  
dat$WatershedBurgetts Fork                               71.11774   84.79399   0.839   0.4034  
dat$WatershedChartiers Run                               46.65832   99.00841   0.471   0.6384  
dat$WatershedDaniels Run                                177.03502  140.50645   1.260   0.2103  
dat$WatershedEnlow Fork                                -232.72591   95.76365  -2.430   0.0166 *
dat$WatershedFishpot Run-Monongahela River              172.04564  115.97707   1.483   0.1407  
dat$WatershedHarmon Creek                               312.76404  189.53849   1.650   0.1017  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  164.58589 138.05350   1.192   0.2357  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     -28.22982   89.32302  -0.316   0.7525  
dat$WatershedLittle Racoon Creek                        431.12190  213.54106   2.019   0.0458 *
dat$WatershedLittle Tenmile Creek                       -66.84301   91.35291  -0.732   0.4659  
dat$WatershedMingo Creek-Monongahela River              107.40453  122.39886   0.877   0.3821  
dat$WatershedNorth Fork Cross Creek                     113.99362   82.12749   1.388   0.1678  
dat$WatershedPigeon Creek                               102.77125  102.83664   0.999   0.3197  
dat$WatershedPike Run                                   158.65558  100.46059   1.579   0.1170  
dat$WatershedPlum Run-Tenmile Creek                     -53.88031   89.09076  -0.605   0.5465  
dat$WatershedShort Creek-Tenmile Creek                    7.40489   73.95024   0.100   0.9204  
dat$WatershedSouth Fork Cross Creek-Cross Creek         106.43185   66.23798   1.607   0.1109  
dat$WatershedTempleton Fork                             -76.78526   78.31464  -0.980   0.3289  
dat$WatershedUpper Chartiers Creek                       73.50691   67.60138   1.087   0.2792  
dat$FormationCasselman Formation                        -91.70280  154.16469  -0.595   0.5531  
dat$FormationGreene Formation                            -2.05317   52.35912  -0.039   0.9688  
dat$FormationMonongahela Group                          106.20048   54.80643   1.938   0.0551 .
dat$FormationWaynesburg Formation                       -61.67316   42.41622  -1.454   0.1487  
dat$HHWSourceMix                                         68.17538  102.38907   0.666   0.5069  
dat$HHWSourceSpring                                      54.87664   33.54740   1.636   0.1046  
dat$Precip_inchAvg                                       -0.74306    8.58581  -0.087   0.9312  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 22904.74)

    Null deviance: 4517893  on 144  degrees of freedom
Residual deviance: 2611140  on 114  degrees of freedom
AIC: 1896.3

Number of Fisher Scoring iterations: 2
```

Manganese

Skewness: 3.0566

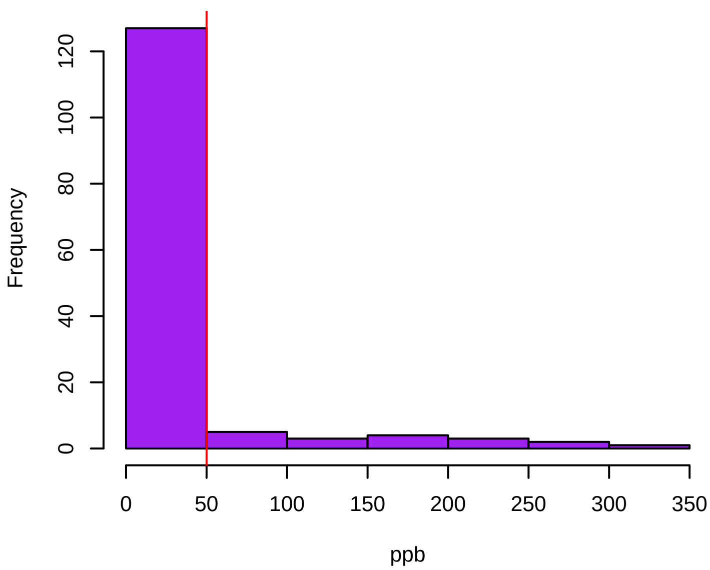
Kurtosis: 11.8622

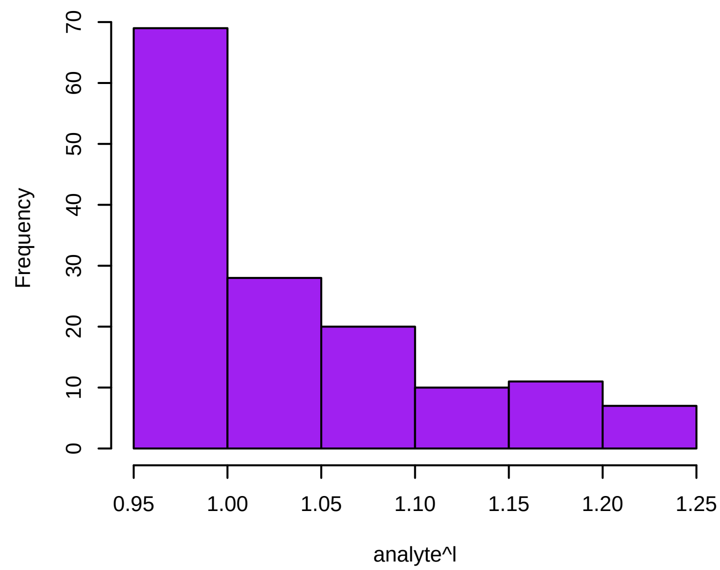
Manganese Box−Cox

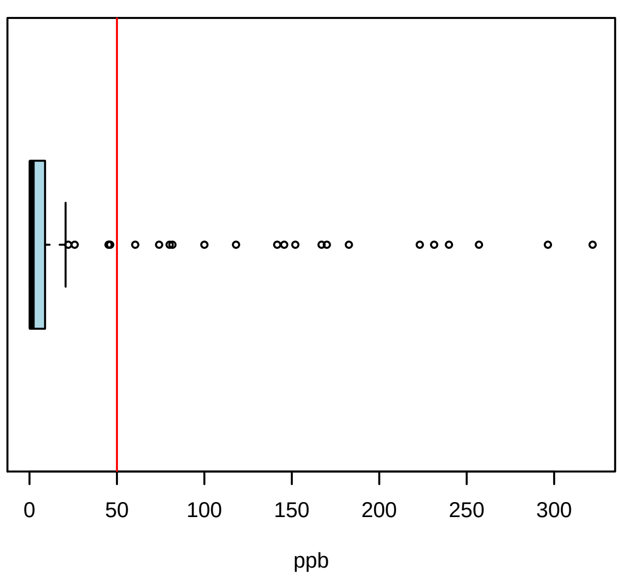
Skewness: 0.9028

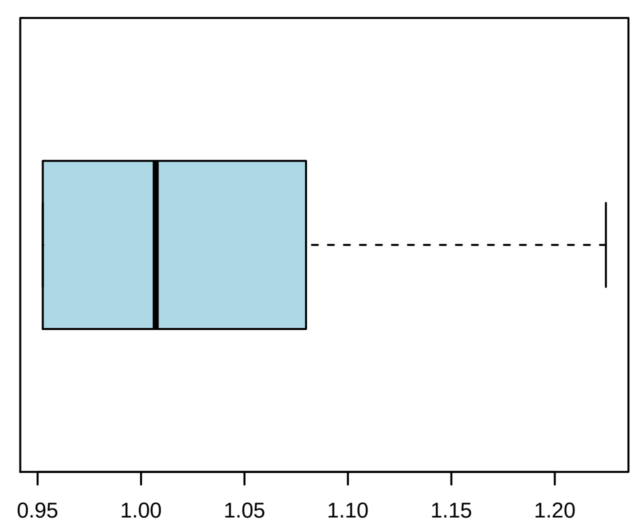
Kurtosis: 2.6825

Optimal lambda: 0.0351



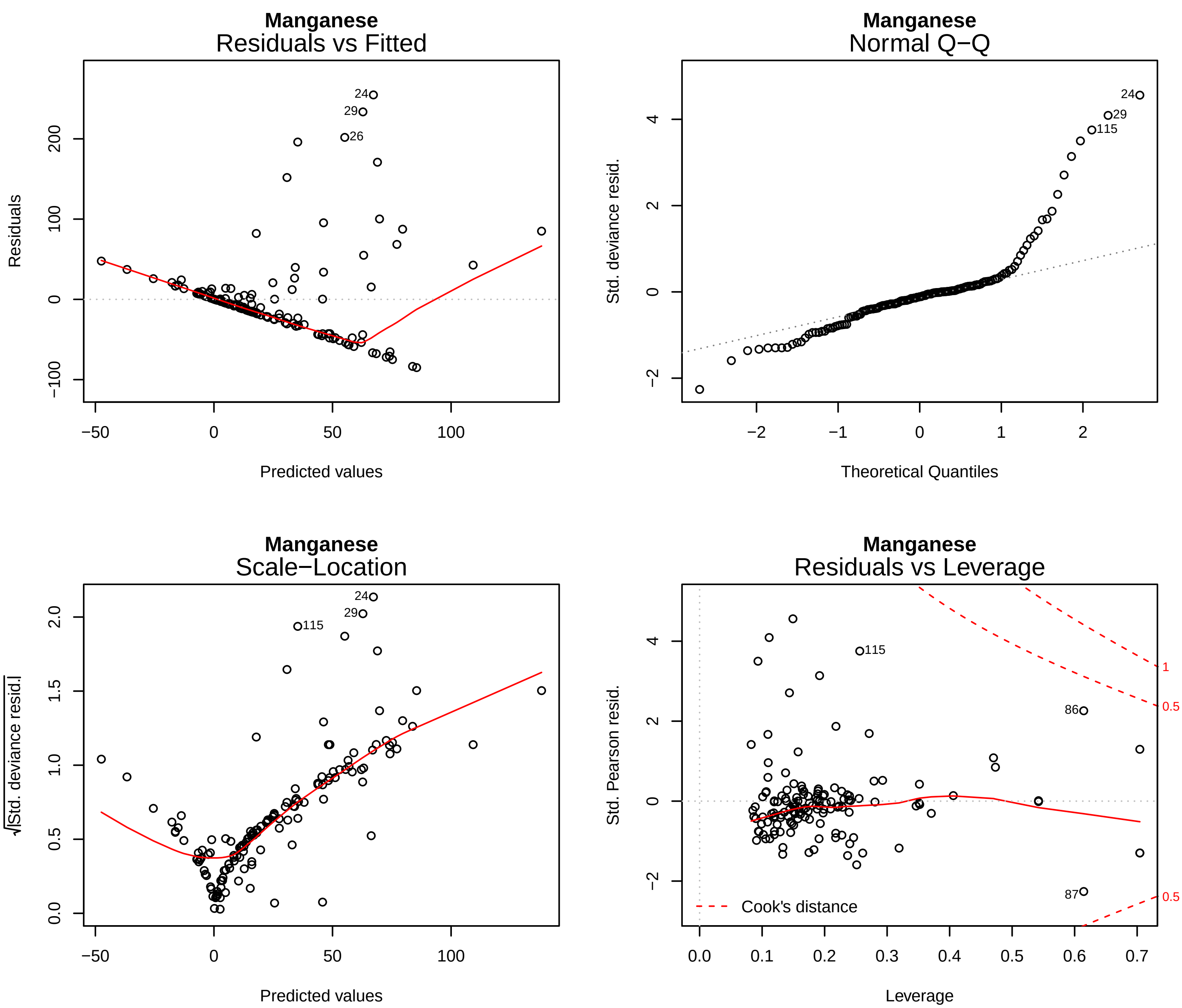






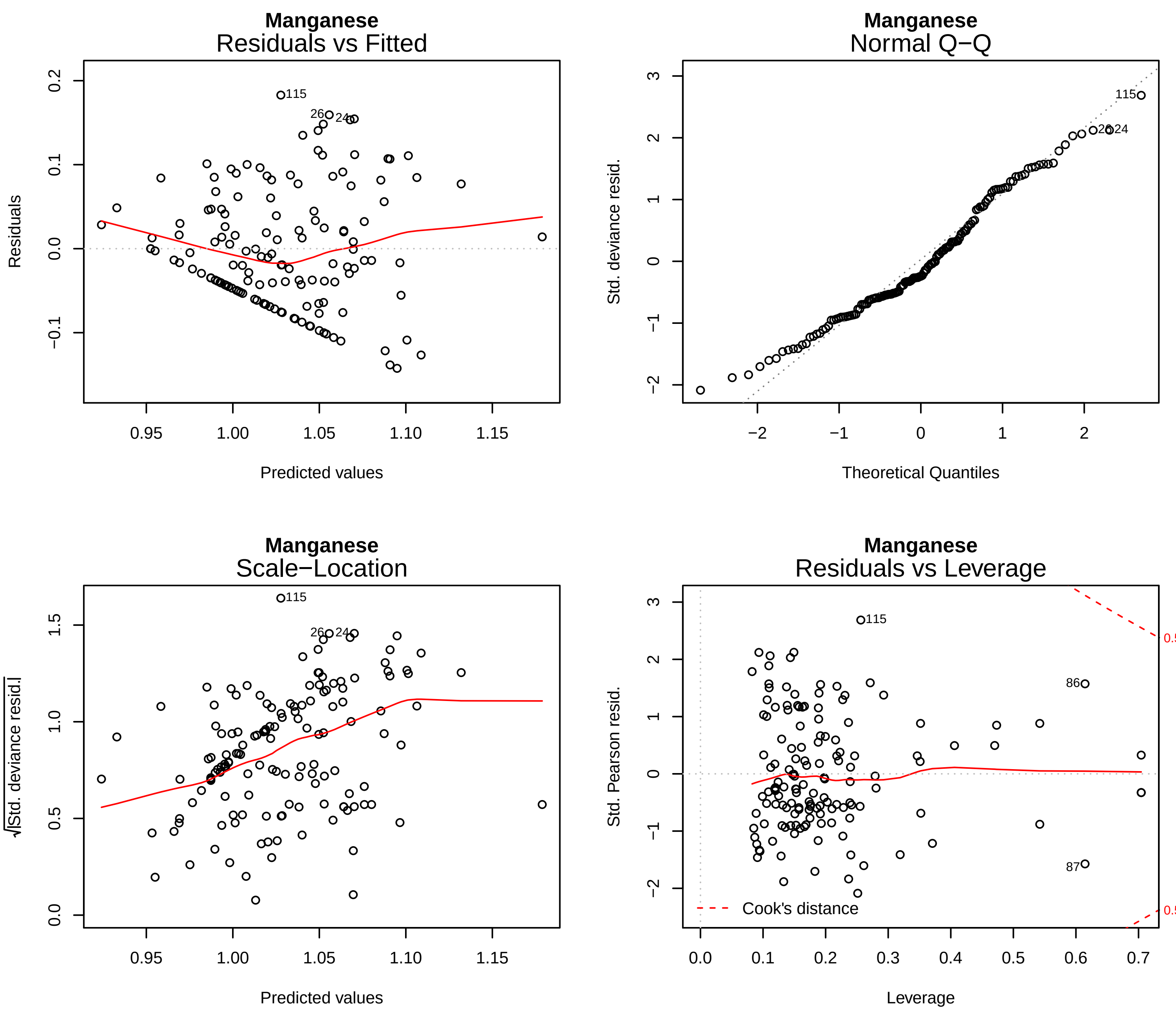
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

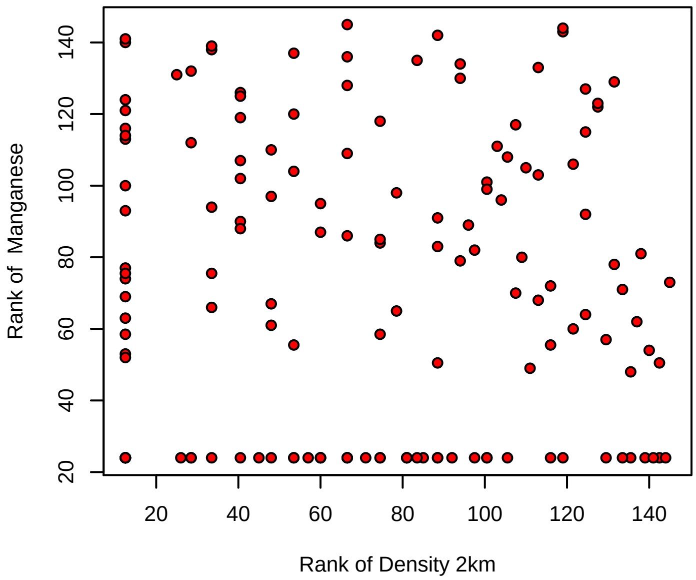
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



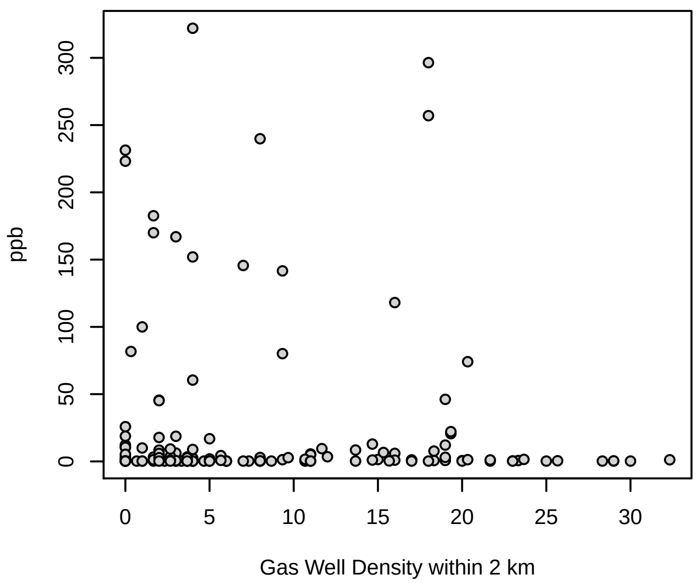


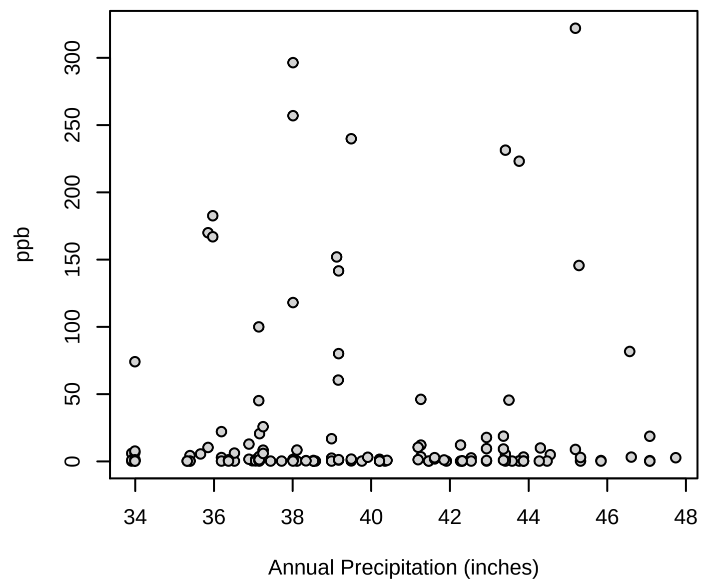
Manganese

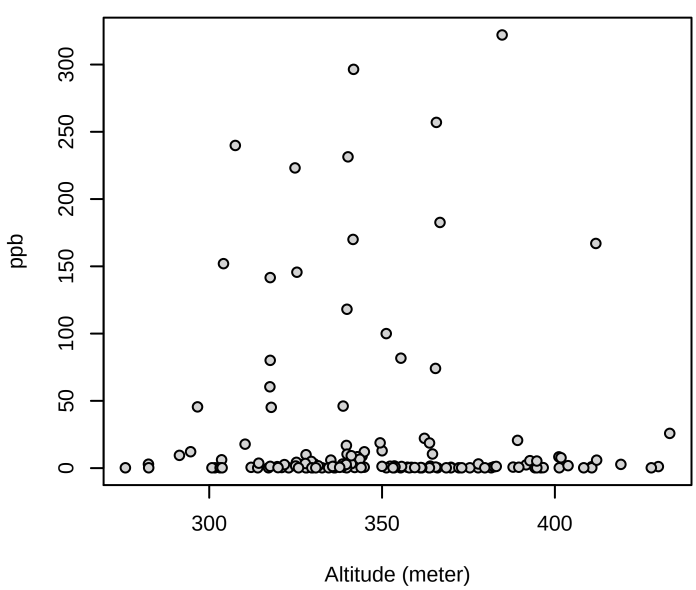
Kendalls Tau Rank Correlation

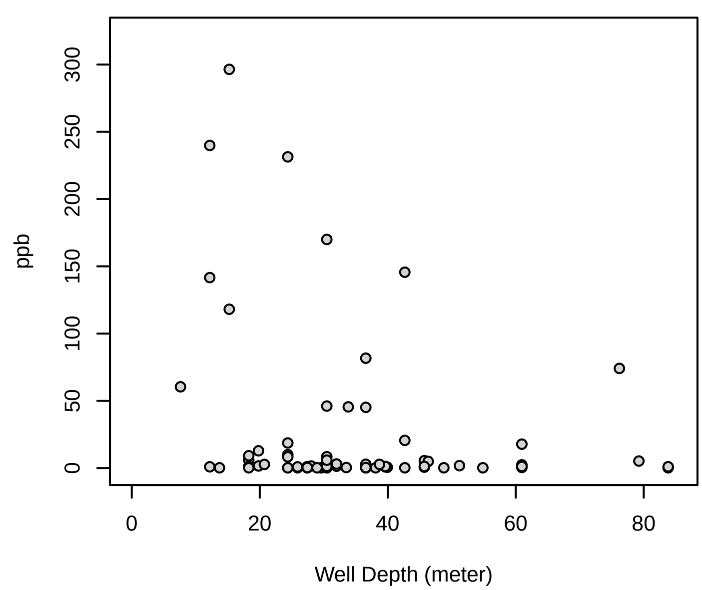
p−value: 0.446

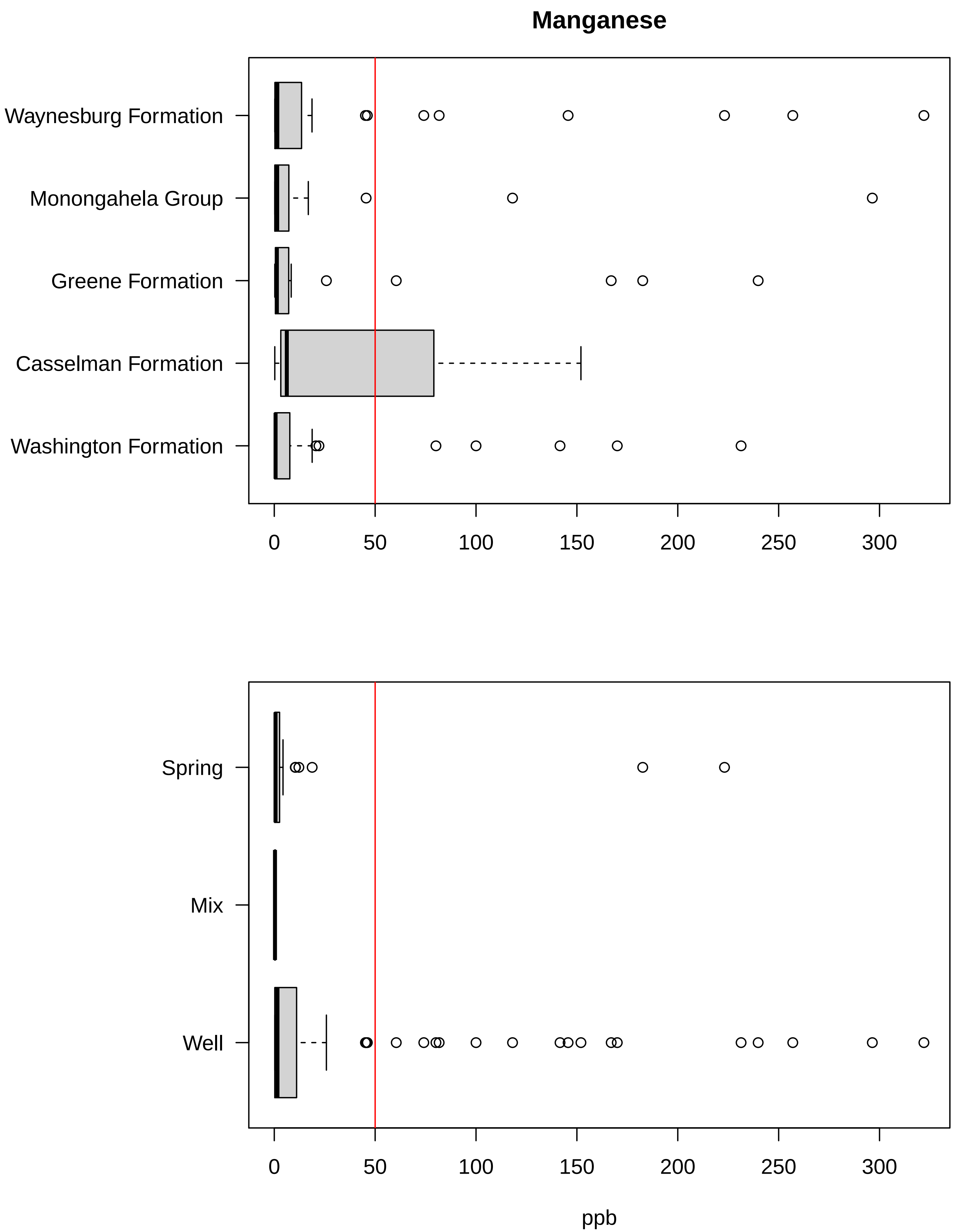
Tau: −0.0452

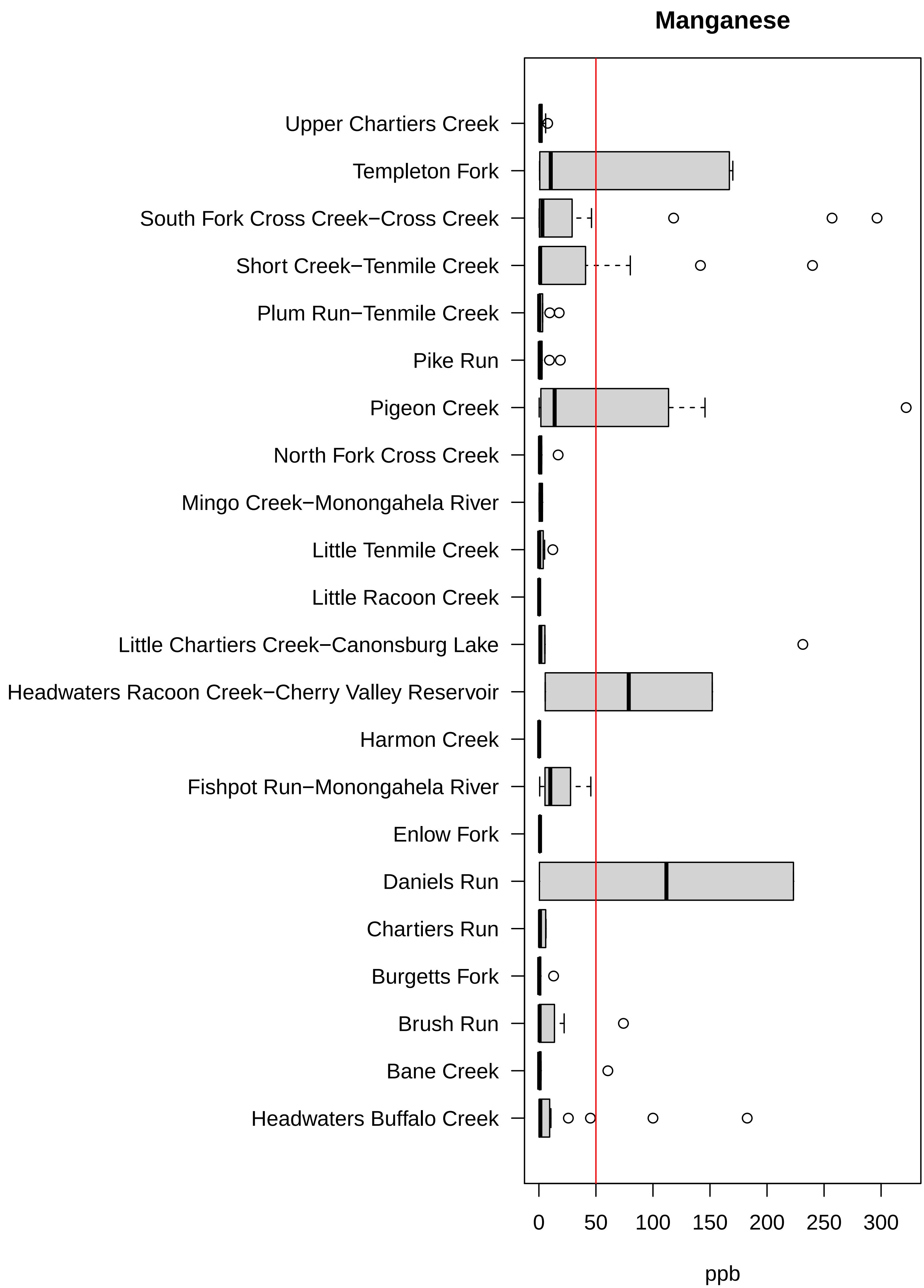









Manganese
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
50
100
150
200
250
300
Spring
Mix
Well
0
50
100
150
200
250
300
ppb


Manganese
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
50
100
150
200
250
300
ppb

```
[1] "ORIGINAL MODEL - Manganese"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-85.012  -24.464   -5.964    7.494  254.763

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                238.857612 166.556590   1.434   0.1543
dat$GWellDensity_2kmAvg                                      0.009443   1.029343   0.009   0.9927
dat$Altitude_meter                                          -0.172877   0.282525  -0.612   0.5418
dat$WatershedBane Creek                                     -3.363433  35.296307  -0.095   0.9243
dat$WatershedBrush Run                                      -4.231107  29.008045  -0.146   0.8843
dat$WatershedBurgetts Fork                                 -21.777457  33.937964  -0.642   0.5224
dat$WatershedChartiers Run                                 -49.956446  39.627146  -1.261   0.2100
dat$WatershedDaniels Run                                   146.761794  56.236328   2.610   0.0103 *
dat$WatershedEnlow Fork                                    -19.726274  38.328463  -0.515   0.6078
dat$WatershedFishpot Run-Monongahela River                  12.114909  46.418685   0.261   0.7946
dat$WatershedHarmon Creek                                   45.936078  75.860924   0.606   0.5460
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  21.743069  55.254561   0.394   0.6947
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         42.654570  35.750664   1.193   0.2353
dat$WatershedLittle Racoon Creek                           -77.393771  85.467714  -0.906   0.3671
dat$WatershedLittle Tenmile Creek                            5.371925  36.563108   0.147   0.8835
dat$WatershedMingo Creek-Monongahela River                   1.377811  48.988943   0.028   0.9776
dat$WatershedNorth Fork Cross Creek                         -9.464081  32.870724  -0.288   0.7739
dat$WatershedPigeon Creek                                   80.544124  41.159356   1.957   0.0528 .
dat$WatershedPike Run                                       25.434799  40.208367   0.633   0.5283
dat$WatershedPlum Run-Tenmile Creek                          3.497484  35.657704   0.098   0.9220
dat$WatershedShort Creek-Tenmile Creek                      31.253050  29.597857   1.056   0.2932
dat$WatershedSouth Fork Cross Creek-Cross Creek             34.049289  26.511103   1.284   0.2016
dat$WatershedTempleton Fork                                 44.747830  31.344668   1.428   0.1561
dat$WatershedUpper Chartiers Creek                         -24.386199  27.056787  -0.901   0.3693
dat$FormationCasselman Formation                            70.088509  61.702907   1.136   0.2584
dat$FormationGreene Formation                               22.383317  20.956225   1.068   0.2877
dat$FormationMonongahela Group                              12.883106  21.935737   0.587   0.5582
dat$FormationWaynesburg Formation                            9.365664  16.976675   0.552   0.5822
dat$HHWSourceMix                                           -65.149487  40.980223  -1.590   0.1147
dat$HHWSourceSpring                                        -11.801923  13.427016  -0.879   0.3813
dat$Precip_inchAvg                                          -4.316337   3.436387  -1.256   0.2117
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 3669.161)

    Null deviance: 542080  on 144  degrees of freedom
Residual deviance: 418284  on 114  degrees of freedom
AIC: 1630.7

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Manganese"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.14244  -0.04504  -0.01404   0.04702   0.18284

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  1.4389225  0.2169565   6.632 1.16e-09 ***
dat$GWellDensity_2kmAvg                                     -0.0006967  0.0013408  -0.520   0.6044
dat$Altitude_meter                                          -0.0006514  0.0003680  -1.770   0.0794 .
dat$WatershedBane Creek                                     -0.0336080  0.0459769  -0.731   0.4663
dat$WatershedBrush Run                                       0.0128988  0.0377859   0.341   0.7335
dat$WatershedBurgetts Fork                                  -0.0372262  0.0442076  -0.842   0.4015
dat$WatershedChartiers Run                                  -0.0555701  0.0516183  -1.077   0.2840
dat$WatershedDaniels Run                                     0.1258186  0.0732534   1.718   0.0886 .
dat$WatershedEnlow Fork                                     -0.0592718  0.0499266  -1.187   0.2376
dat$WatershedFishpot Run-Monongahela River                   0.0377154  0.0604650   0.624   0.5340
dat$WatershedHarmon Creek                                    0.0263753  0.0988164   0.267   0.7900
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.0559506  0.0719746   0.777   0.4386
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          0.0079380  0.0465688   0.170   0.8650
dat$WatershedLittle Racoon Creek                            -0.1321379  0.1113302  -1.187   0.2377
dat$WatershedLittle Tenmile Creek                           -0.0237476  0.0476271  -0.499   0.6190
dat$WatershedMingo Creek-Monongahela River                  -0.0176629  0.0638130  -0.277   0.7824
dat$WatershedNorth Fork Cross Creek                         -0.0177217  0.0428174  -0.414   0.6797
dat$WatershedPigeon Creek                                    0.0833950  0.0536142   1.555   0.1226
dat$WatershedPike Run                                        0.0232255  0.0523754   0.443   0.6583
dat$WatershedPlum Run-Tenmile Creek                         -0.0271585  0.0464477  -0.585   0.5599
dat$WatershedShort Creek-Tenmile Creek                       0.0020275  0.0385541   0.053   0.9582
dat$WatershedSouth Fork Cross Creek-Cross Creek              0.0336037  0.0345333   0.973   0.3326
dat$WatershedTempleton Fork                                  0.0387193  0.0408295   0.948   0.3450
dat$WatershedUpper Chartiers Creek                          -0.0205330  0.0352442  -0.583   0.5613
dat$FormationCasselman Formation                             0.0628603  0.0803742   0.782   0.4358
dat$FormationGreene Formation                                0.0460900  0.0272976   1.688   0.0941 .
dat$FormationMonongahela Group                               0.0033822  0.0285735   0.118   0.9060
dat$FormationWaynesburg Formation                            0.0069263  0.0221138   0.313   0.7547
dat$HHWSourceMix                                            -0.1135890  0.0533808  -2.128   0.0355 *
dat$HHWSourceSpring                                         -0.0289628  0.0174900  -1.656   0.1005
dat$Precip_inchAvg                                          -0.0045510  0.0044762  -1.017   0.3114
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.006225705)

    Null deviance: 0.95493  on 144  degrees of freedom
Residual deviance: 0.70973  on 114  degrees of freedom
AIC: -295.85

Number of Fisher Scoring iterations: 2
```

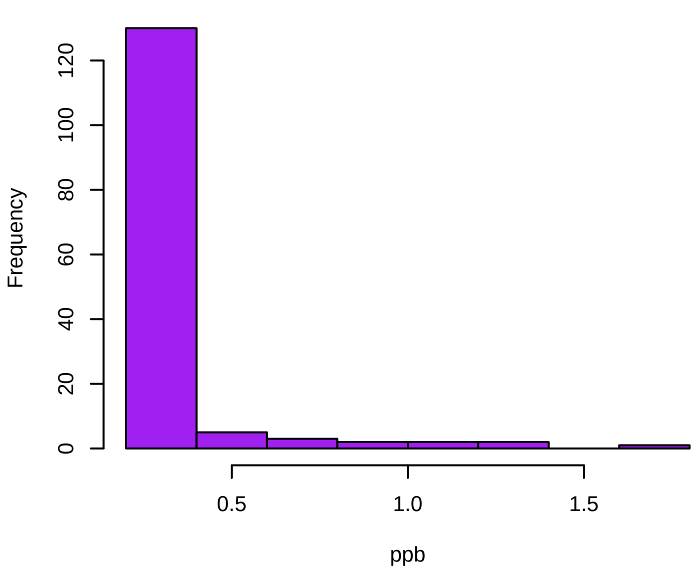
Mercury

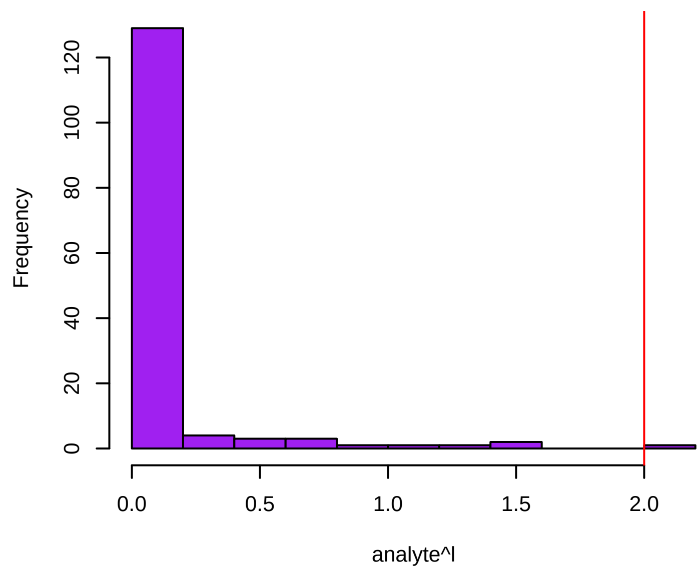
Skewness: 4.0396
Kurtosis: 19.8597

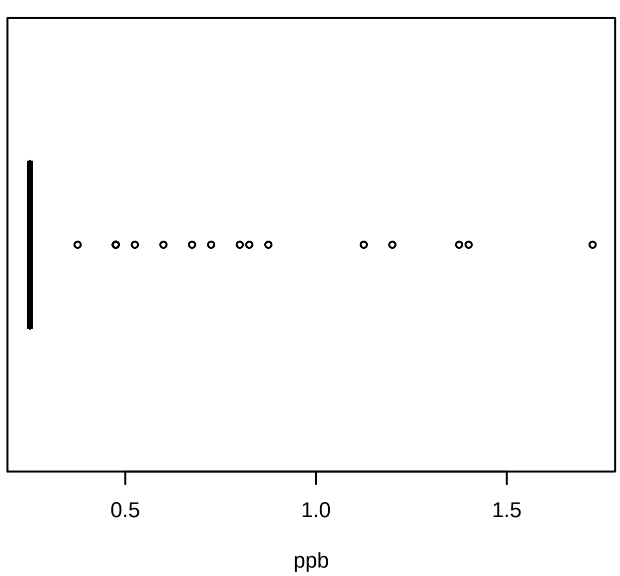
Mercury Box−Cox

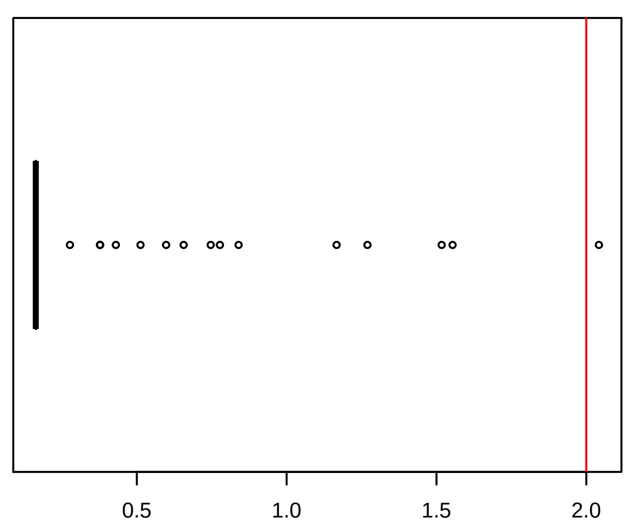
Skewness: 4.4062
Kurtosis: 23.5572

Optimal lambda: 1.31



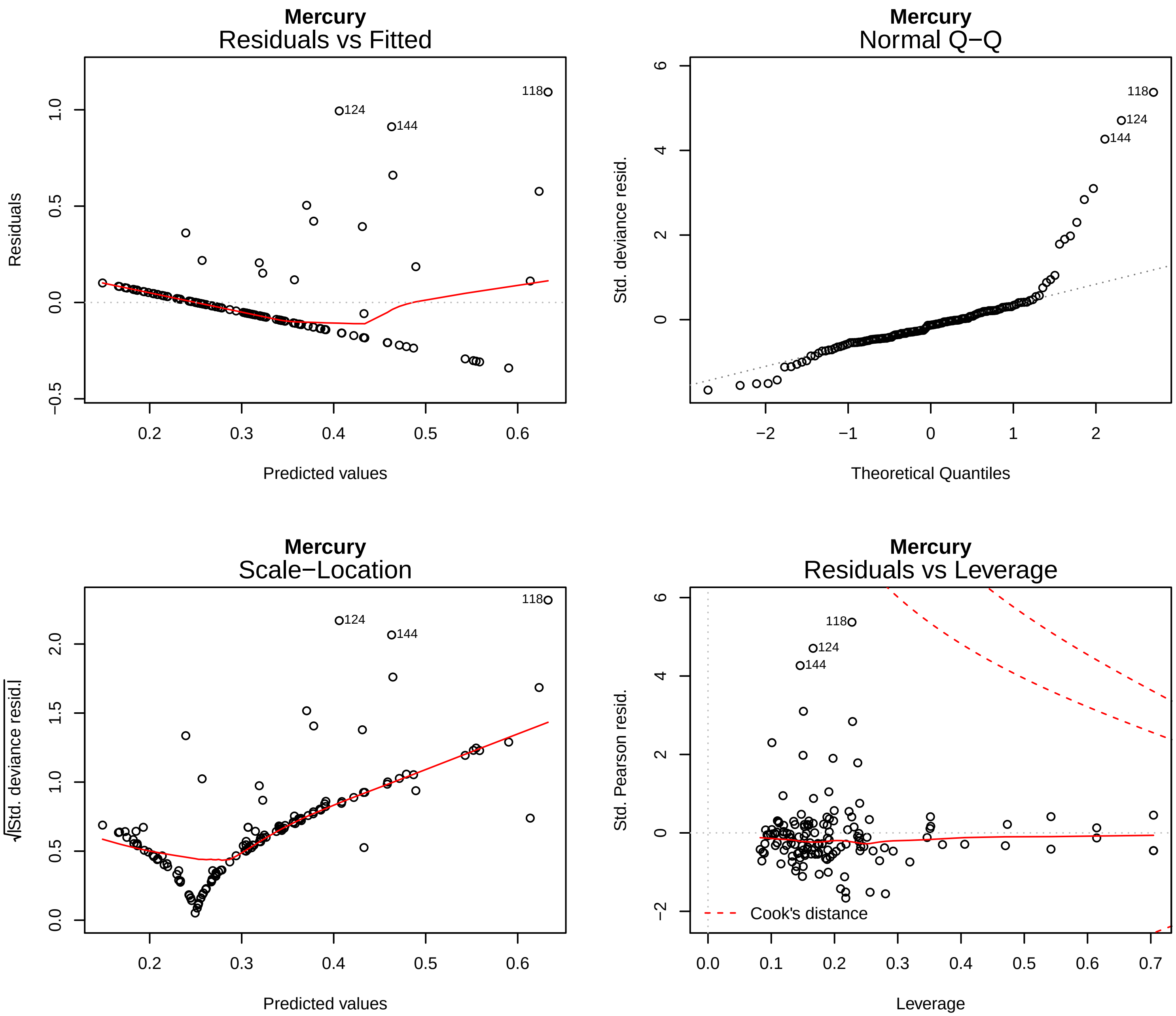






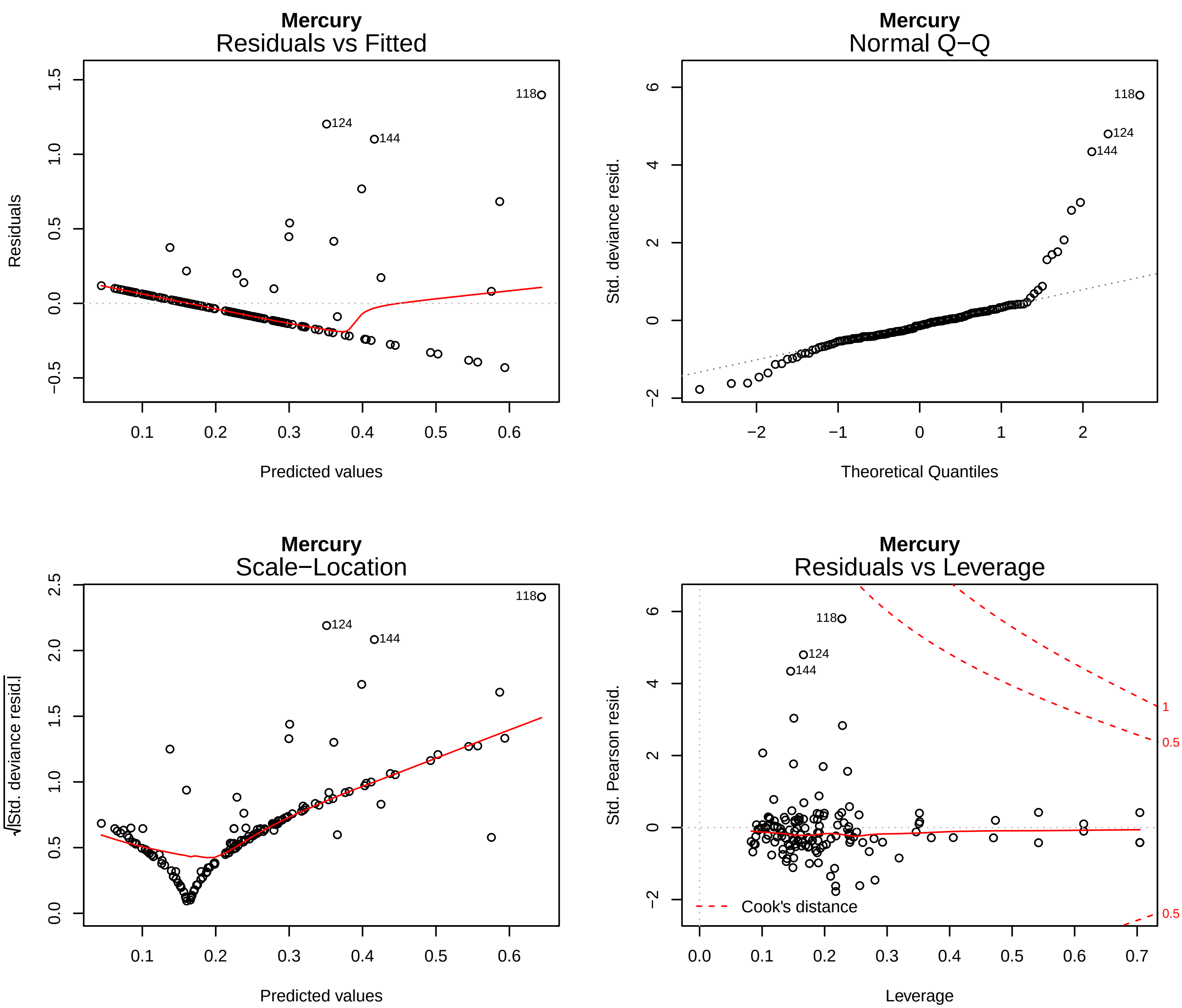
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

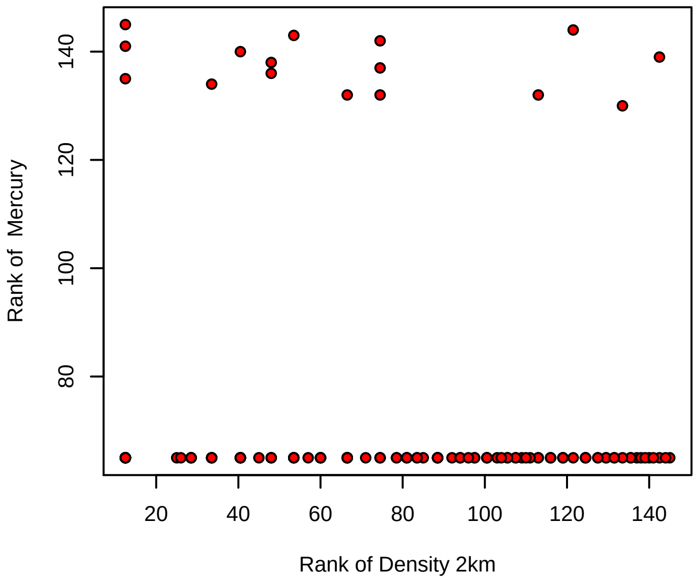
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



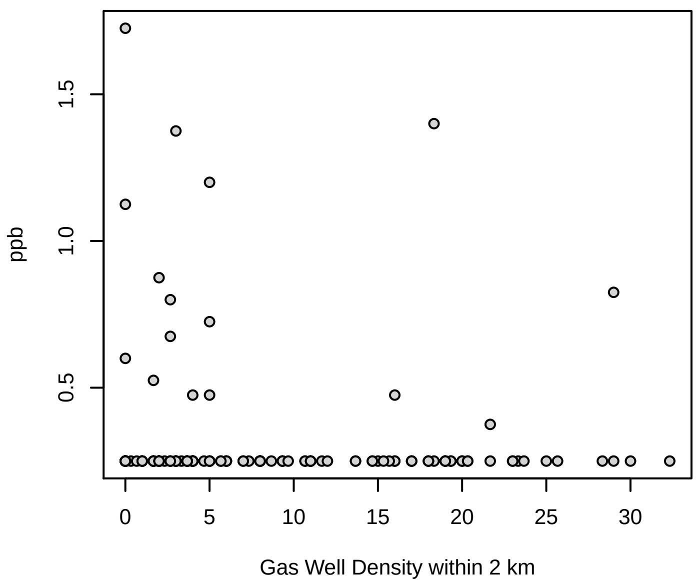


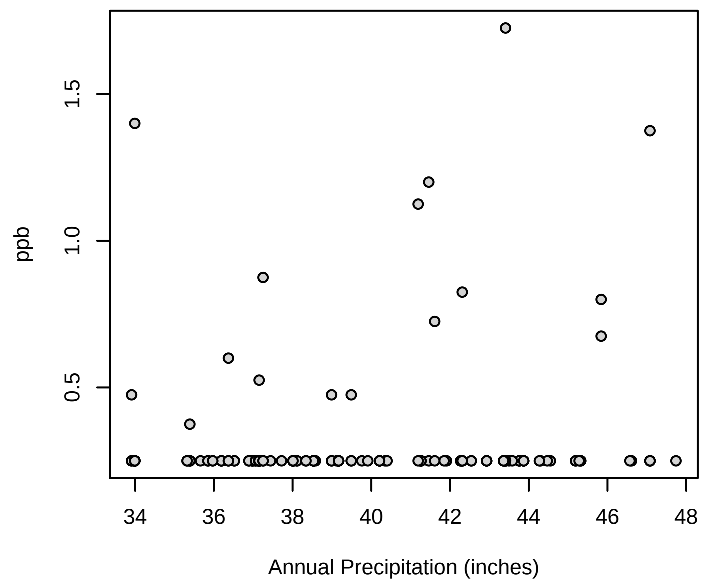
Mercury

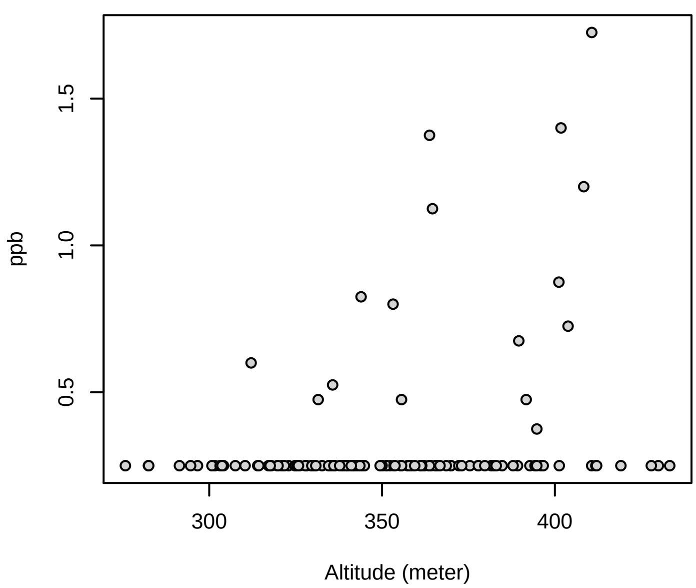
Kendalls Tau Rank Correlation

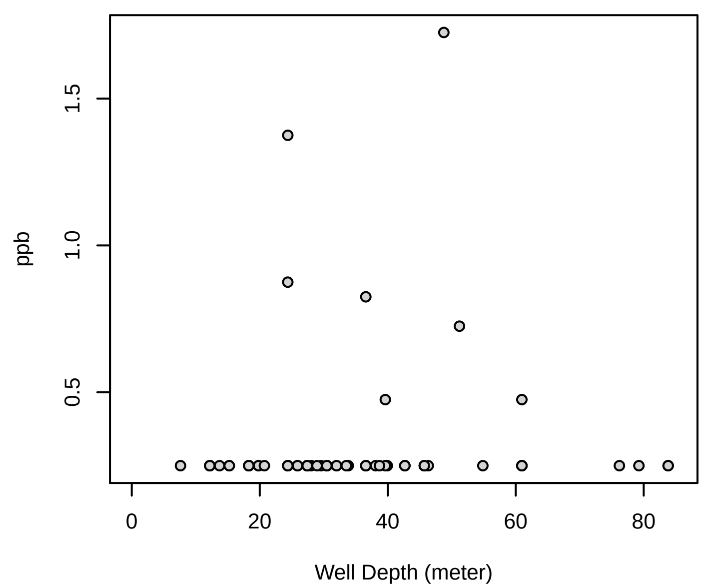
p−value: 0.458

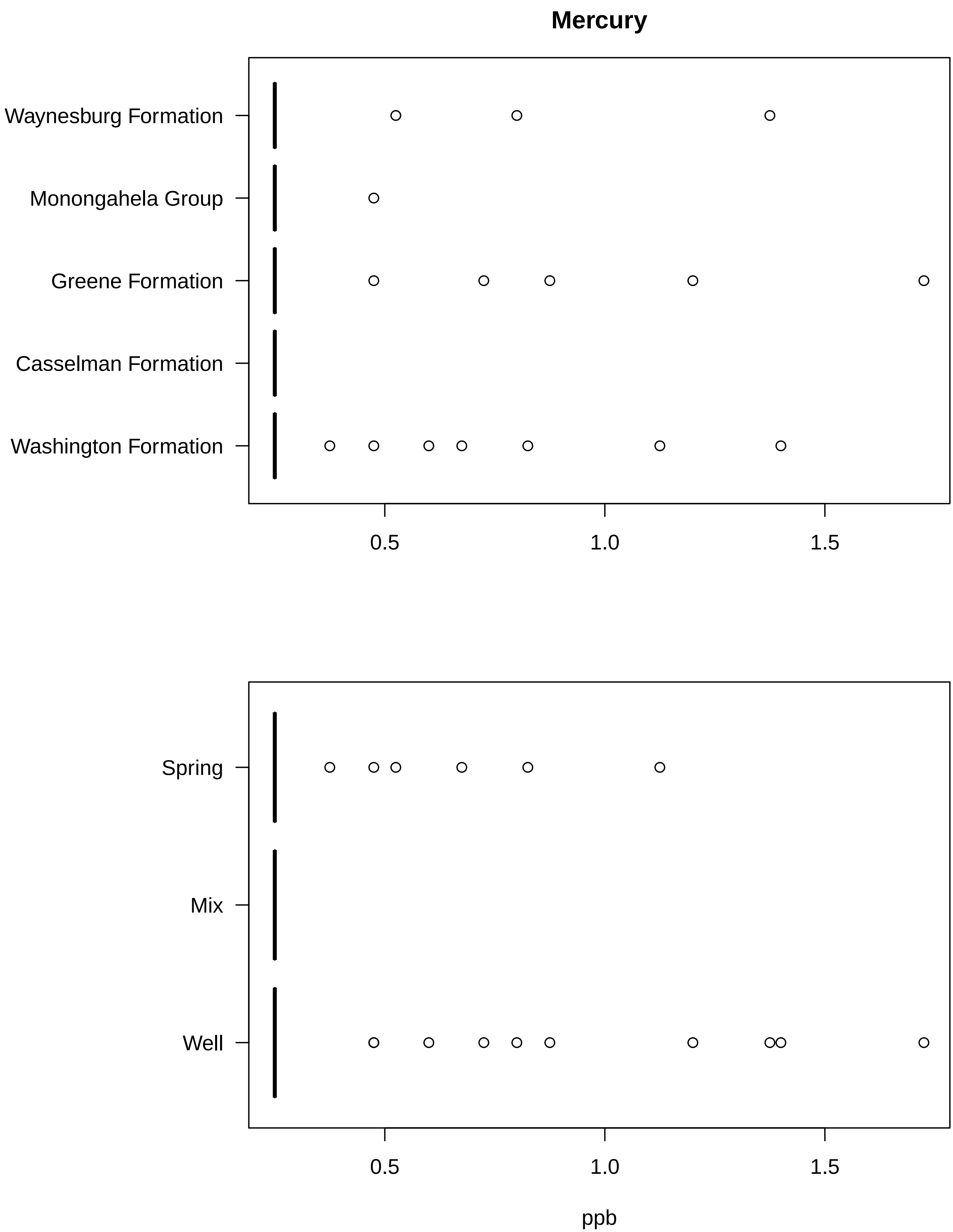
Tau: −0.0504

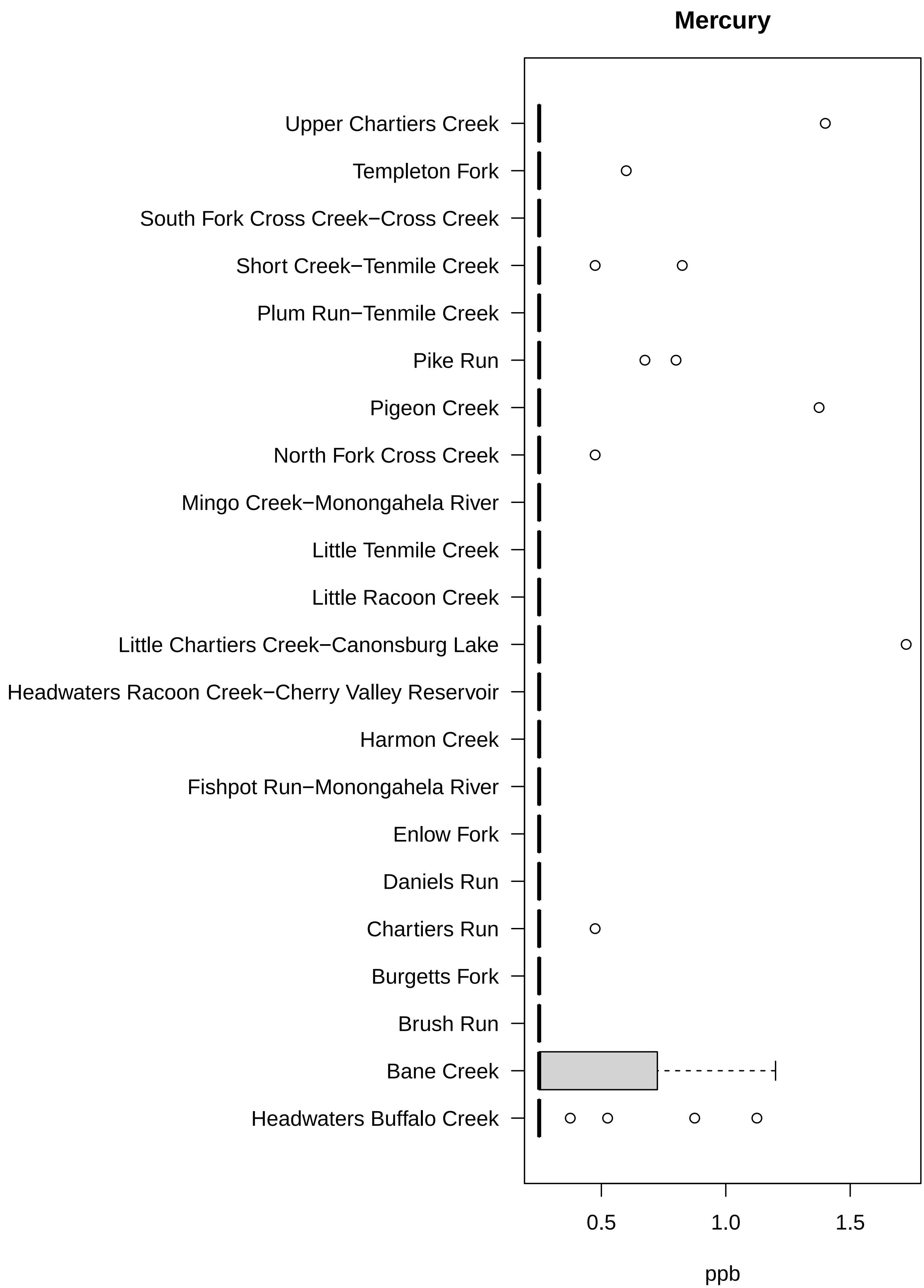









Mercury
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0.5
1.0
1.5
Spring
Mix
Well
0.5
1.0
1.5
ppb


Mercury
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0.5
1.0
1.5
ppb

```
[1] "ORIGINAL MODEL - Mercury"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.34018  -0.09305  -0.02219   0.04112   1.09202

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                             -1.2312701  0.6358838  -1.936   0.0553 .
dat$GWellDensity_2kmAvg                                 -0.0006549  0.0039299  -0.167   0.8679
dat$Altitude_meter                                       0.0026912  0.0010786   2.495   0.0140 *
dat$WatershedBane Creek                                  0.1638061  0.1347551   1.216   0.2267
dat$WatershedBrush Run                                  -0.1136499  0.1107476  -1.026   0.3070
dat$WatershedBurgetts Fork                              -0.0998693  0.1295692  -0.771   0.4424
dat$WatershedChartiers Run                               0.0397805  0.1512895   0.263   0.7931
dat$WatershedDaniels Run                                -0.1345839  0.2147004  -0.627   0.5320
dat$WatershedEnlow Fork                                 -0.0675935  0.1463313  -0.462   0.6450
dat$WatershedFishpot Run-Monongahela River              -0.1228721  0.1772184  -0.693   0.4895
dat$WatershedHarmon Creek                               -0.0891875  0.2896237  -0.308   0.7587
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.1190276  0.2109522  -0.564   0.5737
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      0.1308979  0.1364898   0.959   0.3396
dat$WatershedLittle Racoon Creek                        -0.1182420  0.3263007  -0.362   0.7177
dat$WatershedLittle Tenmile Creek                       -0.1271489  0.1395915  -0.911   0.3643
dat$WatershedMingo Creek-Monongahela River              -0.1481547  0.1870312  -0.792   0.4299
dat$WatershedNorth Fork Cross Creek                     -0.1247002  0.1254947  -0.994   0.3225
dat$WatershedPigeon Creek                               -0.0839061  0.1571392  -0.534   0.5944
dat$WatershedPike Run                                   -0.1194032  0.1535085  -0.778   0.4383
dat$WatershedPlum Run-Tenmile Creek                     -0.0803181  0.1361349  -0.590   0.5564
dat$WatershedShort Creek-Tenmile Creek                   0.0224072  0.1129994   0.198   0.8432
dat$WatershedSouth Fork Cross Creek-Cross Creek         -0.1273164  0.1012147  -1.258   0.2110
dat$WatershedTempleton Fork                              0.0132132  0.1196684   0.110   0.9123
dat$WatershedUpper Chartiers Creek                      -0.0088706  0.1032981  -0.086   0.9317
dat$FormationCasselman Formation                         0.0635631  0.2355709   0.270   0.7878
dat$FormationGreene Formation                           -0.1086289  0.0800072  -1.358   0.1772
dat$FormationMonongahela Group                          -0.0077843  0.0837468  -0.093   0.9261
dat$FormationWaynesburg Formation                        0.0021786  0.0648140   0.034   0.9732
dat$HHWSourceMix                                        -0.0112562  0.1564553  -0.072   0.9428
dat$HHWSourceSpring                                      0.0153019  0.0512620   0.299   0.7659
dat$Precip_inchAvg                                       0.0169724  0.0131195   1.294   0.1984
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.0534809)

    Null deviance: 7.5853  on 144  degrees of freedom
Residual deviance: 6.0968  on 114  degrees of freedom
AIC: 15.992

Number of Fisher Scoring iterations: 2
```

[1] "BOX-COX MODEL - Mercury"

```
Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.43101  -0.10189  -0.02905   0.04740   1.39830

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                 -1.5663846  0.7546939  -2.076   0.0402 *
dat$GWellDensity_2kmAvg                                     -0.0006718  0.0046641  -0.144   0.8857
dat$Altitude_meter                                           0.0031461  0.0012802   2.458   0.0155 *
dat$WatershedBane Creek                                      0.1831461  0.1599331   1.145   0.2545
dat$WatershedBrush Run                                      -0.1263610  0.1314400  -0.961   0.3384
dat$WatershedBurgetts Fork                                  -0.1092520  0.1537782  -0.710   0.4789
dat$WatershedChartiers Run                                   0.0401875  0.1795568   0.224   0.8233
dat$WatershedDaniels Run                                    -0.1450805  0.2548156  -0.569   0.5702
dat$WatershedEnlow Fork                                     -0.0708798  0.1736723  -0.408   0.6839
dat$WatershedFishpot Run-Monongahela River                  -0.1351644  0.2103303  -0.643   0.5218
dat$WatershedHarmon Creek                                   -0.1006517  0.3437377  -0.293   0.7702
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.1359743  0.2503671  -0.543   0.5881
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          0.1913130  0.1619918   1.181   0.2401
dat$WatershedLittle Racoon Creek                            -0.1340957  0.3872676  -0.346   0.7298
dat$WatershedLittle Tenmile Creek                           -0.1373342  0.1656732  -0.829   0.4089
dat$WatershedMingo Creek-Monongahela River                  -0.1623906  0.2219766  -0.732   0.4659
dat$WatershedNorth Fork Cross Creek                         -0.1469841  0.1489424  -0.987   0.3258
dat$WatershedPigeon Creek                                   -0.0822814  0.1864995  -0.441   0.6599
dat$WatershedPike Run                                       -0.1414774  0.1821904  -0.777   0.4390
dat$WatershedPlum Run-Tenmile Creek                         -0.0836878  0.1615706  -0.518   0.6055
dat$WatershedShort Creek-Tenmile Creek                       0.0246286  0.1341125   0.184   0.8546
dat$WatershedSouth Fork Cross Creek-Cross Creek             -0.1422433  0.1201260  -1.184   0.2388
dat$WatershedTempleton Fork                                  0.0103556  0.1420276   0.073   0.9420
dat$WatershedUpper Chartiers Creek                           0.0005349  0.1225985   0.004   0.9965
dat$FormationCasselman Formation                             0.0833584  0.2795855   0.298   0.7661
dat$FormationGreene Formation                               -0.1226290  0.0949559  -1.291   0.1992
dat$FormationMonongahela Group                              -0.0071833  0.0993943  -0.072   0.9425
dat$FormationWaynesburg Formation                            0.0011245  0.0769240   0.015   0.9884
dat$HHWSourceMix                                            -0.0101910  0.1856878  -0.055   0.9563
dat$HHWSourceSpring                                          0.0121093  0.0608399   0.199   0.8426
dat$Precip_inchAvg                                           0.0195690  0.0155708   1.257   0.2114
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.07533293)

    Null deviance: 10.667  on 144  degrees of freedom
Residual deviance:  8.588  on 114  degrees of freedom
AIC: 65.668

Number of Fisher Scoring iterations: 2
```

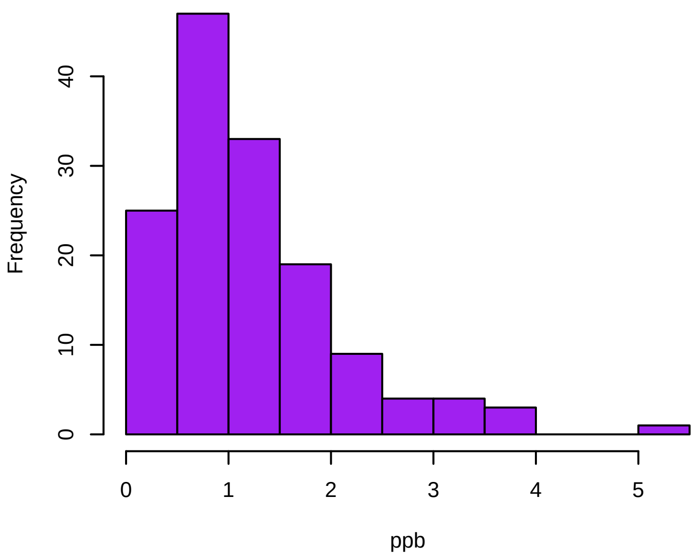
Nickel

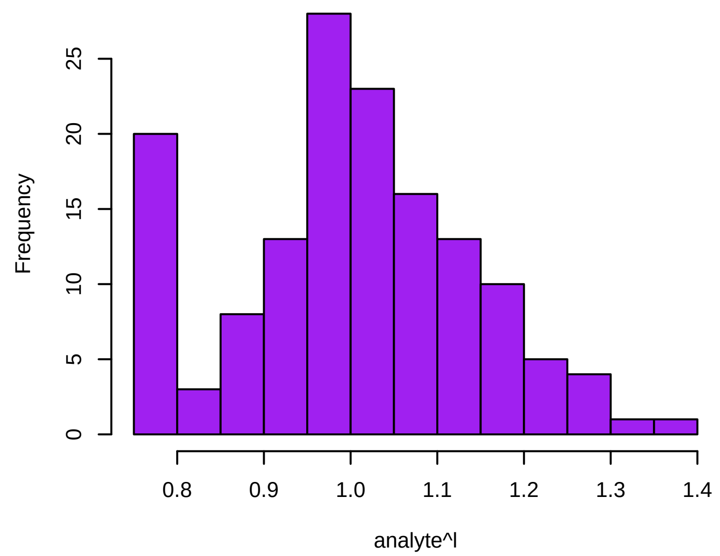
Skewness: 1.5215
Kurtosis: 6.1304

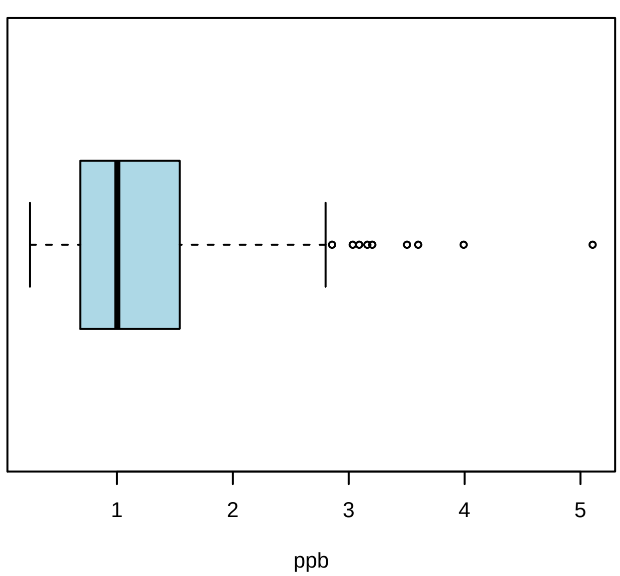
Nickel Box−Cox

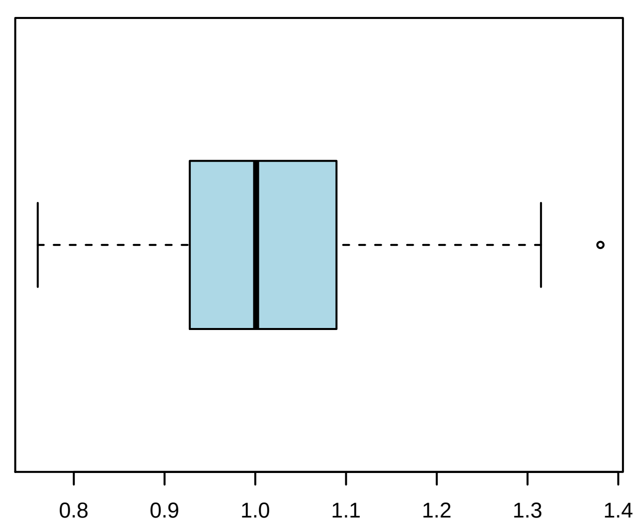
Skewness: −0.0257
Kurtosis: 2.6666

Optimal lambda: 0.1977



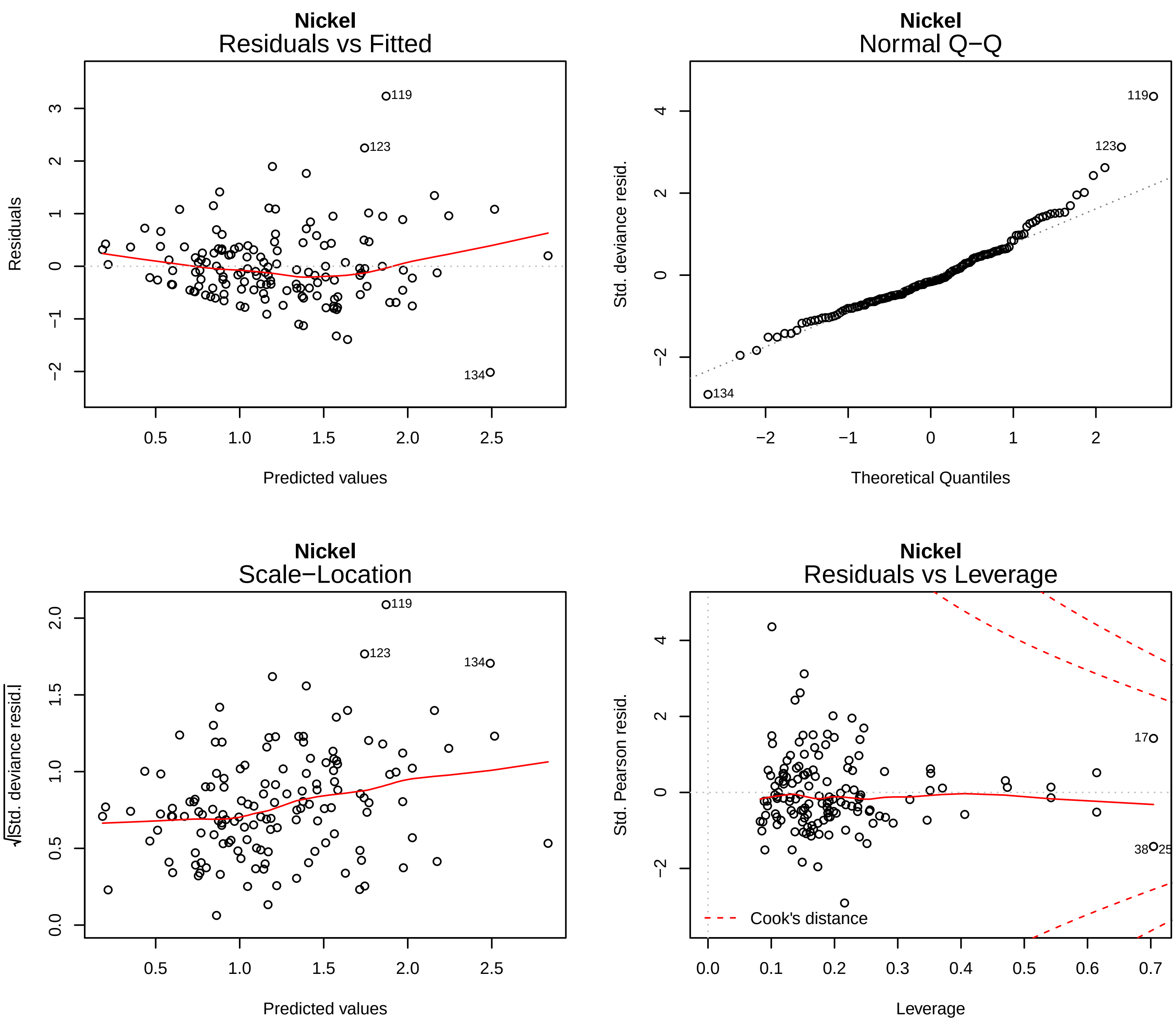






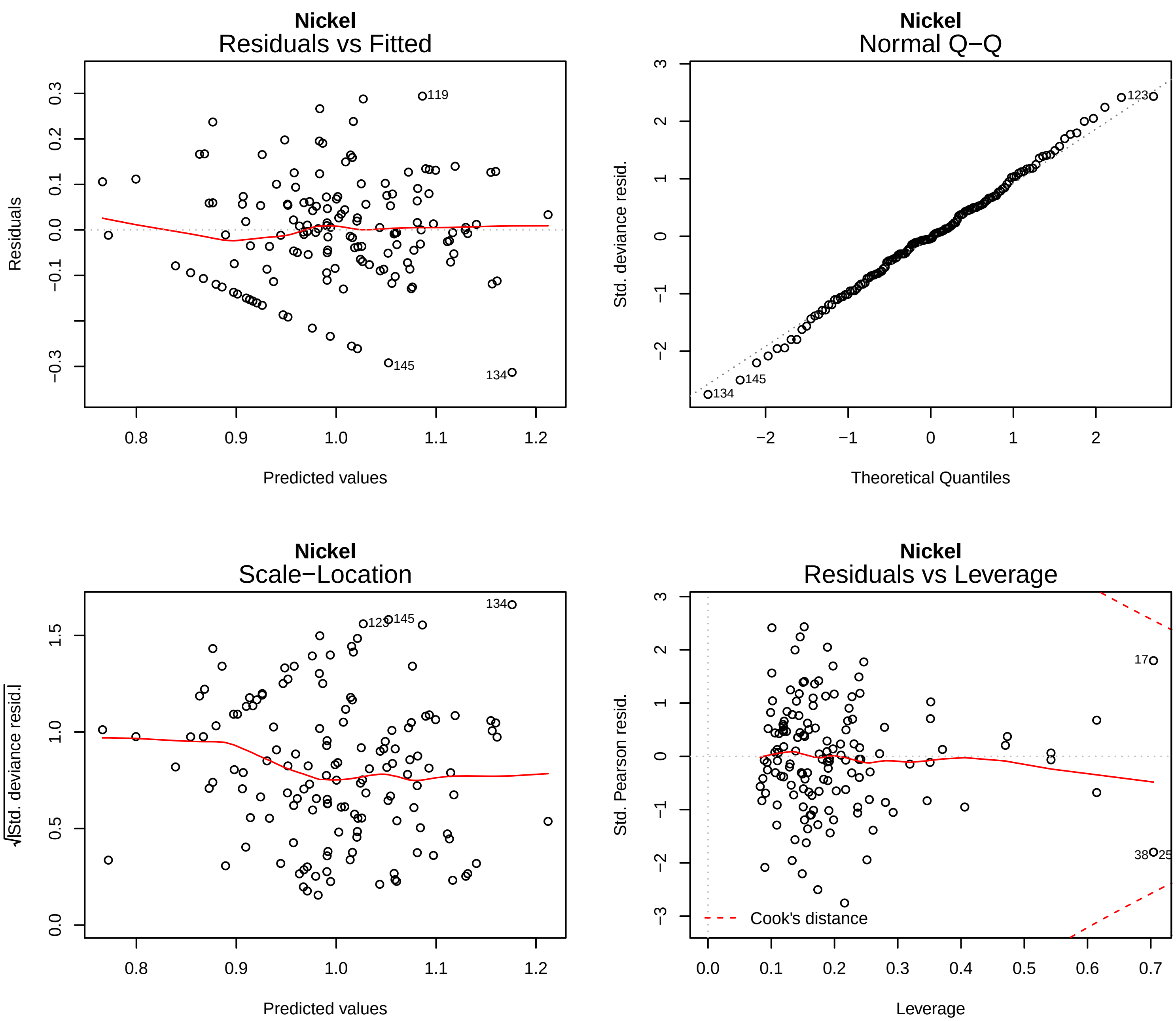
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

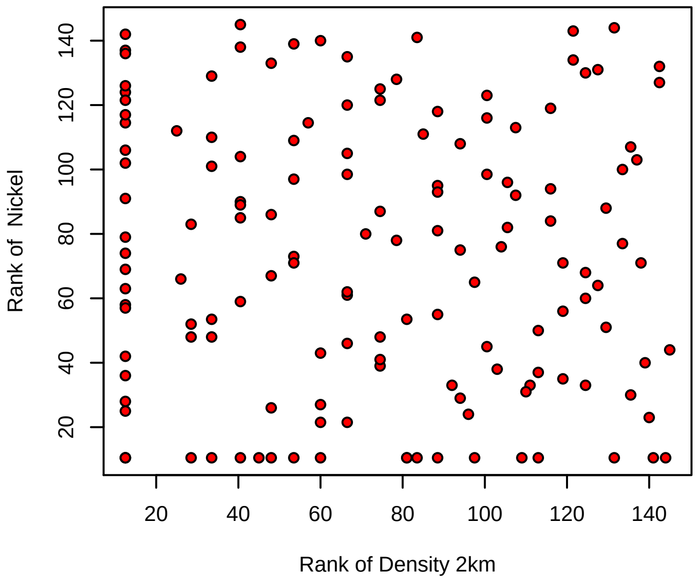
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



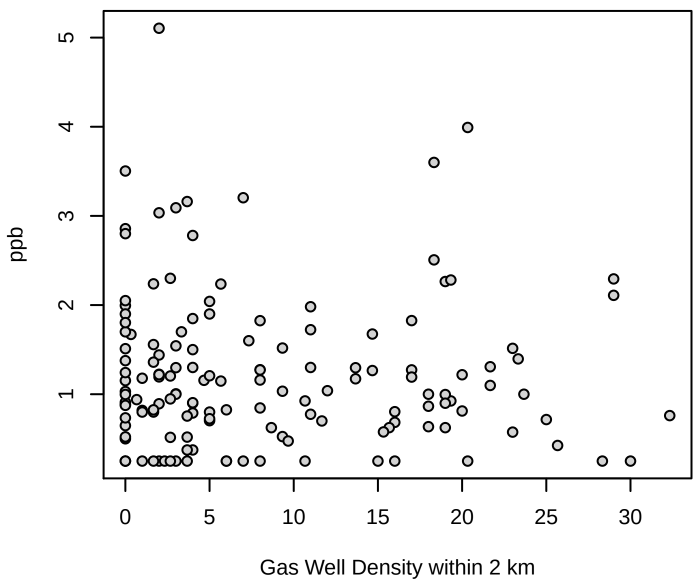


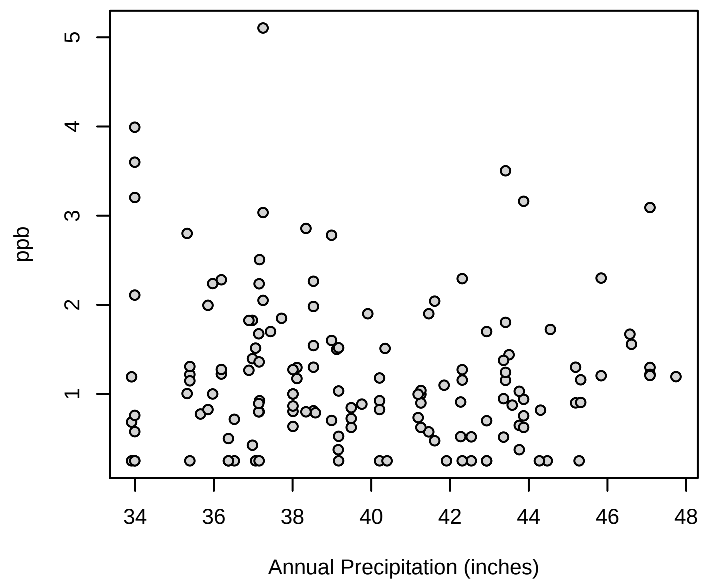
Nickel

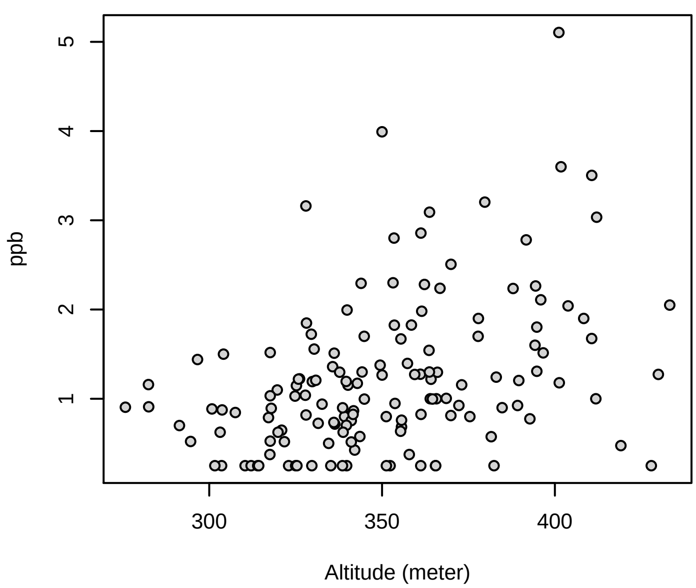
Kendalls Tau Rank Correlation

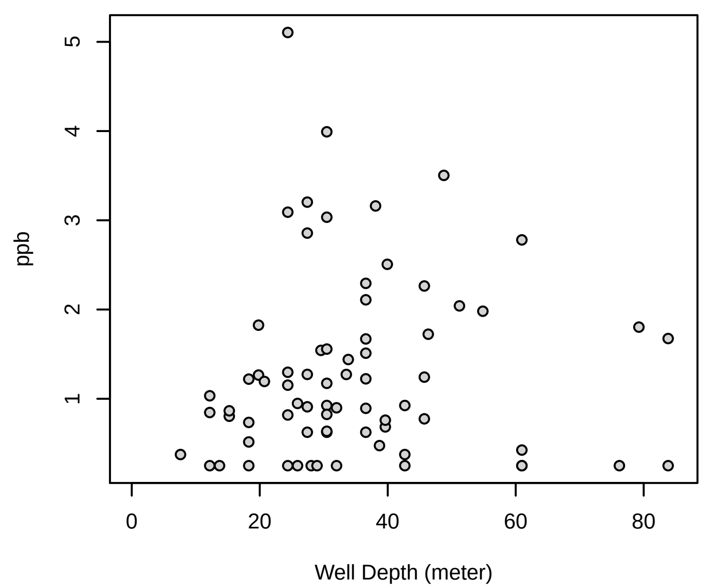
p−value: 0.556

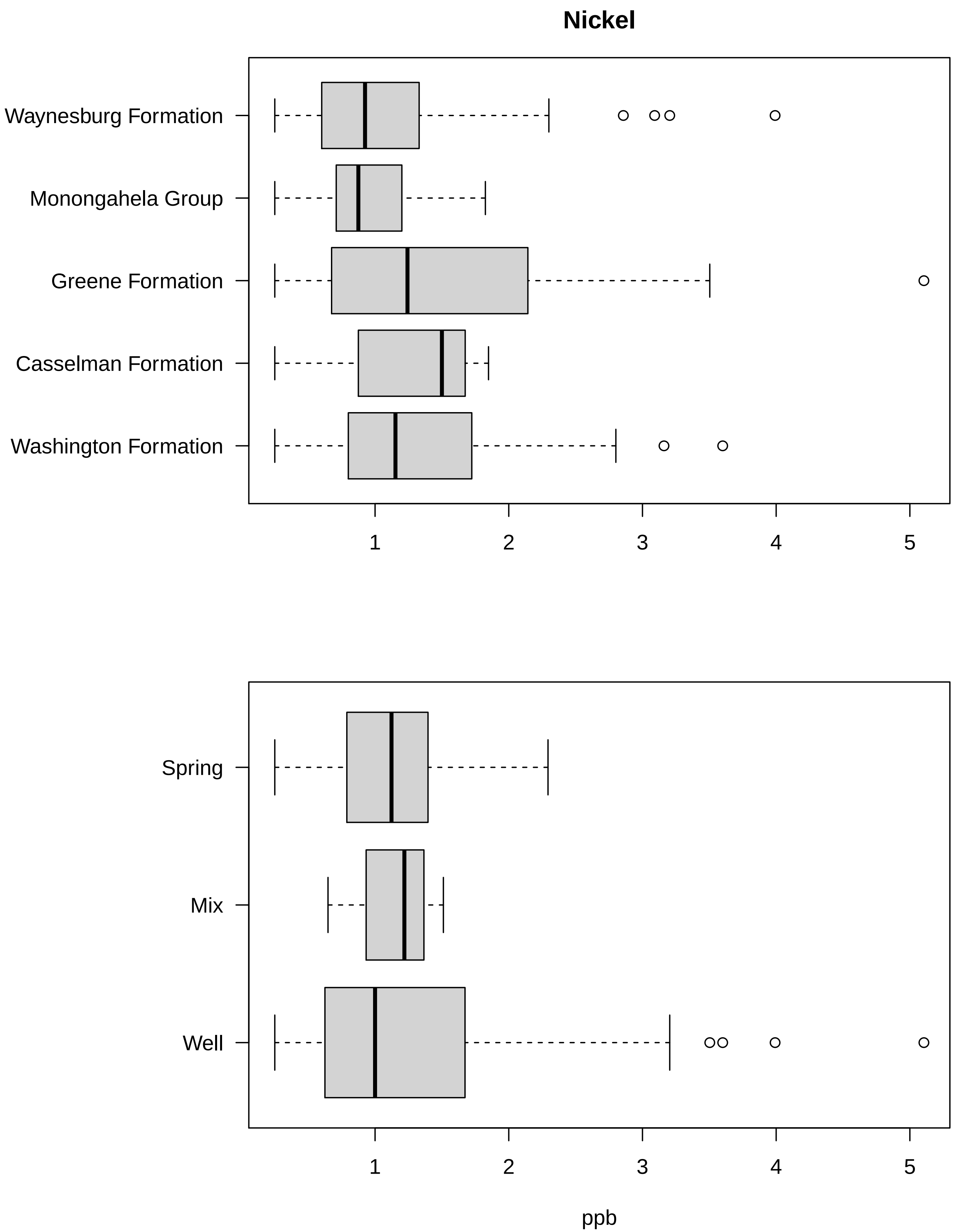
Tau: −0.0339

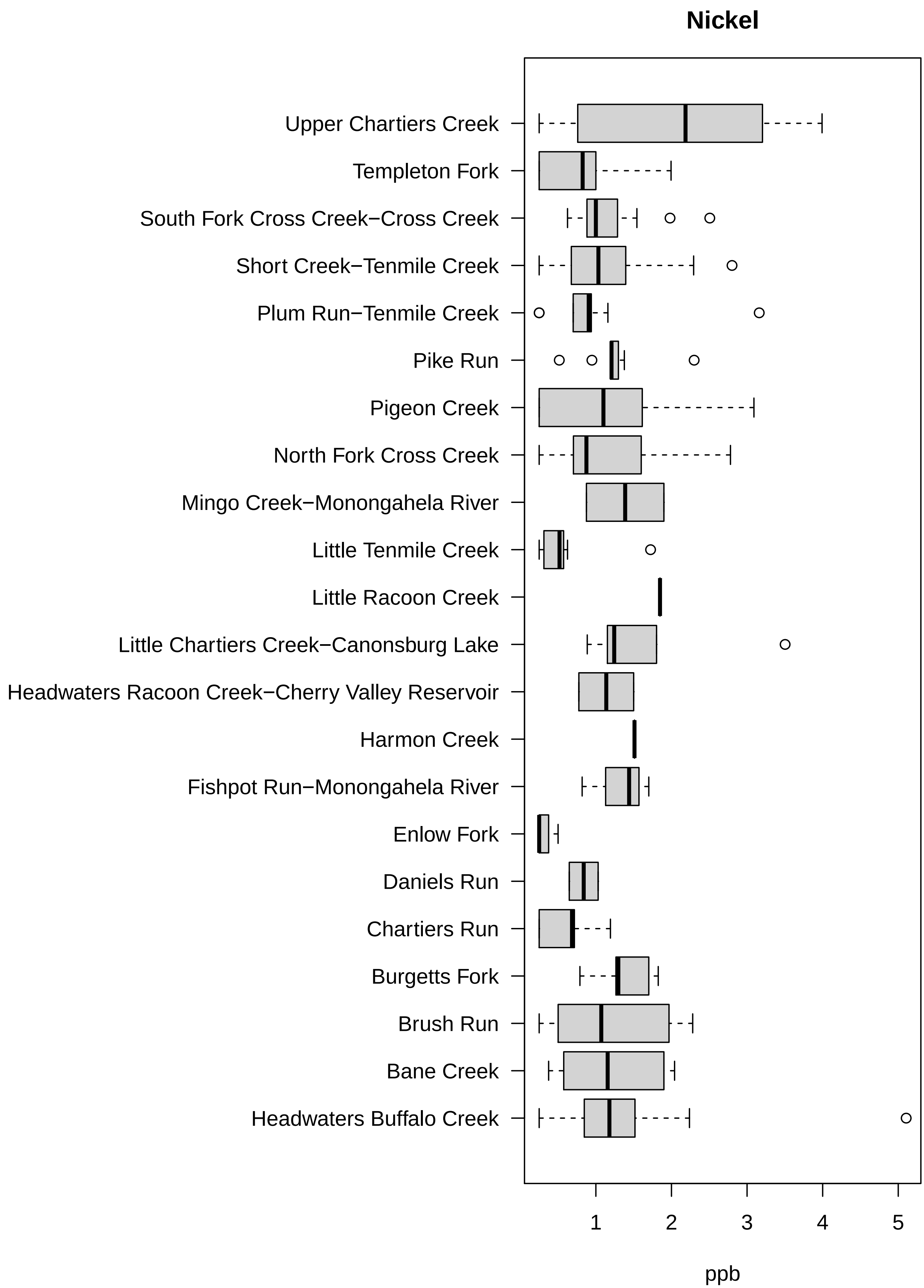









Nickel
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
1
2
3
4
5
Spring
Mix
Well
1
2
3
4
5
ppb


Nickel
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
1
2
3
4
5
ppb

[1] "ORIGINAL MODEL - Nickel"

Call:
```
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)
```

Deviance Residuals:
```
    Min       1Q   Median       3Q      Max
-2.0160  -0.4355  -0.1123   0.3335   3.2338
```

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.661009	2.151840	0.307	0.7593	
dat$GWellDensity_2kmAvg	-0.019116	0.013299	-1.437	0.1533	
dat$Altitude_meter	0.008273	0.003650	2.266	0.0253	*
dat$WatershedBane Creek	-0.122786	0.456013	-0.269	0.7882	
dat$WatershedBrush Run	0.005586	0.374772	0.015	0.9881	
dat$WatershedBurgetts Fork	0.521456	0.438464	1.189	0.2368	
dat$WatershedChartiers Run	-0.131247	0.511966	-0.256	0.7981	
dat$WatershedDaniels Run	0.228008	0.726549	0.314	0.7542	
dat$WatershedEnlow Fork	-1.114386	0.495187	-2.250	0.0263	*
dat$WatershedFishpot Run-Monongahela River	0.936837	0.599710	1.562	0.1210	
dat$WatershedHarmon Creek	0.623064	0.980091	0.636	0.5262	
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir	0.075730	0.713865	0.106	0.9157	
dat$WatershedLittle Chartiers Creek-Canonsburg Lake	0.531571	0.461883	1.151	0.2522	
dat$WatershedLittle Racoon Creek	0.676521	1.104207	0.613	0.5413	
dat$WatershedLittle Tenmile Creek	0.075255	0.472380	0.159	0.8737	
dat$WatershedMingo Creek-Monongahela River	0.524708	0.632916	0.829	0.4088	
dat$WatershedNorth Fork Cross Creek	0.226322	0.424676	0.533	0.5951	
dat$WatershedPigeon Creek	0.646864	0.531761	1.216	0.2263	
dat$WatershedPike Run	0.673429	0.519475	1.296	0.1975	
dat$WatershedPlum Run-Tenmile Creek	0.662051	0.460682	1.437	0.1534	
dat$WatershedShort Creek-Tenmile Creek	0.335175	0.382392	0.877	0.3826	
dat$WatershedSouth Fork Cross Creek-Cross Creek	0.360975	0.342512	1.054	0.2942	
dat$WatershedTempleton Fork	-0.601286	0.404960	-1.485	0.1404	
dat$WatershedUpper Chartiers Creek	0.873380	0.349562	2.498	0.0139	*
dat$FormationCasselman Formation	0.010387	0.797175	0.013	0.9896	
dat$FormationGreene Formation	0.111772	0.270746	0.413	0.6805	
dat$FormationMonongahela Group	-0.416475	0.283400	-1.470	0.1444	
dat$FormationWaynesburg Formation	-0.306856	0.219331	-1.399	0.1645	
dat$HHWSourceMix	0.226100	0.529447	0.427	0.6701	
dat$HHWSourceSpring	0.072069	0.173471	0.415	0.6786	
dat$Precip_inchAvg	-0.058576	0.044397	-1.319	0.1897	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.6124396)

    Null deviance: 103.692 on 144 degrees of freedom
Residual deviance: 69.818 on 114 degrees of freedom
AIC: 369.52

Number of Fisher Scoring iterations: 2

```
[1] "BOX-COX MODEL - Nickel"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.312995  -0.074277  -0.003607   0.067860   0.294009

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              0.6733187  0.3530783   1.907  0.05904 .
dat$GWellDensity_2kmAvg                                 -0.0036506  0.0021821  -1.673  0.09707 .
dat$Altitude_meter                                       0.0014567  0.0005989   2.432  0.01656 *
dat$WatershedBane Creek                                 -0.0119306  0.0748236  -0.159  0.87360
dat$WatershedBrush Run                                   0.0070524  0.0614933   0.115  0.90890
dat$WatershedBurgetts Fork                               0.1111973  0.0719441   1.546  0.12497
dat$WatershedChartiers Run                              -0.0162455  0.0840044  -0.193  0.84700
dat$WatershedDaniels Run                                -0.0011965  0.1192137  -0.010  0.99201
dat$WatershedEnlow Fork                                 -0.2428075  0.0812514  -2.988  0.00344 **
dat$WatershedFishpot Run-Monongahela River               0.1506767  0.0984016   1.531  0.12848
dat$WatershedHarmon Creek                                0.0913788  0.1608153   0.568  0.57100
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.0696688  0.1171325   0.595  0.55316
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      0.0730371  0.0757868   0.964  0.33723
dat$WatershedLittle Racoon Creek                         0.1612250  0.1811805   0.890  0.37542
dat$WatershedLittle Tenmile Creek                       -0.0508412  0.0775090  -0.656  0.51319
dat$WatershedMingo Creek-Monongahela River               0.0724585  0.1038502   0.698  0.48677
dat$WatershedNorth Fork Cross Creek                      0.0229799  0.0696817   0.330  0.74217
dat$WatershedPigeon Creek                                0.0376601  0.0872525   0.432  0.66683
dat$WatershedPike Run                                    0.0774993  0.0852365   0.909  0.36515
dat$WatershedPlum Run-Tenmile Creek                      0.0625345  0.0755897   0.827  0.40980
dat$WatershedShort Creek-Tenmile Creek                   0.0523579  0.0627436   0.834  0.40576
dat$WatershedSouth Fork Cross Creek-Cross Creek          0.0820558  0.0562001   1.460  0.14702
dat$WatershedTempleton Fork                             -0.1091821  0.0664466  -1.643  0.10311
dat$WatershedUpper Chartiers Creek                       0.1098301  0.0573569   1.915  0.05802 .
dat$FormationCasselman Formation                        -0.0502544  0.1308021  -0.384  0.70154
dat$FormationGreene Formation                           -0.0086644  0.0444245  -0.195  0.84571
dat$FormationMonongahela Group                          -0.0657414  0.0465009  -1.414  0.16016
dat$FormationWaynesburg Formation                       -0.0498758  0.0359883  -1.386  0.16849
dat$HHWSourceMix                                         0.0647170  0.0868727   0.745  0.45783
dat$HHWSourceSpring                                      0.0388298  0.0284635   1.364  0.17519
dat$Precip_inchAvg                                      -0.0041714  0.0072847  -0.573  0.56803
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.01648866)

    Null deviance: 2.8739  on 144  degrees of freedom
Residual deviance: 1.8797  on 114  degrees of freedom
AIC: -154.62

Number of Fisher Scoring iterations: 2
```

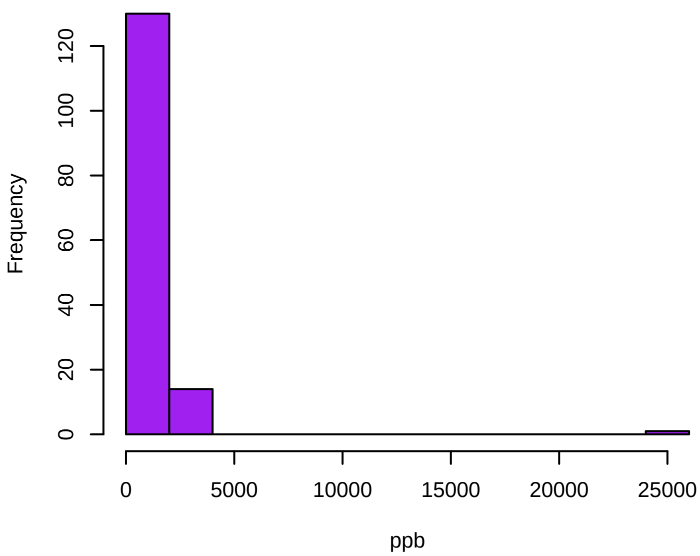
Potassium

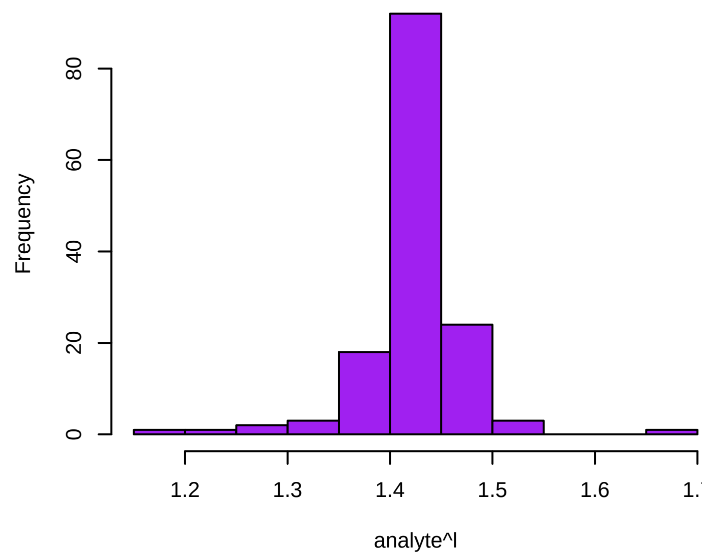
Skewness: 10.1942
Kurtosis: 115.8879

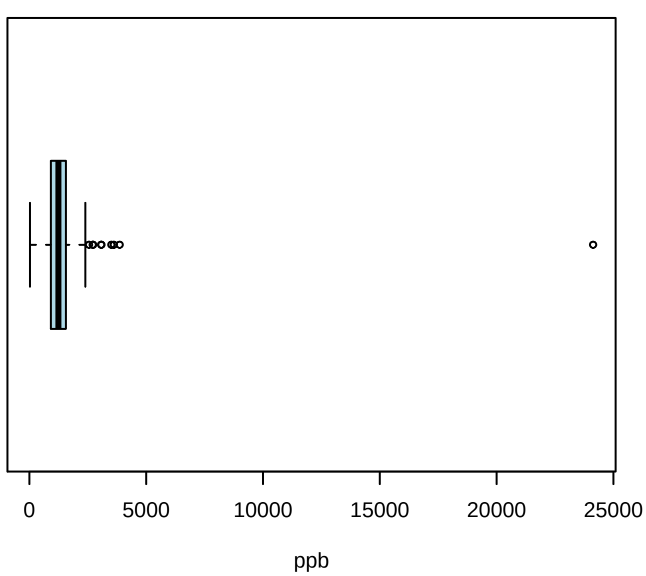
Potassium Box−Cox

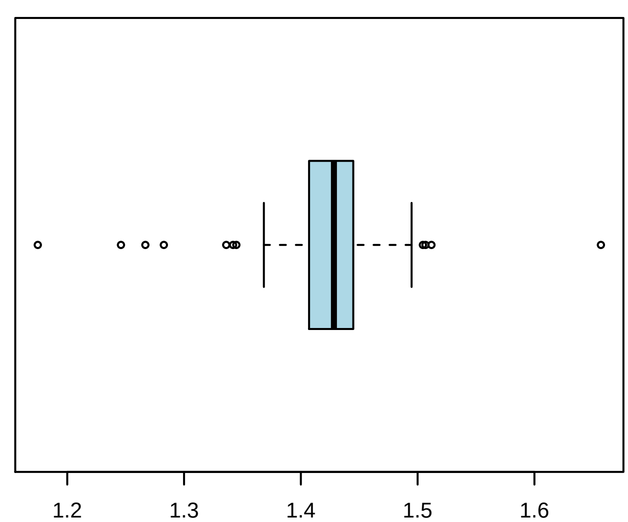
Skewness: −0.9118
Kurtosis: 12.8949

Optimal lambda: 0.05004



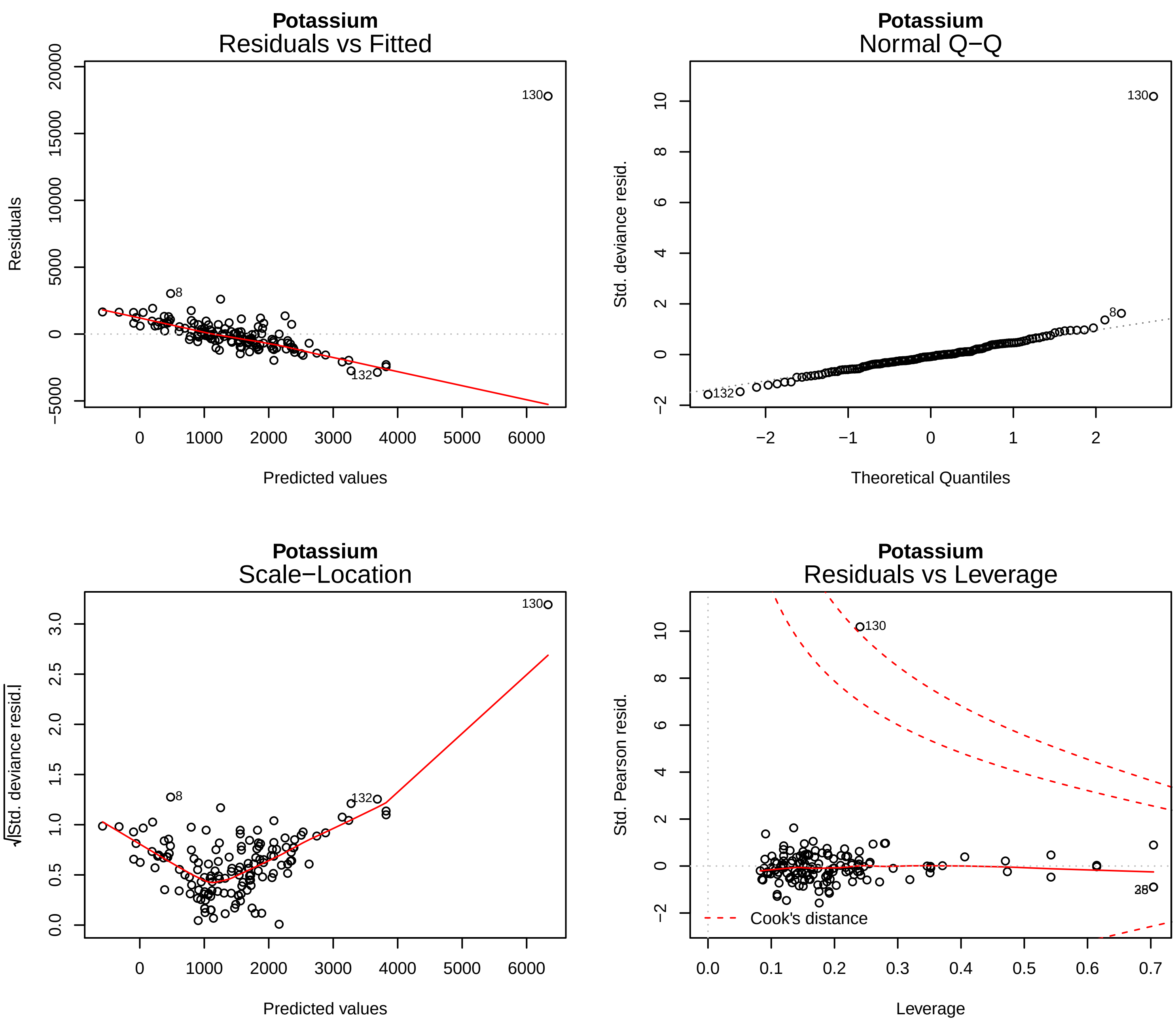






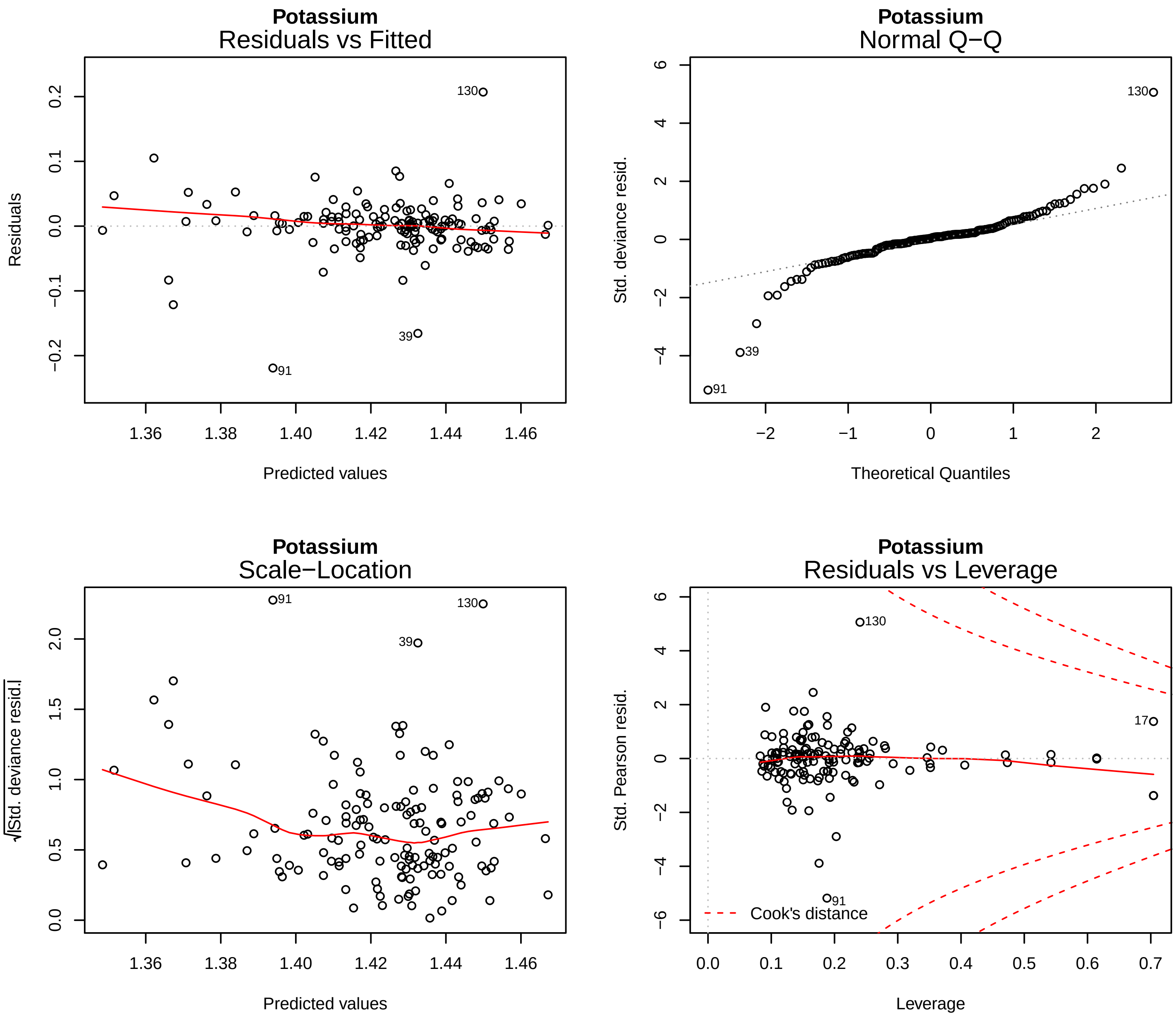
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

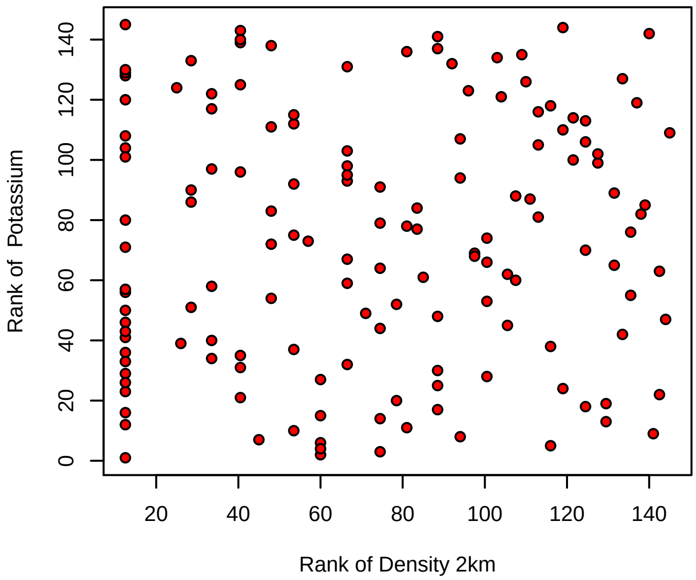
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



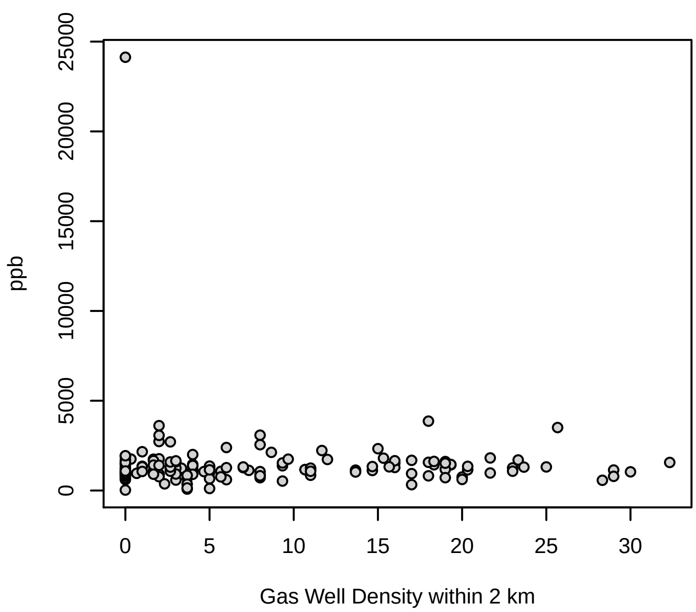


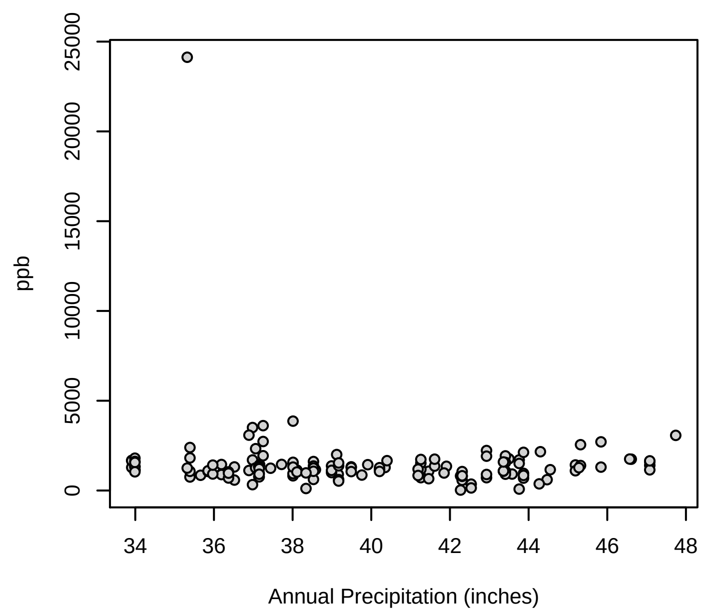
Potassium

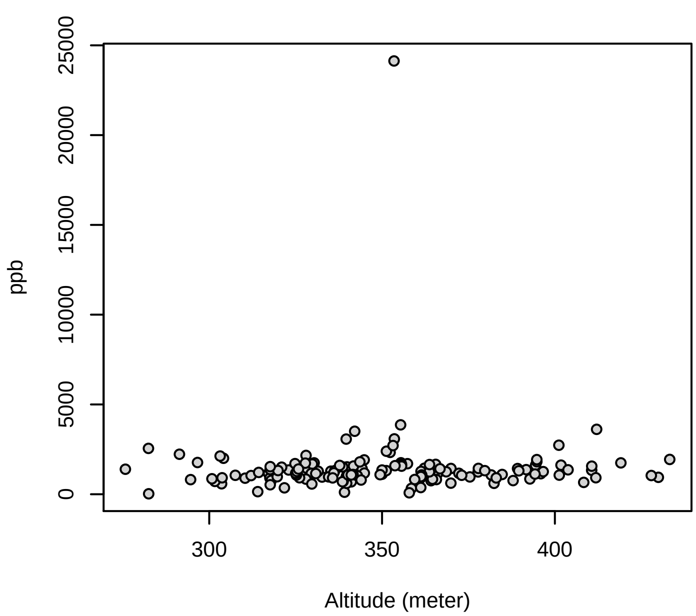
Kendalls Tau Rank Correlation

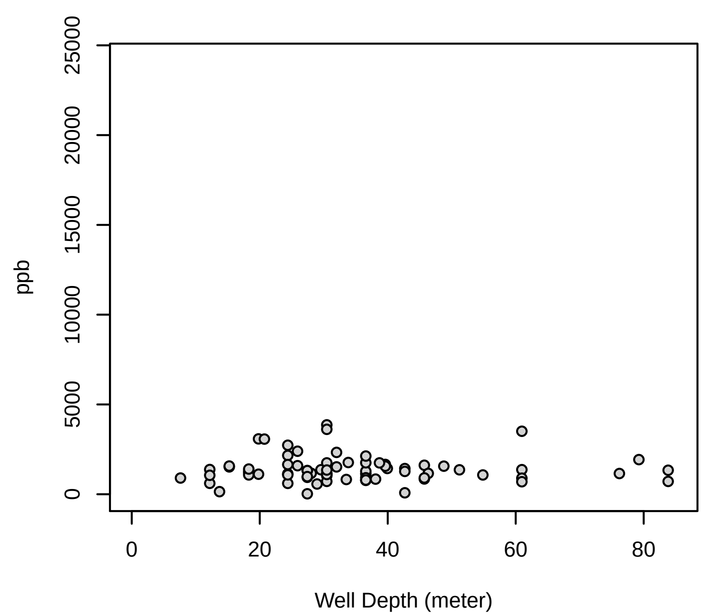
p−value: 0.516

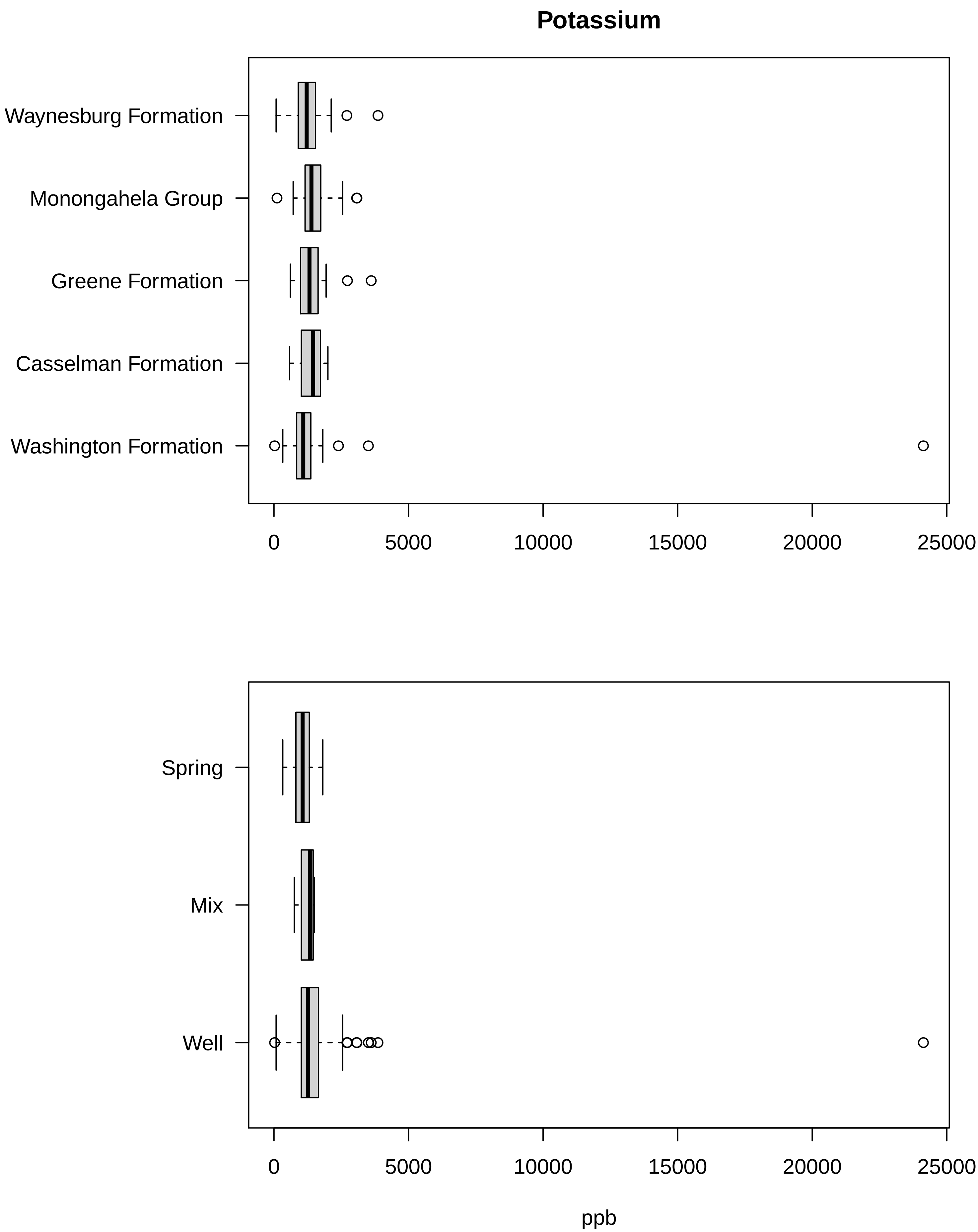
Tau: 0.0371

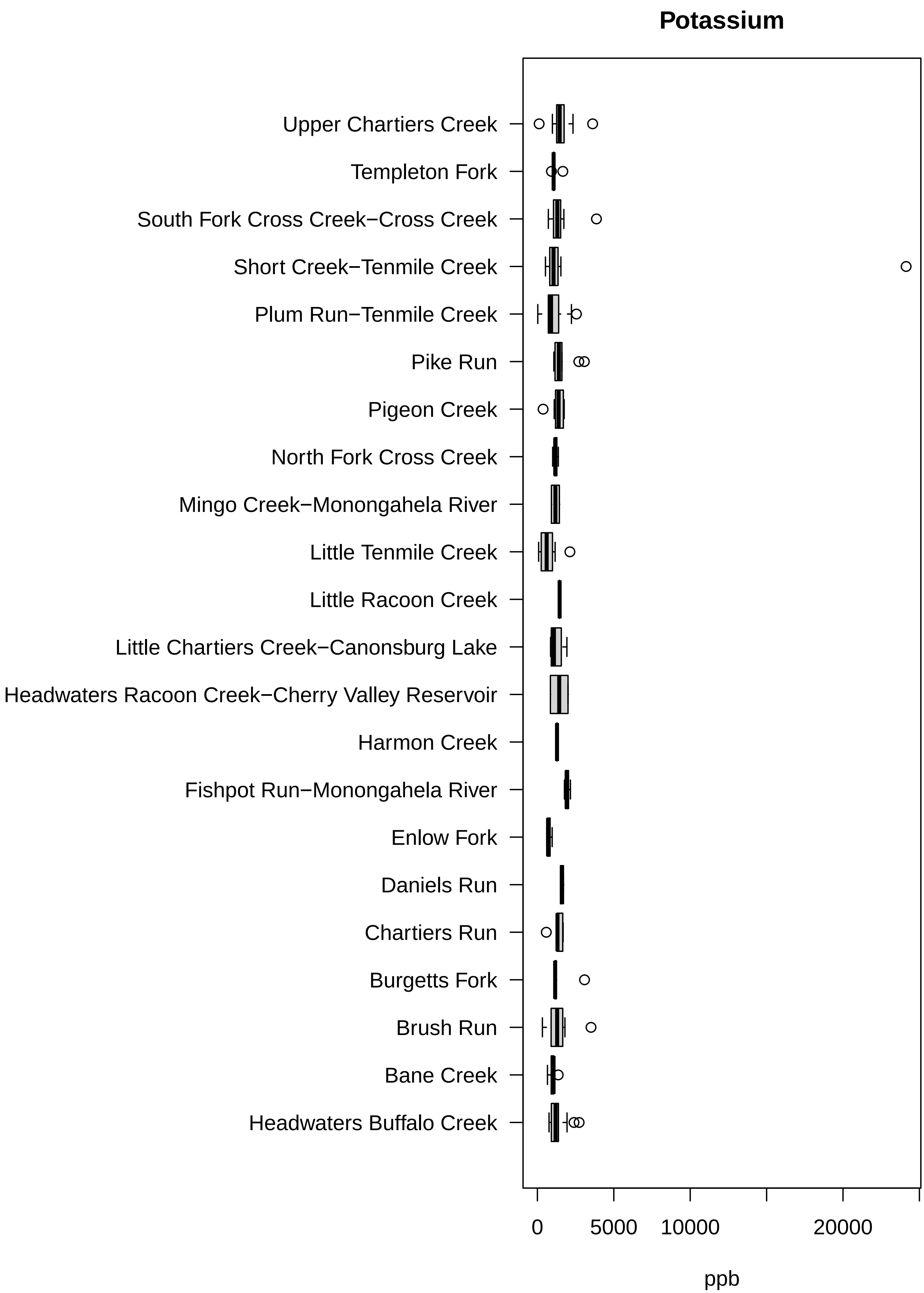









Potassium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
5000
10000
15000
20000
25000
Spring
Mix
Well
0
5000
10000
15000
20000
25000
ppb


Potassium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
5000
10000
20000
ppb

```
[1] "ORIGINAL MODEL - Potassium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2863.4   -674.8   -132.3    551.1  17797.8

Coefficients:
                                                        Estimate Std. Error t value Pr(>|t|)
(Intercept)                                             7056.828   5510.617   1.281  0.20294
dat$GWellDensity_2kmAvg                                  -78.815     34.056  -2.314  0.02245 *
dat$Altitude_meter                                        17.025      9.347   1.821  0.07118 .
dat$WatershedBane Creek                                 1307.542   1167.798   1.120  0.26521
dat$WatershedBrush Run                                   828.838    959.747   0.864  0.38962
dat$WatershedBurgetts Fork                               -28.053   1122.856  -0.025  0.98011
dat$WatershedChartiers Run                              -640.874   1311.086  -0.489  0.62591
dat$WatershedDaniels Run                                2892.300   1860.610   1.554  0.12284
dat$WatershedEnlow Fork                                 -629.580   1268.118  -0.496  0.62052
dat$WatershedFishpot Run-Monongahela River              1906.604   1535.788   1.241  0.21699
dat$WatershedHarmon Creek                                360.196   2509.901   0.144  0.88614
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -311.411   1828.128  -0.170  0.86504
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     1113.605   1182.831   0.941  0.34845
dat$WatershedLittle Racoon Creek                        -175.478   2827.747  -0.062  0.95063
dat$WatershedLittle Tenmile Creek                       1892.545   1209.711   1.564  0.12048
dat$WatershedMingo Creek-Monongahela River               683.913   1620.826   0.422  0.67385
dat$WatershedNorth Fork Cross Creek                      -66.023   1087.546  -0.061  0.95170
dat$WatershedPigeon Creek                               2029.323   1361.780   1.490  0.13893
dat$WatershedPike Run                                   2541.504   1330.316   1.910  0.05859 .
dat$WatershedPlum Run-Tenmile Creek                     2180.173   1179.755   1.848  0.06720 .
dat$WatershedShort Creek-Tenmile Creek                  3963.116    979.262   4.047 9.48e-05 ***
dat$WatershedSouth Fork Cross Creek-Cross Creek         1016.858    877.135   1.159  0.24876
dat$WatershedTempleton Fork                             -334.143   1037.056  -0.322  0.74789
dat$WatershedUpper Chartiers Creek                       144.823    895.189   0.162  0.87177
dat$FormationCasselman Formation                        1278.306   2041.475   0.626  0.53246
dat$FormationGreene Formation                           -516.348    693.348  -0.745  0.45798
dat$FormationMonongahela Group                          1119.255    725.756   1.542  0.12580
dat$FormationWaynesburg Formation                         68.661    561.683   0.122  0.90292
dat$HHWSourceMix                                        -747.014   1355.853  -0.551  0.58274
dat$HHWSourceSpring                                     -543.214    444.240  -1.223  0.22393
dat$Precip_inchAvg                                      -303.097    113.695  -2.666  0.00879 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 4016462)

    Null deviance: 574894957  on 144  degrees of freedom
Residual deviance: 457876641  on 114  degrees of freedom
AIC: 2645.5

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Potassium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-0.219125  -0.014860   0.001233   0.014315   0.206994

Coefficients:
                                                     Estimate Std. Error t value Pr(>|t|)
(Intercept)                                         1.5154840  0.1290305  11.745   <2e-16 ***
dat$GWellDensity_2kmAvg                             0.0004436  0.0007974   0.556   0.5791
dat$Altitude_meter                                  0.0001277  0.0002189   0.584   0.5606
dat$WatershedBane Creek                            -0.0196976  0.0273439  -0.720   0.4728
dat$WatershedBrush Run                             -0.0108679  0.0224724  -0.484   0.6296
dat$WatershedBurgetts Fork                          0.0030727  0.0262916   0.117   0.9072
dat$WatershedChartiers Run                         -0.0257262  0.0306989  -0.838   0.4038
dat$WatershedDaniels Run                            0.0767828  0.0435660   1.762   0.0807 .
dat$WatershedEnlow Fork                            -0.0339317  0.0296929  -1.143   0.2555
dat$WatershedFishpot Run-Monongahela River          0.0489887  0.0359603   1.362   0.1758
dat$WatershedHarmon Creek                           0.0258330  0.0587690   0.440   0.6611
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.0005993  0.0428054   0.014   0.9889
dat$WatershedLittle Chartiers Creek-Canonsburg Lake  0.0075459  0.0276958   0.272   0.7858
dat$WatershedLittle Racoon Creek                    0.0229771  0.0662114   0.347   0.7292
dat$WatershedLittle Tenmile Creek                  -0.0320452  0.0283252  -1.131   0.2603
dat$WatershedMingo Creek-Monongahela River          0.0128889  0.0379515   0.340   0.7348
dat$WatershedNorth Fork Cross Creek                -0.0073869  0.0254648  -0.290   0.7723
dat$WatershedPigeon Creek                           0.0311363  0.0318859   0.976   0.3309
dat$WatershedPike Run                               0.0522007  0.0311492   1.676   0.0965 .
dat$WatershedPlum Run-Tenmile Creek                -0.0067467  0.0276238  -0.244   0.8075
dat$WatershedShort Creek-Tenmile Creek              0.0153999  0.0229293   0.672   0.5032
dat$WatershedSouth Fork Cross Creek-Cross Creek     0.0007023  0.0205380   0.034   0.9728
dat$WatershedTempleton Fork                        -0.0101028  0.0242825  -0.416   0.6782
dat$WatershedUpper Chartiers Creek                 -0.0101817  0.0209607  -0.486   0.6281
dat$FormationCasselman Formation                    0.0108028  0.0478009   0.226   0.8216
dat$FormationGreene Formation                       0.0150546  0.0162347   0.927   0.3557
dat$FormationMonongahela Group                      0.0185862  0.0169935   1.094   0.2764
dat$FormationWaynesburg Formation                  -0.0071903  0.0131517  -0.547   0.5856
dat$HHWSourceMix                                   -0.0281610  0.0317472  -0.887   0.3769
dat$HHWSourceSpring                                -0.0185999  0.0104018  -1.788   0.0764 .
dat$Precip_inchAvg                                 -0.0035706  0.0026622  -1.341   0.1825
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.002202053)

    Null deviance: 0.32328  on 144  degrees of freedom
Residual deviance: 0.25103  on 114  degrees of freedom
AIC: -446.55

Number of Fisher Scoring iterations: 2
```

Selenium

Skewness: 5.1705

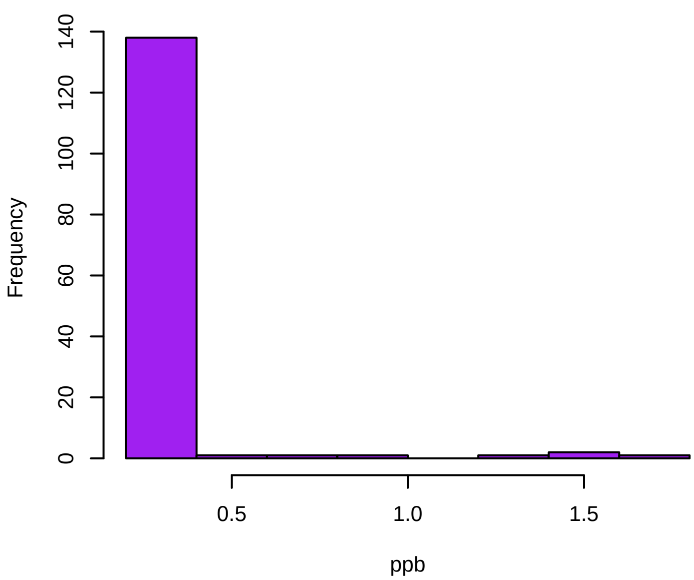
Kurtosis: 29.0737

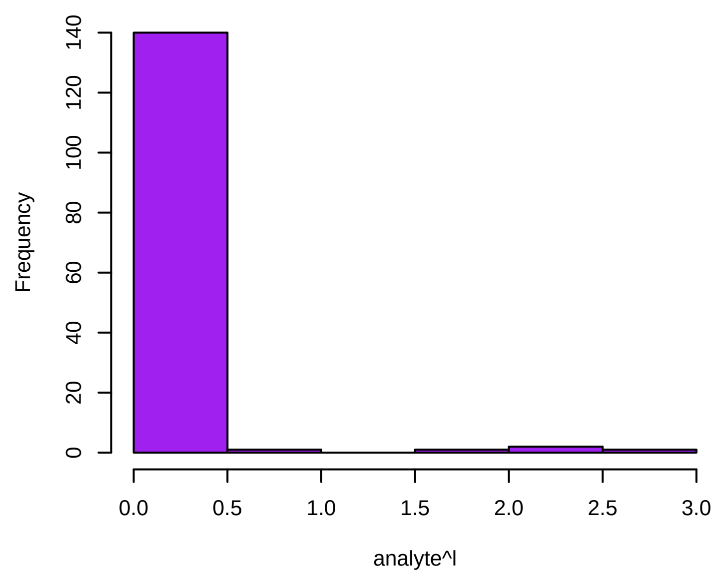
Selenium Box−Cox

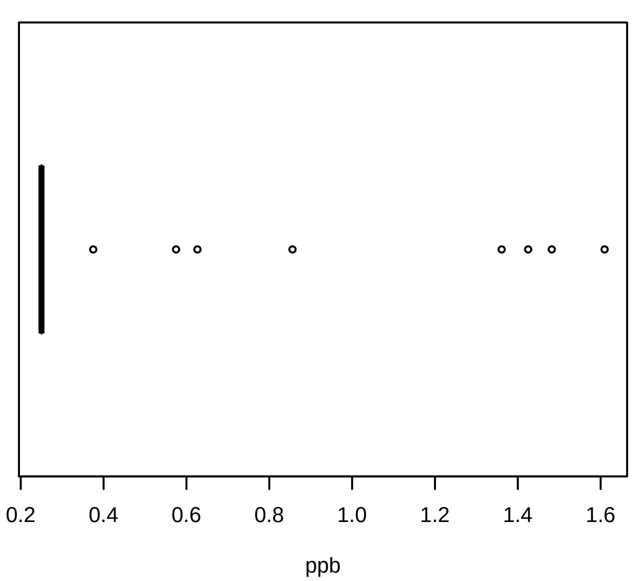
Skewness: 5.6617

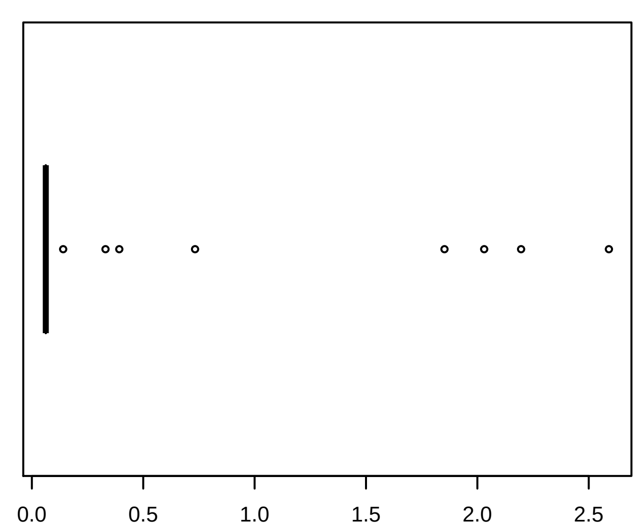
Kurtosis: 34.4146

Optimal lambda: 2



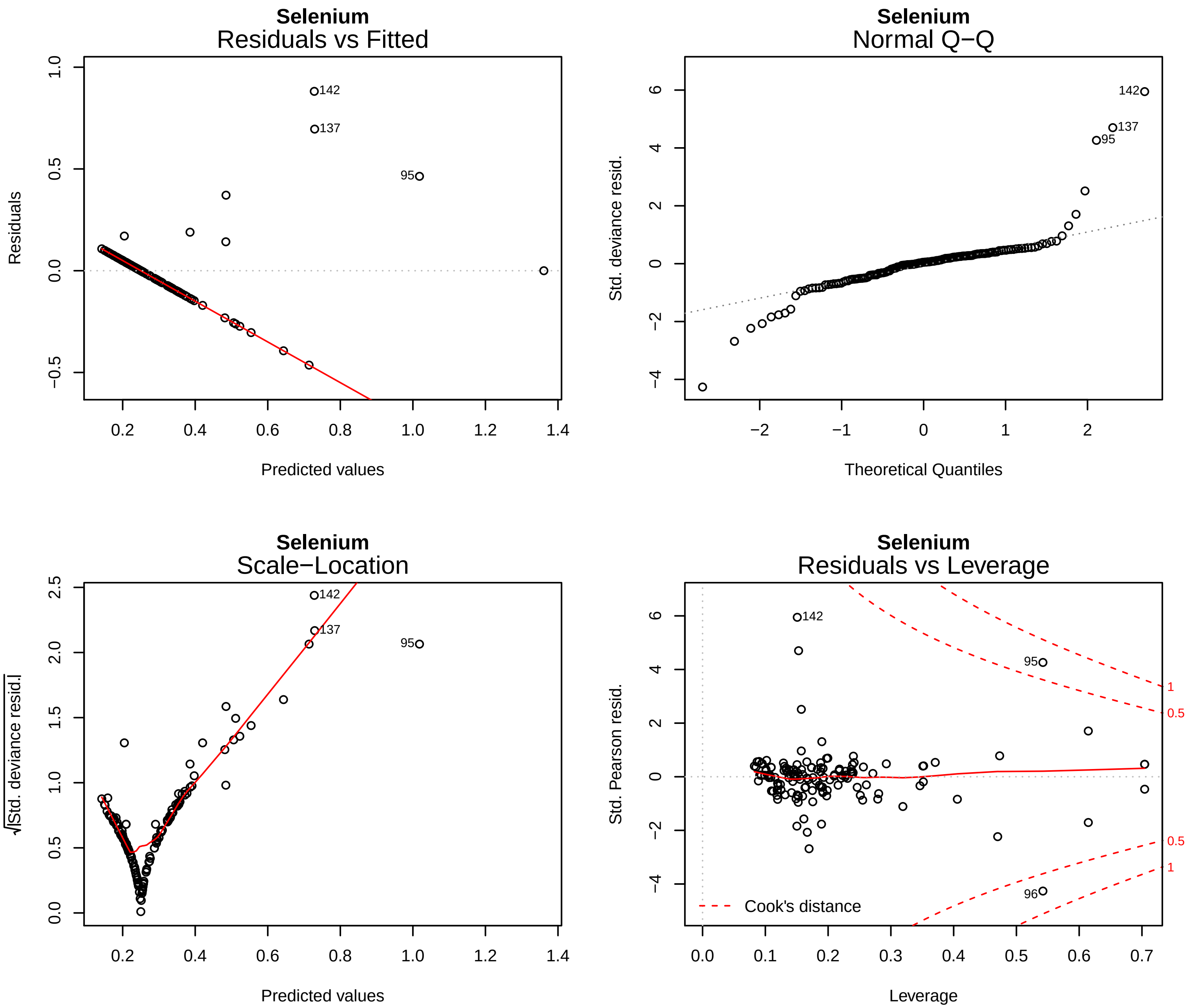






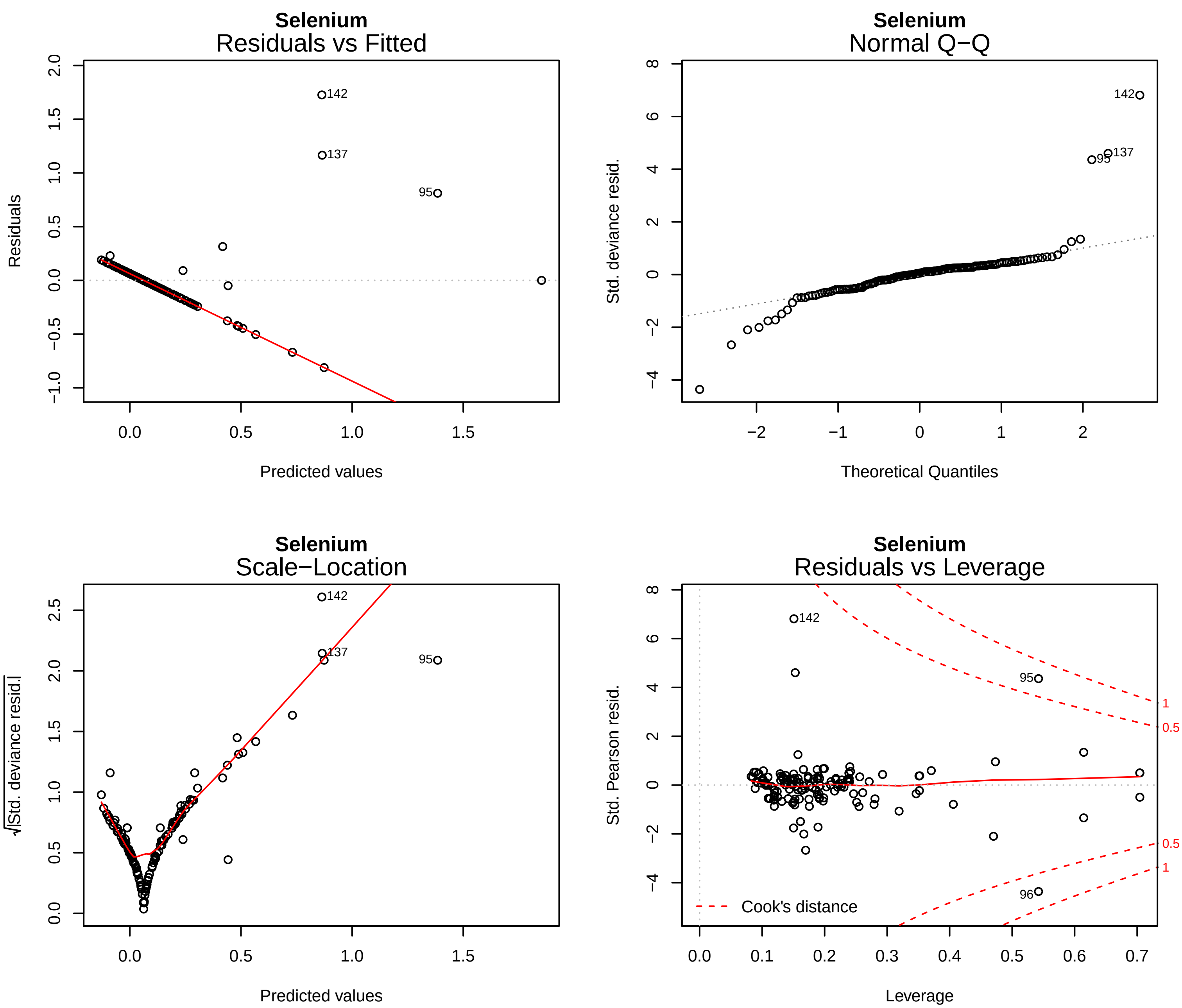
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

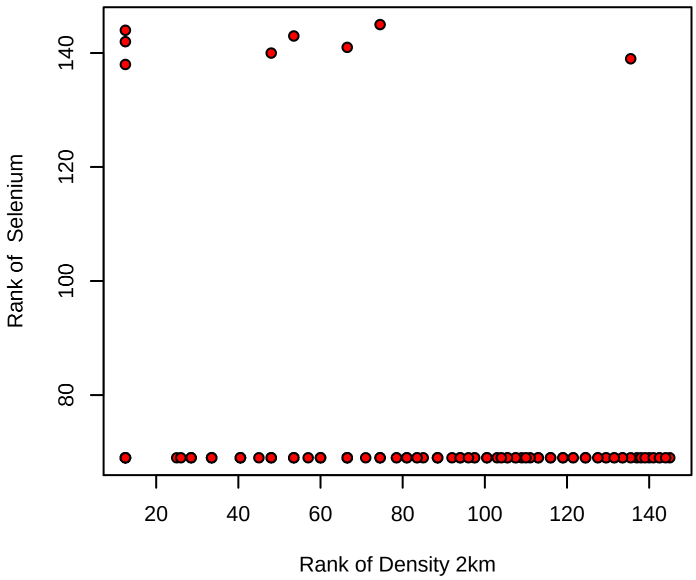
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



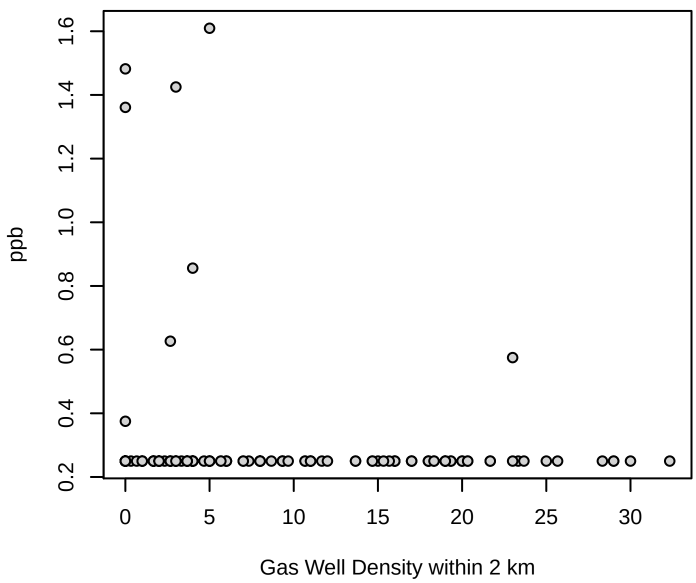


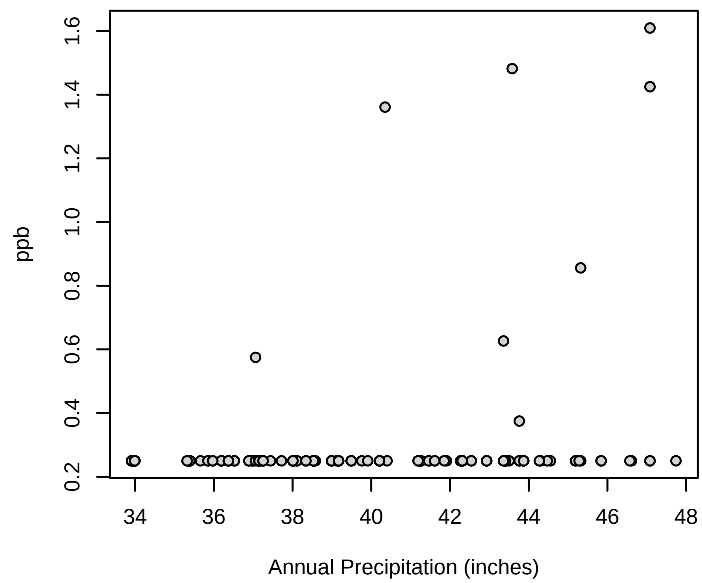
Selenium

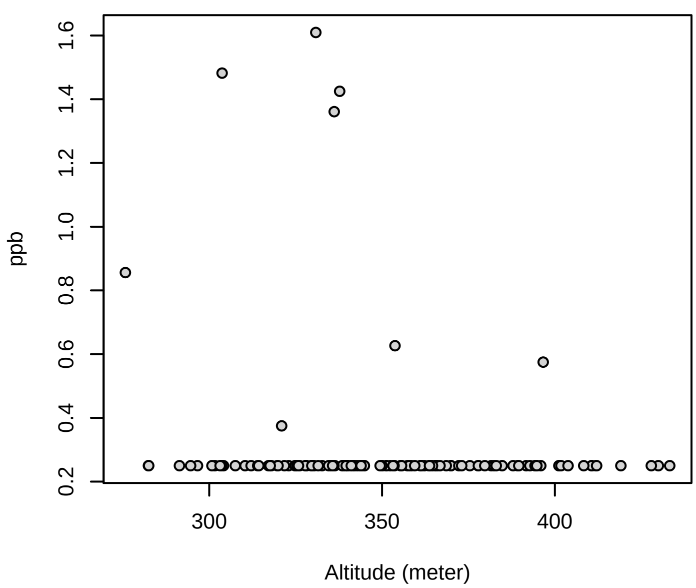
Kendalls Tau Rank Correlation

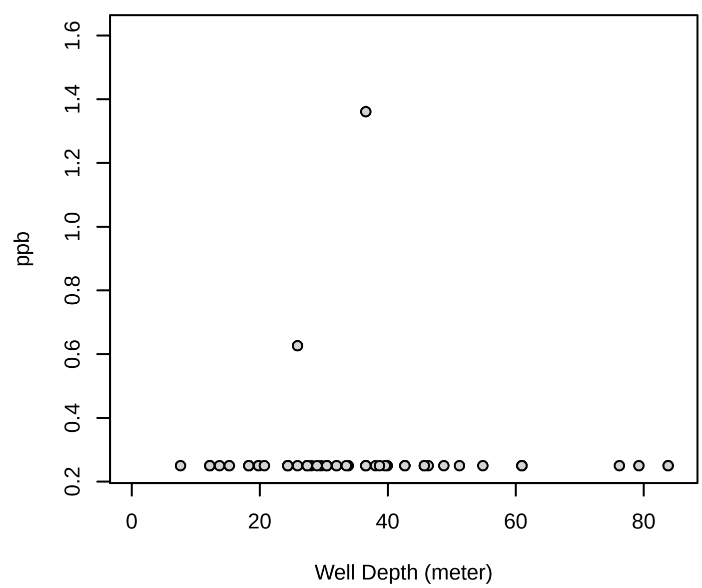
p−value: 0.145

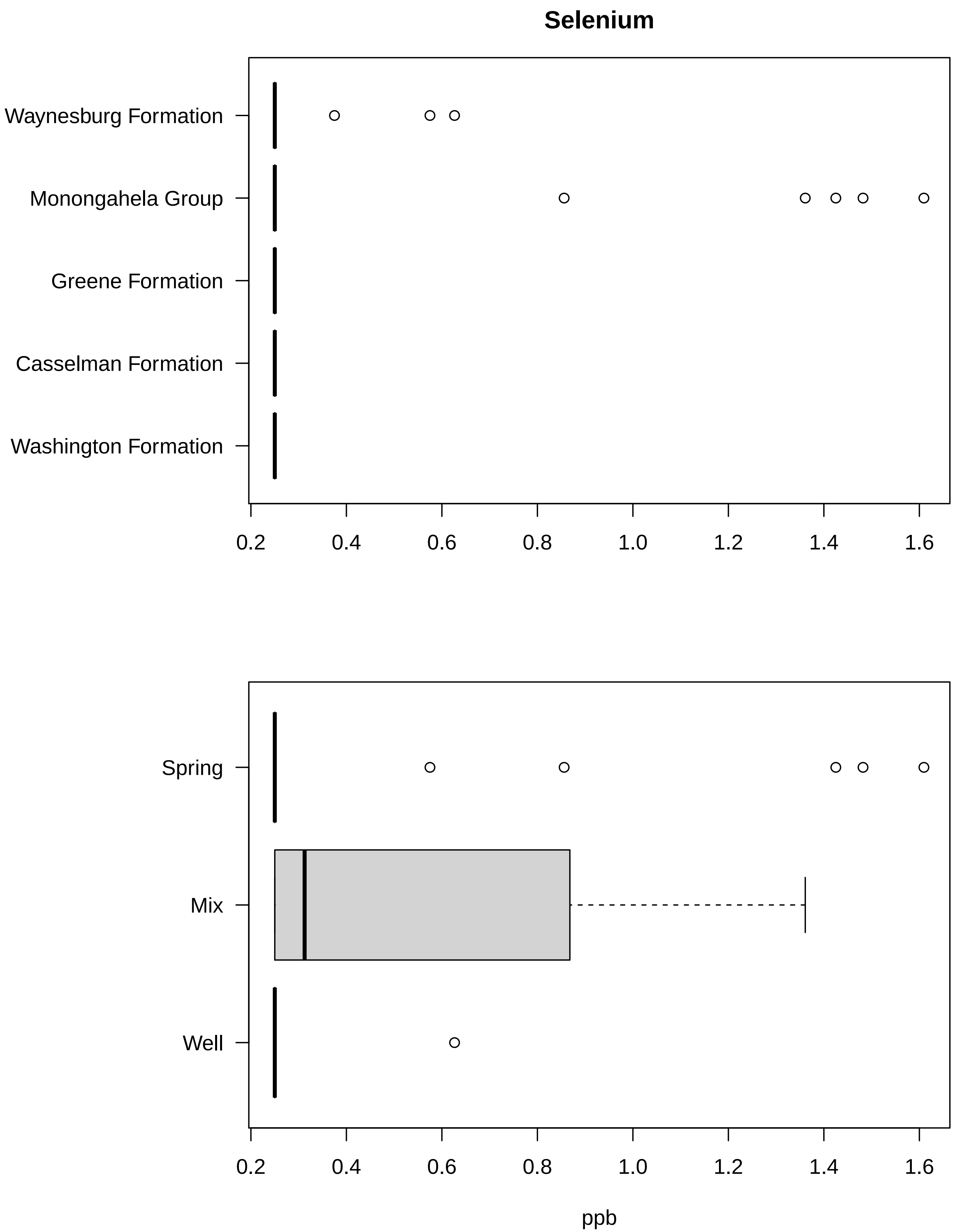
Tau: −0.1

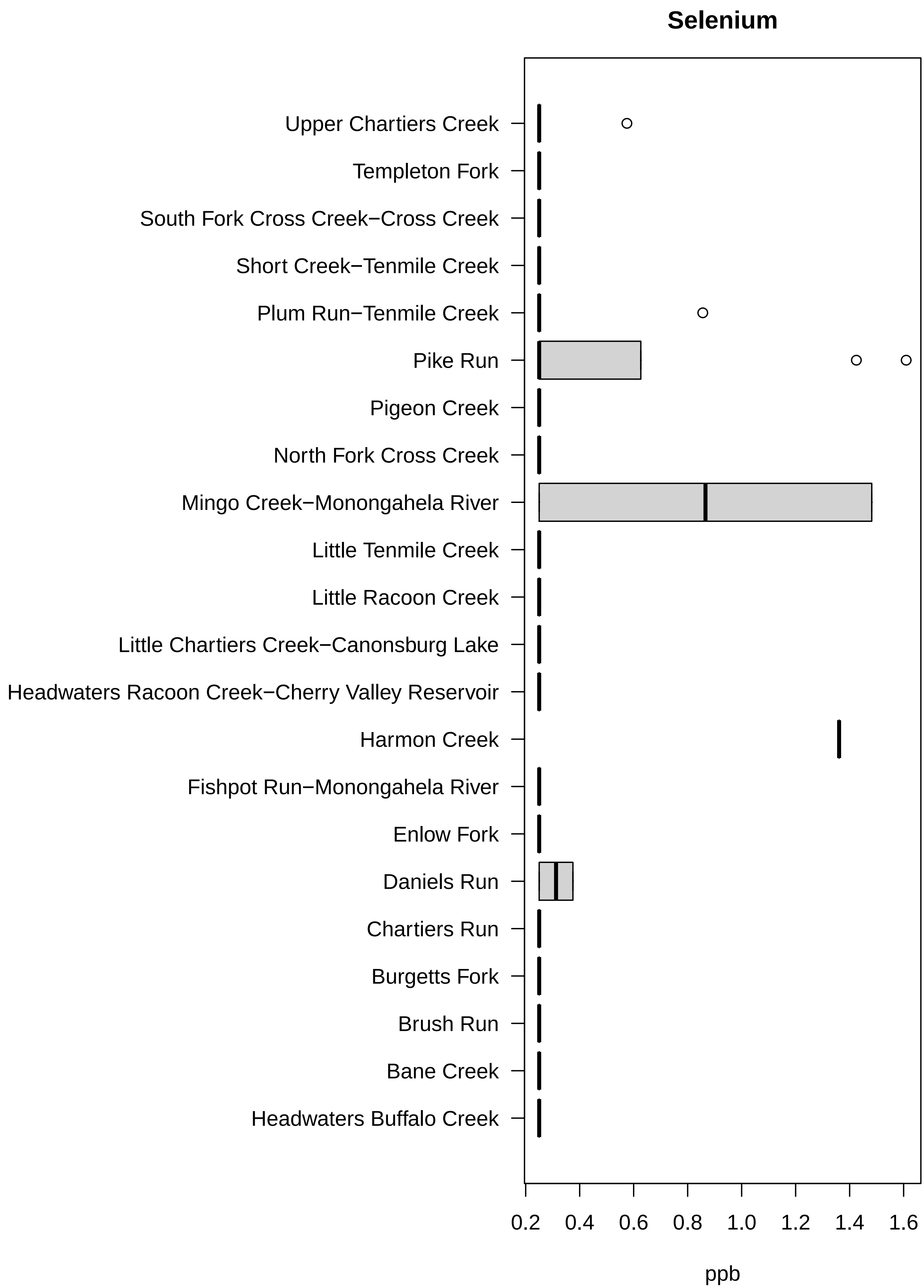









Selenium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Spring
Mix
Well
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
ppb



Selenium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
ppb

```
[1] "ORIGINAL MODEL - Selenium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.46383  -0.05683   0.00653   0.04473   0.88132  

Coefficients:
                                                            Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                               -0.4686101  0.4421990  -1.060  0.29151    
dat$GWellDensity_2kmAvg                                    0.0002489  0.0027329   0.091  0.92758    
dat$Altitude_meter                                         0.0002205  0.0007501   0.294  0.76929    
dat$WatershedBane Creek                                   -0.0346582  0.0937098  -0.370  0.71218    
dat$WatershedBrush Run                                     0.0354608  0.0770148   0.460  0.64608    
dat$WatershedBurgetts Fork                                -0.0966384  0.0901035  -1.073  0.28575    
dat$WatershedChartiers Run                                -0.0811855  0.1052080  -0.772  0.44191    
dat$WatershedDaniels Run                                  -0.0349580  0.1493045  -0.234  0.81530    
dat$WatershedEnlow Fork                                    0.0248713  0.1017601   0.244  0.80735    
dat$WatershedFishpot Run-Monongahela River                -0.1686958  0.1232392  -1.369  0.17374    
dat$WatershedHarmon Creek                                  1.0773343  0.2014068   5.349 4.61e-07 ***
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0409638  0.1466980  -0.279  0.78057    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       -0.0843028  0.0949161  -0.888  0.37631    
dat$WatershedLittle Racoon Creek                          -0.1612769  0.2269123  -0.711  0.47869    
dat$WatershedLittle Tenmile Creek                         -0.1009073  0.0970731  -1.039  0.30077    
dat$WatershedMingo Creek-Monongahela River                 0.4763612  0.1300631   3.663  0.00038 ***
dat$WatershedNorth Fork Cross Creek                       -0.0771624  0.0872701  -0.884  0.37846    
dat$WatershedPigeon Creek                                 -0.1739643  0.1092759  -1.592  0.11416    
dat$WatershedPike Run                                      0.1245281  0.1067511   1.167  0.24584    
dat$WatershedPlum Run-Tenmile Creek                       -0.0789050  0.0946693  -0.833  0.40632    
dat$WatershedShort Creek-Tenmile Creek                    -0.0180758  0.0785808  -0.230  0.81848    
dat$WatershedSouth Fork Cross Creek-Cross Creek           -0.0403846  0.0703856  -0.574  0.56726    
dat$WatershedTempleton Fork                                0.0429566  0.0832185   0.516  0.60672    
dat$WatershedUpper Chartiers Creek                         0.0133637  0.0718344   0.186  0.85275    
dat$FormationCasselman Formation                           0.1216721  0.1638180   0.743  0.45917    
dat$FormationGreene Formation                              0.0059528  0.0556377   0.107  0.91498    
dat$FormationMonongahela Group                             0.1671472  0.0582382   2.870  0.00489 ** 
dat$FormationWaynesburg Formation                          0.0732090  0.0450722   1.624  0.10708    
dat$HHWSourceMix                                          -0.1186140  0.1088004  -1.090  0.27792    
dat$HHWSourceSpring                                        0.0962838  0.0356480   2.701  0.00797 ** 
dat$Precip_inchAvg                                         0.0156037  0.0091234   1.710  0.08993 .  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.02586299)

    Null deviance: 6.3367  on 144  degrees of freedom
Residual deviance: 2.9484  on 114  degrees of freedom
AIC: -89.352

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Selenium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.81154  -0.09112   0.01225   0.06997   1.72650

Coefficients:
                                                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               -1.1165306  0.7563979  -1.476 0.142670
dat$GWellDensity_2kmAvg                                    0.0001266  0.0046746   0.027 0.978437
dat$Altitude_meter                                         0.0002485  0.0012831   0.194 0.846746
dat$WatershedBane Creek                                   -0.0665519  0.1602942  -0.415 0.678786
dat$WatershedBrush Run                                     0.0678237  0.1317368   0.515 0.607660
dat$WatershedBurgetts Fork                                -0.1596038  0.1541254  -1.036 0.302606
dat$WatershedChartiers Run                                -0.1354040  0.1799622  -0.752 0.453360
dat$WatershedDaniels Run                                  -0.1045783  0.2553909  -0.409 0.682953
dat$WatershedEnlow Fork                                    0.0333134  0.1740644   0.191 0.848564
dat$WatershedFishpot Run-Monongahela River                -0.2938275  0.2108052  -1.394 0.166079
dat$WatershedHarmon Creek                                  1.7489660  0.3445138   5.077 1.51e-06 ***
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0568050  0.2509323  -0.226 0.821315
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       -0.1534832  0.1623576  -0.945 0.346484
dat$WatershedLittle Racoon Creek                          -0.2514379  0.3881420  -0.648 0.518418
dat$WatershedLittle Tenmile Creek                         -0.1725916  0.1660472  -1.039 0.300812
dat$WatershedMingo Creek-Monongahela River                 0.8228942  0.2224777   3.699 0.000335 ***
dat$WatershedNorth Fork Cross Creek                       -0.1342059  0.1492787  -0.899 0.370532
dat$WatershedPigeon Creek                                 -0.2915914  0.1869206  -1.560 0.121538
dat$WatershedPike Run                                      0.2005645  0.1826017   1.098 0.274357
dat$WatershedPlum Run-Tenmile Creek                       -0.1845350  0.1619354  -1.140 0.256859
dat$WatershedShort Creek-Tenmile Creek                    -0.0392700  0.1344153  -0.292 0.770700
dat$WatershedSouth Fork Cross Creek-Cross Creek           -0.0675959  0.1203972  -0.561 0.575599
dat$WatershedTempleton Fork                                0.0631965  0.1423483   0.444 0.657915
dat$WatershedUpper Chartiers Creek                         0.0020420  0.1228753   0.017 0.986770
dat$FormationCasselman Formation                           0.1816436  0.2802168   0.648 0.518143
dat$FormationGreene Formation                              0.0120089  0.0951703   0.126 0.899809
dat$FormationMonongahela Group                             0.2785090  0.0996187   2.796 0.006078 **
dat$FormationWaynesburg Formation                          0.1030020  0.0770977   1.336 0.184212
dat$HHWSourceMix                                          -0.2277689  0.1861070  -1.224 0.223529
dat$HHWSourceSpring                                        0.1519261  0.0609773   2.492 0.014159 *
dat$Precip_inchAvg                                         0.0269045  0.0156060   1.724 0.087421 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.07567349)

    Null deviance: 17.9992  on 144  degrees of freedom
Residual deviance:  8.6268  on 114  degrees of freedom
AIC: 66.322

Number of Fisher Scoring iterations: 2
```

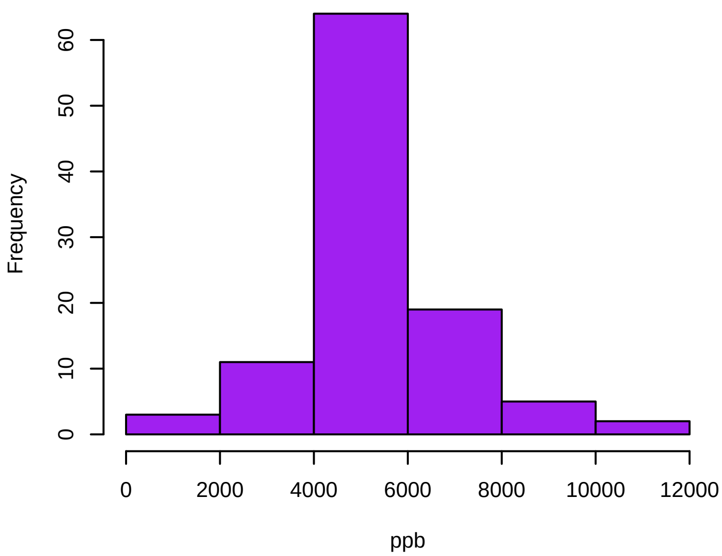
Silicon

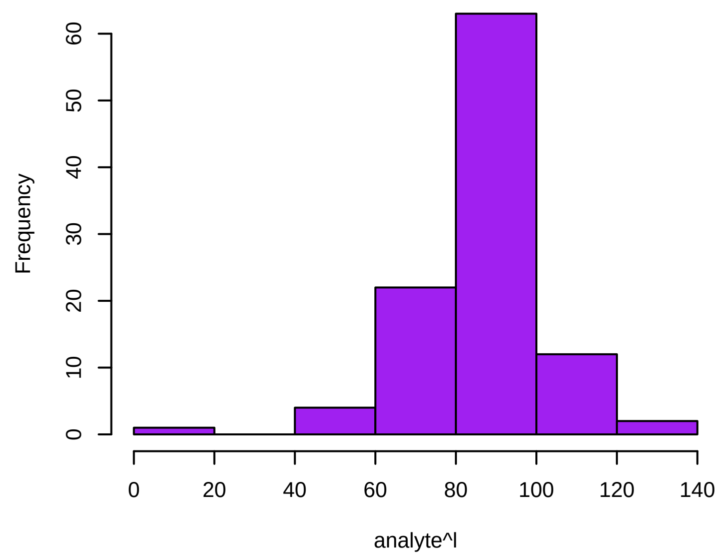
Skewness: 0.6226
Kurtosis: 5.5077

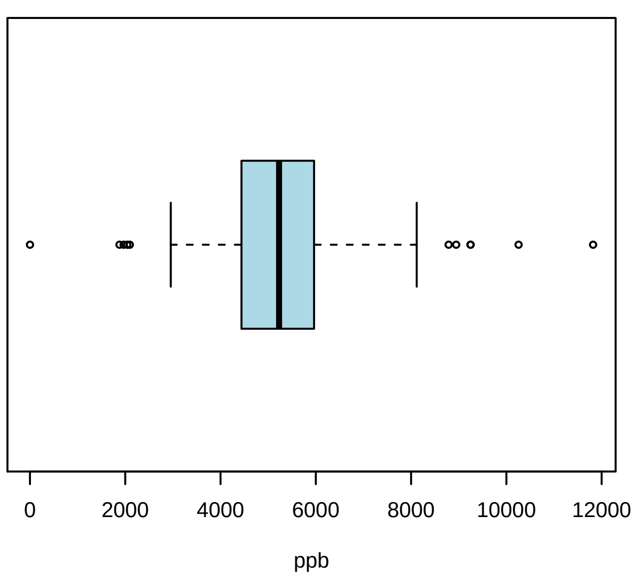
Silicon Box−Cox

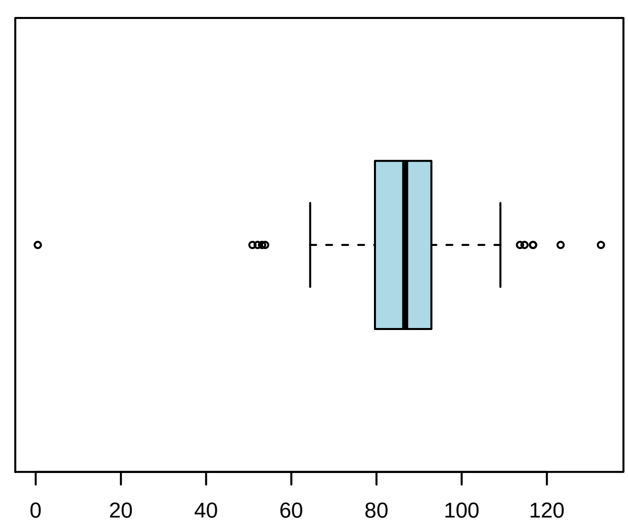
Skewness: −1.2414
Kurtosis: 10.5558

Optimal lambda: 0.5212



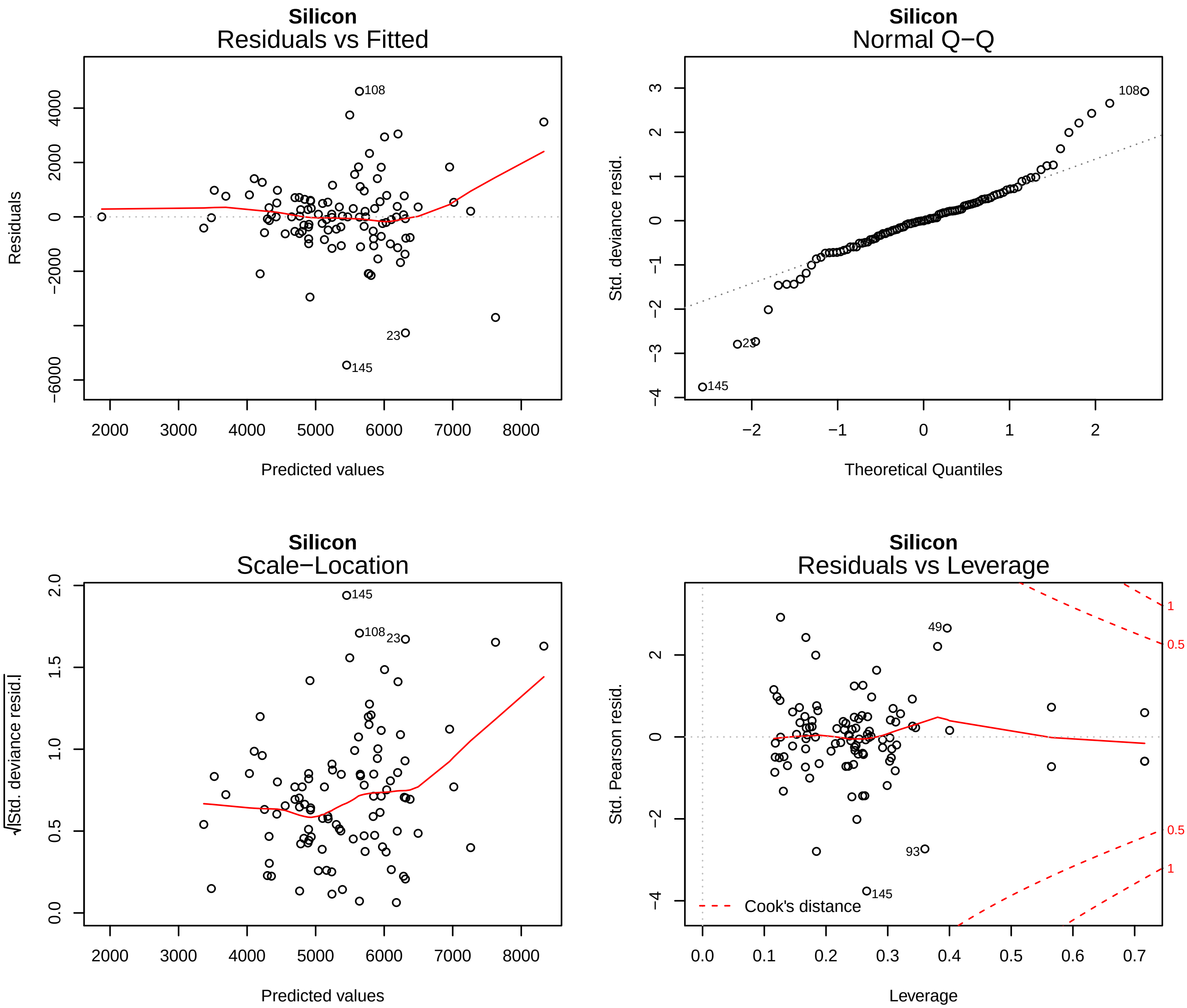






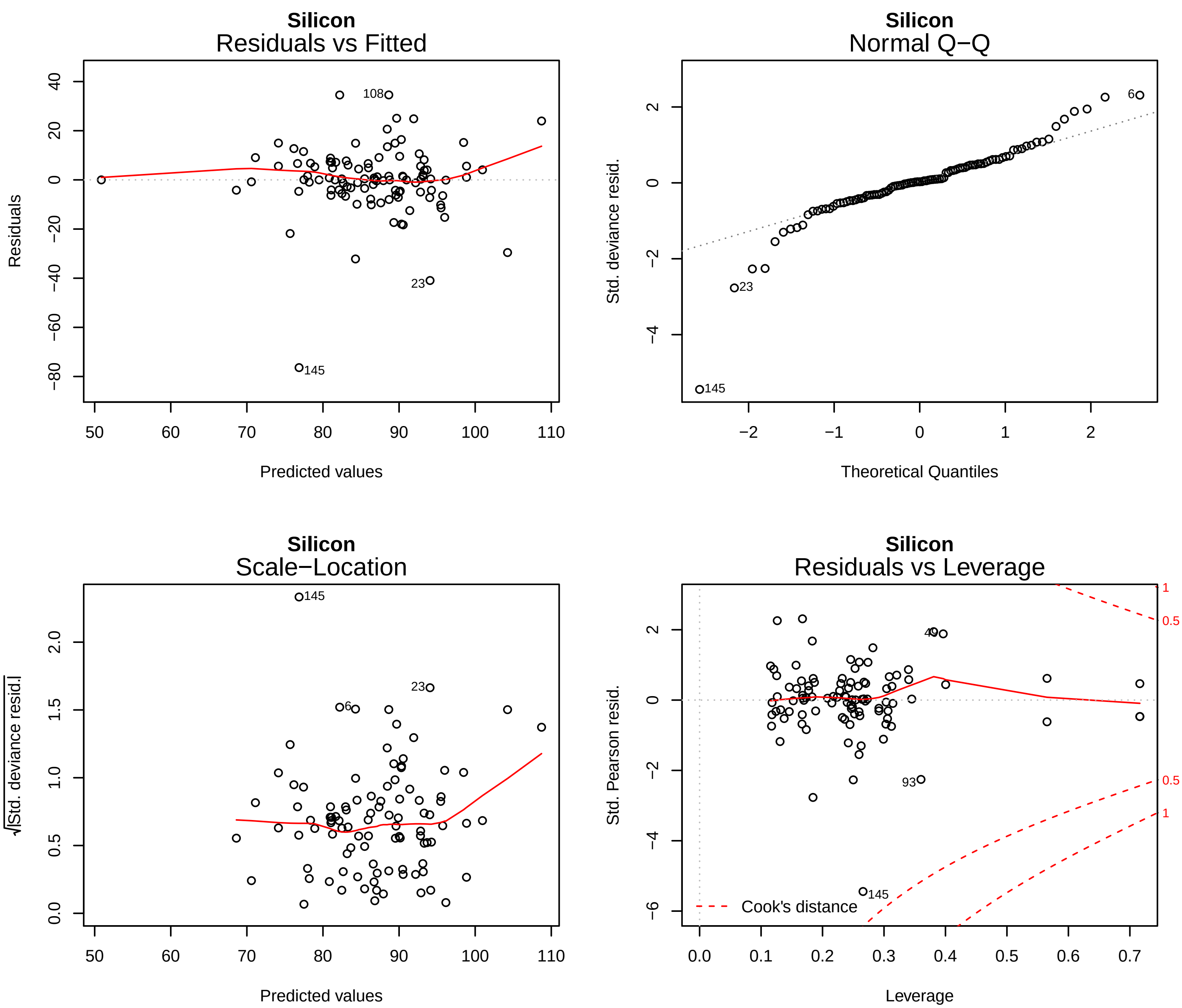
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

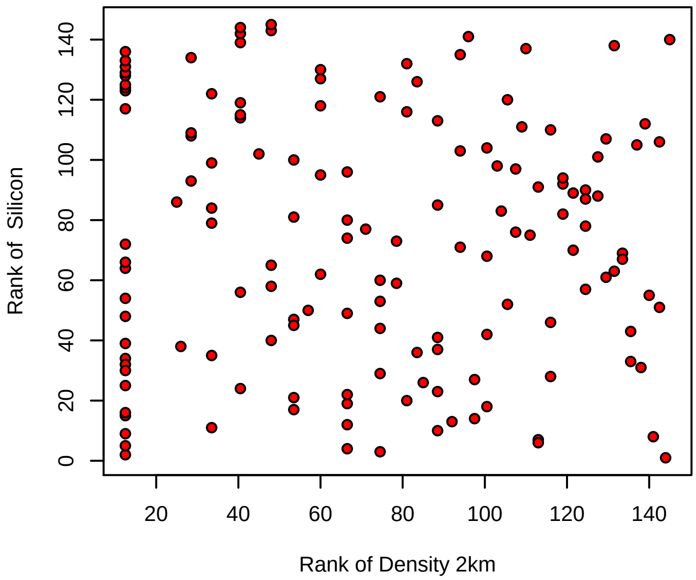
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



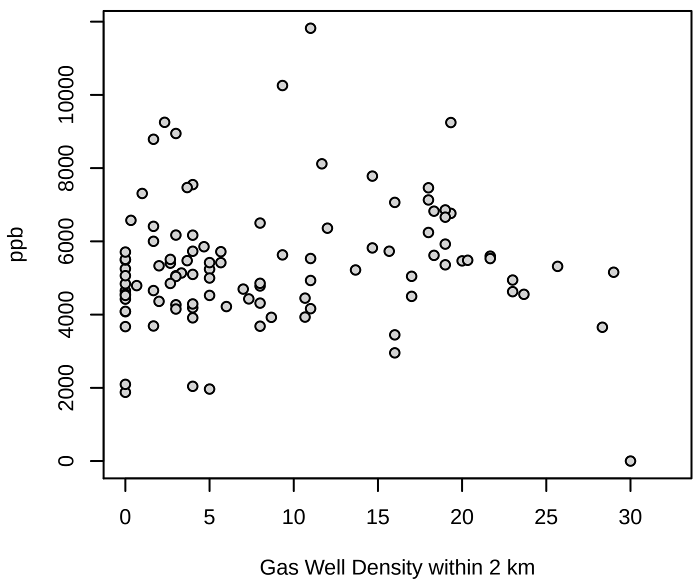


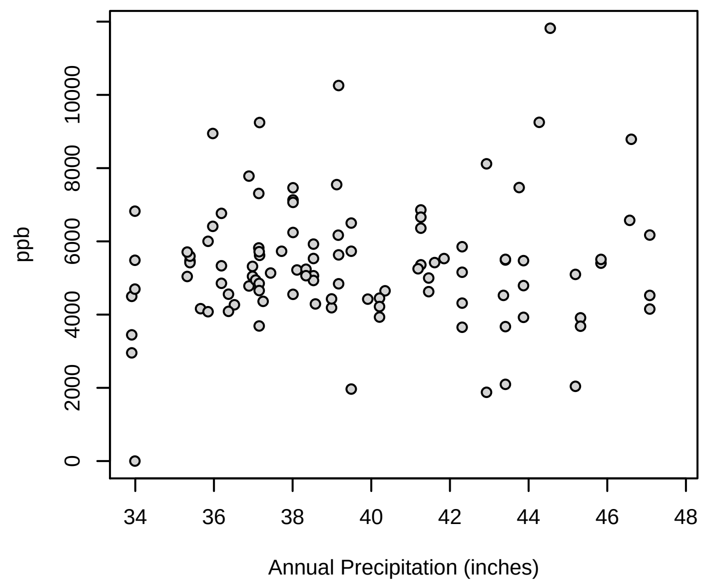
Silicon

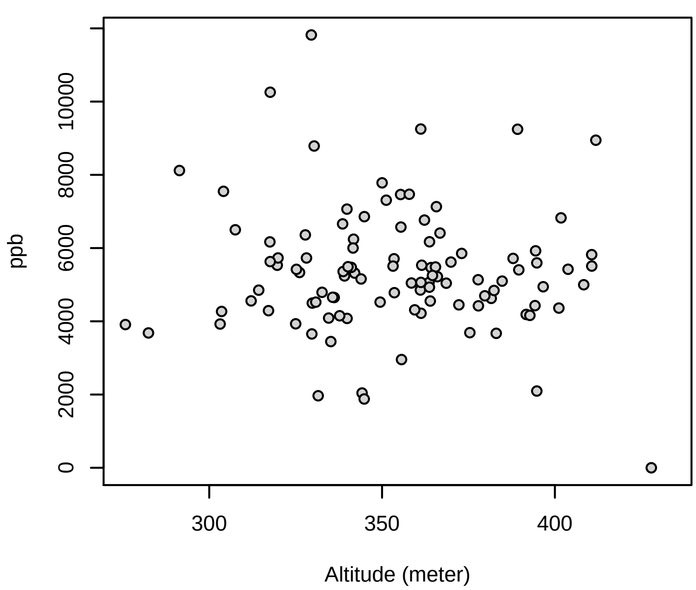
Kendalls Tau Rank Correlation

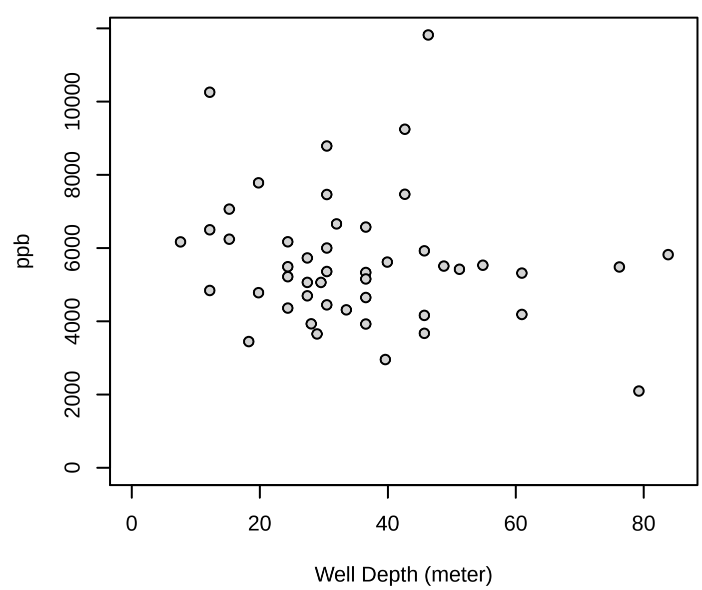
p−value: 0.109

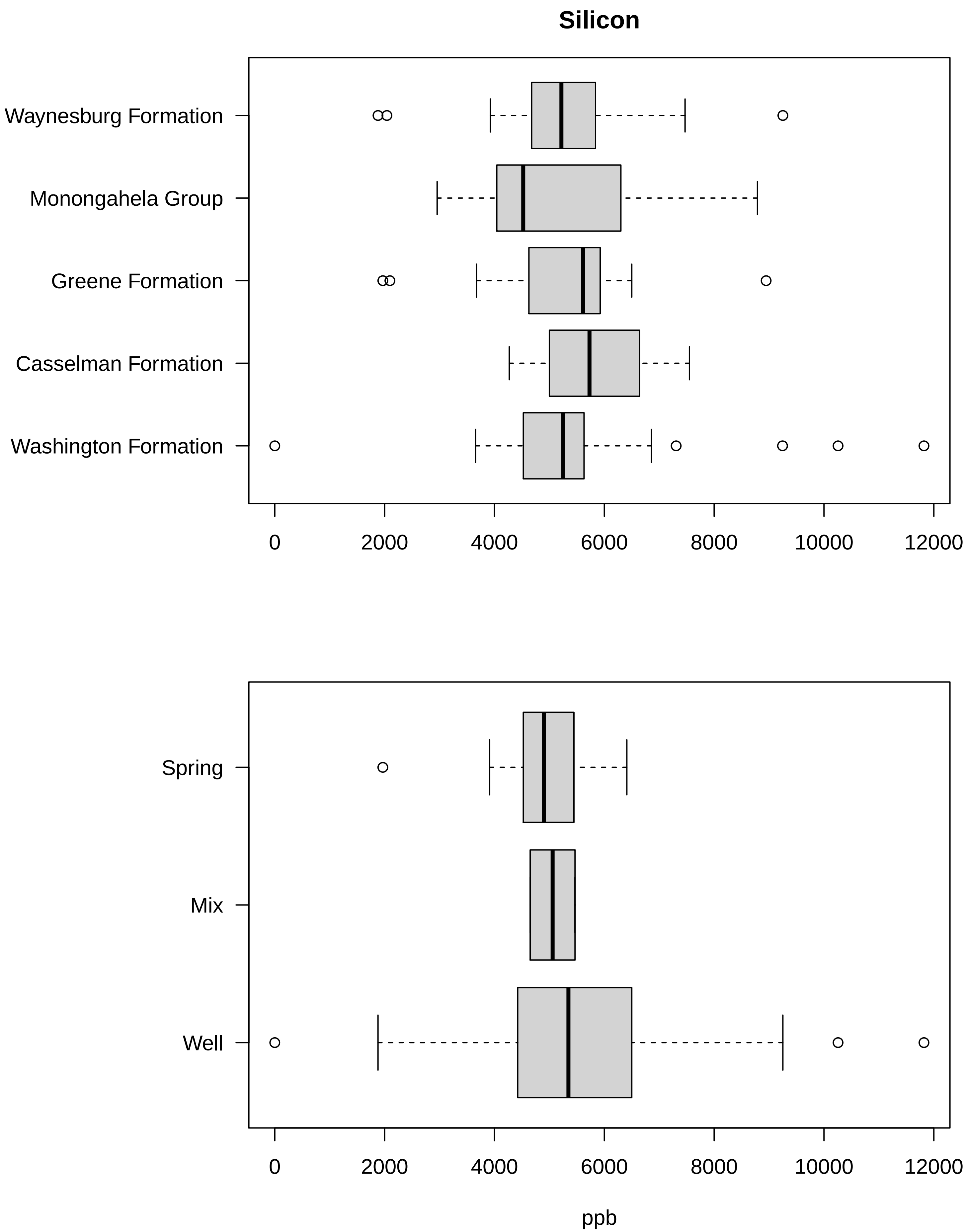
Tau: 0.109



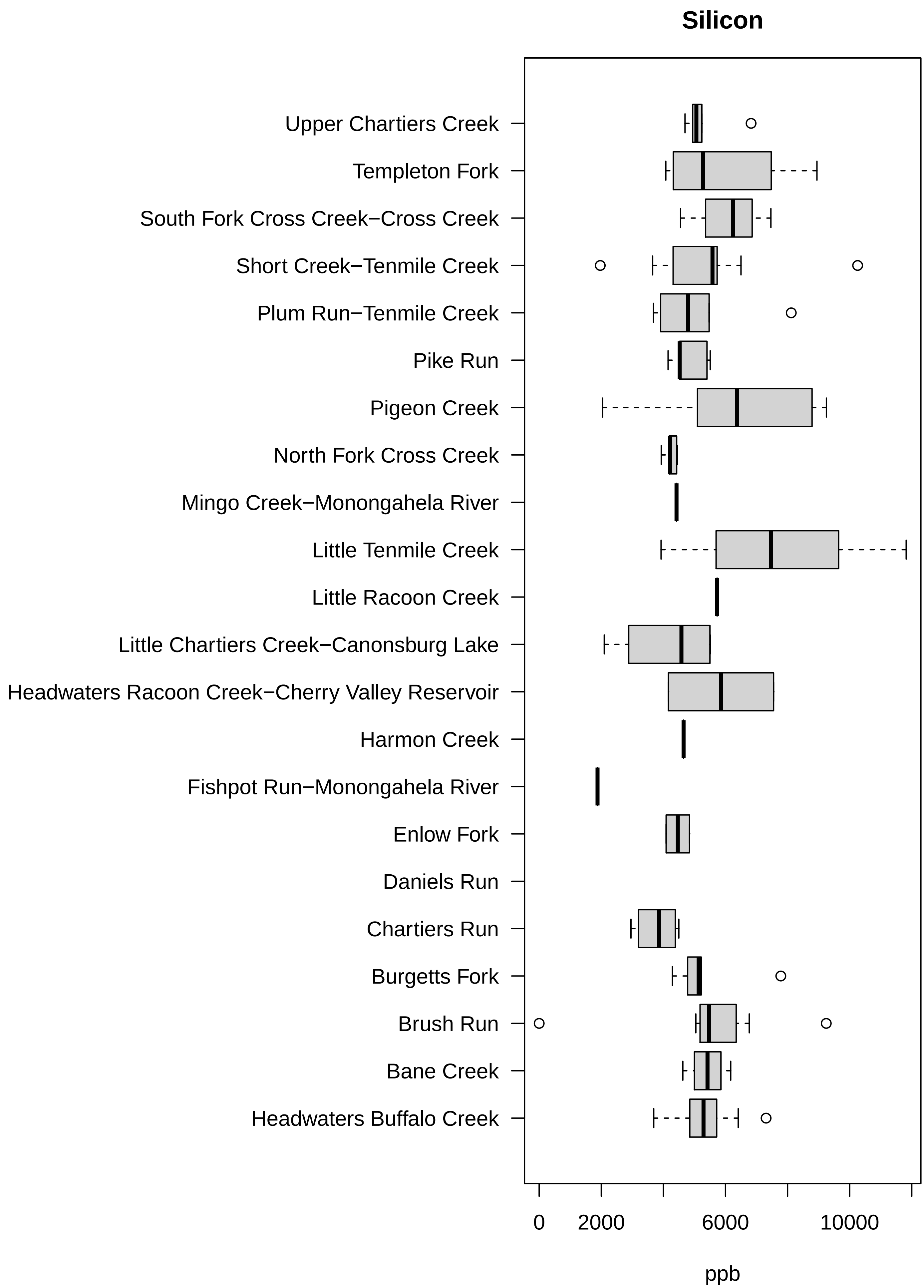








Silicon
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
2000
4000
6000
8000
10000
12000
Spring
Mix
Well
0
2000
4000
6000
8000
10000
12000
ppb



Silicon
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
2000
6000
10000
ppb

```
[1] "ORIGINAL MODEL - Silicon"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-5452.2   -589.3      0.0    587.8   4616.8

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               8038.763   6327.169   1.271   0.2079
dat$GWellDensity_2kmAvg                                     13.450     34.016   0.395   0.6937
dat$Altitude_meter                                          -5.421      9.730  -0.557   0.5791
dat$WatershedBane Creek                                   -513.958   1173.278  -0.438   0.6626
dat$WatershedBrush Run                                    -443.214    996.748  -0.445   0.6579
dat$WatershedBurgetts Fork                                  75.392   1024.777   0.074   0.9416
dat$WatershedChartiers Run                               -2521.105   1334.072  -1.890   0.0627 .
dat$WatershedEnlow Fork                                  -1084.489   1312.190  -0.826   0.4112
dat$WatershedFishpot Run-Monongahela River               -3182.550   2015.868  -1.579   0.1187
dat$WatershedHarmon Creek                                -1720.067   2674.226  -0.643   0.5221
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -301.884   1610.603  -0.187   0.8518
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -1684.488   1400.473  -1.203   0.2329
dat$WatershedLittle Racoon Creek                          -614.488   2464.438  -0.249   0.8038
dat$WatershedLittle Tenmile Creek                         2226.881   1520.463   1.465   0.1473
dat$WatershedMingo Creek-Monongahela River               -1300.850   1870.246  -0.696   0.4889
dat$WatershedNorth Fork Cross Creek                      -1385.340   1079.341  -1.284   0.2033
dat$WatershedPigeon Creek                                 1206.390   1579.634   0.764   0.4475
dat$WatershedPike Run                                     -106.259   1518.839  -0.070   0.9444
dat$WatershedPlum Run-Tenmile Creek                       -333.226   1352.613  -0.246   0.8061
dat$WatershedShort Creek-Tenmile Creek                    -541.587    993.759  -0.545   0.5874
dat$WatershedSouth Fork Cross Creek-Cross Creek            345.946    875.619   0.395   0.6939
dat$WatershedTempleton Fork                                133.599   1000.306   0.134   0.8941
dat$WatershedUpper Chartiers Creek                         156.109    998.413   0.156   0.8762
dat$FormationCasselman Formation                          1134.848   1872.953   0.606   0.5464
dat$FormationGreene Formation                              265.628    667.459   0.398   0.6918
dat$FormationMonongahela Group                            -211.102    784.706  -0.269   0.7887
dat$FormationWaynesburg Formation                         -821.238    582.762  -1.409   0.1630
dat$HHWSourceMix                                           634.104   1872.828   0.339   0.7359
dat$HHWSourceSpring                                       -852.286    505.324  -1.687   0.0959 .
dat$Precip_inchAvg                                          -6.678    134.912  -0.050   0.9607
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 2861014)

    Null deviance: 299376881  on 103  degrees of freedom
Residual deviance: 211715006  on  74  degrees of freedom
  (41 observations deleted due to missingness)
AIC: 1867.9

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Silicon"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-76.373   -4.741    0.221    6.642   34.572

Coefficients:
                                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                                            106.855722  61.253388   1.744   0.0852 .
dat$GWellDensity_2kmAvg                                  0.008315   0.329305   0.025   0.9799
dat$Altitude_meter                                      -0.096694   0.094194  -1.027   0.3080
dat$WatershedBane Creek                                 -6.365734  11.358517  -0.560   0.5769
dat$WatershedBrush Run                                  -6.939852   9.649524  -0.719   0.4743
dat$WatershedBurgetts Fork                               1.853666   9.920877   0.187   0.8523
dat$WatershedChartiers Run                             -17.707488  12.915169  -1.371   0.1745
dat$WatershedEnlow Fork                                -10.875027  12.703327  -0.856   0.3947
dat$WatershedFishpot Run-Monongahela River             -38.820274  19.515639  -1.989   0.0504 .
dat$WatershedHarmon Creek                              -21.637159  25.889210  -0.836   0.4060
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -0.200183  15.592266  -0.013   0.9898
dat$WatershedLittle Chartiers Creek-Canonsburg Lake    -19.596235  13.557996  -1.445   0.1526
dat$WatershedLittle Racoon Creek                        -0.433923  23.858251  -0.018   0.9855
dat$WatershedLittle Tenmile Creek                        9.956382  14.719622   0.676   0.5009
dat$WatershedMingo Creek-Monongahela River             -12.046090  18.105870  -0.665   0.5079
dat$WatershedNorth Fork Cross Creek                    -11.545300  10.449109  -1.105   0.2728
dat$WatershedPigeon Creek                                3.077322  15.292451   0.201   0.8411
dat$WatershedPike Run                                   -5.769737  14.703896  -0.392   0.6959
dat$WatershedPlum Run-Tenmile Creek                     -8.859306  13.094663  -0.677   0.5008
dat$WatershedShort Creek-Tenmile Creek                  -8.392096   9.620596  -0.872   0.3859
dat$WatershedSouth Fork Cross Creek-Cross Creek          3.257930   8.476879   0.384   0.7018
dat$WatershedTempleton Fork                             -0.018681   9.683975  -0.002   0.9985
dat$WatershedUpper Chartiers Creek                       3.847585   9.665651   0.398   0.6917
dat$FormationCasselman Formation                         2.879914  18.132079   0.159   0.8742
dat$FormationGreene Formation                            3.520300   6.461676   0.545   0.5875
dat$FormationMonongahela Group                          -4.302133   7.596751  -0.566   0.5729
dat$FormationWaynesburg Formation                       -6.638291   5.641724  -1.177   0.2431
dat$HHWSourceMix                                        11.726161  18.130862   0.647   0.5198
dat$HHWSourceSpring                                     -6.686961   4.892051  -1.367   0.1758
dat$Precip_inchAvg                                       0.531595   1.306086   0.407   0.6852
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 268.1398)

    Null deviance: 26460  on 103  degrees of freedom
Residual deviance: 19842  on  74  degrees of freedom
  (41 observations deleted due to missingness)
AIC: 903.26

Number of Fisher Scoring iterations: 2
```

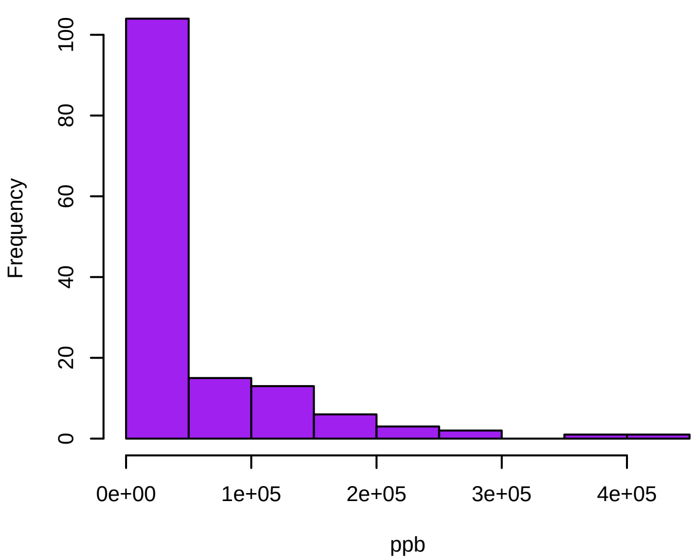
Sodium

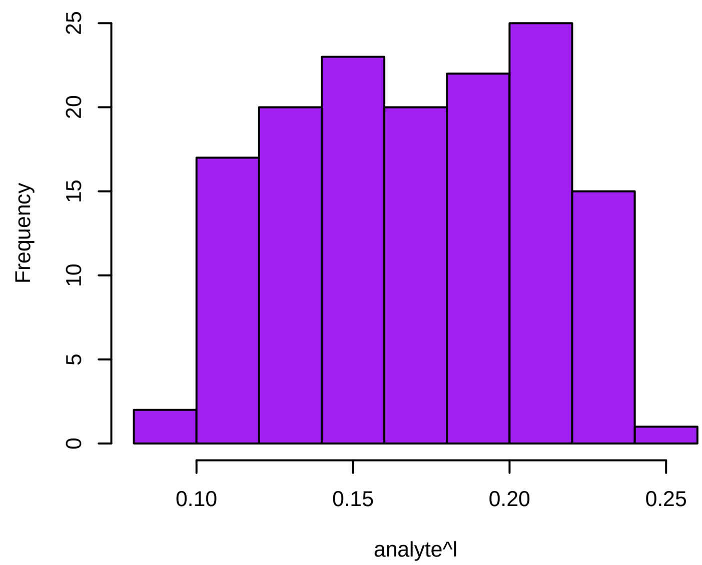
Skewness: 2.5386
Kurtosis: 10.9020

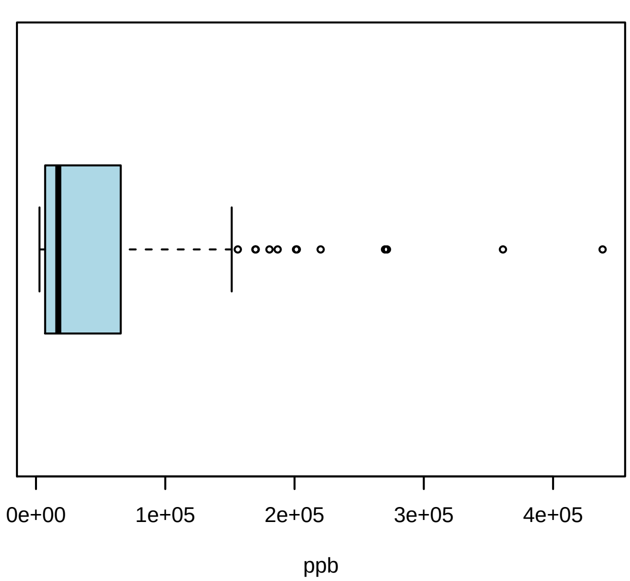
Sodium Box−Cox

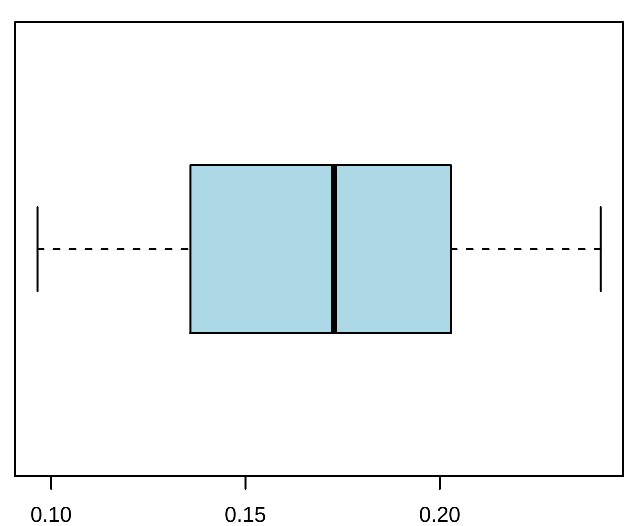
Skewness: −0.0572
Kurtosis: 1.8562

Optimal lambda: −0.18



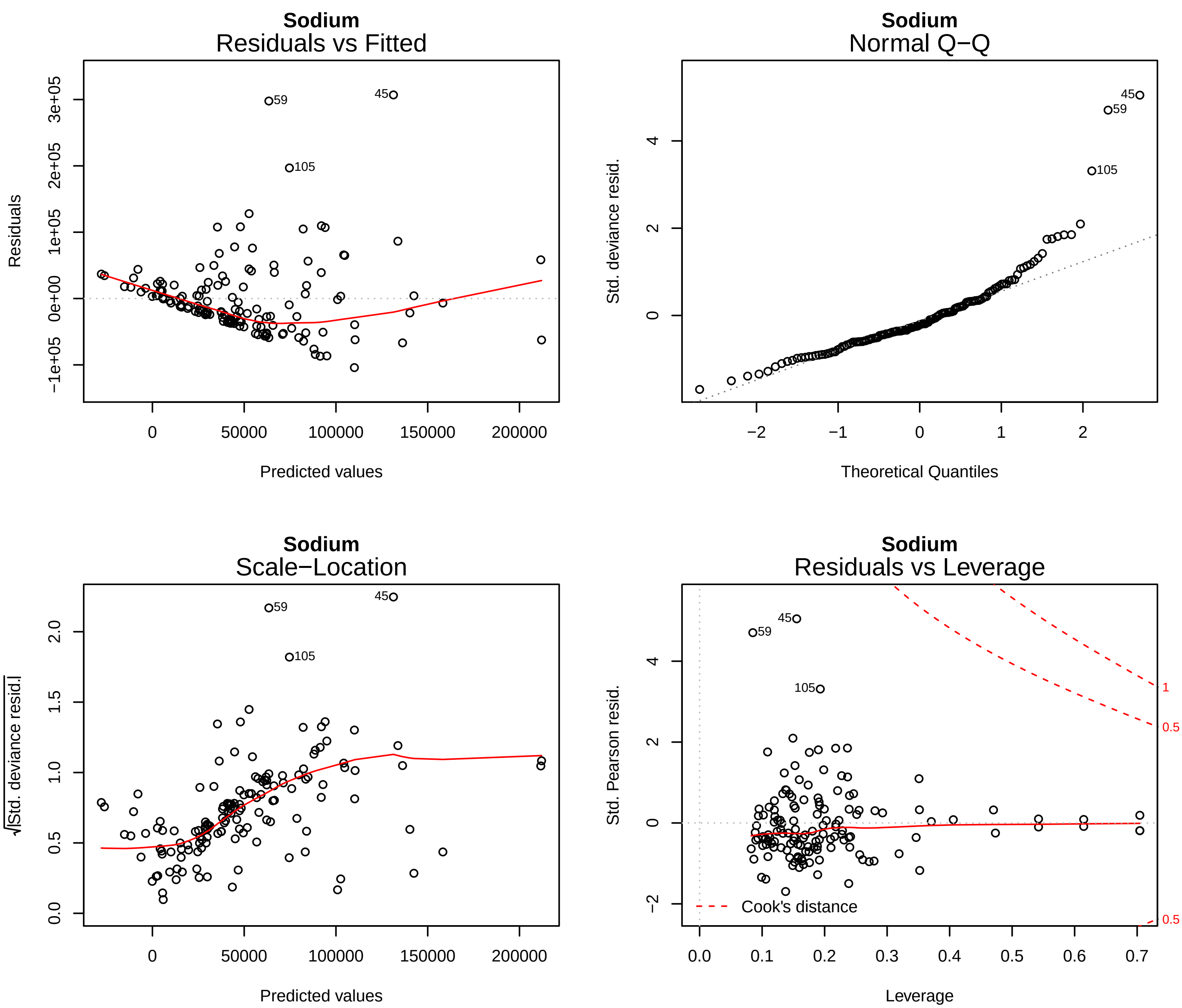






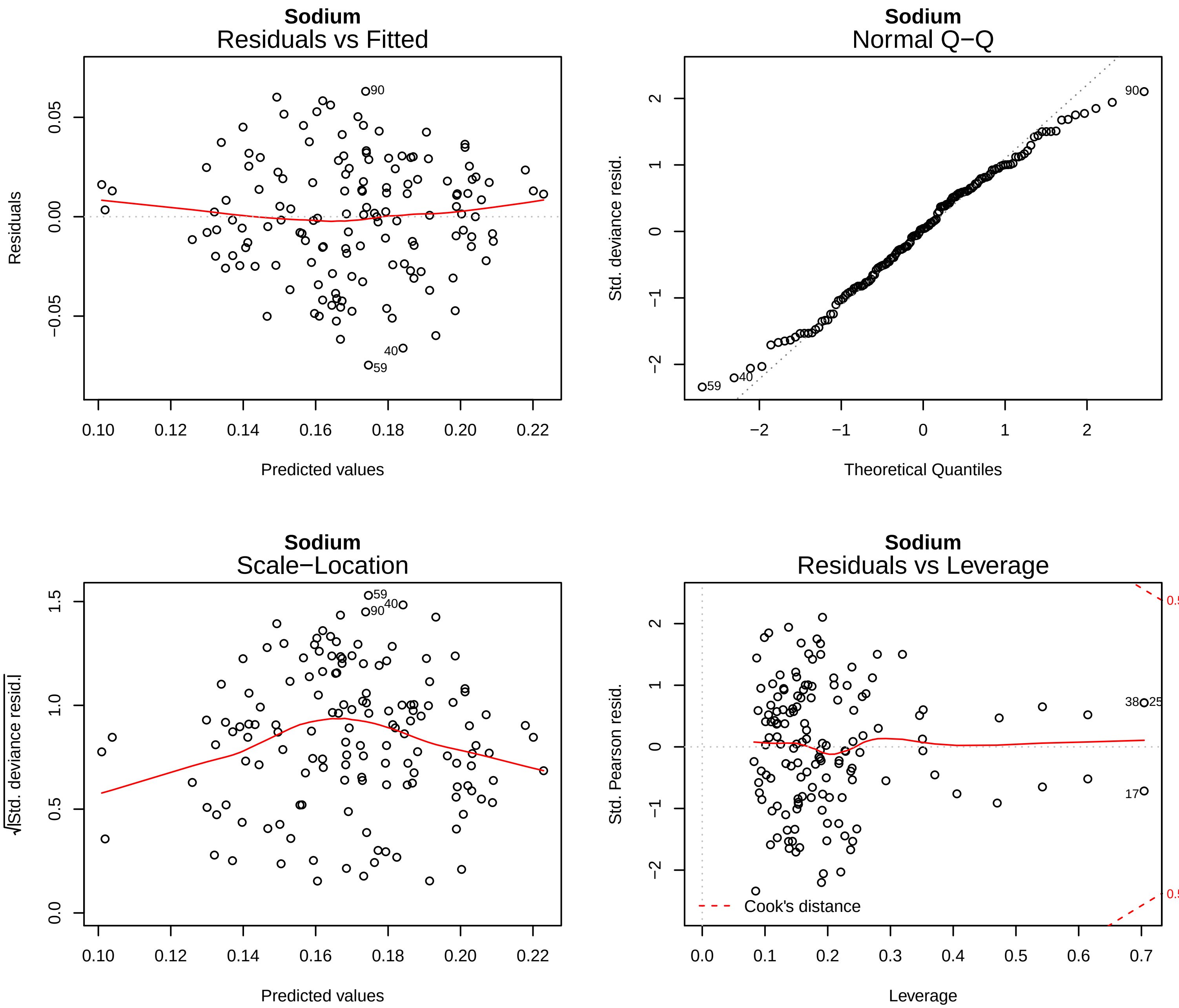
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

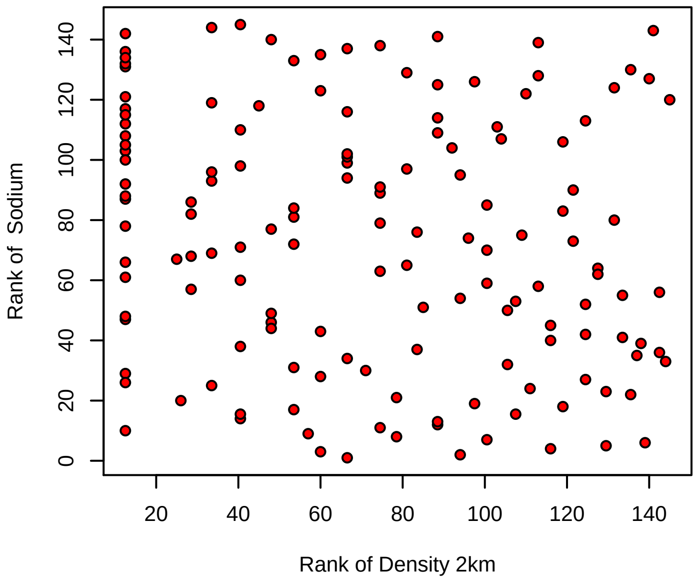
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



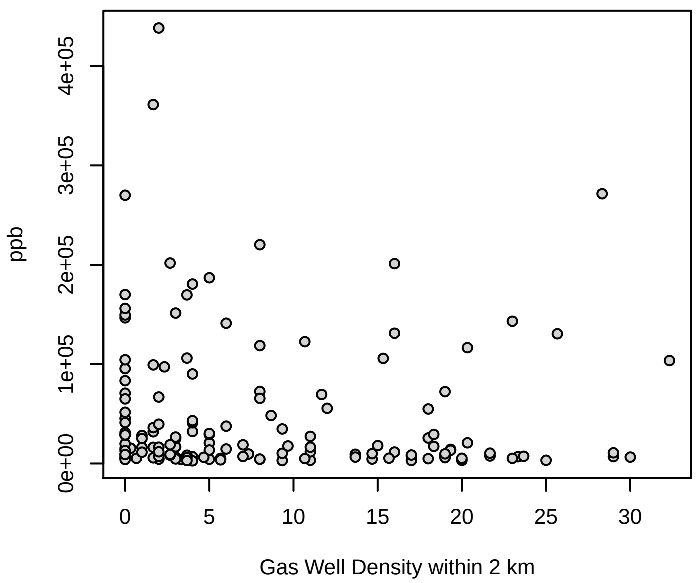


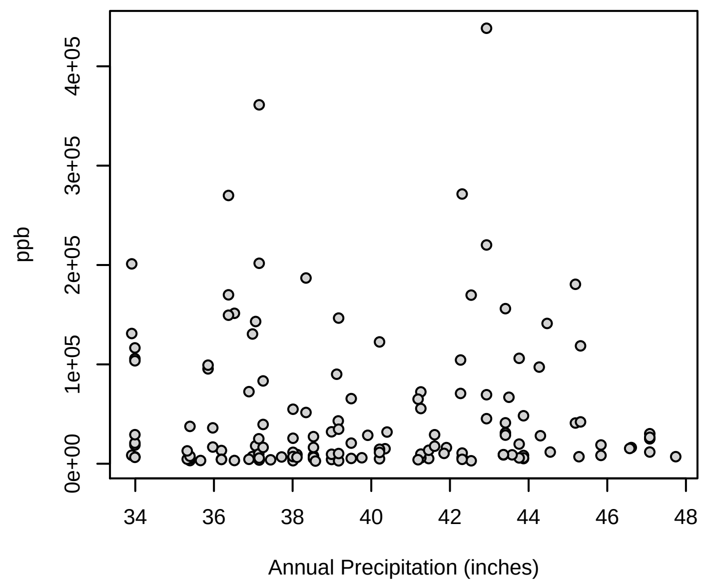
Sodium

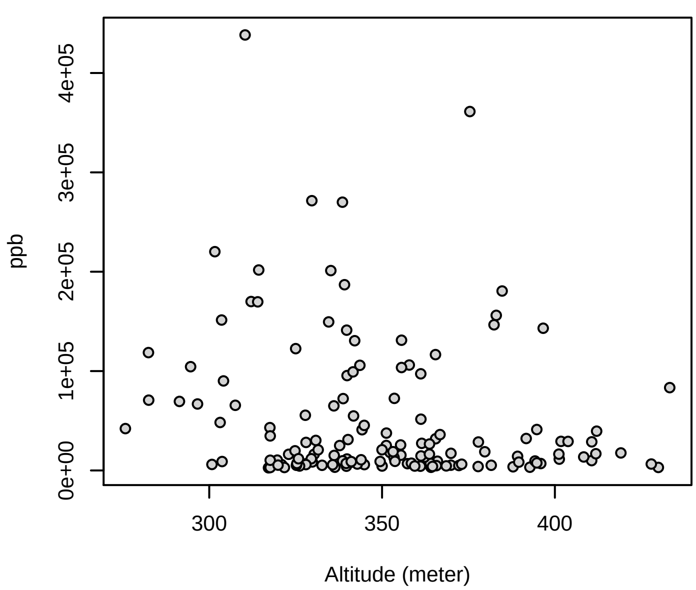
Kendalls Tau Rank Correlation

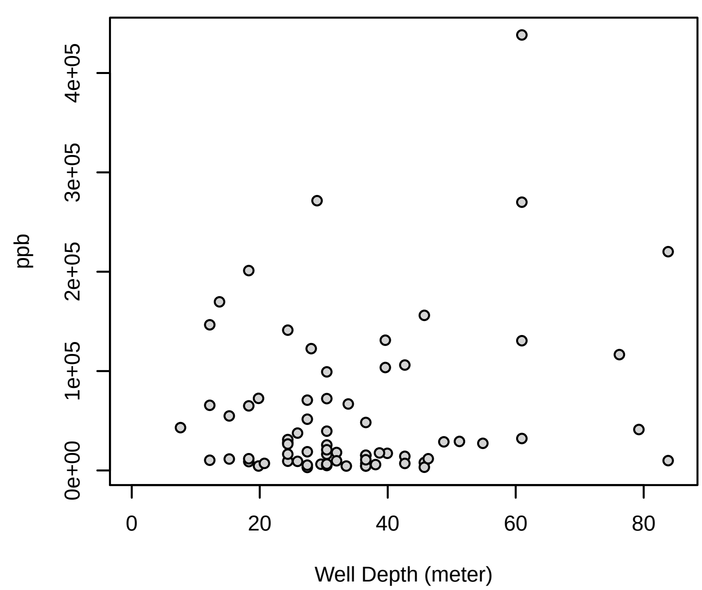
p−value: 0.0258

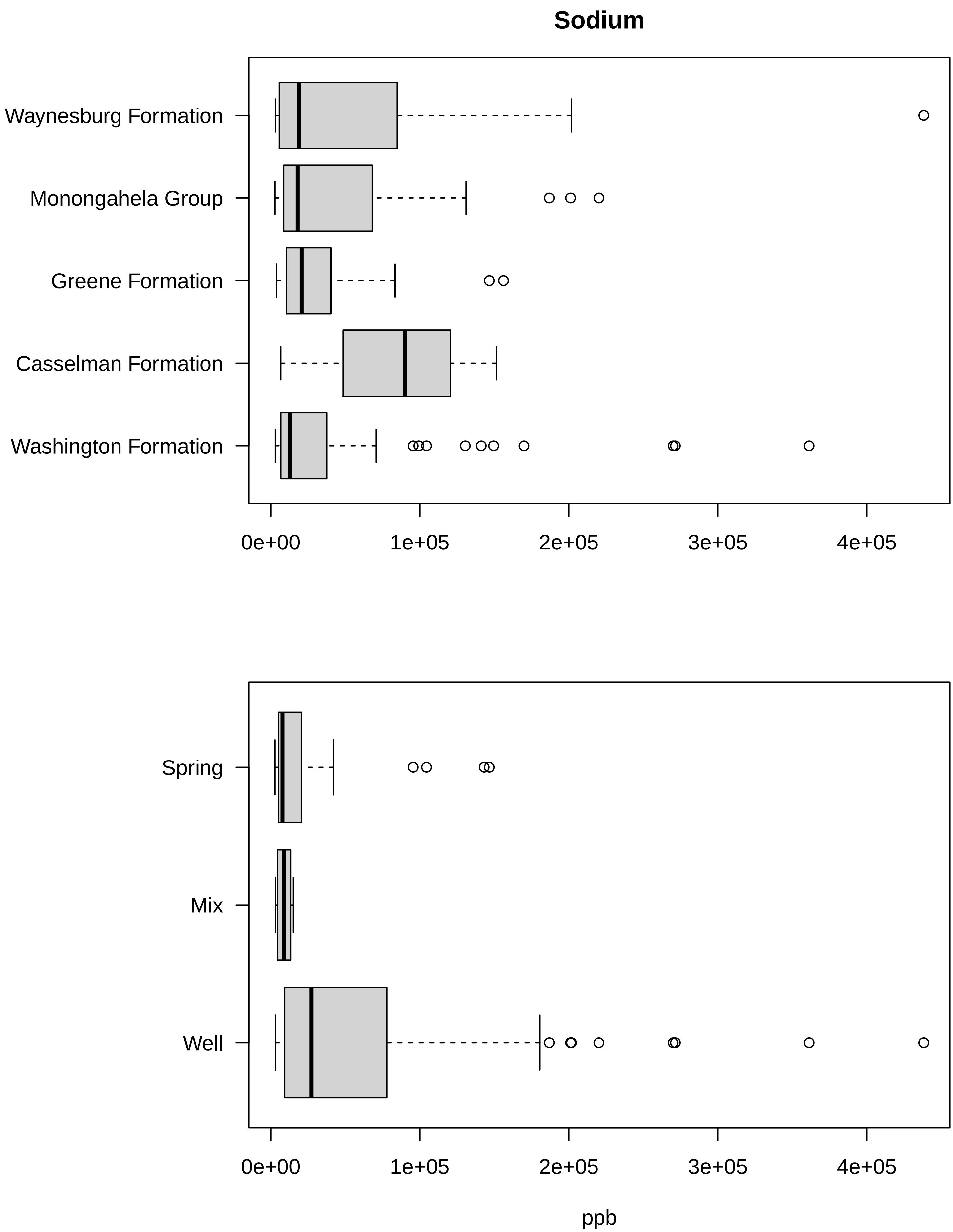
Tau: −0.127

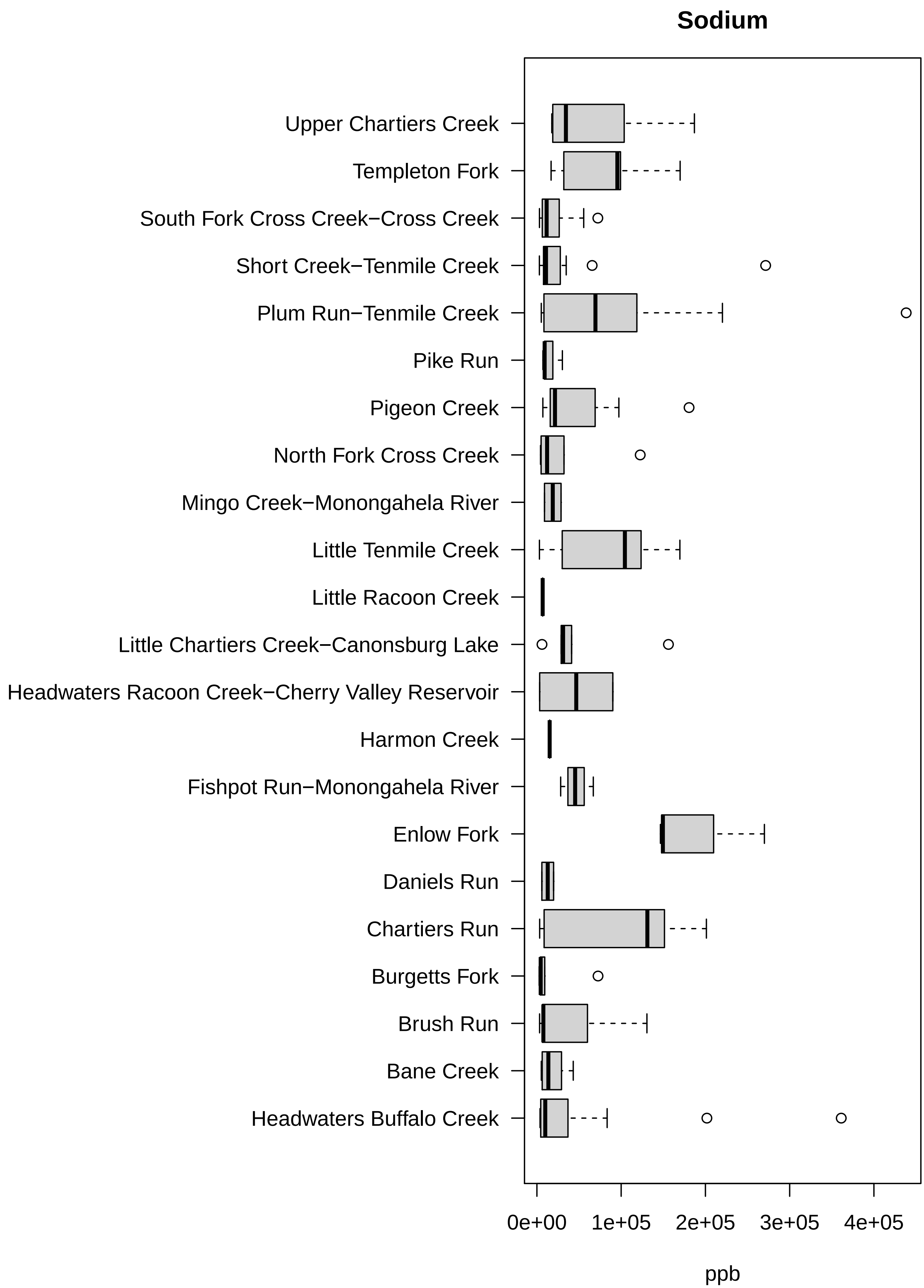









Sodium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0e+00
1e+05
2e+05
3e+05
4e+05
Spring
Mix
Well
0e+00
1e+05
2e+05
3e+05
4e+05
ppb



Sodium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0e+00
1e+05
2e+05
3e+05
4e+05
ppb

```
[1] "ORIGINAL MODEL - Sodium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-104121   -34533   -11985    19619   306982

Coefficients:
                                                        Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              30548.6   181928.8   0.168 0.866948
dat$GWellDensity_2kmAvg                                    401.8     1124.3   0.357 0.721476
dat$Altitude_meter                                        -102.8      308.6  -0.333 0.739628
dat$WatershedBane Creek                                 -21391.1    38554.0  -0.555 0.580093
dat$WatershedBrush Run                                  -21690.1    31685.3  -0.685 0.495019
dat$WatershedBurgetts Fork                              -62943.4    37070.2  -1.698 0.092246 .
dat$WatershedChartiers Run                                5872.5    43284.5   0.136 0.892321
dat$WatershedDaniels Run                                -39801.5    61426.6  -0.648 0.518319
dat$WatershedEnlow Fork                                 146534.3    41866.0   3.500 0.000665 ***
dat$WatershedFishpot Run-Monongahela River              -55318.1    50702.9  -1.091 0.277563
dat$WatershedHarmon Creek                               -25141.7    82862.5  -0.303 0.762126
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -74399.3    60354.2  -1.233 0.220220
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -2455.8    39050.3  -0.063 0.949966
dat$WatershedLittle Racoon Creek                        -99272.3    93355.9  -1.063 0.289859
dat$WatershedLittle Tenmile Creek                         1994.4    39937.7   0.050 0.960259
dat$WatershedMingo Creek-Monongahela River              -43585.2    53510.3  -0.815 0.417046
dat$WatershedNorth Fork Cross Creek                     -54364.0    35904.5  -1.514 0.132761
dat$WatershedPigeon Creek                               -48024.9    44958.1  -1.068 0.287681
dat$WatershedPike Run                                   -58678.9    43919.4  -1.336 0.184190
dat$WatershedPlum Run-Tenmile Creek                      28103.7    38948.7   0.722 0.472044
dat$WatershedShort Creek-Tenmile Creek                  -14056.7    32329.6  -0.435 0.664533
dat$WatershedSouth Fork Cross Creek-Cross Creek         -65744.5    28957.9  -2.270 0.025065 *
dat$WatershedTempleton Fork                              36431.7    34237.6   1.064 0.289539
dat$WatershedUpper Chartiers Creek                       -9724.1    29554.0  -0.329 0.742737
dat$FormationCasselman Formation                         82213.4    67397.7   1.220 0.225049
dat$FormationGreene Formation                           -23527.4    22890.4  -1.028 0.306205
dat$FormationMonongahela Group                           21059.3    23960.3   0.879 0.381291
dat$FormationWaynesburg Formation                        21933.5    18543.5   1.183 0.239344
dat$HHWSourceMix                                        -53695.5    44762.5  -1.200 0.232795
dat$HHWSourceSpring                                     -46441.1    14666.3  -3.167 0.001979 **
dat$Precip_inchAvg                                        1906.3     3753.5   0.508 0.612524
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 4377702251)

    Null deviance: 7.3697e+11  on 144  degrees of freedom
Residual deviance: 4.9906e+11  on 114  degrees of freedom
AIC: 3659.6

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Sodium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-0.074659  -0.019884   0.000996   0.021313   0.063072

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  0.0963886  0.0917241   1.051  0.29555
dat$GWellDensity_2kmAvg                                     -0.0001829  0.0005669  -0.323  0.74762
dat$Altitude_meter                                           0.0002341  0.0001556   1.504  0.13526
dat$WatershedBane Creek                                      0.0090644  0.0194380   0.466  0.64187
dat$WatershedBrush Run                                      -0.0004961  0.0159750  -0.031  0.97528
dat$WatershedBurgetts Fork                                   0.0322584  0.0186899   1.726  0.08706 .
dat$WatershedChartiers Run                                   0.0037759  0.0218230   0.173  0.86294
dat$WatershedDaniels Run                                    -0.0159205  0.0309698  -0.514  0.60820
dat$WatershedEnlow Fork                                     -0.0645771  0.0211078  -3.059  0.00277 **
dat$WatershedFishpot Run-Monongahela River                  -0.0099839  0.0255631  -0.391  0.69685
dat$WatershedHarmon Creek                                   -0.0340754  0.0417772  -0.816  0.41640
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.0419052  0.0304291   1.377  0.17117
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         -0.0149161  0.0196882  -0.758  0.45024
dat$WatershedLittle Racoon Creek                             0.0658372  0.0470678   1.399  0.16460
dat$WatershedLittle Tenmile Creek                           -0.0203139  0.0201356  -1.009  0.31518
dat$WatershedMingo Creek-Monongahela River                  -0.0024039  0.0269786  -0.089  0.92916
dat$WatershedNorth Fork Cross Creek                          0.0139786  0.0181022   0.772  0.44159
dat$WatershedPigeon Creek                                   -0.0094808  0.0226668  -0.418  0.67654
dat$WatershedPike Run                                        0.0006144  0.0221431   0.028  0.97791
dat$WatershedPlum Run-Tenmile Creek                         -0.0121268  0.0196370  -0.618  0.53811
dat$WatershedShort Creek-Tenmile Creek                       0.0091537  0.0162998   0.562  0.57550
dat$WatershedSouth Fork Cross Creek-Cross Creek              0.0169329  0.0145999   1.160  0.24855
dat$WatershedTempleton Fork                                 -0.0343171  0.0172618  -1.988  0.04920 *
dat$WatershedUpper Chartiers Creek                          -0.0253610  0.0149004  -1.702  0.09147 .
dat$FormationCasselman Formation                            -0.0576028  0.0339803  -1.695  0.09277 .
dat$FormationGreene Formation                               -0.0072512  0.0115408  -0.628  0.53106
dat$FormationMonongahela Group                              -0.0074408  0.0120802  -0.616  0.53915
dat$FormationWaynesburg Formation                            0.0008983  0.0093492   0.096  0.92363
dat$HHWSourceMix                                             0.0534977  0.0225681   2.370  0.01944 *
dat$HHWSourceSpring                                          0.0329333  0.0073944   4.454 1.98e-05 ***
dat$Precip_inchAvg                                          -0.0002525  0.0018924  -0.133  0.89408
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.001112781)

    Null deviance: 0.20975  on 144  degrees of freedom
Residual deviance: 0.12686  on 114  degrees of freedom
AIC: -545.51

Number of Fisher Scoring iterations: 2
```

Strontium

Skewness: 1.7176

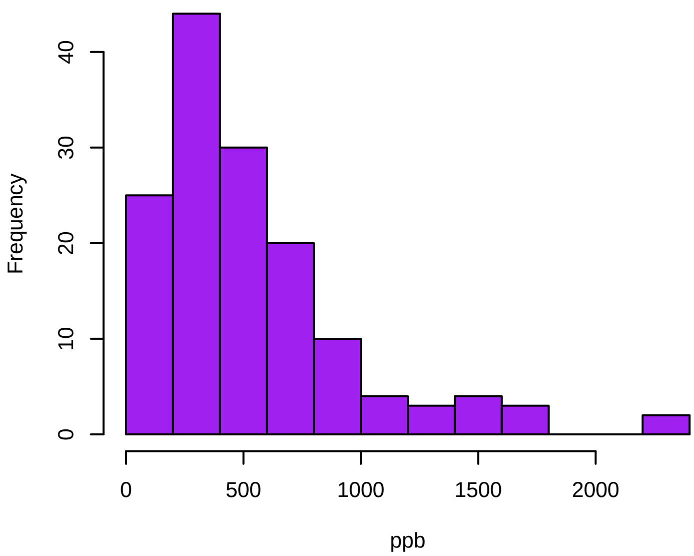
Kurtosis: 6.5263

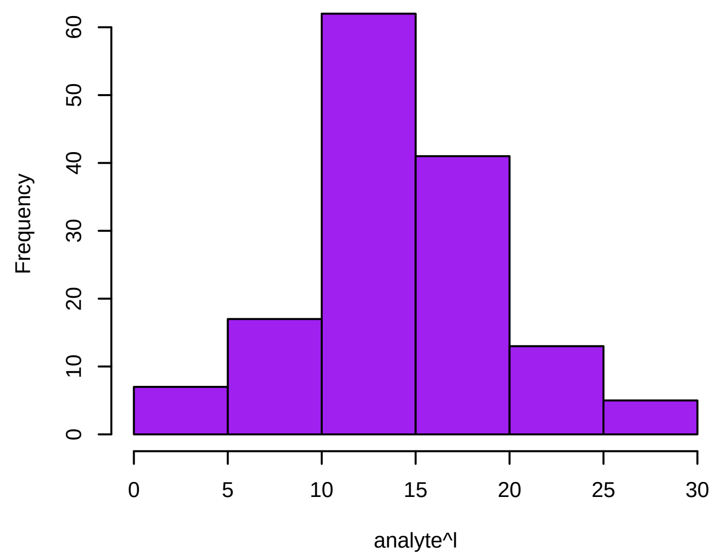
Strontium Box−Cox

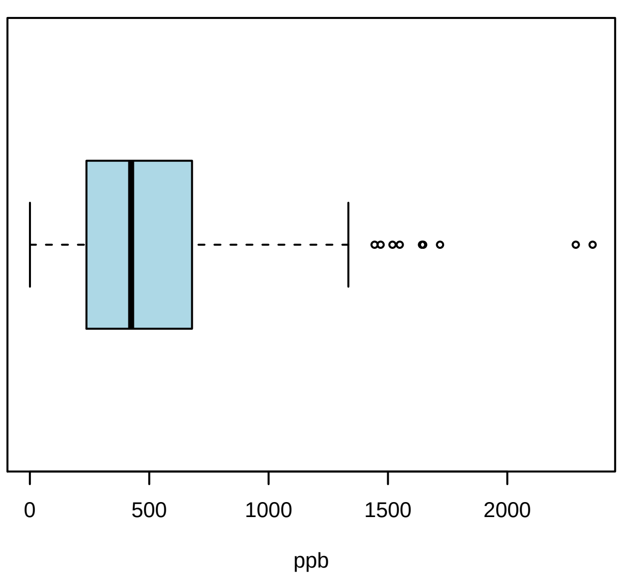
Skewness: 0.1050

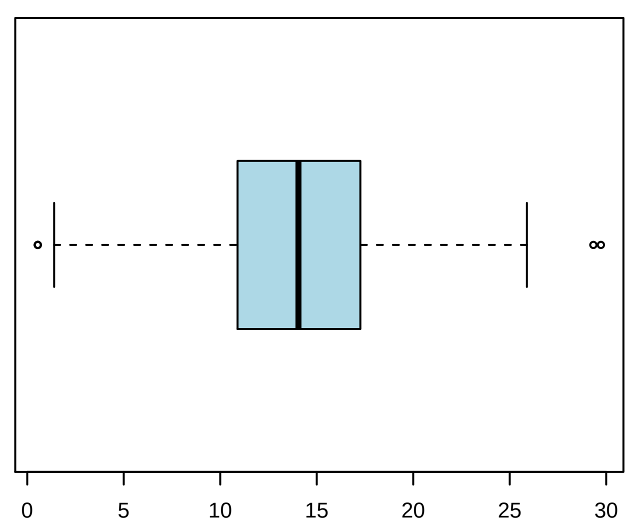
Kurtosis: 3.6536

Optimal lambda: 0.4368



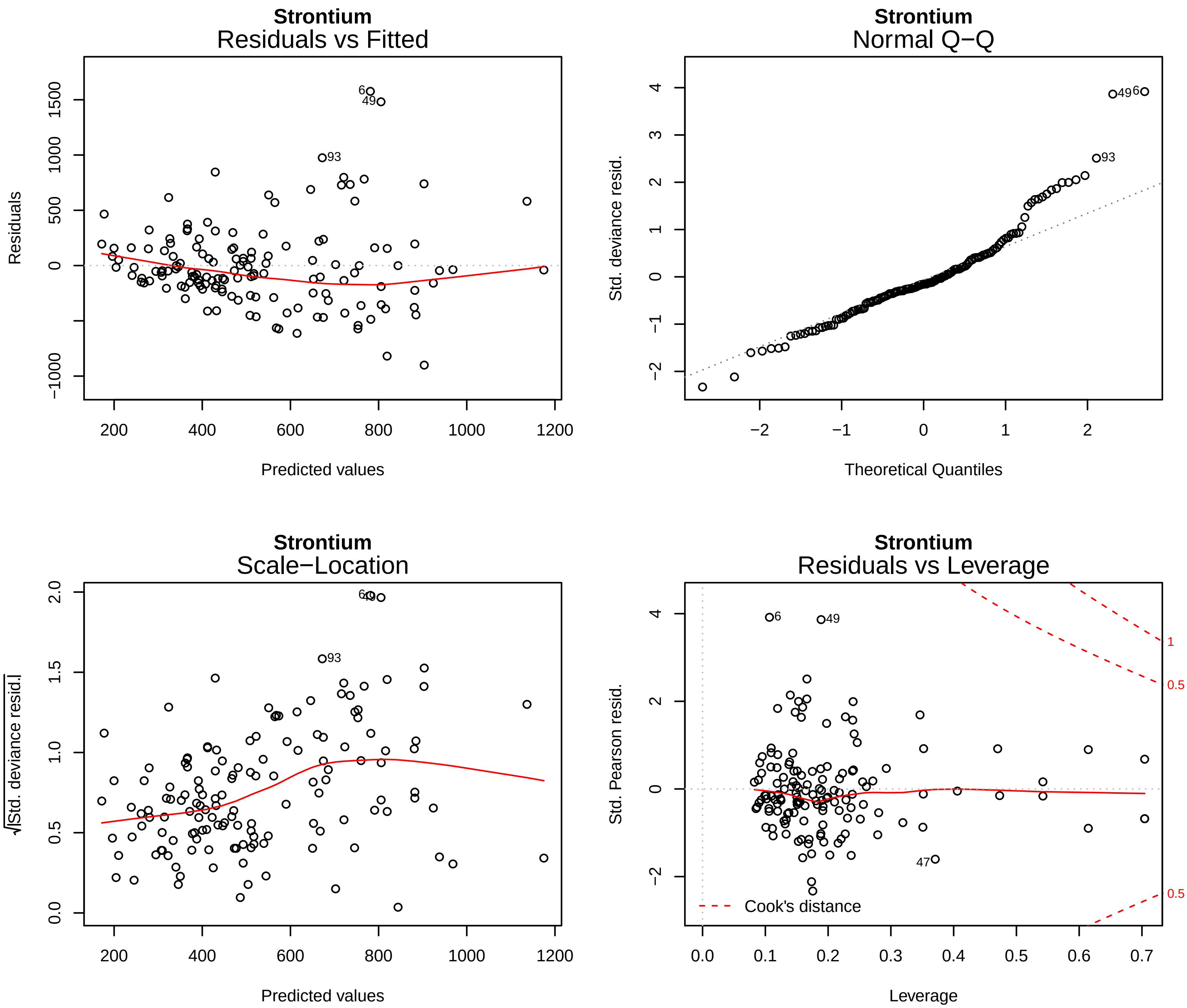






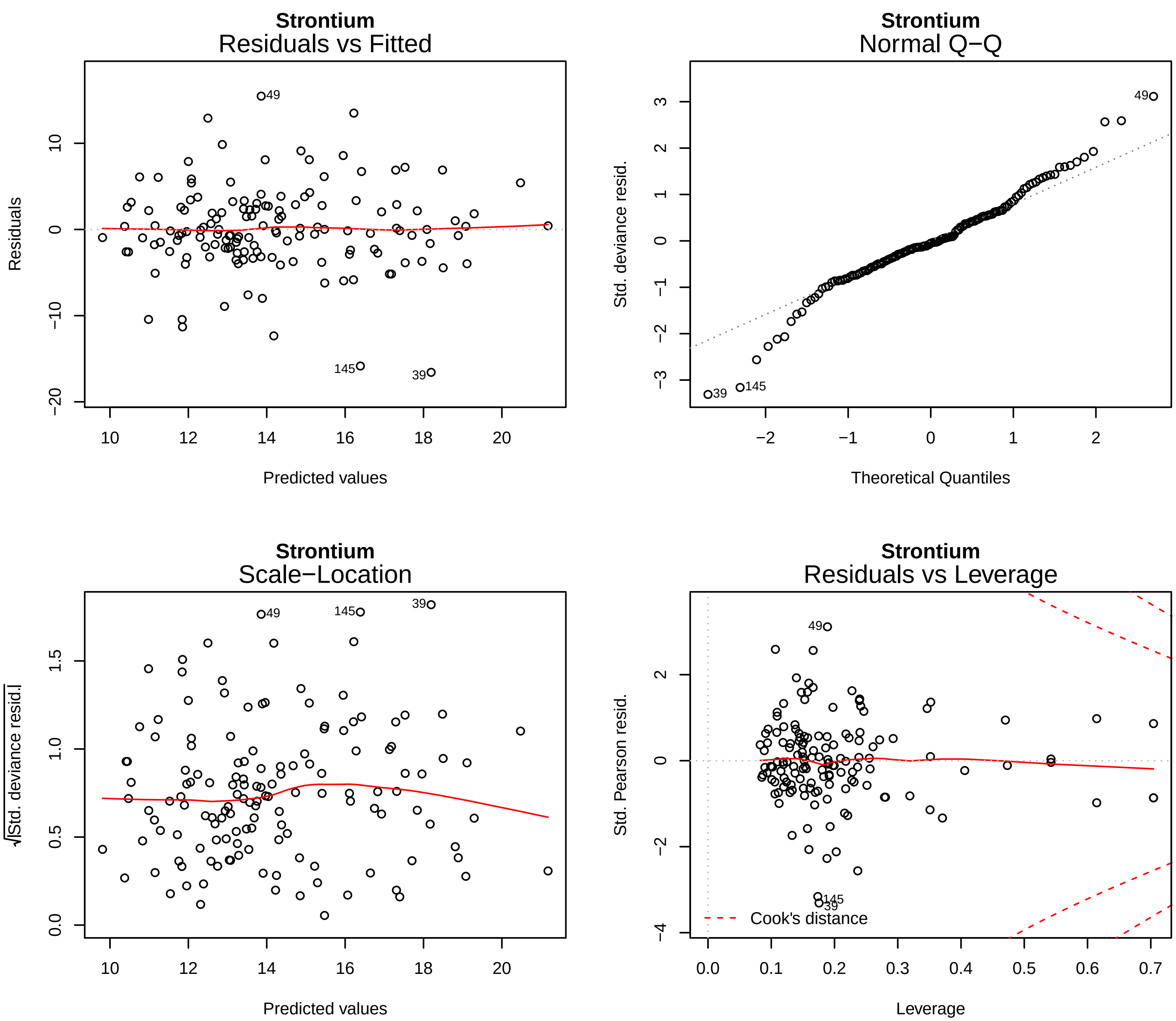
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

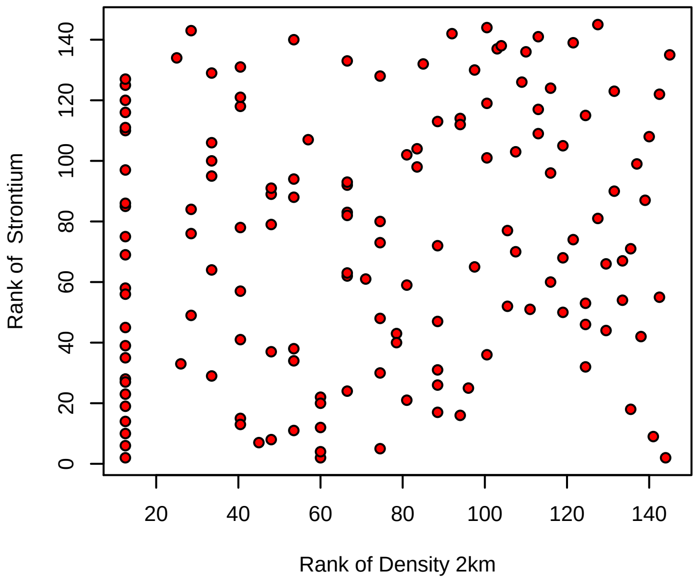
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



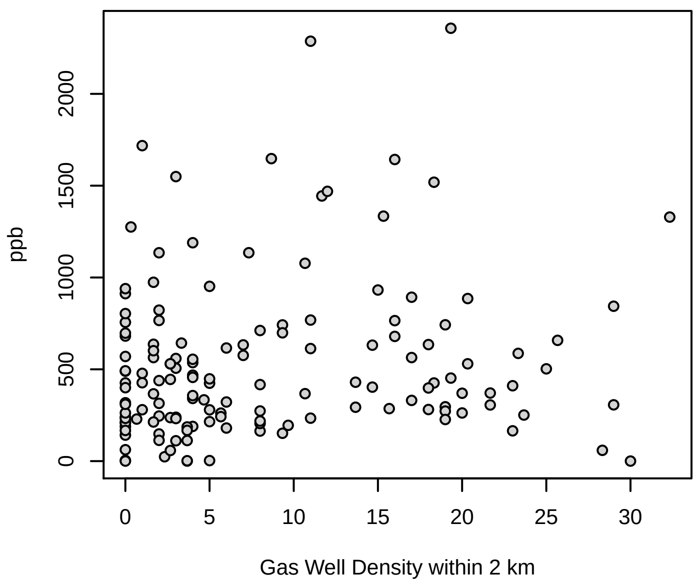


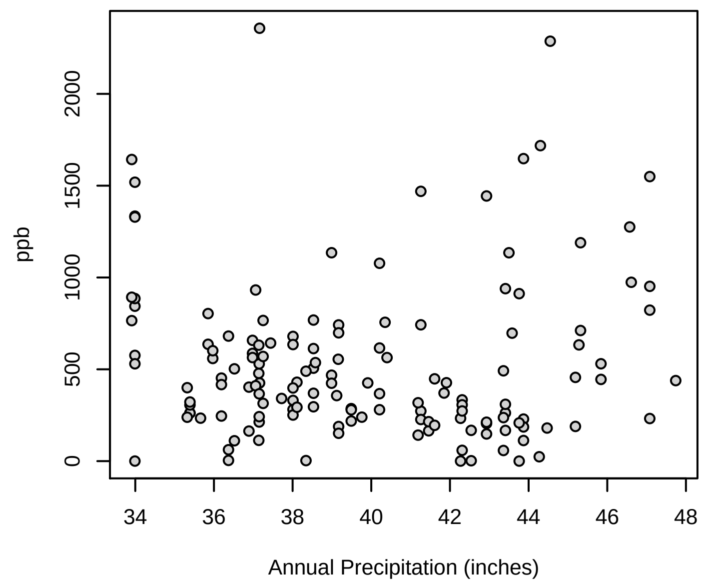
Strontium

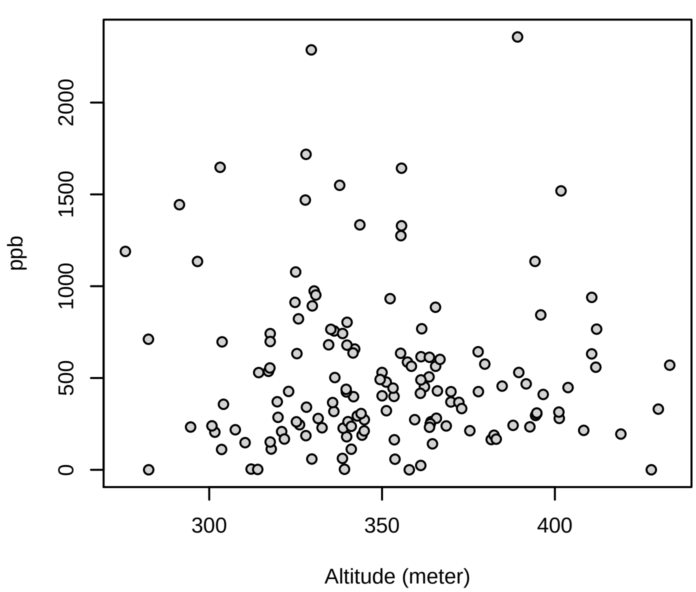
Kendalls Tau Rank Correlation

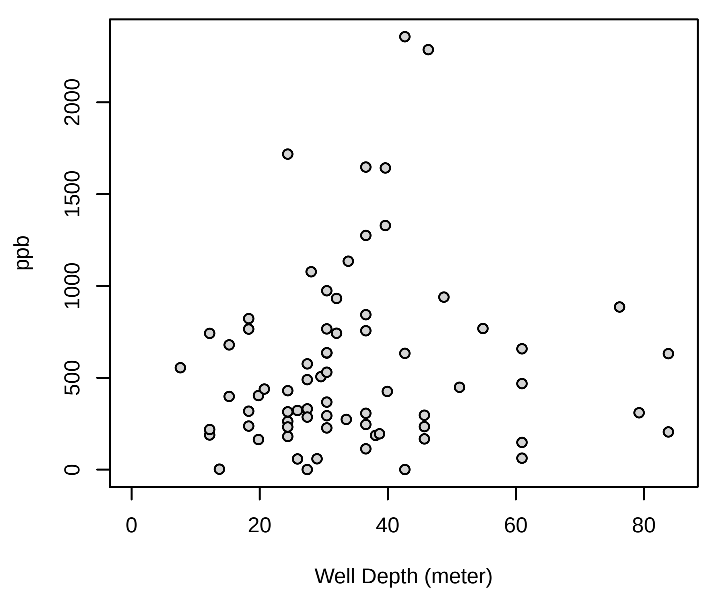
p−value: 0.0651

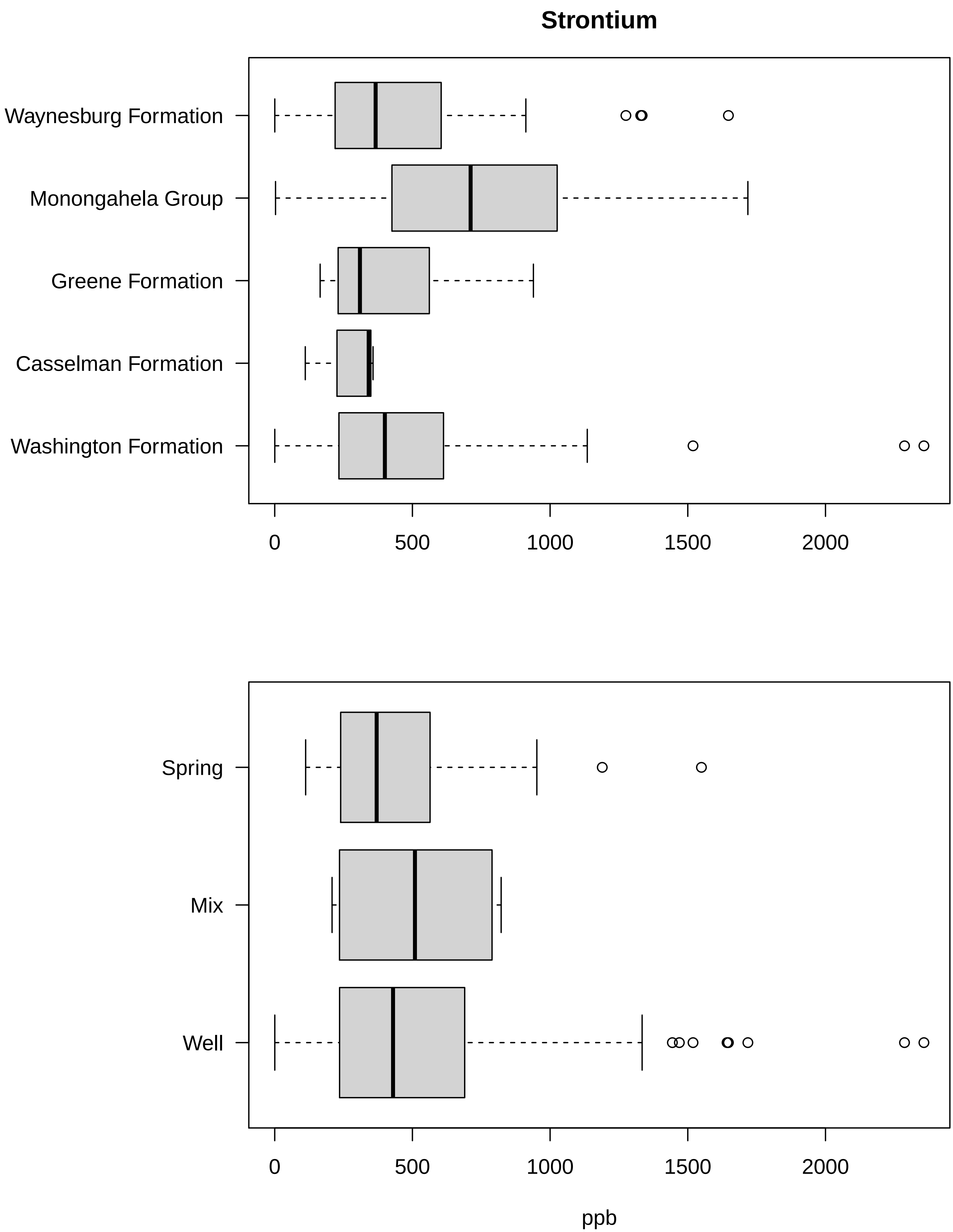
Tau: 0.105



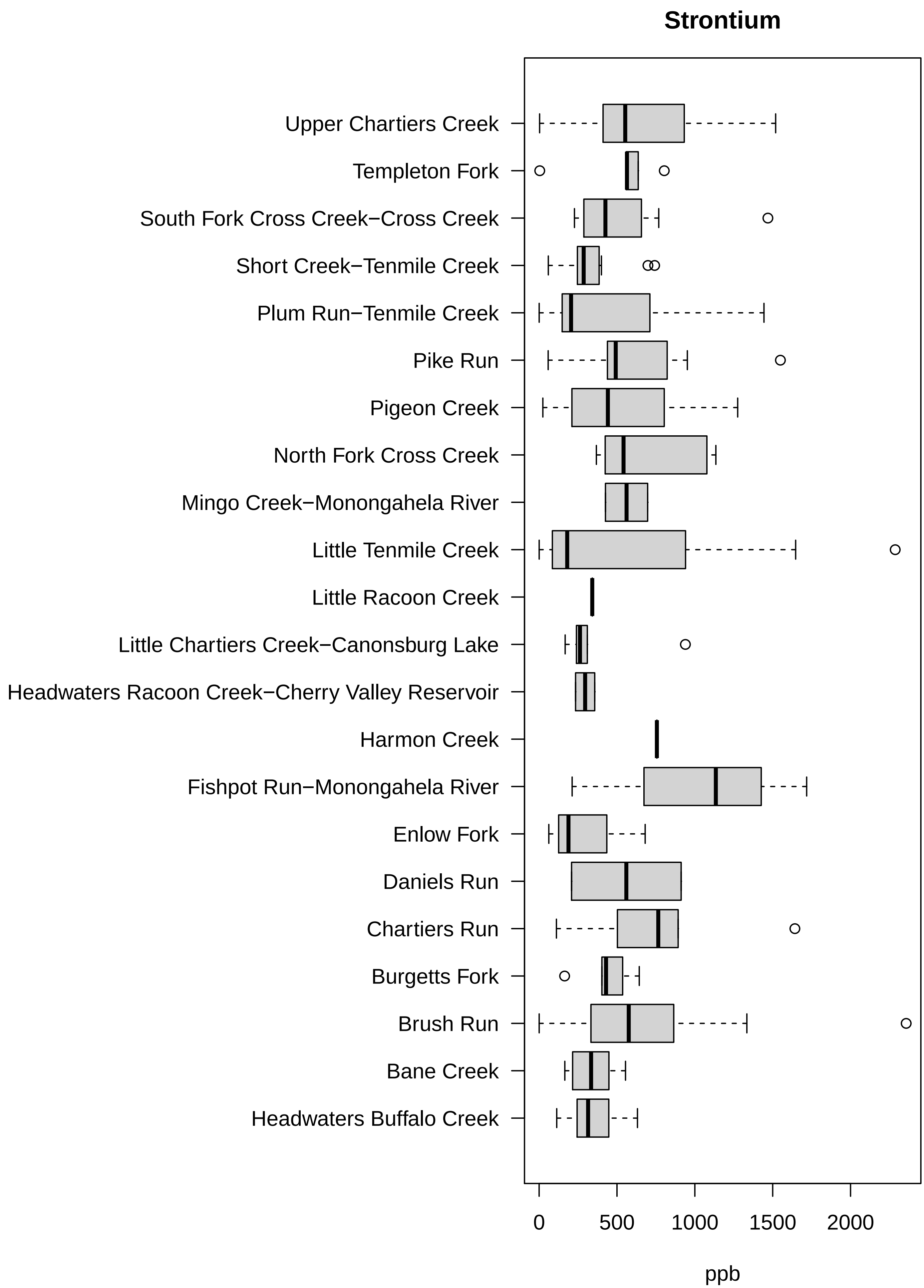








Strontium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
500
1000
1500
2000
Spring
Mix
Well
0
500
1000
1500
2000
ppb



Strontium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
500
1000
1500
2000
ppb

```
[1] "ORIGINAL MODEL - Strontium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-900.48  -202.73   -52.48   157.19  1576.17

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                    647.507   1170.500   0.553    0.581
dat$GWellDensity_2kmAvg                                          8.306      7.234   1.148    0.253
dat$Altitude_meter                                              -1.037      1.985  -0.522    0.602
dat$WatershedBane Creek                                        -98.788    248.050  -0.398    0.691
dat$WatershedBrush Run                                         253.526    203.858   1.244    0.216
dat$WatershedBurgetts Fork                                     -91.189    238.504  -0.382    0.703
dat$WatershedChartiers Run                                     165.020    278.485   0.593    0.555
dat$WatershedDaniels Run                                       483.354    395.209   1.223    0.224
dat$WatershedEnlow Fork                                        -55.532    269.359  -0.206    0.837
dat$WatershedFishpot Run-Monongahela River                     460.145    326.214   1.411    0.161
dat$WatershedHarmon Creek                                      468.251    533.124   0.878    0.382
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir    80.279    388.309   0.207    0.837
dat$WatershedLittle Chartiers Creek-Canonsburg Lake            -46.531    251.243  -0.185    0.853
dat$WatershedLittle Racoon Creek                               376.783    600.637   0.627    0.532
dat$WatershedLittle Tenmile Creek                              260.492    256.952   1.014    0.313
dat$WatershedMingo Creek-Monongahela River                      84.764    344.277   0.246    0.806
dat$WatershedNorth Fork Cross Creek                            135.791    231.004   0.588    0.558
dat$WatershedPigeon Creek                                      132.223    289.253   0.457    0.648
dat$WatershedPike Run                                          200.534    282.570   0.710    0.479
dat$WatershedPlum Run-Tenmile Creek                            -82.816    250.590  -0.330    0.742
dat$WatershedShort Creek-Tenmile Creek                        -159.110    208.003  -0.765    0.446
dat$WatershedSouth Fork Cross Creek-Cross Creek                -22.482    186.311  -0.121    0.904
dat$WatershedTempleton Fork                                    123.546    220.279   0.561    0.576
dat$WatershedUpper Chartiers Creek                             225.106    190.145   1.184    0.239
dat$FormationCasselman Formation                              -375.583    433.626  -0.866    0.388
dat$FormationGreene Formation                                    4.661    147.273   0.032    0.975
dat$FormationMonongahela Group                                 213.852    154.157   1.387    0.168
dat$FormationWaynesburg Formation                             -138.938    119.306  -1.165    0.247
dat$HHWSourceMix                                              -358.745    287.994  -1.246    0.215
dat$HHWSourceSpring                                           -125.523     94.360  -1.330    0.186
dat$Precip_inchAvg                                               3.318     24.150   0.137    0.891

(Dispersion parameter for gaussian family taken to be 181211.7)

    Null deviance: 26915326  on 144  degrees of freedom
Residual deviance: 20658132  on 114  degrees of freedom
AIC: 2196.2

Number of Fisher Scoring iterations: 2

[1] "BOX-COX MODEL - Strontium"
```

```
Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-16.5787   -2.5893   -0.1643    2.5893   15.4745  

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                 19.537988  15.168101   1.288    0.200
dat$GWellDensity_2kmAvg                                      0.087911   0.093741   0.938    0.350
dat$Altitude_meter                                          -0.019659   0.025729  -0.764    0.446
dat$WatershedBane Creek                                     -1.463146   3.214391  -0.455    0.650
dat$WatershedBrush Run                                       2.506256   2.641726   0.949    0.345
dat$WatershedBurgetts Fork                                  -0.108291   3.090688  -0.035    0.972
dat$WatershedChartiers Run                                   2.244438   3.608795   0.622    0.535
dat$WatershedDaniels Run                                     5.200480   5.121372   1.015    0.312
dat$WatershedEnlow Fork                                     -1.857777   3.490525  -0.532    0.596
dat$WatershedFishpot Run-Monongahela River                   4.974197   4.227292   1.177    0.242
dat$WatershedHarmon Creek                                    6.110855   6.908560   0.885    0.378
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  2.188291   5.031964   0.435    0.664
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         -0.704101   3.255768  -0.216    0.829
dat$WatershedLittle Racoon Creek                             5.555152   7.783438   0.714    0.477
dat$WatershedLittle Tenmile Creek                           -0.324387   3.329757  -0.097    0.923
dat$WatershedMingo Creek-Monongahela River                   1.976040   4.461362   0.443    0.659
dat$WatershedNorth Fork Cross Creek                          2.896533   2.993496   0.968    0.335
dat$WatershedPigeon Creek                                    1.794769   3.748331   0.479    0.633
dat$WatershedPike Run                                        2.588273   3.661726   0.707    0.481
dat$WatershedPlum Run-Tenmile Creek                         -2.281512   3.247303  -0.703    0.484
dat$WatershedShort Creek-Tenmile Creek                      -2.173129   2.695440  -0.806    0.422
dat$WatershedSouth Fork Cross Creek-Cross Creek              0.829143   2.414333   0.343    0.732
dat$WatershedTempleton Fork                                  0.650771   2.854520   0.228    0.820
dat$WatershedUpper Chartiers Creek                           2.581337   2.464028   1.048    0.297
dat$FormationCasselman Formation                            -5.792935   5.619207  -1.031    0.305
dat$FormationGreene Formation                                1.086991   1.908457   0.570    0.570
dat$FormationMonongahela Group                               2.168481   1.997660   1.086    0.280
dat$FormationWaynesburg Formation                           -1.670793   1.546045  -1.081    0.282
dat$HHWSourceMix                                            -3.262052   3.732018  -0.874    0.384
dat$HHWSourceSpring                                         -0.555019   1.222782  -0.454    0.651
dat$Precip_inchAvg                                           0.003502   0.312947   0.011    0.991

(Dispersion parameter for gaussian family taken to be 30.43025)

    Null deviance: 4288  on 144  degrees of freedom
Residual deviance: 3469  on 114  degrees of freedom
AIC: 935.85

Number of Fisher Scoring iterations: 2
```

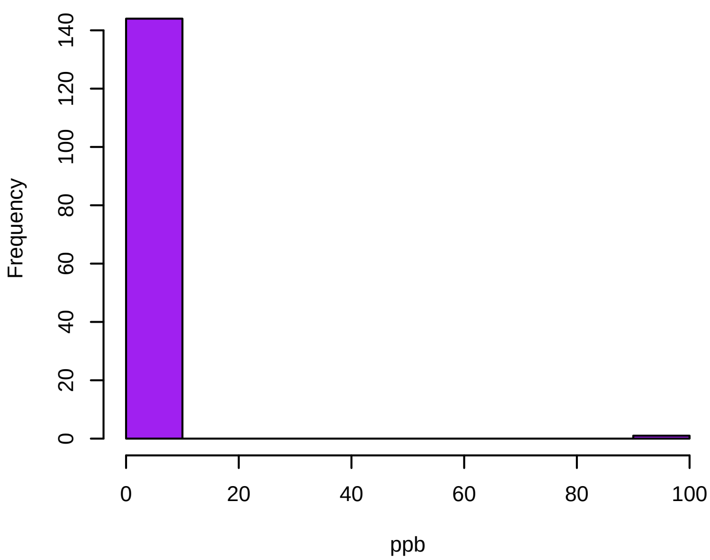
Tin

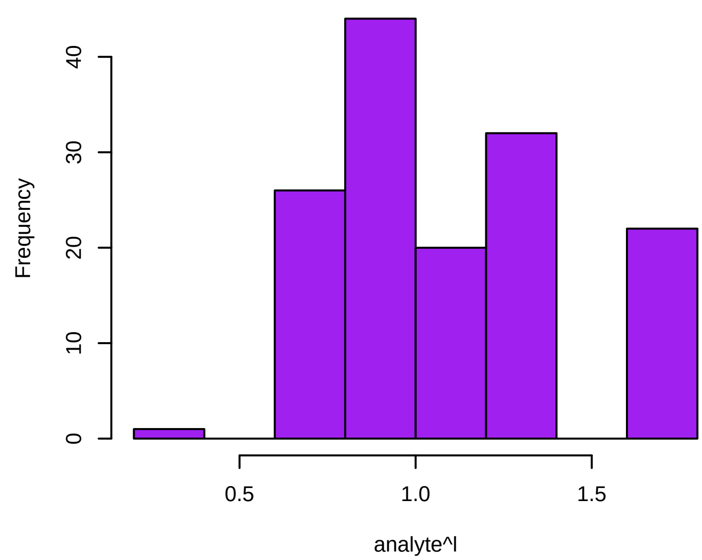
Skewness: 11.7811
Kurtosis: 140.8626

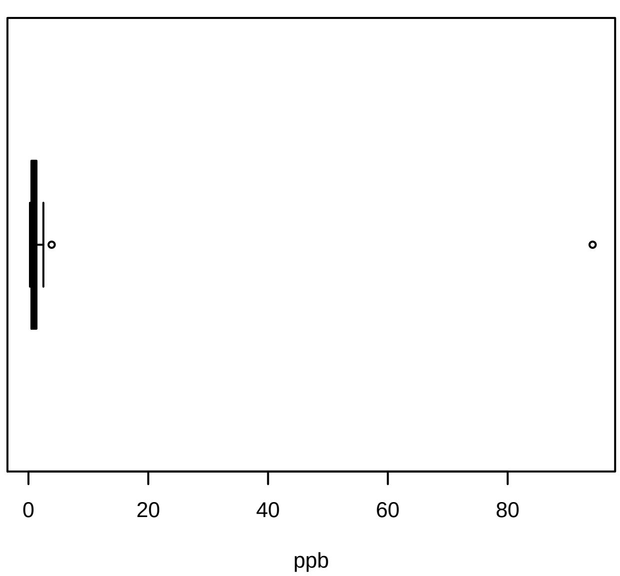
Tin Box−Cox

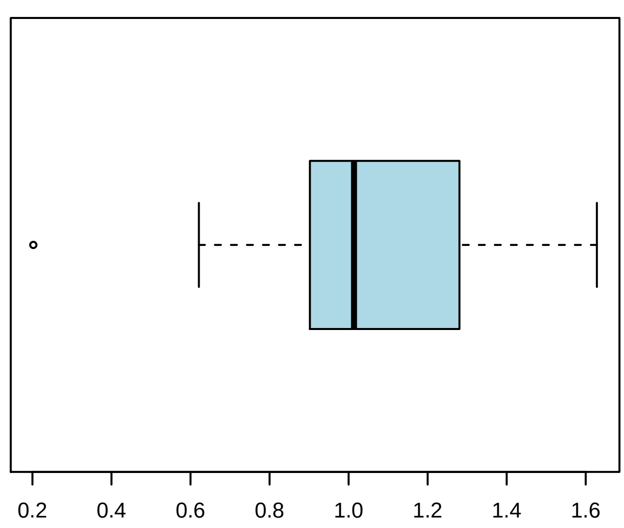
Skewness: 0.3719
Kurtosis: 2.6278

Optimal lambda: −0.3516



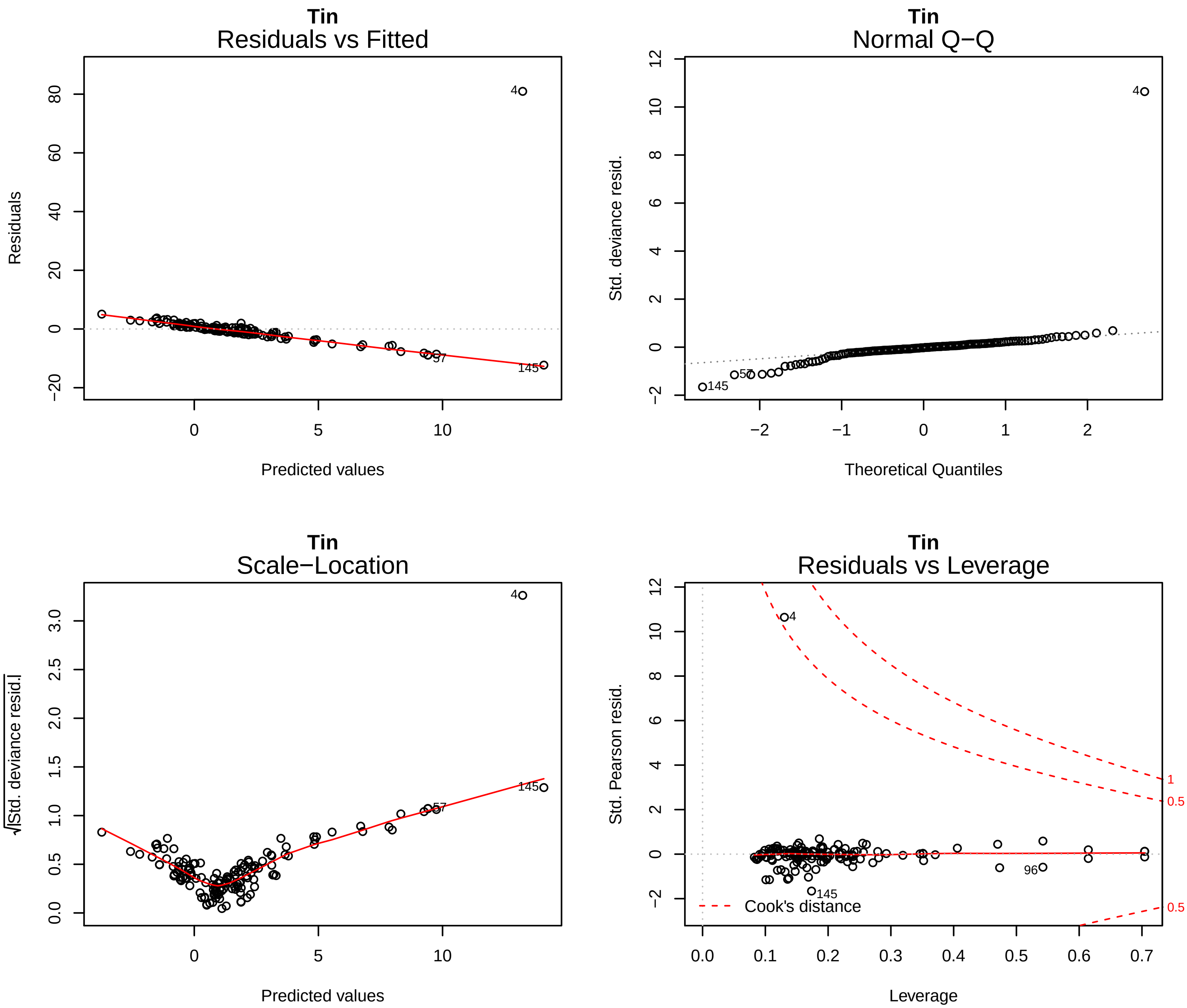






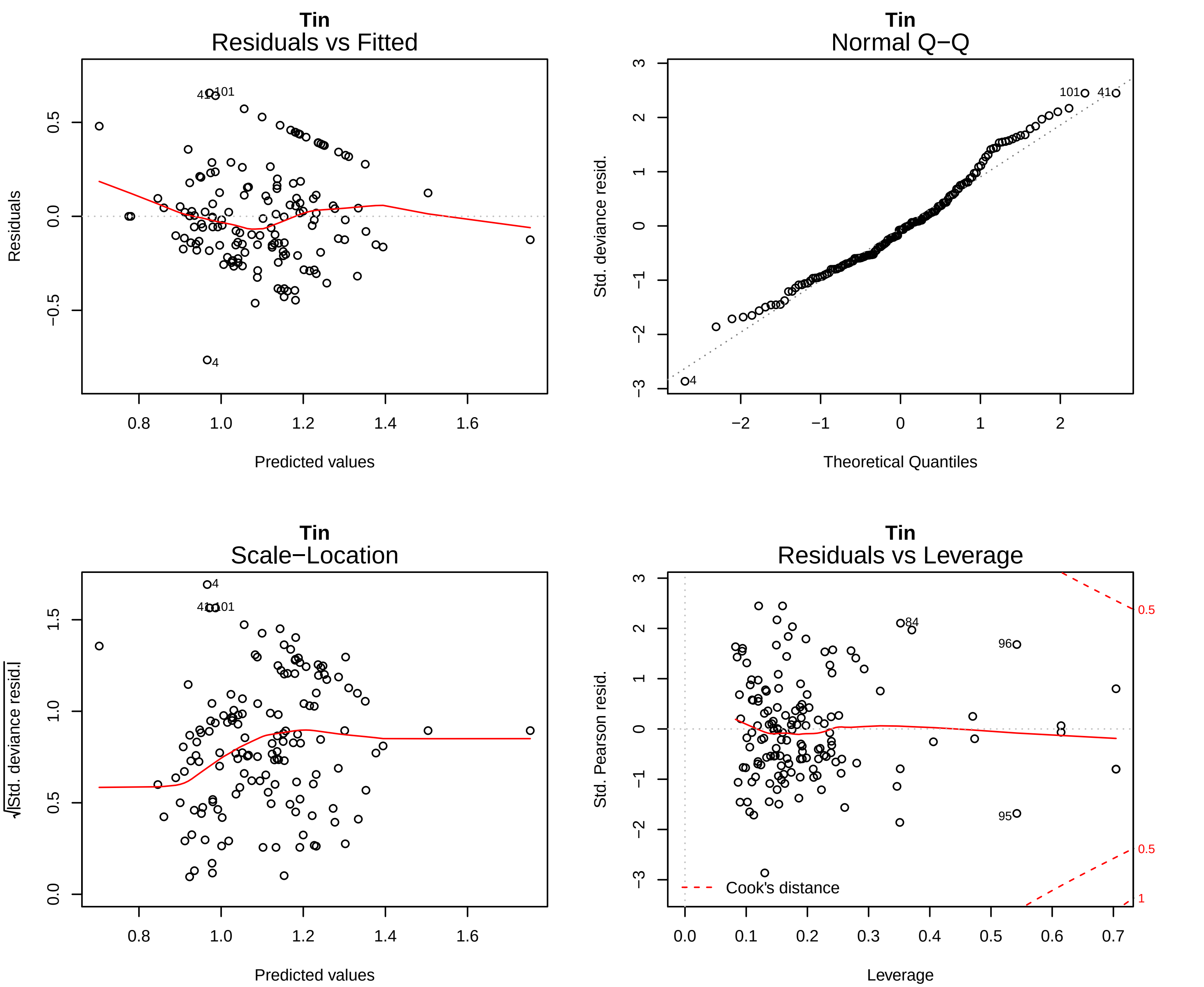
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

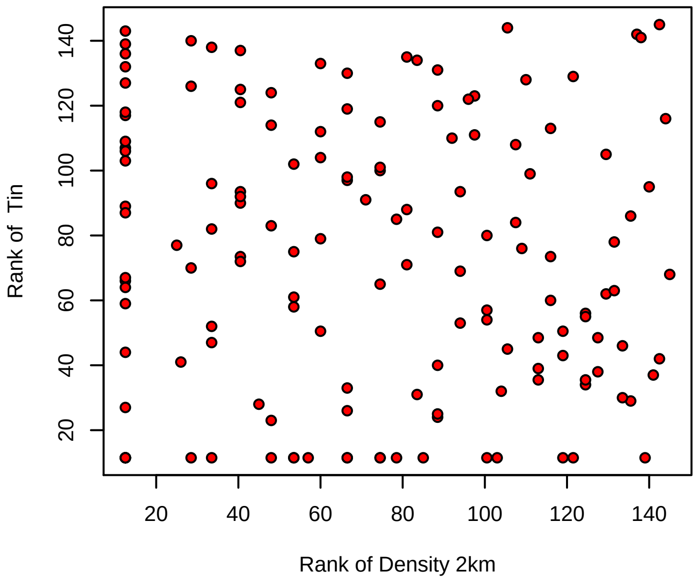
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



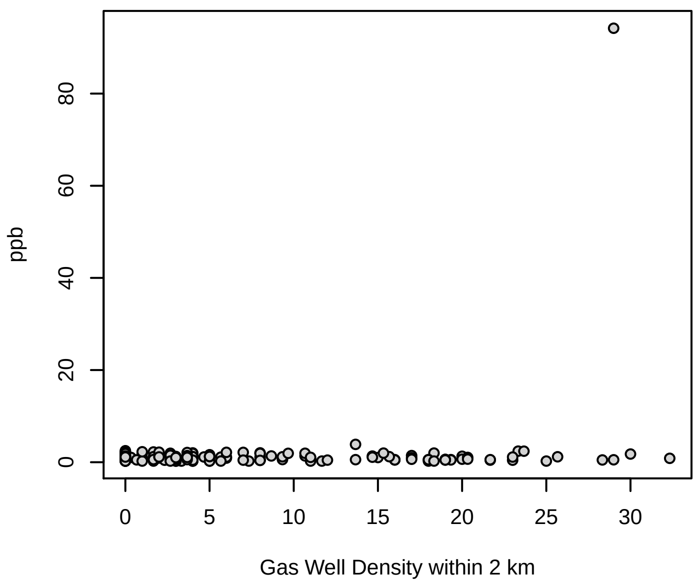


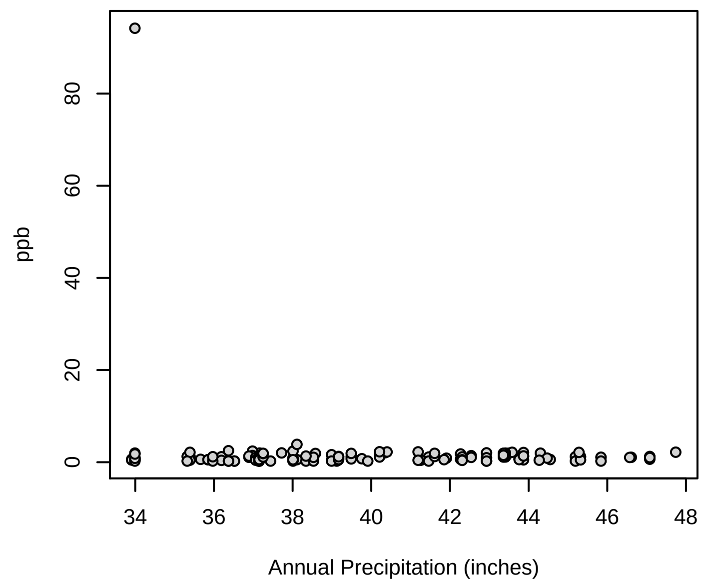
Tin

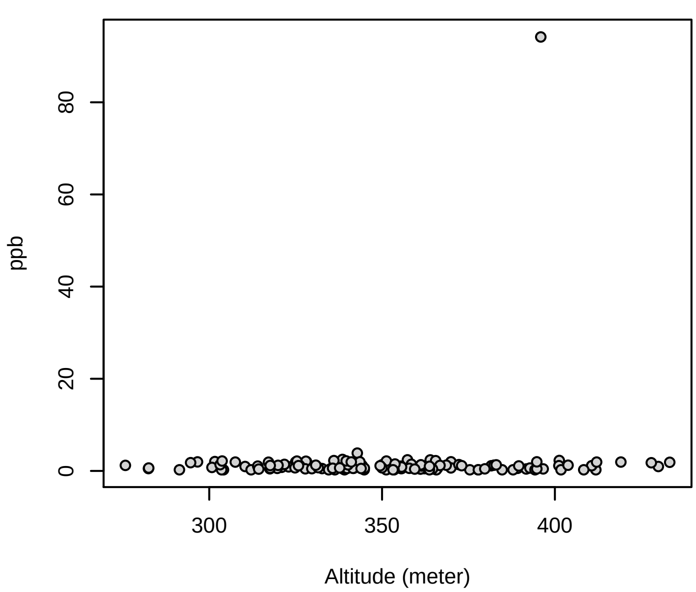
Kendalls Tau Rank Correlation

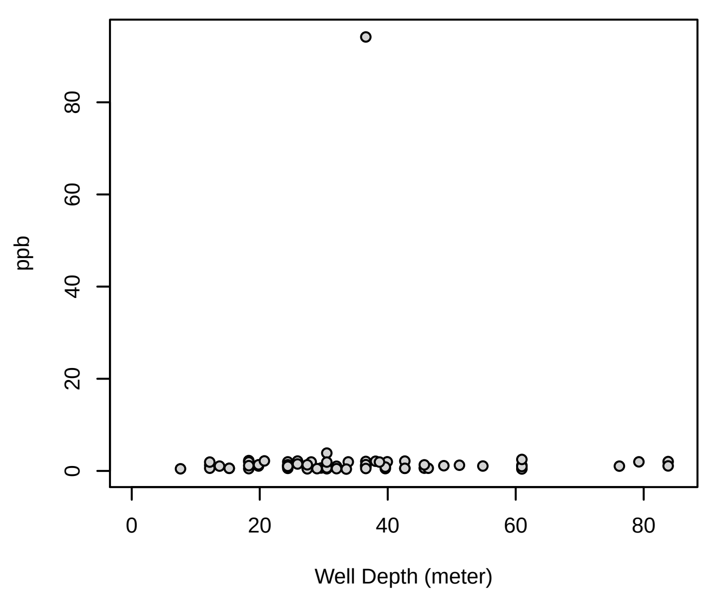
p−value: 0.284

Tau: −0.0618

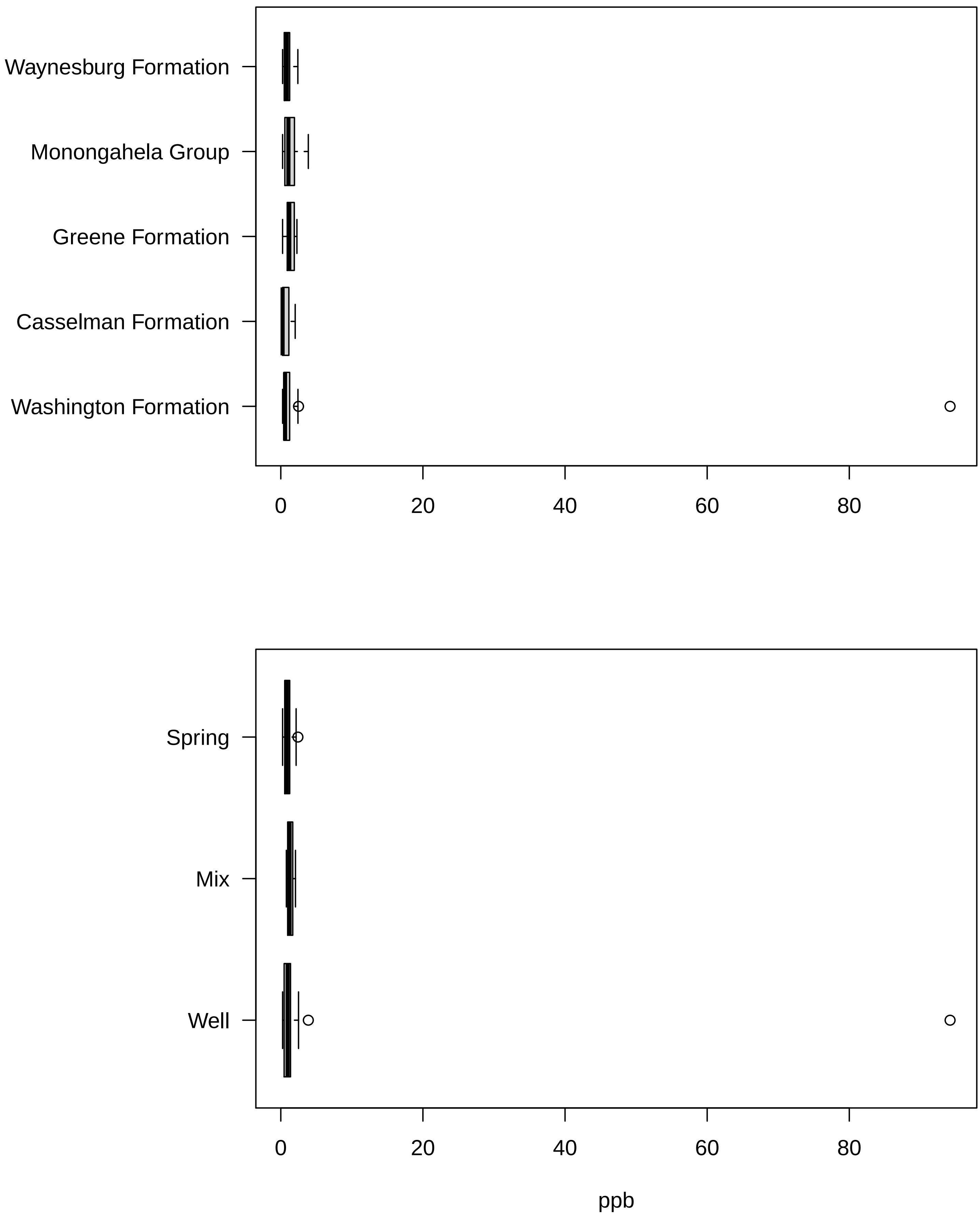




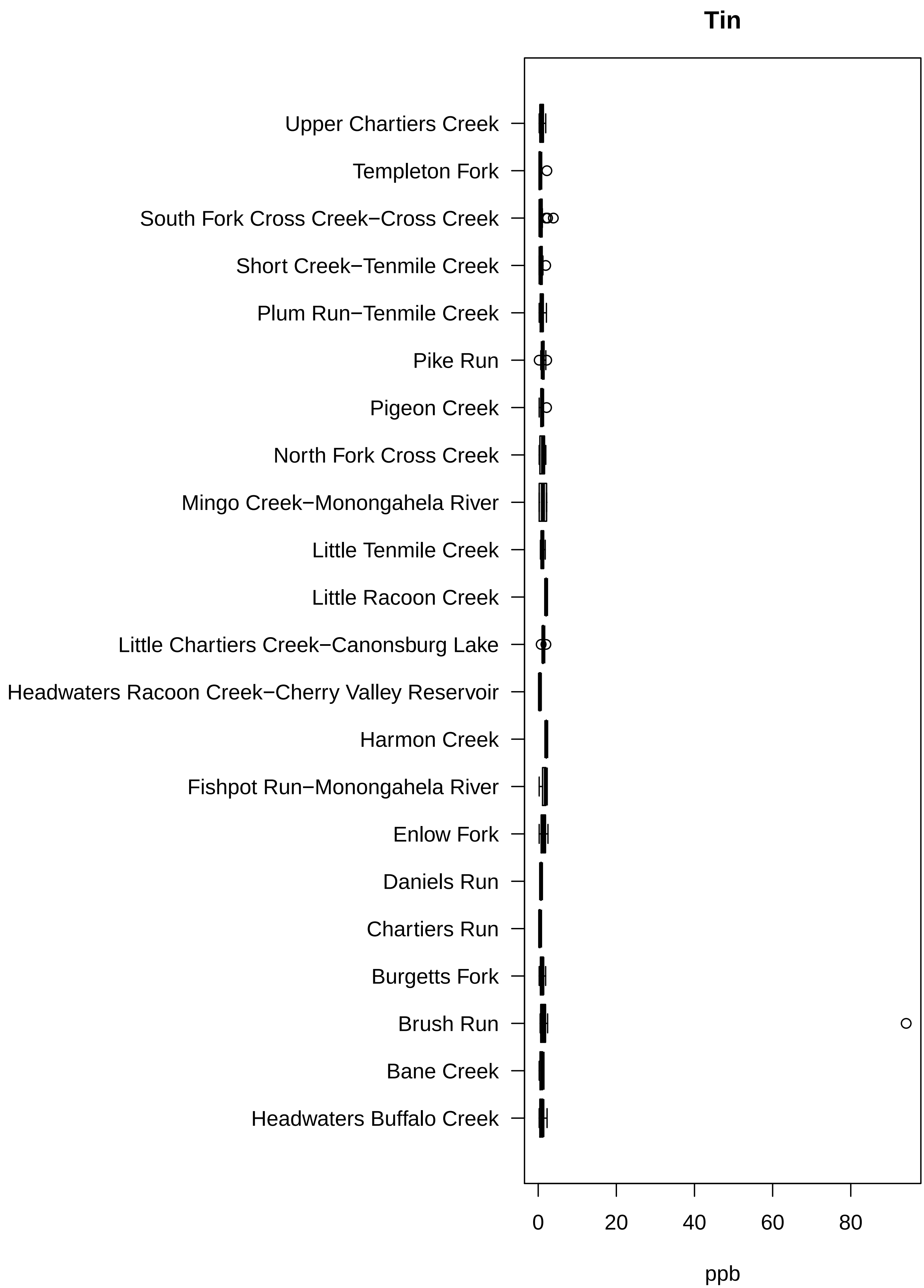




Tin



Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
20
40
60
80
Spring
Mix
Well
0
20
40
60
80
ppb


Tin
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
20
40
60
80
ppb

```
[1] "ORIGINAL MODEL - Tin"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-12.300   -1.180   -0.087    0.986   80.955

Coefficients:
                                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              15.28654   22.43110   0.681    0.497
dat$GWellDensity_2kmAvg                                   0.19150    0.13863   1.381    0.170
dat$Altitude_meter                                        0.02068    0.03805   0.543    0.588
dat$WatershedBane Creek                                   0.59363    4.75355   0.125    0.901
dat$WatershedBrush Run                                    3.79526    3.90667   0.971    0.333
dat$WatershedBurgetts Fork                               -1.00016    4.57061  -0.219    0.827
dat$WatershedChartiers Run                               -5.61902    5.33681  -1.053    0.295
dat$WatershedDaniels Run                                  8.21912    7.57366   1.085    0.280
dat$WatershedEnlow Fork                                   0.94019    5.16191   0.182    0.856
dat$WatershedFishpot Run-Monongahela River                4.43449    6.25146   0.709    0.480
dat$WatershedHarmon Creek                                 5.79998   10.21661   0.568    0.571
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -3.20425    7.44144  -0.431    0.668
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       3.44940    4.81474   0.716    0.475
dat$WatershedLittle Racoon Creek                         -1.64490   11.51041  -0.143    0.887
dat$WatershedLittle Tenmile Creek                         4.59803    4.92416   0.934    0.352
dat$WatershedMingo Creek-Monongahela River                3.39743    6.59761   0.515    0.608
dat$WatershedNorth Fork Cross Creek                      -0.33465    4.42688  -0.076    0.940
dat$WatershedPigeon Creek                                 5.33215    5.54316   0.962    0.338
dat$WatershedPike Run                                     5.96151    5.41508   1.101    0.273
dat$WatershedPlum Run-Tenmile Creek                       4.18229    4.80222   0.871    0.386
dat$WatershedShort Creek-Tenmile Creek                   -0.03851    3.98611  -0.010    0.992
dat$WatershedSouth Fork Cross Creek-Cross Creek          -1.86079    3.57040  -0.521    0.603
dat$WatershedTempleton Fork                              -0.35217    4.22136  -0.083    0.934
dat$WatershedUpper Chartiers Creek                       -2.69729    3.64389  -0.740    0.461
dat$FormationCasselman Formation                          4.22478    8.30987   0.508    0.612
dat$FormationGreene Formation                            -0.34377    2.82229  -0.122    0.903
dat$FormationMonongahela Group                            0.72417    2.95421   0.245    0.807
dat$FormationWaynesburg Formation                        -1.68212    2.28634  -0.736    0.463
dat$HHWSourceMix                                         -3.43673    5.51903  -0.623    0.535
dat$HHWSourceSpring                                      -1.64671    1.80829  -0.911    0.364
dat$Precip_inchAvg                                       -0.57650    0.46280  -1.246    0.215

(Dispersion parameter for gaussian family taken to be 66.54941)

    Null deviance: 8683.3  on 144  degrees of freedom
Residual deviance: 7586.6  on 114  degrees of freedom
AIC: 1049.3

Number of Fisher Scoring iterations: 2

[1] "BOX-COX MODEL - Tin"
```

```
Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.76396  -0.16477  -0.01826   0.15362   0.65661

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               0.3276226  0.7864444   0.417  0.67776
dat$GWellDensity_2kmAvg                                  -0.0037934  0.0048603  -0.780  0.43672
dat$Altitude_meter                                        0.0024581  0.0013340   1.843  0.06798 .
dat$WatershedBane Creek                                   0.2346921  0.1666616   1.408  0.16179
dat$WatershedBrush Run                                   -0.2181496  0.1369697  -1.593  0.11400
dat$WatershedBurgetts Fork                               -0.0373302  0.1602478  -0.233  0.81622
dat$WatershedChartiers Run                                0.2653560  0.1871109   1.418  0.15887
dat$WatershedDaniels Run                                 -0.0363668  0.2655358  -0.137  0.89131
dat$WatershedEnlow Fork                                   0.0004941  0.1809787   0.003  0.99783
dat$WatershedFishpot Run-Monongahela River               -0.0222815  0.2191790  -0.102  0.91921
dat$WatershedHarmon Creek                                -0.3170194  0.3581989  -0.885  0.37800
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.0194710  0.2609001   0.075  0.94064
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -0.1038231  0.1688069  -0.615  0.53975
dat$WatershedLittle Racoon Creek                         -0.7788371  0.4035601  -1.930  0.05610 .
dat$WatershedLittle Tenmile Creek                        -0.1130590  0.1726431  -0.655  0.51387
dat$WatershedMingo Creek-Monongahela River                0.0542306  0.2313152   0.234  0.81506
dat$WatershedNorth Fork Cross Creek                      -0.0921679  0.1552085  -0.594  0.55380
dat$WatershedPigeon Creek                                -0.0981505  0.1943456  -0.505  0.61451
dat$WatershedPike Run                                    -0.1576076  0.1898552  -0.830  0.40819
dat$WatershedPlum Run-Tenmile Creek                       0.0423133  0.1683680   0.251  0.80202
dat$WatershedShort Creek-Tenmile Creek                    0.1612006  0.1397547   1.153  0.25114
dat$WatershedSouth Fork Cross Creek-Cross Creek           0.0190872  0.1251797   0.152  0.87908
dat$WatershedTempleton Fork                               0.2226556  0.1480028   1.504  0.13524
dat$WatershedUpper Chartiers Creek                        0.0122166  0.1277563   0.096  0.92399
dat$FormationCasselman Formation                          0.4317580  0.2913478   1.482  0.14112
dat$FormationGreene Formation                            -0.2963975  0.0989508  -2.995  0.00336 **
dat$FormationMonongahela Group                           -0.0474457  0.1035758  -0.458  0.64777
dat$FormationWaynesburg Formation                         0.0367894  0.0801602   0.459  0.64715
dat$HHWSourceMix                                         -0.0066557  0.1934998  -0.034  0.97262
dat$HHWSourceSpring                                       0.0154375  0.0633995   0.243  0.80806
dat$Precip_inchAvg                                       -0.0001905  0.0162259  -0.012  0.99066
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.08180487)

    Null deviance: 12.4380  on 144  degrees of freedom
Residual deviance:  9.3258  on 114  degrees of freedom
AIC: 77.619

Number of Fisher Scoring iterations: 2
```

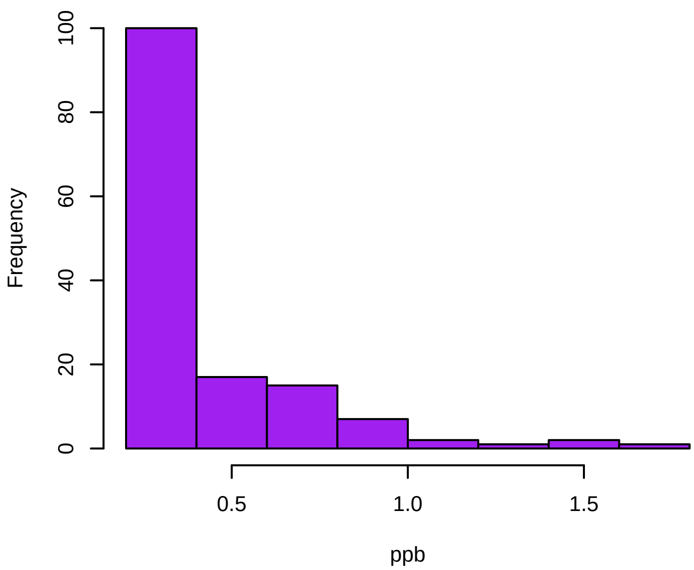
Uranium

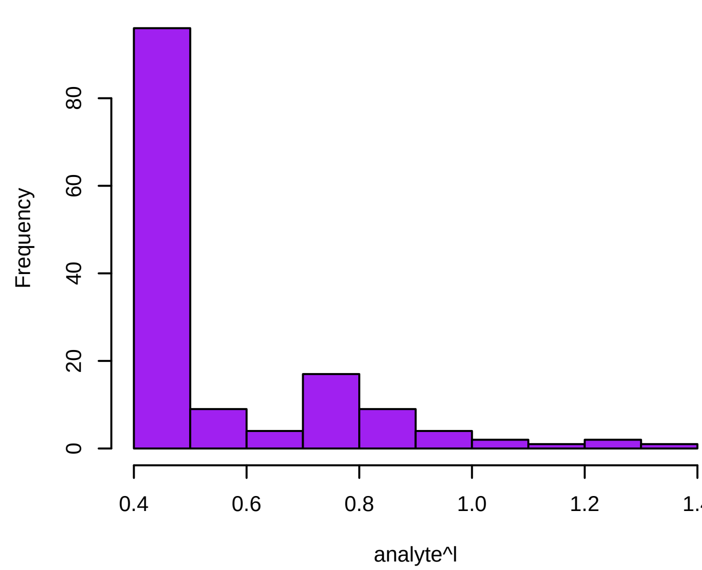
Skewness: 2.2430
Kurtosis: 8.4890

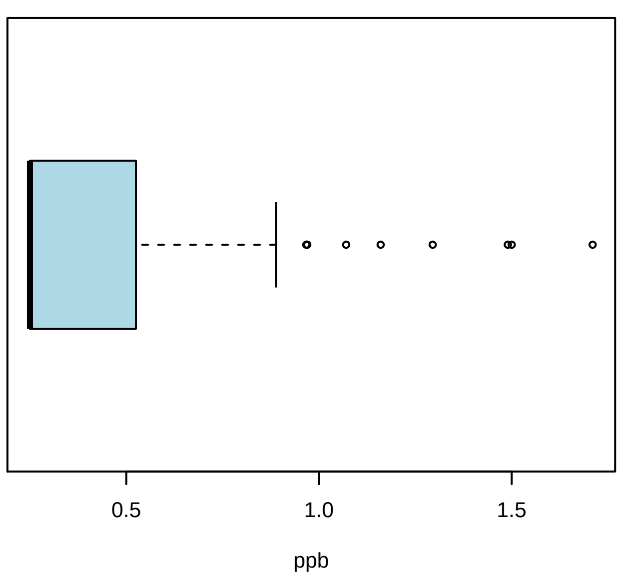
Uranium Box−Cox

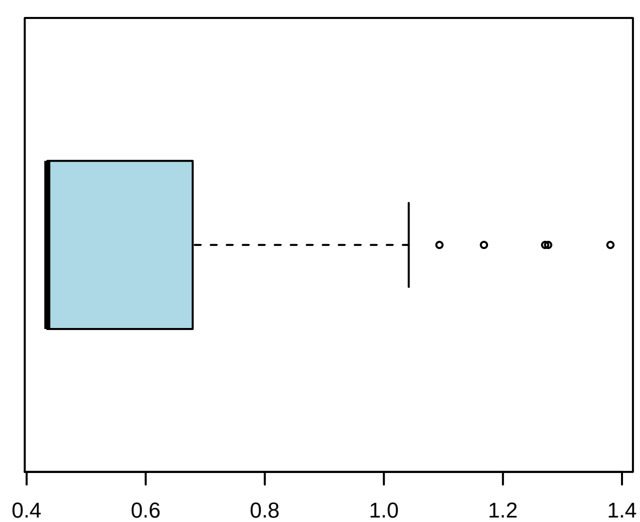
Skewness: 1.7536
Kurtosis: 5.7068

Optimal lambda: 0.601



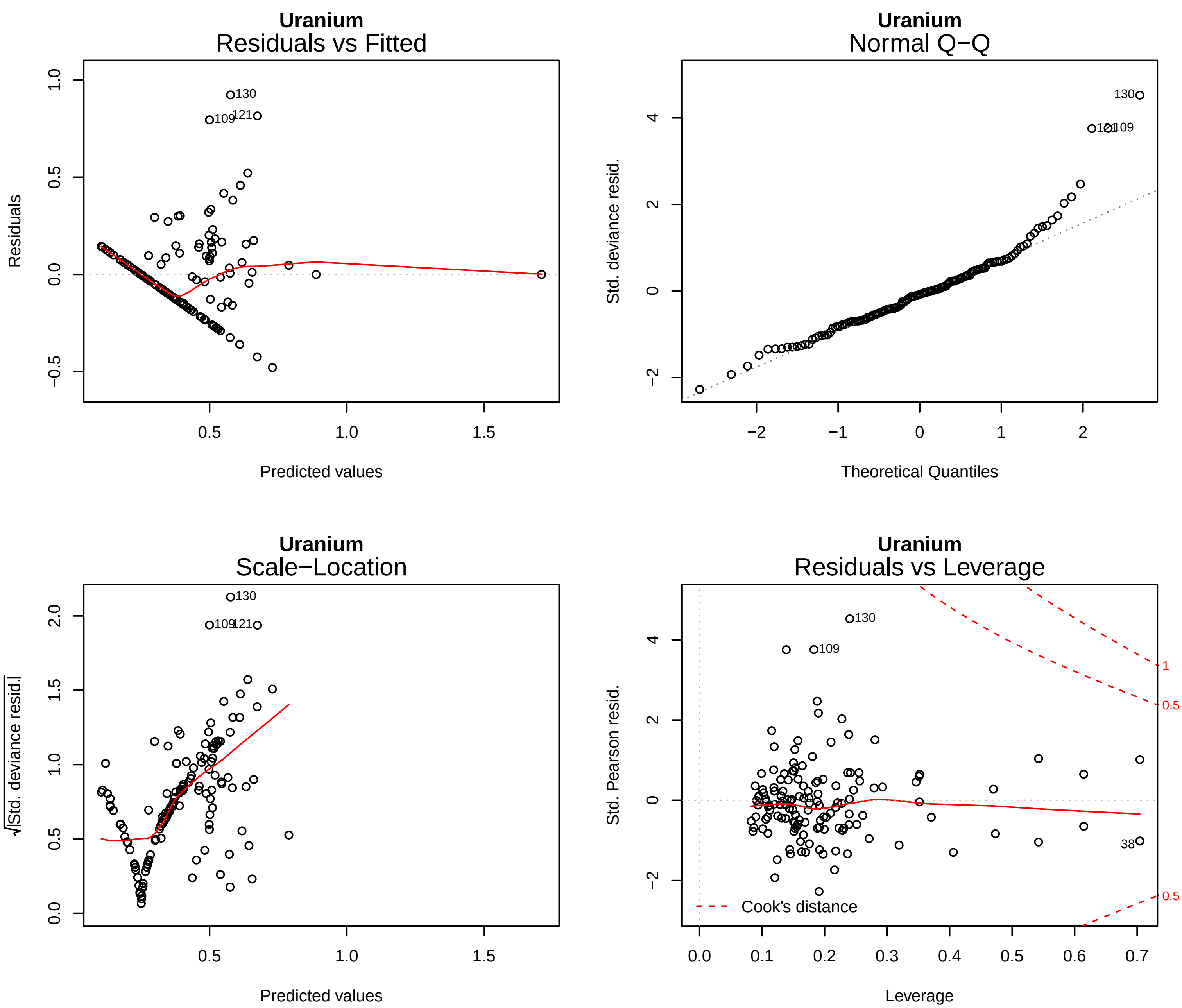






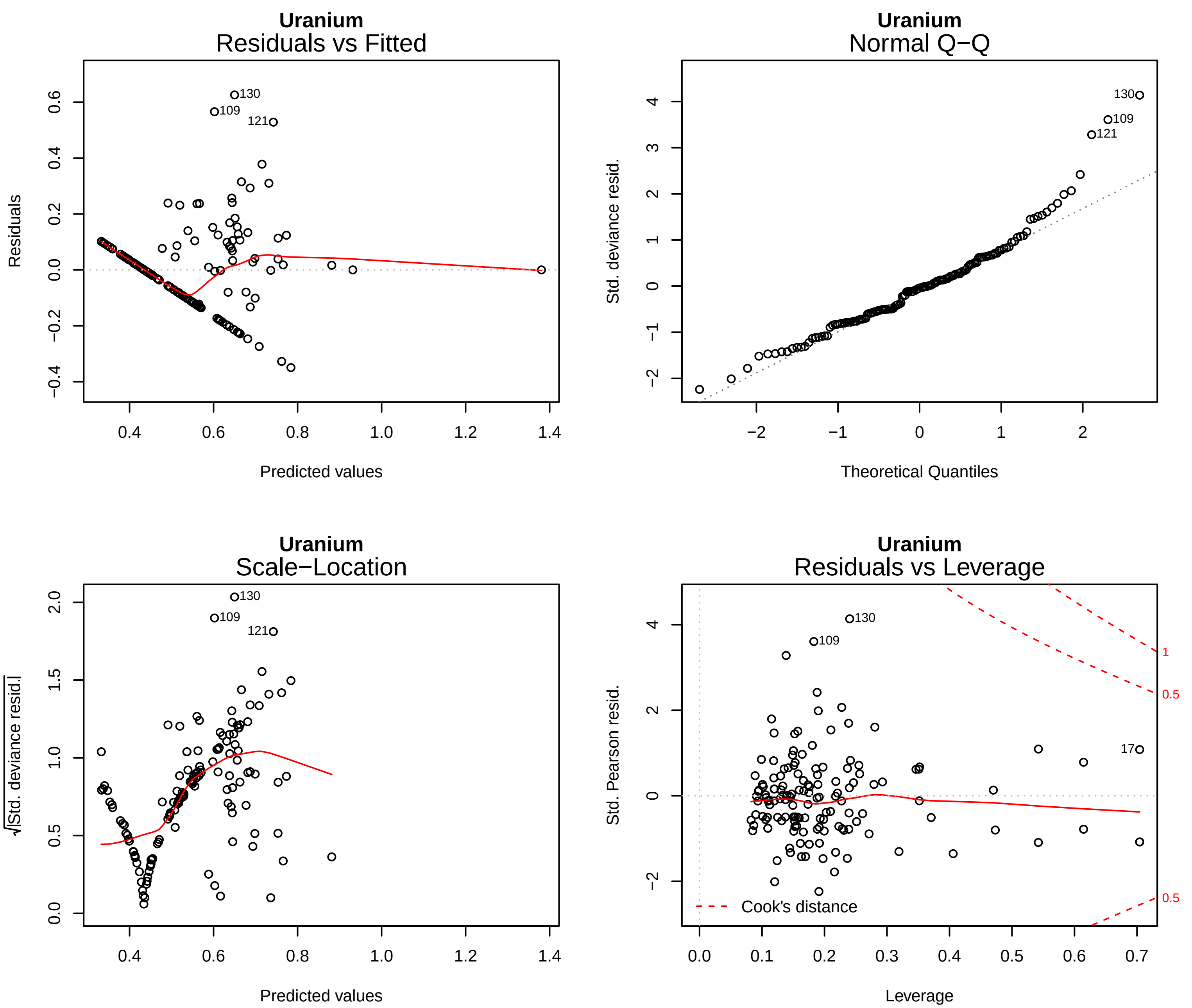
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model

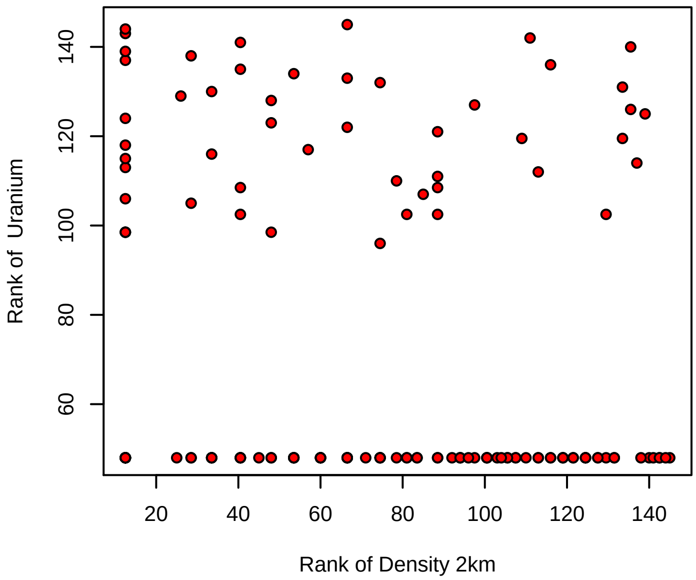


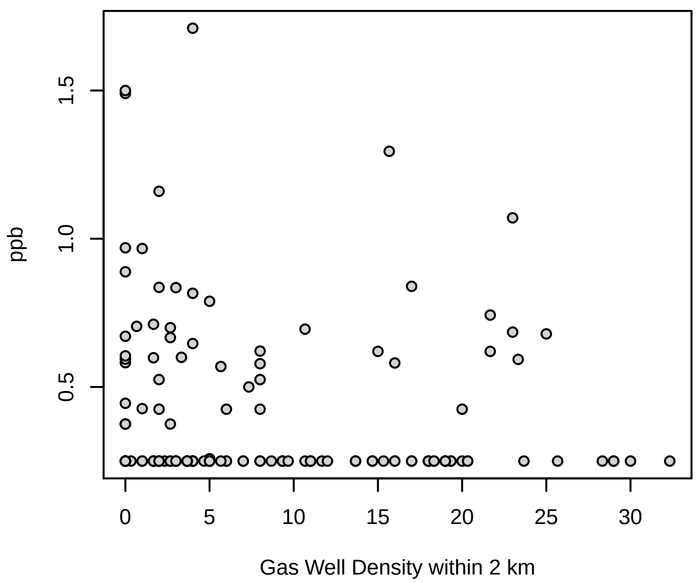
Uranium

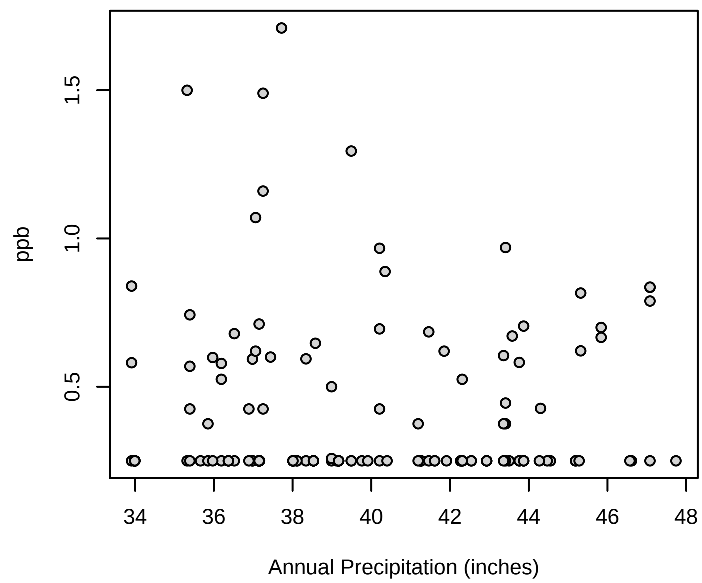
Kendalls Tau Rank Correlation

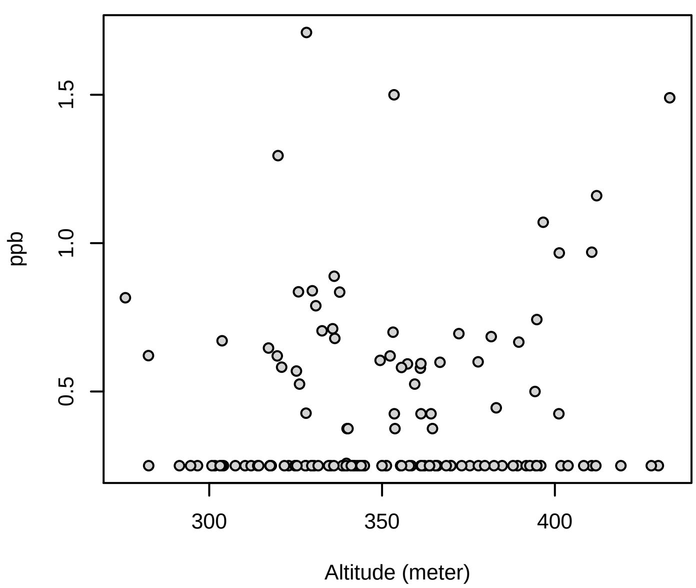
p−value: 0.0482

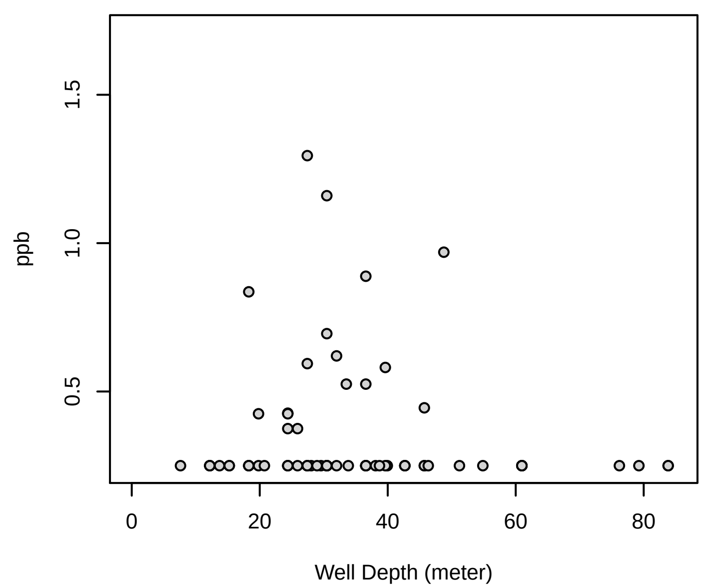
Tau: −0.127

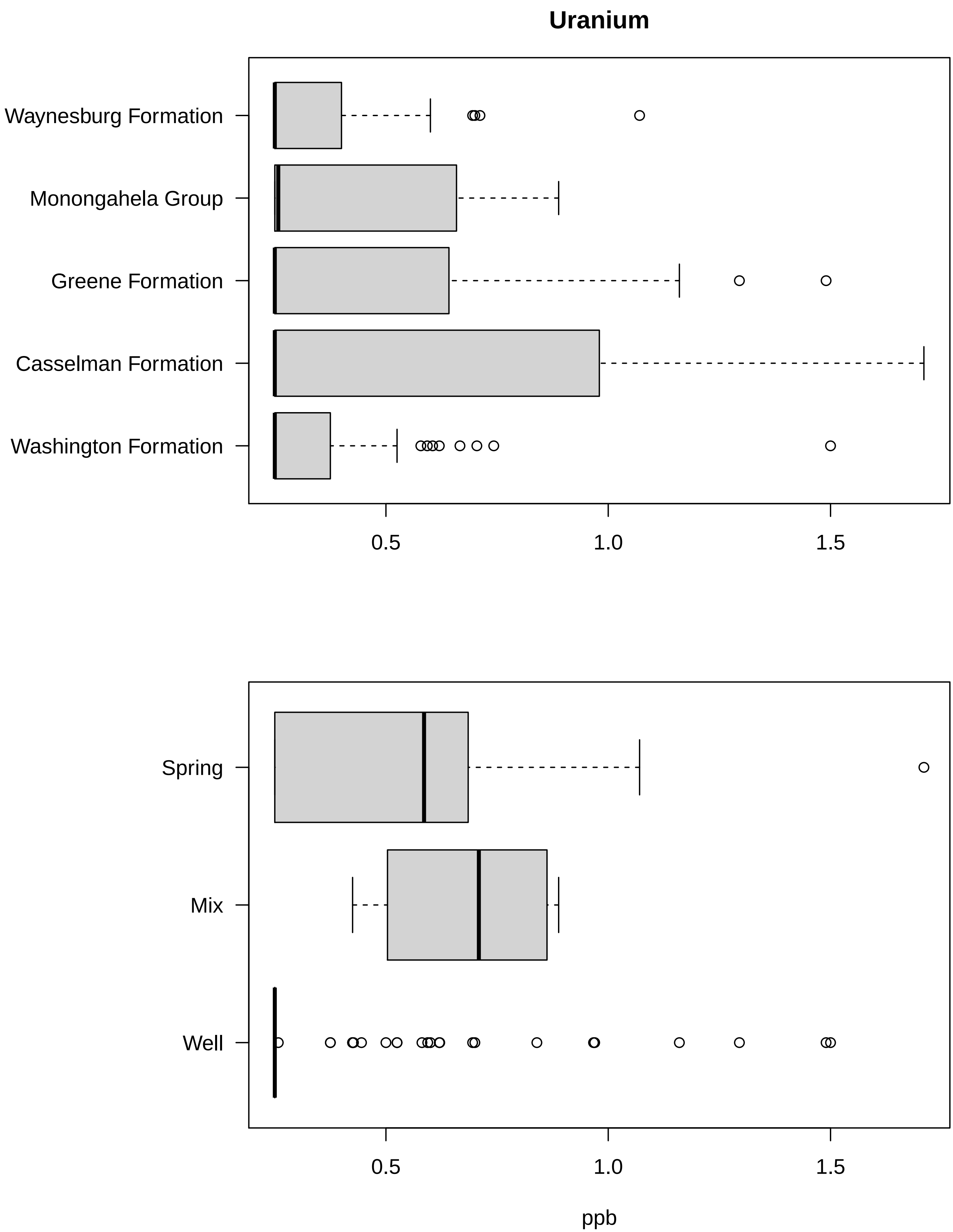


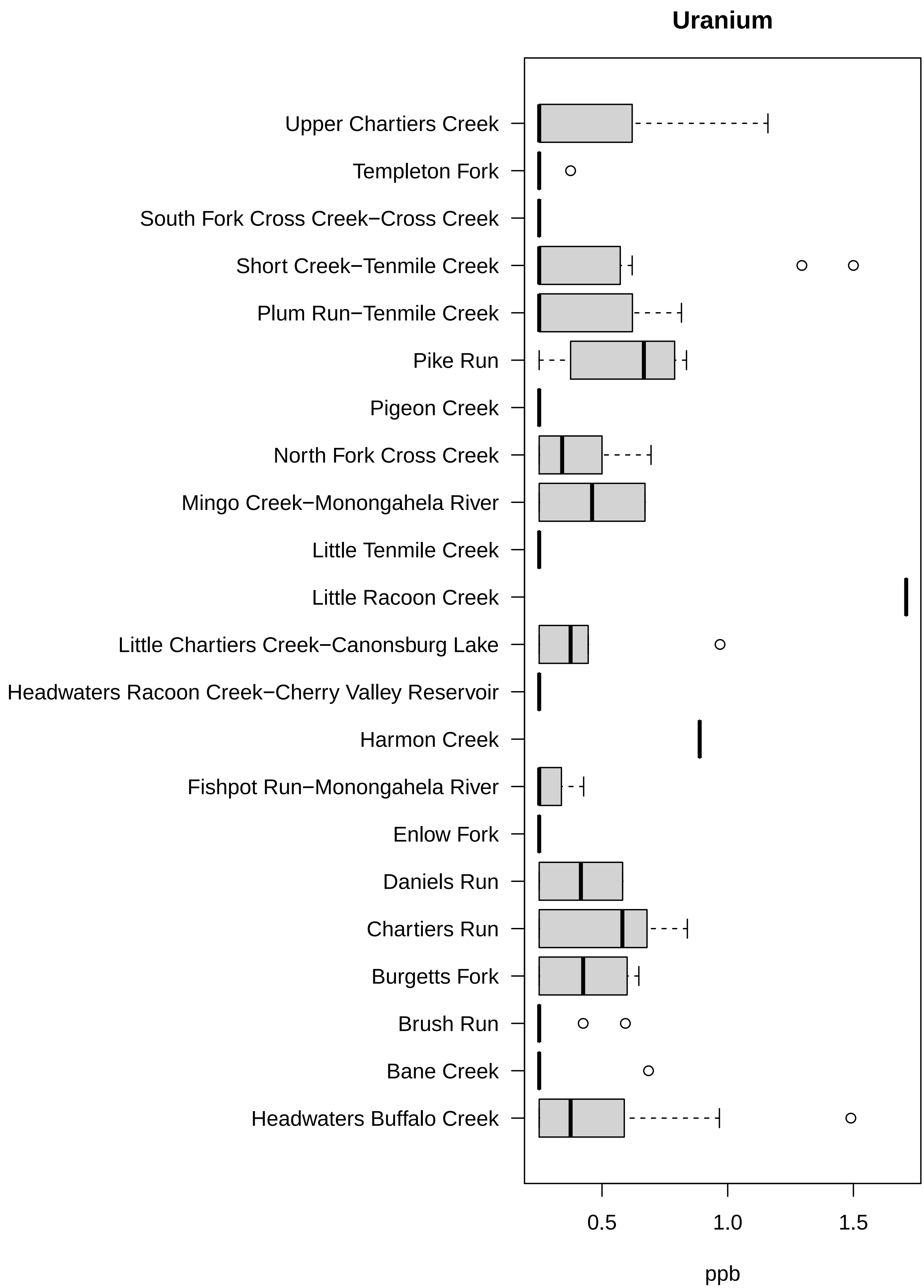









Uranium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0.5
1.0
1.5
Spring
Mix
Well
0.5
1.0
1.5
ppb


Uranium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0.5
1.0
1.5
ppb

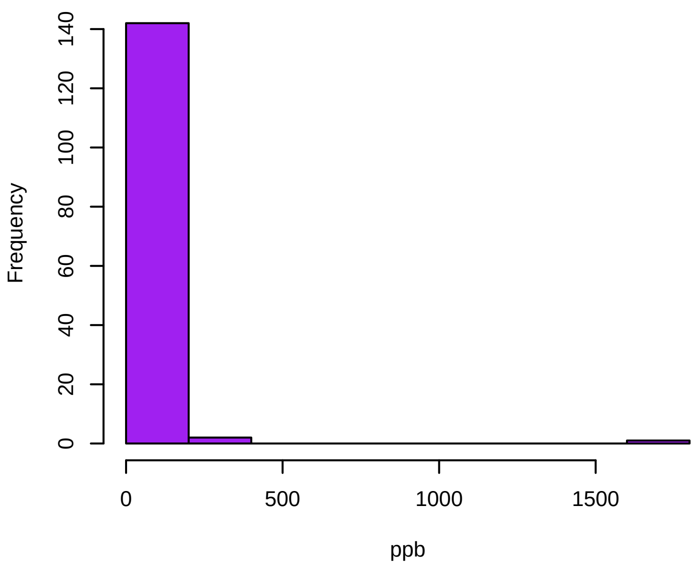
```
[1] "ORIGINAL MODEL - Uranium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.47899  -0.12754  -0.01446   0.09295   0.92365  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                              -0.461581   0.644017  -0.717 0.475012    
dat$GWellDensity_2kmAvg                                  -0.005333   0.003980  -1.340 0.182949    
dat$Altitude_meter                                        0.002513   0.001092   2.300 0.023242 *  
dat$WatershedBane Creek                                  -0.174725   0.136479  -1.280 0.203061    
dat$WatershedBrush Run                                   -0.106772   0.112164  -0.952 0.343148    
dat$WatershedBurgetts Fork                               -0.037677   0.131226  -0.287 0.774548    
dat$WatershedChartiers Run                                0.133628   0.153224   0.872 0.384983    
dat$WatershedDaniels Run                                 -0.172890   0.217446  -0.795 0.428212    
dat$WatershedEnlow Fork                                  -0.203057   0.148203  -1.370 0.173339    
dat$WatershedFishpot Run-Monongahela River               -0.096956   0.179485  -0.540 0.590118    
dat$WatershedHarmon Creek                                 0.123636   0.293328   0.421 0.674187    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.117614   0.213650  -0.550 0.583054    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -0.057854   0.138235  -0.419 0.676357    
dat$WatershedLittle Racoon Creek                          1.266242   0.330474   3.832 0.000209 ***
dat$WatershedLittle Tenmile Creek                        -0.099643   0.141377  -0.705 0.482371    
dat$WatershedMingo Creek-Monongahela River               -0.020172   0.189423  -0.106 0.915380    
dat$WatershedNorth Fork Cross Creek                      -0.048036   0.127100  -0.378 0.706177    
dat$WatershedPigeon Creek                                -0.199403   0.159149  -1.253 0.212794    
dat$WatershedPike Run                                     0.069479   0.155472   0.447 0.655801    
dat$WatershedPlum Run-Tenmile Creek                       0.064002   0.137876   0.464 0.643392    
dat$WatershedShort Creek-Tenmile Creek                    0.196549   0.114445   1.717 0.088618 .  
dat$WatershedSouth Fork Cross Creek-Cross Creek          -0.111539   0.102509  -1.088 0.278852    
dat$WatershedTempleton Fork                              -0.165123   0.121199  -1.362 0.175752    
dat$WatershedUpper Chartiers Creek                        0.028246   0.104619   0.270 0.787659    
dat$FormationCasselman Formation                          0.008853   0.238584   0.037 0.970466    
dat$FormationGreene Formation                             0.096702   0.081030   1.193 0.235192    
dat$FormationMonongahela Group                            0.139182   0.084818   1.641 0.103563    
dat$FormationWaynesburg Formation                         0.077478   0.065643   1.180 0.240339    
dat$HHWSourceMix                                          0.296055   0.158456   1.868 0.064278 .  
dat$HHWSourceSpring                                       0.143282   0.051918   2.760 0.006741 ** 
dat$Precip_inchAvg                                       -0.001328   0.013287  -0.100 0.920590    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.05485768)

    Null deviance: 11.2419  on 144  degrees of freedom
Residual deviance:  6.2538  on 114  degrees of freedom
AIC: 19.678

Number of Fisher Scoring iterations: 2
```

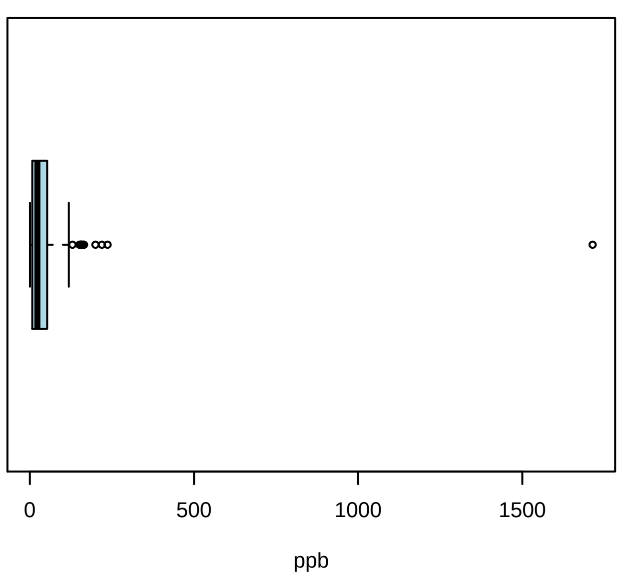
```
[1] "BOX-COX MODEL - Uranium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.34951  -0.09467  -0.00562   0.07673   0.62596

Coefficients:
                                                                  Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                     -0.1733533  0.4770594  -0.363  0.71699
dat$GWellDensity_2kmAvg                                         -0.0036421  0.0029483  -1.235  0.21925
dat$Altitude_meter                                               0.0018010  0.0008092   2.226  0.02800 *
dat$WatershedBane Creek                                         -0.1356803  0.1010974  -1.342  0.18224
dat$WatershedBrush Run                                          -0.0893434  0.0830862  -1.075  0.28451
dat$WatershedBurgetts Fork                                      -0.0190413  0.0972068  -0.196  0.84505
dat$WatershedChartiers Run                                       0.1175727  0.1135020   1.036  0.30246
dat$WatershedDaniels Run                                        -0.1620494  0.1610748  -1.006  0.31652
dat$WatershedEnlow Fork                                         -0.1609091  0.1097822  -1.466  0.14548
dat$WatershedFishpot Run-Monongahela River                      -0.0885312  0.1329546  -0.666  0.50684
dat$WatershedHarmon Creek                                        0.0715430  0.2172845   0.329  0.74256
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0886721  0.1582628  -0.560  0.57639
dat$WatershedLittle Chartiers Creek-Canonsburg Lake             -0.0475682  0.1023988  -0.465  0.64315
dat$WatershedLittle Racoon Creek                                 0.7964364  0.2448008   3.253  0.00150 **
dat$WatershedLittle Tenmile Creek                               -0.1102156  0.1047258  -1.052  0.29483
dat$WatershedMingo Creek-Monongahela River                      -0.0235394  0.1403165  -0.168  0.86707
dat$WatershedNorth Fork Cross Creek                             -0.0321650  0.0941499  -0.342  0.73325
dat$WatershedPigeon Creek                                       -0.1844267  0.1178906  -1.564  0.12050
dat$WatershedPike Run                                            0.0339757  0.1151667   0.295  0.76852
dat$WatershedPlum Run-Tenmile Creek                              0.0238046  0.1021325   0.233  0.81612
dat$WatershedShort Creek-Tenmile Creek                           0.1166328  0.0847756   1.376  0.17159
dat$WatershedSouth Fork Cross Creek-Cross Creek                 -0.1006973  0.0759344  -1.326  0.18745
dat$WatershedTempleton Fork                                     -0.1235402  0.0897789  -1.376  0.17150
dat$WatershedUpper Chartiers Creek                               0.0183003  0.0774974   0.236  0.81375
dat$FormationCasselman Formation                                -0.0160222  0.1767324  -0.091  0.92792
dat$FormationGreene Formation                                    0.0614600  0.0600238   1.024  0.30804
dat$FormationMonongahela Group                                   0.0997510  0.0628294   1.588  0.11514
dat$FormationWaynesburg Formation                                0.0604332  0.0486254   1.243  0.21648
dat$HHWSourceMix                                                 0.2479420  0.1173775   2.112  0.03684 *
dat$HHWSourceSpring                                              0.1221560  0.0384583   3.176  0.00192 **
dat$Precip_inchAvg                                               0.0019852  0.0098427   0.202  0.84052
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.0301015)

    Null deviance: 6.1091  on 144  degrees of freedom
Residual deviance: 3.4316  on 114  degrees of freedom
AIC: -67.347

Number of Fisher Scoring iterations: 2
```

Zinc

Skewness: 10.1735

Kurtosis: 115.2820



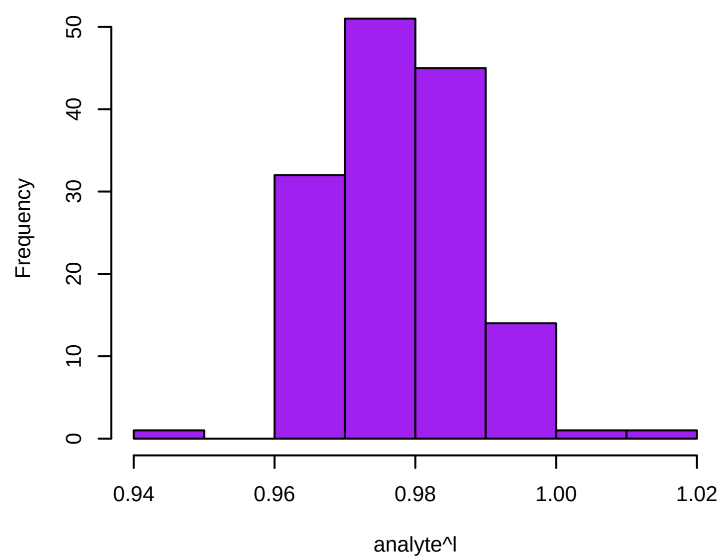


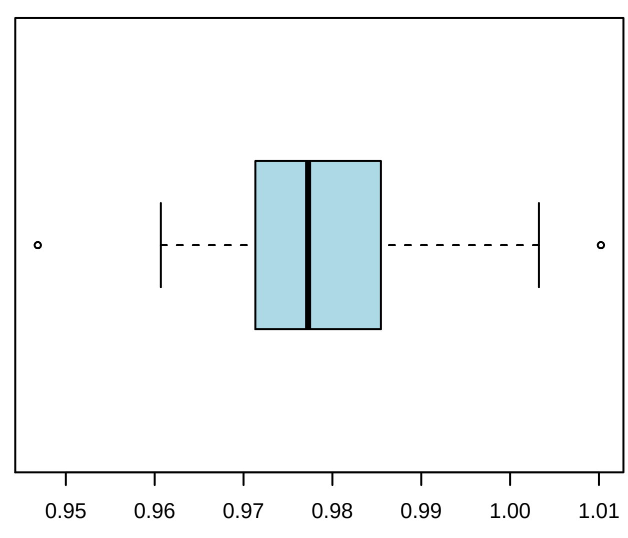
Zinc Box−Cox

Skewness: 0.1572

Kurtosis: 3.3499

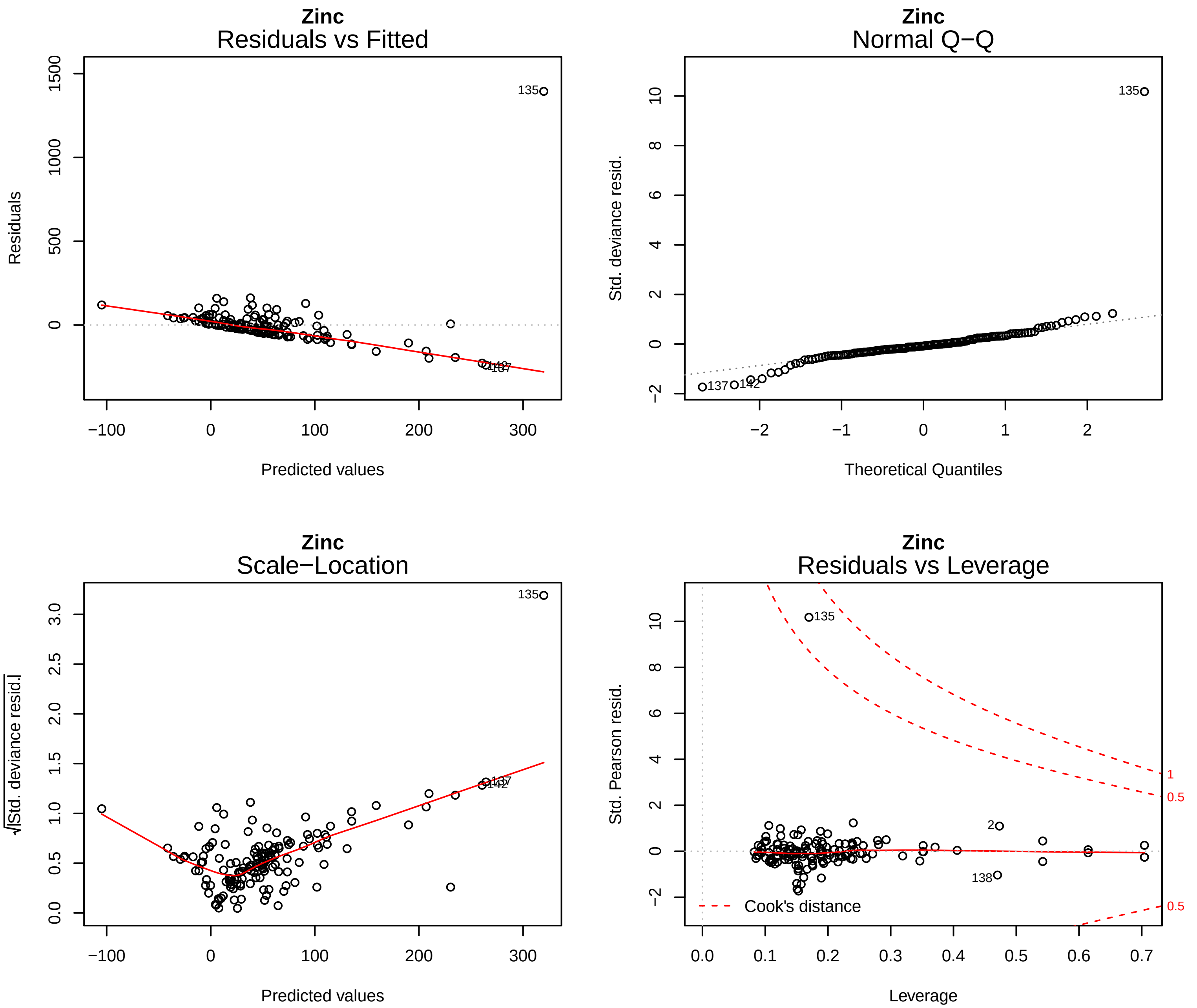
Optimal lambda: −0.007335





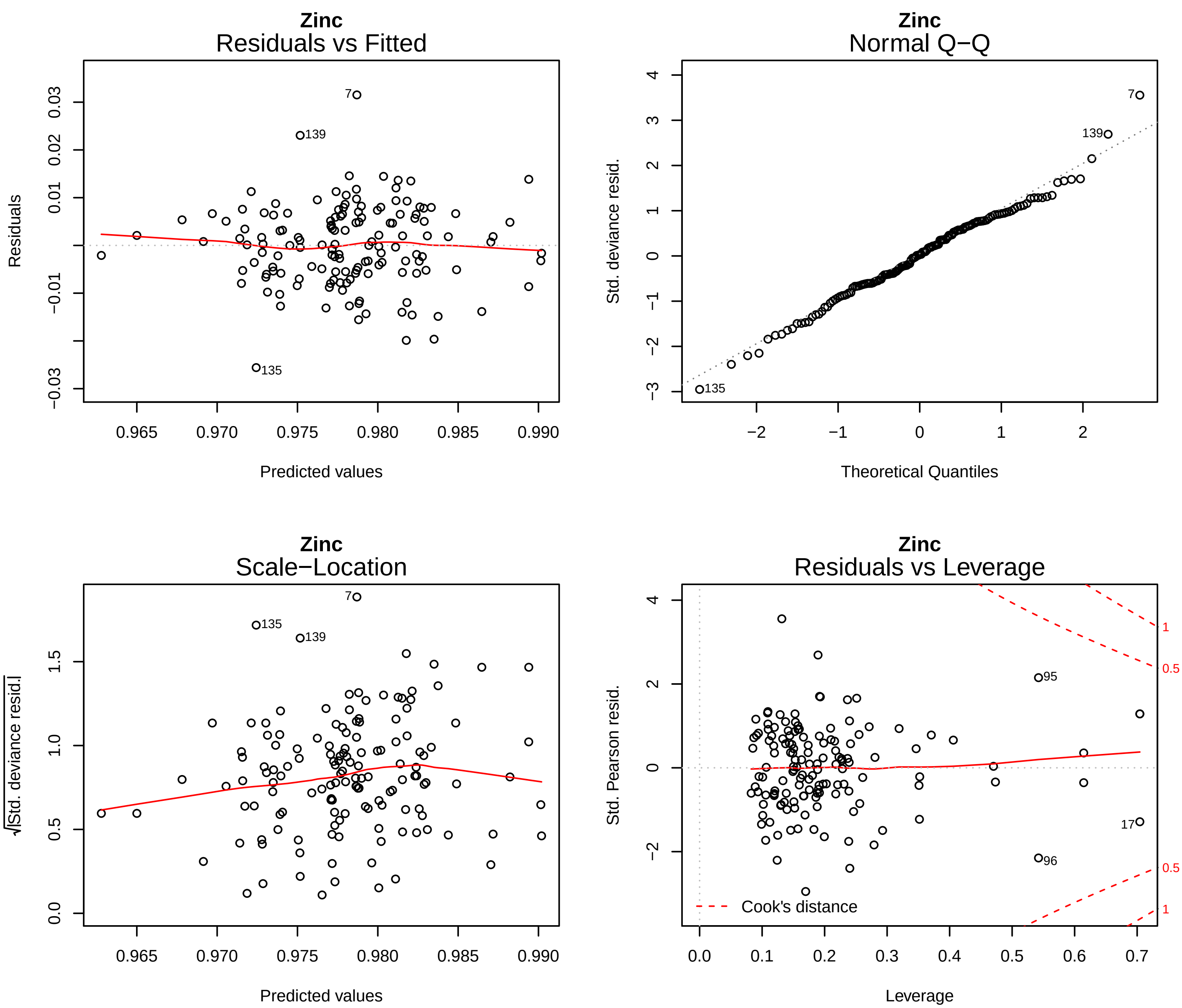
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

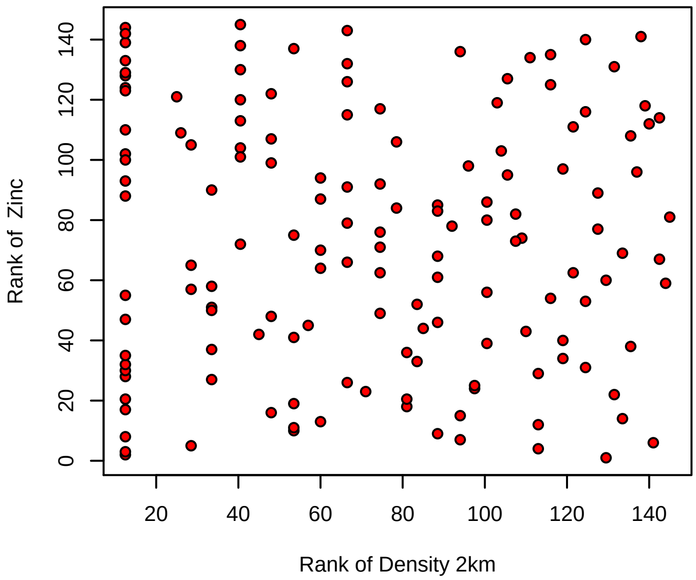
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



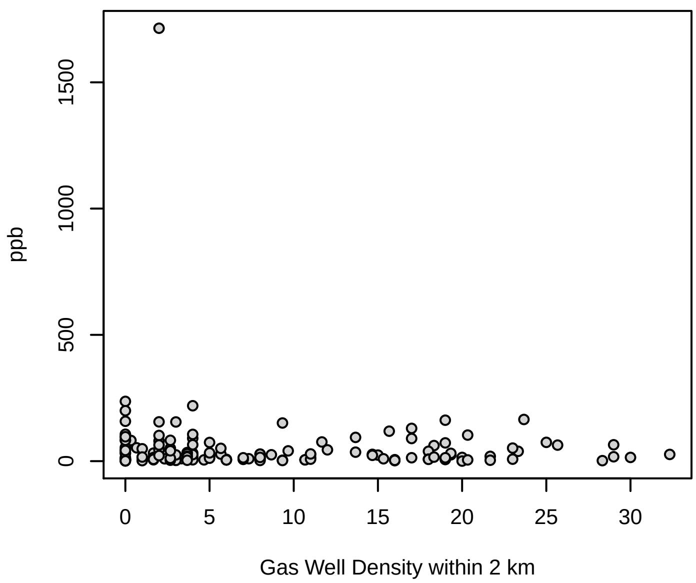


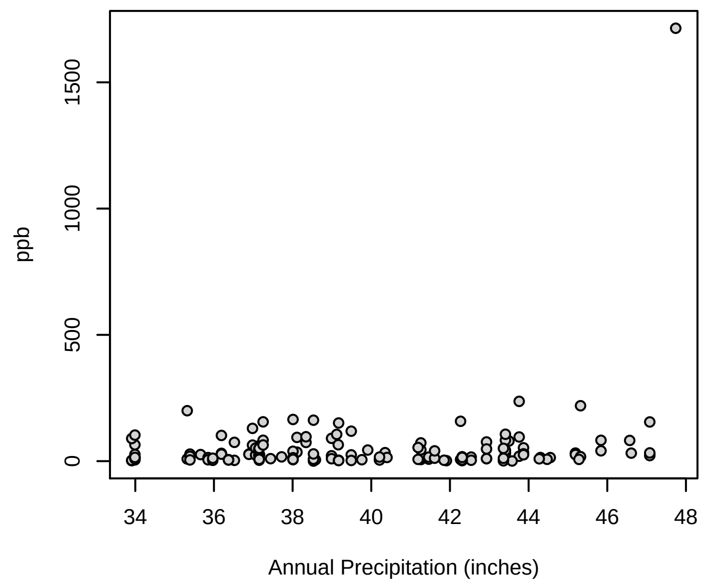
Zinc

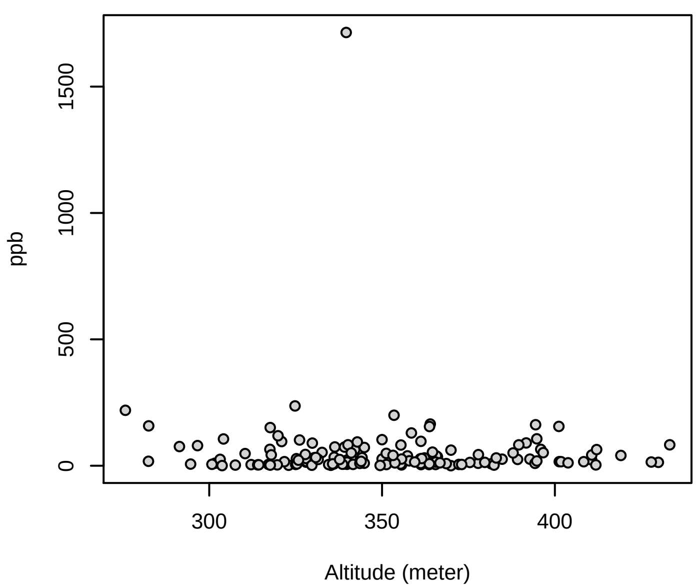
Kendalls Tau Rank Correlation

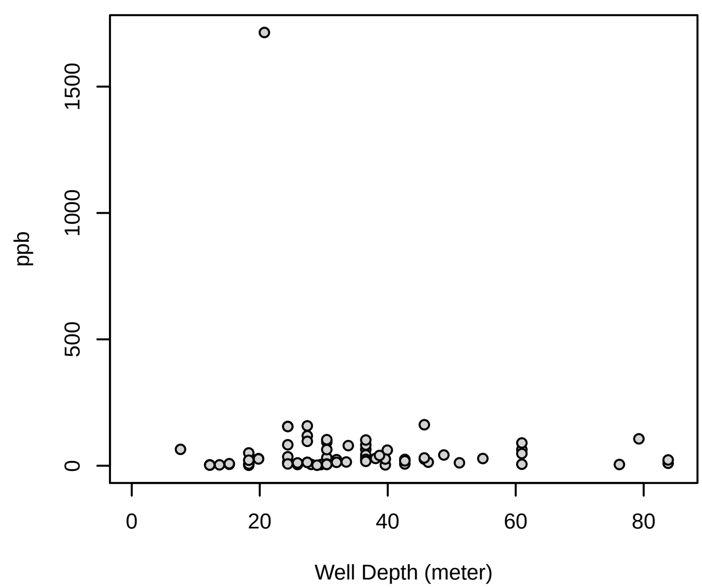
p−value: 0.63

Tau: −0.0275

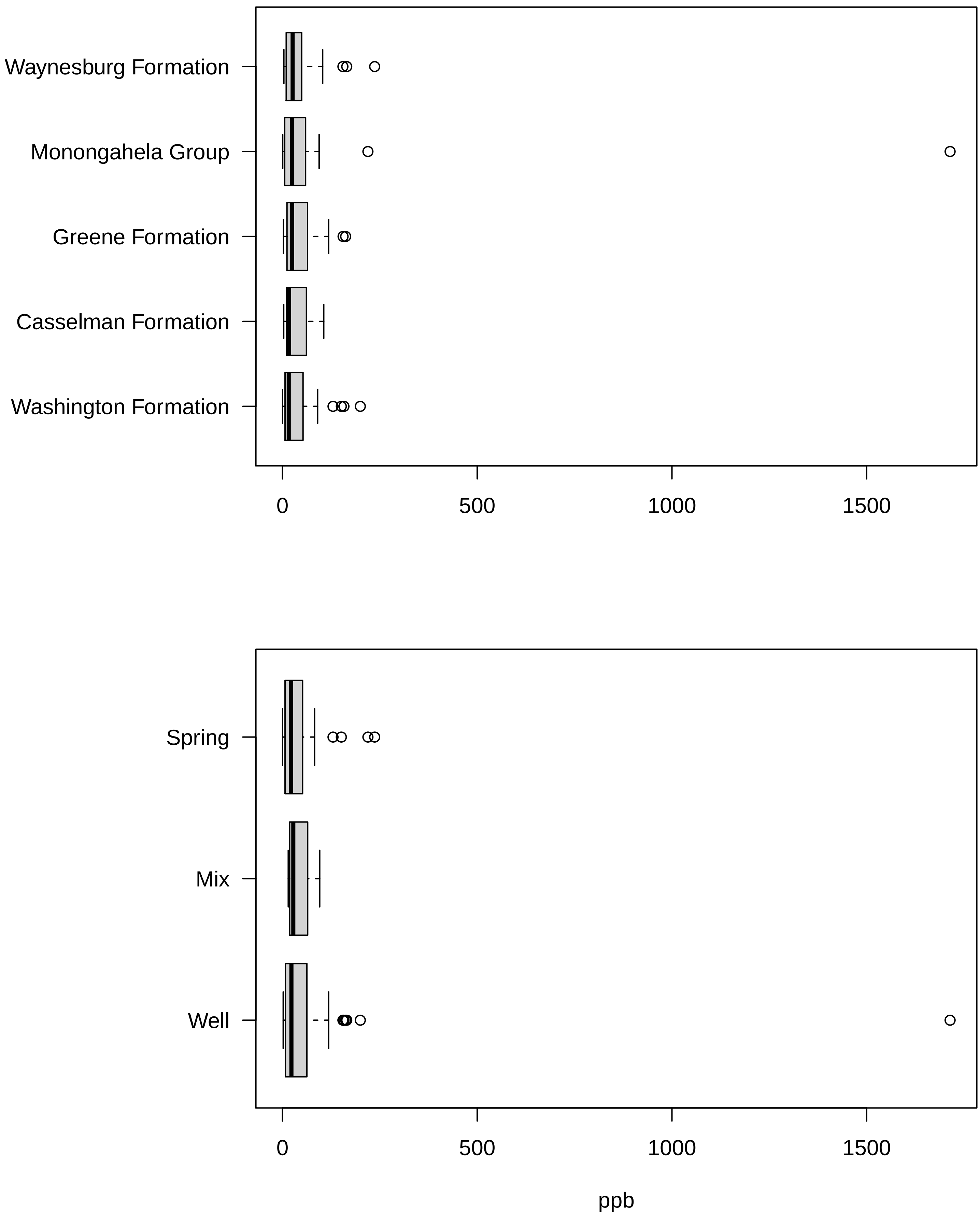


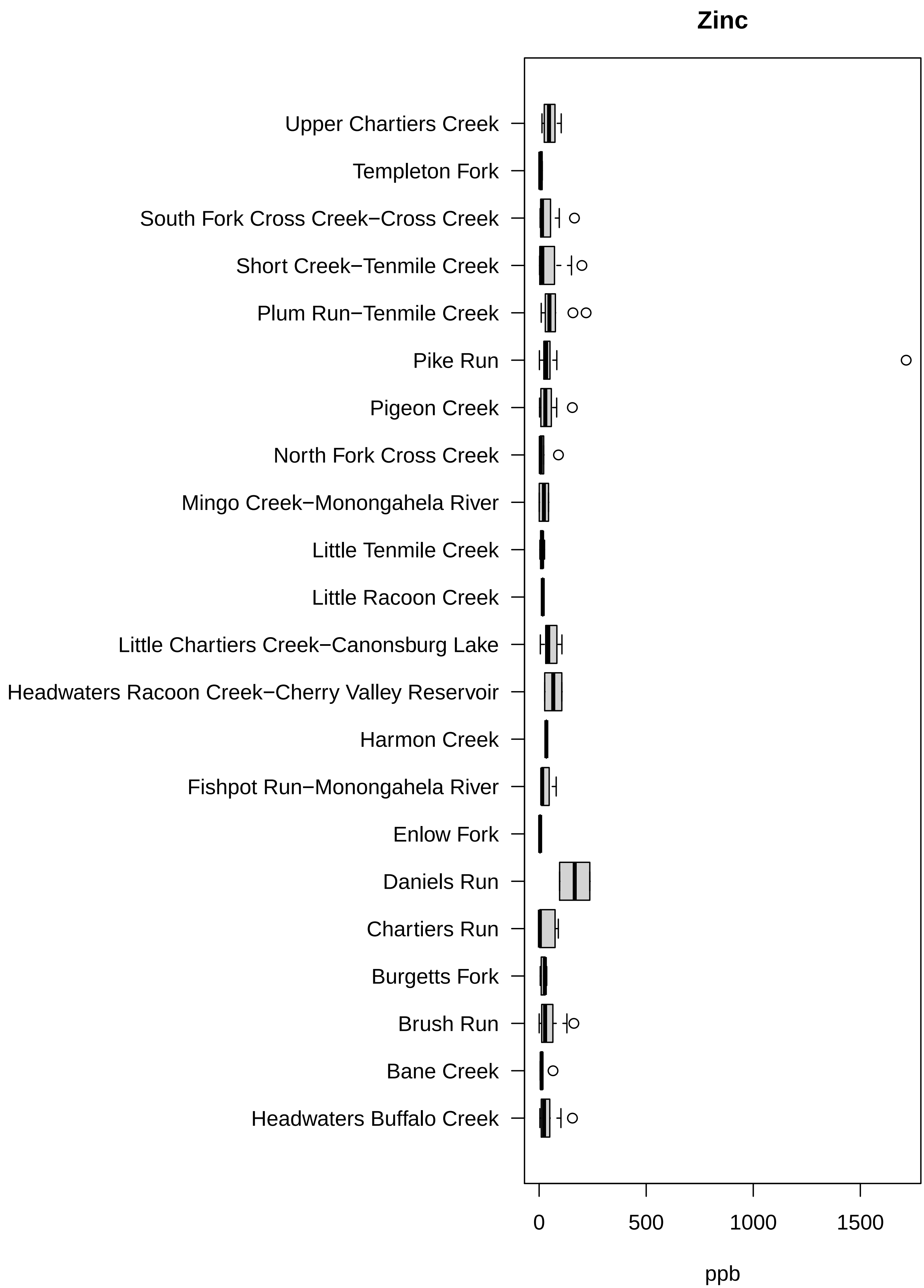






Zinc


Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
500
1000
1500
Spring
Mix
Well
0
500
1000
1500
ppb


Zinc
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
500
1000
1500
ppb

```
[1] "ORIGINAL MODEL - Zinc"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-239.53   -42.21    -8.21    30.03  1394.27

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                 -401.1938   413.3779  -0.971   0.3338
dat$GWellDensity_2kmAvg                                       -1.0969     2.5547  -0.429   0.6685
dat$Altitude_meter                                             0.2130     0.7012   0.304   0.7619
dat$WatershedBane Creek                                      -61.1909    87.6021  -0.699   0.4863
dat$WatershedBrush Run                                        47.2904    71.9953   0.657   0.5126
dat$WatershedBurgetts Fork                                   -65.3288    84.2309  -0.776   0.4396
dat$WatershedChartiers Run                                   -29.4906    98.3509  -0.300   0.7648
dat$WatershedDaniels Run                                     155.3857   139.5733   1.113   0.2679
dat$WatershedEnlow Fork                                      -35.8935    95.1277  -0.377   0.7066
dat$WatershedFishpot Run-Monongahela River                  -129.3907   115.2068  -1.123   0.2637
dat$WatershedHarmon Creek                                     51.2741   188.2797   0.272   0.7859
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir   5.5166   137.1367   0.040   0.9680
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          -65.4791    88.7298  -0.738   0.4621
dat$WatershedLittle Racoon Creek                              -5.9125   212.1229  -0.028   0.9778
dat$WatershedLittle Tenmile Creek                            -83.7311    90.7462  -0.923   0.3581
dat$WatershedMingo Creek-Monongahela River                   -90.1762   121.5860  -0.742   0.4598
dat$WatershedNorth Fork Cross Creek                          -89.2925    81.5821  -1.095   0.2760
dat$WatershedPigeon Creek                                   -107.4220   102.1537  -1.052   0.2952
dat$WatershedPike Run                                         88.1689    99.7934   0.884   0.3788
dat$WatershedPlum Run-Tenmile Creek                          -52.6842    88.4991  -0.595   0.5528
dat$WatershedShort Creek-Tenmile Creek                         1.6852    73.4591   0.023   0.9817
dat$WatershedSouth Fork Cross Creek-Cross Creek              -39.9461    65.7981  -0.607   0.5450
dat$WatershedTempleton Fork                                  -33.0769    77.7945  -0.425   0.6715
dat$WatershedUpper Chartiers Creek                            -0.9698    67.1524  -0.014   0.9885
dat$FormationCasselman Formation                              18.9317   153.1409   0.124   0.9018
dat$FormationGreene Formation                                 -0.8737    52.0114  -0.017   0.9866
dat$FormationMonongahela Group                                73.0314    54.4425   1.341   0.1824
dat$FormationWaynesburg Formation                              5.4288    42.1345   0.129   0.8977
dat$HHWSourceMix                                            -174.9186   101.7091  -1.720   0.0882 .
dat$HHWSourceSpring                                          -47.2907    33.3246  -1.419   0.1586
dat$Precip_inchAvg                                            10.2586     8.5288   1.203   0.2315
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 22601.52)

    Null deviance: 3101274  on 144  degrees of freedom
Residual deviance: 2576573  on 114  degrees of freedom
AIC: 1894.4

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Zinc"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
       Min          1Q      Median          3Q         Max
-0.0255863  -0.0054884   0.0001236   0.0061352   0.0315236

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  9.932e-01  2.616e-02  37.967   <2e-16 ***
dat$GWellDensity_2kmAvg                                      1.936e-05  1.617e-04   0.120   0.9049
dat$Altitude_meter                                          -1.142e-05  4.438e-05  -0.257   0.7973
dat$WatershedBane Creek                                      7.534e-03  5.544e-03   1.359   0.1769
dat$WatershedBrush Run                                      -7.590e-04  4.556e-03  -0.167   0.8680
dat$WatershedBurgetts Fork                                   7.810e-04  5.331e-03   0.147   0.8838
dat$WatershedChartiers Run                                   2.291e-03  6.224e-03   0.368   0.7135
dat$WatershedDaniels Run                                    -1.596e-02  8.833e-03  -1.807   0.0734 .
dat$WatershedEnlow Fork                                      1.240e-02  6.020e-03   2.059   0.0417 *
dat$WatershedFishpot Run-Monongahela River                   9.334e-04  7.291e-03   0.128   0.8984
dat$WatershedHarmon Creek                                   -7.394e-03  1.192e-02  -0.621   0.5362
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -8.708e-03  8.679e-03  -1.003   0.3178
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         -3.716e-04  5.615e-03  -0.066   0.9474
dat$WatershedLittle Racoon Creek                            -4.839e-03  1.342e-02  -0.360   0.7192
dat$WatershedLittle Tenmile Creek                            5.655e-03  5.743e-03   0.985   0.3268
dat$WatershedMingo Creek-Monongahela River                   1.031e-02  7.695e-03   1.339   0.1831
dat$WatershedNorth Fork Cross Creek                          5.125e-03  5.163e-03   0.993   0.3230
dat$WatershedPigeon Creek                                    1.842e-03  6.465e-03   0.285   0.7762
dat$WatershedPike Run                                       -2.591e-03  6.315e-03  -0.410   0.6824
dat$WatershedPlum Run-Tenmile Creek                         -4.990e-03  5.601e-03  -0.891   0.3748
dat$WatershedShort Creek-Tenmile Creek                       3.858e-03  4.649e-03   0.830   0.4083
dat$WatershedSouth Fork Cross Creek-Cross Creek              5.746e-04  4.164e-03   0.138   0.8905
dat$WatershedTempleton Fork                                  9.125e-03  4.923e-03   1.853   0.0664 .
dat$WatershedUpper Chartiers Creek                          -4.629e-03  4.250e-03  -1.089   0.2784
dat$FormationCasselman Formation                             4.398e-03  9.691e-03   0.454   0.6508
dat$FormationGreene Formation                               -2.894e-03  3.292e-03  -0.879   0.3811
dat$FormationMonongahela Group                               8.809e-04  3.445e-03   0.256   0.7987
dat$FormationWaynesburg Formation                            8.392e-04  2.666e-03   0.315   0.7535
dat$HHWSourceMix                                             4.535e-03  6.437e-03   0.705   0.4825
dat$HHWSourceSpring                                          2.369e-03  2.109e-03   1.123   0.2636
dat$Precip_inchAvg                                          -3.197e-04  5.397e-04  -0.592   0.5548
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 9.051748e-05)

    Null deviance: 0.013442  on 144  degrees of freedom
Residual deviance: 0.010319  on 114  degrees of freedom
AIC: -909.33

Number of Fisher Scoring iterations: 2
```

Bromide

Skewness: 9.2325

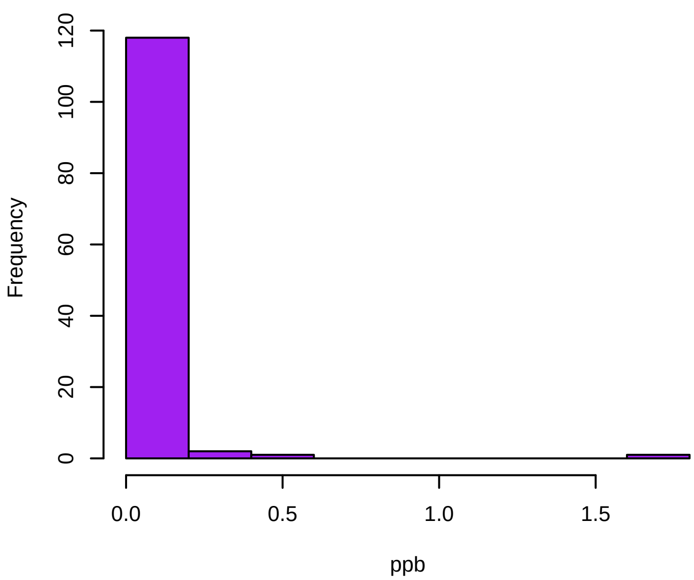
Kurtosis: 94.0335

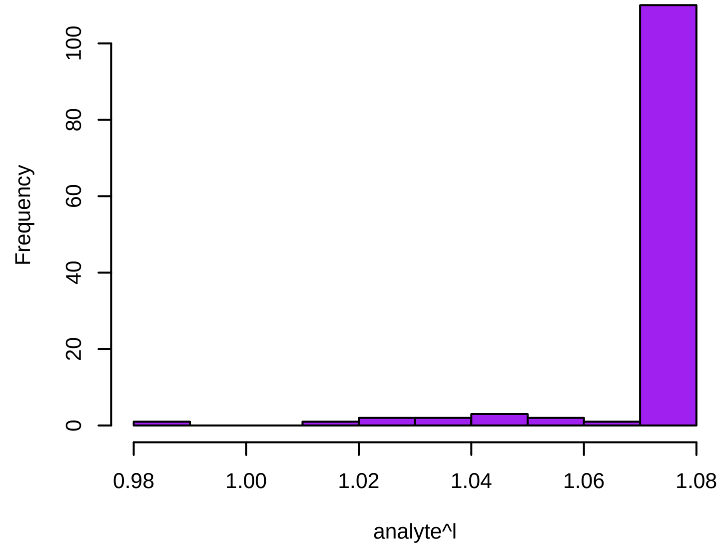
Bromide Box−Cox

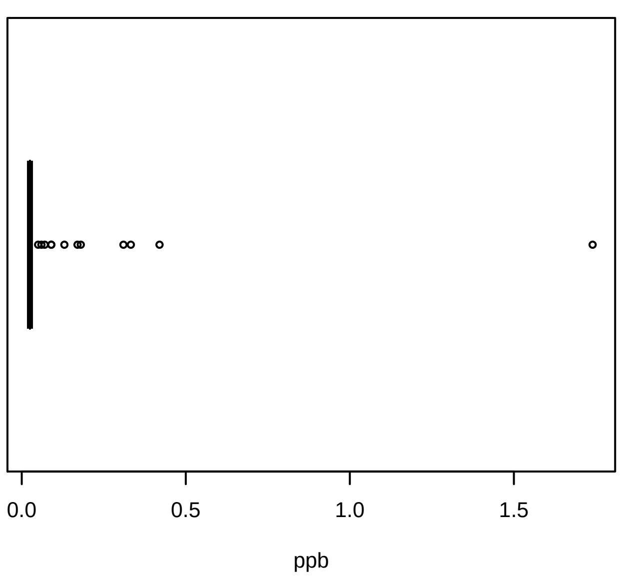
Skewness: −3.8861

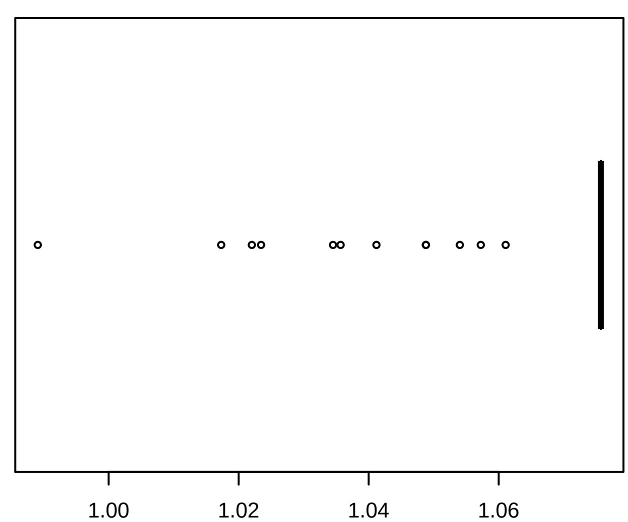
Kurtosis: 18.8902

Optimal lambda: −0.01979



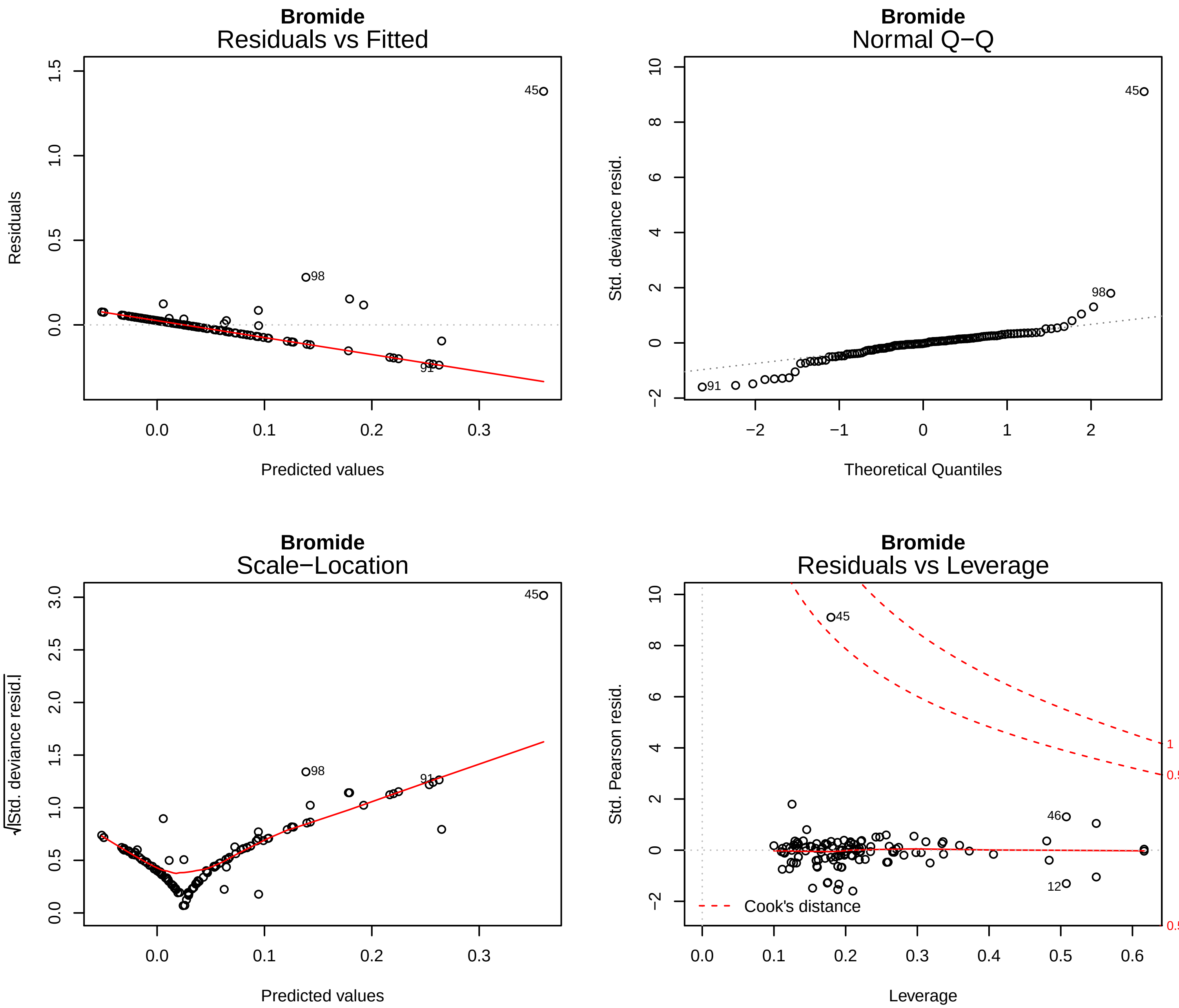






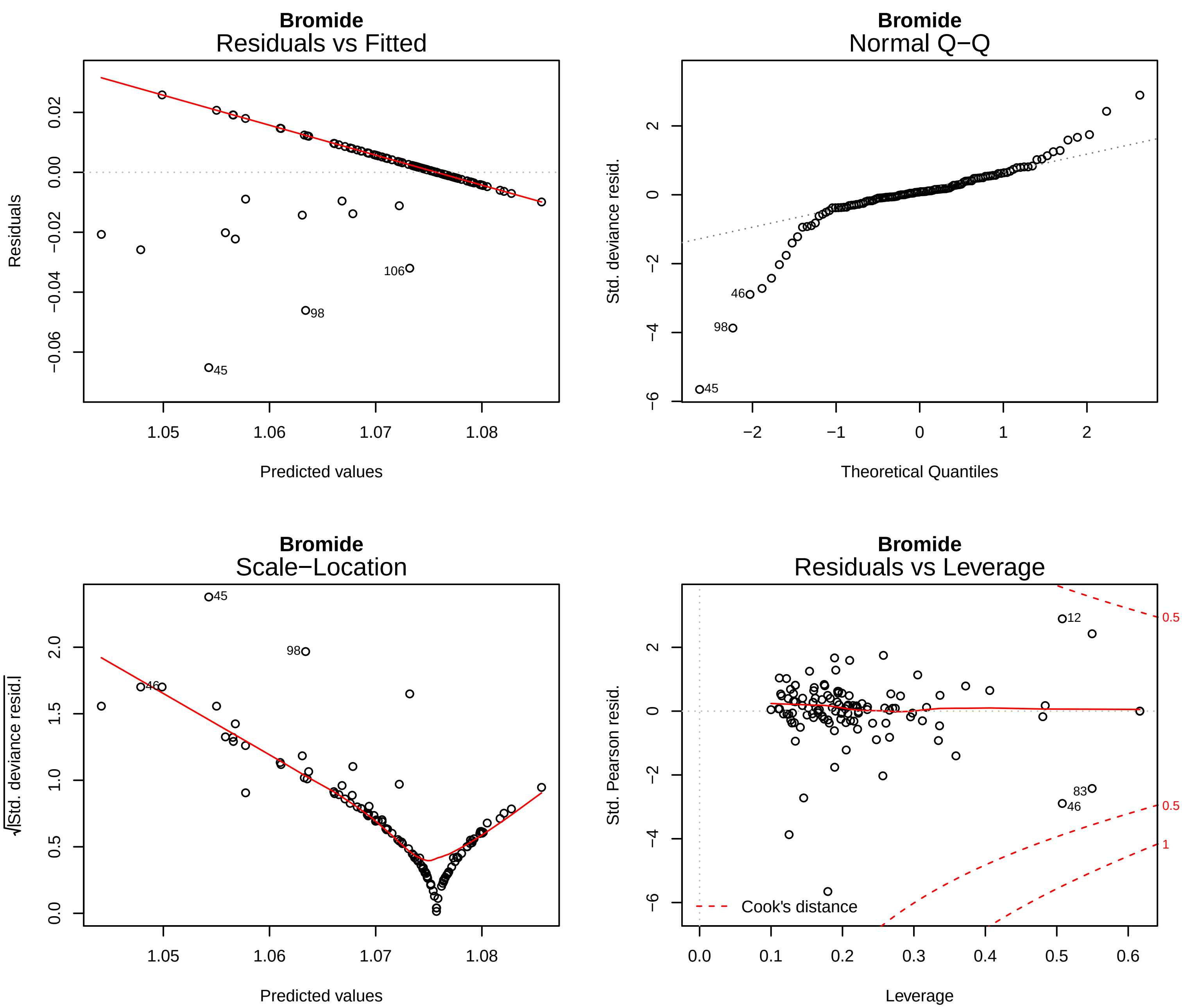
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

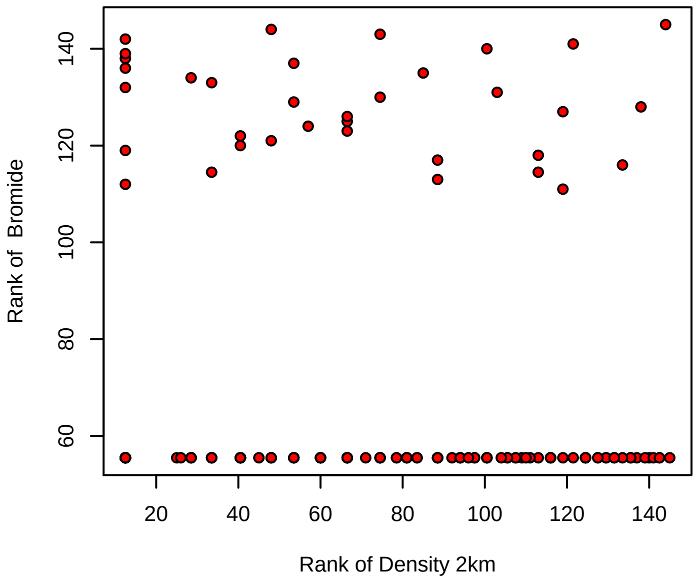
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



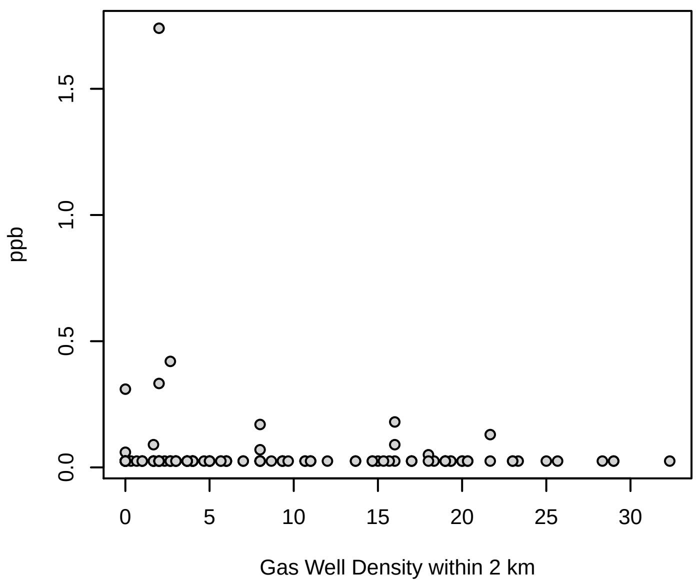


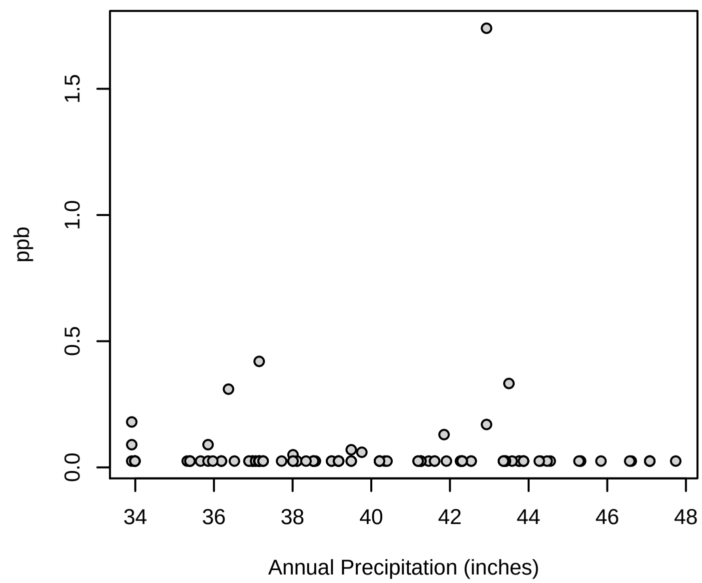
Bromide

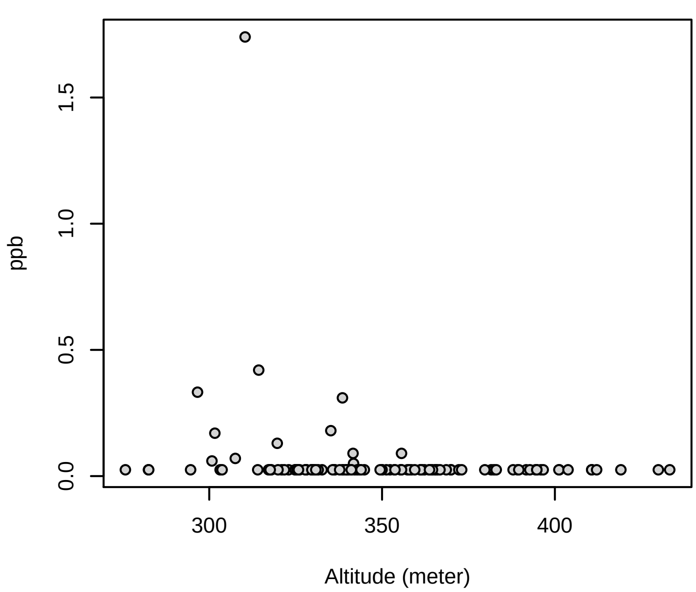
Kendalls Tau Rank Correlation

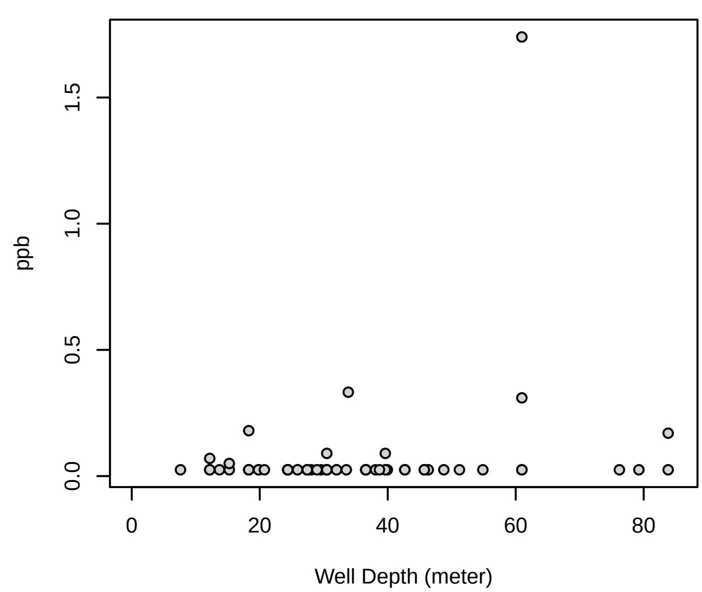
p−value: 0.692

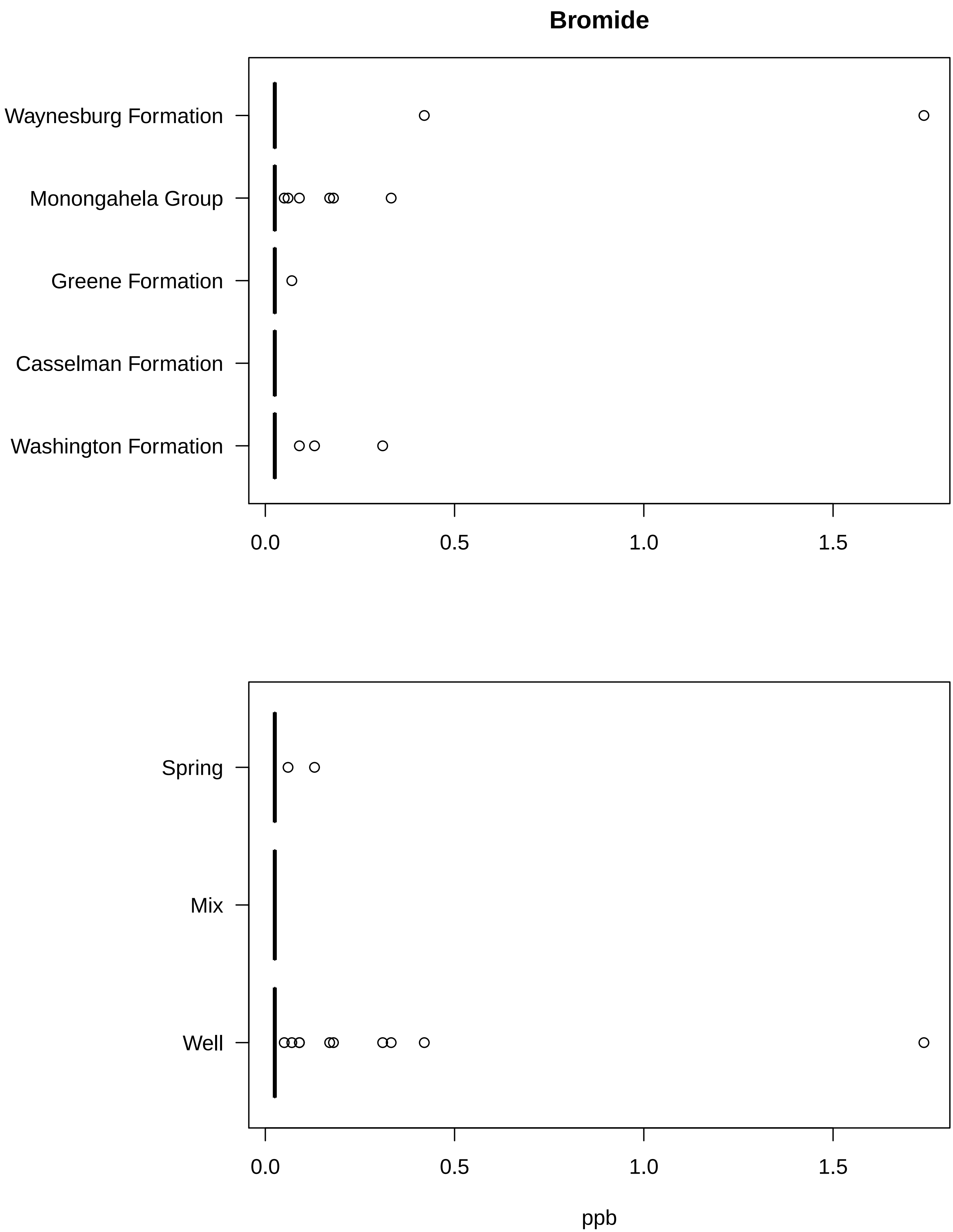
Tau: −0.0294

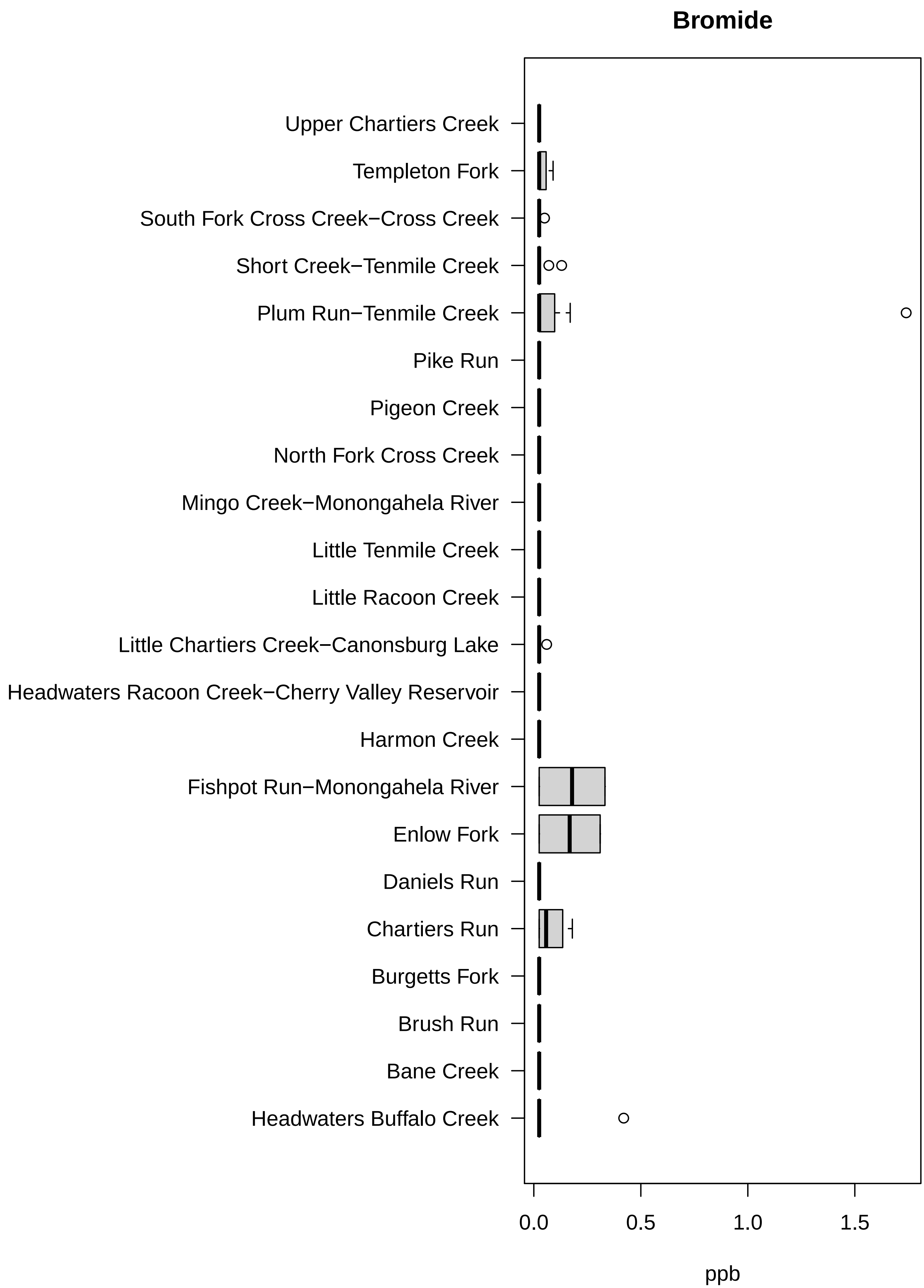









Bromide
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0.0
0.5
1.0
1.5
Spring
Mix
Well
0.0
0.5
1.0
1.5
ppb


Bromide
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0.0
0.5
1.0
1.5
ppb

```
[1] "ORIGINAL MODEL - Bromide"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.23764  -0.04125  -0.00041   0.02891   1.38003

Coefficients: (1 not defined because of singularities)
                                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  1.575e-01  4.812e-01   0.327   0.7442
dat$GWellDensity_2kmAvg                                     -1.206e-03  3.139e-03  -0.384   0.7017
dat$Altitude_meter                                           1.045e-05  8.932e-04   0.012   0.9907
dat$WatershedBane Creek                                      2.160e-02  1.087e-01   0.199   0.8430
dat$WatershedBrush Run                                      -6.890e-03  8.337e-02  -0.083   0.9343
dat$WatershedBurgetts Fork                                  -2.854e-02  1.049e-01  -0.272   0.7861
dat$WatershedChartiers Run                                   4.868e-02  1.179e-01   0.413   0.6806
dat$WatershedDaniels Run                                    -5.467e-02  1.607e-01  -0.340   0.7346
dat$WatershedEnlow Fork                                      1.494e-01  1.269e-01   1.177   0.2424
dat$WatershedFishpot Run-Monongahela River                   1.483e-01  1.555e-01   0.954   0.3428
dat$WatershedHarmon Creek                                    2.566e-02  2.120e-01   0.121   0.9039
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -1.092e-01  1.824e-01  -0.599   0.5508
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          1.627e-02  1.024e-01   0.159   0.8741
dat$WatershedLittle Racoon Creek                             2.821e-02  1.775e-01   0.159   0.8741
dat$WatershedLittle Tenmile Creek                           -3.615e-02  1.082e-01  -0.334   0.7390
dat$WatershedMingo Creek-Monongahela River                   2.869e-02  1.945e-01   0.148   0.8830
dat$WatershedNorth Fork Cross Creek                         -2.729e-02  1.004e-01  -0.272   0.7863
dat$WatershedPigeon Creek                                   -5.230e-02  1.248e-01  -0.419   0.6762
dat$WatershedPike Run                                        6.566e-03  1.197e-01   0.055   0.9564
dat$WatershedPlum Run-Tenmile Creek                          2.393e-01  1.104e-01   2.168   0.0327 *
dat$WatershedShort Creek-Tenmile Creek                       4.377e-02  9.405e-02   0.465   0.6427
dat$WatershedSouth Fork Cross Creek-Cross Creek             -1.876e-02  8.010e-02  -0.234   0.8153
dat$WatershedTempleton Fork                                  2.182e-02  1.077e-01   0.203   0.8399
dat$WatershedUpper Chartiers Creek                          -6.059e-02  8.216e-02  -0.737   0.4627
dat$FormationCasselman Formation                                    NA         NA      NA       NA
dat$FormationGreene Formation                               -4.204e-03  6.212e-02  -0.068   0.9462
dat$FormationMonongahela Group                               1.396e-02  6.678e-02   0.209   0.8348
dat$FormationWaynesburg Formation                            1.016e-01  5.239e-02   1.939   0.0555 .
dat$HHWSourceMix                                            -4.471e-02  1.142e-01  -0.391   0.6964
dat$HHWSourceSpring                                         -3.693e-02  3.886e-02  -0.950   0.3445
dat$Precip_inchAvg                                          -3.244e-03  1.033e-02  -0.314   0.7543
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.02798891)

    Null deviance: 3.2499  on 121  degrees of freedom
Residual deviance: 2.5750  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: -62.477
```

```
Number of Fisher Scoring iterations: 2

[1] "BOX-COX MODEL - Bromide"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
      Min         1Q     Median         3Q        Max  
-0.065179  -0.002279   0.000854   0.005037   0.025842  

Coefficients: (1 not defined because of singularities)
                                                          Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                              1.028e+00  3.661e-02  28.083   <2e-16 ***
dat$GWellDensity_2kmAvg                                  2.437e-05  2.388e-04   0.102   0.9189    
dat$Altitude_meter                                       4.724e-05  6.796e-05   0.695   0.4887    
dat$WatershedBane Creek                                 -1.678e-03  8.273e-03  -0.203   0.8397    
dat$WatershedBrush Run                                   4.202e-03  6.343e-03   0.662   0.5093    
dat$WatershedBurgetts Fork                               7.708e-03  7.978e-03   0.966   0.3365    
dat$WatershedChartiers Run                              -7.523e-03  8.970e-03  -0.839   0.4038    
dat$WatershedDaniels Run                                 2.506e-03  1.223e-02   0.205   0.8381    
dat$WatershedEnlow Fork                                 -2.506e-02  9.657e-03  -2.595   0.0110 *  
dat$WatershedFishpot Run-Monongahela River              -2.091e-02  1.183e-02  -1.768   0.0805 .  
dat$WatershedHarmon Creek                                2.325e-03  1.613e-02   0.144   0.8857    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  9.448e-03  1.388e-02   0.681   0.4977    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     -4.336e-03  7.789e-03  -0.557   0.5791    
dat$WatershedLittle Racoon Creek                         1.137e-03  1.351e-02   0.084   0.9331    
dat$WatershedLittle Tenmile Creek                        3.865e-03  8.231e-03   0.470   0.6398    
dat$WatershedMingo Creek-Monongahela River               1.777e-03  1.480e-02   0.120   0.9046    
dat$WatershedNorth Fork Cross Creek                      6.212e-03  7.635e-03   0.814   0.4180    
dat$WatershedPigeon Creek                                3.915e-03  9.497e-03   0.412   0.6811    
dat$WatershedPike Run                                   -2.996e-04  9.108e-03  -0.033   0.9738    
dat$WatershedPlum Run-Tenmile Creek                     -1.292e-02  8.399e-03  -1.538   0.1274    
dat$WatershedShort Creek-Tenmile Creek                  -4.276e-03  7.156e-03  -0.598   0.5516    
dat$WatershedSouth Fork Cross Creek-Cross Creek          4.719e-03  6.094e-03   0.774   0.4407    
dat$WatershedTempleton Fork                             -5.962e-03  8.193e-03  -0.728   0.4687    
dat$WatershedUpper Chartiers Creek                       6.714e-03  6.251e-03   1.074   0.2856    
dat$FormationCasselman Formation                                NA         NA      NA       NA    
dat$FormationGreene Formation                            2.014e-03  4.726e-03   0.426   0.6711    
dat$FormationMonongahela Group                          -3.446e-03  5.080e-03  -0.678   0.4992    
dat$FormationWaynesburg Formation                       -5.283e-03  3.986e-03  -1.325   0.1883    
dat$HHWSourceMix                                         4.982e-03  8.691e-03   0.573   0.5678    
dat$HHWSourceSpring                                      4.826e-03  2.957e-03   1.632   0.1060    
dat$Precip_inchAvg                                       6.923e-04  7.861e-04   0.881   0.3808    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.0001620025)

    Null deviance: 0.021650  on 121  degrees of freedom
Residual deviance: 0.014904  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: -691.01
```

Number of Fisher Scoring iterations: 2

Chloride

Skewness: 3.0287

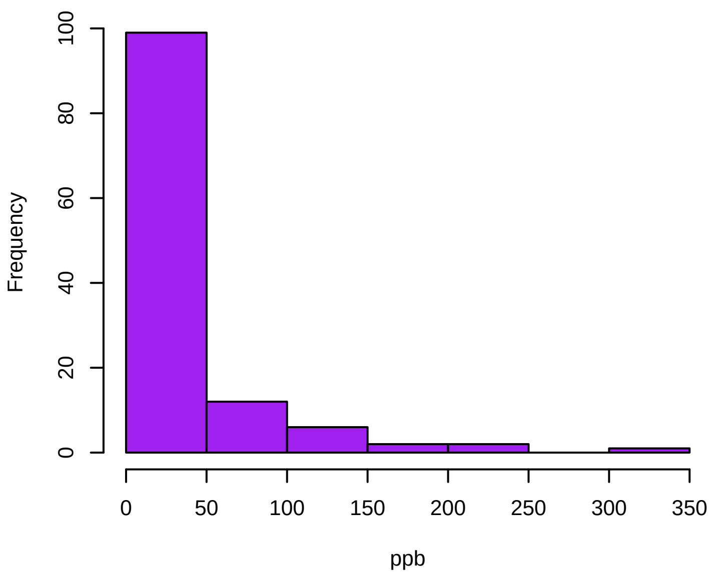
Kurtosis: 14.0589

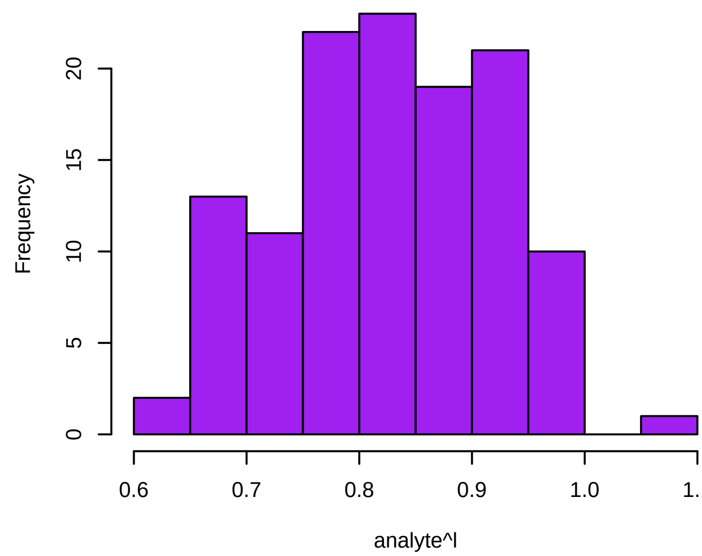
Chloride Box−Cox

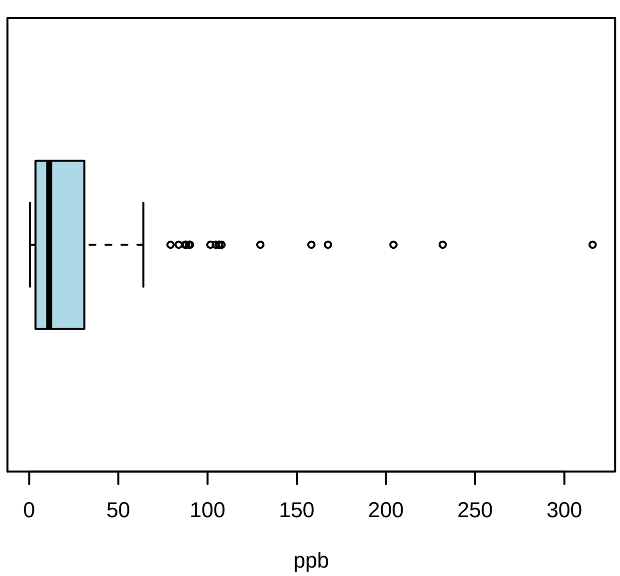
Skewness: −0.0320

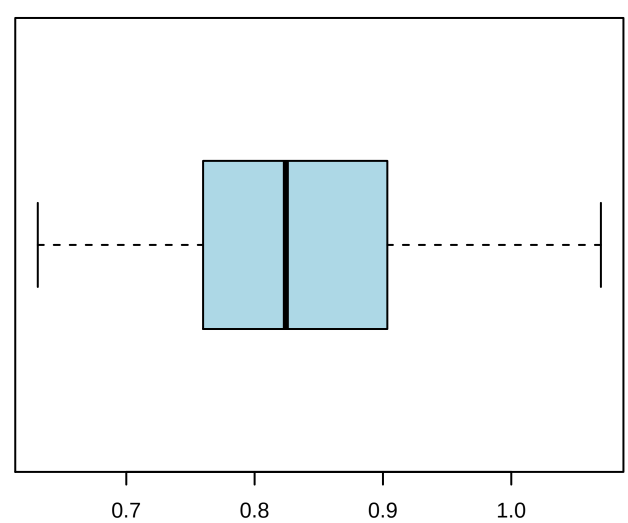
Kurtosis: 2.1884

Optimal lambda: −0.08



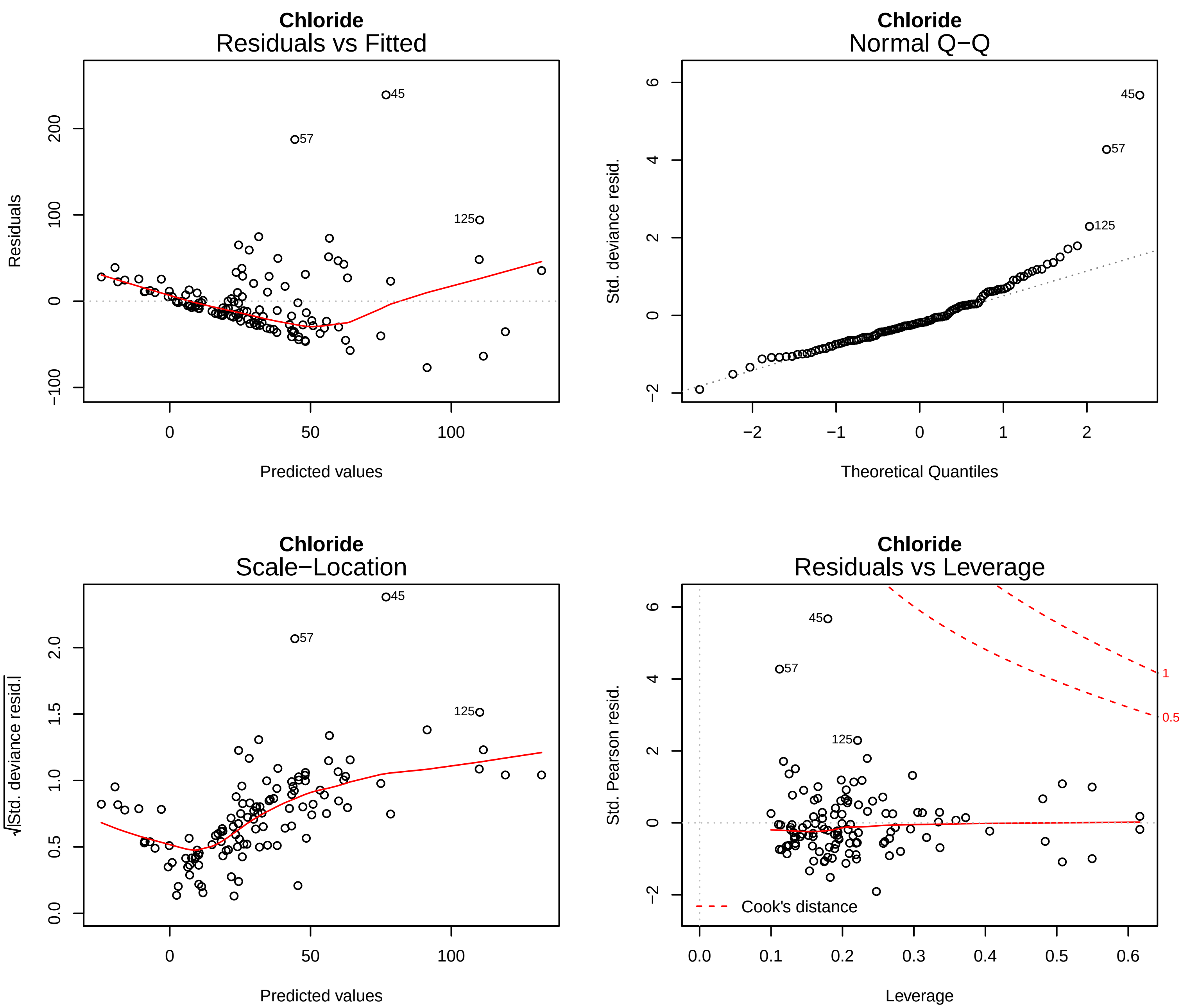






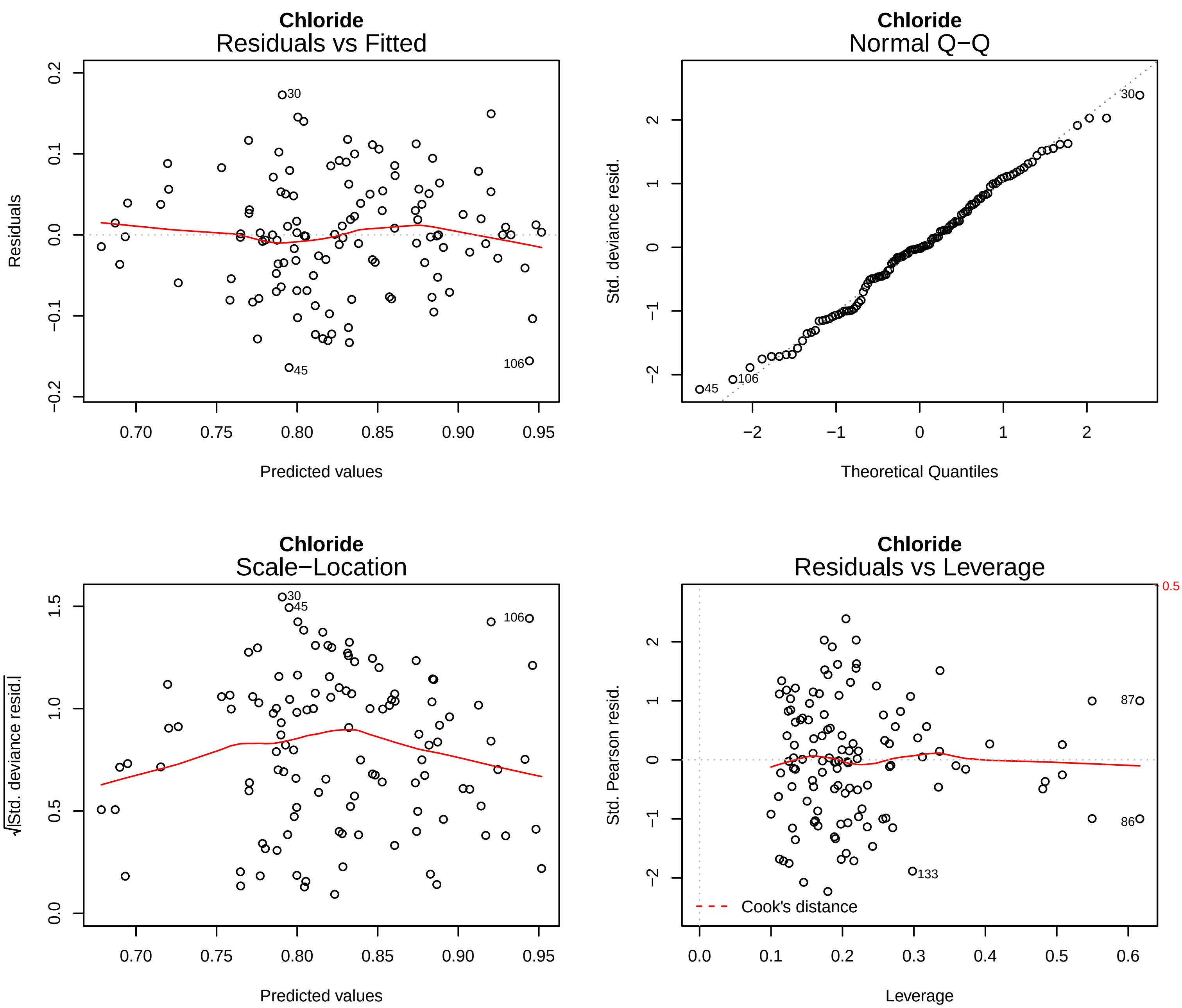
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

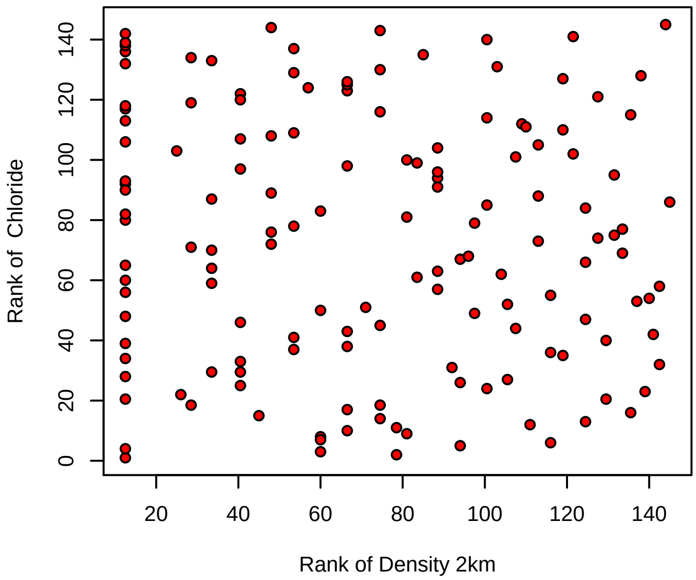
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



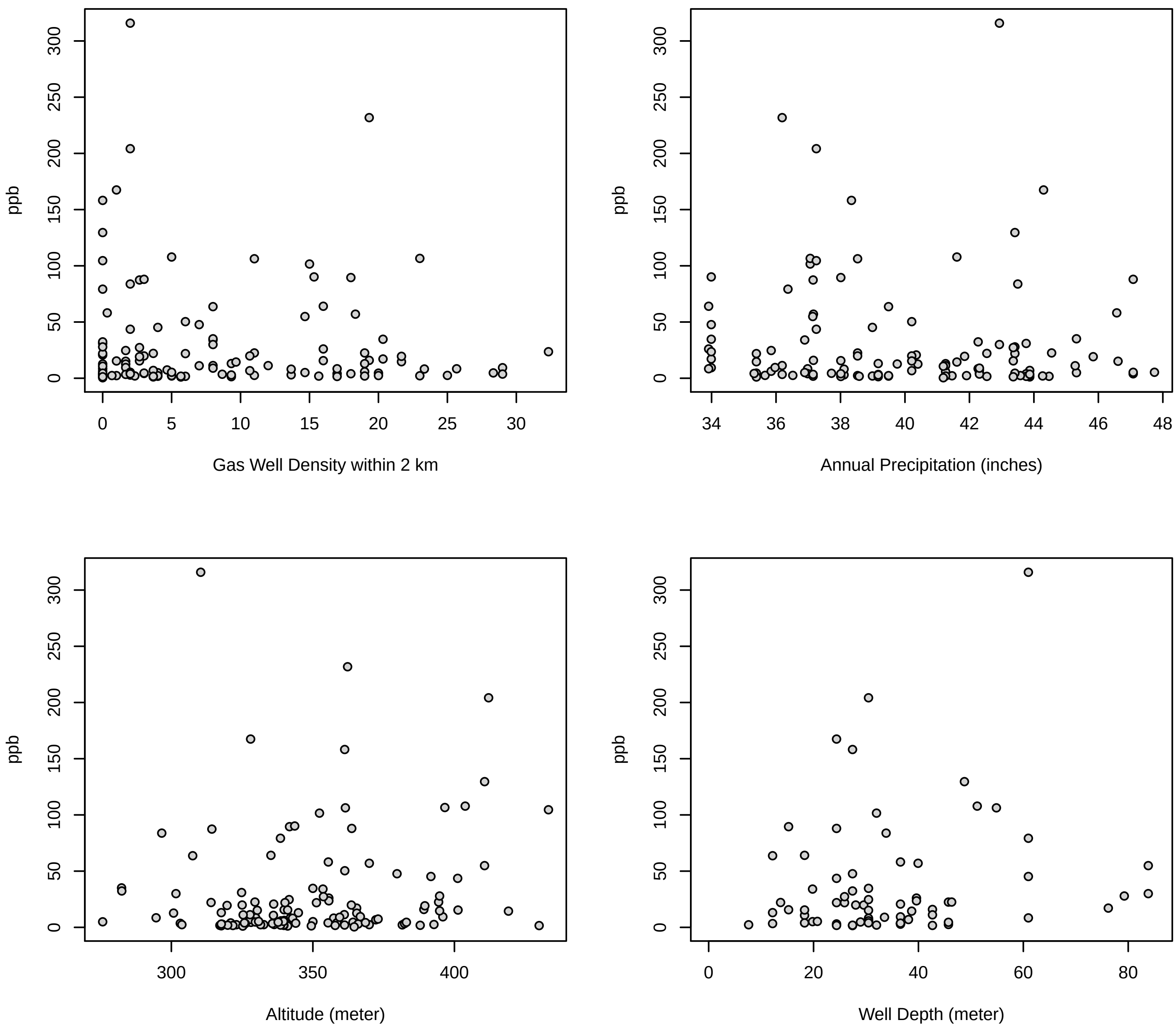


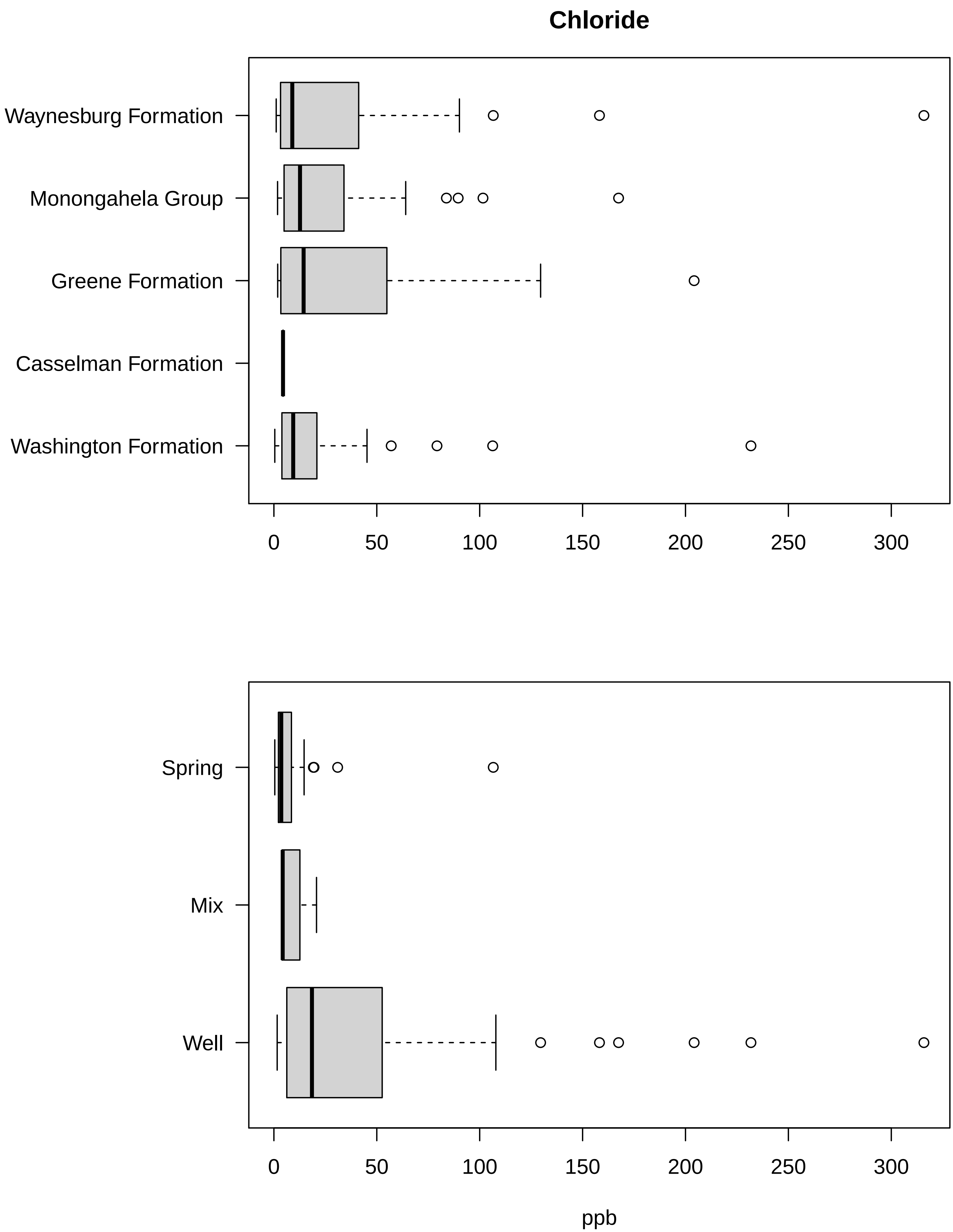
Chloride

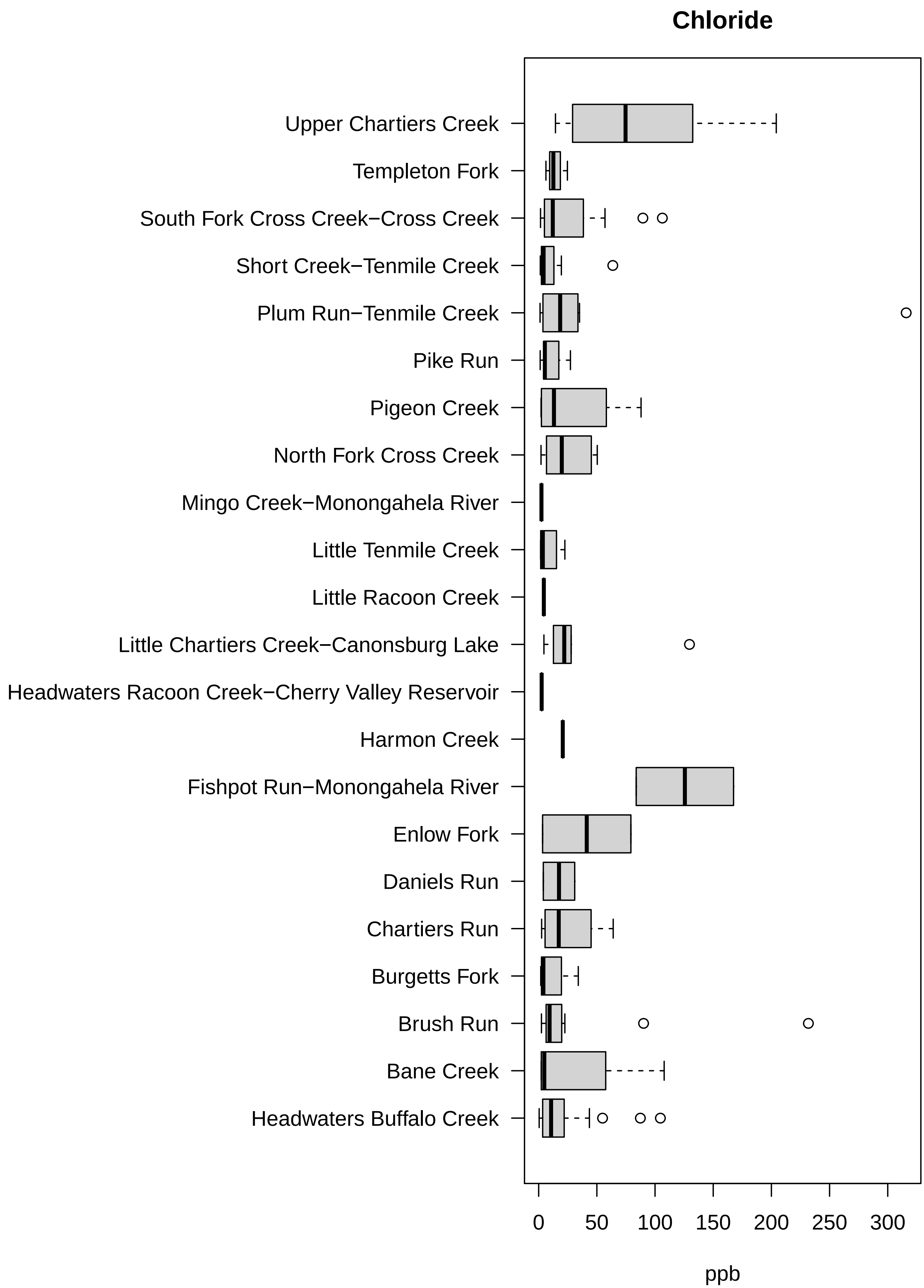
Kendalls Tau Rank Correlation

p−value: 0.783

Tau: −0.0172




Chloride
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
50
100
150
200
250
300
Spring
Mix
Well
0
50
100
150
200
250
300
ppb


Chloride
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
50
100
150
200
250
300
ppb

```
[1] "ORIGINAL MODEL - Chloride"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-76.979  -23.286   -6.991   11.430  239.028

Coefficients: (1 not defined because of singularities)
                                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              -43.7287   133.8002  -0.327  0.74455
dat$GWellDensity_2kmAvg                                   -1.8572     0.8728  -2.128  0.03601 *
dat$Altitude_meter                                         0.3928     0.2484   1.582  0.11719
dat$WatershedBane Creek                                   22.6729    30.2372   0.750  0.45527
dat$WatershedBrush Run                                    41.7408    23.1831   1.800  0.07506 .
dat$WatershedBurgetts Fork                                -7.8366    29.1605  -0.269  0.78873
dat$WatershedChartiers Run                                20.5005    32.7865   0.625  0.53334
dat$WatershedDaniels Run                                  22.8781    44.6981   0.512  0.60999
dat$WatershedEnlow Fork                                   19.2100    35.2959   0.544  0.58758
dat$WatershedFishpot Run-Monongahela River               109.5074    43.2383   2.533  0.01301 *
dat$WatershedHarmon Creek                                 25.0139    58.9437   0.424  0.67229
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -43.4483    50.7240  -0.857  0.39391
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       13.9547    28.4678   0.490  0.62517
dat$WatershedLittle Racoon Creek                          12.6571    49.3616   0.256  0.79820
dat$WatershedLittle Tenmile Creek                          5.5452    30.0832   0.184  0.85416
dat$WatershedMingo Creek-Monongahela River                 9.7420    54.0834   0.180  0.85745
dat$WatershedNorth Fork Cross Creek                       -3.3597    27.9068  -0.120  0.90444
dat$WatershedPigeon Creek                                  7.8664    34.7128   0.227  0.82123
dat$WatershedPike Run                                      4.7823    33.2902   0.144  0.88609
dat$WatershedPlum Run-Tenmile Creek                       58.5166    30.6974   1.906  0.05974 .
dat$WatershedShort Creek-Tenmile Creek                    31.7376    26.1538   1.213  0.22805
dat$WatershedSouth Fork Cross Creek-Cross Creek           17.6163    22.2741   0.791  0.43104
dat$WatershedTempleton Fork                               -6.0745    29.9467  -0.203  0.83971
dat$WatershedUpper Chartiers Creek                        60.3287    22.8474   2.641  0.00973 **
dat$FormationCasselman Formation                               NA         NA      NA       NA
dat$FormationGreene Formation                             -2.8830    17.2742  -0.167  0.86782
dat$FormationMonongahela Group                            12.7499    18.5686   0.687  0.49404
dat$FormationWaynesburg Formation                         14.9908    14.5676   1.029  0.30615
dat$HHWSourceMix                                         -38.4877    31.7652  -1.212  0.22876
dat$HHWSourceSpring                                      -23.4398    10.8063  -2.169  0.03265 *
dat$Precip_inchAvg                                        -1.6576     2.8731  -0.577  0.56539
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 2164.229)

    Null deviance: 296575  on 121  degrees of freedom
Residual deviance: 199109  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: 1310.7
```

```
Number of Fisher Scoring iterations: 2

[1] "BOX-COX MODEL - Chloride"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.16397  -0.04604   0.00000   0.05042   0.17282  

Coefficients: (1 not defined because of singularities)
                                                               Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                                   0.7142911  0.2333371   3.061  0.00289 ** 
dat$GWellDensity_2kmAvg                                       0.0006078  0.0015220   0.399  0.69057    
dat$Altitude_meter                                           -0.0004184  0.0004332  -0.966  0.33662    
dat$WatershedBane Creek                                       0.0001625  0.0527313   0.003  0.99755    
dat$WatershedBrush Run                                       -0.0313722  0.0404295  -0.776  0.43975    
dat$WatershedBurgetts Fork                                    0.0537941  0.0508536   1.058  0.29291    
dat$WatershedChartiers Run                                    0.0136031  0.0571772   0.238  0.81248    
dat$WatershedDaniels Run                                     -0.1529257  0.0779500  -1.962  0.05280 .  
dat$WatershedEnlow Fork                                      -0.0470751  0.0615533  -0.765  0.44636    
dat$WatershedFishpot Run-Monongahela River                   -0.1556027  0.0754042  -2.064  0.04187 *  
dat$WatershedHarmon Creek                                    -0.1476804  0.1027933  -1.437  0.15420    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.1324659  0.0884587   1.497  0.13769    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          -0.0631321  0.0496457  -1.272  0.20670    
dat$WatershedLittle Racoon Creek                             -0.0280366  0.0860828  -0.326  0.74540    
dat$WatershedLittle Tenmile Creek                            -0.0104858  0.0524628  -0.200  0.84202    
dat$WatershedMingo Creek-Monongahela River                   -0.0005138  0.0943172  -0.005  0.99567    
dat$WatershedNorth Fork Cross Creek                           0.0029045  0.0486672   0.060  0.95254    
dat$WatershedPigeon Creek                                    -0.0542201  0.0605364  -0.896  0.37277    
dat$WatershedPike Run                                        -0.0565559  0.0580554  -0.974  0.33253    
dat$WatershedPlum Run-Tenmile Creek                          -0.0757792  0.0535339  -1.416  0.16029    
dat$WatershedShort Creek-Tenmile Creek                       -0.0124266  0.0456102  -0.272  0.78588    
dat$WatershedSouth Fork Cross Creek-Cross Creek               0.0019963  0.0388442   0.051  0.95912    
dat$WatershedTempleton Fork                                  -0.0222903  0.0522246  -0.427  0.67051    
dat$WatershedUpper Chartiers Creek                           -0.0925948  0.0398441  -2.324  0.02233 *  
dat$FormationCasselman Formation                                     NA         NA      NA       NA    
dat$FormationGreene Formation                                 0.0002576  0.0301249   0.009  0.99319    
dat$FormationMonongahela Group                               -0.0279995  0.0323822  -0.865  0.38948    
dat$FormationWaynesburg Formation                             0.0095100  0.0254048   0.374  0.70901    
dat$HHWSourceMix                                              0.1276927  0.0553961   2.305  0.02341 *  
dat$HHWSourceSpring                                           0.0941857  0.0188453   4.998 2.75e-06 ***
dat$Precip_inchAvg                                            0.0064199  0.0050105   1.281  0.20332    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.006581993)

    Null deviance: 1.05479  on 121  degrees of freedom
Residual deviance: 0.60554  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: -239.07
```

Number of Fisher Scoring iterations: 2

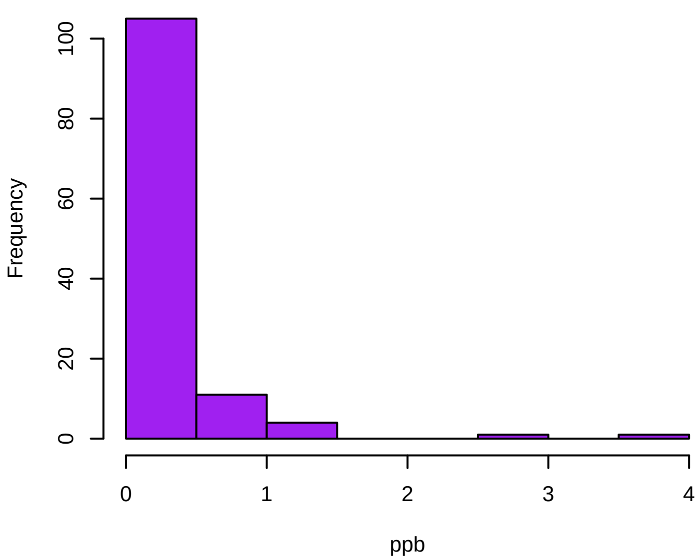
Fluoride

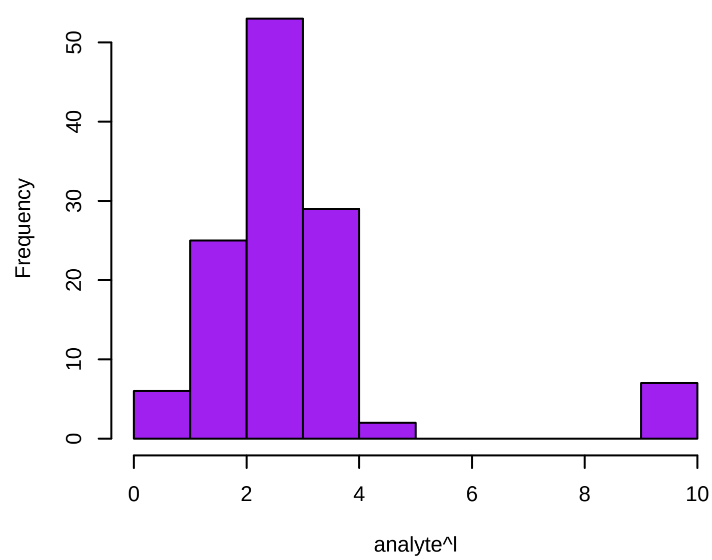
Skewness: 5.5572
Kurtosis: 40.5260

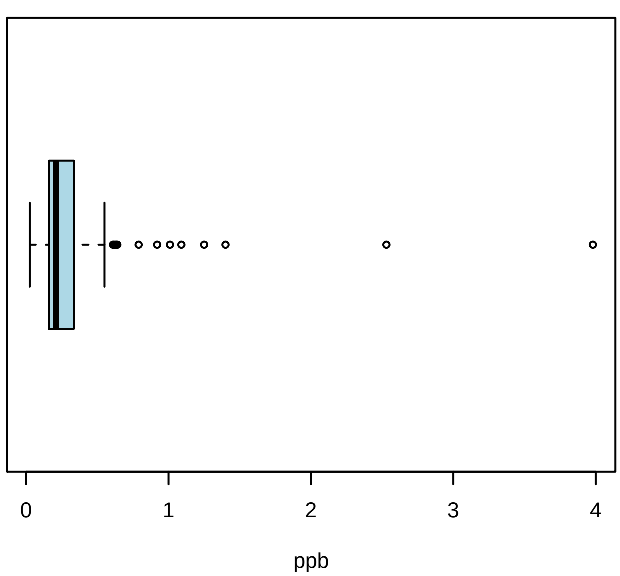
Fluoride Box−Cox

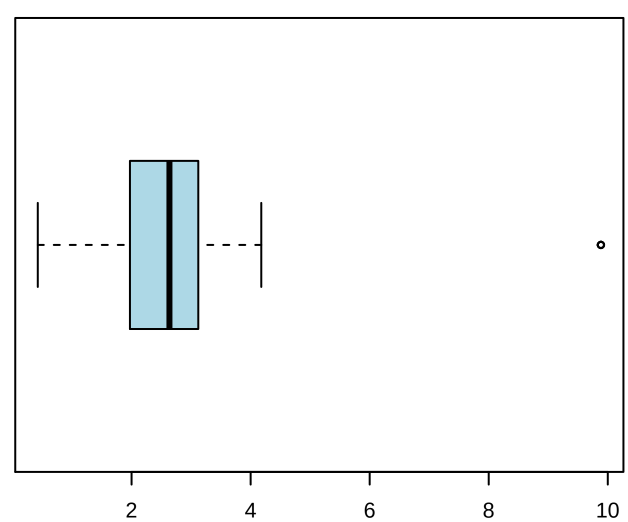
Skewness: 2.7681
Kurtosis: 10.9407

Optimal lambda: −0.6211



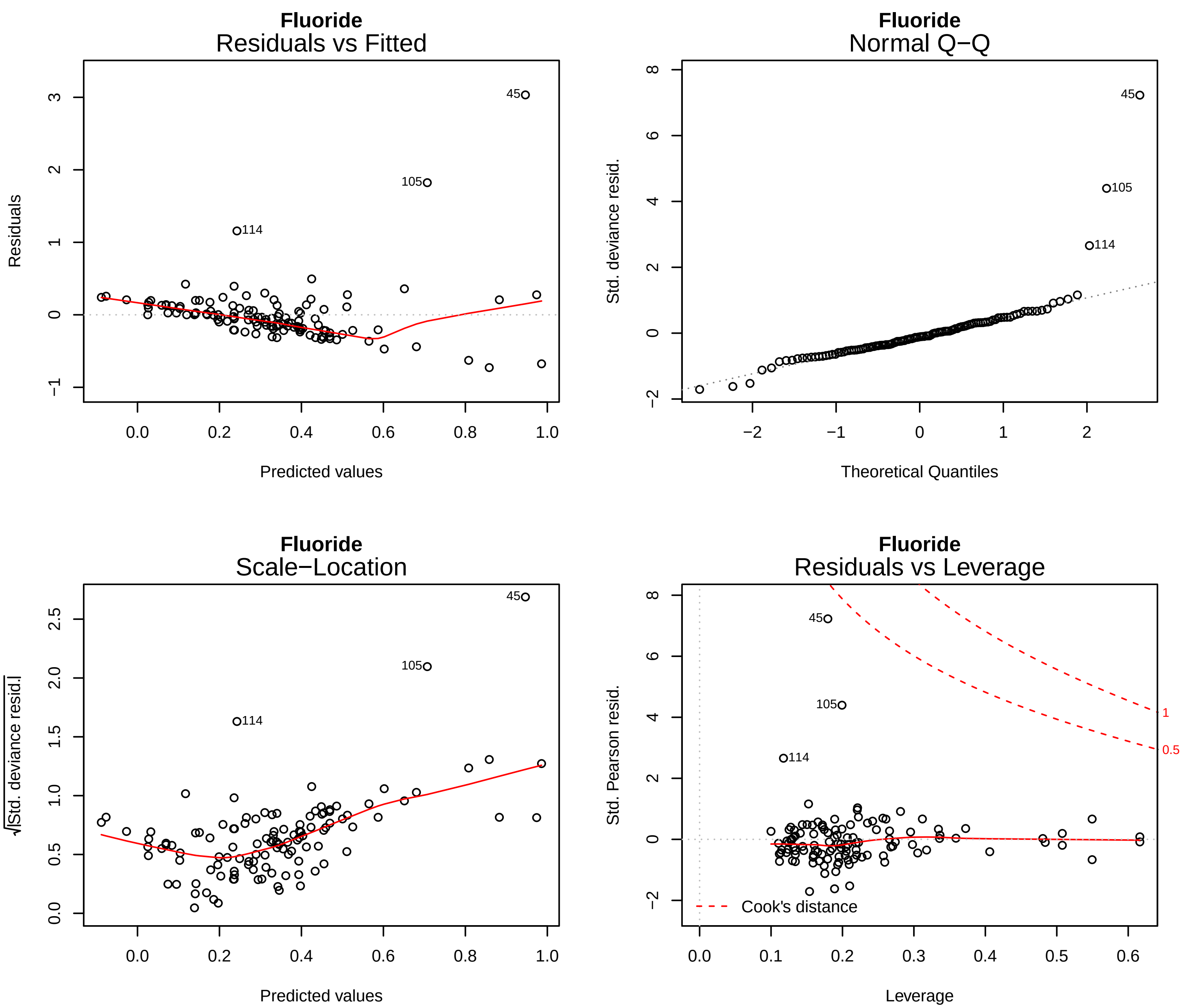






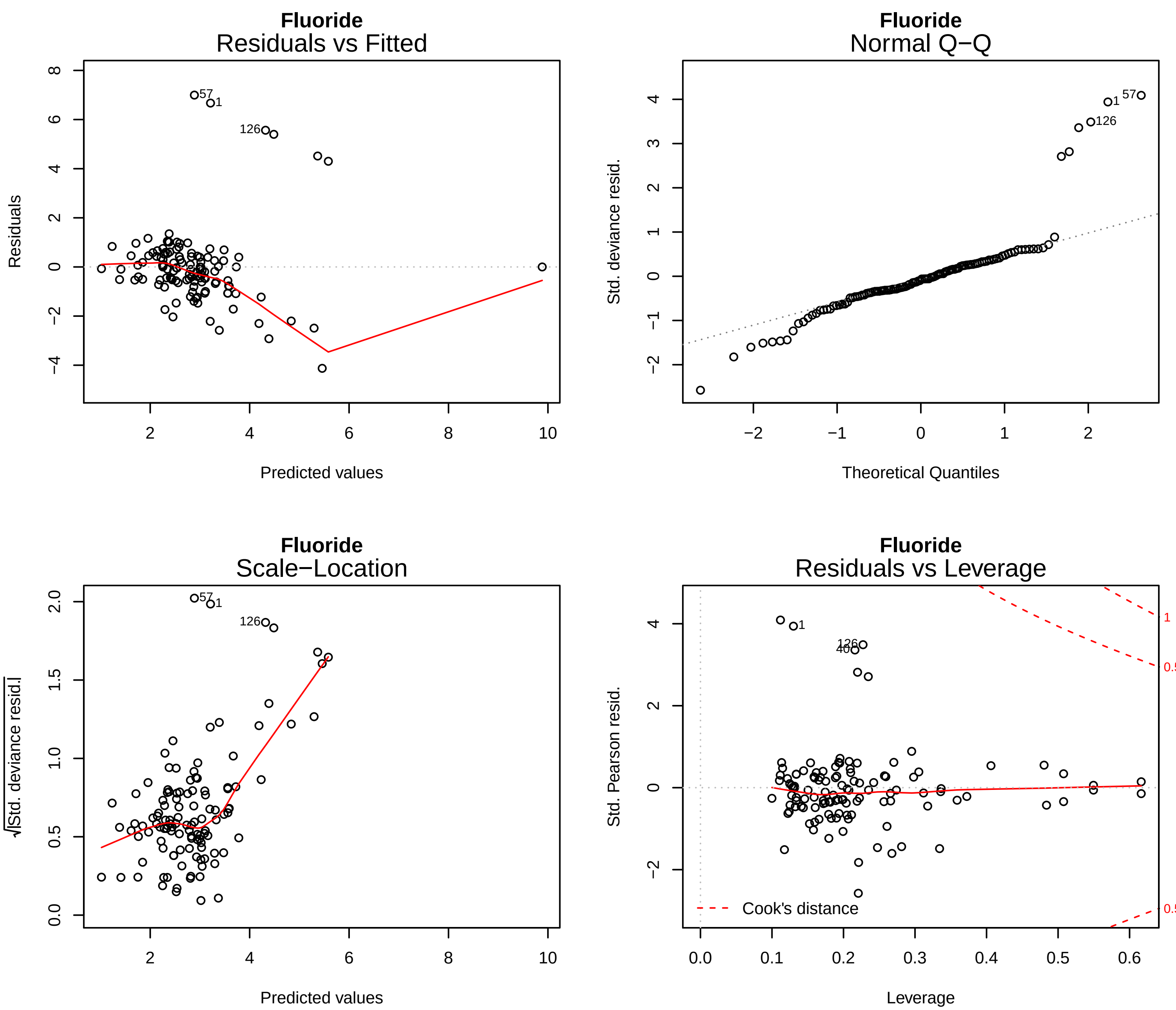
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

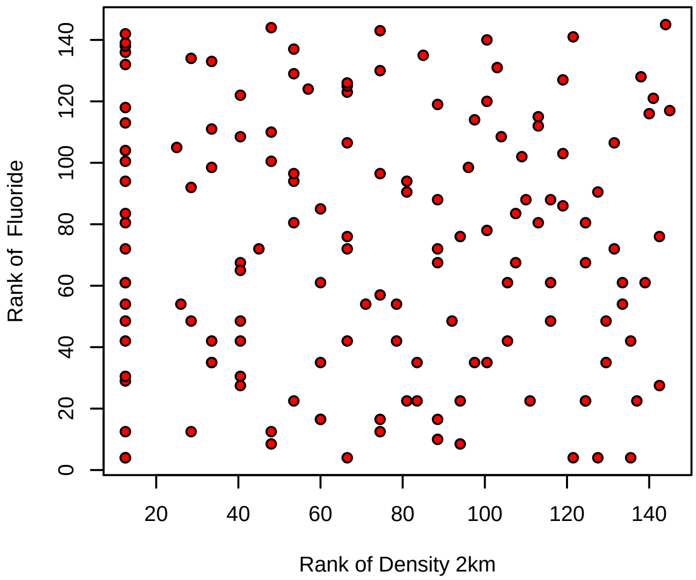
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model



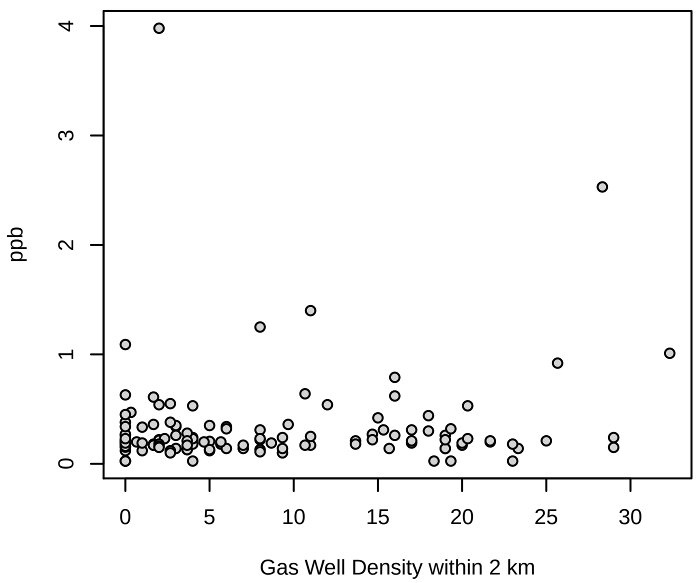


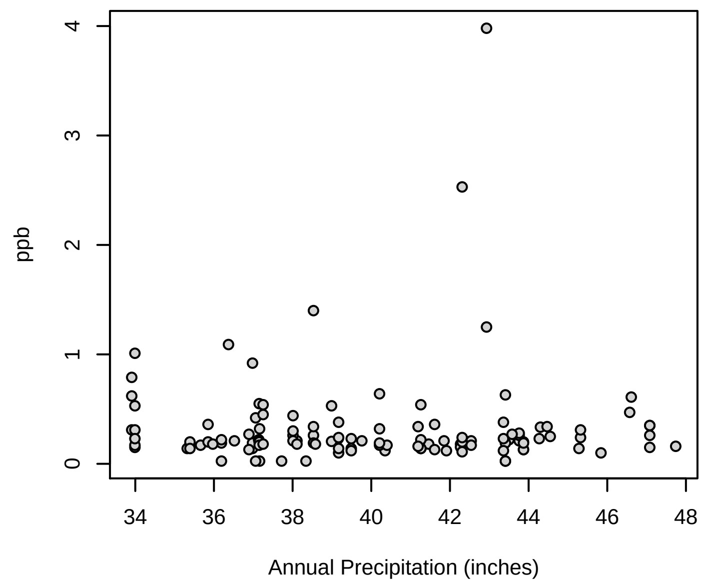
Fluoride

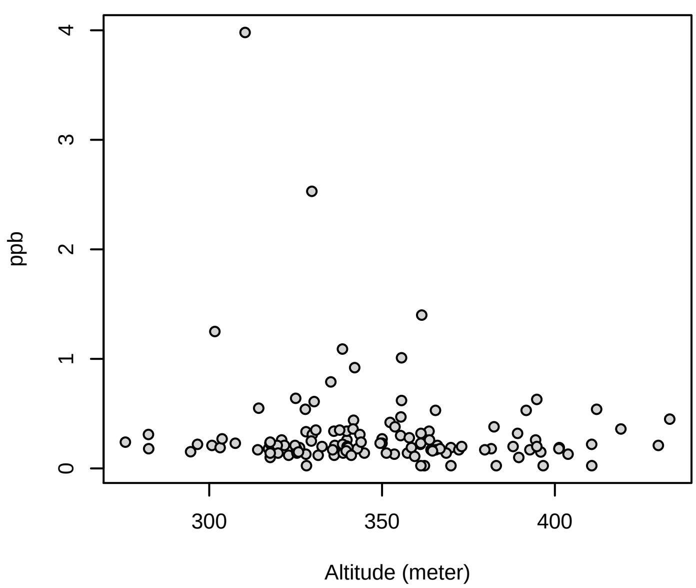
Kendalls Tau Rank Correlation

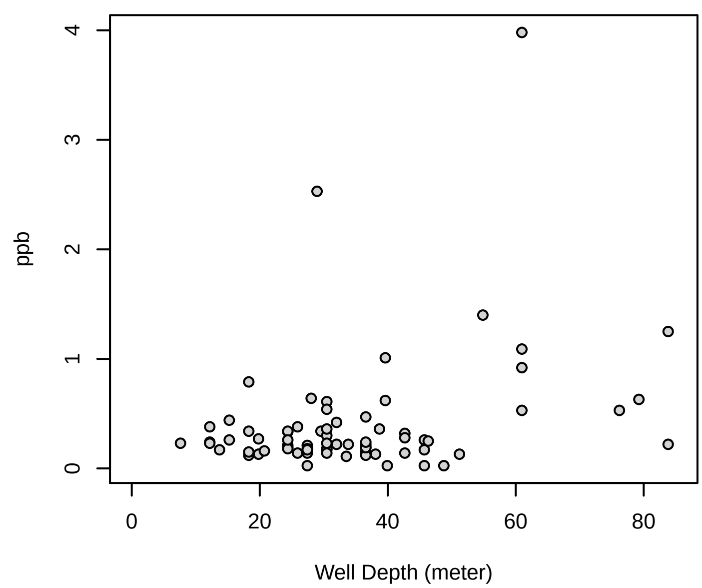
p−value: 0.531

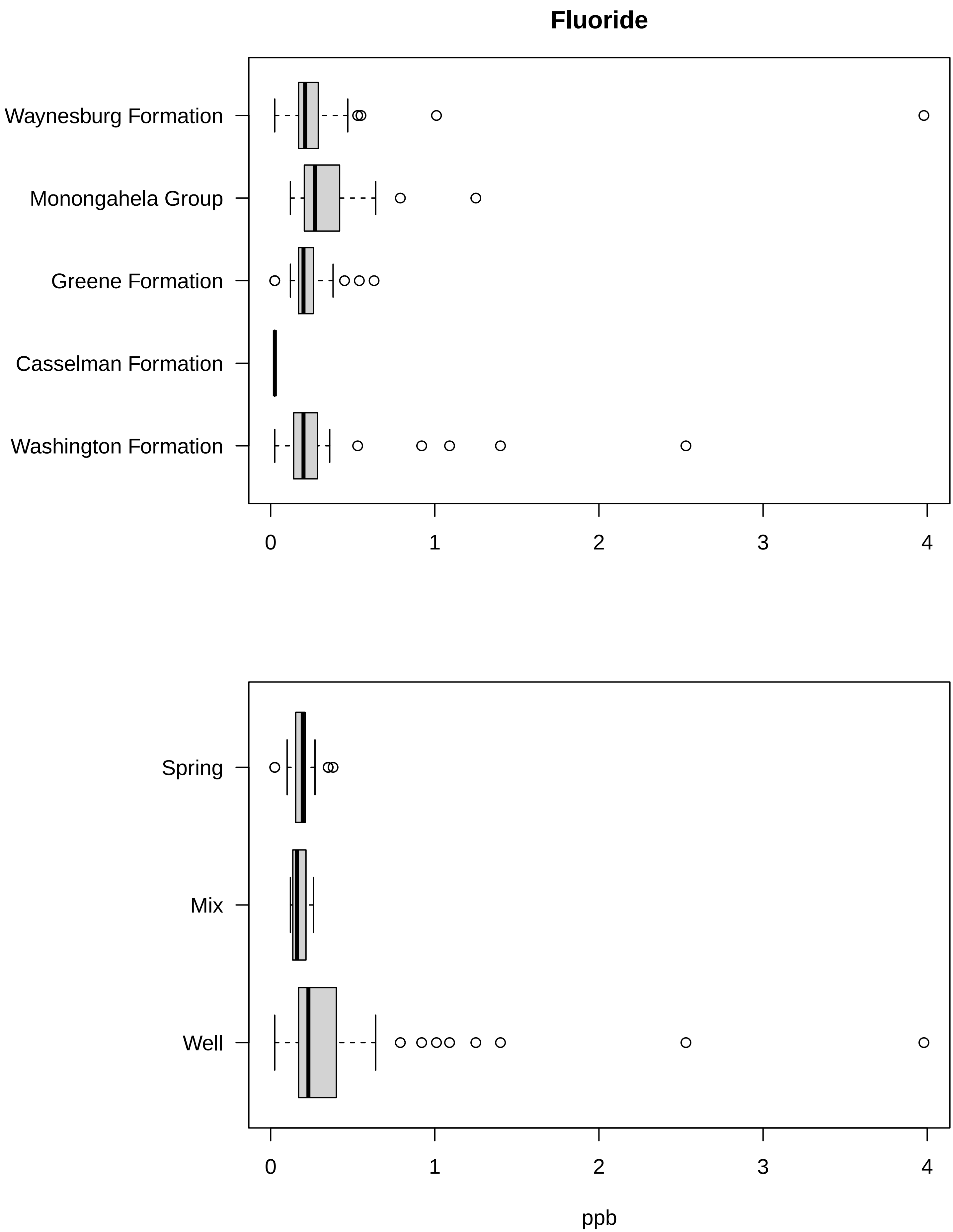
Tau: 0.0395



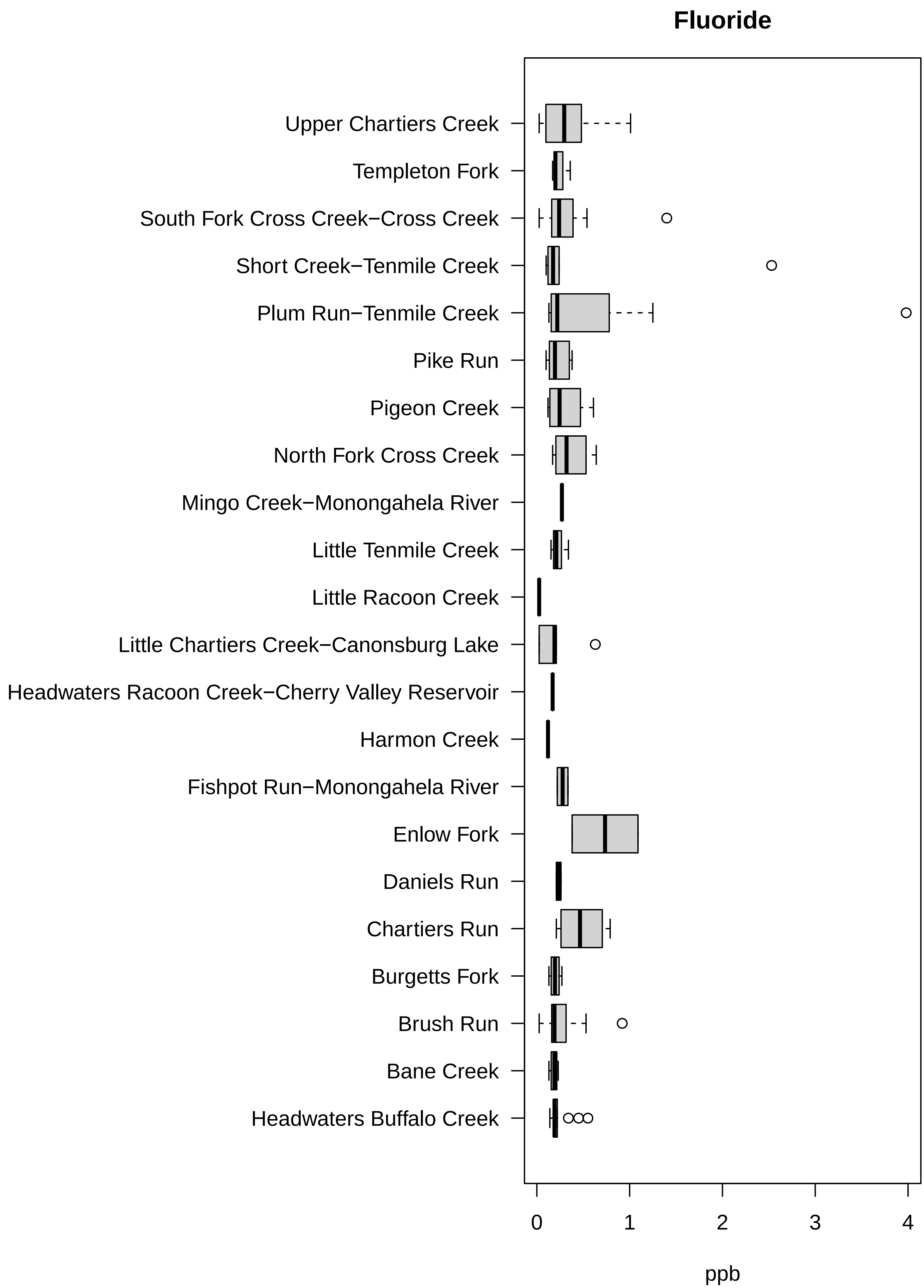








Fluoride
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
1
2
3
4
Spring
Mix
Well
0
1
2
3
4
ppb


Fluoride
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
1
2
3
4
ppb

```
[1] "ORIGINAL MODEL - Fluoride"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.72826  -0.19068  -0.03809   0.12349   3.03351  

Coefficients: (1 not defined because of singularities)
                                                            Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                                1.240e-01  1.333e+00   0.093   0.9261  
dat$GWellDensity_2kmAvg                                    1.261e-02  8.693e-03   1.451   0.1502  
dat$Altitude_meter                                        -7.045e-05  2.474e-03  -0.028   0.9773  
dat$WatershedBane Creek                                   -9.702e-02  3.012e-01  -0.322   0.7481  
dat$WatershedBrush Run                                    -1.622e-01  2.309e-01  -0.703   0.4841  
dat$WatershedBurgetts Fork                                -2.074e-01  2.905e-01  -0.714   0.4769  
dat$WatershedChartiers Run                                -3.369e-03  3.266e-01  -0.010   0.9918  
dat$WatershedDaniels Run                                   8.255e-02  4.452e-01   0.185   0.8533  
dat$WatershedEnlow Fork                                    6.219e-01  3.516e-01   1.769   0.0802 .
dat$WatershedFishpot Run-Monongahela River                -1.010e-01  4.307e-01  -0.235   0.8151  
dat$WatershedHarmon Creek                                  3.163e-02  5.871e-01   0.054   0.9572  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -3.350e-01  5.052e-01  -0.663   0.5089  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       -2.789e-03  2.836e-01  -0.010   0.9922  
dat$WatershedLittle Racoon Creek                          -3.783e-02  4.917e-01  -0.077   0.9388  
dat$WatershedLittle Tenmile Creek                         -1.231e-01  2.996e-01  -0.411   0.6821  
dat$WatershedMingo Creek-Monongahela River                 1.666e-01  5.387e-01   0.309   0.7579  
dat$WatershedNorth Fork Cross Creek                       -5.363e-02  2.780e-01  -0.193   0.8474  
dat$WatershedPigeon Creek                                 -8.076e-02  3.458e-01  -0.234   0.8158  
dat$WatershedPike Run                                     -3.289e-03  3.316e-01  -0.010   0.9921  
dat$WatershedPlum Run-Tenmile Creek                        5.170e-01  3.058e-01   1.691   0.0942 .
dat$WatershedShort Creek-Tenmile Creek                     6.183e-02  2.605e-01   0.237   0.8129  
dat$WatershedSouth Fork Cross Creek-Cross Creek           -1.650e-01  2.219e-01  -0.744   0.4588  
dat$WatershedTempleton Fork                                6.629e-02  2.983e-01   0.222   0.8246  
dat$WatershedUpper Chartiers Creek                        -1.181e-01  2.276e-01  -0.519   0.6051  
dat$FormationCasselman Formation                                  NA         NA      NA       NA  
dat$FormationGreene Formation                             -4.972e-02  1.721e-01  -0.289   0.7732  
dat$FormationMonongahela Group                             6.340e-02  1.850e-01   0.343   0.7325  
dat$FormationWaynesburg Formation                          1.122e-01  1.451e-01   0.773   0.4413  
dat$HHWSourceMix                                          -2.538e-01  3.164e-01  -0.802   0.4245  
dat$HHWSourceSpring                                       -2.553e-01  1.076e-01  -2.372   0.0198 *
dat$Precip_inchAvg                                         4.424e-03  2.862e-02   0.155   0.8775  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.2147169)

    Null deviance: 24.794  on 121  degrees of freedom
Residual deviance: 19.754  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: 186.1
```

```
Number of Fisher Scoring iterations: 2

[1] "BOX-COX MODEL - Fluoride"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-4.1272  -0.6110  -0.0956   0.4397   6.9962  

Coefficients: (1 not defined because of singularities)
                                                          Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                             -0.1737888  5.2199980  -0.033 0.973513    
dat$GWellDensity_2kmAvg                                 -0.0330881  0.0340492  -0.972 0.333712    
dat$Altitude_meter                                       0.0077495  0.0096901   0.800 0.425926    
dat$WatershedBane Creek                                  0.6345155  1.1796540   0.538 0.591957    
dat$WatershedBrush Run                                   0.8996986  0.9044509   0.995 0.322469    
dat$WatershedBurgetts Fork                               1.1043240  1.1376498   0.971 0.334240    
dat$WatershedChartiers Run                               0.6086183  1.2791135   0.476 0.635336    
dat$WatershedDaniels Run                                -0.5168506  1.7438239  -0.296 0.767601    
dat$WatershedEnlow Fork                                 -1.4251234  1.3770122  -1.035 0.303410    
dat$WatershedFishpot Run-Monongahela River               0.8838050  1.6868722   0.524 0.601586    
dat$WatershedHarmon Creek                                1.4330472  2.2995949   0.623 0.534712    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.5045061  1.9789150   0.255 0.799338    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      2.8396374  1.1106263   2.557 0.012202 *  
dat$WatershedLittle Racoon Creek                         7.0005060  1.9257628   3.635 0.000457 ***
dat$WatershedLittle Tenmile Creek                        0.2620377  1.1736486   0.223 0.823822    
dat$WatershedMingo Creek-Monongahela River               0.2362259  2.1099755   0.112 0.911102    
dat$WatershedNorth Fork Cross Creek                      0.2330763  1.0887371   0.214 0.830959    
dat$WatershedPigeon Creek                                0.2455542  1.3542630   0.181 0.856516    
dat$WatershedPike Run                                    0.3783787  1.2987619   0.291 0.771449    
dat$WatershedPlum Run-Tenmile Creek                      0.2984444  1.1976105   0.249 0.803762    
dat$WatershedShort Creek-Tenmile Creek                   0.8588829  1.0203483   0.842 0.402108    
dat$WatershedSouth Fork Cross Creek-Cross Creek          1.1317390  0.8689867   1.302 0.196042    
dat$WatershedTempleton Fork                             -0.0834432  1.1683206  -0.071 0.943217    
dat$WatershedUpper Chartiers Creek                       1.6991197  0.8913547   1.906 0.059743 .  
dat$FormationCasselman Formation                                NA         NA      NA       NA    
dat$FormationGreene Formation                           -0.2593308  0.6739250  -0.385 0.701269    
dat$FormationMonongahela Group                          -0.8076538  0.7244239  -1.115 0.267801    
dat$FormationWaynesburg Formation                        0.0002677  0.5683320   0.000 0.999625    
dat$HHWSourceMix                                         0.6806441  1.2392692   0.549 0.584178    
dat$HHWSourceSpring                                      0.6528969  0.4215895   1.549 0.124898    
dat$Precip_inchAvg                                      -0.0001446  0.1120903  -0.001 0.998974    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 3.294053)

    Null deviance: 432.75  on 121  degrees of freedom
Residual deviance: 303.05  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: 519.23
```

Number of Fisher Scoring iterations: 2

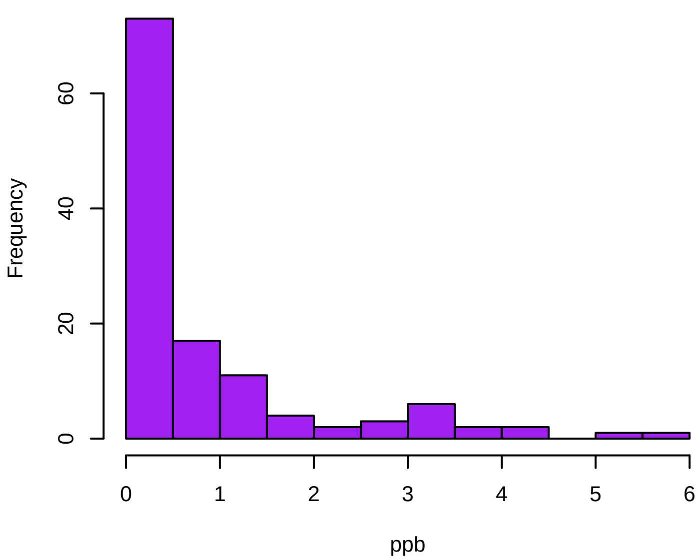
Nitrate

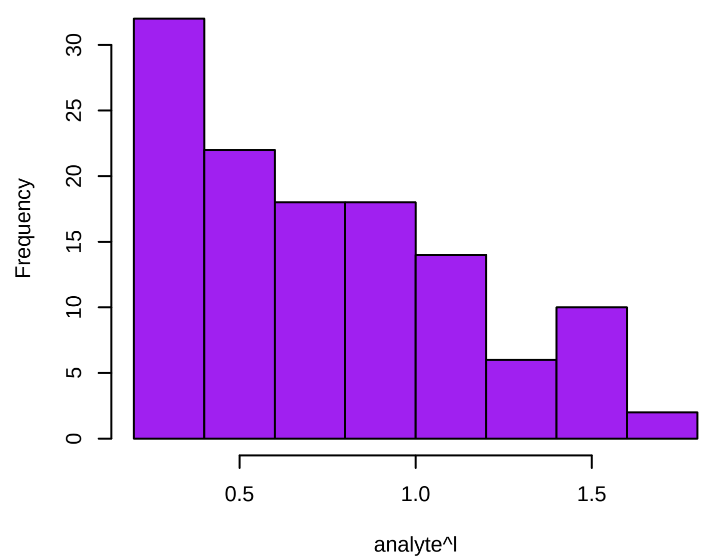
Skewness: 1.9674
Kurtosis: 6.3388

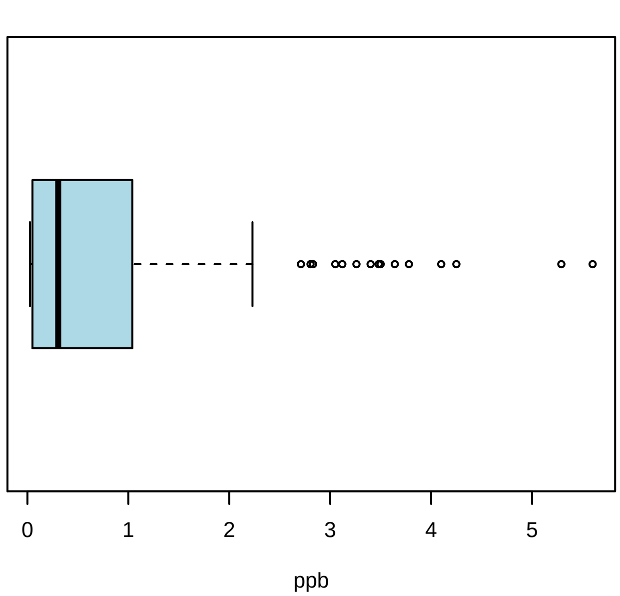
Nitrate Box−Cox

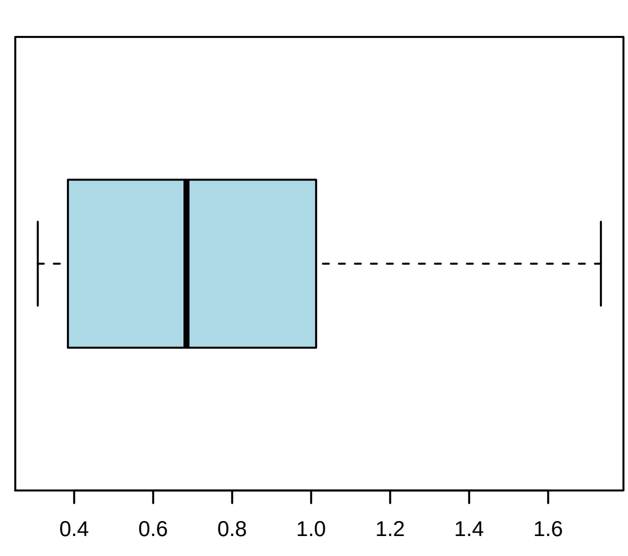
Skewness: 0.6486
Kurtosis: 2.4081

Optimal lambda: 0.3194



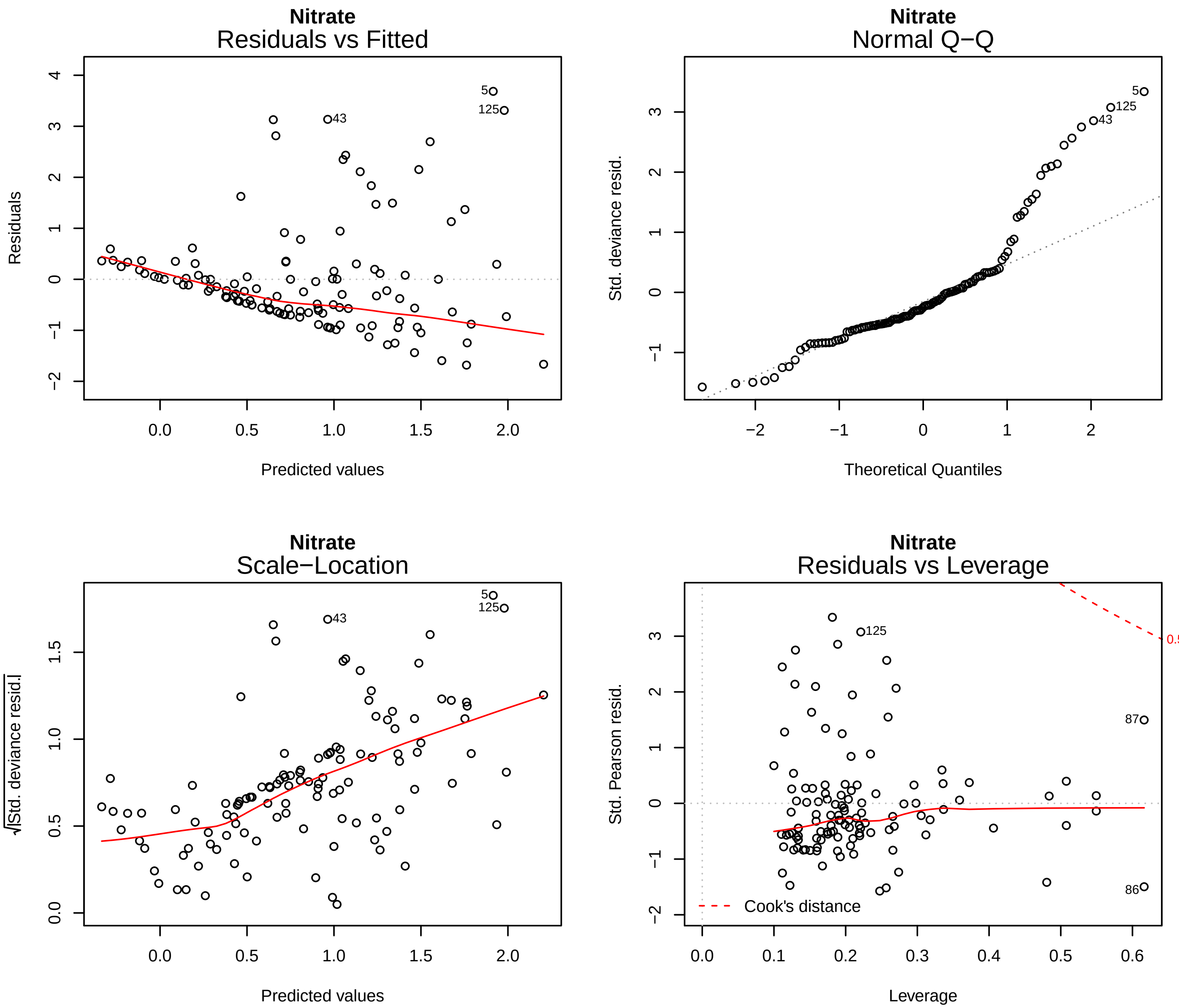






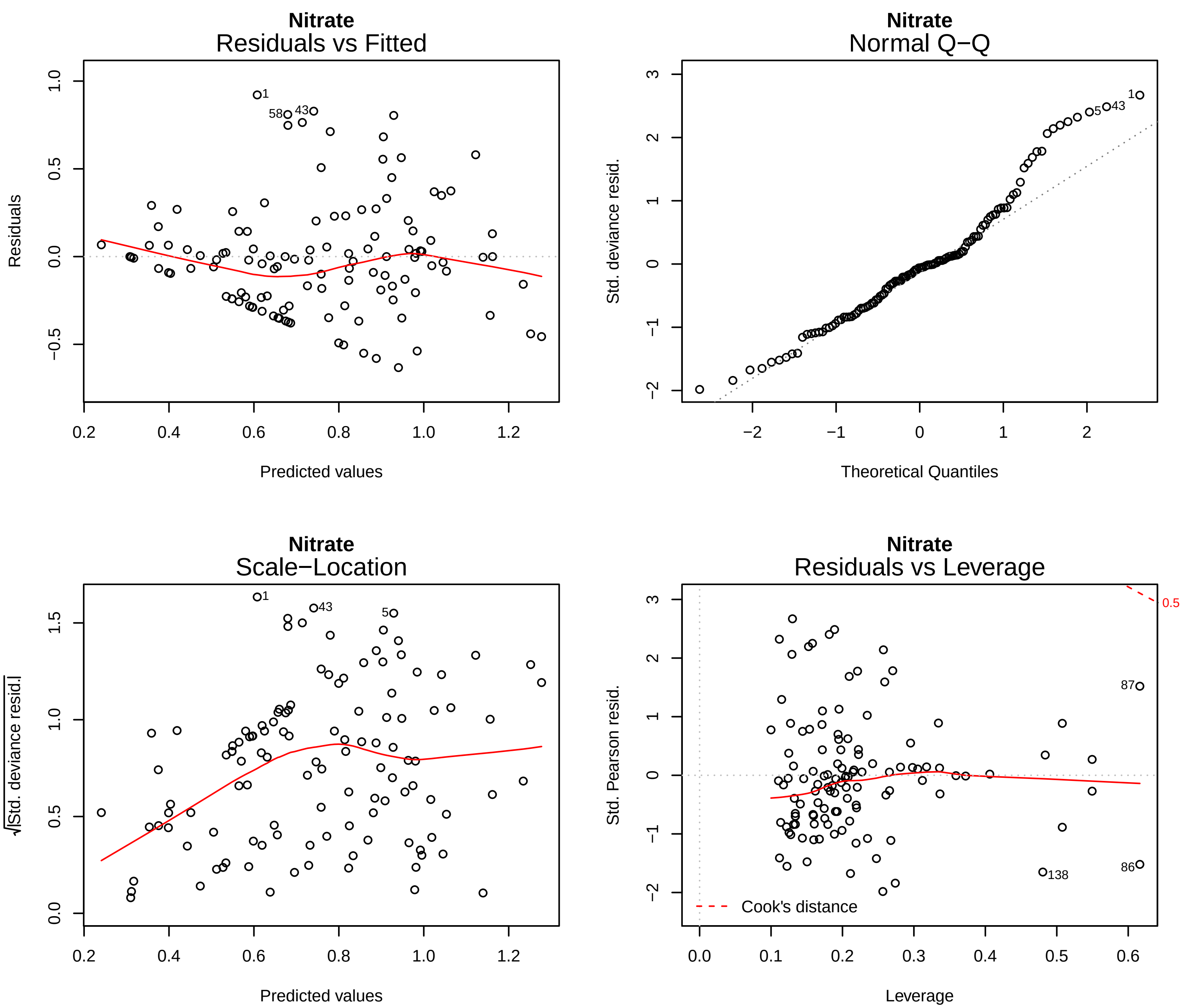
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

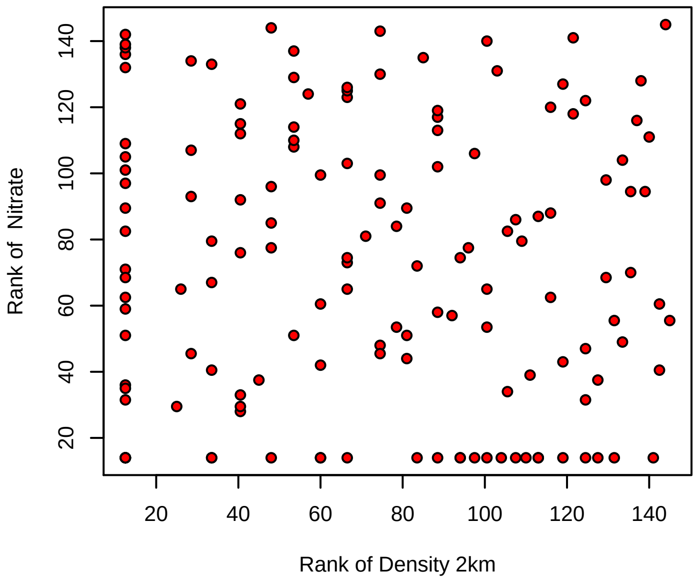
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



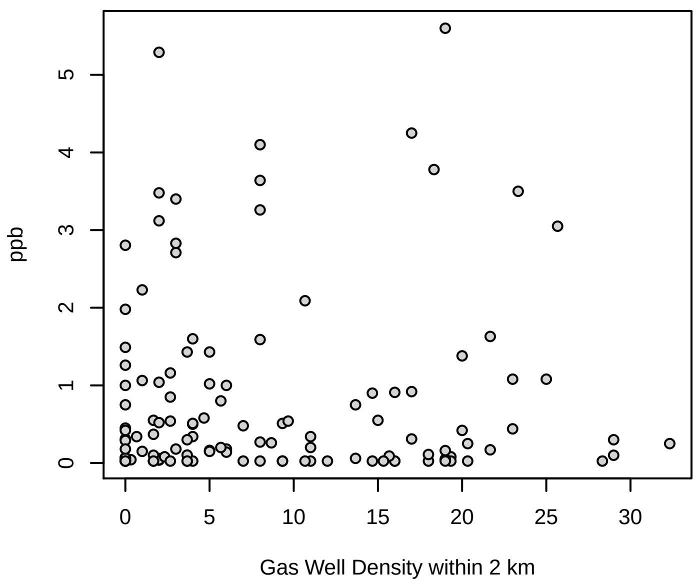


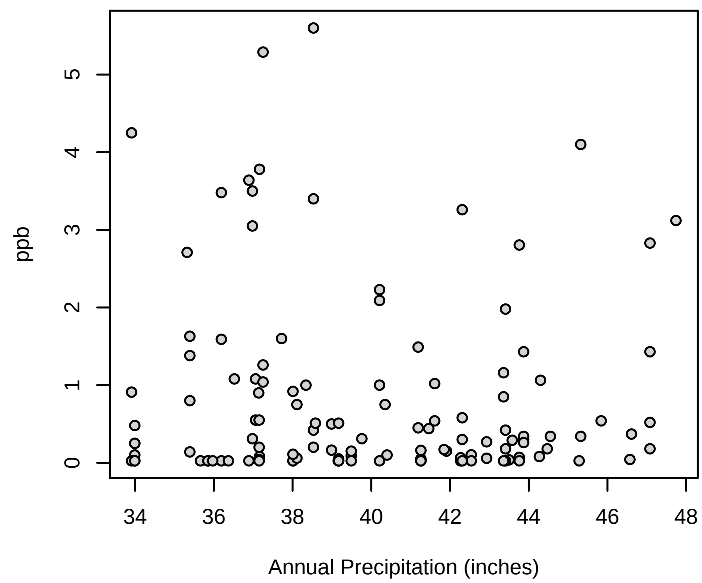
Nitrate

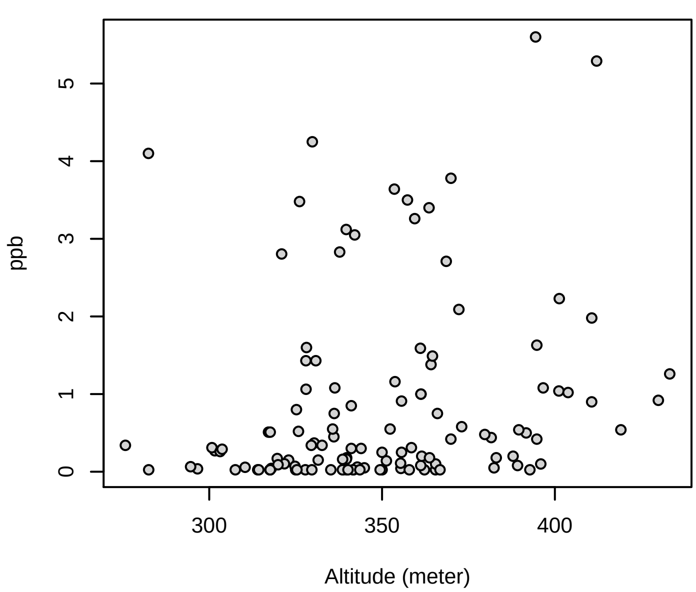
Kendalls Tau Rank Correlation

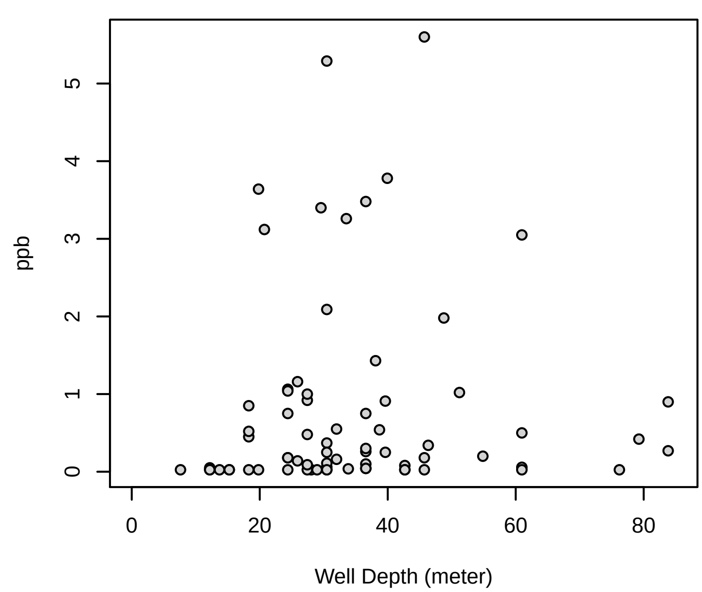
p−value: 0.948

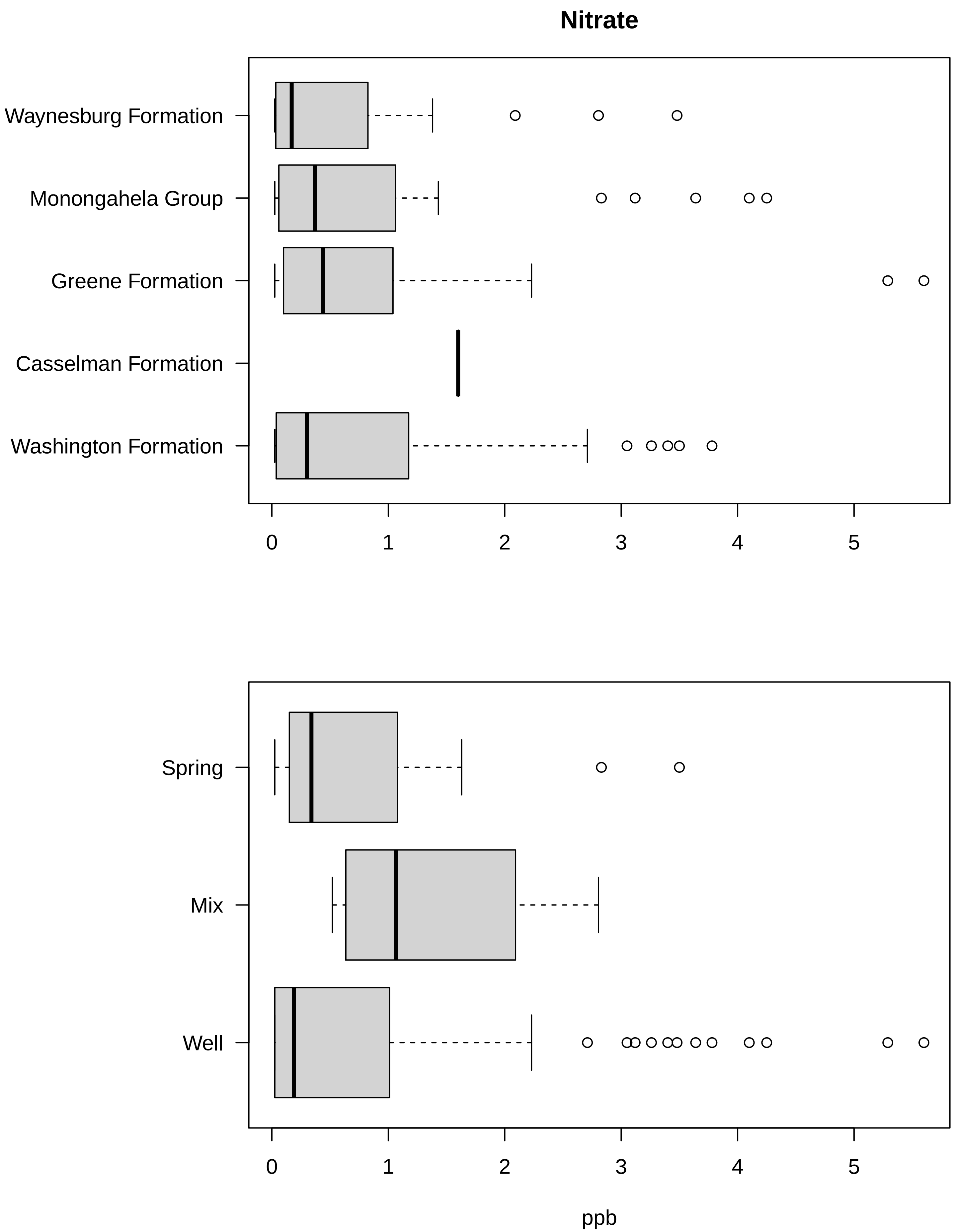
Tau: 0.00412

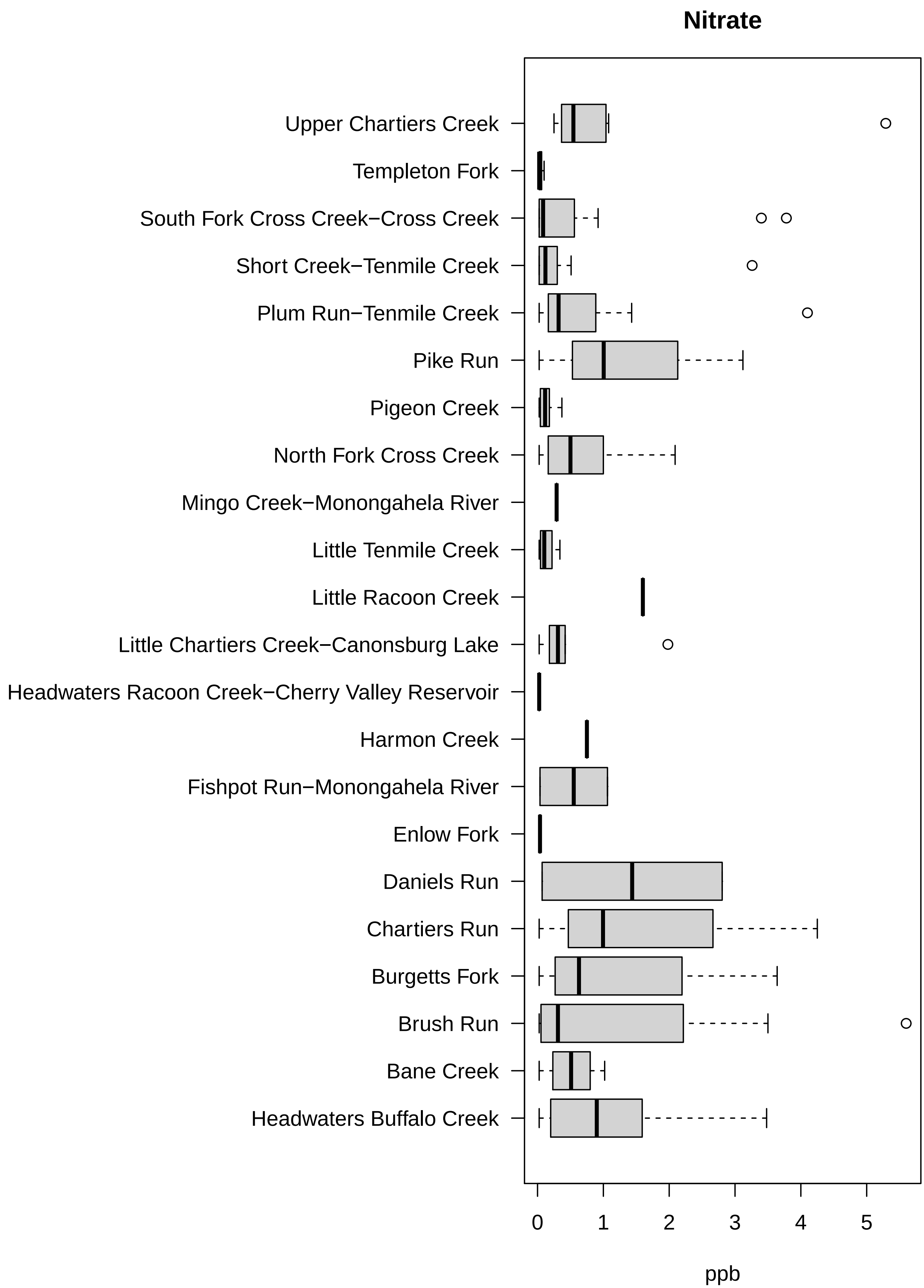









Nitrate
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
1
2
3
4
5
Spring
Mix
Well
0
1
2
3
4
5
ppb


Nitrate
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
1
2
3
4
5
ppb

```
[1] "ORIGINAL MODEL - Nitrate"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.6819  -0.6290  -0.2349   0.2828   3.6847

Coefficients: (1 not defined because of singularities)
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              -4.508579   3.507876  -1.285   0.2019
dat$GWellDensity_2kmAvg                                  -0.022604   0.022881  -0.988   0.3258
dat$Altitude_meter                                        0.008278   0.006512   1.271   0.2069
dat$WatershedBane Creek                                  -0.958466   0.792736  -1.209   0.2297
dat$WatershedBrush Run                                    0.574760   0.607798   0.946   0.3468
dat$WatershedBurgetts Fork                                0.164198   0.764509   0.215   0.8304
dat$WatershedChartiers Run                                0.862379   0.859574   1.003   0.3184
dat$WatershedDaniels Run                                  0.234234   1.171862   0.200   0.8420
dat$WatershedEnlow Fork                                  -1.230876   0.925362  -1.330   0.1868
dat$WatershedFishpot Run-Monongahela River               -1.128229   1.133590  -0.995   0.3222
dat$WatershedHarmon Creek                                -1.060527   1.545344  -0.686   0.4943
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.947404   1.329845  -0.712   0.4780
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -1.251664   0.746349  -1.677   0.0969 .
dat$WatershedLittle Racoon Creek                          0.854654   1.294127   0.660   0.5106
dat$WatershedLittle Tenmile Creek                        -1.032444   0.788700  -1.309   0.1938
dat$WatershedMingo Creek-Monongahela River               -0.999394   1.417919  -0.705   0.4827
dat$WatershedNorth Fork Cross Creek                      -0.701456   0.731639  -0.959   0.3402
dat$WatershedPigeon Creek                                -1.481762   0.910075  -1.628   0.1069
dat$WatershedPike Run                                    -0.441123   0.872777  -0.505   0.6145
dat$WatershedPlum Run-Tenmile Creek                      -0.431059   0.804803  -0.536   0.5935
dat$WatershedShort Creek-Tenmile Creek                   -0.449701   0.685681  -0.656   0.5136
dat$WatershedSouth Fork Cross Creek-Cross Creek          -0.399165   0.583965  -0.684   0.4960
dat$WatershedTempleton Fork                              -1.121833   0.785120  -1.429   0.1564
dat$WatershedUpper Chartiers Creek                        0.208119   0.598997   0.347   0.7291
dat$FormationCasselman Formation                                NA         NA      NA       NA
dat$FormationGreene Formation                            -0.004548   0.452882  -0.010   0.9920
dat$FormationMonongahela Group                            0.196691   0.486818   0.404   0.6871
dat$FormationWaynesburg Formation                        -0.314989   0.381923  -0.825   0.4117
dat$HHWSourceMix                                          0.179058   0.832798   0.215   0.8302
dat$HHWSourceSpring                                      -0.326583   0.283311  -1.153   0.2520
dat$Precip_inchAvg                                        0.078332   0.075326   1.040   0.3011
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1.487574)

    Null deviance: 175.38  on 121  degrees of freedom
Residual deviance: 136.86  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: 422.24
```

```
Number of Fisher Scoring iterations: 2

[1] "BOX-COX MODEL - Nitrate"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.63249  -0.22927  -0.01632   0.14019   0.92132

Coefficients: (1 not defined because of singularities)
                                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                                             -2.403240   1.064040  -2.259  0.02627 *
dat$GWellDensity_2kmAvg                                 -0.005900   0.006941  -0.850  0.39749
dat$Altitude_meter                                       0.005524   0.001975   2.797  0.00628 **
dat$WatershedBane Creek                                 -0.238808   0.240460  -0.993  0.32325
dat$WatershedBrush Run                                  -0.026089   0.184362  -0.142  0.88778
dat$WatershedBurgetts Fork                              -0.033849   0.231898  -0.146  0.88427
dat$WatershedChartiers Run                               0.218655   0.260733   0.839  0.40386
dat$WatershedDaniels Run                                -0.190332   0.355460  -0.535  0.59363
dat$WatershedEnlow Fork                                 -0.574782   0.280689  -2.048  0.04343 *
dat$WatershedFishpot Run-Monongahela River              -0.366302   0.343851  -1.065  0.28953
dat$WatershedHarmon Creek                               -0.436684   0.468747  -0.932  0.35398
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.667172   0.403380  -1.654  0.10155
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     -0.425517   0.226389  -1.880  0.06333 .
dat$WatershedLittle Racoon Creek                         0.376089   0.392546   0.958  0.34054
dat$WatershedLittle Tenmile Creek                       -0.439316   0.239236  -1.836  0.06954 .
dat$WatershedMingo Creek-Monongahela River              -0.328871   0.430096  -0.765  0.44644
dat$WatershedNorth Fork Cross Creek                     -0.273827   0.221927  -1.234  0.22040
dat$WatershedPigeon Creek                               -0.666023   0.276052  -2.413  0.01782 *
dat$WatershedPike Run                                   -0.277828   0.264739  -1.049  0.29672
dat$WatershedPlum Run-Tenmile Creek                     -0.159668   0.244120  -0.654  0.51471
dat$WatershedShort Creek-Tenmile Creek                  -0.200309   0.207987  -0.963  0.33803
dat$WatershedSouth Fork Cross Creek-Cross Creek         -0.302214   0.177134  -1.706  0.09136 .
dat$WatershedTempleton Fork                             -0.493423   0.238149  -2.072  0.04107 *
dat$WatershedUpper Chartiers Creek                       0.016518   0.181693   0.091  0.92776
dat$FormationCasselman Formation                               NA         NA      NA       NA
dat$FormationGreene Formation                           -0.136841   0.137372  -0.996  0.32180
dat$FormationMonongahela Group                           0.110455   0.147666   0.748  0.45636
dat$FormationWaynesburg Formation                       -0.048724   0.115848  -0.421  0.67504
dat$HHWSourceMix                                         0.288640   0.252612   1.143  0.25616
dat$HHWSourceSpring                                      0.001495   0.085936   0.017  0.98616
dat$Precip_inchAvg                                       0.037077   0.022848   1.623  0.10807
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.1368692)

    Null deviance: 19.021  on 121  degrees of freedom
Residual deviance: 12.592  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: 131.16
```

Number of Fisher Scoring iterations: 2

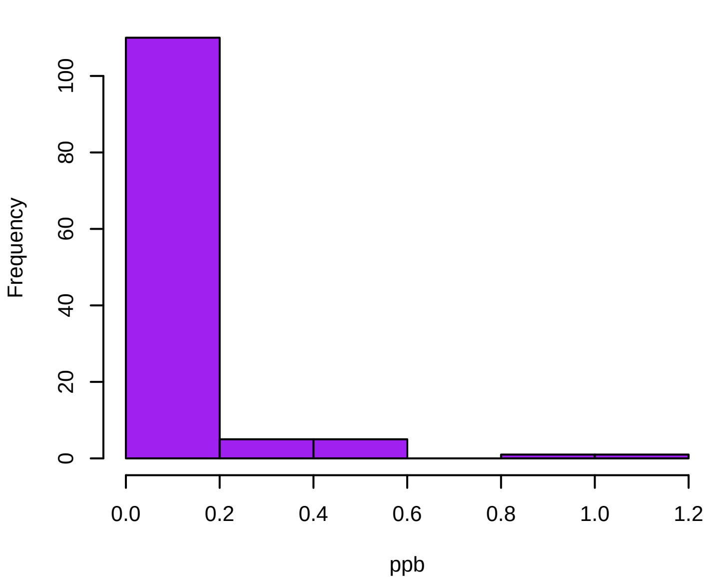
Phosphate

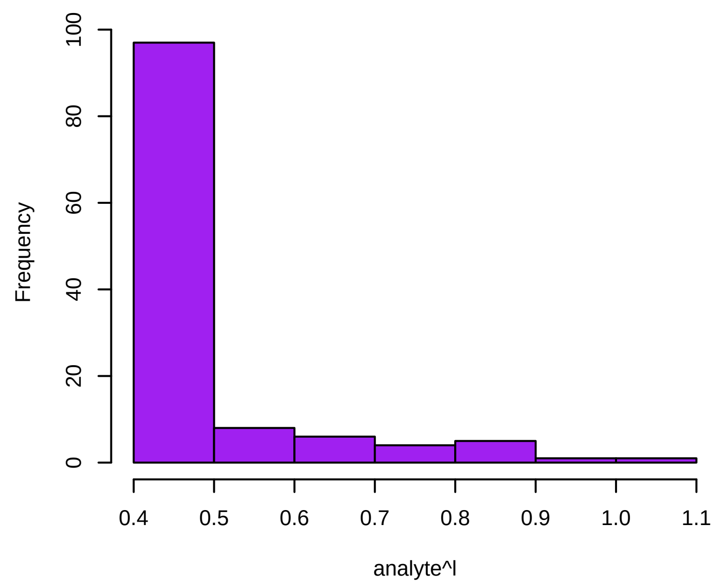
Skewness: 4.6139
Kurtosis: 27.9899

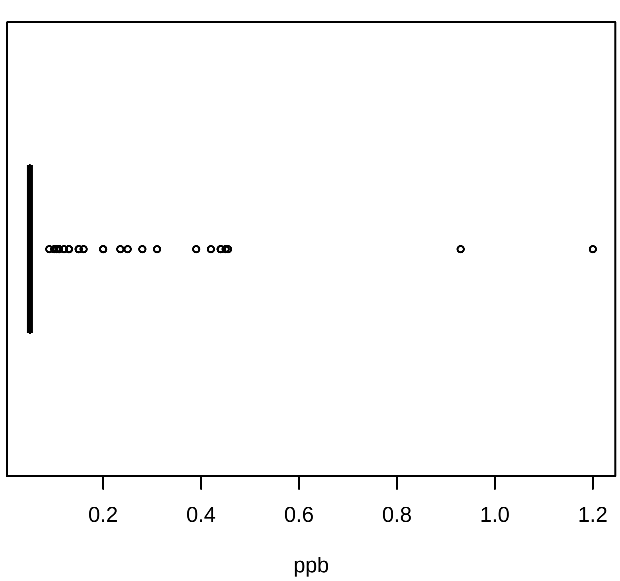
Phosphate Box−Cox

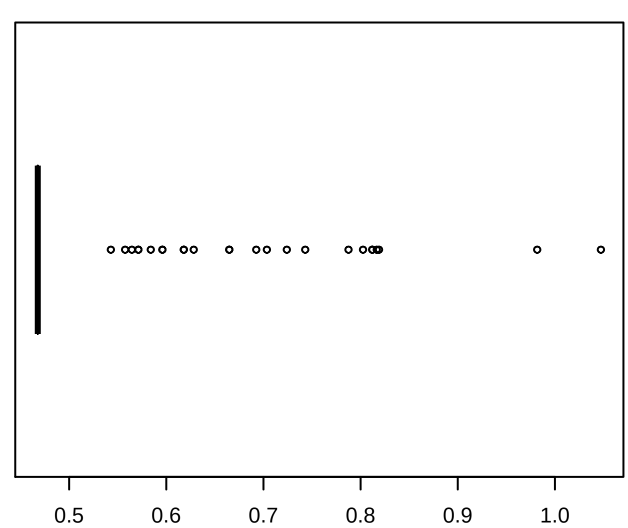
Skewness: 2.6164
Kurtosis: 9.7150

Optimal lambda: 0.2537



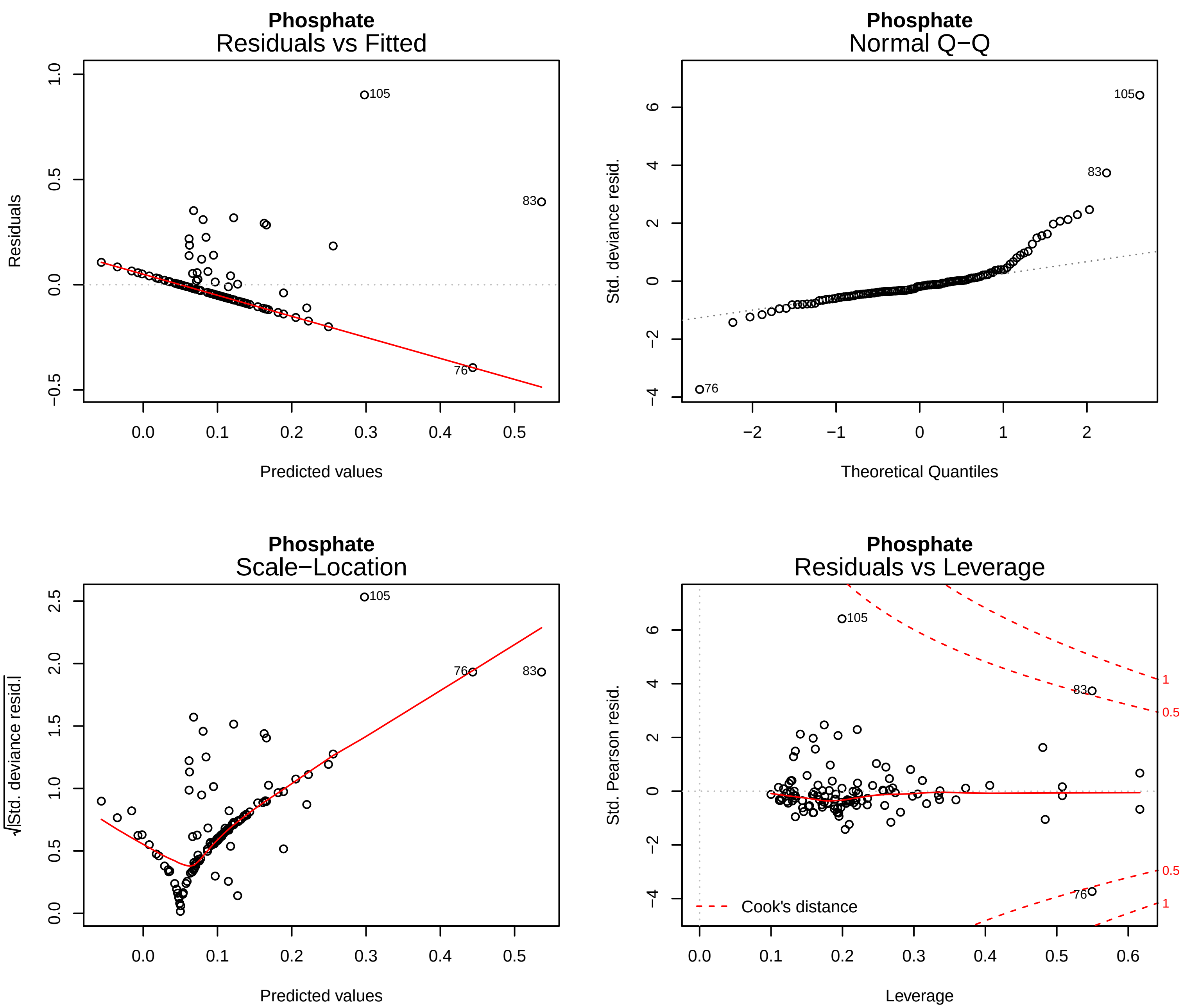






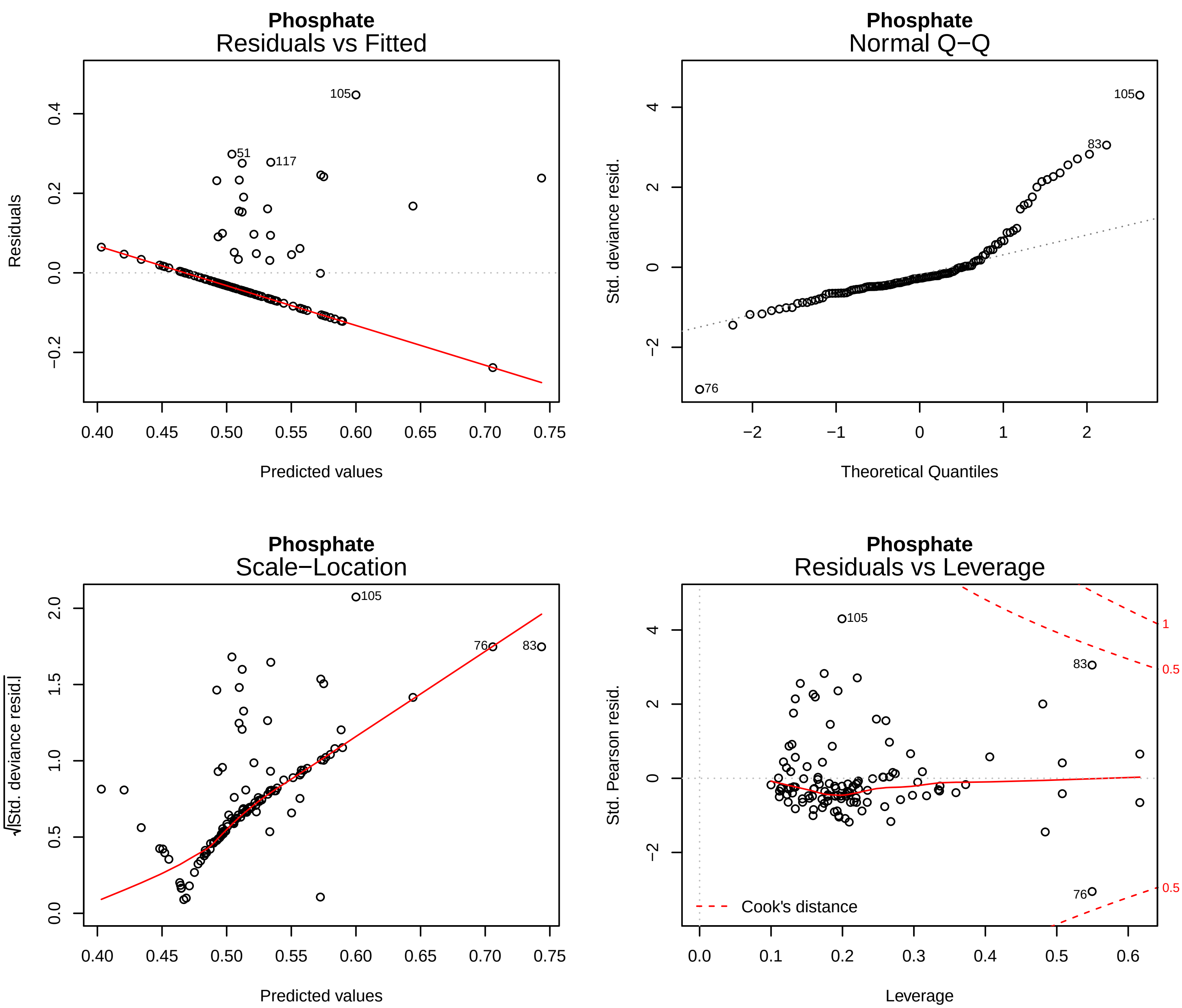
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

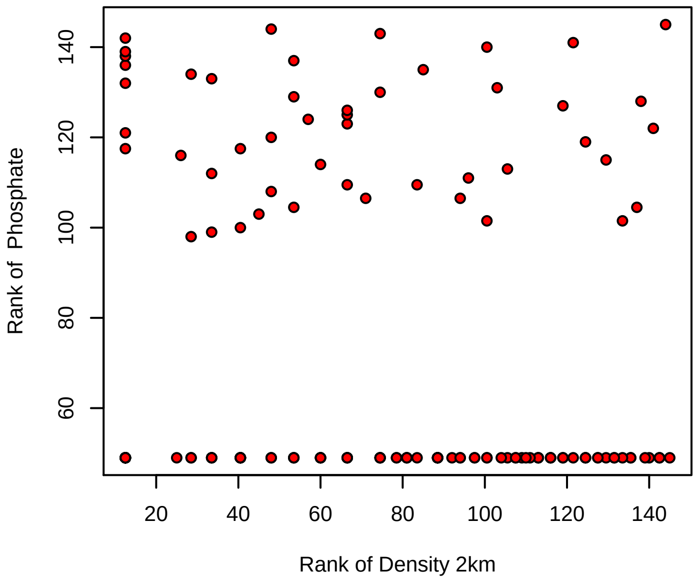
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



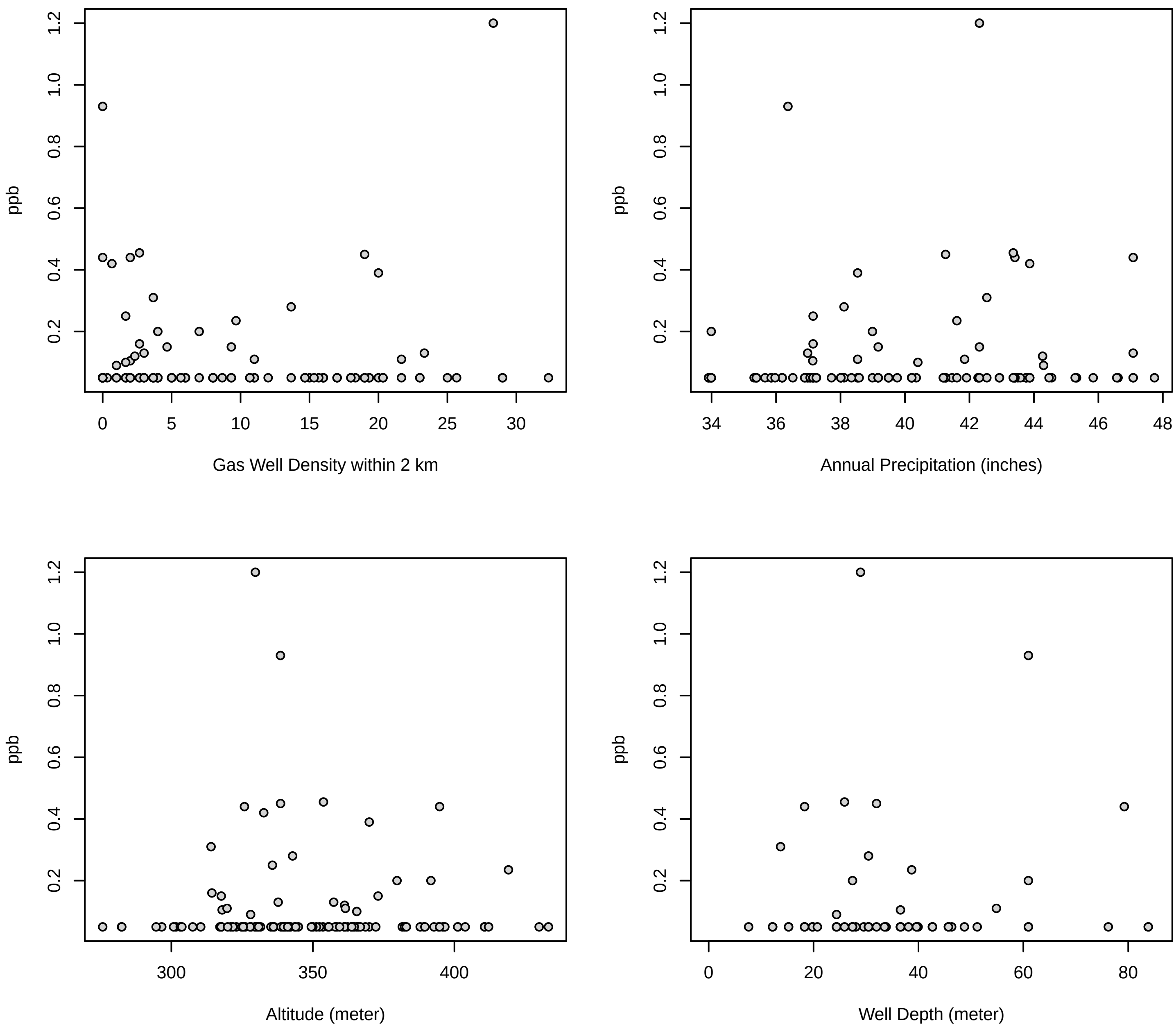


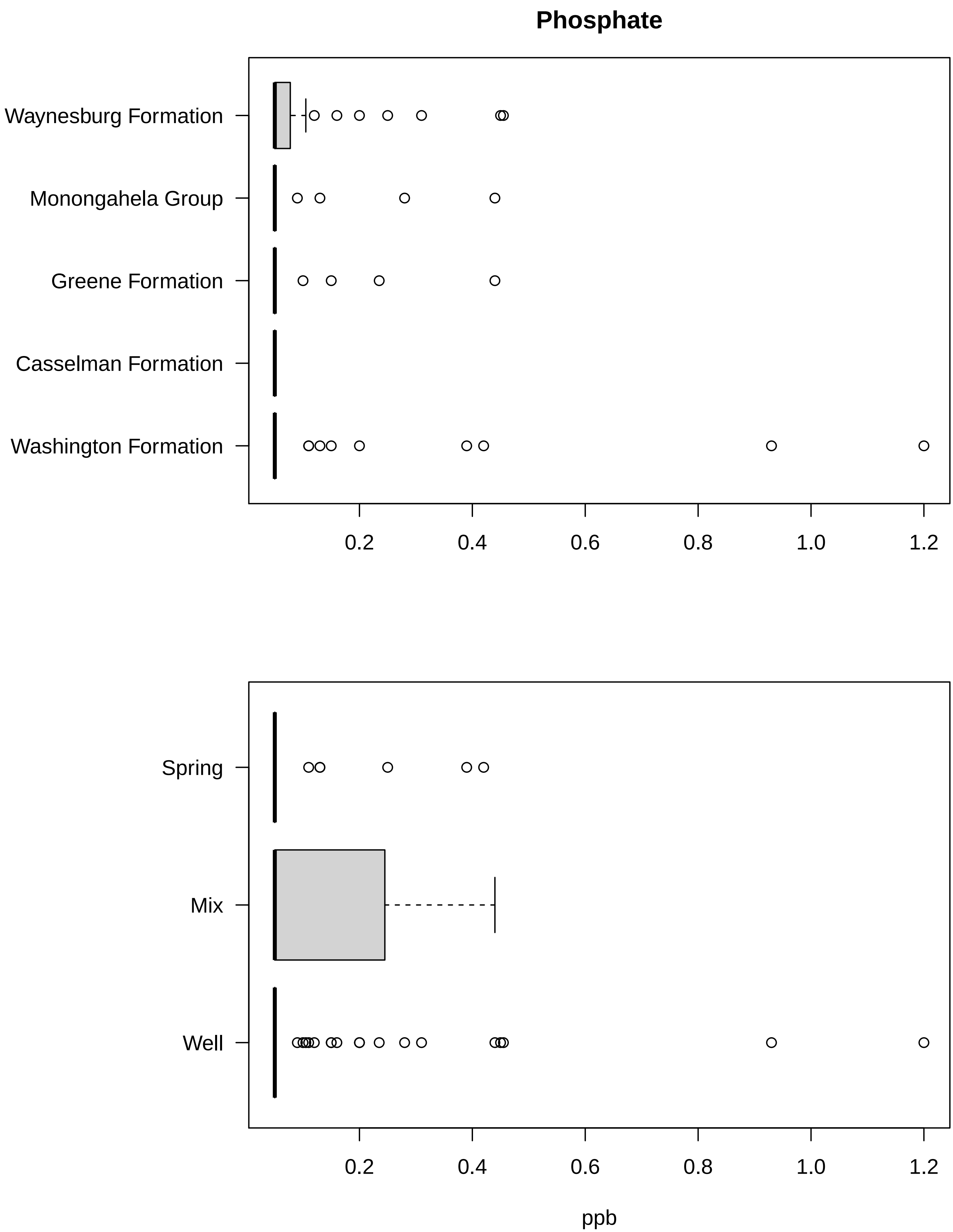
Phosphate

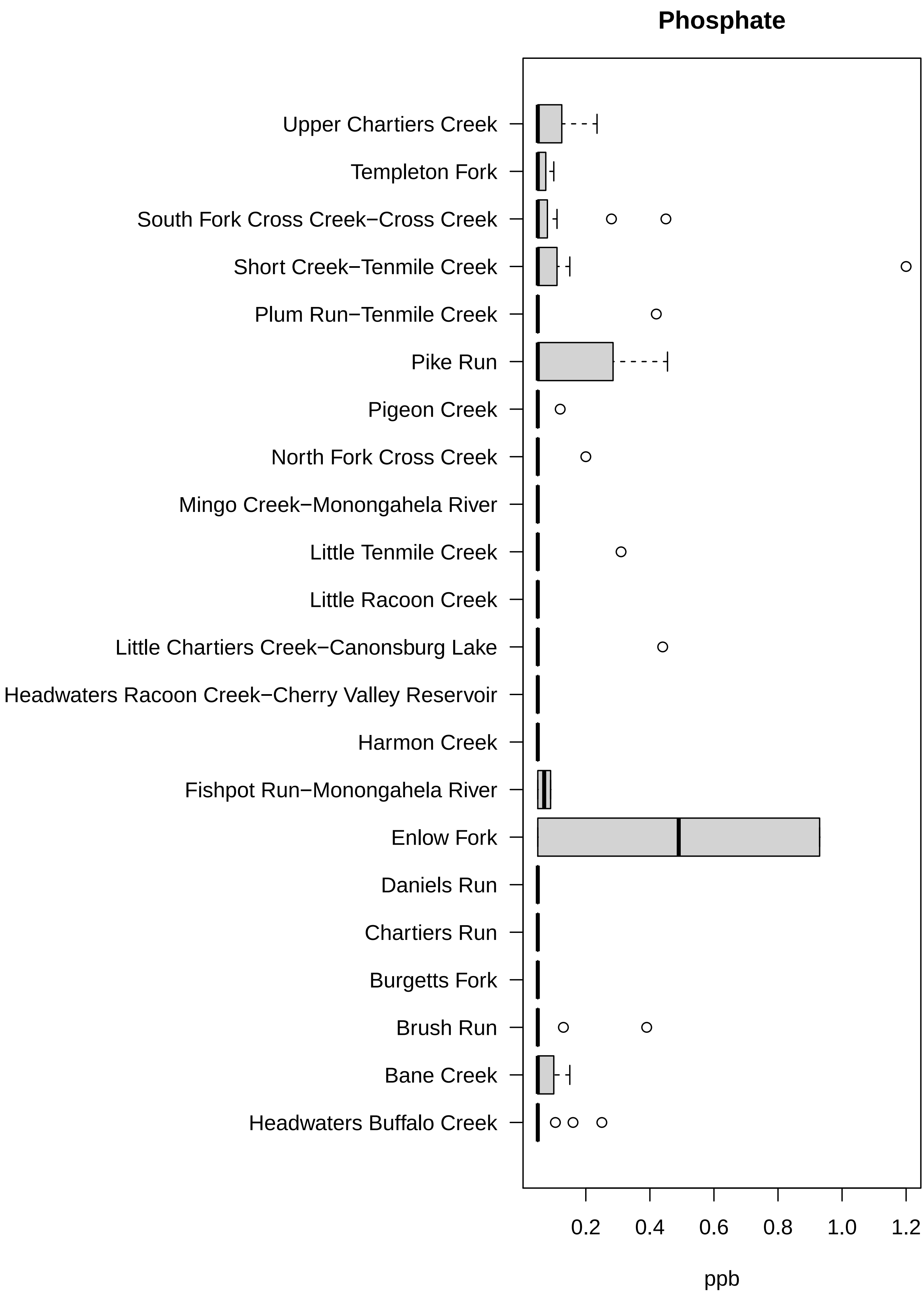
Kendalls Tau Rank Correlation

p−value: 0.646

Tau: −0.0333




Phosphate
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0.2
0.4
0.6
0.8
1.0
1.2
Spring
Mix
Well
0.2
0.4
0.6
0.8
1.0
1.2
ppb


Phosphate
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0.2
0.4
0.6
0.8
1.0
1.2
ppb

```
[1] "ORIGINAL MODEL - Phosphate"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.39369  -0.06127  -0.02025   0.01517   0.90210

Coefficients: (1 not defined because of singularities)
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                             -0.3661167  0.4517594  -0.810 0.419788
dat$GWellDensity_2kmAvg                                  0.0035300  0.0029468   1.198 0.234017
dat$Altitude_meter                                      -0.0001262  0.0008386  -0.150 0.880723
dat$WatershedBane Creek                                 -0.0245592  0.1020920  -0.241 0.810431
dat$WatershedBrush Run                                  -0.0609860  0.0782748  -0.779 0.437904
dat$WatershedBurgetts Fork                              -0.0529448  0.0984567  -0.538 0.592050
dat$WatershedChartiers Run                              -0.0310146  0.1106996  -0.280 0.779977
dat$WatershedDaniels Run                                -0.1647752  0.1509175  -1.092 0.277762
dat$WatershedEnlow Fork                                  0.4421553  0.1191721   3.710 0.000354 ***
dat$WatershedFishpot Run-Monongahela River              -0.0958046  0.1459886  -0.656 0.513303
dat$WatershedHarmon Creek                               -0.1399457  0.1990161  -0.703 0.483714
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0665257  0.1712632  -0.388 0.698587
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      0.0141090  0.0961180   0.147 0.883620
dat$WatershedLittle Racoon Creek                        -0.0291965  0.1666632  -0.175 0.861321
dat$WatershedLittle Tenmile Creek                       -0.1111924  0.1015722  -1.095 0.276500
dat$WatershedMingo Creek-Monongahela River              -0.0581054  0.1826057  -0.318 0.751053
dat$WatershedNorth Fork Cross Creek                     -0.0591000  0.0942236  -0.627 0.532061
dat$WatershedPigeon Creek                               -0.1424978  0.1172033  -1.216 0.227165
dat$WatershedPike Run                                   -0.0356575  0.1124000  -0.317 0.751782
dat$WatershedPlum Run-Tenmile Creek                     -0.0840911  0.1036460  -0.811 0.419270
dat$WatershedShort Creek-Tenmile Creek                   0.0204725  0.0883050   0.232 0.817178
dat$WatershedSouth Fork Cross Creek-Cross Creek         -0.0631104  0.0752056  -0.839 0.403548
dat$WatershedTempleton Fork                             -0.0019462  0.1011111  -0.019 0.984685
dat$WatershedUpper Chartiers Creek                      -0.0191980  0.0771414  -0.249 0.804018
dat$FormationCasselman Formation                                NA         NA      NA       NA
dat$FormationGreene Formation                           -0.0767477  0.0583242  -1.316 0.191483
dat$FormationMonongahela Group                          -0.0410944  0.0626945  -0.655 0.513801
dat$FormationWaynesburg Formation                        0.0002023  0.0491857   0.004 0.996727
dat$HHWSourceMix                                         0.0815415  0.1072513   0.760 0.449028
dat$HHWSourceSpring                                     -0.0490623  0.0364860  -1.345 0.182032
dat$Precip_inchAvg                                       0.0138298  0.0097007   1.426 0.157355
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.024672)

    Null deviance: 2.9556  on 121  degrees of freedom
Residual deviance: 2.2698  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: -77.866
```

```
Number of Fisher Scoring iterations: 2

[1] "BOX-COX MODEL - Phosphate"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.23818  -0.05145  -0.02805   0.01033   0.44732

Coefficients: (1 not defined because of singularities)
                                                               Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                   1.122e-01  3.342e-01   0.336  0.73792
dat$GWellDensity_2kmAvg                                       4.621e-04  2.180e-03   0.212  0.83260
dat$Altitude_meter                                           -3.253e-05  6.205e-04  -0.052  0.95830
dat$WatershedBane Creek                                      -4.215e-03  7.554e-02  -0.056  0.95562
dat$WatershedBrush Run                                       -6.513e-03  5.791e-02  -0.112  0.91070
dat$WatershedBurgetts Fork                                   -3.507e-02  7.285e-02  -0.481  0.63135
dat$WatershedChartiers Run                                    6.059e-03  8.190e-02   0.074  0.94119
dat$WatershedDaniels Run                                     -1.656e-01  1.117e-01  -1.483  0.14150
dat$WatershedEnlow Fork                                       2.377e-01  8.817e-02   2.695  0.00836 **
dat$WatershedFishpot Run-Monongahela River                   -5.819e-02  1.080e-01  -0.539  0.59139
dat$WatershedHarmon Creek                                    -1.292e-01  1.472e-01  -0.877  0.38270
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -5.091e-02  1.267e-01  -0.402  0.68877
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          -5.331e-04  7.112e-02  -0.007  0.99403
dat$WatershedLittle Racoon Creek                             -3.576e-02  1.233e-01  -0.290  0.77245
dat$WatershedLittle Tenmile Creek                            -8.463e-02  7.515e-02  -1.126  0.26306
dat$WatershedMingo Creek-Monongahela River                   -7.216e-02  1.351e-01  -0.534  0.59456
dat$WatershedNorth Fork Cross Creek                          -2.562e-02  6.971e-02  -0.367  0.71413
dat$WatershedPigeon Creek                                    -1.181e-01  8.672e-02  -1.362  0.17663
dat$WatershedPike Run                                        -2.891e-02  8.316e-02  -0.348  0.72892
dat$WatershedPlum Run-Tenmile Creek                          -6.617e-02  7.668e-02  -0.863  0.39048
dat$WatershedShort Creek-Tenmile Creek                        1.461e-02  6.533e-02   0.224  0.82355
dat$WatershedSouth Fork Cross Creek-Cross Creek              -1.135e-02  5.564e-02  -0.204  0.83886
dat$WatershedTempleton Fork                                   2.973e-03  7.481e-02   0.040  0.96839
dat$WatershedUpper Chartiers Creek                            1.334e-02  5.707e-02   0.234  0.81568
dat$FormationCasselman Formation                                     NA         NA      NA       NA
dat$FormationGreene Formation                                -4.777e-02  4.315e-02  -1.107  0.27113
dat$FormationMonongahela Group                               -2.776e-02  4.639e-02  -0.599  0.55095
dat$FormationWaynesburg Formation                             1.729e-02  3.639e-02   0.475  0.63590
dat$HHWSourceMix                                              7.434e-02  7.935e-02   0.937  0.35128
dat$HHWSourceSpring                                          -1.966e-02  2.700e-02  -0.728  0.46840
dat$Precip_inchAvg                                            1.113e-02  7.177e-03   1.551  0.12445
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.01350575)

    Null deviance: 1.5058  on 121  degrees of freedom
Residual deviance: 1.2425  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: -151.38
```

Number of Fisher Scoring iterations: 2

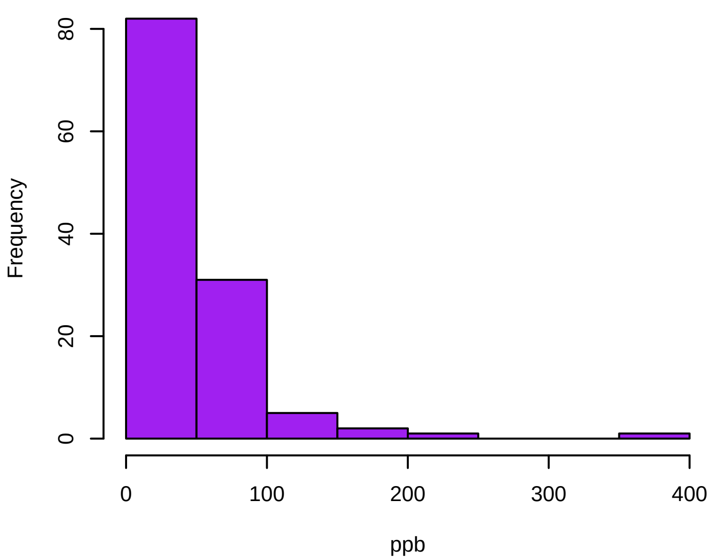
Sulfate

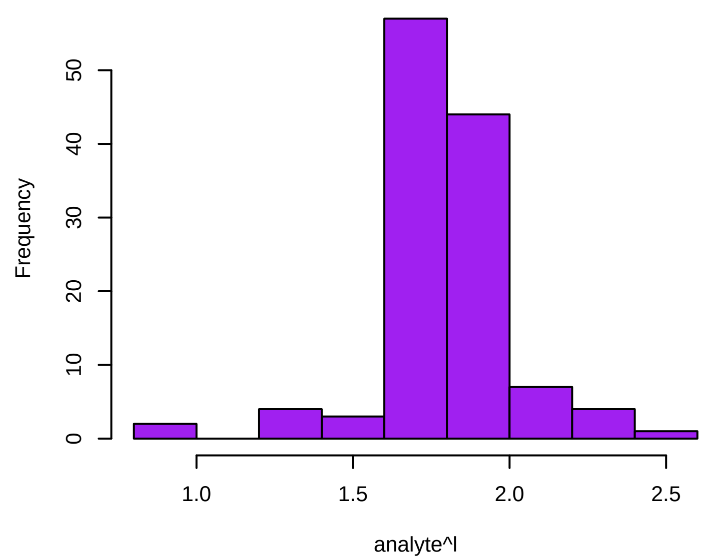
Skewness: 3.9607
Kurtosis: 24.7841

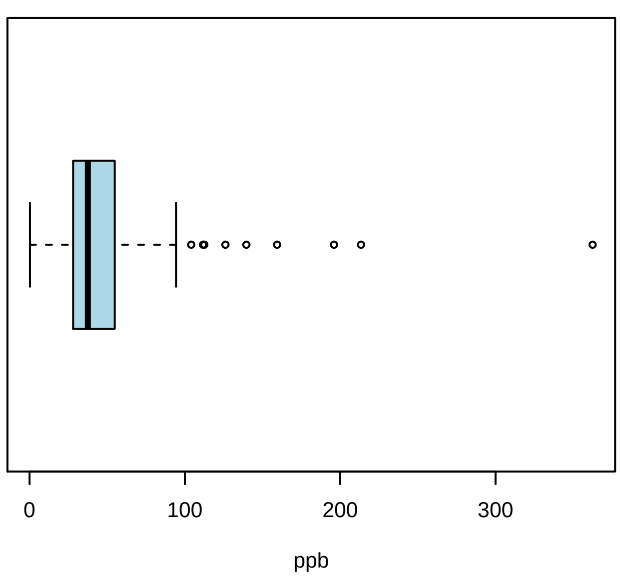
Sulfate Box−Cox

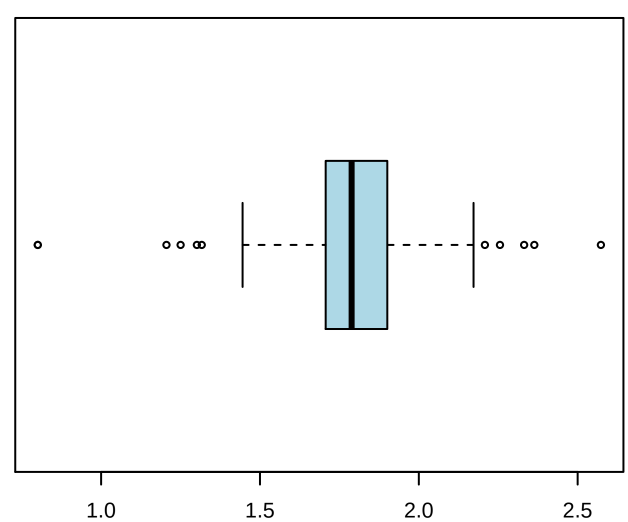
Skewness: −0.9102
Kurtosis: 8.3109

Optimal lambda: 0.1604



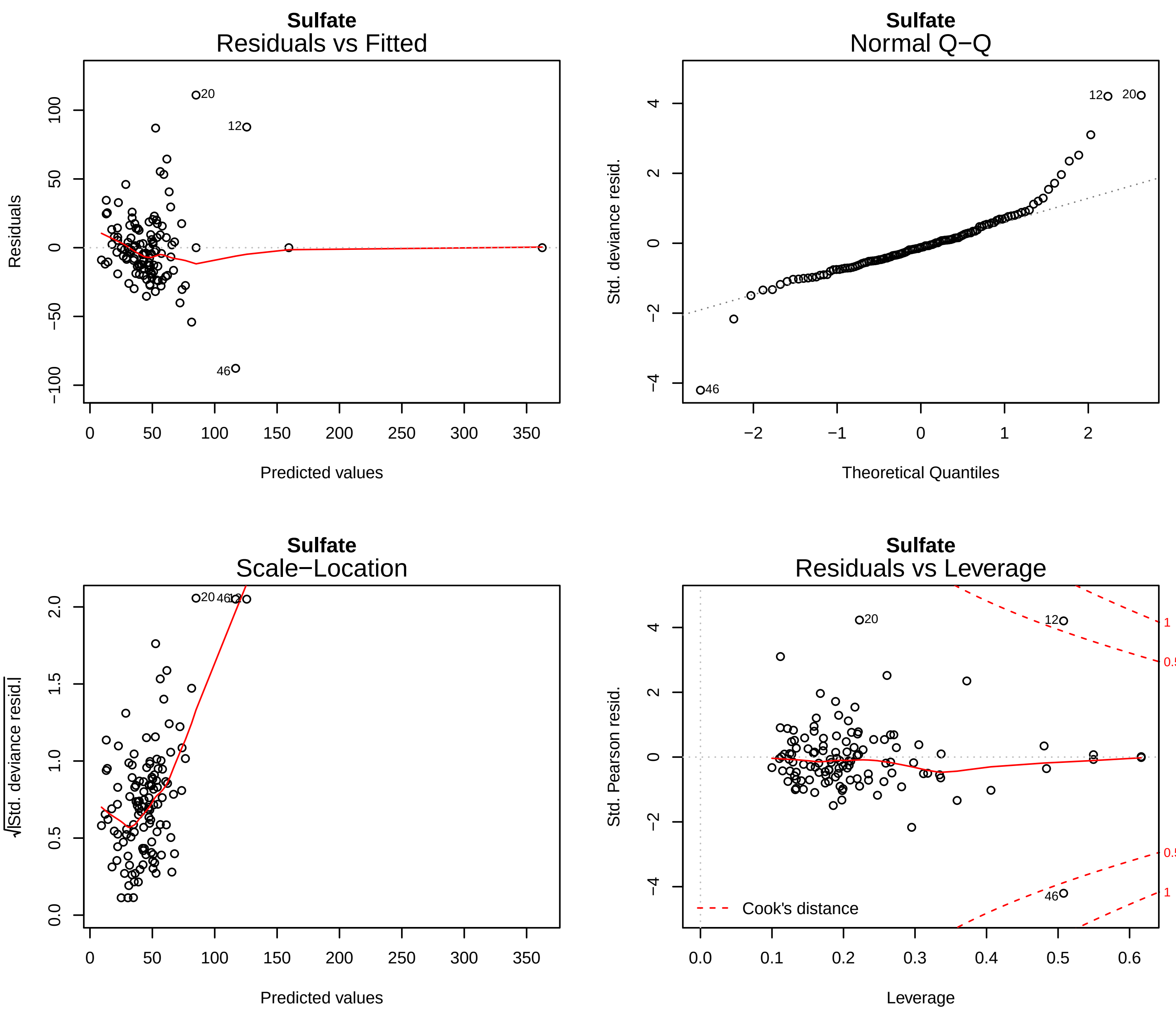






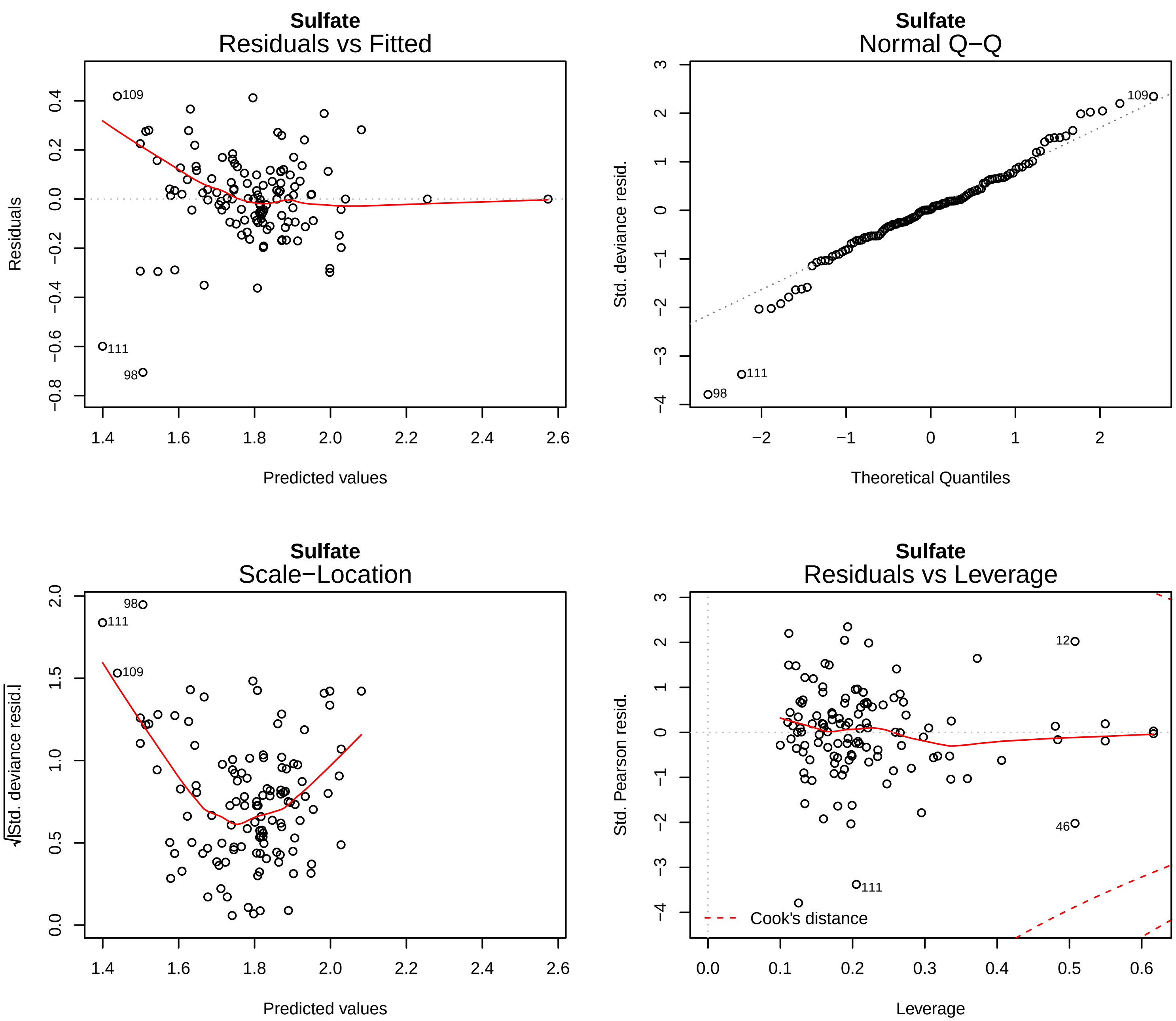
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

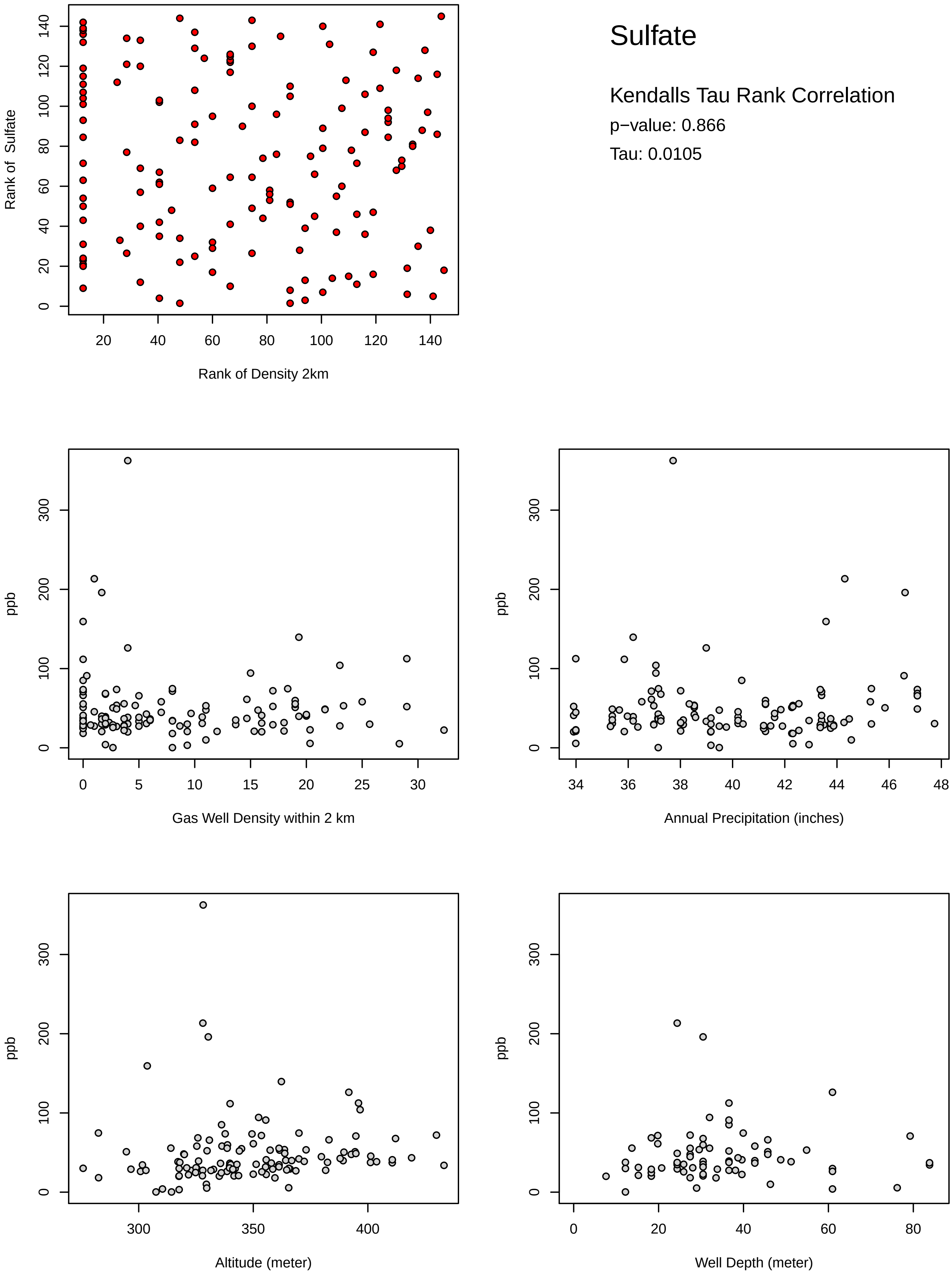
Original Model

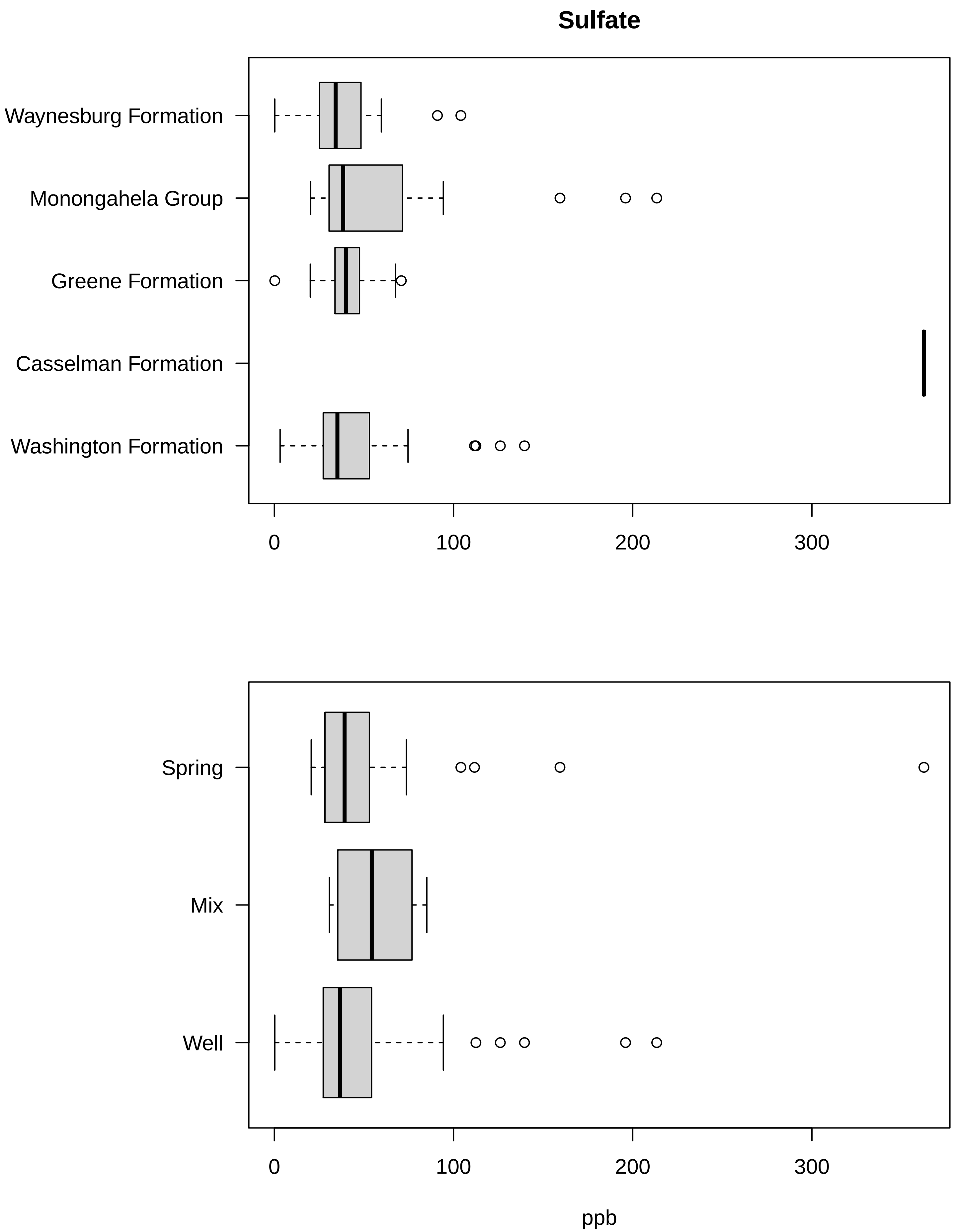


glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox Model




Sulfate
Kendalls Tau Rank Correlation
p−value: 0.866
Tau: 0.0105
Rank of Sulfate
Rank of Density 2km
ppb
Gas Well Density within 2 km
Annual Precipitation (inches)
Altitude (meter)
Well Depth (meter)



Sulfate
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
100
200
300
Spring
Mix
Well
0
100
200
300
ppb

Sulfate
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
100
200
300
ppb

```
[1] "ORIGINAL MODEL - Sulfate"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-87.744  -13.499   -2.391    8.973  110.990

Coefficients: (1 not defined because of singularities)
                                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                                            -100.69221   85.56621  -1.177 0.242321
dat$GWellDensity_2kmAvg                                   0.09421    0.55814   0.169 0.866324
dat$Altitude_meter                                        0.25349    0.15884   1.596 0.113943
dat$WatershedBane Creek                                  -2.54150   19.33689  -0.131 0.895720
dat$WatershedBrush Run                                   12.67995   14.82576   0.855 0.394626
dat$WatershedBurgetts Fork                               14.01255   18.64836   0.751 0.454324
dat$WatershedChartiers Run                                7.42443   20.96723   0.354 0.724077
dat$WatershedDaniels Run                                 -2.65212   28.58476  -0.093 0.926279
dat$WatershedEnlow Fork                                  -4.61091   22.57198  -0.204 0.838589
dat$WatershedFishpot Run-Monongahela River               83.18801   27.65121   3.008 0.003387 **
dat$WatershedHarmon Creek                                34.88438   37.69496   0.925 0.357159
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir   16.78773   32.43837   0.518 0.606031
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       5.40742   18.20539   0.297 0.767119
dat$WatershedLittle Racoon Creek                        326.18393   31.56710  10.333  < 2e-16 ***
dat$WatershedLittle Tenmile Creek                         3.58585   19.23845   0.186 0.852550
dat$WatershedMingo Creek-Monongahela River              119.61239   34.58672   3.458 0.000825 ***
dat$WatershedNorth Fork Cross Creek                      12.06746   17.84658   0.676 0.500624
dat$WatershedPigeon Creek                                38.88445   22.19908   1.752 0.083171 .
dat$WatershedPike Run                                     4.67592   21.28931   0.220 0.826640
dat$WatershedPlum Run-Tenmile Creek                      -4.19456   19.63123  -0.214 0.831279
dat$WatershedShort Creek-Tenmile Creek                   -9.28592   16.72555  -0.555 0.580109
dat$WatershedSouth Fork Cross Creek-Cross Creek           8.56796   14.24443   0.601 0.548989
dat$WatershedTempleton Fork                              19.82720   19.15111   1.035 0.303241
dat$WatershedUpper Chartiers Creek                       24.13266   14.61109   1.652 0.102012
dat$FormationCasselman Formation                               NA         NA      NA       NA
dat$FormationGreene Formation                           -10.77645   11.04698  -0.976 0.331865
dat$FormationMonongahela Group                            2.43227   11.87476   0.205 0.838160
dat$FormationWaynesburg Formation                       -15.27062    9.31610  -1.639 0.104594
dat$HHWSourceMix                                         10.90141   20.31410   0.537 0.592810
dat$HHWSourceSpring                                       4.50422    6.91070   0.652 0.516171
dat$Precip_inchAvg                                        1.29770    1.83738   0.706 0.481801
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 885.1044)

    Null deviance: 235091  on 121  degrees of freedom
Residual deviance:  81430  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: 1201.6
```

```
Number of Fisher Scoring iterations: 2

[1] "BOX-COX MODEL - Sulfate"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.70516  -0.08756   0.00113   0.09843   0.41909

Coefficients: (1 not defined because of singularities)
                                                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                 0.413792   0.571835   0.724 0.471134
dat$GWellDensity_2kmAvg                                     0.001272   0.003730   0.341 0.733775
dat$Altitude_meter                                          0.002378   0.001062   2.241 0.027457 *
dat$WatershedBane Creek                                     0.003923   0.129227   0.030 0.975846
dat$WatershedBrush Run                                      0.055629   0.099080   0.561 0.575851
dat$WatershedBurgetts Fork                                  0.150922   0.124626   1.211 0.228996
dat$WatershedChartiers Run                                  0.117649   0.140123   0.840 0.403304
dat$WatershedDaniels Run                                   -0.021283   0.191031  -0.111 0.911534
dat$WatershedEnlow Fork                                     0.002339   0.150847   0.016 0.987663
dat$WatershedFishpot Run-Monongahela River                  0.342856   0.184792   1.855 0.066746 .
dat$WatershedHarmon Creek                                   0.180211   0.251914   0.715 0.476192
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.173786   0.216784   0.802 0.424819
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         0.066093   0.121666   0.543 0.588284
dat$WatershedLittle Racoon Creek                            0.824698   0.210961   3.909 0.000177 ***
dat$WatershedLittle Tenmile Creek                           0.054254   0.128570   0.422 0.674023
dat$WatershedMingo Creek-Monongahela River                  0.494211   0.231141   2.138 0.035156 *
dat$WatershedNorth Fork Cross Creek                         0.106770   0.119268   0.895 0.373008
dat$WatershedPigeon Creek                                   0.210145   0.148355   1.417 0.160006
dat$WatershedPike Run                                       0.031217   0.142275   0.219 0.826815
dat$WatershedPlum Run-Tenmile Creek                        -0.020612   0.131195  -0.157 0.875500
dat$WatershedShort Creek-Tenmile Creek                     -0.158514   0.111776  -1.418 0.159529
dat$WatershedSouth Fork Cross Creek-Cross Creek             0.107608   0.095195   1.130 0.261248
dat$WatershedTempleton Fork                                 0.122851   0.127986   0.960 0.339632
dat$WatershedUpper Chartiers Creek                          0.176868   0.097645   1.811 0.073353 .
dat$FormationCasselman Formation                                  NA         NA      NA       NA
dat$FormationGreene Formation                              -0.077603   0.073826  -1.051 0.295940
dat$FormationMonongahela Group                              0.004713   0.079358   0.059 0.952774
dat$FormationWaynesburg Formation                          -0.110673   0.062259  -1.778 0.078771 .
dat$HHWSourceMix                                            0.150644   0.135758   1.110 0.270042
dat$HHWSourceSpring                                         0.090492   0.046184   1.959 0.053095 .
dat$Precip_inchAvg                                          0.012159   0.012279   0.990 0.324668
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.03953038)

    Null deviance: 6.6601  on 121  degrees of freedom
Residual deviance: 3.6368  on  92  degrees of freedom
  (23 observations deleted due to missingness)
AIC: -20.355
```

Number of Fisher Scoring iterations: 2

pH

Skewness: 0.7239

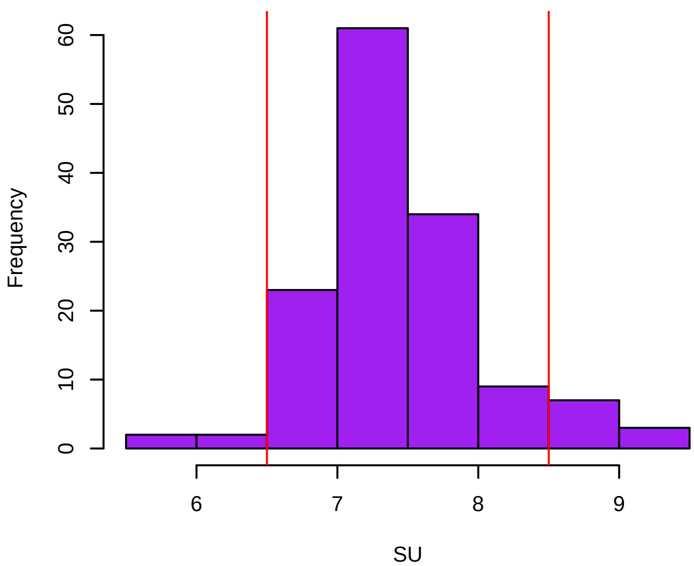
Kurtosis: 4.6941

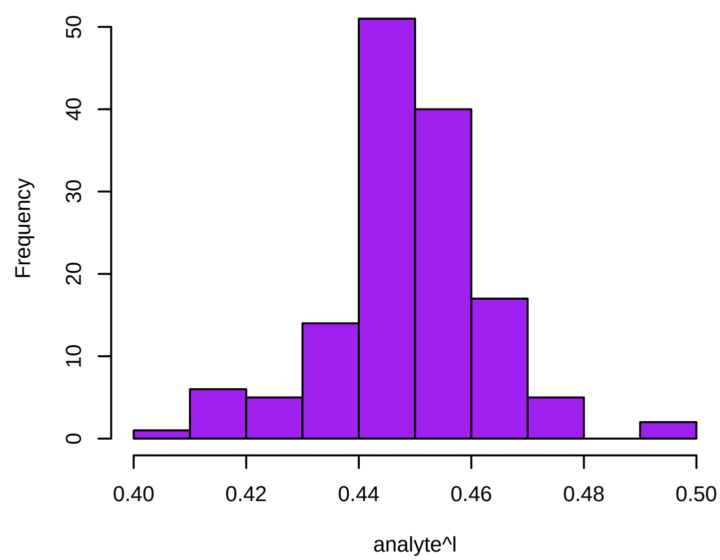
pH Box−Cox

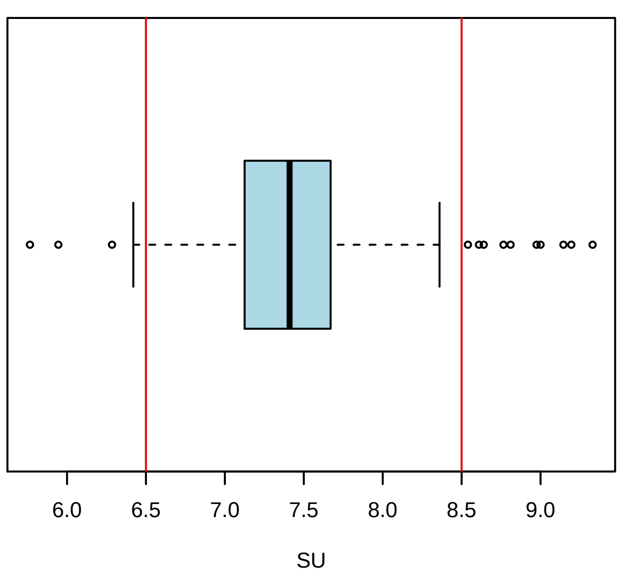
Skewness: −0.1801

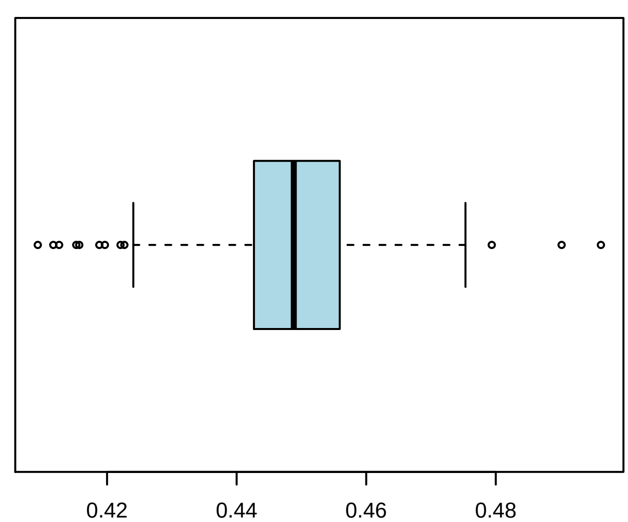
Kurtosis: 4.5769

Optimal lambda: −0.4



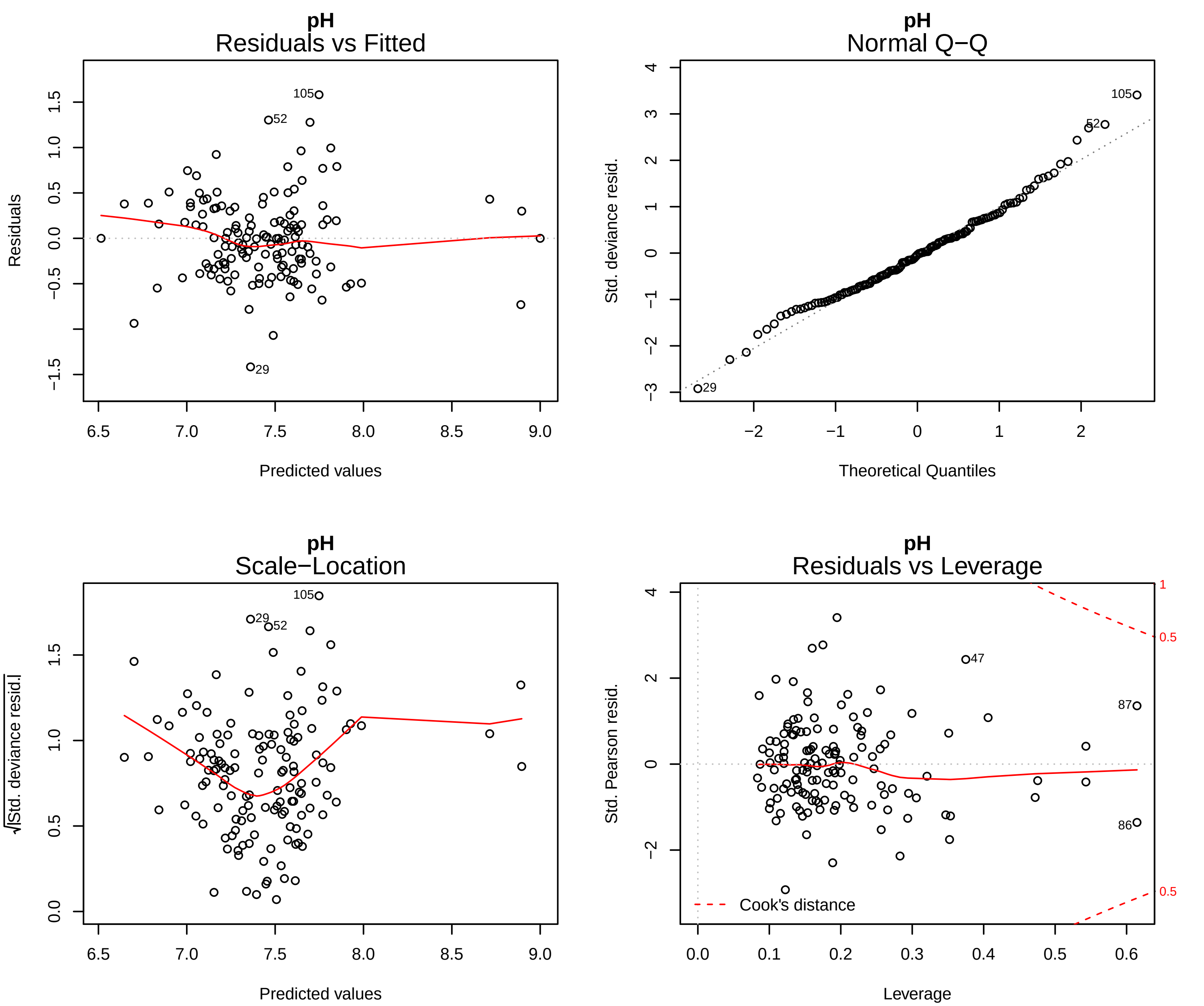






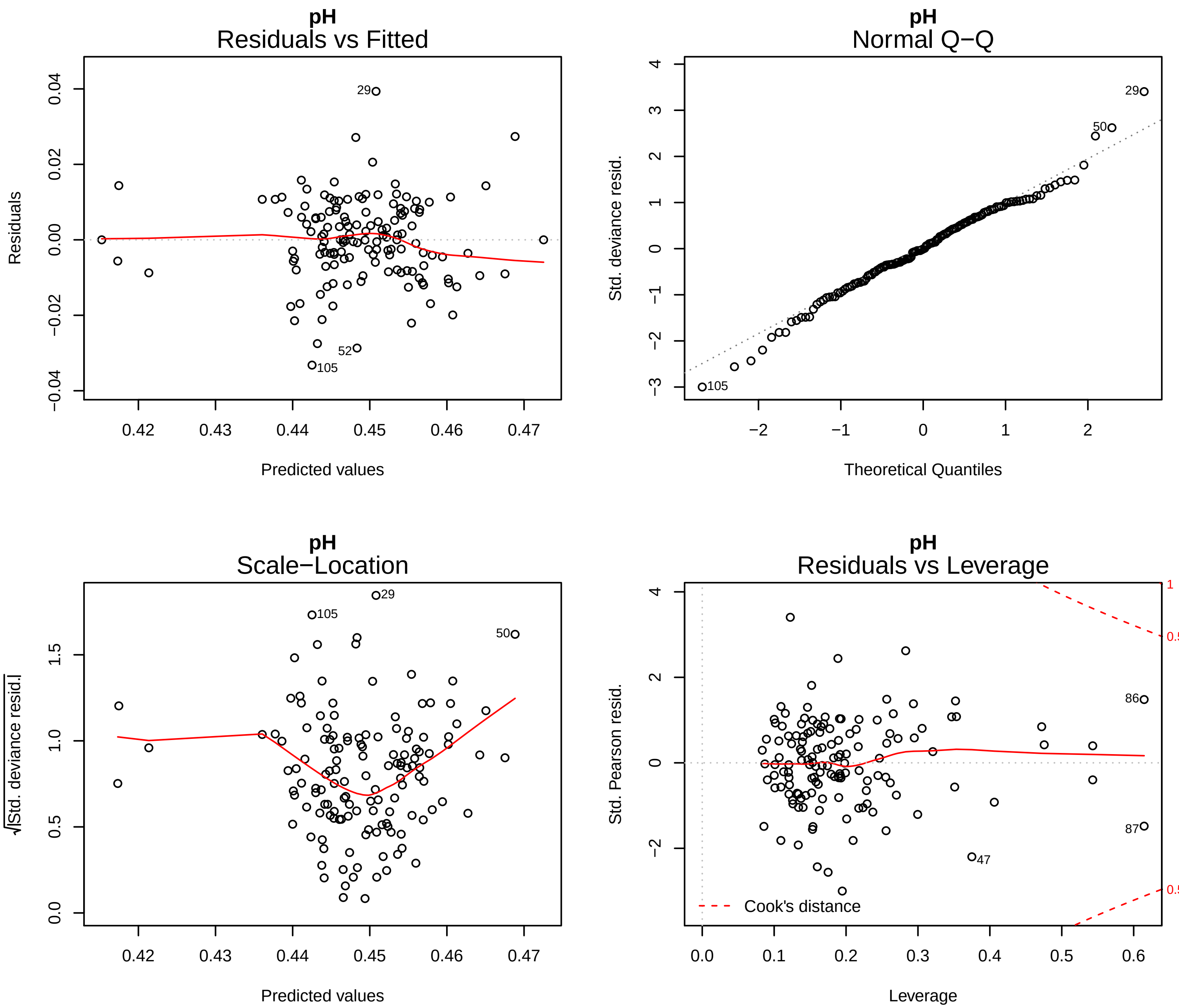
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

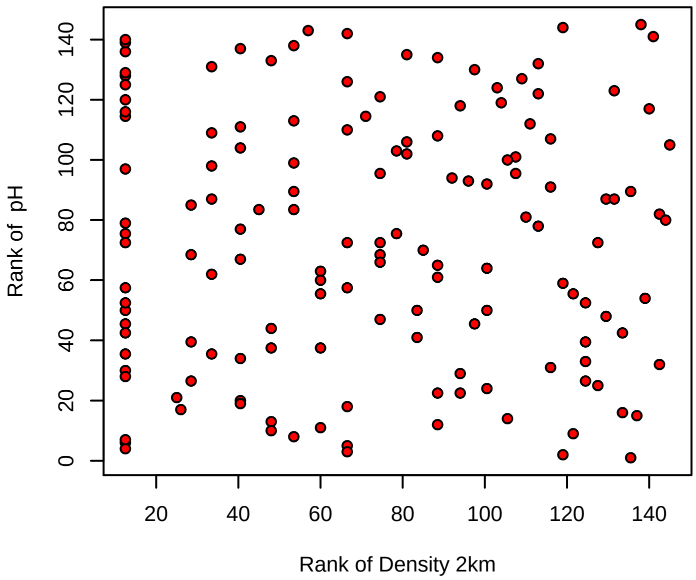
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



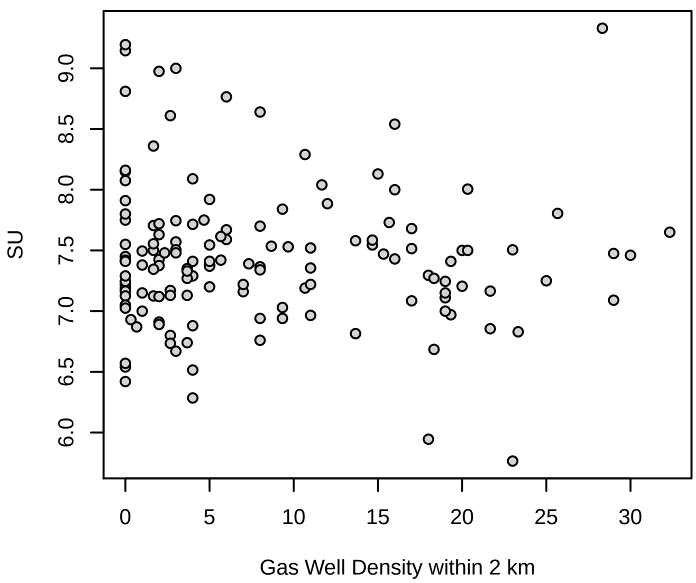


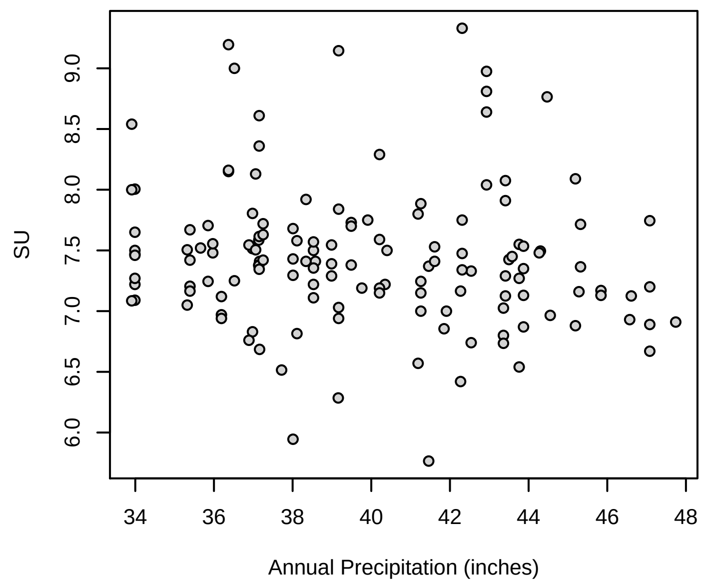
pH

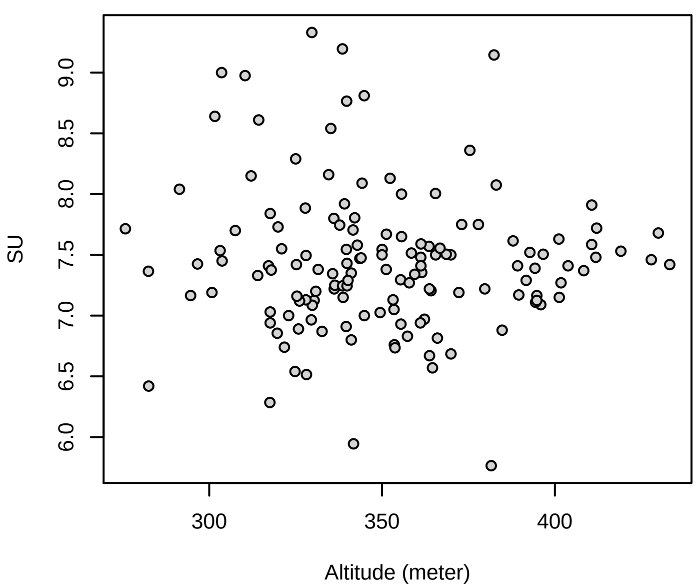
Kendalls Tau Rank Correlation

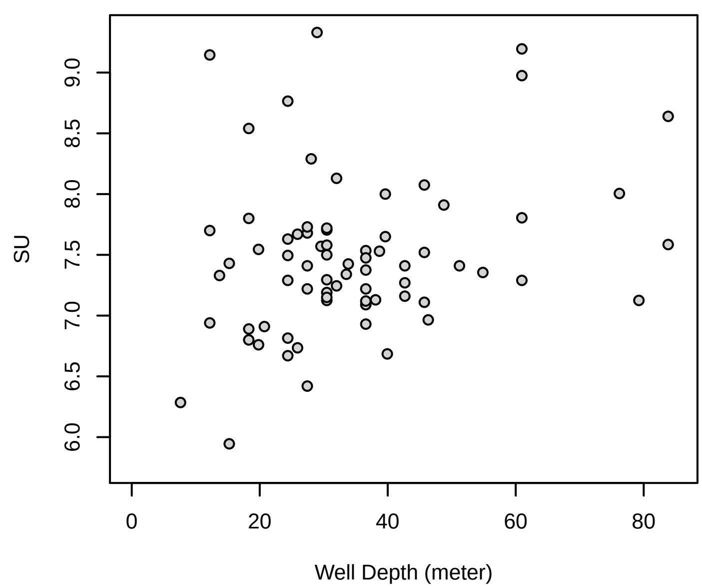
p−value: 0.791

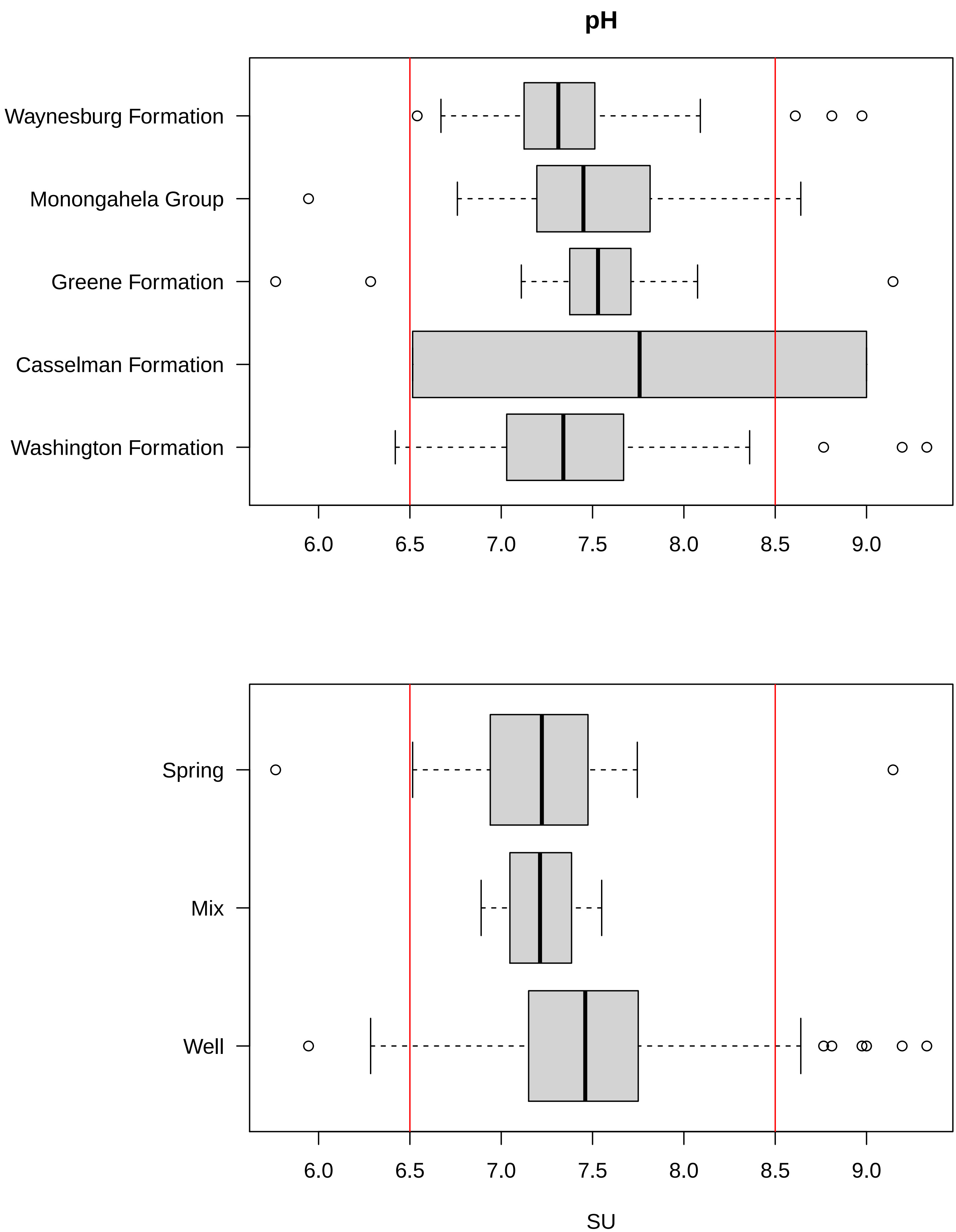
Tau: −0.0154

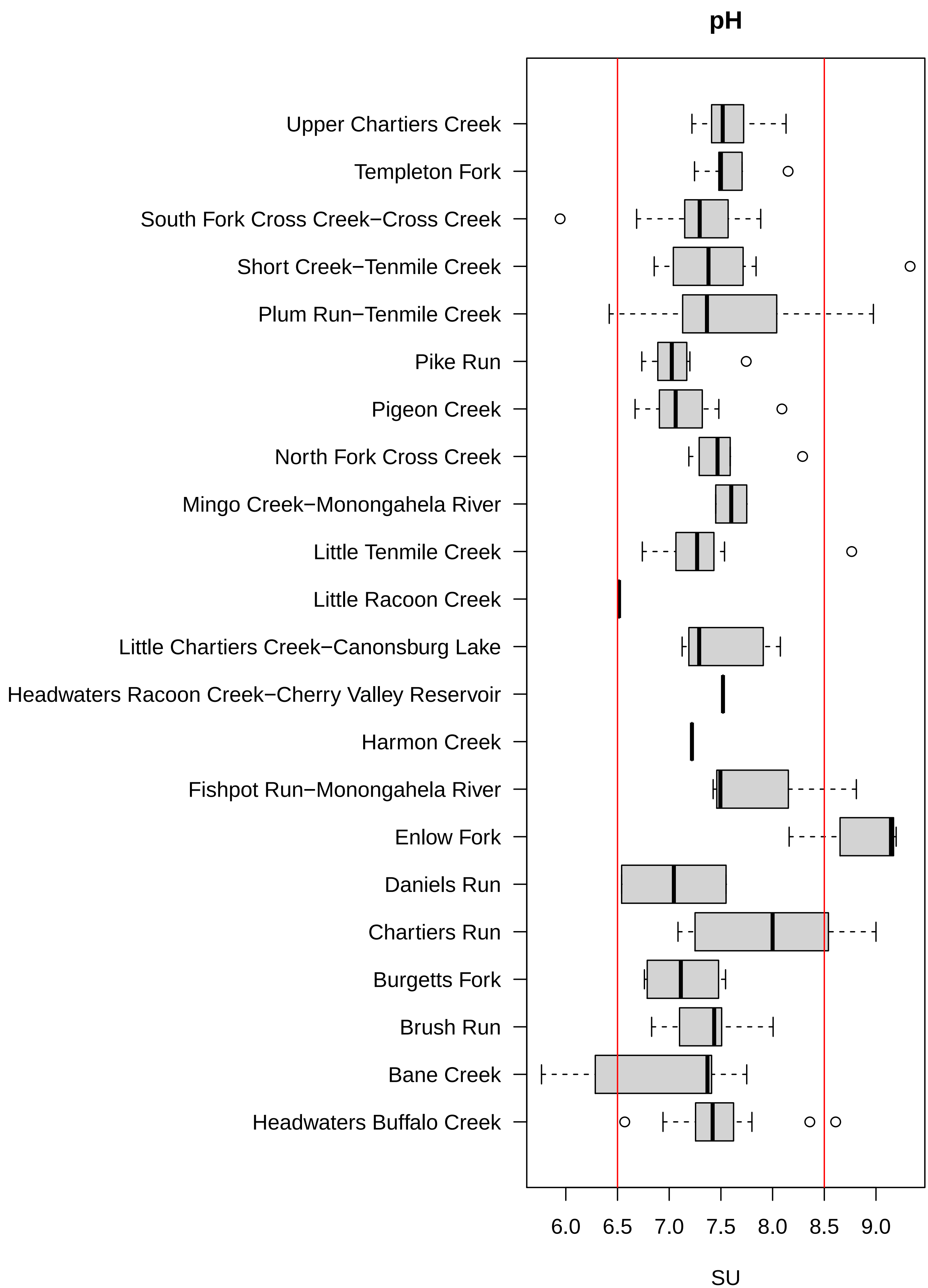









pH
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
6.0
6.5
7.0
7.5
8.0
8.5
9.0
Spring
Mix
Well
6.0
6.5
7.0
7.5
8.0
8.5
9.0
SU


pH
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
6.0
6.5
7.0
7.5
8.0
8.5
9.0
SU

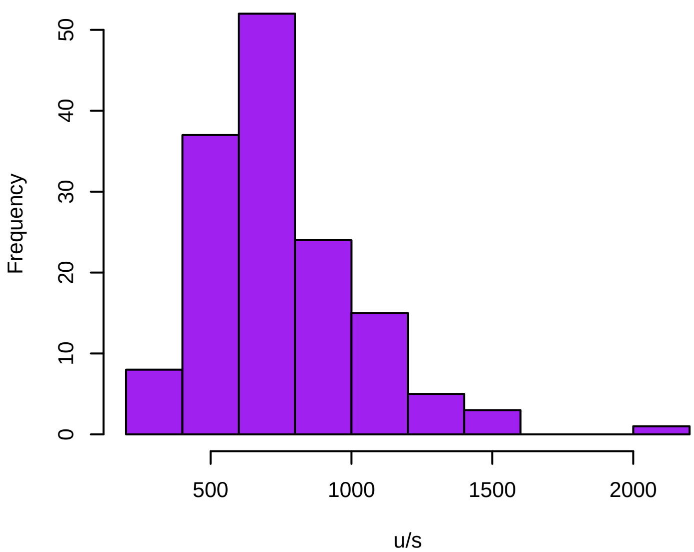
```
[1] "ORIGINAL MODEL - pH"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.41574  -0.31616  -0.00242   0.26599   1.58170

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  5.907098   1.426977   4.140 6.84e-05 ***
dat$GWellDensity_2kmAvg                                      0.002528   0.008958   0.282  0.77830
dat$Altitude_meter                                           0.001226   0.002435   0.503  0.61568
dat$WatershedBane Creek                                     -0.745459   0.301724  -2.471  0.01502 *
dat$WatershedBrush Run                                      -0.157553   0.249099  -0.632  0.52838
dat$WatershedBurgetts Fork                                  -0.615324   0.316068  -1.947  0.05411 .
dat$WatershedChartiers Run                                   0.020592   0.352385   0.058  0.95351
dat$WatershedDaniels Run                                    -0.558719   0.480403  -1.163  0.24734
dat$WatershedEnlow Fork                                      1.398387   0.327515   4.270 4.17e-05 ***
dat$WatershedFishpot Run-Monongahela River                  -0.049259   0.396668  -0.124  0.90140
dat$WatershedHarmon Creek                                   -0.509168   0.648011  -0.786  0.43371
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.195853   0.557000  -0.352  0.72580
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         -0.212981   0.305721  -0.697  0.48749
dat$WatershedLittle Racoon Creek                            -2.203619   0.817640  -2.695  0.00814 **
dat$WatershedLittle Tenmile Creek                           -0.312795   0.312304  -1.002  0.31875
dat$WatershedMingo Creek-Monongahela River                  -0.054750   0.418758  -0.131  0.89622
dat$WatershedNorth Fork Cross Creek                         -0.273851   0.280733  -0.975  0.33146
dat$WatershedPigeon Creek                                   -0.779806   0.351639  -2.218  0.02864 *
dat$WatershedPike Run                                       -0.757297   0.343582  -2.204  0.02960 *
dat$WatershedPlum Run-Tenmile Creek                         -0.129562   0.305876  -0.424  0.67270
dat$WatershedShort Creek-Tenmile Creek                      -0.001286   0.254406  -0.005  0.99598
dat$WatershedSouth Fork Cross Creek-Cross Creek             -0.533637   0.231792  -2.302  0.02320 *
dat$WatershedTempleton Fork                                  0.143620   0.267902   0.536  0.59298
dat$WatershedUpper Chartiers Creek                          -0.098980   0.231726  -0.427  0.67011
dat$FormationCasselman Formation                             1.512897   0.638515   2.369  0.01956 *
dat$FormationGreene Formation                                0.006881   0.179353   0.038  0.96947
dat$FormationMonongahela Group                               0.295016   0.187633   1.572  0.11875
dat$FormationWaynesburg Formation                            0.147562   0.149552   0.987  0.32596
dat$HHWSourceMix                                            -0.188428   0.349853  -0.539  0.59126
dat$HHWSourceSpring                                         -0.332178   0.114699  -2.896  0.00456 **
dat$Precip_inchAvg                                           0.032303   0.029387   1.099  0.27407
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.2674052)

    Null deviance: 48.314  on 140  degrees of freedom
Residual deviance: 29.415  on 110  degrees of freedom
  (4 observations deleted due to missingness)
AIC: 243.16
```

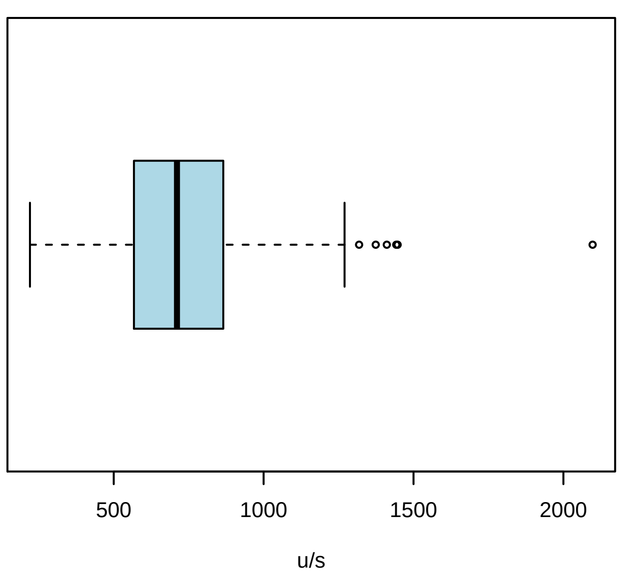
```
Number of Fisher Scoring iterations: 2

[1] "BOX-COX MODEL - pH"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-0.033207  -0.006589   0.000000   0.007491   0.039351

Coefficients:
                                                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                4.863e-01  3.404e-02  14.283  < 2e-16 ***
dat$GWellDensity_2kmAvg                                   -4.988e-06  2.137e-04  -0.023  0.98142
dat$Altitude_meter                                        -3.447e-05  5.810e-05  -0.593  0.55423
dat$WatershedBane Creek                                    1.954e-02  7.199e-03   2.715  0.00770 **
dat$WatershedBrush Run                                     2.737e-03  5.943e-03   0.460  0.64607
dat$WatershedBurgetts Fork                                 1.456e-02  7.541e-03   1.931  0.05600 .
dat$WatershedChartiers Run                                -8.013e-04  8.407e-03  -0.095  0.92424
dat$WatershedDaniels Run                                   1.418e-02  1.146e-02   1.237  0.21870
dat$WatershedEnlow Fork                                   -2.976e-02  7.814e-03  -3.809  0.00023 ***
dat$WatershedFishpot Run-Monongahela River                 1.842e-03  9.464e-03   0.195  0.84606
dat$WatershedHarmon Creek                                  1.254e-02  1.546e-02   0.811  0.41888
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  3.989e-03  1.329e-02   0.300  0.76459
dat$WatershedLittle Chartiers Creek-Canonsburg Lake        5.180e-03  7.294e-03   0.710  0.47909
dat$WatershedLittle Racoon Creek                           5.042e-02  1.951e-02   2.585  0.01105 *
dat$WatershedLittle Tenmile Creek                          7.459e-03  7.451e-03   1.001  0.31901
dat$WatershedMingo Creek-Monongahela River                 1.107e-03  9.991e-03   0.111  0.91195
dat$WatershedNorth Fork Cross Creek                        6.234e-03  6.698e-03   0.931  0.35400
dat$WatershedPigeon Creek                                  1.871e-02  8.389e-03   2.230  0.02777 *
dat$WatershedPike Run                                      1.828e-02  8.197e-03   2.230  0.02776 *
dat$WatershedPlum Run-Tenmile Creek                        3.629e-03  7.298e-03   0.497  0.61998
dat$WatershedShort Creek-Tenmile Creek                    -2.473e-04  6.070e-03  -0.041  0.96757
dat$WatershedSouth Fork Cross Creek-Cross Creek            1.240e-02  5.530e-03   2.242  0.02696 *
dat$WatershedTempleton Fork                               -3.527e-03  6.392e-03  -0.552  0.58216
dat$WatershedUpper Chartiers Creek                         1.683e-03  5.529e-03   0.304  0.76139
dat$FormationCasselman Formation                          -3.212e-02  1.523e-02  -2.108  0.03727 *
dat$FormationGreene Formation                             -1.699e-04  4.279e-03  -0.040  0.96840
dat$FormationMonongahela Group                            -7.235e-03  4.477e-03  -1.616  0.10891
dat$FormationWaynesburg Formation                         -3.506e-03  3.568e-03  -0.983  0.32791
dat$HHWSourceMix                                           4.039e-03  8.347e-03   0.484  0.62942
dat$HHWSourceSpring                                        7.824e-03  2.736e-03   2.859  0.00508 **
dat$Precip_inchAvg                                        -7.561e-04  7.011e-04  -1.078  0.28318
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.0001522075)

    Null deviance: 0.026938  on 140  degrees of freedom
Residual deviance: 0.016743  on 110  degrees of freedom
  (4 observations deleted due to missingness)
AIC: -810.29
```

Number of Fisher Scoring iterations: 2

Cond at 25C

Skewness: 1.3183
Kurtosis: 6.5554

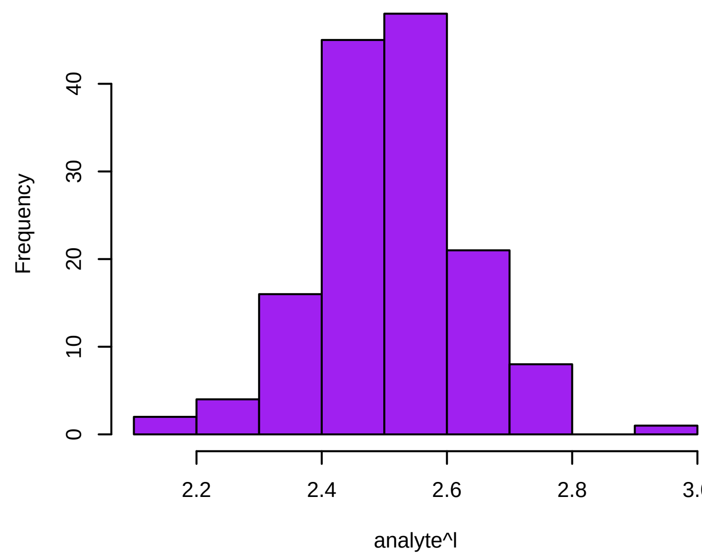


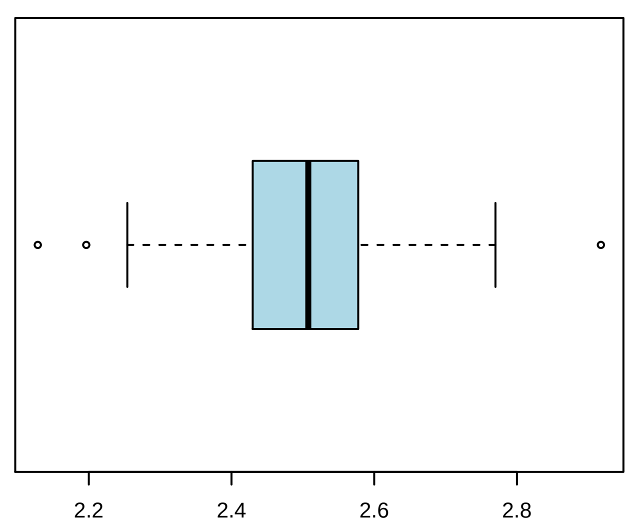


Cond at 25C Box−Cox

Skewness: 0.0799
Kurtosis: 3.6539

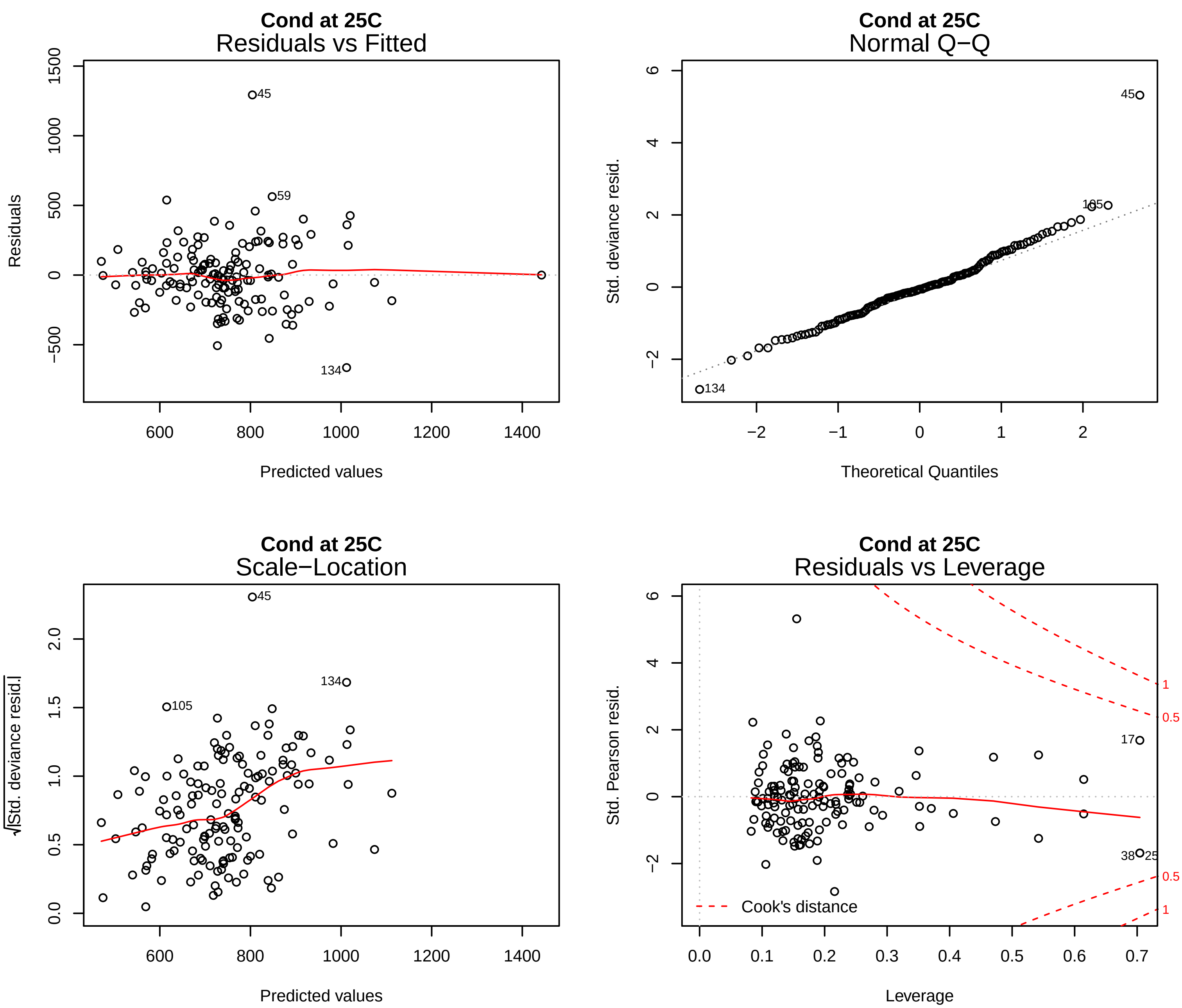
Optimal lambda: 0.14





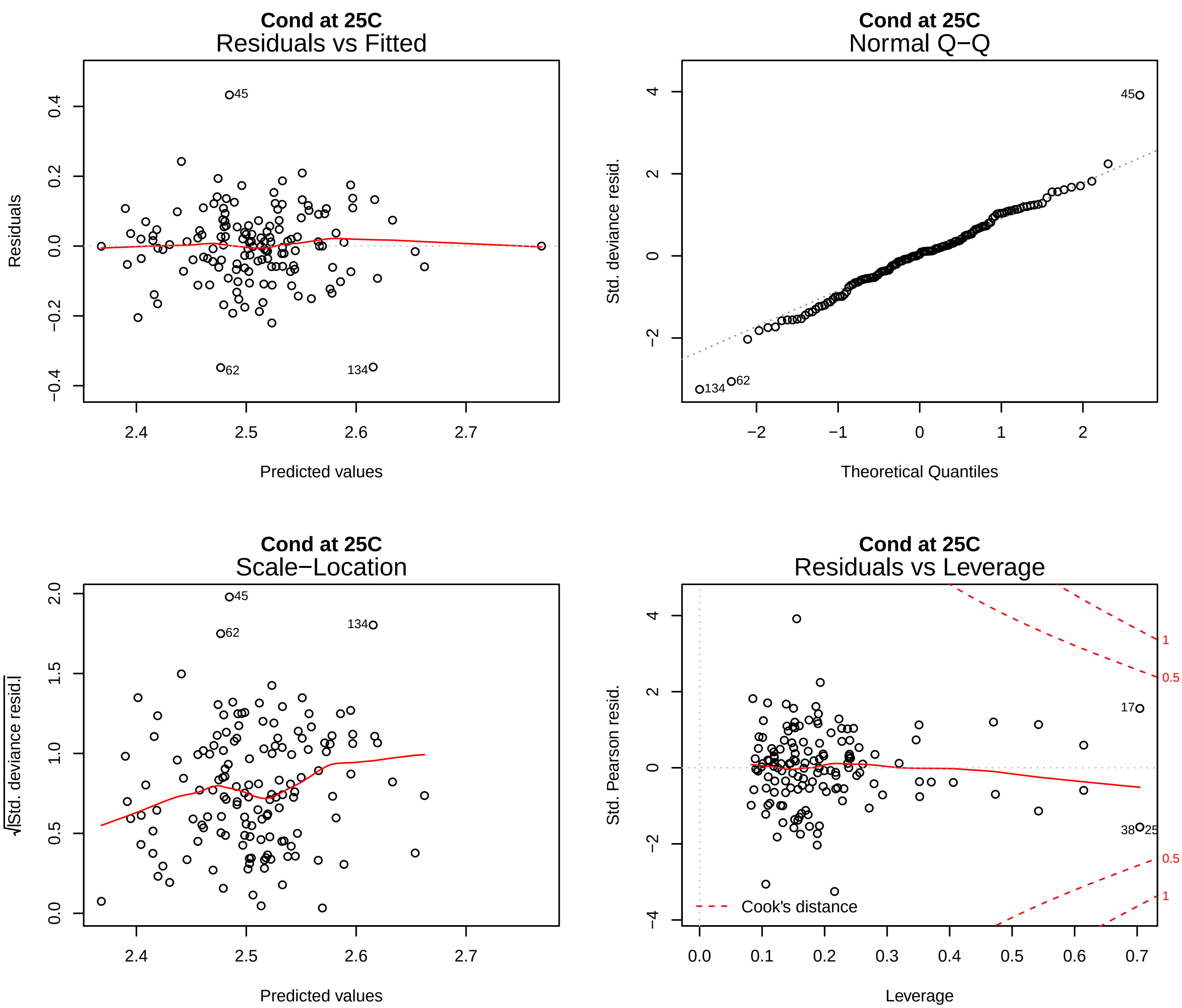
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

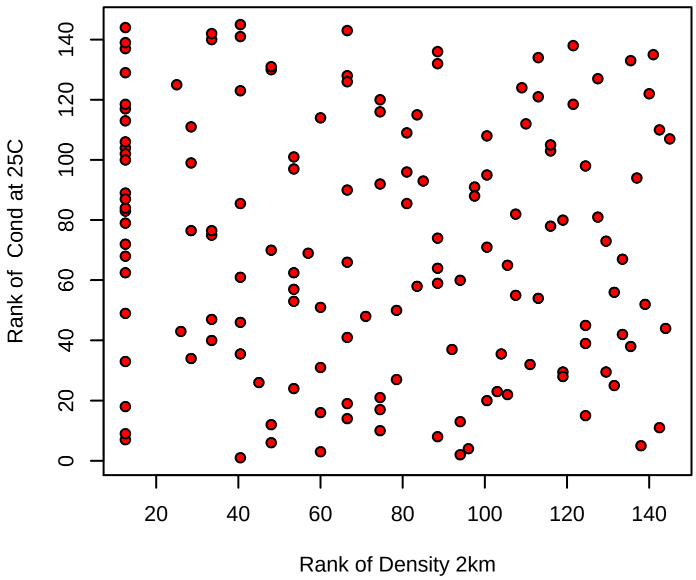
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



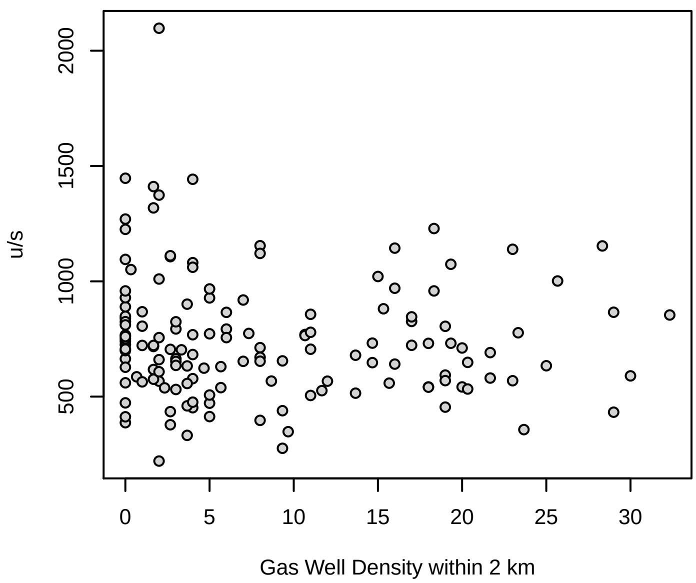


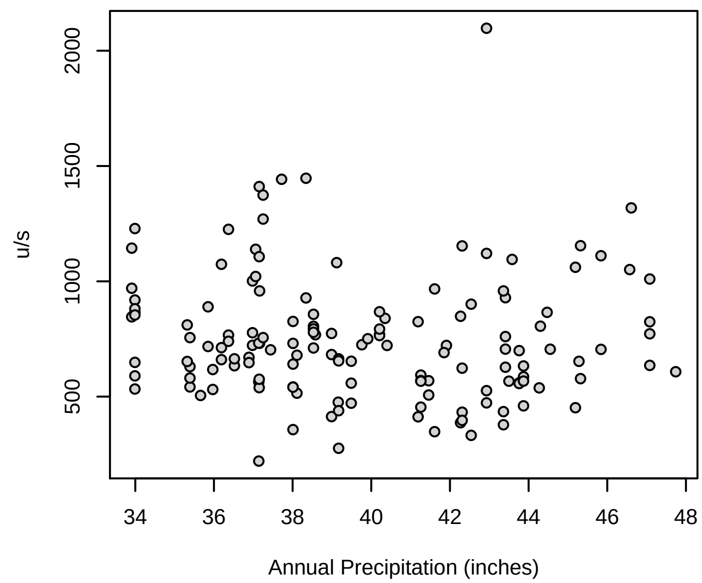
Cond at 25C

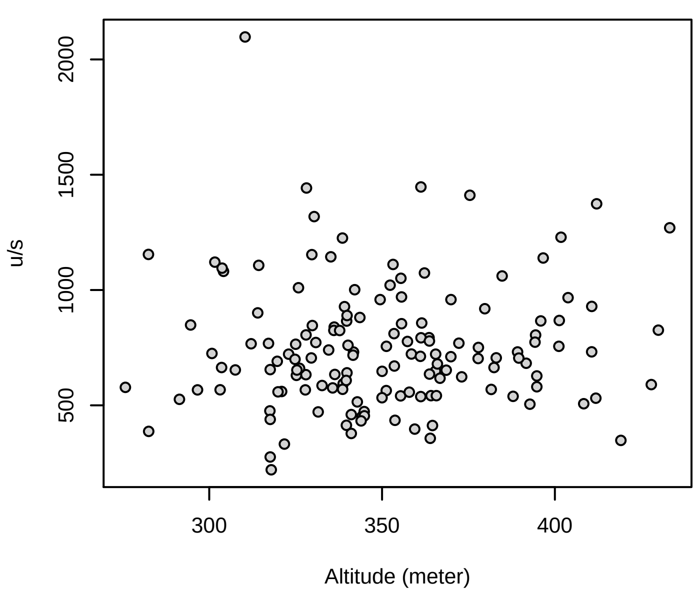
Kendalls Tau Rank Correlation

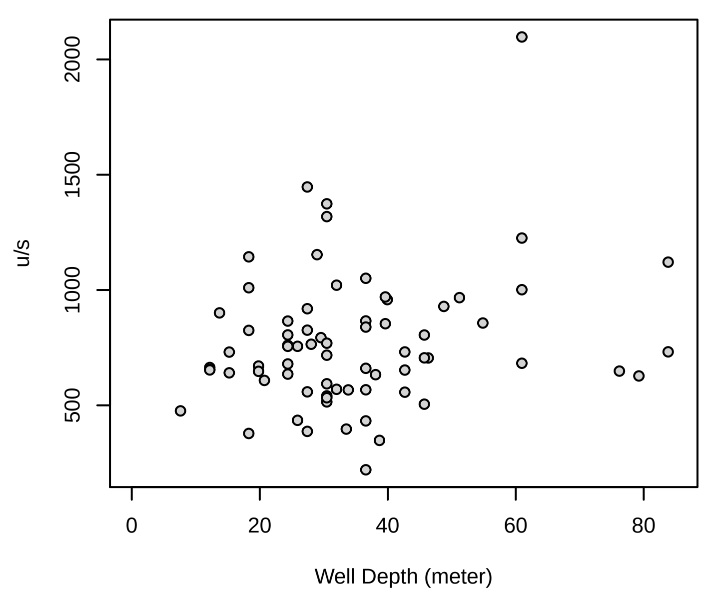
p−value: 0.227

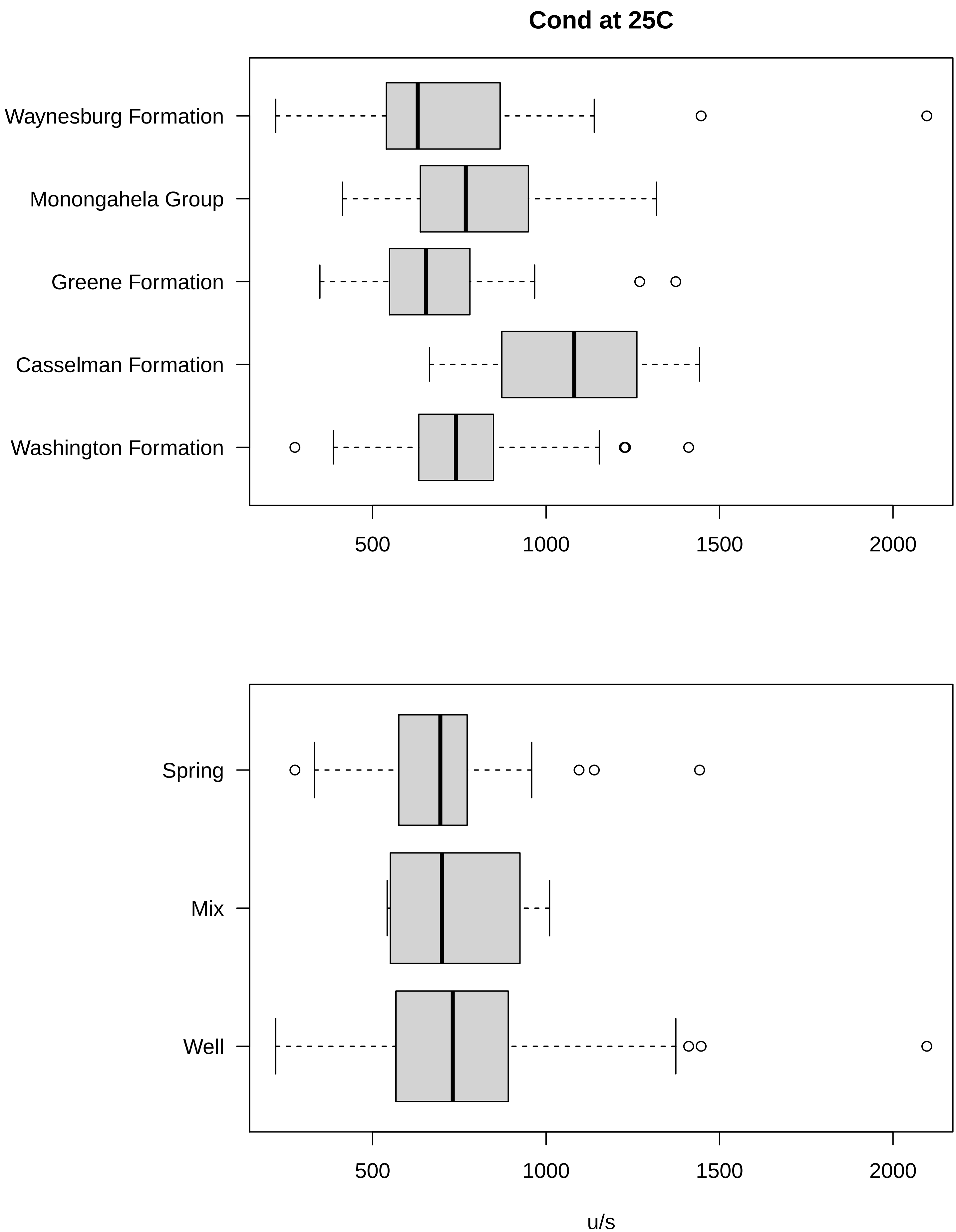
Tau: −0.0691



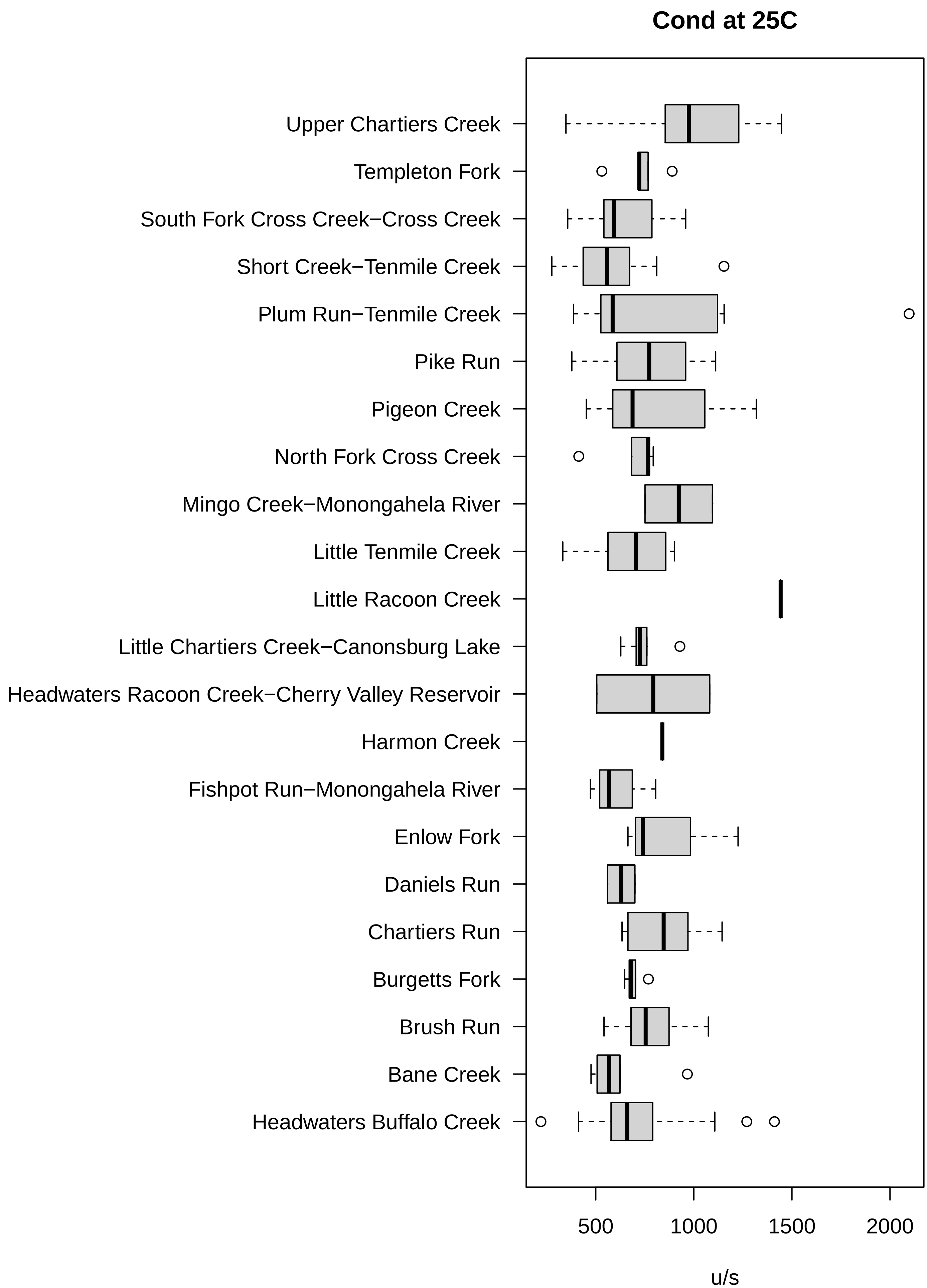








Cond at 25C
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
500
1000
1500
2000
Spring
Mix
Well
500
1000
1500
2000
u/s


Cond at 25C
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
500
1000
1500
2000
u/s

```
[1] "ORIGINAL MODEL - Cond at 25C"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-664.17  -143.30   -13.01   104.64  1293.19  

Coefficients:
                                                           Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                                 252.134    727.357   0.347   0.7295  
dat$GWellDensity_2kmAvg                                      -4.408      4.495  -0.981   0.3288  
dat$Altitude_meter                                            1.021      1.234   0.828   0.4095  
dat$WatershedBane Creek                                     -86.240    154.140  -0.559   0.5769  
dat$WatershedBrush Run                                       90.556    126.679   0.715   0.4762  
dat$WatershedBurgetts Fork                                  -98.991    148.208  -0.668   0.5055  
dat$WatershedChartiers Run                                   71.581    173.053   0.414   0.6799  
dat$WatershedDaniels Run                                    -43.097    245.586  -0.175   0.8610  
dat$WatershedEnlow Fork                                     120.572    167.381   0.720   0.4728  
dat$WatershedFishpot Run-Monongahela River                 -250.713    202.712  -1.237   0.2187  
dat$WatershedHarmon Creek                                    19.833    331.287   0.060   0.9524  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -7.695    241.298  -0.032   0.9746  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         -56.358    156.124  -0.361   0.7188  
dat$WatershedLittle Racoon Creek                            704.093    373.240   1.886   0.0618 .
dat$WatershedLittle Tenmile Creek                           -63.203    159.672  -0.396   0.6930  
dat$WatershedMingo Creek-Monongahela River                  100.020    213.936   0.468   0.6410  
dat$WatershedNorth Fork Cross Creek                        -154.314    143.547  -1.075   0.2846  
dat$WatershedPigeon Creek                                   -17.025    179.744  -0.095   0.9247  
dat$WatershedPike Run                                       -57.601    175.591  -0.328   0.7435  
dat$WatershedPlum Run-Tenmile Creek                          50.721    155.718   0.326   0.7452  
dat$WatershedShort Creek-Tenmile Creek                      -99.108    129.255  -0.767   0.4448  
dat$WatershedSouth Fork Cross Creek-Cross Creek            -128.651    115.775  -1.111   0.2688  
dat$WatershedTempleton Fork                                 -34.485    136.883  -0.252   0.8015  
dat$WatershedUpper Chartiers Creek                          232.934    118.158   1.971   0.0511 .
dat$FormationCasselman Formation                             69.808    269.458   0.259   0.7961  
dat$FormationGreene Formation                              -104.439     91.516  -1.141   0.2562  
dat$FormationMonongahela Group                               75.856     95.794   0.792   0.4301  
dat$FormationWaynesburg Formation                           -60.661     74.138  -0.818   0.4149  
dat$HHWSourceMix                                            -90.326    178.962  -0.505   0.6147  
dat$HHWSourceSpring                                        -124.153     58.636  -2.117   0.0364 *
dat$Precip_inchAvg                                            5.915     15.007   0.394   0.6942  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 69974.33)

    Null deviance: 10542254  on 144  degrees of freedom
Residual deviance:  7977073  on 114  degrees of freedom
AIC: 2058.2

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Cond at 25C"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.34818  -0.05927   0.00280   0.05871   0.43305

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              2.3462588  0.3308949   7.091 1.19e-10 ***
dat$GWellDensity_2kmAvg                                 -0.0012620  0.0020450  -0.617   0.5384
dat$Altitude_meter                                       0.0004320  0.0005613   0.770   0.4431
dat$WatershedBane Creek                                 -0.0373492  0.0701225  -0.533   0.5953
dat$WatershedBrush Run                                   0.0439763  0.0576297   0.763   0.4470
dat$WatershedBurgetts Fork                              -0.0242419  0.0674239  -0.360   0.7199
dat$WatershedChartiers Run                               0.0272050  0.0787265   0.346   0.7303
dat$WatershedDaniels Run                                 0.0219271  0.1117237   0.196   0.8448
dat$WatershedEnlow Fork                                  0.0607637  0.0761464   0.798   0.4265
dat$WatershedFishpot Run-Monongahela River              -0.0933794  0.0922191  -1.013   0.3134
dat$WatershedHarmon Creek                                0.0334511  0.1507115   0.222   0.8247
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0035296  0.1097732  -0.032   0.9744
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     -0.0006657  0.0710252  -0.009   0.9925
dat$WatershedLittle Racoon Creek                         0.2539183  0.1697971   1.495   0.1376
dat$WatershedLittle Tenmile Creek                       -0.0088342  0.0726392  -0.122   0.9034
dat$WatershedMingo Creek-Monongahela River               0.0620390  0.0973254   0.637   0.5251
dat$WatershedNorth Fork Cross Creek                     -0.0556621  0.0653037  -0.852   0.3958
dat$WatershedPigeon Creek                                0.0200002  0.0817705   0.245   0.8072
dat$WatershedPike Run                                   -0.0055827  0.0798812  -0.070   0.9444
dat$WatershedPlum Run-Tenmile Creek                      0.0042621  0.0708405   0.060   0.9521
dat$WatershedShort Creek-Tenmile Creek                  -0.0627531  0.0588015  -1.067   0.2881
dat$WatershedSouth Fork Cross Creek-Cross Creek         -0.0540630  0.0526691  -1.026   0.3068
dat$WatershedTempleton Fork                             -0.0023813  0.0622719  -0.038   0.9696
dat$WatershedUpper Chartiers Creek                       0.0956051  0.0537532   1.779   0.0780 .
dat$FormationCasselman Formation                         0.0410785  0.1225840   0.335   0.7382
dat$FormationGreene Formation                           -0.0451845  0.0416333  -1.085   0.2801
dat$FormationMonongahela Group                           0.0340888  0.0435793   0.782   0.4357
dat$FormationWaynesburg Formation                       -0.0489695  0.0337272  -1.452   0.1493
dat$HHWSourceMix                                        -0.0408201  0.0814146  -0.501   0.6171
dat$HHWSourceSpring                                     -0.0545322  0.0266752  -2.044   0.0432 *
dat$Precip_inchAvg                                       0.0012001  0.0068270   0.176   0.8608
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.01448182)

    Null deviance: 2.1600  on 144  degrees of freedom
Residual deviance: 1.6509  on 114  degrees of freedom
AIC: -173.44

Number of Fisher Scoring iterations: 2
```

Temperature

Skewness: −0.3483

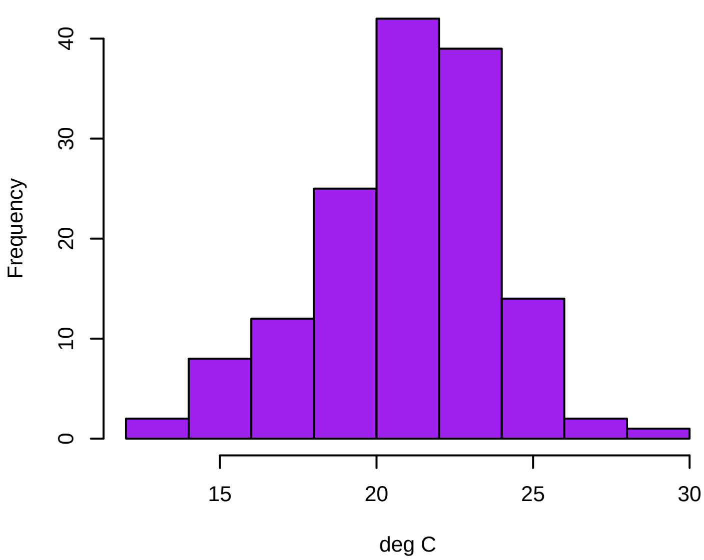
Kurtosis: 3.1199

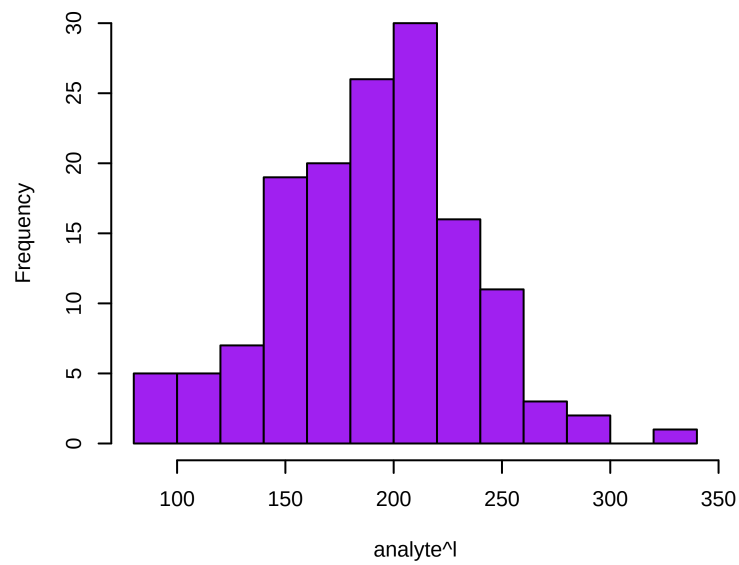
Temperature Box−Cox

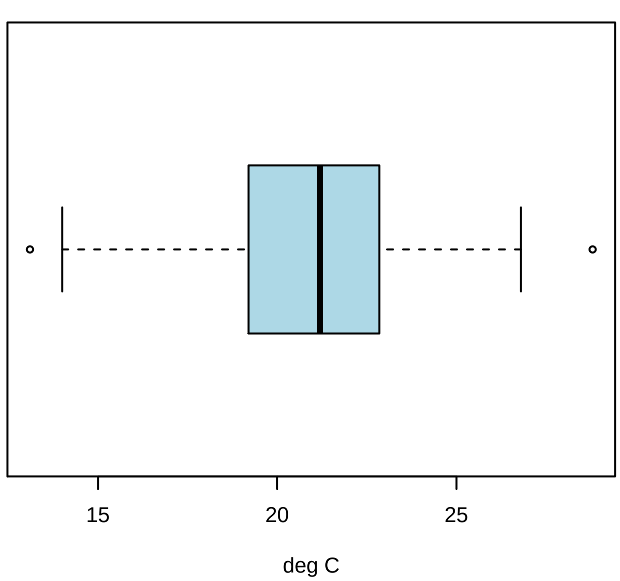
Skewness: −0.0473

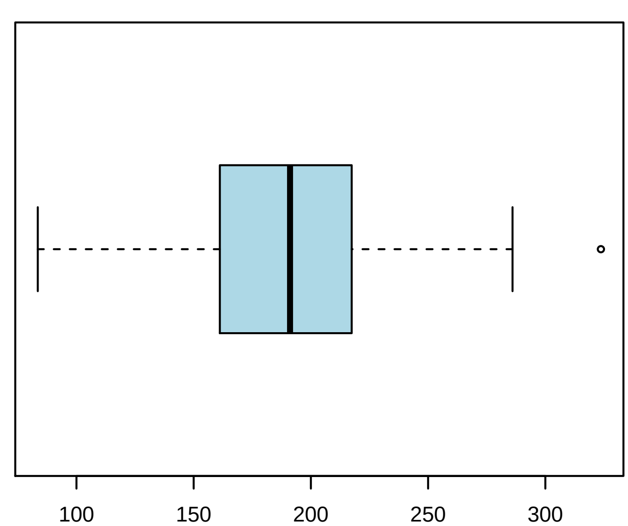
Kurtosis: 3.0427

Optimal lambda: 1.72



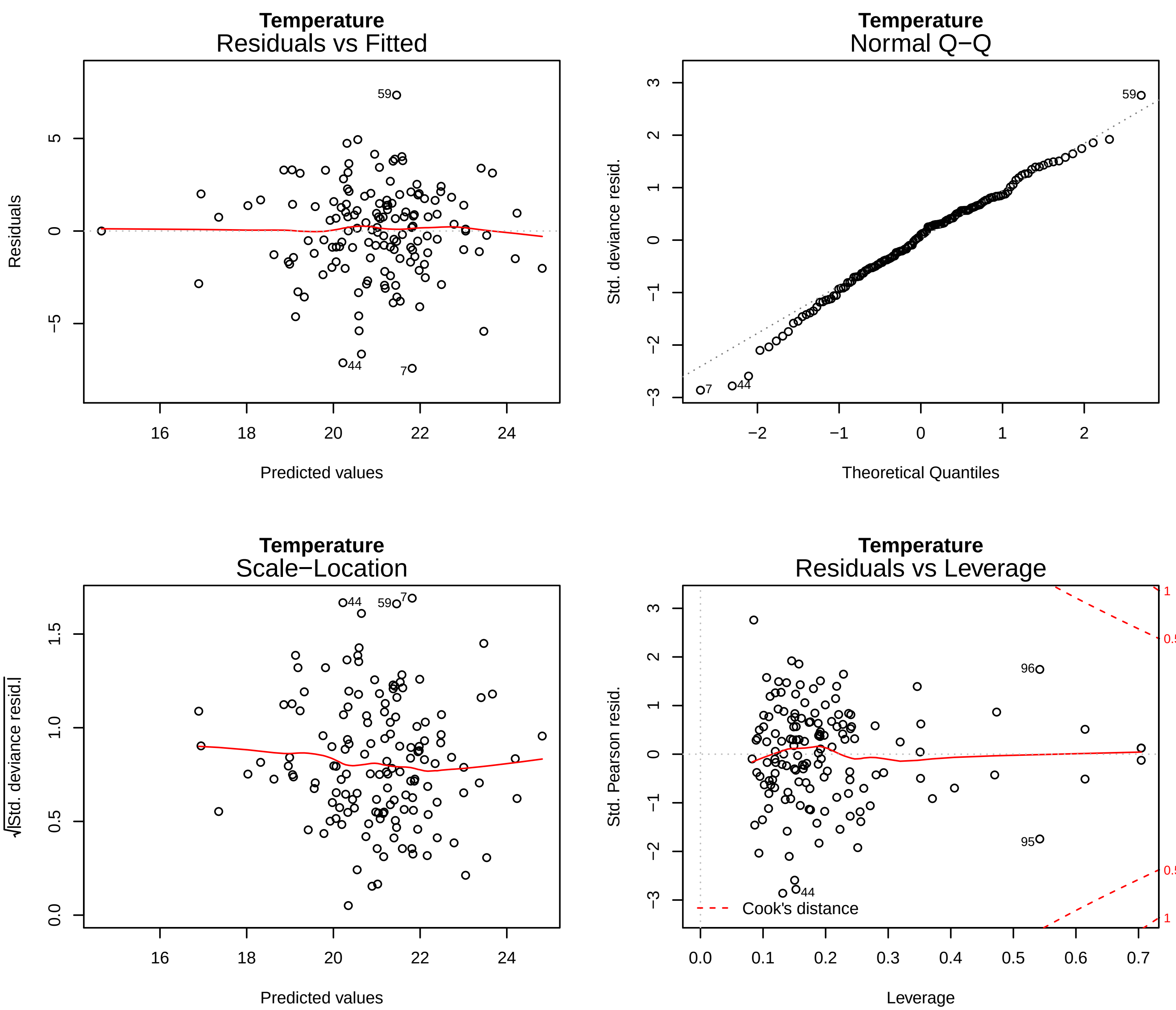






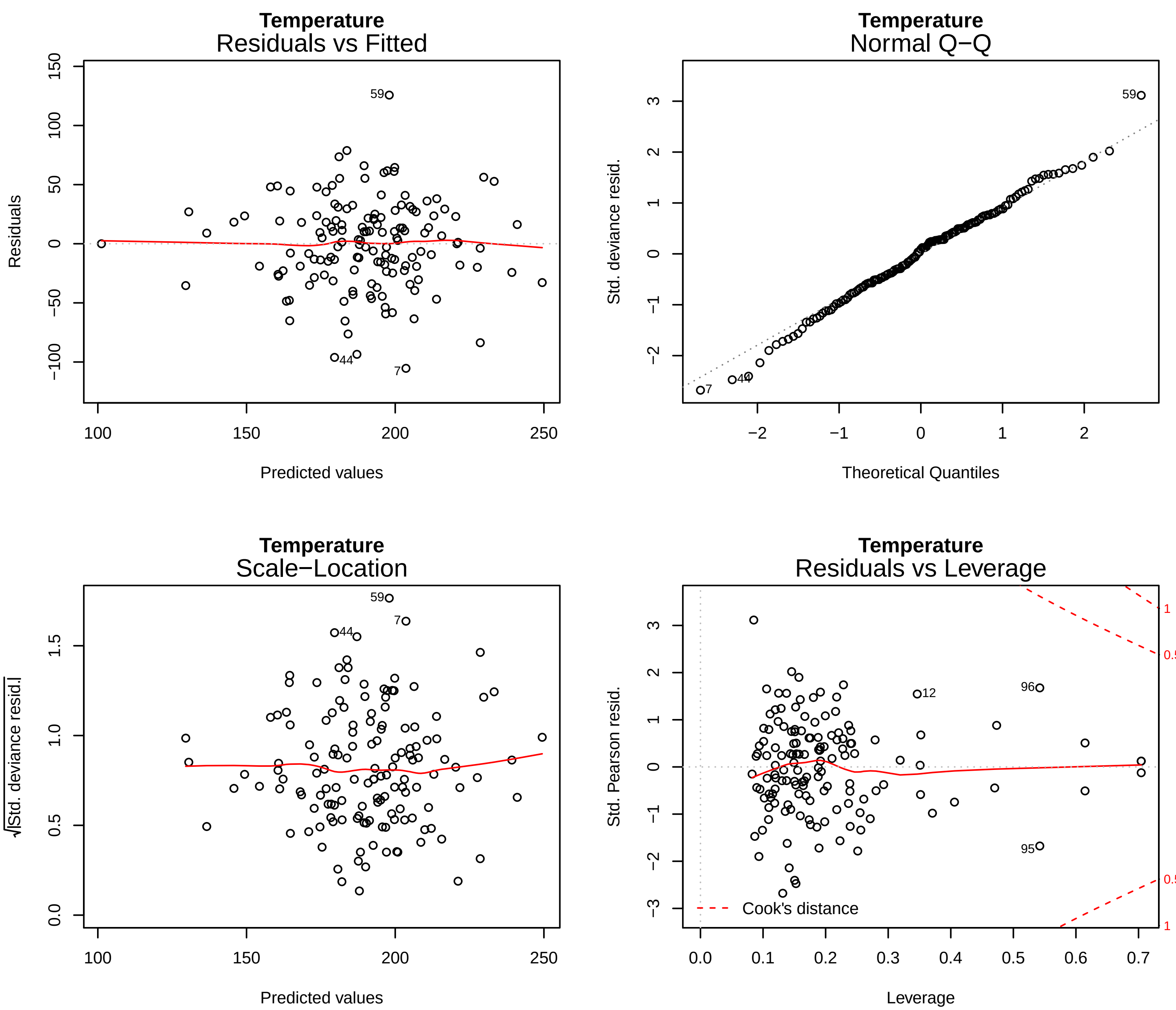
glm(analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershed ...

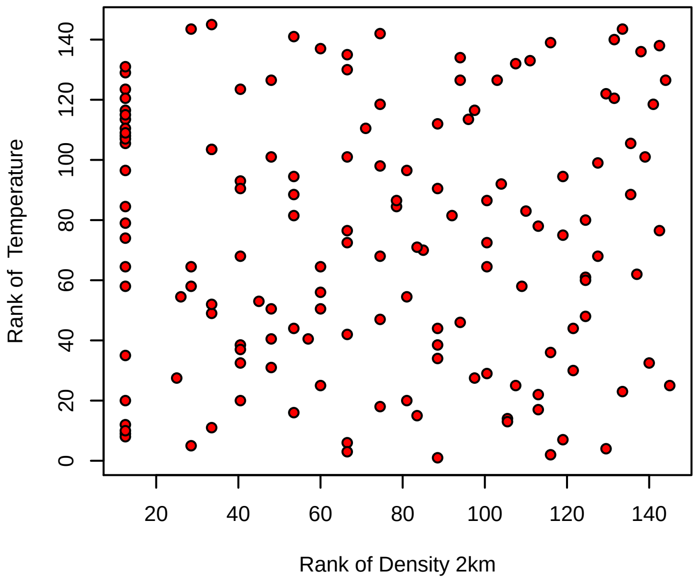
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + dat$Watershe ...

Box−Cox
Model



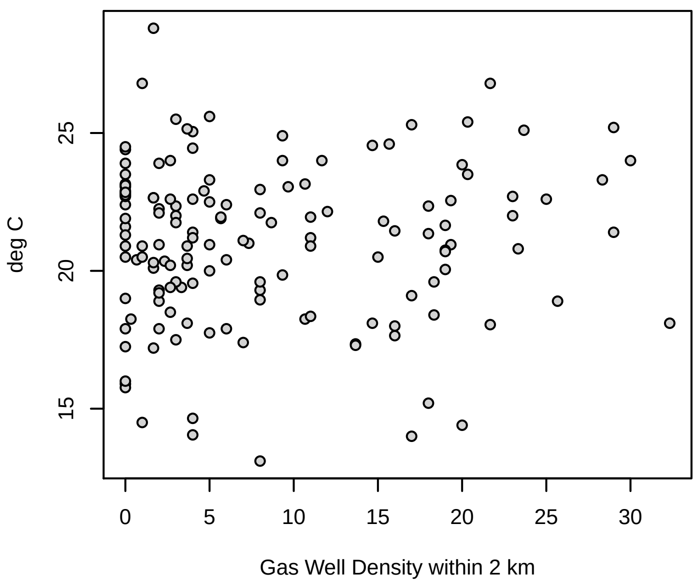


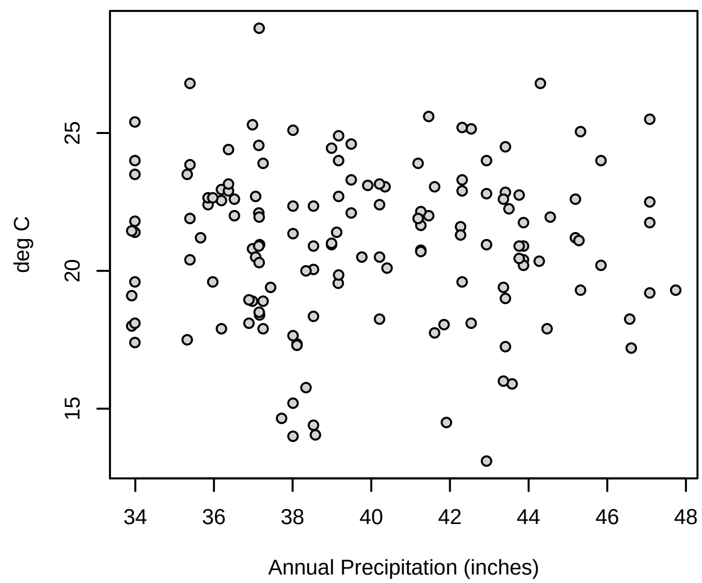
Temperature

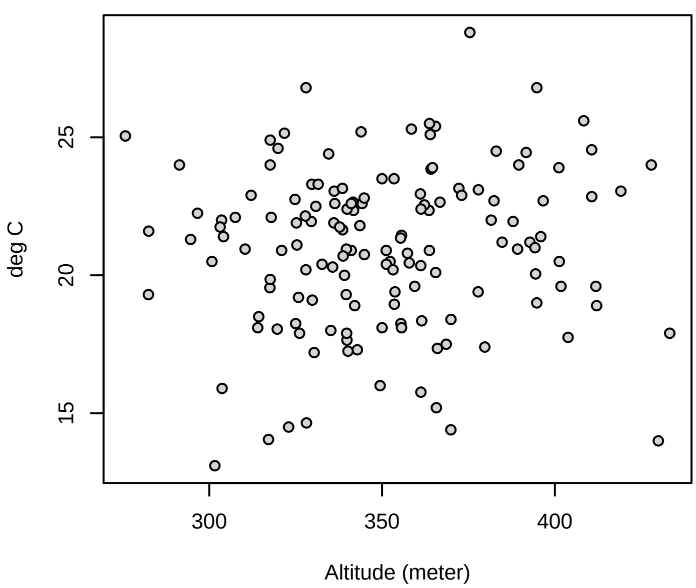
Kendalls Tau Rank Correlation

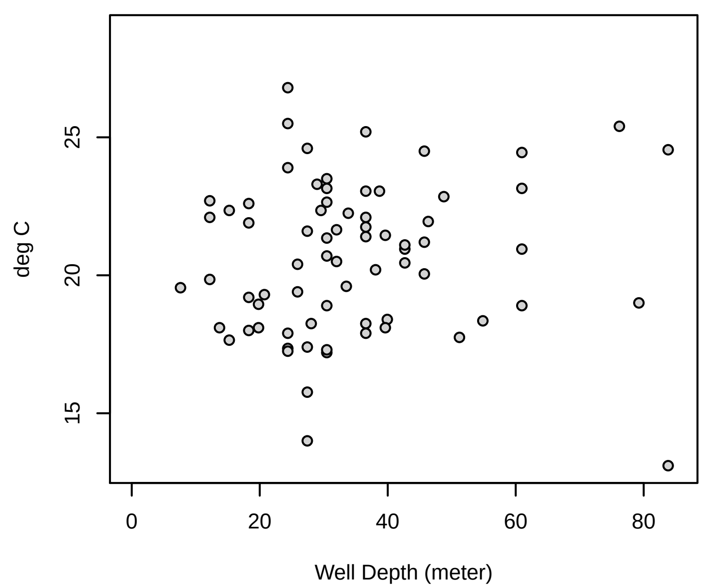
p−value: 0.88

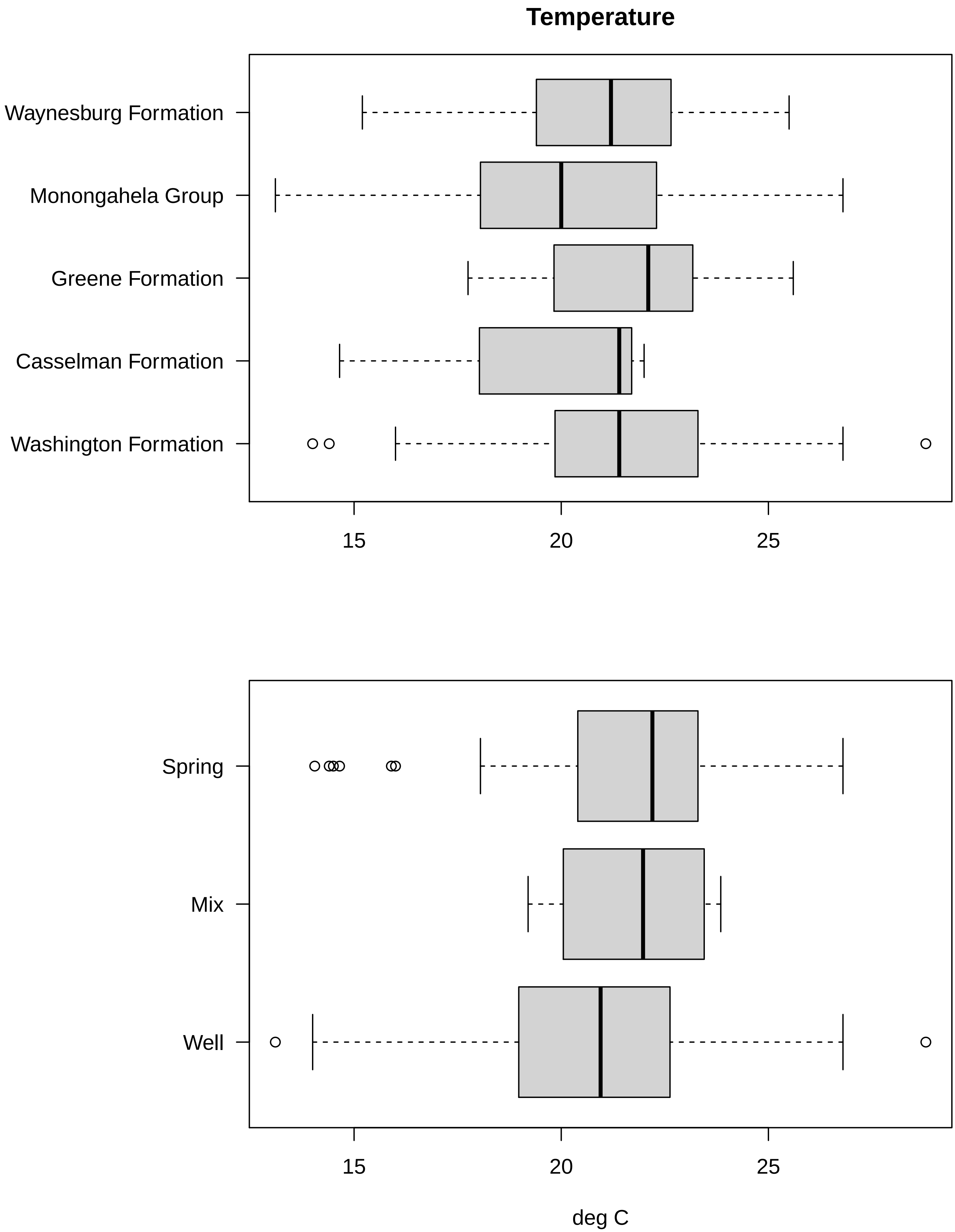
Tau: 0.00864

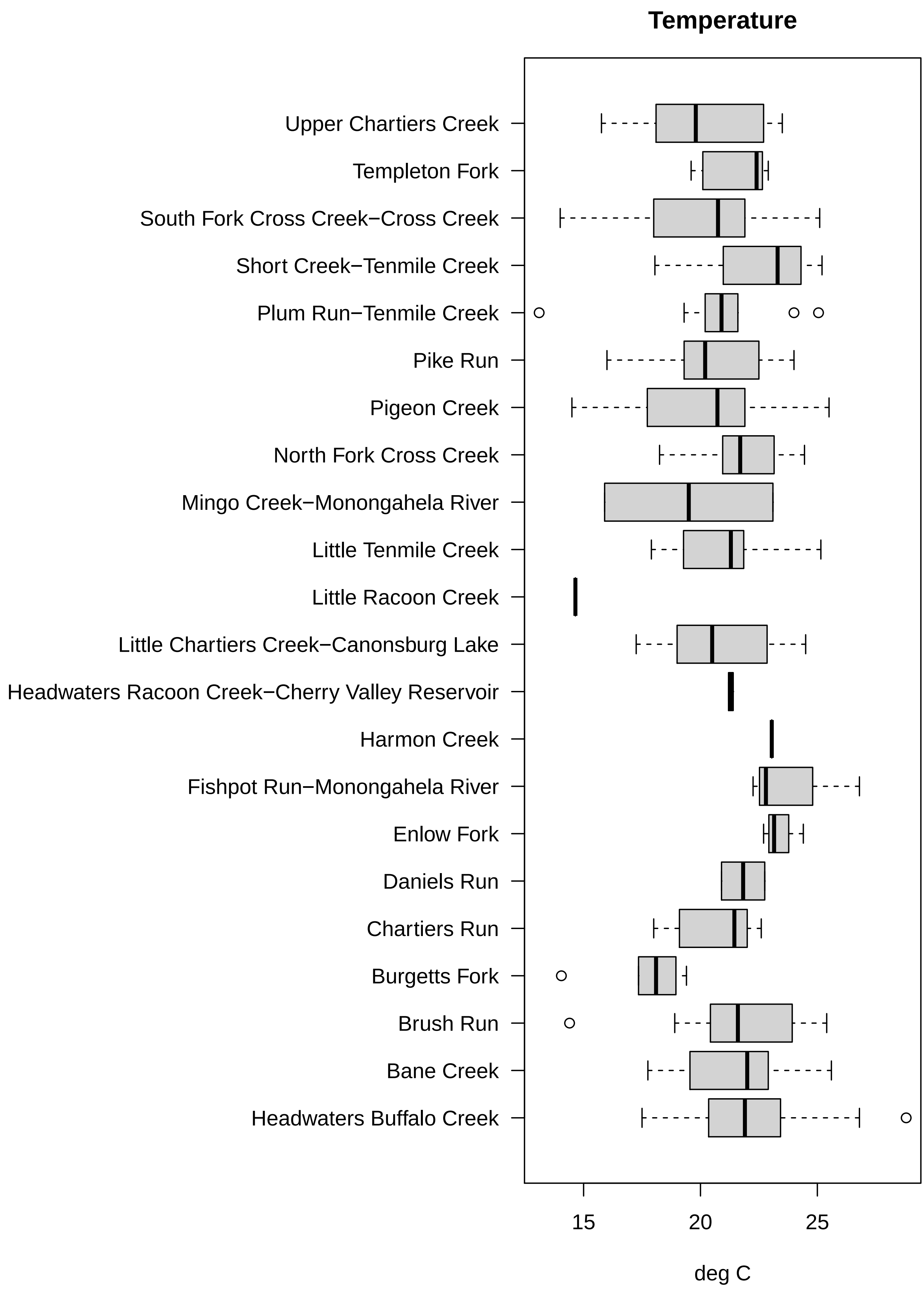









Temperature
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
15
20
25
Spring
Mix
Well
15
20
25
deg C


Temperature
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Mingo Creek−Monongahela River
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
15
20
25
deg C

```
[1] "ORIGINAL MODEL - Temperature"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-7.4172  -1.4523   0.1528   1.5911   7.3425  

Coefficients:
                                                            Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                                 15.46417    7.64975   2.022  0.04557 * 
dat$GWellDensity_2kmAvg                                      0.06663    0.04728   1.409  0.16142   
dat$Altitude_meter                                           0.01047    0.01298   0.807  0.42155   
dat$WatershedBane Creek                                     -0.70472    1.62112  -0.435  0.66459   
dat$WatershedBrush Run                                      -1.38264    1.33231  -1.038  0.30157   
dat$WatershedBurgetts Fork                                  -4.13232    1.55873  -2.651  0.00916 **
dat$WatershedChartiers Run                                  -1.29764    1.82003  -0.713  0.47732   
dat$WatershedDaniels Run                                    -0.35509    2.58287  -0.137  0.89089   
dat$WatershedEnlow Fork                                      2.12922    1.76038   1.210  0.22896   
dat$WatershedFishpot Run-Monongahela River                   2.93453    2.13196   1.376  0.17138   
dat$WatershedHarmon Creek                                    2.04080    3.48420   0.586  0.55922   
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -1.72490    2.53778  -0.680  0.49808   
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         -0.72708    1.64199  -0.443  0.65874   
dat$WatershedLittle Racoon Creek                            -9.34937    3.92543  -2.382  0.01889 * 
dat$WatershedLittle Tenmile Creek                           -0.99325    1.67930  -0.591  0.55538   
dat$WatershedMingo Creek-Monongahela River                  -1.69946    2.25001  -0.755  0.45162   
dat$WatershedNorth Fork Cross Creek                          0.04626    1.50971   0.031  0.97561   
dat$WatershedPigeon Creek                                   -1.93518    1.89040  -1.024  0.30815   
dat$WatershedPike Run                                       -1.32283    1.84672  -0.716  0.47526   
dat$WatershedPlum Run-Tenmile Creek                         -0.63383    1.63772  -0.387  0.69946   
dat$WatershedShort Creek-Tenmile Creek                       0.50853    1.35940   0.374  0.70904   
dat$WatershedSouth Fork Cross Creek-Cross Creek             -2.44872    1.21762  -2.011  0.04668 * 
dat$WatershedTempleton Fork                                  0.22038    1.43962   0.153  0.87861   
dat$WatershedUpper Chartiers Creek                          -2.48344    1.24269  -1.998  0.04805 * 
dat$FormationCasselman Formation                             2.34552    2.83394   0.828  0.40960   
dat$FormationGreene Formation                                0.03376    0.96250   0.035  0.97208   
dat$FormationMonongahela Group                              -0.55809    1.00748  -0.554  0.58070   
dat$FormationWaynesburg Formation                            0.55137    0.77972   0.707  0.48093   
dat$HHWSourceMix                                             0.46365    1.88217   0.246  0.80586   
dat$HHWSourceSpring                                          0.50590    0.61669   0.820  0.41372   
dat$Precip_inchAvg                                           0.05256    0.15783   0.333  0.73971   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 7.739943)

    Null deviance: 1182.32  on 144  degrees of freedom
Residual deviance:  882.35  on 114  degrees of freedom
AIC: 737.34

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Temperature"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-105.35   -22.84     1.37    23.54   125.72

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                98.2614   116.0311   0.847   0.3989
dat$GWellDensity_2kmAvg                                     1.0082     0.7171   1.406   0.1624
dat$Altitude_meter                                          0.1952     0.1968   0.992   0.3235
dat$WatershedBane Creek                                    -9.5003    24.5891  -0.386   0.6999
dat$WatershedBrush Run                                    -21.7043    20.2084  -1.074   0.2851
dat$WatershedBurgetts Fork                                -63.1213    23.6428  -2.670   0.0087 **
dat$WatershedChartiers Run                                -23.4016    27.6061  -0.848   0.3984
dat$WatershedDaniels Run                                   -5.9279    39.1769  -0.151   0.8800
dat$WatershedEnlow Fork                                    32.5381    26.7014   1.219   0.2255
dat$WatershedFishpot Run-Monongahela River                 46.6690    32.3374   1.443   0.1517
dat$WatershedHarmon Creek                                  29.0783    52.8483   0.550   0.5832
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -30.0612    38.4929  -0.781   0.4364
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       -10.8379    24.9056  -0.435   0.6643
dat$WatershedLittle Racoon Creek                         -138.6469    59.5408  -2.329   0.0216 *
dat$WatershedLittle Tenmile Creek                         -14.4608    25.4716  -0.568   0.5713
dat$WatershedMingo Creek-Monongahela River                -24.9747    34.1280  -0.732   0.4658
dat$WatershedNorth Fork Cross Creek                        -1.4182    22.8993  -0.062   0.9507
dat$WatershedPigeon Creek                                 -28.4877    28.6735  -0.994   0.3226
dat$WatershedPike Run                                     -21.2473    28.0110  -0.759   0.4497
dat$WatershedPlum Run-Tenmile Creek                        -7.9961    24.8408  -0.322   0.7481
dat$WatershedShort Creek-Tenmile Creek                      9.1847    20.6193   0.445   0.6568
dat$WatershedSouth Fork Cross Creek-Cross Creek           -37.5495    18.4689  -2.033   0.0444 *
dat$WatershedTempleton Fork                                 2.2324    21.8362   0.102   0.9188
dat$WatershedUpper Chartiers Creek                        -39.4754    18.8490  -2.094   0.0384 *
dat$FormationCasselman Formation                           39.3723    42.9851   0.916   0.3616
dat$FormationGreene Formation                              -1.3293    14.5991  -0.091   0.9276
dat$FormationMonongahela Group                             -6.2392    15.2815  -0.408   0.6838
dat$FormationWaynesburg Formation                           8.5609    11.8267   0.724   0.4706
dat$HHWSourceMix                                            7.0761    28.5487   0.248   0.8047
dat$HHWSourceSpring                                         8.9953     9.3539   0.962   0.3383
dat$Precip_inchAvg                                          0.6670     2.3939   0.279   0.7810
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1780.706)

    Null deviance: 271091  on 144  degrees of freedom
Residual deviance: 203001  on 114  degrees of freedom
AIC: 1525.9

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Aluminum"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-6.3789  -1.6912  -0.4145   1.3781  13.5583  

Coefficients:
                                                               Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                                  -13.544342  15.758832  -0.859 0.394736    
dat$GWellDensity_2kmAvg                                       -0.092639   0.101203  -0.915 0.364984    
dat$Altitude_meter                                            -0.008112   0.027509  -0.295 0.769473    
dat$WatershedBane Creek                                        0.787257   3.521611   0.224 0.824142    
dat$WatershedBrush Run                                         3.550175   2.989051   1.188 0.241313    
dat$WatershedBurgetts Fork                                     6.143042   3.315424   1.853 0.070616 .  
dat$WatershedChartiers Run                                     3.722284   3.925948   0.948 0.348245    
dat$WatershedEnlow Fork                                       13.730120   3.819854   3.594 0.000817 ***
dat$WatershedFishpot Run-Monongahela River                     0.472628   4.280126   0.110 0.912575    
dat$WatershedHarmon Creek                                      5.330388   6.297508   0.846 0.401894    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir   3.396532   4.621673   0.735 0.466291    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake            4.056749   3.243032   1.251 0.217577    
dat$WatershedLittle Tenmile Creek                             -1.136546   3.459367  -0.329 0.744061    
dat$WatershedNorth Fork Cross Creek                            0.525593   3.088449   0.170 0.865648    
dat$WatershedPigeon Creek                                     -3.007202   4.271408  -0.704 0.485123    
dat$WatershedPike Run                                          0.745439   4.073057   0.183 0.855625    
dat$WatershedPlum Run-Tenmile Creek                            2.148946   3.595651   0.598 0.553136    
dat$WatershedShort Creek-Tenmile Creek                         3.329294   3.063147   1.087 0.283005    
dat$WatershedSouth Fork Cross Creek-Cross Creek                1.781101   2.536476   0.702 0.486256    
dat$WatershedTempleton Fork                                    1.509905   4.345307   0.347 0.729888    
dat$WatershedUpper Chartiers Creek                             4.123742   2.547213   1.619 0.112611    
dat$FormationGreene Formation                                  1.498359   1.824017   0.821 0.415813    
dat$FormationMonongahela Group                                -0.043706   2.050324  -0.021 0.983089    
dat$FormationWaynesburg Formation                              1.334634   1.607642   0.830 0.410918    
dat$HHWSourceMix                                              -1.839619   4.676107  -0.393 0.695918    
dat$HHWSourceSpring                                           -5.647127   3.757019  -1.503 0.139961    
dat$Precip_inchAvg                                             0.337675   0.348843   0.968 0.338342    
dat$HHWdepthMeters                                             0.101854   0.038273   2.661 0.010826 *  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 15.12597)

    Null deviance: 1387.54  on 71  degrees of freedom
Residual deviance:  665.54  on 44  degrees of freedom
AIC: 422.45

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Aluminum"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-0.4371  -0.1239   0.0000   0.1217   0.5846  

Coefficients:
                                                               Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                                    0.141779   0.992277   0.143  0.88704   
dat$GWellDensity_2kmAvg                                       -0.010403   0.006372  -1.632  0.10972   
dat$Altitude_meter                                            -0.001151   0.001732  -0.665  0.50975   
dat$WatershedBane Creek                                        0.089231   0.221743   0.402  0.68933   
dat$WatershedBrush Run                                         0.391009   0.188210   2.078  0.04362 * 
dat$WatershedBurgetts Fork                                     0.655505   0.208760   3.140  0.00302 **
dat$WatershedChartiers Run                                     0.203877   0.247203   0.825  0.41397   
dat$WatershedEnlow Fork                                        0.516850   0.240523   2.149  0.03719 * 
dat$WatershedFishpot Run-Monongahela River                     0.111171   0.269504   0.413  0.68197   
dat$WatershedHarmon Creek                                      0.739704   0.396532   1.865  0.06880 . 
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.552710   0.291010   1.899  0.06410 . 
dat$WatershedLittle Chartiers Creek-Canonsburg Lake            0.208650   0.204202   1.022  0.31247   
dat$WatershedLittle Tenmile Creek                              0.028480   0.217824   0.131  0.89657   
dat$WatershedNorth Fork Cross Creek                            0.129180   0.194469   0.664  0.50998   
dat$WatershedPigeon Creek                                     -0.177362   0.268955  -0.659  0.51305   
dat$WatershedPike Run                                          0.169235   0.256466   0.660  0.51277   
dat$WatershedPlum Run-Tenmile Creek                            0.001904   0.226405   0.008  0.99333   
dat$WatershedShort Creek-Tenmile Creek                         0.233052   0.192875   1.208  0.23339   
dat$WatershedSouth Fork Cross Creek-Cross Creek                0.162756   0.159713   1.019  0.31375   
dat$WatershedTempleton Fork                                    0.006929   0.273608   0.025  0.97991   
dat$WatershedUpper Chartiers Creek                             0.374228   0.160389   2.333  0.02427 * 
dat$FormationGreene Formation                                  0.127103   0.114852   1.107  0.27445   
dat$FormationMonongahela Group                                 0.011626   0.129102   0.090  0.92866   
dat$FormationWaynesburg Formation                              0.010349   0.101227   0.102  0.91903   
dat$HHWSourceMix                                              -0.362398   0.294438  -1.231  0.22493   
dat$HHWSourceSpring                                            0.023568   0.236566   0.100  0.92109   
dat$Precip_inchAvg                                             0.022981   0.021965   1.046  0.30117   
dat$HHWdepthMeters                                             0.006919   0.002410   2.871  0.00627 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.05997102)

    Null deviance: 5.5739  on 71  degrees of freedom
Residual deviance: 2.6387  on 44  degrees of freedom
AIC: 24.268

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Arsenic"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.30552  -0.05588  -0.00806   0.04014   0.78561

Coefficients:
                                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                                             1.5698557  0.6990029   2.246   0.0298 *
dat$GWellDensity_2kmAvg                                -0.0039372  0.0044890  -0.877   0.3852
dat$Altitude_meter                                     -0.0015956  0.0012202  -1.308   0.1978
dat$WatershedBane Creek                                -0.2924758  0.1562055  -1.872   0.0678 .
dat$WatershedBrush Run                                 -0.1022828  0.1325831  -0.771   0.4446
dat$WatershedBurgetts Fork                             -0.2112858  0.1470598  -1.437   0.1579
dat$WatershedChartiers Run                             -0.2703053  0.1741404  -1.552   0.1278
dat$WatershedEnlow Fork                                -0.2063244  0.1694345  -1.218   0.2298
dat$WatershedFishpot Run-Monongahela River             -0.2203312  0.1898504  -1.161   0.2521
dat$WatershedHarmon Creek                              -0.2382912  0.2793339  -0.853   0.3982
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.1701366  0.2050001  -0.830   0.4111
dat$WatershedLittle Chartiers Creek-Canonsburg Lake    -0.1369477  0.1438488  -0.952   0.3463
dat$WatershedLittle Tenmile Creek                      -0.0959929  0.1534446  -0.626   0.5348
dat$WatershedNorth Fork Cross Creek                    -0.1331342  0.1369921  -0.972   0.3364
dat$WatershedPigeon Creek                              -0.1141970  0.1894637  -0.603   0.5498
dat$WatershedPike Run                                  -0.1434446  0.1806656  -0.794   0.4315
dat$WatershedPlum Run-Tenmile Creek                    -0.1724529  0.1594896  -1.081   0.2855
dat$WatershedShort Creek-Tenmile Creek                  0.0758959  0.1358698   0.559   0.5793
dat$WatershedSouth Fork Cross Creek-Cross Creek        -0.0642497  0.1125086  -0.571   0.5709
dat$WatershedTempleton Fork                            -0.0625935  0.1927416  -0.325   0.7469
dat$WatershedUpper Chartiers Creek                     -0.2153732  0.1129849  -1.906   0.0632 .
dat$FormationGreene Formation                           0.2187779  0.0809066   2.704   0.0097 **
dat$FormationMonongahela Group                          0.1138074  0.0909447   1.251   0.2174
dat$FormationWaynesburg Formation                       0.1013842  0.0713090   1.422   0.1621
dat$HHWSourceMix                                       -0.0049740  0.2074146  -0.024   0.9810
dat$HHWSourceSpring                                    -0.0700177  0.1666473  -0.420   0.6764
dat$Precip_inchAvg                                     -0.0160002  0.0154734  -1.034   0.3068
dat$HHWdepthMeters                                     -0.0002303  0.0016976  -0.136   0.8927
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.02976002)

    Null deviance: 2.1939  on 71  degrees of freedom
Residual deviance: 1.3094  on 44  degrees of freedom
AIC: -26.182

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Arsenic"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.12578  -0.03158  -0.00137   0.02305   0.29307  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                              1.2537820  0.2905297   4.316 8.89e-05 ***
dat$GWellDensity_2kmAvg                                 -0.0017436  0.0018658  -0.934  0.35515    
dat$Altitude_meter                                      -0.0005765  0.0005072  -1.137  0.26180    
dat$WatershedBane Creek                                 -0.1284531  0.0649244  -1.979  0.05415 .  
dat$WatershedBrush Run                                  -0.0408119  0.0551061  -0.741  0.46287    
dat$WatershedBurgetts Fork                              -0.0964245  0.0611231  -1.578  0.12183    
dat$WatershedChartiers Run                              -0.1275421  0.0723787  -1.762  0.08499 .  
dat$WatershedEnlow Fork                                 -0.0848920  0.0704228  -1.205  0.23447    
dat$WatershedFishpot Run-Monongahela River              -0.0888634  0.0789084  -1.126  0.26620    
dat$WatershedHarmon Creek                               -0.1004781  0.1161008  -0.865  0.39149    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0735868  0.0852051  -0.864  0.39247    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     -0.0461474  0.0597885  -0.772  0.44433    
dat$WatershedLittle Tenmile Creek                       -0.0187545  0.0637769  -0.294  0.77009    
dat$WatershedNorth Fork Cross Creek                     -0.0525255  0.0569386  -0.922  0.36130    
dat$WatershedPigeon Creek                               -0.0340883  0.0787477  -0.433  0.66722    
dat$WatershedPike Run                                   -0.0520199  0.0750909  -0.693  0.49210    
dat$WatershedPlum Run-Tenmile Creek                     -0.0553321  0.0662894  -0.835  0.40839    
dat$WatershedShort Creek-Tenmile Creek                   0.0483743  0.0564722   0.857  0.39630    
dat$WatershedSouth Fork Cross Creek-Cross Creek         -0.0164532  0.0467625  -0.352  0.72663    
dat$WatershedTempleton Fork                              0.0068518  0.0801101   0.086  0.93223    
dat$WatershedUpper Chartiers Creek                      -0.0963179  0.0469604  -2.051  0.04625 *  
dat$FormationGreene Formation                            0.1057176  0.0336276   3.144  0.00298 ** 
dat$FormationMonongahela Group                           0.0621309  0.0377998   1.644  0.10737    
dat$FormationWaynesburg Formation                        0.0458696  0.0296385   1.548  0.12887    
dat$HHWSourceMix                                        -0.0047118  0.0862087  -0.055  0.95666    
dat$HHWSourceSpring                                     -0.0368897  0.0692644  -0.533  0.59700    
dat$Precip_inchAvg                                      -0.0083084  0.0064313  -1.292  0.20315    
dat$HHWdepthMeters                                      -0.0002725  0.0007056  -0.386  0.70121    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.005141105)

    Null deviance: 0.41218  on 71  degrees of freedom
Residual deviance: 0.22621  on 44  degrees of freedom
AIC: -152.61

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Barium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-198.05   -39.17    -0.23    23.42   363.16

Coefficients:
                                                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                939.0441   414.1226   2.268  0.02832 *
dat$GWellDensity_2kmAvg                                     -2.6248     2.6595  -0.987  0.32906
dat$Altitude_meter                                          -1.6315     0.7229  -2.257  0.02903 *
dat$WatershedBane Creek                                      4.7886    92.5436   0.052  0.95897
dat$WatershedBrush Run                                      83.8156    78.5486   1.067  0.29177
dat$WatershedBurgetts Fork                                  82.7347    87.1252   0.950  0.34750
dat$WatershedChartiers Run                                  70.4307   103.1691   0.683  0.49839
dat$WatershedEnlow Fork                                    -66.5169   100.3810  -0.663  0.51101
dat$WatershedFishpot Run-Monongahela River                 108.3538   112.4764   0.963  0.34064
dat$WatershedHarmon Creek                                   21.5022   165.4907   0.130  0.89721
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  47.2998   121.4519   0.389  0.69882
dat$WatershedLittle Chartiers Creek-Canonsburg Lake        -19.1264    85.2229  -0.224  0.82346
dat$WatershedLittle Tenmile Creek                           58.3140    90.9079   0.641  0.52455
dat$WatershedNorth Fork Cross Creek                         82.4625    81.1606   1.016  0.31516
dat$WatershedPigeon Creek                                   57.8355   112.2473   0.515  0.60896
dat$WatershedPike Run                                       72.8845   107.0349   0.681  0.49948
dat$WatershedPlum Run-Tenmile Creek                         -5.5369    94.4893  -0.059  0.95354
dat$WatershedShort Creek-Tenmile Creek                      90.6826    80.4957   1.127  0.26604
dat$WatershedSouth Fork Cross Creek-Cross Creek             99.1153    66.6555   1.487  0.14415
dat$WatershedTempleton Fork                                361.7799   114.1893   3.168  0.00279 **
dat$WatershedUpper Chartiers Creek                          71.2697    66.9376   1.065  0.29281
dat$FormationGreene Formation                               91.3289    47.9329   1.905  0.06328 .
dat$FormationMonongahela Group                             -54.3696    53.8800  -1.009  0.31845
dat$FormationWaynesburg Formation                          -17.3193    42.2468  -0.410  0.68383
dat$HHWSourceMix                                            15.4149   122.8823   0.125  0.90074
dat$HHWSourceSpring                                         14.3825    98.7298   0.146  0.88484
dat$Precip_inchAvg                                          -7.4551     9.1672  -0.813  0.42046
dat$HHWdepthMeters                                           0.5854     1.0058   0.582  0.56351
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 10445.6)

    Null deviance: 757379  on 71  degrees of freedom
Residual deviance: 459606  on 44  degrees of freedom
AIC: 893.15

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Barium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.196713  -0.020246   0.001501   0.023713   0.116399

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              1.352e+00  2.563e-01   5.275 3.86e-06 ***
dat$GWellDensity_2kmAvg                                 -4.824e-05  1.646e-03  -0.029    0.977
dat$Altitude_meter                                      -5.271e-04  4.475e-04  -1.178    0.245
dat$WatershedBane Creek                                  1.463e-02  5.728e-02   0.255    0.800
dat$WatershedBrush Run                                   4.291e-03  4.862e-02   0.088    0.930
dat$WatershedBurgetts Fork                               2.574e-02  5.393e-02   0.477    0.636
dat$WatershedChartiers Run                               2.642e-02  6.386e-02   0.414    0.681
dat$WatershedEnlow Fork                                 -2.872e-02  6.213e-02  -0.462    0.646
dat$WatershedFishpot Run-Monongahela River              -2.145e-03  6.962e-02  -0.031    0.976
dat$WatershedHarmon Creek                                9.437e-03  1.024e-01   0.092    0.927
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  7.884e-03  7.518e-02   0.105    0.917
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     -2.815e-02  5.275e-02  -0.534    0.596
dat$WatershedLittle Tenmile Creek                       -8.085e-02  5.627e-02  -1.437    0.158
dat$WatershedNorth Fork Cross Creek                      1.702e-02  5.024e-02   0.339    0.736
dat$WatershedPigeon Creek                                3.570e-04  6.948e-02   0.005    0.996
dat$WatershedPike Run                                    1.939e-02  6.625e-02   0.293    0.771
dat$WatershedPlum Run-Tenmile Creek                     -8.279e-02  5.849e-02  -1.416    0.164
dat$WatershedShort Creek-Tenmile Creek                  -3.940e-03  4.983e-02  -0.079    0.937
dat$WatershedSouth Fork Cross Creek-Cross Creek          2.174e-02  4.126e-02   0.527    0.601
dat$WatershedTempleton Fork                              6.930e-02  7.068e-02   0.980    0.332
dat$WatershedUpper Chartiers Creek                       2.223e-02  4.143e-02   0.536    0.594
dat$FormationGreene Formation                            9.565e-03  2.967e-02   0.322    0.749
dat$FormationMonongahela Group                          -2.348e-02  3.335e-02  -0.704    0.485
dat$FormationWaynesburg Formation                       -2.121e-02  2.615e-02  -0.811    0.422
dat$HHWSourceMix                                        -2.590e-03  7.606e-02  -0.034    0.973
dat$HHWSourceSpring                                      1.802e-02  6.111e-02   0.295    0.769
dat$Precip_inchAvg                                       5.686e-05  5.674e-03   0.010    0.992
dat$HHWdepthMeters                                       8.020e-04  6.226e-04   1.288    0.204
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.004002048)

    Null deviance: 0.23413  on 71  degrees of freedom
Residual deviance: 0.17609  on 44  degrees of freedom
AIC: -170.64

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Calcium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-71140  -20075   -1384   17666   57544

Coefficients:
                                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              52289.77  148712.54   0.352   0.7268
dat$GWellDensity_2kmAvg                                  -1633.32     955.03  -1.710   0.0943 .
dat$Altitude_meter                                         284.71     259.59   1.097   0.2787
dat$WatershedBane Creek                                   5920.66   33232.65   0.178   0.8594
dat$WatershedBrush Run                                   21621.80   28207.00   0.767   0.4474
dat$WatershedBurgetts Fork                               24441.46   31286.91   0.781   0.4389
dat$WatershedChartiers Run                              -23376.07   37048.28  -0.631   0.5313
dat$WatershedEnlow Fork                                 -92892.28   36047.10  -2.577   0.0134 *
dat$WatershedFishpot Run-Monongahela River               47775.81   40390.59   1.183   0.2432
dat$WatershedHarmon Creek                                -5835.75   59428.17  -0.098   0.9222
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  21007.75   43613.69   0.482   0.6324
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     -19245.96   30603.77  -0.629   0.5327
dat$WatershedLittle Tenmile Creek                       -16265.85   32645.27  -0.498   0.6208
dat$WatershedNorth Fork Cross Creek                      14604.48   29145.00   0.501   0.6188
dat$WatershedPigeon Creek                                58959.42   40308.32   1.463   0.1507
dat$WatershedPike Run                                    11943.95   38436.52   0.311   0.7575
dat$WatershedPlum Run-Tenmile Creek                     -31073.46   33931.35  -0.916   0.3648
dat$WatershedShort Creek-Tenmile Creek                    9539.91   28906.23   0.330   0.7429
dat$WatershedSouth Fork Cross Creek-Cross Creek          33240.76   23936.16   1.389   0.1719
dat$WatershedTempleton Fork                             -46740.67   41005.68  -1.140   0.2605
dat$WatershedUpper Chartiers Creek                       30647.99   24037.48   1.275   0.2090
dat$FormationGreene Formation                            -9613.30   17212.84  -0.558   0.5793
dat$FormationMonongahela Group                          -18902.35   19348.44  -0.977   0.3339
dat$FormationWaynesburg Formation                       -22184.26   15170.96  -1.462   0.1508
dat$HHWSourceMix                                         41665.94   44127.37   0.944   0.3502
dat$HHWSourceSpring                                      21842.04   35454.14   0.616   0.5410
dat$Precip_inchAvg                                       -1787.94    3291.95  -0.543   0.5898
dat$HHWdepthMeters                                          76.75     361.17   0.212   0.8327
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1347009066)

    Null deviance: 1.1829e+11  on 71  degrees of freedom
Residual deviance: 5.9268e+10  on 44  degrees of freedom
AIC: 1740.4

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Calcium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-69381  -19568   -1360   17223   56080

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               51198.71  145061.33   0.353   0.7258
dat$GWellDensity_2kmAvg                                   -1592.42     931.58  -1.709   0.0944 .
dat$Altitude_meter                                          277.53     253.22   1.096   0.2790
dat$WatershedBane Creek                                    5756.82   32416.72   0.178   0.8599
dat$WatershedBrush Run                                    21058.24   27514.46   0.765   0.4481
dat$WatershedBurgetts Fork                                23848.92   30518.75   0.781   0.4387
dat$WatershedChartiers Run                               -22825.56   36138.67  -0.632   0.5309
dat$WatershedEnlow Fork                                  -90713.01   35162.07  -2.580   0.0133 *
dat$WatershedFishpot Run-Monongahela River                46607.52   39398.91   1.183   0.2432
dat$WatershedHarmon Creek                                 -5672.10   57969.08  -0.098   0.9225
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  20505.50   42542.88   0.482   0.6322
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -18789.22   29852.38  -0.629   0.5323
dat$WatershedLittle Tenmile Creek                        -15924.87   31843.75  -0.500   0.6195
dat$WatershedNorth Fork Cross Creek                       14229.22   28429.43   0.501   0.6192
dat$WatershedPigeon Creek                                 57495.25   39318.66   1.462   0.1508
dat$WatershedPike Run                                     11669.84   37492.82   0.311   0.7571
dat$WatershedPlum Run-Tenmile Creek                      -30387.34   33098.26  -0.918   0.3636
dat$WatershedShort Creek-Tenmile Creek                     9272.92   28196.52   0.329   0.7438
dat$WatershedSouth Fork Cross Creek-Cross Creek           32413.51   23348.47   1.388   0.1721
dat$WatershedTempleton Fork                              -45600.34   39998.90  -1.140   0.2604
dat$WatershedUpper Chartiers Creek                        29876.74   23447.31   1.274   0.2093
dat$FormationGreene Formation                             -9373.47   16790.23  -0.558   0.5795
dat$FormationMonongahela Group                           -18458.95   18873.40  -0.978   0.3334
dat$FormationWaynesburg Formation                        -21652.66   14798.48  -1.463   0.1505
dat$HHWSourceMix                                          40634.77   43043.95   0.944   0.3503
dat$HHWSourceSpring                                       21322.05   34583.67   0.617   0.5407
dat$Precip_inchAvg                                        -1744.20    3211.13  -0.543   0.5898
dat$HHWdepthMeters                                           74.85     352.31   0.212   0.8327
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1281677124)

    Null deviance: 1.1261e+11  on 71  degrees of freedom
Residual deviance: 5.6394e+10  on 44  degrees of freedom
AIC: 1736.8

Number of Fisher Scoring iterations: 2
```

[1] "ORIGINAL MODEL - Chromium"

```
Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.1383  -0.2023   0.0000   0.1444   2.1383

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              -2.772659   2.865843  -0.967 0.338590
dat$GWellDensity_2kmAvg                                  -0.022278   0.018404  -1.210 0.232570
dat$Altitude_meter                                        0.007256   0.005003   1.451 0.154004
dat$WatershedBane Creek                                   2.574902   0.640427   4.021 0.000224 ***
dat$WatershedBrush Run                                   -0.396643   0.543578  -0.730 0.469447
dat$WatershedBurgetts Fork                               -0.376657   0.602931  -0.625 0.535388
dat$WatershedChartiers Run                               -0.217241   0.713958  -0.304 0.762352
dat$WatershedEnlow Fork                                  -0.848245   0.694665  -1.221 0.228556
dat$WatershedFishpot Run-Monongahela River               -0.501675   0.778368  -0.645 0.522584
dat$WatershedHarmon Creek                                -0.834808   1.145242  -0.729 0.469903
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.885381   0.840481  -1.053 0.297898
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       0.098526   0.589766   0.167 0.868088
dat$WatershedLittle Tenmile Creek                        -0.502088   0.629108  -0.798 0.429102
dat$WatershedNorth Fork Cross Creek                       0.152248   0.561654   0.271 0.787605
dat$WatershedPigeon Creek                                -0.796171   0.776783  -1.025 0.310984
dat$WatershedPike Run                                    -0.663001   0.740711  -0.895 0.375611
dat$WatershedPlum Run-Tenmile Creek                      -0.576524   0.653892  -0.882 0.382740
dat$WatershedShort Creek-Tenmile Creek                    0.123075   0.557053   0.221 0.826162
dat$WatershedSouth Fork Cross Creek-Cross Creek          -0.393973   0.461274  -0.854 0.397678
dat$WatershedTempleton Fork                               5.426556   0.790222   6.867 1.79e-08 ***
dat$WatershedUpper Chartiers Creek                       -0.290700   0.463227  -0.628 0.533540
dat$FormationGreene Formation                            -0.491126   0.331709  -1.481 0.145841
dat$FormationMonongahela Group                            0.114871   0.372864   0.308 0.759476
dat$FormationWaynesburg Formation                         0.121503   0.292360   0.416 0.679728
dat$HHWSourceMix                                          0.121393   0.850380   0.143 0.887138
dat$HHWSourceSpring                                       0.740999   0.683238   1.085 0.284032
dat$Precip_inchAvg                                        0.020024   0.063439   0.316 0.753773
dat$HHWdepthMeters                                        0.010224   0.006960   1.469 0.148950
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.5002421)

    Null deviance: 75.549  on 71  degrees of freedom
Residual deviance: 22.011  on 44  degrees of freedom
AIC: 177

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Chromium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.93870  -0.09775   0.00313   0.08558   0.93870  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                              -0.770331   1.484122  -0.519  0.60633    
dat$GWellDensity_2kmAvg                                  -0.013172   0.009531  -1.382  0.17395    
dat$Altitude_meter                                        0.003028   0.002591   1.169  0.24874    
dat$WatershedBane Creek                                   1.068726   0.331655   3.222  0.00239 ** 
dat$WatershedBrush Run                                   -0.216323   0.281500  -0.768  0.44632    
dat$WatershedBurgetts Fork                               -0.216875   0.312237  -0.695  0.49097    
dat$WatershedChartiers Run                               -0.130255   0.369735  -0.352  0.72630    
dat$WatershedEnlow Fork                                  -0.581486   0.359743  -1.616  0.11316    
dat$WatershedFishpot Run-Monongahela River               -0.319871   0.403090  -0.794  0.43172    
dat$WatershedHarmon Creek                                -0.475951   0.593082  -0.803  0.42657    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.463655   0.435256  -1.065  0.29258    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       0.107166   0.305420   0.351  0.72735    
dat$WatershedLittle Tenmile Creek                        -0.324934   0.325793  -0.997  0.32404    
dat$WatershedNorth Fork Cross Creek                       0.078521   0.290861   0.270  0.78845    
dat$WatershedPigeon Creek                                -0.458403   0.402269  -1.140  0.26064    
dat$WatershedPike Run                                    -0.391389   0.383589  -1.020  0.31315    
dat$WatershedPlum Run-Tenmile Creek                      -0.379316   0.338628  -1.120  0.26872    
dat$WatershedShort Creek-Tenmile Creek                    0.006798   0.288479   0.024  0.98131    
dat$WatershedSouth Fork Cross Creek-Cross Creek          -0.231134   0.238878  -0.968  0.33854    
dat$WatershedTempleton Fork                               2.205353   0.409229   5.389 2.64e-06 ***
dat$WatershedUpper Chartiers Creek                       -0.133493   0.239889  -0.556  0.58070    
dat$FormationGreene Formation                            -0.255159   0.171781  -1.485  0.14458    
dat$FormationMonongahela Group                            0.021873   0.193094   0.113  0.91033    
dat$FormationWaynesburg Formation                         0.043574   0.151403   0.288  0.77485    
dat$HHWSourceMix                                          0.060989   0.440383   0.138  0.89048    
dat$HHWSourceSpring                                       0.535360   0.353825   1.513  0.13741    
dat$Precip_inchAvg                                        0.009818   0.032853   0.299  0.76647    
dat$HHWdepthMeters                                        0.005084   0.003604   1.411  0.16539    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.1341574)

    Null deviance: 16.9262  on 71  degrees of freedom
Residual deviance:  5.9029  on 44  degrees of freedom
AIC: 82.239

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Cobalt"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.044625  -0.008324  -0.002472   0.006074   0.096627

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  7.563e-02  1.063e-01   0.712    0.480
dat$GWellDensity_2kmAvg                                      3.126e-05  6.825e-04   0.046    0.964
dat$Altitude_meter                                           9.027e-05  1.855e-04   0.487    0.629
dat$WatershedBane Creek                                     -1.779e-02  2.375e-02  -0.749    0.458
dat$WatershedBrush Run                                       2.862e-03  2.016e-02   0.142    0.888
dat$WatershedBurgetts Fork                                   1.174e-02  2.236e-02   0.525    0.602
dat$WatershedChartiers Run                                   2.843e-02  2.648e-02   1.074    0.289
dat$WatershedEnlow Fork                                      2.349e-03  2.576e-02   0.091    0.928
dat$WatershedFishpot Run-Monongahela River                   2.370e-01  2.887e-02   8.211 2.01e-10 ***
dat$WatershedHarmon Creek                                    4.664e-02  4.247e-02   1.098    0.278
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  6.336e-03  3.117e-02   0.203    0.840
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         -2.904e-02  2.187e-02  -1.328    0.191
dat$WatershedLittle Tenmile Creek                           -1.764e-02  2.333e-02  -0.756    0.454
dat$WatershedNorth Fork Cross Creek                         -2.517e-03  2.083e-02  -0.121    0.904
dat$WatershedPigeon Creek                                   -4.428e-03  2.881e-02  -0.154    0.879
dat$WatershedPike Run                                        2.344e-02  2.747e-02   0.853    0.398
dat$WatershedPlum Run-Tenmile Creek                         -1.045e-02  2.425e-02  -0.431    0.669
dat$WatershedShort Creek-Tenmile Creek                      -8.480e-03  2.066e-02  -0.410    0.683
dat$WatershedSouth Fork Cross Creek-Cross Creek              1.739e-03  1.711e-02   0.102    0.919
dat$WatershedTempleton Fork                                  1.042e-02  2.931e-02   0.356    0.724
dat$WatershedUpper Chartiers Creek                           2.479e-02  1.718e-02   1.443    0.156
dat$FormationGreene Formation                                9.752e-03  1.230e-02   0.793    0.432
dat$FormationMonongahela Group                              -1.160e-02  1.383e-02  -0.839    0.406
dat$FormationWaynesburg Formation                           -7.017e-04  1.084e-02  -0.065    0.949
dat$HHWSourceMix                                            -4.086e-02  3.154e-02  -1.296    0.202
dat$HHWSourceSpring                                         -1.150e-02  2.534e-02  -0.454    0.652
dat$Precip_inchAvg                                           3.679e-03  2.353e-03   1.564    0.125
dat$HHWdepthMeters                                           3.786e-05  2.581e-04   0.147    0.884
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.0006880277)

    Null deviance: 0.152709  on 71  degrees of freedom
Residual deviance: 0.030273  on 44  degrees of freedom
AIC: -297.41

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Cobalt"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
      Min         1Q     Median         3Q        Max  
-0.028376  -0.005657  -0.001582   0.003872   0.062534  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              -5.507e-02  6.780e-02  -0.812    0.421
dat$GWellDensity_2kmAvg                                   3.446e-05  4.354e-04   0.079    0.937
dat$Altitude_meter                                        6.611e-05  1.184e-04   0.559    0.579
dat$WatershedBane Creek                                  -1.167e-02  1.515e-02  -0.771    0.445
dat$WatershedBrush Run                                    1.666e-03  1.286e-02   0.130    0.898
dat$WatershedBurgetts Fork                                6.935e-03  1.426e-02   0.486    0.629
dat$WatershedChartiers Run                                1.792e-02  1.689e-02   1.061    0.294
dat$WatershedEnlow Fork                                   1.863e-03  1.643e-02   0.113    0.910
dat$WatershedFishpot Run-Monongahela River                1.760e-01  1.842e-02   9.556 2.66e-12 ***
dat$WatershedHarmon Creek                                 2.906e-02  2.709e-02   1.072    0.289
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  3.810e-03  1.988e-02   0.192    0.849
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -1.907e-02  1.395e-02  -1.367    0.179
dat$WatershedLittle Tenmile Creek                        -1.176e-02  1.488e-02  -0.790    0.434
dat$WatershedNorth Fork Cross Creek                      -2.080e-03  1.329e-02  -0.157    0.876
dat$WatershedPigeon Creek                                -4.898e-03  1.838e-02  -0.267    0.791
dat$WatershedPike Run                                     1.348e-02  1.752e-02   0.769    0.446
dat$WatershedPlum Run-Tenmile Creek                      -6.715e-03  1.547e-02  -0.434    0.666
dat$WatershedShort Creek-Tenmile Creek                   -5.670e-03  1.318e-02  -0.430    0.669
dat$WatershedSouth Fork Cross Creek-Cross Creek           6.050e-04  1.091e-02   0.055    0.956
dat$WatershedTempleton Fork                               6.904e-03  1.870e-02   0.369    0.714
dat$WatershedUpper Chartiers Creek                        1.573e-02  1.096e-02   1.435    0.158
dat$FormationGreene Formation                             6.152e-03  7.848e-03   0.784    0.437
dat$FormationMonongahela Group                           -7.001e-03  8.821e-03  -0.794    0.432
dat$FormationWaynesburg Formation                        -3.569e-04  6.917e-03  -0.052    0.959
dat$HHWSourceMix                                         -2.582e-02  2.012e-02  -1.283    0.206
dat$HHWSourceSpring                                      -8.002e-03  1.616e-02  -0.495    0.623
dat$Precip_inchAvg                                        2.444e-03  1.501e-03   1.628    0.111
dat$HHWdepthMeters                                        1.383e-05  1.647e-04   0.084    0.933
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.0002799986)

    Null deviance: 0.078362  on 71  degrees of freedom
Residual deviance: 0.012320  on 44  degrees of freedom
AIC: -362.14

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Copper"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-49.998  -11.348    0.000    9.891  131.823

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              140.81826  122.70389   1.148   0.2573
dat$GWellDensity_2kmAvg                                    1.61268    0.78800   2.047   0.0467 *
dat$Altitude_meter                                         0.03887    0.21419   0.181   0.8568
dat$WatershedBane Creek                                  -28.85761   27.42052  -1.052   0.2984
dat$WatershedBrush Run                                   -48.04375   23.27382  -2.064   0.0449 *
dat$WatershedBurgetts Fork                                11.42624   25.81507   0.443   0.6602
dat$WatershedChartiers Run                               -28.92298   30.56883  -0.946   0.3492
dat$WatershedEnlow Fork                                  -32.73211   29.74275  -1.101   0.2771
dat$WatershedFishpot Run-Monongahela River                74.83290   33.32659   2.245   0.0298 *
dat$WatershedHarmon Creek                                 64.03065   49.03465   1.306   0.1984
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir   0.12335   35.98600   0.003   0.9973
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       20.13288   25.25141   0.797   0.4296
dat$WatershedLittle Tenmile Creek                          5.14366   26.93586   0.191   0.8494
dat$WatershedNorth Fork Cross Creek                        7.60481   24.04777   0.316   0.7533
dat$WatershedPigeon Creek                                 52.57830   33.25871   1.581   0.1211
dat$WatershedPike Run                                     78.43881   31.71428   2.473   0.0173 *
dat$WatershedPlum Run-Tenmile Creek                       14.10931   27.99702   0.504   0.6168
dat$WatershedShort Creek-Tenmile Creek                   -33.18378   23.85076  -1.391   0.1711
dat$WatershedSouth Fork Cross Creek-Cross Creek          -23.11781   19.74991  -1.171   0.2481
dat$WatershedTempleton Fork                              -28.45716   33.83411  -0.841   0.4049
dat$WatershedUpper Chartiers Creek                        13.96503   19.83351   0.704   0.4851
dat$FormationGreene Formation                             14.76019   14.20245   1.039   0.3044
dat$FormationMonongahela Group                           -28.38520   15.96455  -1.778   0.0823 .
dat$FormationWaynesburg Formation                         -9.52339   12.51767  -0.761   0.4508
dat$HHWSourceMix                                         -30.61477   36.40984  -0.841   0.4050
dat$HHWSourceSpring                                       14.04970   29.25349   0.480   0.6334
dat$Precip_inchAvg                                        -3.63395    2.71621  -1.338   0.1878
dat$HHWdepthMeters                                         0.17657    0.29801   0.593   0.5565
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 917.0477)

    Null deviance: 75722  on 71  degrees of freedom
Residual deviance: 40350  on 44  degrees of freedom
AIC: 717.99

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Copper"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-1.08564  -0.22348   0.01035   0.22024   0.98083  

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                                   1.681744   1.772563   0.949  0.34792   
dat$GWellDensity_2kmAvg                                       0.010658   0.011383   0.936  0.35423   
dat$Altitude_meter                                            0.002447   0.003094   0.791  0.43337   
dat$WatershedBane Creek                                      -0.545034   0.396113  -1.376  0.17580   
dat$WatershedBrush Run                                       -0.487705   0.336210  -1.451  0.15398   
dat$WatershedBurgetts Fork                                    0.577330   0.372921   1.548  0.12875   
dat$WatershedChartiers Run                                   -0.129354   0.441593  -0.293  0.77096   
dat$WatershedEnlow Fork                                      -0.874072   0.429660  -2.034  0.04797 * 
dat$WatershedFishpot Run-Monongahela River                    0.860130   0.481431   1.787  0.08089 . 
dat$WatershedHarmon Creek                                     1.122065   0.708348   1.584  0.12034   
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.240073   0.519849   0.462  0.64649   
dat$WatershedLittle Chartiers Creek-Canonsburg Lake           0.109259   0.364778   0.300  0.76595   
dat$WatershedLittle Tenmile Creek                            -0.124709   0.389112  -0.320  0.75011   
dat$WatershedNorth Fork Cross Creek                           0.067267   0.347391   0.194  0.84735   
dat$WatershedPigeon Creek                                     0.434299   0.480451   0.904  0.37095   
dat$WatershedPike Run                                         1.057788   0.458140   2.309  0.02571 * 
dat$WatershedPlum Run-Tenmile Creek                           0.053095   0.404441   0.131  0.89615   
dat$WatershedShort Creek-Tenmile Creek                       -0.770241   0.344545  -2.236  0.03051 * 
dat$WatershedSouth Fork Cross Creek-Cross Creek              -0.366221   0.285304  -1.284  0.20600   
dat$WatershedTempleton Fork                                  -0.677441   0.488763  -1.386  0.17272   
dat$WatershedUpper Chartiers Creek                            0.233169   0.286512   0.814  0.42013   
dat$FormationGreene Formation                                 0.017074   0.205167   0.083  0.93406   
dat$FormationMonongahela Group                               -0.655507   0.230622  -2.842  0.00676 **
dat$FormationWaynesburg Formation                            -0.276806   0.180829  -1.531  0.13299   
dat$HHWSourceMix                                             -0.474061   0.525971  -0.901  0.37233   
dat$HHWSourceSpring                                           0.471400   0.422592   1.115  0.27069   
dat$Precip_inchAvg                                           -0.020145   0.039238  -0.513  0.61024   
dat$HHWdepthMeters                                            0.005639   0.004305   1.310  0.19703   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.1913722)

    Null deviance: 20.0853  on 71  degrees of freedom
Residual deviance:  8.4204  on 44  degrees of freedom
AIC: 107.81

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Iron"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-77.733  -10.052    0.000    6.591   77.733  

Coefficients: (1 not defined because of singularities)
                                                               Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                                   -352.2129   210.3636  -1.674   0.1076    
dat$GWellDensity_2kmAvg                                         -0.9835     1.4165  -0.694   0.4944    
dat$Altitude_meter                                               0.5255     0.3476   1.512   0.1442    
dat$WatershedBane Creek                                        107.2359    40.8289   2.626   0.0151 *  
dat$WatershedBrush Run                                          16.1161    35.7797   0.450   0.6566    
dat$WatershedBurgetts Fork                                      -3.5434    37.6624  -0.094   0.9259    
dat$WatershedChartiers Run                                      14.9464    45.2785   0.330   0.7443    
dat$WatershedEnlow Fork                                        -31.0086    68.8160  -0.451   0.6565    
dat$WatershedHarmon Creek                                      -28.0822    55.7752  -0.503   0.6194    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -15.3451    48.0307  -0.319   0.7522    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake           -12.1507    46.8366  -0.259   0.7976    
dat$WatershedLittle Tenmile Creek                              -10.1458    52.1085  -0.195   0.8473    
dat$WatershedNorth Fork Cross Creek                              7.8170    37.0378   0.211   0.8347    
dat$WatershedPigeon Creek                                      -52.0655    64.8149  -0.803   0.4300    
dat$WatershedShort Creek-Tenmile Creek                          15.1241    39.7911   0.380   0.7074    
dat$WatershedSouth Fork Cross Creek-Cross Creek                 -4.1713    32.5015  -0.128   0.8990    
dat$WatershedTempleton Fork                                    241.0411    46.4604   5.188 2.93e-05 ***
dat$WatershedUpper Chartiers Creek                               5.9400    38.7568   0.153   0.8795    
dat$FormationGreene Formation                                  -21.7309    21.5448  -1.009   0.3236    
dat$FormationMonongahela Group                                   9.4353    26.7486   0.353   0.7275    
dat$FormationWaynesburg Formation                               -2.7632    19.3187  -0.143   0.8875    
dat$HHWSourceMix                                                     NA         NA      NA       NA    
dat$HHWSourceSpring                                             25.3843    46.2734   0.549   0.5886    
dat$Precip_inchAvg                                               4.6073     5.2412   0.879   0.3885    
dat$HHWdepthMeters                                               0.2339     0.5110   0.458   0.6515    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1326.603)

    Null deviance: 113884  on 46  degrees of freedom
Residual deviance:  30512  on 23  degrees of freedom
  (25 observations deleted due to missingness)
AIC: 487.74

Number of Fisher Scoring iterations: 2


[1] "BOX-COX MODEL - Iron"
```

```
Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-0.5226  -0.1334   0.0000   0.0784   0.6406

Coefficients: (1 not defined because of singularities)
                                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  2.086e+00  2.225e+00   0.938    0.358
dat$GWellDensity_2kmAvg                                      3.106e-05  1.498e-02   0.002    0.998
dat$Altitude_meter                                          -6.392e-04  3.676e-03  -0.174    0.863
dat$WatershedBane Creek                                      1.536e-01  4.318e-01   0.356    0.725
dat$WatershedBrush Run                                       8.532e-02  3.784e-01   0.225    0.824
dat$WatershedBurgetts Fork                                   1.895e-01  3.983e-01   0.476    0.639
dat$WatershedChartiers Run                                   7.884e-03  4.789e-01   0.016    0.987
dat$WatershedEnlow Fork                                      7.384e-01  7.278e-01   1.015    0.321
dat$WatershedHarmon Creek                                    6.444e-01  5.899e-01   1.092    0.286
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  5.241e-01  5.080e-01   1.032    0.313
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          5.743e-02  4.953e-01   0.116    0.909
dat$WatershedLittle Tenmile Creek                            2.261e-01  5.511e-01   0.410    0.685
dat$WatershedNorth Fork Cross Creek                         -4.829e-02  3.917e-01  -0.123    0.903
dat$WatershedPigeon Creek                                    3.663e-01  6.855e-01   0.534    0.598
dat$WatershedShort Creek-Tenmile Creek                       3.375e-01  4.208e-01   0.802    0.431
dat$WatershedSouth Fork Cross Creek-Cross Creek              4.214e-01  3.437e-01   1.226    0.233
dat$WatershedTempleton Fork                                 -5.190e-01  4.914e-01  -1.056    0.302
dat$WatershedUpper Chartiers Creek                          -1.977e-01  4.099e-01  -0.482    0.634
dat$FormationGreene Formation                               -3.754e-02  2.279e-01  -0.165    0.871
dat$FormationMonongahela Group                               2.277e-01  2.829e-01   0.805    0.429
dat$FormationWaynesburg Formation                            1.537e-01  2.043e-01   0.752    0.459
dat$HHWSourceMix                                                    NA         NA      NA       NA
dat$HHWSourceSpring                                         -5.245e-01  4.894e-01  -1.072    0.295
dat$Precip_inchAvg                                          -3.697e-02  5.543e-02  -0.667    0.511
dat$HHWdepthMeters                                           6.210e-03  5.405e-03   1.149    0.262

(Dispersion parameter for gaussian family taken to be 0.1483815)

    Null deviance: 6.7487  on 46  degrees of freedom
Residual deviance: 3.4128  on 23  degrees of freedom
  (25 observations deleted due to missingness)
AIC: 60.117

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Lead"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.5663  -0.2296  -0.0573   0.0969   5.5075

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               6.073822   4.016163   1.512    0.138
dat$GWellDensity_2kmAvg                                   0.039472   0.025792   1.530    0.133
dat$Altitude_meter                                       -0.002978   0.007011  -0.425    0.673
dat$WatershedBane Creek                                   0.404323   0.897488   0.451    0.655
dat$WatershedBrush Run                                   -0.764576   0.761764  -1.004    0.321
dat$WatershedBurgetts Fork                                0.010921   0.844941   0.013    0.990
dat$WatershedChartiers Run                               -0.728387   1.000534  -0.728    0.470
dat$WatershedEnlow Fork                                   0.433296   0.973496   0.445    0.658
dat$WatershedFishpot Run-Monongahela River                1.011847   1.090797   0.928    0.359
dat$WatershedHarmon Creek                                 0.773921   1.604930   0.482    0.632
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.555826   1.177841  -0.472    0.639
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       1.321065   0.826492   1.598    0.117
dat$WatershedLittle Tenmile Creek                         0.813744   0.881625   0.923    0.361
dat$WatershedNorth Fork Cross Creek                       0.181427   0.787096   0.231    0.819
dat$WatershedPigeon Creek                                 1.028942   1.088575   0.945    0.350
dat$WatershedPike Run                                     0.905412   1.038025   0.872    0.388
dat$WatershedPlum Run-Tenmile Creek                       0.675804   0.916357   0.737    0.465
dat$WatershedShort Creek-Tenmile Creek                   -0.165595   0.780648  -0.212    0.833
dat$WatershedSouth Fork Cross Creek-Cross Creek          -0.261296   0.646425  -0.404    0.688
dat$WatershedTempleton Fork                              -0.175479   1.107408  -0.158    0.875
dat$WatershedUpper Chartiers Creek                        0.825016   0.649161   1.271    0.210
dat$FormationGreene Formation                             0.027199   0.464854   0.059    0.954
dat$FormationMonongahela Group                           -0.254933   0.522528  -0.488    0.628
dat$FormationWaynesburg Formation                         0.217822   0.409710   0.532    0.598
dat$HHWSourceMix                                          0.474835   1.191713   0.398    0.692
dat$HHWSourceSpring                                      -0.176583   0.957482  -0.184    0.855
dat$Precip_inchAvg                                       -0.126696   0.088903  -1.425    0.161
dat$HHWdepthMeters                                       -0.005082   0.009754  -0.521    0.605

(Dispersion parameter for gaussian family taken to be 0.9824216)

    Null deviance: 62.166  on 71  degrees of freedom
Residual deviance: 43.227  on 44  degrees of freedom
AIC: 225.59

Number of Fisher Scoring iterations: 2


[1] "BOX-COX MODEL - Lead"
```

```
Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.95219  -0.10920   0.01541   0.19208   0.63561

Coefficients:
                                                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               0.6093844  1.5176570   0.402   0.6900
dat$GWellDensity_2kmAvg                                  -0.0150527  0.0097464  -1.544   0.1296
dat$Altitude_meter                                        0.0002779  0.0026492   0.105   0.9169
dat$WatershedBane Creek                                  -0.2472004  0.3391493  -0.729   0.4699
dat$WatershedBrush Run                                    0.3148805  0.2878611   1.094   0.2800
dat$WatershedBurgetts Fork                               -0.3315627  0.3192925  -1.038   0.3047
dat$WatershedChartiers Run                                0.2773947  0.3780891   0.734   0.4670
dat$WatershedEnlow Fork                                  -0.4794258  0.3678717  -1.303   0.1993
dat$WatershedFishpot Run-Monongahela River               -0.2725060  0.4121983  -0.661   0.5120
dat$WatershedHarmon Creek                                -0.9993052  0.6064826  -1.648   0.1065
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.4171477  0.4450910   0.937   0.3538
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -0.6062345  0.3123208  -1.941   0.0587 .
dat$WatershedLittle Tenmile Creek                        -0.2386159  0.3331549  -0.716   0.4776
dat$WatershedNorth Fork Cross Creek                       0.0826892  0.2974336   0.278   0.7823
dat$WatershedPigeon Creek                                -0.1156979  0.4113587  -0.281   0.7798
dat$WatershedPike Run                                    -0.2658123  0.3922565  -0.678   0.5015
dat$WatershedPlum Run-Tenmile Creek                      -0.1122786  0.3462798  -0.324   0.7473
dat$WatershedShort Creek-Tenmile Creek                    0.1190617  0.2949969   0.404   0.6885
dat$WatershedSouth Fork Cross Creek-Cross Creek           0.1649609  0.2442758   0.675   0.5030
dat$WatershedTempleton Fork                               0.1039263  0.4184755   0.248   0.8050
dat$WatershedUpper Chartiers Creek                       -0.1916391  0.2453098  -0.781   0.4389
dat$FormationGreene Formation                            -0.0205591  0.1756623  -0.117   0.9074
dat$FormationMonongahela Group                            0.1095318  0.1974568   0.555   0.5819
dat$FormationWaynesburg Formation                        -0.2025803  0.1548242  -1.308   0.1975
dat$HHWSourceMix                                         -0.0956795  0.4503333  -0.212   0.8327
dat$HHWSourceSpring                                       0.3236231  0.3618204   0.894   0.3760
dat$Precip_inchAvg                                        0.0340953  0.0335954   1.015   0.3157
dat$HHWdepthMeters                                        0.0014477  0.0036859   0.393   0.6964
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.1402887)

    Null deviance: 10.7197  on 71  degrees of freedom
Residual deviance:  6.1727  on 44  degrees of freedom
AIC: 85.457

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Lithium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-10.302   -1.772    0.000    1.734   18.347

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              -9.878326  20.983999  -0.471   0.6401
dat$GWellDensity_2kmAvg                                   0.292803   0.134759   2.173   0.0352 *
dat$Altitude_meter                                        0.038176   0.036630   1.042   0.3030
dat$WatershedBane Creek                                   0.107985   4.689274   0.023   0.9817
dat$WatershedBrush Run                                   -3.400441   3.980133  -0.854   0.3975
dat$WatershedBurgetts Fork                               -9.115406   4.414721  -2.065   0.0449 *
dat$WatershedChartiers Run                                2.740814   5.227677   0.524   0.6027
dat$WatershedEnlow Fork                                   2.977700   5.086406   0.585   0.5613
dat$WatershedFishpot Run-Monongahela River                5.410698   5.699291   0.949   0.3476
dat$WatershedHarmon Creek                                -4.500090   8.385578  -0.537   0.5942
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -10.577418   6.154085  -1.719   0.0927 .
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -0.432248   4.318327  -0.100   0.9207
dat$WatershedLittle Tenmile Creek                        -4.818953   4.606392  -1.046   0.3012
dat$WatershedNorth Fork Cross Creek                      -4.468673   4.112489  -1.087   0.2831
dat$WatershedPigeon Creek                                 0.560855   5.687682   0.099   0.9219
dat$WatershedPike Run                                    -5.795888   5.423564  -1.069   0.2911
dat$WatershedPlum Run-Tenmile Creek                       6.386599   4.787863   1.334   0.1891
dat$WatershedShort Creek-Tenmile Creek                   -2.750517   4.078798  -0.674   0.5036
dat$WatershedSouth Fork Cross Creek-Cross Creek          -3.460293   3.377498  -1.025   0.3112
dat$WatershedTempleton Fork                               0.529744   5.786083   0.092   0.9275
dat$WatershedUpper Chartiers Creek                       -3.761028   3.391795  -1.109   0.2735
dat$FormationGreene Formation                            -1.161016   2.428808  -0.478   0.6350
dat$FormationMonongahela Group                            4.891312   2.730151   1.792   0.0801 .
dat$FormationWaynesburg Formation                         4.316561   2.140689   2.016   0.0499 *
dat$HHWSourceMix                                          2.470287   6.226567   0.397   0.6935
dat$HHWSourceSpring                                      -2.909145   5.002737  -0.582   0.5639
dat$Precip_inchAvg                                        0.075116   0.464509   0.162   0.8723
dat$HHWdepthMeters                                        0.003069   0.050963   0.060   0.9523
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 26.81957)

    Null deviance: 2211.7  on 71  degrees of freedom
Residual deviance: 1180.1  on 44  degrees of freedom
AIC: 463.69

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Lithium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-2.1945  -0.3693   0.0000   0.3959   2.7321  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                               0.223113   3.867756   0.058   0.9543  
dat$GWellDensity_2kmAvg                                   0.057975   0.024839   2.334   0.0242 *
dat$Altitude_meter                                        0.004803   0.006752   0.711   0.4806  
dat$WatershedBane Creek                                  -0.012776   0.864324  -0.015   0.9883  
dat$WatershedBrush Run                                   -0.746000   0.733615  -1.017   0.3148  
dat$WatershedBurgetts Fork                               -1.730155   0.813718  -2.126   0.0391 *
dat$WatershedChartiers Run                                0.277265   0.963562   0.288   0.7749  
dat$WatershedEnlow Fork                                   0.495271   0.937523   0.528   0.6000  
dat$WatershedFishpot Run-Monongahela River                0.775056   1.050489   0.738   0.4646  
dat$WatershedHarmon Creek                                -0.808688   1.545624  -0.523   0.6035  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -1.849019   1.134317  -1.630   0.1102  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -0.134641   0.795951  -0.169   0.8664  
dat$WatershedLittle Tenmile Creek                        -1.236371   0.849047  -1.456   0.1524  
dat$WatershedNorth Fork Cross Creek                      -0.790640   0.758011  -1.043   0.3026  
dat$WatershedPigeon Creek                                 0.108522   1.048350   0.104   0.9180  
dat$WatershedPike Run                                    -1.062923   0.999668  -1.063   0.2935  
dat$WatershedPlum Run-Tenmile Creek                       0.265564   0.882496   0.301   0.7649  
dat$WatershedShort Creek-Tenmile Creek                   -0.718832   0.751801  -0.956   0.3442  
dat$WatershedSouth Fork Cross Creek-Cross Creek          -0.680727   0.622538  -1.093   0.2801  
dat$WatershedTempleton Fork                               0.064291   1.066487   0.060   0.9522  
dat$WatershedUpper Chartiers Creek                       -0.669441   0.625173  -1.071   0.2901  
dat$FormationGreene Formation                            -0.193074   0.447676  -0.431   0.6684  
dat$FormationMonongahela Group                            0.775435   0.503220   1.541   0.1305  
dat$FormationWaynesburg Formation                         0.621678   0.394570   1.576   0.1223  
dat$HHWSourceMix                                          0.508287   1.147677   0.443   0.6600  
dat$HHWSourceSpring                                      -0.440653   0.922101  -0.478   0.6351  
dat$Precip_inchAvg                                        0.017821   0.085618   0.208   0.8361  
dat$HHWdepthMeters                                        0.002954   0.009393   0.314   0.7546  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.9111576)

    Null deviance: 71.183  on 71  degrees of freedom
Residual deviance: 40.091  on 44  degrees of freedom
AIC: 220.17

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Magnesium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
   Min      1Q  Median      3Q     Max  
-12088   -3425       0    4410   12358  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                               17534.21   28987.63   0.605   0.5484  
dat$GWellDensity_2kmAvg                                     -82.97     186.16  -0.446   0.6580  
dat$Altitude_meter                                           94.48      50.60   1.867   0.0686 .
dat$WatershedBane Creek                                   -1053.24    6477.84  -0.163   0.8716  
dat$WatershedBrush Run                                     3318.48    5498.22   0.604   0.5492  
dat$WatershedBurgetts Fork                                -4549.91    6098.57  -0.746   0.4596  
dat$WatershedChartiers Run                                -6541.88    7221.60  -0.906   0.3699  
dat$WatershedEnlow Fork                                  -14464.57    7026.44  -2.059   0.0455 *
dat$WatershedFishpot Run-Monongahela River                20004.13    7873.09   2.541   0.0147 *
dat$WatershedHarmon Creek                                  7449.33   11583.97   0.643   0.5235  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -7016.70    8501.35  -0.825   0.4136  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake        1073.57    5965.40   0.180   0.8580  
dat$WatershedLittle Tenmile Creek                          2249.44    6363.34   0.353   0.7254  
dat$WatershedNorth Fork Cross Creek                       -1358.34    5681.06  -0.239   0.8121  
dat$WatershedPigeon Creek                                 22148.34    7857.05   2.819   0.0072 **
dat$WatershedPike Run                                      8254.67    7492.20   1.102   0.2766  
dat$WatershedPlum Run-Tenmile Creek                       -1934.47    6614.03  -0.292   0.7713  
dat$WatershedShort Creek-Tenmile Creek                     1896.77    5634.51   0.337   0.7380  
dat$WatershedSouth Fork Cross Creek-Cross Creek            5038.12    4665.73   1.080   0.2861  
dat$WatershedTempleton Fork                               -8937.08    7992.99  -1.118   0.2696  
dat$WatershedUpper Chartiers Creek                         3232.01    4685.48   0.690   0.4939  
dat$FormationGreene Formation                             -3994.97    3355.19  -1.191   0.2402  
dat$FormationMonongahela Group                             2793.95    3771.47   0.741   0.4627  
dat$FormationWaynesburg Formation                         -5135.77    2957.18  -1.737   0.0894 .
dat$HHWSourceMix                                          20881.54    8601.48   2.428   0.0194 *
dat$HHWSourceSpring                                        2883.57    6910.86   0.417   0.6785  
dat$Precip_inchAvg                                         -909.32     641.68  -1.417   0.1635  
dat$HHWdepthMeters                                          -34.40      70.40  -0.489   0.6275  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 51180036)

    Null deviance: 7070787970  on 71  degrees of freedom
Residual deviance: 2251921582  on 44  degrees of freedom
AIC: 1504.9

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Magnesium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-330.63   -90.67     0.22   112.35   338.40  

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                                   743.8702   760.2426   0.978   0.3332  
dat$GWellDensity_2kmAvg                                        -1.7550     4.8823  -0.359   0.7210  
dat$Altitude_meter                                              1.9689     1.3271   1.484   0.1450  
dat$WatershedBane Creek                                       -41.5811   169.8907  -0.245   0.8078  
dat$WatershedBrush Run                                         52.6768   144.1988   0.365   0.7166  
dat$WatershedBurgetts Fork                                    -89.7864   159.9437  -0.561   0.5774  
dat$WatershedChartiers Run                                   -140.0611   189.3968  -0.740   0.4635  
dat$WatershedEnlow Fork                                      -494.1394   184.2786  -2.681   0.0103 *
dat$WatershedFishpot Run-Monongahela River                    477.3869   206.4832   2.312   0.0255 *
dat$WatershedHarmon Creek                                     167.9686   303.8064   0.553   0.5831  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -160.6315   222.9602  -0.720   0.4751  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake            14.3628   156.4514   0.092   0.9273  
dat$WatershedLittle Tenmile Creek                             -23.2487   166.8879  -0.139   0.8898  
dat$WatershedNorth Fork Cross Creek                           -15.1158   148.9940  -0.101   0.9197  
dat$WatershedPigeon Creek                                     528.7116   206.0626   2.566   0.0138 *
dat$WatershedPike Run                                         233.8515   196.4937   1.190   0.2404  
dat$WatershedPlum Run-Tenmile Creek                          -167.6444   173.4625  -0.966   0.3391  
dat$WatershedShort Creek-Tenmile Creek                          5.1873   147.7733   0.035   0.9722  
dat$WatershedSouth Fork Cross Creek-Cross Creek               132.7470   122.3655   1.085   0.2839  
dat$WatershedTempleton Fork                                  -240.5549   209.6277  -1.148   0.2574  
dat$WatershedUpper Chartiers Creek                             81.9164   122.8835   0.667   0.5085  
dat$FormationGreene Formation                                 -89.8195    87.9948  -1.021   0.3130  
dat$FormationMonongahela Group                                 35.2172    98.9124   0.356   0.7235  
dat$FormationWaynesburg Formation                            -145.5084    77.5564  -1.876   0.0673 .
dat$HHWSourceMix                                              433.9049   225.5862   1.923   0.0609 .
dat$HHWSourceSpring                                           111.5091   181.2473   0.615   0.5416  
dat$Precip_inchAvg                                            -22.7992    16.8290  -1.355   0.1824  
dat$HHWdepthMeters                                             -0.5073     1.8464  -0.275   0.7848  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 35203)

    Null deviance: 4710420  on 71  degrees of freedom
Residual deviance: 1548932  on 44  degrees of freedom
AIC: 980.63

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Manganese"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-91.847  -24.796   -1.851   11.394  207.847  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                               461.2422   237.0069   1.946   0.0580 .
dat$GWellDensity_2kmAvg                                    -0.7755     1.5221  -0.510   0.6129  
dat$Altitude_meter                                         -0.5424     0.4137  -1.311   0.1966  
dat$WatershedBane Creek                                    25.7174    52.9637   0.486   0.6297  
dat$WatershedBrush Run                                     42.9886    44.9542   0.956   0.3442  
dat$WatershedBurgetts Fork                                -26.4083    49.8627  -0.530   0.5990  
dat$WatershedChartiers Run                                -51.7923    59.0448  -0.877   0.3852  
dat$WatershedEnlow Fork                                     2.5482    57.4492   0.044   0.9648  
dat$WatershedFishpot Run-Monongahela River                  5.3110    64.3715   0.083   0.9346  
dat$WatershedHarmon Creek                                  -9.7621    94.7122  -0.103   0.9184  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  16.3035    69.5082   0.235   0.8156  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       102.6494    48.7740   2.105   0.0411 *
dat$WatershedLittle Tenmile Creek                          17.2140    52.0276   0.331   0.7423  
dat$WatershedNorth Fork Cross Creek                        11.3949    46.4491   0.245   0.8073  
dat$WatershedPigeon Creek                                  91.5772    64.2404   1.426   0.1611  
dat$WatershedPike Run                                      12.3657    61.2572   0.202   0.8410  
dat$WatershedPlum Run-Tenmile Creek                        13.3261    54.0772   0.246   0.8065  
dat$WatershedShort Creek-Tenmile Creek                     66.1094    46.0686   1.435   0.1584  
dat$WatershedSouth Fork Cross Creek-Cross Creek            46.6728    38.1477   1.223   0.2277  
dat$WatershedTempleton Fork                               143.2265    65.3518   2.192   0.0337 *
dat$WatershedUpper Chartiers Creek                         -6.4197    38.3091  -0.168   0.8677  
dat$FormationGreene Formation                              18.3871    27.4325   0.670   0.5062  
dat$FormationMonongahela Group                             28.3426    30.8361   0.919   0.3630  
dat$FormationWaynesburg Formation                           9.1931    24.1783   0.380   0.7056  
dat$HHWSourceMix                                          -16.3181    70.3269  -0.232   0.8176  
dat$HHWSourceSpring                                       -22.8282    56.5042  -0.404   0.6882  
dat$Precip_inchAvg                                         -6.1939     5.2465  -1.181   0.2441  
dat$HHWdepthMeters                                         -0.8475     0.5756  -1.472   0.1480  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 3421.349)

    Null deviance: 258206  on 71  degrees of freedom
Residual deviance: 150539  on 44  degrees of freedom
AIC: 812.79

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Manganese"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
      Min         1Q     Median         3Q        Max  
-0.057243  -0.022652  -0.003361   0.021451   0.064942  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                              1.2085666  0.1559890   7.748 9.31e-10 ***
dat$GWellDensity_2kmAvg                                 -0.0008168  0.0010018  -0.815   0.4193    
dat$Altitude_meter                                      -0.0003874  0.0002723  -1.423   0.1618    
dat$WatershedBane Creek                                  0.0210442  0.0348587   0.604   0.5491    
dat$WatershedBrush Run                                   0.0291078  0.0295872   0.984   0.3306    
dat$WatershedBurgetts Fork                              -0.0154357  0.0328178  -0.470   0.6404    
dat$WatershedChartiers Run                              -0.0174579  0.0388610  -0.449   0.6555    
dat$WatershedEnlow Fork                                 -0.0109010  0.0378109  -0.288   0.7745    
dat$WatershedFishpot Run-Monongahela River               0.0116282  0.0423669   0.274   0.7850    
dat$WatershedHarmon Creek                               -0.0082220  0.0623360  -0.132   0.8957    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.0281352  0.0457477   0.615   0.5417    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      0.0238354  0.0321012   0.743   0.4617    
dat$WatershedLittle Tenmile Creek                       -0.0305807  0.0342426  -0.893   0.3767    
dat$WatershedNorth Fork Cross Creek                     -0.0104214  0.0305711  -0.341   0.7348    
dat$WatershedPigeon Creek                                0.0428471  0.0422806   1.013   0.3164    
dat$WatershedPike Run                                   -0.0056587  0.0403172  -0.140   0.8890    
dat$WatershedPlum Run-Tenmile Creek                     -0.0312879  0.0355916  -0.879   0.3841    
dat$WatershedShort Creek-Tenmile Creek                   0.0100053  0.0303206   0.330   0.7430    
dat$WatershedSouth Fork Cross Creek-Cross Creek          0.0153505  0.0251073   0.611   0.5441    
dat$WatershedTempleton Fork                              0.0758480  0.0430121   1.763   0.0848 .  
dat$WatershedUpper Chartiers Creek                      -0.0086689  0.0252136  -0.344   0.7326    
dat$FormationGreene Formation                            0.0185984  0.0180551   1.030   0.3086    
dat$FormationMonongahela Group                           0.0241238  0.0202952   1.189   0.2410    
dat$FormationWaynesburg Formation                        0.0143089  0.0159133   0.899   0.3735    
dat$HHWSourceMix                                        -0.0549149  0.0462865  -1.186   0.2418    
dat$HHWSourceSpring                                     -0.0113229  0.0371889  -0.304   0.7622    
dat$Precip_inchAvg                                      -0.0013628  0.0034530  -0.395   0.6950    
dat$HHWdepthMeters                                      -0.0002316  0.0003788  -0.611   0.5441    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.001482051)

    Null deviance: 0.11249  on 71  degrees of freedom
Residual deviance: 0.06521  on 44  degrees of freedom
AIC: -242.16

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Mercury"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.37399  -0.07720   0.00040   0.04719   0.98678

Coefficients:
                                                        Estimate Std. Error t value Pr(>|t|)
(Intercept)                                           -1.1917530  1.0103915  -1.179   0.2445
dat$GWellDensity_2kmAvg                                0.0024176  0.0064887   0.373   0.7112
dat$Altitude_meter                                     0.0043273  0.0017637   2.453   0.0182 *
dat$WatershedBane Creek                                0.1462860  0.2257912   0.648   0.5204
dat$WatershedBrush Run                                -0.1987872  0.1916457  -1.037   0.3053
dat$WatershedBurgetts Fork                            -0.2166477  0.2125714  -1.019   0.3137
dat$WatershedChartiers Run                            -0.0485168  0.2517156  -0.193   0.8480
dat$WatershedEnlow Fork                               -0.1764622  0.2449134  -0.721   0.4750
dat$WatershedFishpot Run-Monongahela River             0.0090215  0.2744241   0.033   0.9739
dat$WatershedHarmon Creek                             -0.1508373  0.4037704  -0.374   0.7105
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.3273170  0.2963227  -1.105   0.2753
dat$WatershedLittle Chartiers Creek-Canonsburg Lake    0.2231941  0.2079299   1.073   0.2889
dat$WatershedLittle Tenmile Creek                     -0.0328040  0.2218004  -0.148   0.8831
dat$WatershedNorth Fork Cross Creek                   -0.0995562  0.1980187  -0.503   0.6176
dat$WatershedPigeon Creek                              0.1551869  0.2738651   0.567   0.5738
dat$WatershedPike Run                                 -0.1490088  0.2611477  -0.571   0.5712
dat$WatershedPlum Run-Tenmile Creek                    0.1210834  0.2305384   0.525   0.6021
dat$WatershedShort Creek-Tenmile Creek                 0.0541605  0.1963964   0.276   0.7840
dat$WatershedSouth Fork Cross Creek-Cross Creek       -0.1797363  0.1626285  -1.105   0.2751
dat$WatershedTempleton Fork                           -0.0171864  0.2786032  -0.062   0.9511
dat$WatershedUpper Chartiers Creek                    -0.2484104  0.1633169  -1.521   0.1354
dat$FormationGreene Formation                         -0.0211178  0.1169485  -0.181   0.8575
dat$FormationMonongahela Group                         0.0916917  0.1314583   0.697   0.4892
dat$FormationWaynesburg Formation                      0.0932815  0.1030754   0.905   0.3704
dat$HHWSourceMix                                       0.0765170  0.2998128   0.255   0.7997
dat$HHWSourceSpring                                    0.2027636  0.2408846   0.842   0.4045
dat$Precip_inchAvg                                     0.0008528  0.0223664   0.038   0.9698
dat$HHWdepthMeters                                    -0.0017683  0.0024539  -0.721   0.4750
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.06218057)

    Null deviance: 4.1793  on 71  degrees of freedom
Residual deviance: 2.7359  on 44  degrees of freedom
AIC: 26.874

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Mercury"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.36952  -0.07676   0.00026   0.04690   0.97497

Coefficients:
                                                        Estimate Std. Error t value Pr(>|t|)
(Intercept)                                           -1.1741758  1.0005756  -1.174    0.247
dat$GWellDensity_2kmAvg                                0.0023858  0.0064257   0.371    0.712
dat$Altitude_meter                                     0.0042907  0.0017466   2.457    0.018 *
dat$WatershedBane Creek                                0.1461679  0.2235976   0.654    0.517
dat$WatershedBrush Run                                -0.1975554  0.1897839  -1.041    0.304
dat$WatershedBurgetts Fork                            -0.2148290  0.2105062  -1.021    0.313
dat$WatershedChartiers Run                            -0.0472682  0.2492702  -0.190    0.850
dat$WatershedEnlow Fork                               -0.1762942  0.2425340  -0.727    0.471
dat$WatershedFishpot Run-Monongahela River             0.0087762  0.2717581   0.032    0.974
dat$WatershedHarmon Creek                             -0.1499069  0.3998477  -0.375    0.710
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.3248534  0.2934439  -1.107    0.274
dat$WatershedLittle Chartiers Creek-Canonsburg Lake    0.2196662  0.2059099   1.067    0.292
dat$WatershedLittle Tenmile Creek                     -0.0327214  0.2196456  -0.149    0.882
dat$WatershedNorth Fork Cross Creek                   -0.0983897  0.1960949  -0.502    0.618
dat$WatershedPigeon Creek                              0.1535210  0.2712045   0.566    0.574
dat$WatershedPike Run                                 -0.1477330  0.2586106  -0.571    0.571
dat$WatershedPlum Run-Tenmile Creek                    0.1195015  0.2282987   0.523    0.603
dat$WatershedShort Creek-Tenmile Creek                 0.0536751  0.1944884   0.276    0.784
dat$WatershedSouth Fork Cross Creek-Cross Creek       -0.1783878  0.1610485  -1.108    0.274
dat$WatershedTempleton Fork                           -0.0175756  0.2758966  -0.064    0.949
dat$WatershedUpper Chartiers Creek                    -0.2464289  0.1617302  -1.524    0.135
dat$FormationGreene Formation                         -0.0212462  0.1158123  -0.183    0.855
dat$FormationMonongahela Group                         0.0906861  0.1301812   0.697    0.490
dat$FormationWaynesburg Formation                      0.0921698  0.1020740   0.903    0.371
dat$HHWSourceMix                                       0.0758798  0.2969001   0.256    0.799
dat$HHWSourceSpring                                    0.2027979  0.2385444   0.850    0.400
dat$Precip_inchAvg                                     0.0008306  0.0221491   0.037    0.970
dat$HHWdepthMeters                                    -0.0017404  0.0024301  -0.716    0.478
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.06097827)

    Null deviance: 4.1016  on 71  degrees of freedom
Residual deviance: 2.6830  on 44  degrees of freedom
AIC: 25.468

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Nickel"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.90567  -0.41985  -0.07387   0.38455   2.52478

Coefficients:
                                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              1.796926   3.955428   0.454   0.6519
dat$GWellDensity_2kmAvg                                 -0.028482   0.025402  -1.121   0.2683
dat$Altitude_meter                                       0.015493   0.006905   2.244   0.0299 *
dat$WatershedBane Creek                                 -0.212534   0.883916  -0.240   0.8111
dat$WatershedBrush Run                                  -0.426201   0.750245  -0.568   0.5729
dat$WatershedBurgetts Fork                               0.311117   0.832163   0.374   0.7103
dat$WatershedChartiers Run                              -0.812248   0.985403  -0.824   0.4142
dat$WatershedEnlow Fork                                 -2.174666   0.958774  -2.268   0.0283 *
dat$WatershedFishpot Run-Monongahela River               1.364504   1.074301   1.270   0.2107
dat$WatershedHarmon Creek                               -0.150449   1.580659  -0.095   0.9246
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -1.200135   1.160029  -1.035   0.3065
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      0.538093   0.813993   0.661   0.5120
dat$WatershedLittle Tenmile Creek                        0.492564   0.868293   0.567   0.5734
dat$WatershedNorth Fork Cross Creek                      0.211502   0.775193   0.273   0.7863
dat$WatershedPigeon Creek                                1.706423   1.072113   1.592   0.1186
dat$WatershedPike Run                                    0.664942   1.022327   0.650   0.5188
dat$WatershedPlum Run-Tenmile Creek                      1.203447   0.902500   1.333   0.1892
dat$WatershedShort Creek-Tenmile Creek                   0.315972   0.768843   0.411   0.6831
dat$WatershedSouth Fork Cross Creek-Cross Creek          0.172771   0.636649   0.271   0.7874
dat$WatershedTempleton Fork                             -1.035258   1.090661  -0.949   0.3477
dat$WatershedUpper Chartiers Creek                       0.408049   0.639344   0.638   0.5266
dat$FormationGreene Formation                           -0.016320   0.457824  -0.036   0.9717
dat$FormationMonongahela Group                          -0.511494   0.514626  -0.994   0.3257
dat$FormationWaynesburg Formation                       -0.385991   0.403514  -0.957   0.3440
dat$HHWSourceMix                                         1.007848   1.173691   0.859   0.3952
dat$HHWSourceSpring                                      1.051530   0.943003   1.115   0.2709
dat$Precip_inchAvg                                      -0.141580   0.087559  -1.617   0.1130
dat$HHWdepthMeters                                      -0.003477   0.009606  -0.362   0.7191
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.9529329)

    Null deviance: 74.003  on 71  degrees of freedom
Residual deviance: 41.929  on 44  degrees of freedom
AIC: 223.4

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Nickel"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-0.5099  -0.1241   0.0000   0.1282   0.4966  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                              9.865e-01  1.011e+00   0.976  0.33451   
dat$GWellDensity_2kmAvg                                 -9.033e-03  6.493e-03  -1.391  0.17113   
dat$Altitude_meter                                       3.623e-03  1.765e-03   2.053  0.04605 * 
dat$WatershedBane Creek                                 -2.199e-02  2.259e-01  -0.097  0.92292   
dat$WatershedBrush Run                                  -5.073e-02  1.918e-01  -0.265  0.79259   
dat$WatershedBurgetts Fork                               2.180e-01  2.127e-01   1.025  0.31101   
dat$WatershedChartiers Run                              -1.556e-01  2.519e-01  -0.618  0.53994   
dat$WatershedEnlow Fork                                 -6.601e-01  2.451e-01  -2.694  0.00996 **
dat$WatershedFishpot Run-Monongahela River               3.979e-01  2.746e-01   1.449  0.15438   
dat$WatershedHarmon Creek                                2.833e-02  4.040e-01   0.070  0.94442   
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -2.025e-01  2.965e-01  -0.683  0.49821   
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      1.541e-01  2.081e-01   0.741  0.46291   
dat$WatershedLittle Tenmile Creek                        7.347e-02  2.219e-01   0.331  0.74217   
dat$WatershedNorth Fork Cross Creek                      5.801e-02  1.981e-01   0.293  0.77109   
dat$WatershedPigeon Creek                                4.119e-01  2.740e-01   1.503  0.13996   
dat$WatershedPike Run                                    2.070e-01  2.613e-01   0.792  0.43259   
dat$WatershedPlum Run-Tenmile Creek                      2.156e-01  2.307e-01   0.935  0.35502   
dat$WatershedShort Creek-Tenmile Creek                   1.183e-01  1.965e-01   0.602  0.55042   
dat$WatershedSouth Fork Cross Creek-Cross Creek          1.372e-01  1.627e-01   0.843  0.40381   
dat$WatershedTempleton Fork                             -2.010e-01  2.788e-01  -0.721  0.47467   
dat$WatershedUpper Chartiers Creek                       1.266e-01  1.634e-01   0.775  0.44251   
dat$FormationGreene Formation                           -3.443e-02  1.170e-01  -0.294  0.76999   
dat$FormationMonongahela Group                          -1.644e-01  1.315e-01  -1.250  0.21803   
dat$FormationWaynesburg Formation                       -1.228e-01  1.031e-01  -1.191  0.23999   
dat$HHWSourceMix                                         2.752e-01  3.000e-01   0.917  0.36392   
dat$HHWSourceSpring                                      3.027e-01  2.410e-01   1.256  0.21577   
dat$Precip_inchAvg                                      -2.973e-02  2.238e-02  -1.328  0.19091   
dat$HHWdepthMeters                                      -7.052e-05  2.455e-03  -0.029  0.97722   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.06225517)

    Null deviance: 5.0129  on 71  degrees of freedom
Residual deviance: 2.7392  on 44  degrees of freedom
AIC: 26.96

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Potassium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-804.5  -360.5  -123.8   207.5  2619.8

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               1811.639   3076.535   0.589    0.559
dat$GWellDensity_2kmAvg                                     -1.206     19.757  -0.061    0.952
dat$Altitude_meter                                          -2.331      5.370  -0.434    0.666
dat$WatershedBane Creek                                   -833.710    687.510  -1.213    0.232
dat$WatershedBrush Run                                     254.277    583.541   0.436    0.665
dat$WatershedBurgetts Fork                                 391.334    647.257   0.605    0.549
dat$WatershedChartiers Run                                 -72.701    766.447  -0.095    0.925
dat$WatershedEnlow Fork                                  -1013.672    745.735  -1.359    0.181
dat$WatershedFishpot Run-Monongahela River                 222.418    835.592   0.266    0.791
dat$WatershedHarmon Creek                                  441.465   1229.438   0.359    0.721
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -257.194    902.271  -0.285    0.777
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       -546.369    633.124  -0.863    0.393
dat$WatershedLittle Tenmile Creek                         -600.452    675.359  -0.889    0.379
dat$WatershedNorth Fork Cross Creek                       -213.232    602.946  -0.354    0.725
dat$WatershedPigeon Creek                                  208.974    833.890   0.251    0.803
dat$WatershedPike Run                                      546.477    795.167   0.687    0.496
dat$WatershedPlum Run-Tenmile Creek                      -1071.629    701.965  -1.527    0.134
dat$WatershedShort Creek-Tenmile Creek                    -686.241    598.006  -1.148    0.257
dat$WatershedSouth Fork Cross Creek-Cross Creek             95.839    495.186   0.194    0.847
dat$WatershedTempleton Fork                               -404.561    848.317  -0.477    0.636
dat$WatershedUpper Chartiers Creek                         455.350    497.282   0.916    0.365
dat$FormationGreene Formation                              466.400    356.096   1.310    0.197
dat$FormationMonongahela Group                              91.325    400.277   0.228    0.821
dat$FormationWaynesburg Formation                         -326.382    313.854  -1.040    0.304
dat$HHWSourceMix                                          -841.040    912.898  -0.921    0.362
dat$HHWSourceSpring                                       -148.632    733.468  -0.203    0.840
dat$Precip_inchAvg                                          10.280     68.103   0.151    0.881
dat$HHWdepthMeters                                           4.040      7.472   0.541    0.591

(Dispersion parameter for gaussian family taken to be 576499.5)

    Null deviance: 39766110  on 71  degrees of freedom
Residual deviance: 25365978  on 44  degrees of freedom
AIC: 1181.9

Number of Fisher Scoring iterations: 2


[1] "BOX-COX MODEL - Potassium"
```

```
Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-18.984   -4.767   -0.935    3.550   32.727  

Coefficients:
                                                      Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                          43.10361   45.13433   0.955   0.3448  
dat$GWellDensity_2kmAvg                               0.03629    0.28985   0.125   0.9009  
dat$Altitude_meter                                   -0.03191    0.07879  -0.405   0.6874  
dat$WatershedBane Creek                             -11.58659   10.08612  -1.149   0.2569  
dat$WatershedBrush Run                                2.15872    8.56084   0.252   0.8021  
dat$WatershedBurgetts Fork                            5.19646    9.49559   0.547   0.5870  
dat$WatershedChartiers Run                           -0.64709   11.24417  -0.058   0.9544  
dat$WatershedEnlow Fork                             -15.83436   10.94031  -1.447   0.1549  
dat$WatershedFishpot Run-Monongahela River            3.79452   12.25856   0.310   0.7584  
dat$WatershedHarmon Creek                             6.13679   18.03648   0.340   0.7353  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -4.69160   13.23678  -0.354   0.7247  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake  -7.85659    9.28826  -0.846   0.4022  
dat$WatershedLittle Tenmile Creek                   -13.50560    9.90785  -1.363   0.1798  
dat$WatershedNorth Fork Cross Creek                  -2.87964    8.84552  -0.326   0.7463  
dat$WatershedPigeon Creek                             3.89326   12.23359   0.318   0.7518  
dat$WatershedPike Run                                 7.98445   11.66550   0.684   0.4973  
dat$WatershedPlum Run-Tenmile Creek                 -20.86083   10.29818  -2.026   0.0489 *
dat$WatershedShort Creek-Tenmile Creek              -10.50530    8.77306  -1.197   0.2375  
dat$WatershedSouth Fork Cross Creek-Cross Creek       0.75091    7.26464   0.103   0.9181  
dat$WatershedTempleton Fork                          -5.00410   12.44524  -0.402   0.6896  
dat$WatershedUpper Chartiers Creek                    6.43909    7.29539   0.883   0.3822  
dat$FormationGreene Formation                         6.62637    5.22410   1.268   0.2113  
dat$FormationMonongahela Group                        1.72184    5.87226   0.293   0.7707  
dat$FormationWaynesburg Formation                    -5.01607    4.60439  -1.089   0.2819  
dat$HHWSourceMix                                    -11.37418   13.39268  -0.849   0.4003  
dat$HHWSourceSpring                                  -3.19861   10.76035  -0.297   0.7677  
dat$Precip_inchAvg                                    0.20176    0.99911   0.202   0.8409  
dat$HHWdepthMeters                                    0.09124    0.10962   0.832   0.4097  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 124.0764)

    Null deviance: 9718.1  on 71  degrees of freedom
Residual deviance: 5459.4  on 44  degrees of freedom
AIC: 573.97

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Selenium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-0.136809  -0.005378  -0.000680   0.004755   0.238178

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  3.658e-01  1.829e-01   2.000  0.05175 .
dat$GWellDensity_2kmAvg                                     -1.327e-04  1.175e-03  -0.113  0.91059
dat$Altitude_meter                                           7.886e-05  3.193e-04   0.247  0.80609
dat$WatershedBane Creek                                      1.289e-02  4.088e-02   0.315  0.75396
dat$WatershedBrush Run                                      -4.333e-03  3.470e-02  -0.125  0.90119
dat$WatershedBurgetts Fork                                   1.125e-02  3.848e-02   0.292  0.77146
dat$WatershedChartiers Run                                   4.810e-03  4.557e-02   0.106  0.91641
dat$WatershedEnlow Fork                                     -1.930e-03  4.434e-02  -0.044  0.96548
dat$WatershedFishpot Run-Monongahela River                   4.501e-02  4.968e-02   0.906  0.36991
dat$WatershedHarmon Creek                                    1.242e+00  7.310e-02  16.992  < 2e-16 ***
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -1.205e-02  5.365e-02  -0.225  0.82332
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          2.153e-02  3.764e-02   0.572  0.57029
dat$WatershedLittle Tenmile Creek                            2.754e-02  4.016e-02   0.686  0.49637
dat$WatershedNorth Fork Cross Creek                          1.442e-02  3.585e-02   0.402  0.68941
dat$WatershedPigeon Creek                                    3.857e-02  4.958e-02   0.778  0.44073
dat$WatershedPike Run                                        1.600e-01  4.728e-02   3.385  0.00151 **
dat$WatershedPlum Run-Tenmile Creek                          2.934e-02  4.174e-02   0.703  0.48584
dat$WatershedShort Creek-Tenmile Creek                       1.853e-02  3.556e-02   0.521  0.60481
dat$WatershedSouth Fork Cross Creek-Cross Creek              1.163e-02  2.944e-02   0.395  0.69463
dat$WatershedTempleton Fork                                 -2.708e-03  5.044e-02  -0.054  0.95743
dat$WatershedUpper Chartiers Creek                          -2.285e-03  2.957e-02  -0.077  0.93875
dat$FormationGreene Formation                                1.284e-03  2.117e-02   0.061  0.95190
dat$FormationMonongahela Group                              -1.349e-02  2.380e-02  -0.567  0.57376
dat$FormationWaynesburg Formation                            4.762e-03  1.866e-02   0.255  0.79976
dat$HHWSourceMix                                            -1.027e-01  5.428e-02  -1.893  0.06501 .
dat$HHWSourceSpring                                          8.109e-03  4.361e-02   0.186  0.85335
dat$Precip_inchAvg                                          -3.956e-03  4.049e-03  -0.977  0.33390
dat$HHWdepthMeters                                           6.766e-05  4.443e-04   0.152  0.87965
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.002038045)

    Null deviance: 1.345342  on 71  degrees of freedom
Residual deviance: 0.089674  on 44  degrees of freedom
AIC: -219.23

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Selenium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-0.136809  -0.005378  -0.000680   0.004755   0.238178

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  3.658e-01  1.829e-01   2.000  0.05175 .
dat$GWellDensity_2kmAvg                                     -1.327e-04  1.175e-03  -0.113  0.91059
dat$Altitude_meter                                           7.886e-05  3.193e-04   0.247  0.80609
dat$WatershedBane Creek                                      1.289e-02  4.088e-02   0.315  0.75396
dat$WatershedBrush Run                                      -4.333e-03  3.470e-02  -0.125  0.90119
dat$WatershedBurgetts Fork                                   1.125e-02  3.848e-02   0.292  0.77146
dat$WatershedChartiers Run                                   4.810e-03  4.557e-02   0.106  0.91641
dat$WatershedEnlow Fork                                     -1.930e-03  4.434e-02  -0.044  0.96548
dat$WatershedFishpot Run-Monongahela River                   4.501e-02  4.968e-02   0.906  0.36991
dat$WatershedHarmon Creek                                    1.242e+00  7.310e-02  16.992  < 2e-16 ***
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -1.205e-02  5.365e-02  -0.225  0.82332
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          2.153e-02  3.764e-02   0.572  0.57029
dat$WatershedLittle Tenmile Creek                            2.754e-02  4.016e-02   0.686  0.49637
dat$WatershedNorth Fork Cross Creek                          1.442e-02  3.585e-02   0.402  0.68941
dat$WatershedPigeon Creek                                    3.857e-02  4.958e-02   0.778  0.44073
dat$WatershedPike Run                                        1.600e-01  4.728e-02   3.385  0.00151 **
dat$WatershedPlum Run-Tenmile Creek                          2.934e-02  4.174e-02   0.703  0.48584
dat$WatershedShort Creek-Tenmile Creek                       1.853e-02  3.556e-02   0.521  0.60481
dat$WatershedSouth Fork Cross Creek-Cross Creek              1.163e-02  2.944e-02   0.395  0.69463
dat$WatershedTempleton Fork                                 -2.708e-03  5.044e-02  -0.054  0.95743
dat$WatershedUpper Chartiers Creek                          -2.285e-03  2.957e-02  -0.077  0.93875
dat$FormationGreene Formation                                1.284e-03  2.117e-02   0.061  0.95190
dat$FormationMonongahela Group                              -1.349e-02  2.380e-02  -0.567  0.57376
dat$FormationWaynesburg Formation                            4.762e-03  1.866e-02   0.255  0.79976
dat$HHWSourceMix                                            -1.027e-01  5.428e-02  -1.893  0.06501 .
dat$HHWSourceSpring                                          8.109e-03  4.361e-02   0.186  0.85335
dat$Precip_inchAvg                                          -3.956e-03  4.049e-03  -0.977  0.33390
dat$HHWdepthMeters                                           6.766e-05  4.443e-04   0.152  0.87965
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.002038045)

    Null deviance: 1.345342  on 71  degrees of freedom
Residual deviance: 0.089674  on 44  degrees of freedom
AIC: -219.23

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Silicon"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3458.3   -639.3      0.0    471.2   3454.6

Coefficients: (1 not defined because of singularities)
                                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                 12364.936  10540.954   1.173    0.253
dat$GWellDensity_2kmAvg                                        24.224     70.977   0.341    0.736
dat$Altitude_meter                                              7.157     17.418   0.411    0.685
dat$WatershedBane Creek                                       741.243   2045.866   0.362    0.720
dat$WatershedBrush Run                                        787.512   1792.857   0.439    0.665
dat$WatershedBurgetts Fork                                   -391.173   1887.199  -0.207    0.838
dat$WatershedChartiers Run                                  -3826.678   2268.828  -1.687    0.105
dat$WatershedEnlow Fork                                      -154.756   3448.251  -0.045    0.965
dat$WatershedHarmon Creek                                    -366.319   2794.797  -0.131    0.897
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -1321.858   2406.738  -0.549    0.588
dat$WatershedLittle Chartiers Creek-Canonsburg Lake           180.213   2346.901   0.077    0.939
dat$WatershedLittle Tenmile Creek                            3933.116   2611.069   1.506    0.146
dat$WatershedNorth Fork Cross Creek                         -1069.506   1855.903  -0.576    0.570
dat$WatershedPigeon Creek                                    3654.375   3247.762   1.125    0.272
dat$WatershedShort Creek-Tenmile Creek                        340.909   1993.861   0.171    0.866
dat$WatershedSouth Fork Cross Creek-Cross Creek               305.301   1628.592   0.187    0.853
dat$WatershedTempleton Fork                                  -587.360   2328.050  -0.252    0.803
dat$WatershedUpper Chartiers Creek                           -792.852   1942.034  -0.408    0.687
dat$FormationGreene Formation                                -865.723   1079.571  -0.802    0.431
dat$FormationMonongahela Group                               -378.235   1340.328  -0.282    0.780
dat$FormationWaynesburg Formation                           -1209.479    968.027  -1.249    0.224
dat$HHWSourceMix                                                   NA         NA      NA       NA
dat$HHWSourceSpring                                          -942.550   2318.680  -0.407    0.688
dat$Precip_inchAvg                                           -201.063    262.629  -0.766    0.452
dat$HHWdepthMeters                                            -34.543     25.607  -1.349    0.190

(Dispersion parameter for gaussian family taken to be 3330887)

    Null deviance: 151588626  on 46  degrees of freedom
Residual deviance:  76610390  on 23  degrees of freedom
  (25 observations deleted due to missingness)
AIC: 855.67

Number of Fisher Scoring iterations: 2


[1] "BOX-COX MODEL - Silicon"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
```

```
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
      Min         1Q     Median         3Q        Max  
-0.018595  -0.004795   0.000000   0.004370   0.022314  

Coefficients: (1 not defined because of singularities)
                                                           Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                               2.477e-01  7.187e-02   3.446   0.0022 **
dat$GWellDensity_2kmAvg                                  -1.526e-04  4.839e-04  -0.315   0.7553   
dat$Altitude_meter                                       -6.434e-05  1.188e-04  -0.542   0.5932   
dat$WatershedBane Creek                                  -5.845e-03  1.395e-02  -0.419   0.6791   
dat$WatershedBrush Run                                   -6.368e-03  1.222e-02  -0.521   0.6074   
dat$WatershedBurgetts Fork                                3.682e-03  1.287e-02   0.286   0.7773   
dat$WatershedChartiers Run                                3.339e-02  1.547e-02   2.159   0.0415 * 
dat$WatershedEnlow Fork                                   7.643e-03  2.351e-02   0.325   0.7480   
dat$WatershedHarmon Creek                                 9.661e-04  1.906e-02   0.051   0.9600   
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  1.262e-02  1.641e-02   0.769   0.4498   
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       2.137e-03  1.600e-02   0.134   0.8949   
dat$WatershedLittle Tenmile Creek                        -2.360e-02  1.780e-02  -1.326   0.1979   
dat$WatershedNorth Fork Cross Creek                       8.349e-03  1.265e-02   0.660   0.5159   
dat$WatershedPigeon Creek                                -2.590e-02  2.214e-02  -1.170   0.2542   
dat$WatershedShort Creek-Tenmile Creek                   -8.026e-04  1.359e-02  -0.059   0.9534   
dat$WatershedSouth Fork Cross Creek-Cross Creek          -2.788e-03  1.110e-02  -0.251   0.8040   
dat$WatershedTempleton Fork                               2.974e-03  1.587e-02   0.187   0.8530   
dat$WatershedUpper Chartiers Creek                        8.186e-03  1.324e-02   0.618   0.5425   
dat$FormationGreene Formation                             5.062e-03  7.361e-03   0.688   0.4985   
dat$FormationMonongahela Group                            2.981e-03  9.139e-03   0.326   0.7472   
dat$FormationWaynesburg Formation                         6.113e-03  6.600e-03   0.926   0.3640   
dat$HHWSourceMix                                                 NA         NA      NA       NA   
dat$HHWSourceSpring                                       2.107e-03  1.581e-02   0.133   0.8951   
dat$Precip_inchAvg                                        1.612e-03  1.791e-03   0.900   0.3774   
dat$HHWdepthMeters                                        3.166e-04  1.746e-04   1.813   0.0828 . 
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.0001548486)

    Null deviance: 0.0080050  on 46  degrees of freedom
Residual deviance: 0.0035615  on 23  degrees of freedom
  (25 observations deleted due to missingness)
AIC: -262.54

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Sodium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-150337   -28852     -327    20565   230952

Coefficients:
                                                      Estimate Std. Error t value Pr(>|t|)
(Intercept)                                          -140356.4   274198.2  -0.512  0.61130
dat$GWellDensity_2kmAvg                                 1749.8     1760.9   0.994  0.32581
dat$Altitude_meter                                      -197.0      478.6  -0.412  0.68269
dat$WatershedBane Creek                                19361.3    61274.8   0.316  0.75352
dat$WatershedBrush Run                                  8126.3    52008.5   0.156  0.87655
dat$WatershedBurgetts Fork                            -24963.9    57687.2  -0.433  0.66731
dat$WatershedChartiers Run                            118430.8    68310.1   1.734  0.08997 .
dat$WatershedEnlow Fork                               257604.6    66464.1   3.876  0.00035 ***
dat$WatershedFishpot Run-Monongahela River            -32793.9    74472.7  -0.440  0.66184
dat$WatershedHarmon Creek                             -37704.0   109574.5  -0.344  0.73241
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -49539.2    80415.5  -0.616  0.54104
dat$WatershedLittle Chartiers Creek-Canonsburg Lake    32319.8    56427.6   0.573  0.56972
dat$WatershedLittle Tenmile Creek                      19854.8    60191.8   0.330  0.74307
dat$WatershedNorth Fork Cross Creek                    -3044.0    53737.9  -0.057  0.95508
dat$WatershedPigeon Creek                             -79471.2    74321.0  -1.069  0.29077
dat$WatershedPike Run                                 -71336.5    70869.8  -1.007  0.31964
dat$WatershedPlum Run-Tenmile Creek                   108422.1    62563.1   1.733  0.09010 .
dat$WatershedShort Creek-Tenmile Creek                 32055.7    53297.7   0.601  0.55063
dat$WatershedSouth Fork Cross Creek-Cross Creek       -32346.4    44133.8  -0.733  0.46750
dat$WatershedTempleton Fork                           102986.1    75606.8   1.362  0.18009
dat$WatershedUpper Chartiers Creek                     -3520.4    44320.6  -0.079  0.93705
dat$FormationGreene Formation                          -3410.1    31737.3  -0.107  0.91492
dat$FormationMonongahela Group                         37930.7    35674.9   1.063  0.29348
dat$FormationWaynesburg Formation                      43058.3    27972.4   1.539  0.13089
dat$HHWSourceMix                                       -5953.0    81362.6  -0.073  0.94201
dat$HHWSourceSpring                                  -100773.7    65370.8  -1.542  0.13034
dat$Precip_inchAvg                                      5147.3     6069.7   0.848  0.40101
dat$HHWdepthMeters                                       539.4      665.9   0.810  0.42228
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 4579356054)

    Null deviance: 4.3321e+11  on 71  degrees of freedom
Residual deviance: 2.0149e+11  on 44  degrees of freedom
AIC: 1828.5

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Sodium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.06252  -0.01972   0.00000   0.01448   0.05599

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                 0.6223135  0.1255340   4.957 1.11e-05 ***
dat$GWellDensity_2kmAvg                                    -0.0003528  0.0008062  -0.438   0.6638
dat$Altitude_meter                                          0.0003610  0.0002191   1.648   0.1066
dat$WatershedBane Creek                                    -0.0204192  0.0280530  -0.728   0.4705
dat$WatershedBrush Run                                     -0.0169284  0.0238106  -0.711   0.4809
dat$WatershedBurgetts Fork                                 -0.0004327  0.0264105  -0.016   0.9870
dat$WatershedChartiers Run                                 -0.0613950  0.0312739  -1.963   0.0560 .
dat$WatershedEnlow Fork                                    -0.0773702  0.0304288  -2.543   0.0146 *
dat$WatershedFishpot Run-Monongahela River                 -0.0064607  0.0340953  -0.189   0.8506
dat$WatershedHarmon Creek                                   0.0086960  0.0501656   0.173   0.8632
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.0297312  0.0368160   0.808   0.4237
dat$WatershedLittle Chartiers Creek-Canonsburg Lake        -0.0307155  0.0258338  -1.189   0.2408
dat$WatershedLittle Tenmile Creek                          -0.0238060  0.0275571  -0.864   0.3923
dat$WatershedNorth Fork Cross Creek                        -0.0144498  0.0246024  -0.587   0.5600
dat$WatershedPigeon Creek                                   0.0153612  0.0340258   0.451   0.6539
dat$WatershedPike Run                                       0.0253667  0.0324458   0.782   0.4385
dat$WatershedPlum Run-Tenmile Creek                        -0.0164065  0.0286428  -0.573   0.5697
dat$WatershedShort Creek-Tenmile Creek                      0.0055189  0.0244009   0.226   0.8221
dat$WatershedSouth Fork Cross Creek-Cross Creek             0.0005604  0.0202054   0.028   0.9780
dat$WatershedTempleton Fork                                -0.0548088  0.0346145  -1.583   0.1205
dat$WatershedUpper Chartiers Creek                         -0.0262370  0.0202910  -1.293   0.2027
dat$FormationGreene Formation                              -0.0074395  0.0145300  -0.512   0.6112
dat$FormationMonongahela Group                             -0.0051894  0.0163328  -0.318   0.7522
dat$FormationWaynesburg Formation                          -0.0040454  0.0128064  -0.316   0.7536
dat$HHWSourceMix                                            0.0003296  0.0372496   0.009   0.9930
dat$HHWSourceSpring                                         0.0116461  0.0299282   0.389   0.6991
dat$Precip_inchAvg                                         -0.0014488  0.0027789  -0.521   0.6047
dat$HHWdepthMeters                                         -0.0002348  0.0003049  -0.770   0.4453
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.0009598388)

    Null deviance: 0.079708  on 71  degrees of freedom
Residual deviance: 0.042233  on 44  degrees of freedom
AIC: -273.44

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Strontium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-719.06  -209.49    -6.58   130.97  1381.16  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                              1157.0395  1905.2082   0.607   0.5468  
dat$GWellDensity_2kmAvg                                     9.4884    12.2352   0.775   0.4422  
dat$Altitude_meter                                         -1.8649     3.3257  -0.561   0.5778  
dat$WatershedBane Creek                                   233.3926   425.7550   0.548   0.5863  
dat$WatershedBrush Run                                    432.6358   361.3698   1.197   0.2376  
dat$WatershedBurgetts Fork                                 -0.4367   400.8275  -0.001   0.9991  
dat$WatershedChartiers Run                                699.0053   474.6385   1.473   0.1479  
dat$WatershedEnlow Fork                                  -238.9223   461.8120  -0.517   0.6075  
dat$WatershedFishpot Run-Monongahela River               1063.5729   517.4579   2.055   0.0458 *
dat$WatershedHarmon Creek                                 -57.5645   761.3550  -0.076   0.9401  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -11.8639   558.7502  -0.021   0.9832  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       143.0732   392.0755   0.365   0.7169  
dat$WatershedLittle Tenmile Creek                         514.7970   418.2299   1.231   0.2249  
dat$WatershedNorth Fork Cross Creek                       273.9954   373.3868   0.734   0.4670  
dat$WatershedPigeon Creek                                 594.1437   516.4039   1.151   0.2561  
dat$WatershedPike Run                                      91.2500   492.4237   0.185   0.8538  
dat$WatershedPlum Run-Tenmile Creek                      -343.6852   434.7063  -0.791   0.4334  
dat$WatershedShort Creek-Tenmile Creek                   -189.8625   370.3278  -0.513   0.6107  
dat$WatershedSouth Fork Cross Creek-Cross Creek            84.3803   306.6544   0.275   0.7845  
dat$WatershedTempleton Fork                               213.4921   525.3381   0.406   0.6864  
dat$WatershedUpper Chartiers Creek                        398.8701   307.9525   1.295   0.2020  
dat$FormationGreene Formation                            -111.3888   220.5197  -0.505   0.6160  
dat$FormationMonongahela Group                            -53.5626   247.8796  -0.216   0.8299  
dat$FormationWaynesburg Formation                        -234.7527   194.3604  -1.208   0.2336  
dat$HHWSourceMix                                          454.7344   565.3311   0.804   0.4255  
dat$HHWSourceSpring                                        71.1364   454.2154   0.157   0.8763  
dat$Precip_inchAvg                                         -6.6812    42.1743  -0.158   0.8749  
dat$HHWdepthMeters                                          4.1538     4.6271   0.898   0.3742  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 221085.5)

    Null deviance: 17199912  on 71  degrees of freedom
Residual deviance:  9727761  on 44  degrees of freedom
AIC: 1112.9

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Strontium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
   Min      1Q  Median      3Q     Max  
-8.212  -2.075   0.000   1.529   9.185  

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                                   18.97404   15.94496   1.190   0.2404  
dat$GWellDensity_2kmAvg                                        0.06928    0.10240   0.677   0.5022  
dat$Altitude_meter                                            -0.02036    0.02783  -0.732   0.4683  
dat$WatershedBane Creek                                        2.43582    3.56320   0.684   0.4978  
dat$WatershedBrush Run                                         3.01223    3.02435   0.996   0.3247  
dat$WatershedBurgetts Fork                                     0.41480    3.35458   0.124   0.9022  
dat$WatershedChartiers Run                                     5.11200    3.97232   1.287   0.2049  
dat$WatershedEnlow Fork                                       -4.20192    3.86497  -1.087   0.2829  
dat$WatershedFishpot Run-Monongahela River                     7.68034    4.33068   1.773   0.0831 .
dat$WatershedHarmon Creek                                     -0.95571    6.37189  -0.150   0.8815  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.06412    4.67626   0.014   0.9891  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake            1.01417    3.28134   0.309   0.7587  
dat$WatershedLittle Tenmile Creek                              0.89697    3.50022   0.256   0.7989  
dat$WatershedNorth Fork Cross Creek                            2.82106    3.12493   0.903   0.3716  
dat$WatershedPigeon Creek                                      5.45387    4.32186   1.262   0.2136  
dat$WatershedPike Run                                          0.66291    4.12116   0.161   0.8729  
dat$WatershedPlum Run-Tenmile Creek                           -5.05215    3.63812  -1.389   0.1719  
dat$WatershedShort Creek-Tenmile Creek                        -1.86237    3.09933  -0.601   0.5510  
dat$WatershedSouth Fork Cross Creek-Cross Creek                1.48708    2.56643   0.579   0.5653  
dat$WatershedTempleton Fork                                    2.50007    4.39663   0.569   0.5725  
dat$WatershedUpper Chartiers Creek                             3.80145    2.57730   1.475   0.1473  
dat$FormationGreene Formation                                 -0.44690    1.84556  -0.242   0.8098  
dat$FormationMonongahela Group                                -0.22645    2.07454  -0.109   0.9136  
dat$FormationWaynesburg Formation                             -2.12099    1.62663  -1.304   0.1990  
dat$HHWSourceMix                                               4.70724    4.73134   0.995   0.3252  
dat$HHWSourceSpring                                            1.98796    3.80139   0.523   0.6036  
dat$Precip_inchAvg                                            -0.09144    0.35296  -0.259   0.7968  
dat$HHWdepthMeters                                             0.04861    0.03872   1.255   0.2160  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 15.48538)

    Null deviance: 1256.20  on 71  degrees of freedom
Residual deviance:  681.36  on 44  degrees of freedom
AIC: 424.14

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Tin"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-20.940   -3.065    0.000    2.648   61.666

Coefficients:
                                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              17.05532   46.51350   0.367    0.716
dat$GWellDensity_2kmAvg                                   0.43592    0.29871   1.459    0.152
dat$Altitude_meter                                        0.13221    0.08119   1.628    0.111
dat$WatershedBane Creek                                   3.96519   10.39433   0.381    0.705
dat$WatershedBrush Run                                    7.81853    8.82243   0.886    0.380
dat$WatershedBurgetts Fork                               -9.46299    9.78575  -0.967    0.339
dat$WatershedChartiers Run                              -14.58197   11.58776  -1.258    0.215
dat$WatershedEnlow Fork                                   5.70857   11.27462   0.506    0.615
dat$WatershedFishpot Run-Monongahela River               12.22397   12.63315   0.968    0.339
dat$WatershedHarmon Creek                                 3.70236   18.58762   0.199    0.843
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -9.33025   13.64125  -0.684    0.498
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      11.15091    9.57208   1.165    0.250
dat$WatershedLittle Tenmile Creek                         9.69440   10.21061   0.949    0.348
dat$WatershedNorth Fork Cross Creek                      -0.58662    9.11581  -0.064    0.949
dat$WatershedPigeon Creek                                13.67581   12.60742   1.085    0.284
dat$WatershedPike Run                                     9.30196   12.02197   0.774    0.443
dat$WatershedPlum Run-Tenmile Creek                      16.62523   10.61286   1.567    0.124
dat$WatershedShort Creek-Tenmile Creek                    0.71295    9.04113   0.079    0.938
dat$WatershedSouth Fork Cross Creek-Cross Creek          -6.67524    7.48662  -0.892    0.377
dat$WatershedTempleton Fork                              -3.59706   12.82553  -0.280    0.780
dat$WatershedUpper Chartiers Creek                       -8.27646    7.51831  -1.101    0.277
dat$FormationGreene Formation                            -4.61728    5.38374  -0.858    0.396
dat$FormationMonongahela Group                            1.01843    6.05170   0.168    0.867
dat$FormationWaynesburg Formation                        -2.12149    4.74509  -0.447    0.657
dat$HHWSourceMix                                          2.48806   13.80192   0.180    0.858
dat$HHWSourceSpring                                      -6.73335   11.08915  -0.607    0.547
dat$Precip_inchAvg                                       -1.46223    1.02964  -1.420    0.163
dat$HHWdepthMeters                                       -0.20898    0.11297  -1.850    0.071 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 131.7751)

    Null deviance: 8557.4  on 71  degrees of freedom
Residual deviance: 5798.1  on 44  degrees of freedom
AIC: 578.31

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Tin"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-0.8337  -0.1709   0.0000   0.1676   0.6583  

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                                 -0.4060810  1.4289543  -0.284   0.7776  
dat$GWellDensity_2kmAvg                                     -0.0024549  0.0091767  -0.268   0.7903  
dat$Altitude_meter                                           0.0008420  0.0024944   0.338   0.7373  
dat$WatershedBane Creek                                      0.4962300  0.3193270   1.554   0.1274  
dat$WatershedBrush Run                                       0.1606781  0.2710365   0.593   0.5563  
dat$WatershedBurgetts Fork                                   0.2488259  0.3006307   0.828   0.4123  
dat$WatershedChartiers Run                                   0.9080952  0.3559908   2.551   0.0143 *
dat$WatershedEnlow Fork                                     -0.1723627  0.3463707  -0.498   0.6212  
dat$WatershedFishpot Run-Monongahela River                  -0.2438927  0.3881065  -0.628   0.5330  
dat$WatershedHarmon Creek                                   -0.5515383  0.5710355  -0.966   0.3394  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.3485328  0.4190767   0.832   0.4101  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         -0.0810003  0.2940665  -0.275   0.7843  
dat$WatershedLittle Tenmile Creek                            0.0434199  0.3136830   0.138   0.8905  
dat$WatershedNorth Fork Cross Creek                          0.1284660  0.2800495   0.459   0.6487  
dat$WatershedPigeon Creek                                   -0.2933320  0.3873160  -0.757   0.4529  
dat$WatershedPike Run                                       -0.4408338  0.3693302  -1.194   0.2390  
dat$WatershedPlum Run-Tenmile Creek                         -0.0656050  0.3260407  -0.201   0.8415  
dat$WatershedShort Creek-Tenmile Creek                       0.4230630  0.2777552   1.523   0.1349  
dat$WatershedSouth Fork Cross Creek-Cross Creek              0.2999932  0.2299986   1.304   0.1989  
dat$WatershedTempleton Fork                                  0.6278037  0.3940168   1.593   0.1182  
dat$WatershedUpper Chartiers Creek                           0.1678177  0.2309722   0.727   0.4713  
dat$FormationGreene Formation                               -0.1860240  0.1653953  -1.125   0.2668  
dat$FormationMonongahela Group                              -0.0903440  0.1859160  -0.486   0.6294  
dat$FormationWaynesburg Formation                            0.1683381  0.1457752   1.155   0.2544  
dat$HHWSourceMix                                             0.3601305  0.4240126   0.849   0.4003  
dat$HHWSourceSpring                                          0.2209849  0.3406730   0.649   0.5199  
dat$Precip_inchAvg                                           0.0261550  0.0316318   0.827   0.4128  
dat$HHWdepthMeters                                          -0.0003388  0.0034705  -0.098   0.9227  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.124369)

    Null deviance: 9.4195  on 71  degrees of freedom
Residual deviance: 5.4722  on 44  degrees of freedom
AIC: 76.785

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Uranium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.42584  -0.05148  -0.00379   0.04188   0.67091

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              0.3264647  0.8187003   0.399   0.6920
dat$GWellDensity_2kmAvg                                 -0.0064861  0.0052577  -1.234   0.2239
dat$Altitude_meter                                       0.0008132  0.0014291   0.569   0.5722
dat$WatershedBane Creek                                 -0.1626399  0.1829542  -0.889   0.3789
dat$WatershedBrush Run                                   0.0610083  0.1552867   0.393   0.6963
dat$WatershedBurgetts Fork                               0.0329832  0.1722424   0.191   0.8490
dat$WatershedChartiers Run                               0.1476384  0.2039602   0.724   0.4730
dat$WatershedEnlow Fork                                 -0.0453491  0.1984485  -0.229   0.8203
dat$WatershedFishpot Run-Monongahela River               0.0881048  0.2223604   0.396   0.6939
dat$WatershedHarmon Creek                                0.0198174  0.3271672   0.061   0.9520
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0483137  0.2401044  -0.201   0.8415
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      0.1388122  0.1684815   0.824   0.4144
dat$WatershedLittle Tenmile Creek                        0.0586693  0.1797205   0.326   0.7456
dat$WatershedNorth Fork Cross Creek                      0.1544617  0.1604506   0.963   0.3410
dat$WatershedPigeon Creek                                0.0176493  0.2219075   0.080   0.9370
dat$WatershedPike Run                                    0.0311642  0.2116028   0.147   0.8836
dat$WatershedPlum Run-Tenmile Creek                      0.0685836  0.1868007   0.367   0.7153
dat$WatershedShort Creek-Tenmile Creek                   0.3079198  0.1591362   1.935   0.0594 .
dat$WatershedSouth Fork Cross Creek-Cross Creek          0.0422347  0.1317746   0.321   0.7501
dat$WatershedTempleton Fork                             -0.0160660  0.2257467  -0.071   0.9436
dat$WatershedUpper Chartiers Creek                       0.1659849  0.1323324   1.254   0.2164
dat$FormationGreene Formation                            0.1869344  0.0947610   1.973   0.0548 .
dat$FormationMonongahela Group                           0.0740344  0.1065181   0.695   0.4907
dat$FormationWaynesburg Formation                        0.0616013  0.0835200   0.738   0.4647
dat$HHWSourceMix                                         0.5650663  0.2429324   2.326   0.0247 *
dat$HHWSourceSpring                                     -0.1385896  0.1951841  -0.710   0.4814
dat$Precip_inchAvg                                      -0.0084588  0.0181230  -0.467   0.6430
dat$HHWdepthMeters                                      -0.0007907  0.0019883  -0.398   0.6928
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.04082491)

    Null deviance: 3.4014  on 71  degrees of freedom
Residual deviance: 1.7963  on 44  degrees of freedom
AIC: -3.4205

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Uranium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.34009  -0.04551  -0.00658   0.03708   0.53041  

Coefficients:
                                                           Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                               0.3570650  0.6791268   0.526   0.6017  
dat$GWellDensity_2kmAvg                                  -0.0057770  0.0043614  -1.325   0.1921  
dat$Altitude_meter                                        0.0008419  0.0011855   0.710   0.4813  
dat$WatershedBane Creek                                  -0.1350942  0.1517638  -0.890   0.3782  
dat$WatershedBrush Run                                    0.0466898  0.1288132   0.362   0.7187  
dat$WatershedBurgetts Fork                                0.0154708  0.1428782   0.108   0.9143  
dat$WatershedChartiers Run                                0.1244625  0.1691887   0.736   0.4659  
dat$WatershedEnlow Fork                                  -0.0440081  0.1646166  -0.267   0.7905  
dat$WatershedFishpot Run-Monongahela River                0.0616989  0.1844520   0.334   0.7396  
dat$WatershedHarmon Creek                                -0.0045072  0.2713911  -0.017   0.9868  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0613916  0.1991710  -0.308   0.7594  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       0.1177594  0.1397585   0.843   0.4040  
dat$WatershedLittle Tenmile Creek                         0.0300262  0.1490814   0.201   0.8413  
dat$WatershedNorth Fork Cross Creek                       0.1175155  0.1330967   0.883   0.3821  
dat$WatershedPigeon Creek                                -0.0145684  0.1840763  -0.079   0.9373  
dat$WatershedPike Run                                     0.0035434  0.1755284   0.020   0.9840  
dat$WatershedPlum Run-Tenmile Creek                       0.0437600  0.1549546   0.282   0.7790  
dat$WatershedShort Creek-Tenmile Creek                    0.2517544  0.1320063   1.907   0.0630 .
dat$WatershedSouth Fork Cross Creek-Cross Creek           0.0193298  0.1093094   0.177   0.8604  
dat$WatershedTempleton Fork                              -0.0227983  0.1872610  -0.122   0.9037  
dat$WatershedUpper Chartiers Creek                        0.1303684  0.1097722   1.188   0.2414  
dat$FormationGreene Formation                             0.1388808  0.0786060   1.767   0.0842 .
dat$FormationMonongahela Group                            0.0725543  0.0883587   0.821   0.4160  
dat$FormationWaynesburg Formation                         0.0596565  0.0692813   0.861   0.3939  
dat$HHWSourceMix                                          0.4800530  0.2015168   2.382   0.0216 *
dat$HHWSourceSpring                                      -0.1154799  0.1619087  -0.713   0.4795  
dat$Precip_inchAvg                                       -0.0059743  0.0150334  -0.397   0.6930  
dat$HHWdepthMeters                                       -0.0007464  0.0016494  -0.453   0.6531  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.02809164)

    Null deviance: 2.3858  on 71  degrees of freedom
Residual deviance: 1.2360  on 44  degrees of freedom
AIC: -30.336

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Zinc"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-478.96   -42.18     2.26    46.64   922.49

Coefficients:
                                                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              -1020.4968   788.3523  -1.294  0.20226
dat$GWellDensity_2kmAvg                                     -0.2706     5.0628  -0.053  0.95762
dat$Altitude_meter                                          -0.2538     1.3762  -0.184  0.85453
dat$WatershedBane Creek                                   -129.3242   176.1723  -0.734  0.46680
dat$WatershedBrush Run                                      55.1625   149.5305   0.369  0.71397
dat$WatershedBurgetts Fork                                -100.8127   165.8576  -0.608  0.54643
dat$WatershedChartiers Run                                 -74.9884   196.3997  -0.382  0.70444
dat$WatershedEnlow Fork                                    -43.9305   191.0923  -0.230  0.81924
dat$WatershedFishpot Run-Monongahela River                -359.1057   214.1179  -1.677  0.10061
dat$WatershedHarmon Creek                                  498.9524   315.0395   1.584  0.12041
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir   64.0891   231.2041   0.277  0.78293
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       -189.7784   162.2361  -1.170  0.24839
dat$WatershedLittle Tenmile Creek                         -241.1762   173.0585  -1.394  0.17043
dat$WatershedNorth Fork Cross Creek                       -134.1812   154.5030  -0.868  0.38985
dat$WatershedPigeon Creek                                 -288.0338   213.6817  -1.348  0.18457
dat$WatershedPike Run                                      270.1882   203.7590   1.326  0.19168
dat$WatershedPlum Run-Tenmile Creek                       -215.5493   179.8762  -1.198  0.23721
dat$WatershedShort Creek-Tenmile Creek                    -145.5276   153.2372  -0.950  0.34746
dat$WatershedSouth Fork Cross Creek-Cross Creek           -105.7998   126.8899  -0.834  0.40890
dat$WatershedTempleton Fork                                -18.4413   217.3786  -0.085  0.93278
dat$WatershedUpper Chartiers Creek                          20.0210   127.4271   0.157  0.87587
dat$FormationGreene Formation                                5.6900    91.2484   0.062  0.95056
dat$FormationMonongahela Group                             119.8677   102.5696   1.169  0.24884
dat$FormationWaynesburg Formation                          -38.6454    80.4240  -0.481  0.63324
dat$HHWSourceMix                                          -752.5345   233.9272  -3.217  0.00243 **
dat$HHWSourceSpring                                        -68.4323   187.9489  -0.364  0.71753
dat$Precip_inchAvg                                          31.6521    17.4512   1.814  0.07654 .
dat$HHWdepthMeters                                          -0.1072     1.9146  -0.056  0.95560
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 37854.36)

    Null deviance: 2892096  on 71  degrees of freedom
Residual deviance: 1665592  on 44  degrees of freedom
AIC: 985.86

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Zinc"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
      Min         1Q     Median         3Q        Max  
-0.223993  -0.070335   0.004428   0.065126   0.186597  

Coefficients:
                                                            Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                                0.4578541  0.4894068   0.936   0.3546  
dat$GWellDensity_2kmAvg                                    0.0017436  0.0031430   0.555   0.5819  
dat$Altitude_meter                                         0.0005787  0.0008543   0.677   0.5017  
dat$WatershedBane Creek                                    0.0378209  0.1093673   0.346   0.7311  
dat$WatershedBrush Run                                    -0.0567294  0.0928281  -0.611   0.5443  
dat$WatershedBurgetts Fork                                -0.0965428  0.1029639  -0.938   0.3535  
dat$WatershedChartiers Run                                 0.1937475  0.1219244   1.589   0.1192  
dat$WatershedEnlow Fork                                    0.2673200  0.1186295   2.253   0.0293 *
dat$WatershedFishpot Run-Monongahela River                -0.0415622  0.1329237  -0.313   0.7560  
dat$WatershedHarmon Creek                                 -0.1719351  0.1955756  -0.879   0.3841  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0819537  0.1435308  -0.571   0.5709  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       -0.0247648  0.1007157  -0.246   0.8069  
dat$WatershedLittle Tenmile Creek                          0.0699174  0.1074342   0.651   0.5186  
dat$WatershedNorth Fork Cross Creek                        0.0386931  0.0959150   0.403   0.6886  
dat$WatershedPigeon Creek                                 -0.0715744  0.1326530  -0.540   0.5922  
dat$WatershedPike Run                                     -0.1414759  0.1264930  -1.118   0.2694  
dat$WatershedPlum Run-Tenmile Creek                       -0.0023877  0.1116666  -0.021   0.9830  
dat$WatershedShort Creek-Tenmile Creek                     0.1341621  0.0951292   1.410   0.1655  
dat$WatershedSouth Fork Cross Creek-Cross Creek            0.0115095  0.0787729   0.146   0.8845  
dat$WatershedTempleton Fork                                0.1750178  0.1349480   1.297   0.2014  
dat$WatershedUpper Chartiers Creek                        -0.0974738  0.0791063  -1.232   0.2244  
dat$FormationGreene Formation                             -0.0448498  0.0566467  -0.792   0.4328  
dat$FormationMonongahela Group                             0.0514318  0.0636749   0.808   0.4236  
dat$FormationWaynesburg Formation                          0.0561777  0.0499270   1.125   0.2666  
dat$HHWSourceMix                                           0.1181126  0.1452213   0.813   0.4204  
dat$HHWSourceSpring                                       -0.0573690  0.1166781  -0.492   0.6254  
dat$Precip_inchAvg                                        -0.0010398  0.0108337  -0.096   0.9240  
dat$HHWdepthMeters                                        -0.0010521  0.0011886  -0.885   0.3809  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.01458865)

    Null deviance: 1.1678  on 71  degrees of freedom
Residual deviance: 0.6419  on 44  degrees of freedom
AIC: -77.512

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Bromide"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.39483  -0.05647   0.00000   0.04757   1.13324

Coefficients:
                                                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               -0.3071749  0.8564816  -0.359   0.7216
dat$GWellDensity_2kmAvg                                   -0.0026597  0.0055003  -0.484   0.6311
dat$Altitude_meter                                         0.0003579  0.0014951   0.239   0.8119
dat$WatershedBane Creek                                    0.0513018  0.1913971   0.268   0.7899
dat$WatershedBrush Run                                     0.0393406  0.1624529   0.242   0.8098
dat$WatershedBurgetts Fork                                 0.0078089  0.1801910   0.043   0.9656
dat$WatershedChartiers Run                                 0.1558025  0.2133725   0.730   0.4691
dat$WatershedEnlow Fork                                    0.2226371  0.2076064   1.072   0.2894
dat$WatershedFishpot Run-Monongahela River                 0.1465726  0.2326219   0.630   0.5319
dat$WatershedHarmon Creek                                 -0.0858997  0.3422652  -0.251   0.8030
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.1034924  0.2511847  -0.412   0.6823
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       -0.0100199  0.1762566  -0.057   0.9549
dat$WatershedLittle Tenmile Creek                         -0.0303321  0.1880142  -0.161   0.8726
dat$WatershedNorth Fork Cross Creek                       -0.0214003  0.1678551  -0.127   0.8991
dat$WatershedPigeon Creek                                 -0.0923842  0.2321481  -0.398   0.6926
dat$WatershedPike Run                                     -0.0621281  0.2213678  -0.281   0.7803
dat$WatershedPlum Run-Tenmile Creek                        0.4380190  0.1954211   2.241   0.0301 *
dat$WatershedShort Creek-Tenmile Creek                     0.1267461  0.1664799   0.761   0.4505
dat$WatershedSouth Fork Cross Creek-Cross Creek            0.0274916  0.1378557   0.199   0.8429
dat$WatershedTempleton Fork                                0.1322947  0.2361644   0.560   0.5782
dat$WatershedUpper Chartiers Creek                        -0.0193370  0.1384393  -0.140   0.8896
dat$FormationGreene Formation                              0.0067738  0.0991341   0.068   0.9458
dat$FormationMonongahela Group                             0.0659806  0.1114337   0.592   0.5568
dat$FormationWaynesburg Formation                          0.1508974  0.0873742   1.727   0.0912 .
dat$HHWSourceMix                                           0.0622596  0.2541432   0.245   0.8076
dat$HHWSourceSpring                                       -0.0863463  0.2041914  -0.423   0.6745
dat$Precip_inchAvg                                         0.0026019  0.0189594   0.137   0.8915
dat$HHWdepthMeters                                         0.0017641  0.0020801   0.848   0.4010
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.04467981)

    Null deviance: 3.0637  on 71  degrees of freedom
Residual deviance: 1.9659  on 44  degrees of freedom
AIC: 3.076

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Bromide"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-0.253910  -0.014792   0.000648   0.020841   0.136567

Coefficients:
                                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                  1.3029205  0.2679601   4.862 1.52e-05 ***
dat$GWellDensity_2kmAvg                                      0.0007437  0.0017208   0.432  0.66774
dat$Altitude_meter                                           0.0002755  0.0004678   0.589  0.55887
dat$WatershedBane Creek                                     -0.0200460  0.0598808  -0.335  0.73939
dat$WatershedBrush Run                                      -0.0046684  0.0508252  -0.092  0.92723
dat$WatershedBurgetts Fork                                  -0.0032499  0.0563748  -0.058  0.95429
dat$WatershedChartiers Run                                  -0.1791114  0.0667560  -2.683  0.01024 *
dat$WatershedEnlow Fork                                     -0.2001345  0.0649521  -3.081  0.00355 **
dat$WatershedFishpot Run-Monongahela River                  -0.1291726  0.0727784  -1.775  0.08284 .
dat$WatershedHarmon Creek                                    0.0264600  0.1070816   0.247  0.80598
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.0177750  0.0785860   0.226  0.82210
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         -0.0048019  0.0551439  -0.087  0.93100
dat$WatershedLittle Tenmile Creek                           -0.0043833  0.0588224  -0.075  0.94094
dat$WatershedNorth Fork Cross Creek                          0.0039102  0.0525154   0.074  0.94098
dat$WatershedPigeon Creek                                    0.0064009  0.0726302   0.088  0.93017
dat$WatershedPike Run                                       -0.0056542  0.0692575  -0.082  0.93530
dat$WatershedPlum Run-Tenmile Creek                         -0.1400235  0.0611397  -2.290  0.02686 *
dat$WatershedShort Creek-Tenmile Creek                      -0.0707001  0.0520852  -1.357  0.18158
dat$WatershedSouth Fork Cross Creek-Cross Creek             -0.0208645  0.0431297  -0.484  0.63095
dat$WatershedTempleton Fork                                 -0.1699608  0.0738867  -2.300  0.02623 *
dat$WatershedUpper Chartiers Creek                          -0.0029727  0.0433123  -0.069  0.94559
dat$FormationGreene Formation                               -0.0113616  0.0310152  -0.366  0.71588
dat$FormationMonongahela Group                              -0.0396029  0.0348633  -1.136  0.26213
dat$FormationWaynesburg Formation                           -0.0349862  0.0273360  -1.280  0.20730
dat$HHWSourceMix                                             0.0009174  0.0795116   0.012  0.99085
dat$HHWSourceSpring                                          0.0946832  0.0638836   1.482  0.14544
dat$Precip_inchAvg                                           0.0015504  0.0059317   0.261  0.79501
dat$HHWdepthMeters                                          -0.0012599  0.0006508  -1.936  0.05931 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 0.004373363)

    Null deviance: 0.48899  on 71  degrees of freedom
Residual deviance: 0.19243  on 44  degrees of freedom
AIC: -164.25

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Chloride"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-79.504  -26.012   -0.186   17.275  199.827  

Coefficients:
                                                        Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                             -58.1757   212.3058  -0.274   0.7854  
dat$GWellDensity_2kmAvg                                  -2.8361     1.3634  -2.080   0.0434 *
dat$Altitude_meter                                        0.3715     0.3706   1.003   0.3216  
dat$WatershedBane Creek                                  42.9765    47.4438   0.906   0.3700  
dat$WatershedBrush Run                                   28.1404    40.2690   0.699   0.4883  
dat$WatershedBurgetts Fork                               13.9106    44.6660   0.311   0.7569  
dat$WatershedChartiers Run                               49.8909    52.8911   0.943   0.3507  
dat$WatershedEnlow Fork                                  16.6791    51.4618   0.324   0.7474  
dat$WatershedFishpot Run-Monongahela River              119.9176    57.6626   2.080   0.0434 *
dat$WatershedHarmon Creek                                -9.7434    84.8411  -0.115   0.9091  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -32.2833    62.2640  -0.518   0.6067  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       8.5581    43.6907   0.196   0.8456  
dat$WatershedLittle Tenmile Creek                        16.1820    46.6052   0.347   0.7301  
dat$WatershedNorth Fork Cross Creek                      10.1534    41.6081   0.244   0.8083  
dat$WatershedPigeon Creek                                30.9022    57.5452   0.537   0.5940  
dat$WatershedPike Run                                     5.9875    54.8729   0.109   0.9136  
dat$WatershedPlum Run-Tenmile Creek                      90.7697    48.4412   1.874   0.0676 .
dat$WatershedShort Creek-Tenmile Creek                   58.5652    41.2673   1.419   0.1629  
dat$WatershedSouth Fork Cross Creek-Cross Creek          42.8340    34.1719   1.253   0.2166  
dat$WatershedTempleton Fork                               8.7898    58.5407   0.150   0.8813  
dat$WatershedUpper Chartiers Creek                       71.6510    34.3165   2.088   0.0426 *
dat$FormationGreene Formation                             6.0905    24.5735   0.248   0.8054  
dat$FormationMonongahela Group                           15.8209    27.6223   0.573   0.5697  
dat$FormationWaynesburg Formation                        17.2110    21.6584   0.795   0.4311  
dat$HHWSourceMix                                          0.7532    62.9973   0.012   0.9905  
dat$HHWSourceSpring                                     -12.1263    50.6152  -0.240   0.8118  
dat$Precip_inchAvg                                       -1.8357     4.6997  -0.391   0.6980  
dat$HHWdepthMeters                                        0.5803     0.5156   1.126   0.2665  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 2745.357)

    Null deviance: 207116  on 71  degrees of freedom
Residual deviance: 120796  on 44  degrees of freedom
AIC: 796.94

Number of Fisher Scoring iterations: 2
```

[1] "BOX-COX MODEL - Chloride"

Call:
```
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
       Min          1Q      Median          3Q         Max  
-4.663e-15  -2.443e-15  -1.776e-15  -1.554e-15  -8.882e-16  

Coefficients:
                                                              Estimate Std. Error    t value Pr(>|t|)    
(Intercept)                                                  1.000e+00  1.116e-14  8.958e+13   <2e-16 ***
dat$GWellDensity_2kmAvg                                      2.103e-17  7.169e-17  2.930e-01    0.771    
dat$Altitude_meter                                          -6.173e-18  1.949e-17 -3.170e-01    0.753    
dat$WatershedBane Creek                                      3.195e-16  2.495e-15  1.280e-01    0.899    
dat$WatershedBrush Run                                      -8.860e-16  2.117e-15 -4.180e-01    0.678    
dat$WatershedBurgetts Fork                                   1.107e-15  2.348e-15  4.710e-01    0.640    
dat$WatershedChartiers Run                                   2.797e-16  2.781e-15  1.010e-01    0.920    
dat$WatershedEnlow Fork                                     -5.111e-16  2.706e-15 -1.890e-01    0.851    
dat$WatershedFishpot Run-Monongahela River                   2.397e-15  3.032e-15  7.910e-01    0.433    
dat$WatershedHarmon Creek                                    1.186e-15  4.461e-15  2.660e-01    0.792    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  5.381e-16  3.274e-15  1.640e-01    0.870    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake          8.966e-16  2.297e-15  3.900e-01    0.698    
dat$WatershedLittle Tenmile Creek                            1.483e-15  2.450e-15  6.050e-01    0.548    
dat$WatershedNorth Fork Cross Creek                          9.470e-16  2.188e-15  4.330e-01    0.667    
dat$WatershedPigeon Creek                                    2.789e-15  3.026e-15  9.220e-01    0.362    
dat$WatershedPike Run                                        2.656e-15  2.885e-15  9.210e-01    0.362    
dat$WatershedPlum Run-Tenmile Creek                          9.362e-16  2.547e-15  3.680e-01    0.715    
dat$WatershedShort Creek-Tenmile Creek                      -1.279e-16  2.170e-15 -5.900e-02    0.953    
dat$WatershedSouth Fork Cross Creek-Cross Creek              2.062e-15  1.797e-15  1.148e+00    0.257    
dat$WatershedTempleton Fork                                 -7.602e-16  3.078e-15 -2.470e-01    0.806    
dat$WatershedUpper Chartiers Creek                           4.236e-16  1.804e-15  2.350e-01    0.815    
dat$FormationGreene Formation                               -9.255e-17  1.292e-15 -7.200e-02    0.943    
dat$FormationMonongahela Group                              -1.692e-15  1.452e-15 -1.165e+00    0.250    
dat$FormationWaynesburg Formation                           -1.398e-15  1.139e-15 -1.227e+00    0.226    
dat$HHWSourceMix                                             5.846e-16  3.312e-15  1.760e-01    0.861    
dat$HHWSourceSpring                                          5.290e-16  2.661e-15  1.990e-01    0.843    
dat$Precip_inchAvg                                          -2.020e-16  2.471e-16 -8.180e-01    0.418    
dat$HHWdepthMeters                                           1.184e-17  2.711e-17  4.370e-01    0.664    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 7.589425e-30)

    Null deviance: 0.0000e+00  on 71  degrees of freedom
Residual deviance: 3.3393e-28  on 44  degrees of freedom
AIC: -4600.8

Number of Fisher Scoring iterations: 1
```

```
[1] "ORIGINAL MODEL - Fluoride"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.08704  -0.18079  -0.04818   0.15067   2.45800

Coefficients:
                                                        Estimate Std. Error t value Pr(>|t|)
(Intercept)                                            -1.661479   2.338487  -0.710   0.4811
dat$GWellDensity_2kmAvg                                 0.016003   0.015018   1.066   0.2924
dat$Altitude_meter                                     -0.000848   0.004082  -0.208   0.8364
dat$WatershedBane Creek                                 0.041891   0.522579   0.080   0.9365
dat$WatershedBrush Run                                 -0.134860   0.443552  -0.304   0.7625
dat$WatershedBurgetts Fork                             -0.071131   0.491983  -0.145   0.8857
dat$WatershedChartiers Run                              0.465149   0.582580   0.798   0.4289
dat$WatershedEnlow Fork                                 0.976602   0.566836   1.723   0.0919 .
dat$WatershedFishpot Run-Monongahela River             -0.226046   0.635137  -0.356   0.7236
dat$WatershedHarmon Creek                              -0.134981   0.934501  -0.144   0.8858
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.255106   0.685820  -0.372   0.7117
dat$WatershedLittle Chartiers Creek-Canonsburg Lake    -0.197252   0.481241  -0.410   0.6839
dat$WatershedLittle Tenmile Creek                      -0.363552   0.513343  -0.708   0.4826
dat$WatershedNorth Fork Cross Creek                    -0.031404   0.458302  -0.069   0.9457
dat$WatershedPigeon Creek                              -0.336678   0.633844  -0.531   0.5980
dat$WatershedPike Run                                  -0.284828   0.604410  -0.471   0.6398
dat$WatershedPlum Run-Tenmile Creek                     0.685936   0.533566   1.286   0.2053
dat$WatershedShort Creek-Tenmile Creek                  0.264731   0.454547   0.582   0.5633
dat$WatershedSouth Fork Cross Creek-Cross Creek        -0.092366   0.376393  -0.245   0.8073
dat$WatershedTempleton Fork                             0.319675   0.644810   0.496   0.6225
dat$WatershedUpper Chartiers Creek                      0.104475   0.377987   0.276   0.7835
dat$FormationGreene Formation                          -0.132762   0.270670  -0.490   0.6262
dat$FormationMonongahela Group                          0.078544   0.304252   0.258   0.7975
dat$FormationWaynesburg Formation                       0.141884   0.238562   0.595   0.5551
dat$HHWSourceMix                                       -0.110125   0.693898  -0.159   0.8746
dat$HHWSourceSpring                                    -0.641525   0.557512  -1.151   0.2561
dat$Precip_inchAvg                                      0.046669   0.051765   0.902   0.3722
dat$HHWdepthMeters                                      0.009569   0.005679   1.685   0.0991 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.3330775)

    Null deviance: 23.056  on 71  degrees of freedom
Residual deviance: 14.655  on 44  degrees of freedom
AIC: 147.71

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Fluoride"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.8171  -0.4430  -0.1277   0.4174   4.6132

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                               1.988367   5.662349   0.351   0.7271
dat$GWellDensity_2kmAvg                                  -0.032450   0.036364  -0.892   0.3770
dat$Altitude_meter                                        0.007544   0.009884   0.763   0.4494
dat$WatershedBane Creek                                   0.292055   1.265360   0.231   0.8185
dat$WatershedBrush Run                                    0.118003   1.074004   0.110   0.9130
dat$WatershedBurgetts Fork                                0.278680   1.191274   0.234   0.8161
dat$WatershedChartiers Run                               -0.578183   1.410643  -0.410   0.6839
dat$WatershedEnlow Fork                                  -1.244922   1.372522  -0.907   0.3693
dat$WatershedFishpot Run-Monongahela River                0.461741   1.537904   0.300   0.7654
dat$WatershedHarmon Creek                                 0.444414   2.262775   0.196   0.8452
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.056942   1.660626   0.034   0.9728
dat$WatershedLittle Chartiers Creek-Canonsburg Lake       2.311952   1.165263   1.984   0.0535 .
dat$WatershedLittle Tenmile Creek                         0.278490   1.242994   0.224   0.8238
dat$WatershedNorth Fork Cross Creek                      -0.256977   1.109719  -0.232   0.8179
dat$WatershedPigeon Creek                                -0.026833   1.534771  -0.017   0.9861
dat$WatershedPike Run                                     0.282973   1.463501   0.193   0.8476
dat$WatershedPlum Run-Tenmile Creek                       0.307016   1.291963   0.238   0.8133
dat$WatershedShort Creek-Tenmile Creek                    0.455964   1.100628   0.414   0.6807
dat$WatershedSouth Fork Cross Creek-Cross Creek           0.563620   0.911388   0.618   0.5395
dat$WatershedTempleton Fork                              -0.674644   1.561324  -0.432   0.6678
dat$WatershedUpper Chartiers Creek                        0.148747   0.915246   0.163   0.8716
dat$FormationGreene Formation                             0.017941   0.655393   0.027   0.9783
dat$FormationMonongahela Group                           -0.279478   0.736707  -0.379   0.7062
dat$FormationWaynesburg Formation                         0.241668   0.577646   0.418   0.6777
dat$HHWSourceMix                                          0.800545   1.680185   0.476   0.6361
dat$HHWSourceSpring                                       0.280919   1.349945   0.208   0.8361
dat$Precip_inchAvg                                       -0.046363   0.125344  -0.370   0.7132
dat$HHWdepthMeters                                       -0.015013   0.013752  -1.092   0.2809
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1.952848)

    Null deviance: 123.713  on 71  degrees of freedom
Residual deviance:  85.925  on 44  degrees of freedom
AIC: 275.06

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Nitrate"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-2.1734  -0.5314  -0.2631   0.2620   3.0595  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                              -3.635564   5.357671  -0.679   0.5010  
dat$GWellDensity_2kmAvg                                  -0.066635   0.034407  -1.937   0.0592 .
dat$Altitude_meter                                        0.004161   0.009352   0.445   0.6586  
dat$WatershedBane Creek                                  -1.148830   1.197273  -0.960   0.3425  
dat$WatershedBrush Run                                    1.854800   1.016214   1.825   0.0748 .
dat$WatershedBurgetts Fork                                1.553648   1.127174   1.378   0.1751  
dat$WatershedChartiers Run                                1.038464   1.334739   0.778   0.4407  
dat$WatershedEnlow Fork                                  -1.627850   1.298670  -1.253   0.2167  
dat$WatershedFishpot Run-Monongahela River               -0.559109   1.455153  -0.384   0.7027  
dat$WatershedHarmon Creek                                 1.065103   2.141020   0.497   0.6213  
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.105464   1.571271  -0.067   0.9468  
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -1.732395   1.102563  -1.571   0.1233  
dat$WatershedLittle Tenmile Creek                        -0.800791   1.176112  -0.681   0.4995  
dat$WatershedNorth Fork Cross Creek                       0.166430   1.050008   0.159   0.8748  
dat$WatershedPigeon Creek                                -1.144589   1.452189  -0.788   0.4348  
dat$WatershedPike Run                                     0.593591   1.384754   0.429   0.6703  
dat$WatershedPlum Run-Tenmile Creek                      -0.819188   1.222445  -0.670   0.5063  
dat$WatershedShort Creek-Tenmile Creek                    0.124944   1.041406   0.120   0.9050  
dat$WatershedSouth Fork Cross Creek-Cross Creek           0.781888   0.862349   0.907   0.3695  
dat$WatershedTempleton Fork                              -0.959078   1.477313  -0.649   0.5196  
dat$WatershedUpper Chartiers Creek                        0.960488   0.865999   1.109   0.2734  
dat$FormationGreene Formation                             0.419515   0.620127   0.676   0.5023  
dat$FormationMonongahela Group                           -0.437941   0.697067  -0.628   0.5331  
dat$FormationWaynesburg Formation                        -0.557784   0.546564  -1.021   0.3131  
dat$HHWSourceMix                                         -1.384532   1.589778  -0.871   0.3885  
dat$HHWSourceSpring                                       0.133318   1.277307   0.104   0.9173  
dat$Precip_inchAvg                                        0.085113   0.118599   0.718   0.4768  
dat$HHWdepthMeters                                        0.008476   0.013012   0.651   0.5182  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1.748346)

    Null deviance: 116.064  on 71  degrees of freedom
Residual deviance:  76.927  on 44  degrees of freedom
AIC: 267.09

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Nitrate"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.57171  -0.17563  -0.03724   0.08071   0.78857

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              -1.638240   1.422018  -1.152   0.2555
dat$GWellDensity_2kmAvg                                  -0.014938   0.009132  -1.636   0.1090
dat$Altitude_meter                                        0.003666   0.002482   1.477   0.1468
dat$WatershedBane Creek                                  -0.300778   0.317777  -0.947   0.3491
dat$WatershedBrush Run                                    0.156756   0.269721   0.581   0.5641
dat$WatershedBurgetts Fork                                0.330963   0.299171   1.106   0.2746
dat$WatershedChartiers Run                                0.256577   0.354263   0.724   0.4727
dat$WatershedEnlow Fork                                  -0.676364   0.344689  -1.962   0.0561 .
dat$WatershedFishpot Run-Monongahela River               -0.107603   0.386223  -0.279   0.7819
dat$WatershedHarmon Creek                                 0.374498   0.568264   0.659   0.5133
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.416134   0.417042  -0.998   0.3238
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -0.569300   0.292639  -1.945   0.0581 .
dat$WatershedLittle Tenmile Creek                        -0.321842   0.312160  -1.031   0.3082
dat$WatershedNorth Fork Cross Creek                      -0.061334   0.278690  -0.220   0.8268
dat$WatershedPigeon Creek                                -0.460967   0.385436  -1.196   0.2381
dat$WatershedPike Run                                     0.218682   0.367537   0.595   0.5549
dat$WatershedPlum Run-Tenmile Creek                      -0.261374   0.324458  -0.806   0.4248
dat$WatershedShort Creek-Tenmile Creek                   -0.107550   0.276407  -0.389   0.6991
dat$WatershedSouth Fork Cross Creek-Cross Creek           0.030983   0.228882   0.135   0.8929
dat$WatershedTempleton Fork                              -0.484549   0.392104  -1.236   0.2231
dat$WatershedUpper Chartiers Creek                        0.217737   0.229851   0.947   0.3487
dat$FormationGreene Formation                            -0.021236   0.164592  -0.129   0.8979
dat$FormationMonongahela Group                           -0.162949   0.185014  -0.881   0.3832
dat$FormationWaynesburg Formation                        -0.175027   0.145068  -1.207   0.2341
dat$HHWSourceMix                                         -0.296840   0.421954  -0.703   0.4855
dat$HHWSourceSpring                                       0.121736   0.339019   0.359   0.7213
dat$Precip_inchAvg                                        0.031186   0.031478   0.991   0.3272
dat$HHWdepthMeters                                        0.004221   0.003454   1.222   0.2282
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.1231645)

    Null deviance: 9.8242  on 71  degrees of freedom
Residual deviance: 5.4192  on 44  degrees of freedom
AIC: 76.084

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Phosphate"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.30479  -0.07892  -0.01261   0.04575   0.66665  

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                             -1.0892855  0.7080813  -1.538 0.131121    
dat$GWellDensity_2kmAvg                                  0.0094413  0.0045473   2.076 0.043745 *  
dat$Altitude_meter                                       0.0001996  0.0012360   0.162 0.872435    
dat$WatershedBane Creek                                 -0.0062923  0.1582342  -0.040 0.968460    
dat$WatershedBrush Run                                  -0.1877404  0.1343051  -1.398 0.169162    
dat$WatershedBurgetts Fork                              -0.0617055  0.1489698  -0.414 0.680729    
dat$WatershedChartiers Run                              -0.0014845  0.1764020  -0.008 0.993323    
dat$WatershedEnlow Fork                                  0.7829032  0.1716350   4.561 4.04e-05 ***
dat$WatershedFishpot Run-Monongahela River              -0.1065473  0.1923161  -0.554 0.582369    
dat$WatershedHarmon Creek                               -0.2739830  0.2829618  -0.968 0.338203    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.0864193  0.2076626  -0.416 0.679321    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake     -0.0099491  0.1457171  -0.068 0.945875    
dat$WatershedLittle Tenmile Creek                       -0.1741640  0.1554375  -1.120 0.268589    
dat$WatershedNorth Fork Cross Creek                     -0.0881781  0.1387713  -0.635 0.528445    
dat$WatershedPigeon Creek                               -0.2572199  0.1919244  -1.340 0.187056    
dat$WatershedPike Run                                   -0.0518009  0.1830120  -0.283 0.778469    
dat$WatershedPlum Run-Tenmile Creek                     -0.1880130  0.1615610  -1.164 0.250806    
dat$WatershedShort Creek-Tenmile Creek                   0.1058209  0.1376344   0.769 0.446087    
dat$WatershedSouth Fork Cross Creek-Cross Creek         -0.0888014  0.1139698  -0.779 0.440053    
dat$WatershedTempleton Fork                              0.0428277  0.1952448   0.219 0.827389    
dat$WatershedUpper Chartiers Creek                      -0.0121603  0.1144523  -0.106 0.915868    
dat$FormationGreene Formation                           -0.1014766  0.0819574  -1.238 0.222221    
dat$FormationMonongahela Group                          -0.0371544  0.0921259  -0.403 0.688681    
dat$FormationWaynesburg Formation                        0.0112475  0.0722351   0.156 0.876976    
dat$HHWSourceMix                                         0.2400336  0.2101085   1.142 0.259455    
dat$HHWSourceSpring                                     -0.5976518  0.1688117  -3.540 0.000958 ***
dat$Precip_inchAvg                                       0.0268590  0.0156743   1.714 0.093647 .  
dat$HHWdepthMeters                                       0.0016274  0.0017197   0.946 0.349149    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.03053807)

    Null deviance: 2.6204  on 71  degrees of freedom
Residual deviance: 1.3437  on 44  degrees of freedom
AIC: -24.323

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Phosphate"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.25080  -0.08386  -0.01592   0.04185   0.53026  

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                                -6.724e-01  6.822e-01  -0.986 0.329702    
dat$GWellDensity_2kmAvg                                     5.907e-03  4.381e-03   1.348 0.184416    
dat$Altitude_meter                                          4.893e-05  1.191e-03   0.041 0.967410    
dat$WatershedBane Creek                                    -9.641e-03  1.524e-01  -0.063 0.949860    
dat$WatershedBrush Run                                     -1.353e-01  1.294e-01  -1.046 0.301301    
dat$WatershedBurgetts Fork                                 -2.920e-02  1.435e-01  -0.203 0.839705    
dat$WatershedChartiers Run                                  2.293e-02  1.699e-01   0.135 0.893296    
dat$WatershedEnlow Fork                                     6.327e-01  1.654e-01   3.826 0.000407 ***
dat$WatershedFishpot Run-Monongahela River                 -6.566e-02  1.853e-01  -0.354 0.724750    
dat$WatershedHarmon Creek                                  -3.227e-01  2.726e-01  -1.184 0.242853    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -7.322e-02  2.001e-01  -0.366 0.716131    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         3.355e-03  1.404e-01   0.024 0.981043    
dat$WatershedLittle Tenmile Creek                          -1.186e-01  1.497e-01  -0.792 0.432625    
dat$WatershedNorth Fork Cross Creek                        -3.552e-02  1.337e-01  -0.266 0.791710    
dat$WatershedPigeon Creek                                  -2.149e-01  1.849e-01  -1.162 0.251414    
dat$WatershedPike Run                                       1.043e-03  1.763e-01   0.006 0.995306    
dat$WatershedPlum Run-Tenmile Creek                        -1.721e-01  1.556e-01  -1.106 0.274925    
dat$WatershedShort Creek-Tenmile Creek                      9.792e-02  1.326e-01   0.738 0.464163    
dat$WatershedSouth Fork Cross Creek-Cross Creek            -2.197e-02  1.098e-01  -0.200 0.842343    
dat$WatershedTempleton Fork                                 2.930e-02  1.881e-01   0.156 0.876914    
dat$WatershedUpper Chartiers Creek                          2.907e-02  1.103e-01   0.264 0.793321    
dat$FormationGreene Formation                              -7.333e-02  7.896e-02  -0.929 0.358080    
dat$FormationMonongahela Group                             -3.403e-02  8.875e-02  -0.383 0.703280    
dat$FormationWaynesburg Formation                           1.851e-02  6.959e-02   0.266 0.791498    
dat$HHWSourceMix                                            2.880e-01  2.024e-01   1.423 0.161876    
dat$HHWSourceSpring                                        -4.683e-01  1.626e-01  -2.880 0.006127 ** 
dat$Precip_inchAvg                                          2.134e-02  1.510e-02   1.413 0.164721    
dat$HHWdepthMeters                                          1.998e-03  1.657e-03   1.206 0.234301    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.02834403)

    Null deviance: 2.2025  on 71  degrees of freedom
Residual deviance: 1.2471  on 44  degrees of freedom
AIC: -29.692

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Sulfate"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-87.506  -10.624   -2.339    6.131   87.506

Coefficients:
                                                      Estimate Std. Error t value Pr(>|t|)
(Intercept)                                           -3.83912  131.14028  -0.029   0.9768
dat$GWellDensity_2kmAvg                               -0.76347    0.84218  -0.907   0.3696
dat$Altitude_meter                                     0.33745    0.22892   1.474   0.1476
dat$WatershedBane Creek                                1.65453   29.30579   0.056   0.9552
dat$WatershedBrush Run                                12.85033   24.87399   0.517   0.6080
dat$WatershedBurgetts Fork                            13.57672   27.58996   0.492   0.6251
dat$WatershedChartiers Run                           -19.17668   32.67056  -0.587   0.5602
dat$WatershedEnlow Fork                              -24.35936   31.78768  -0.766   0.4476
dat$WatershedFishpot Run-Monongahela River            90.47122   35.61793   2.540   0.0147 *
dat$WatershedHarmon Creek                              5.92100   52.40598   0.113   0.9106
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir   8.44443   38.46018   0.220   0.8272
dat$WatershedLittle Chartiers Creek-Canonsburg Lake   16.65978   26.98754   0.617   0.5402
dat$WatershedLittle Tenmile Creek                     22.00233   28.78782   0.764   0.4488
dat$WatershedNorth Fork Cross Creek                   27.70310   25.70115   1.078   0.2870
dat$WatershedPigeon Creek                             83.66573   35.54538   2.354   0.0231 *
dat$WatershedPike Run                                  8.02796   33.89476   0.237   0.8139
dat$WatershedPlum Run-Tenmile Creek                    4.14282   29.92193   0.138   0.8905
dat$WatershedShort Creek-Tenmile Creek                 5.90493   25.49060   0.232   0.8179
dat$WatershedSouth Fork Cross Creek-Cross Creek       16.30503   21.10780   0.772   0.4440
dat$WatershedTempleton Fork                          -23.27573   36.16034  -0.644   0.5231
dat$WatershedUpper Chartiers Creek                    14.94603   21.19715   0.705   0.4845
dat$FormationGreene Formation                        -11.83948   15.17892  -0.780   0.4396
dat$FormationMonongahela Group                        12.00102   17.06218   0.703   0.4855
dat$FormationWaynesburg Formation                    -15.79267   13.37832  -1.180   0.2442
dat$HHWSourceMix                                      32.16423   38.91316   0.827   0.4129
dat$HHWSourceSpring                                   28.25380   31.26479   0.904   0.3711
dat$Precip_inchAvg                                    -1.89303    2.90297  -0.652   0.5177
dat$HHWdepthMeters                                     0.04926    0.31850   0.155   0.8778
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1047.484)

    Null deviance: 91480  on 71  degrees of freedom
Residual deviance: 46089  on 44  degrees of freedom
AIC: 727.57

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Sulfate"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.93065  -0.13612  -0.01179   0.14850   0.89523

Coefficients:
                                                        Estimate Std. Error t value Pr(>|t|)
(Intercept)                                            1.0890548  1.6057201   0.678    0.501
dat$GWellDensity_2kmAvg                               -0.0084478  0.0103119  -0.819    0.417
dat$Altitude_meter                                     0.0048898  0.0028030   1.745    0.088 .
dat$WatershedBane Creek                               -0.0101520  0.3588287  -0.028    0.978
dat$WatershedBrush Run                                 0.0000289  0.3045645   0.000    1.000
dat$WatershedBurgetts Fork                             0.1777961  0.3378196   0.526    0.601
dat$WatershedChartiers Run                            -0.1982769  0.4000280  -0.496    0.623
dat$WatershedEnlow Fork                               -0.4229089  0.3892177  -1.087    0.283
dat$WatershedFishpot Run-Monongahela River             0.6249331  0.4361164   1.433    0.159
dat$WatershedHarmon Creek                             -0.0258659  0.6416742  -0.040    0.968
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  0.1031749  0.4709178   0.219    0.828
dat$WatershedLittle Chartiers Creek-Canonsburg Lake    0.1466647  0.3304434   0.444    0.659
dat$WatershedLittle Tenmile Creek                      0.1064364  0.3524865   0.302    0.764
dat$WatershedNorth Fork Cross Creek                    0.2009524  0.3146924   0.639    0.526
dat$WatershedPigeon Creek                              0.7080969  0.4352281   1.627    0.111
dat$WatershedPike Run                                 -0.0357551  0.4150174  -0.086    0.932
dat$WatershedPlum Run-Tenmile Creek                   -0.2025896  0.3663729  -0.553    0.583
dat$WatershedShort Creek-Tenmile Creek                -0.3127936  0.3121144  -1.002    0.322
dat$WatershedSouth Fork Cross Creek-Cross Creek        0.1587961  0.2584501   0.614    0.542
dat$WatershedTempleton Fork                           -0.3899282  0.4427579  -0.881    0.383
dat$WatershedUpper Chartiers Creek                     0.1628789  0.2595441   0.628    0.534
dat$FormationGreene Formation                         -0.2449197  0.1858552  -1.318    0.194
dat$FormationMonongahela Group                         0.0812442  0.2089143   0.389    0.699
dat$FormationWaynesburg Formation                     -0.2075786  0.1638080  -1.267    0.212
dat$HHWSourceMix                                       0.4557882  0.4764642   0.957    0.344
dat$HHWSourceSpring                                    0.5773904  0.3828153   1.508    0.139
dat$Precip_inchAvg                                    -0.0084280  0.0355448  -0.237    0.814
dat$HHWdepthMeters                                     0.0008651  0.0038998   0.222    0.825
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.1570417)

    Null deviance: 14.1147  on 71  degrees of freedom
Residual deviance:  6.9098  on 44  degrees of freedom
AIC: 93.579

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - pH"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.37096  -0.26279  -0.00292   0.25378   1.26630

Coefficients:
                                                               Estimate Std. Error t value Pr(>|t|)
(Intercept)                                                    3.921769   2.272303   1.726 0.091382 .
dat$GWellDensity_2kmAvg                                        0.015564   0.014593   1.067 0.291977
dat$Altitude_meter                                             0.002415   0.003967   0.609 0.545712
dat$WatershedBane Creek                                       -0.761900   0.507789  -1.500 0.140646
dat$WatershedBrush Run                                        -0.374408   0.430998  -0.869 0.389726
dat$WatershedBurgetts Fork                                    -0.802098   0.478059  -1.678 0.100472
dat$WatershedChartiers Run                                     0.471332   0.566092   0.833 0.409562
dat$WatershedEnlow Fork                                        1.992437   0.550794   3.617 0.000763 ***
dat$WatershedFishpot Run-Monongahela River                    -0.680397   0.617161  -1.102 0.276255
dat$WatershedHarmon Creek                                     -0.579399   0.908053  -0.638 0.526736
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.240975   0.666410  -0.362 0.719381
dat$WatershedLittle Chartiers Creek-Canonsburg Lake           -0.319207   0.467620  -0.683 0.498425
dat$WatershedLittle Tenmile Creek                             -0.361603   0.498814  -0.725 0.472336
dat$WatershedNorth Fork Cross Creek                           -0.342605   0.445331  -0.769 0.445809
dat$WatershedPigeon Creek                                     -1.239423   0.615904  -2.012 0.050328 .
dat$WatershedPike Run                                         -1.240846   0.587304  -2.113 0.040328 *
dat$WatershedPlum Run-Tenmile Creek                           -0.161440   0.518465  -0.311 0.756982
dat$WatershedShort Creek-Tenmile Creek                         0.085135   0.441682   0.193 0.848040
dat$WatershedSouth Fork Cross Creek-Cross Creek               -0.687667   0.365741  -1.880 0.066711 .
dat$WatershedTempleton Fork                                    0.428697   0.626560   0.684 0.497432
dat$WatershedUpper Chartiers Creek                            -0.116245   0.367289  -0.316 0.753123
dat$FormationGreene Formation                                 -0.044051   0.263009  -0.167 0.867753
dat$FormationMonongahela Group                                 0.424861   0.295641   1.437 0.157767
dat$FormationWaynesburg Formation                              0.136342   0.231810   0.588 0.559430
dat$HHWSourceMix                                              -0.190534   0.674259  -0.283 0.778822
dat$HHWSourceSpring                                           -0.514518   0.541733  -0.950 0.347421
dat$Precip_inchAvg                                             0.064709   0.050300   1.286 0.205016
dat$HHWdepthMeters                                             0.006026   0.005519   1.092 0.280825
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.3144907)

    Null deviance: 29.475  on 71  degrees of freedom
Residual deviance: 13.838  on 44  degrees of freedom
AIC: 143.58

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - pH"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg + 
    dat$HHWdepthMeters)

Deviance Residuals: 
      Min         1Q     Median         3Q        Max  
-0.027712  -0.006496   0.000000   0.006359   0.036962  

Coefficients:
                                                             Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                                 5.487e-01  5.324e-02  10.305 2.62e-13 ***
dat$GWellDensity_2kmAvg                                    -2.999e-04  3.419e-04  -0.877  0.38520    
dat$Altitude_meter                                         -5.783e-05  9.294e-05  -0.622  0.53699    
dat$WatershedBane Creek                                     1.945e-02  1.190e-02   1.635  0.10917    
dat$WatershedBrush Run                                      8.109e-03  1.010e-02   0.803  0.42632    
dat$WatershedBurgetts Fork                                  1.845e-02  1.120e-02   1.647  0.10660    
dat$WatershedChartiers Run                                 -1.119e-02  1.326e-02  -0.844  0.40345    
dat$WatershedEnlow Fork                                    -4.072e-02  1.291e-02  -3.155  0.00289 ** 
dat$WatershedFishpot Run-Monongahela River                  1.517e-02  1.446e-02   1.049  0.30002    
dat$WatershedHarmon Creek                                   1.408e-02  2.128e-02   0.662  0.51149    
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  5.388e-03  1.561e-02   0.345  0.73171    
dat$WatershedLittle Chartiers Creek-Canonsburg Lake         8.077e-03  1.096e-02   0.737  0.46494    
dat$WatershedLittle Tenmile Creek                           8.650e-03  1.169e-02   0.740  0.46320    
dat$WatershedNorth Fork Cross Creek                         7.984e-03  1.043e-02   0.765  0.44828    
dat$WatershedPigeon Creek                                   2.935e-02  1.443e-02   2.034  0.04802 *  
dat$WatershedPike Run                                       2.960e-02  1.376e-02   2.151  0.03701 *  
dat$WatershedPlum Run-Tenmile Creek                         6.052e-03  1.215e-02   0.498  0.62083    
dat$WatershedShort Creek-Tenmile Creek                     -1.839e-03  1.035e-02  -0.178  0.85975    
dat$WatershedSouth Fork Cross Creek-Cross Creek             1.587e-02  8.570e-03   1.852  0.07068 .  
dat$WatershedTempleton Fork                                -1.006e-02  1.468e-02  -0.685  0.49671    
dat$WatershedUpper Chartiers Creek                          2.163e-03  8.606e-03   0.251  0.80270    
dat$FormationGreene Formation                               9.537e-04  6.163e-03   0.155  0.87772    
dat$FormationMonongahela Group                             -9.563e-03  6.927e-03  -1.381  0.17440    
dat$FormationWaynesburg Formation                          -3.263e-03  5.432e-03  -0.601  0.55115    
dat$HHWSourceMix                                            3.767e-03  1.580e-02   0.238  0.81266    
dat$HHWSourceSpring                                         1.027e-02  1.269e-02   0.809  0.42279    
dat$Precip_inchAvg                                         -1.483e-03  1.179e-03  -1.258  0.21486    
dat$HHWdepthMeters                                         -1.602e-04  1.293e-04  -1.239  0.22202    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.0001726623)

    Null deviance: 0.0155633  on 71  degrees of freedom
Residual deviance: 0.0075971  on 44  degrees of freedom
AIC: -396.95

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Cond at 25C"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-602.92   -91.66     0.00    88.55  1029.13

Coefficients:
                                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              -357.331   1214.798  -0.294    0.770
dat$GWellDensity_2kmAvg                                    -4.637      7.801  -0.594    0.555
dat$Altitude_meter                                          2.197      2.121   1.036    0.306
dat$WatershedBane Creek                                   151.660    271.470   0.559    0.579
dat$WatershedBrush Run                                    153.627    230.416   0.667    0.508
dat$WatershedBurgetts Fork                                -60.517    255.575  -0.237    0.814
dat$WatershedChartiers Run                                337.017    302.639   1.114    0.271
dat$WatershedEnlow Fork                                   465.610    294.460   1.581    0.121
dat$WatershedFishpot Run-Monongahela River                -87.316    329.941  -0.265    0.793
dat$WatershedHarmon Creek                                -474.303    485.455  -0.977    0.334
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -262.143    356.270  -0.736    0.466
dat$WatershedLittle Chartiers Creek-Canonsburg Lake        25.673    249.995   0.103    0.919
dat$WatershedLittle Tenmile Creek                          54.705    266.672   0.205    0.838
dat$WatershedNorth Fork Cross Creek                       -24.100    238.079  -0.101    0.920
dat$WatershedPigeon Creek                                 148.009    329.269   0.450    0.655
dat$WatershedPike Run                                    -275.554    313.979  -0.878    0.385
dat$WatershedPlum Run-Tenmile Creek                       367.894    277.177   1.327    0.191
dat$WatershedShort Creek-Tenmile Creek                    167.397    236.128   0.709    0.482
dat$WatershedSouth Fork Cross Creek-Cross Creek            11.437    195.529   0.058    0.954
dat$WatershedTempleton Fork                                61.270    334.966   0.183    0.856
dat$WatershedUpper Chartiers Creek                        251.256    196.357   1.280    0.207
dat$FormationGreene Formation                            -139.774    140.608  -0.994    0.326
dat$FormationMonongahela Group                            136.252    158.053   0.862    0.393
dat$FormationWaynesburg Formation                          12.994    123.928   0.105    0.917
dat$HHWSourceMix                                          487.124    360.466   1.351    0.183
dat$HHWSourceSpring                                      -359.292    289.617  -1.241    0.221
dat$Precip_inchAvg                                          5.883     26.891   0.219    0.828
dat$HHWdepthMeters                                          1.960      2.950   0.664    0.510

(Dispersion parameter for gaussian family taken to be 89884.25)

    Null deviance: 5937862  on 71  degrees of freedom
Residual deviance: 3954907  on 44  degrees of freedom
AIC: 1048.1

Number of Fisher Scoring iterations: 2


[1] "BOX-COX MODEL - Cond at 25C"
```

```
Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.31256  -0.04363   0.00087   0.04829   0.34636

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              2.0978954  0.5304177   3.955 0.000274 ***
dat$GWellDensity_2kmAvg                                 -0.0005662  0.0034063  -0.166 0.868756
dat$Altitude_meter                                       0.0011244  0.0009259   1.214 0.231084
dat$WatershedBane Creek                                  0.0735430  0.1185319   0.620 0.538163
dat$WatershedBrush Run                                   0.0607165  0.1006068   0.604 0.549273
dat$WatershedBurgetts Fork                              -0.0179158  0.1115920  -0.161 0.873185
dat$WatershedChartiers Run                               0.1294216  0.1321413   0.979 0.332728
dat$WatershedEnlow Fork                                  0.2248167  0.1285703   1.749 0.087336 .
dat$WatershedFishpot Run-Monongahela River               0.0076942  0.1440624   0.053 0.957648
dat$WatershedHarmon Creek                               -0.1951285  0.2119643  -0.921 0.362294
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.1164266  0.1555583  -0.748 0.458175
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      0.0552459  0.1091554   0.506 0.615298
dat$WatershedLittle Tenmile Creek                        0.0736476  0.1164369   0.633 0.530326
dat$WatershedNorth Fork Cross Creek                      0.0202161  0.1039524   0.194 0.846700
dat$WatershedPigeon Creek                                0.1222992  0.1437689   0.851 0.399561
dat$WatershedPike Run                                   -0.0998797  0.1370927  -0.729 0.470133
dat$WatershedPlum Run-Tenmile Creek                      0.1502851  0.1210240   1.242 0.220897
dat$WatershedShort Creek-Tenmile Creek                   0.0648153  0.1031008   0.629 0.532822
dat$WatershedSouth Fork Cross Creek-Cross Creek          0.0109087  0.0853738   0.128 0.898909
dat$WatershedTempleton Fork                              0.0440709  0.1462562   0.301 0.764585
dat$WatershedUpper Chartiers Creek                       0.0941741  0.0857352   1.098 0.277992
dat$FormationGreene Formation                           -0.0614764  0.0613936  -1.001 0.322133
dat$FormationMonongahela Group                           0.0565073  0.0690107   0.819 0.417302
dat$FormationWaynesburg Formation                       -0.0203135  0.0541107  -0.375 0.709162
dat$HHWSourceMix                                         0.2442966  0.1573905   1.552 0.127786
dat$HHWSourceSpring                                     -0.1791285  0.1264554  -1.417 0.163660
dat$Precip_inchAvg                                      -0.0008414  0.0117415  -0.072 0.943194
dat$HHWdepthMeters                                       0.0005206  0.0012882   0.404 0.688058
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.01713607)

    Null deviance: 1.13181  on 71  degrees of freedom
Residual deviance: 0.75399  on 44  degrees of freedom
AIC: -65.924

Number of Fisher Scoring iterations: 2
```

```
[1] "ORIGINAL MODEL - Temperature"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-5.378  -1.597   0.075   1.385   4.525

Coefficients:
                                                        Estimate Std. Error t value Pr(>|t|)
(Intercept)                                           20.9487365 10.8491631   1.931   0.0600 .
dat$GWellDensity_2kmAvg                                0.0871436  0.0696733   1.251   0.2176
dat$Altitude_meter                                    -0.0087738  0.0189384  -0.463   0.6454
dat$WatershedBane Creek                               -4.7891579  2.4244519  -1.975   0.0545 .
dat$WatershedBrush Run                                -1.4209791  2.0578116  -0.691   0.4935
dat$WatershedBurgetts Fork                            -2.1649465  2.2825025  -0.948   0.3481
dat$WatershedChartiers Run                             0.0192939  2.7028175   0.007   0.9943
dat$WatershedEnlow Fork                                0.8098127  2.6297775   0.308   0.7596
dat$WatershedFishpot Run-Monongahela River             5.0867625  2.9466517   1.726   0.0913 .
dat$WatershedHarmon Creek                              4.1202236  4.3355179   0.950   0.3471
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir -0.1829988  3.1817896  -0.058   0.9544
dat$WatershedLittle Chartiers Creek-Canonsburg Lake   -1.5945126  2.2326646  -0.714   0.4789
dat$WatershedLittle Tenmile Creek                     -1.9514915  2.3816001  -0.819   0.4170
dat$WatershedNorth Fork Cross Creek                    1.1579877  2.1262420   0.545   0.5888
dat$WatershedPigeon Creek                             -0.7526180  2.9406498  -0.256   0.7992
dat$WatershedPike Run                                 -0.4535179  2.8040949  -0.162   0.8723
dat$WatershedPlum Run-Tenmile Creek                   -2.2707725  2.4754248  -0.917   0.3640
dat$WatershedShort Creek-Tenmile Creek                -0.8903509  2.1088230  -0.422   0.6749
dat$WatershedSouth Fork Cross Creek-Cross Creek       -1.9895333  1.7462365  -1.139   0.2607
dat$WatershedTempleton Fork                            1.9932543  2.9915252   0.666   0.5087
dat$WatershedUpper Chartiers Creek                    -2.3374001  1.7536283  -1.333   0.1894
dat$FormationGreene Formation                          2.3838401  1.2557440   1.898   0.0642 .
dat$FormationMonongahela Group                        -2.0280478  1.4115447  -1.437   0.1579
dat$FormationWaynesburg Formation                      0.3617061  1.1067807   0.327   0.7454
dat$HHWSourceMix                                       0.0754520  3.2192645   0.023   0.9814
dat$HHWSourceSpring                                    0.8728633  2.5865187   0.337   0.7374
dat$Precip_inchAvg                                     0.0706273  0.2401607   0.294   0.7701
dat$HHWdepthMeters                                     0.0009067  0.0263490   0.034   0.9727
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 7.169152)

    Null deviance: 535.49  on 71  degrees of freedom
Residual deviance: 315.44  on 44  degrees of freedom
AIC: 368.69

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Temperature"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmAvg + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchAvg +
    dat$HHWdepthMeters)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-69.096  -23.208    0.853   19.070   67.066

Coefficients:
                                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                              168.31974  151.39641   1.112   0.2723
dat$GWellDensity_2kmAvg                                    1.22732    0.97227   1.262   0.2135
dat$Altitude_meter                                        -0.08173    0.26428  -0.309   0.7586
dat$WatershedBane Creek                                  -66.33413   33.83241  -1.961   0.0563 .
dat$WatershedBrush Run                                   -21.75058   28.71607  -0.757   0.4528
dat$WatershedBurgetts Fork                               -32.13422   31.85155  -1.009   0.3186
dat$WatershedChartiers Run                                -2.84634   37.71691  -0.075   0.9402
dat$WatershedEnlow Fork                                   10.79818   36.69766   0.294   0.7700
dat$WatershedFishpot Run-Monongahela River                75.81502   41.11953   1.844   0.0720 .
dat$WatershedHarmon Creek                                 56.77824   60.50069   0.938   0.3531
dat$WatershedHeadwaters Racoon Creek-Cherry Valley Reservoir  -7.06904   44.40080  -0.159   0.8742
dat$WatershedLittle Chartiers Creek-Canonsburg Lake      -21.51078   31.15608  -0.690   0.4936
dat$WatershedLittle Tenmile Creek                        -26.38176   33.23443  -0.794   0.4316
dat$WatershedNorth Fork Cross Creek                       15.88408   29.67099   0.535   0.5951
dat$WatershedPigeon Creek                                 -8.80691   41.03578  -0.215   0.8311
dat$WatershedPike Run                                     -6.60331   39.13020  -0.169   0.8668
dat$WatershedPlum Run-Tenmile Creek                      -28.17589   34.54372  -0.816   0.4191
dat$WatershedShort Creek-Tenmile Creek                    -9.94271   29.42791  -0.338   0.7371
dat$WatershedSouth Fork Cross Creek-Cross Creek          -28.31364   24.36814  -1.162   0.2515
dat$WatershedTempleton Fork                               28.21485   41.74573   0.676   0.5027
dat$WatershedUpper Chartiers Creek                       -33.95613   24.47129  -1.388   0.1722
dat$FormationGreene Formation                             32.57951   17.52348   1.859   0.0697 .
dat$FormationMonongahela Group                           -25.99105   19.69763  -1.320   0.1938
dat$FormationWaynesburg Formation                          6.13126   15.44475   0.397   0.6933
dat$HHWSourceMix                                           1.18272   44.92375   0.026   0.9791
dat$HHWSourceSpring                                       14.15814   36.09400   0.392   0.6968
dat$Precip_inchAvg                                         0.81608    3.35136   0.244   0.8087
dat$HHWdepthMeters                                         0.04174    0.36769   0.114   0.9101
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1396.068)

    Null deviance: 105466  on 71  degrees of freedom
Residual deviance:  61427  on 44  degrees of freedom
AIC: 748.25

Number of Fisher Scoring iterations: 2
```

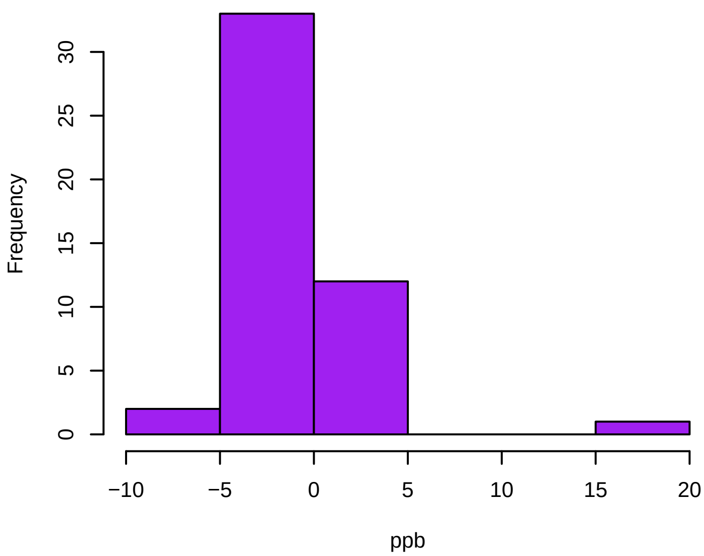
Aluminum

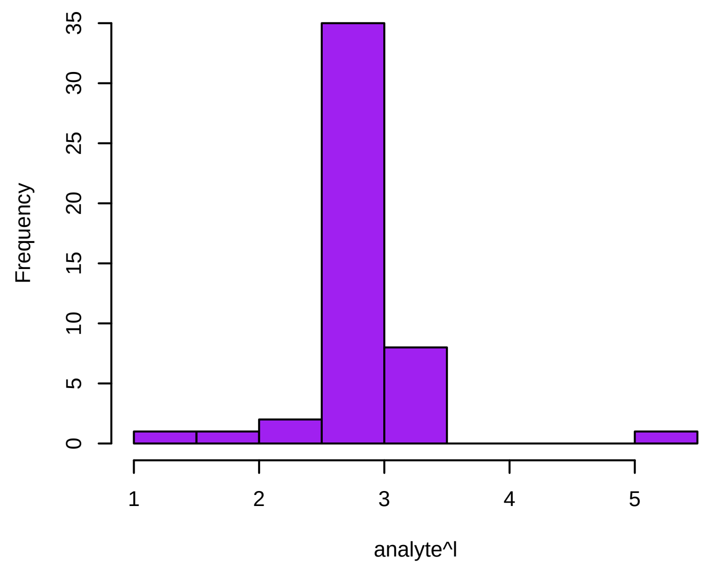
Skewness: 3.3955
Kurtosis: 22.6508

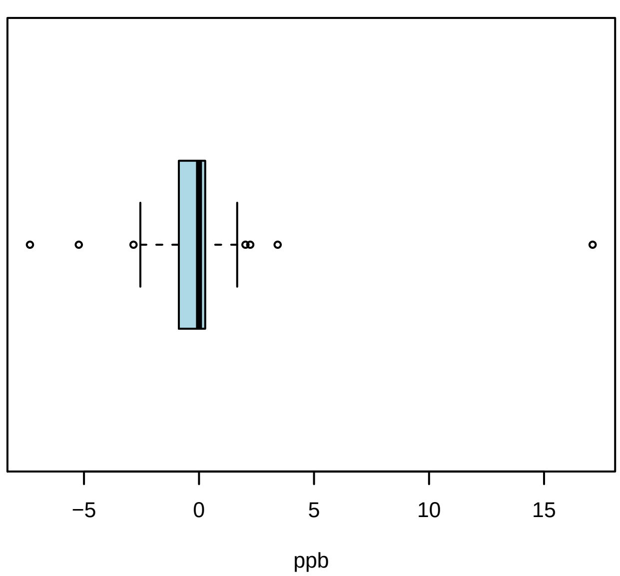
Aluminum Box−Cox

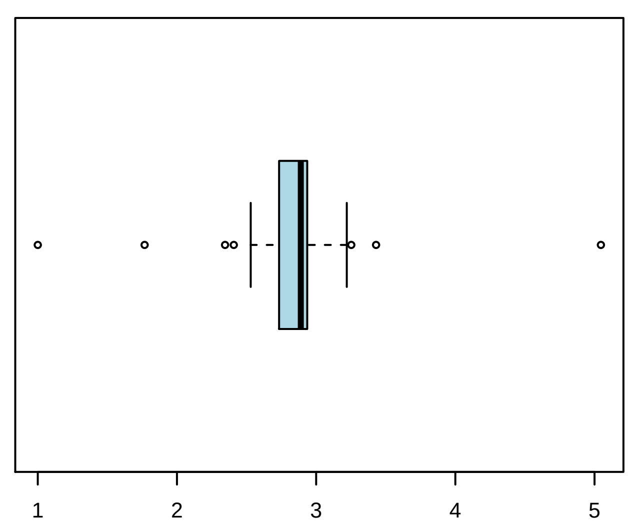
Skewness: 0.5543
Kurtosis: 13.7756

Optimal lambda: 0.5



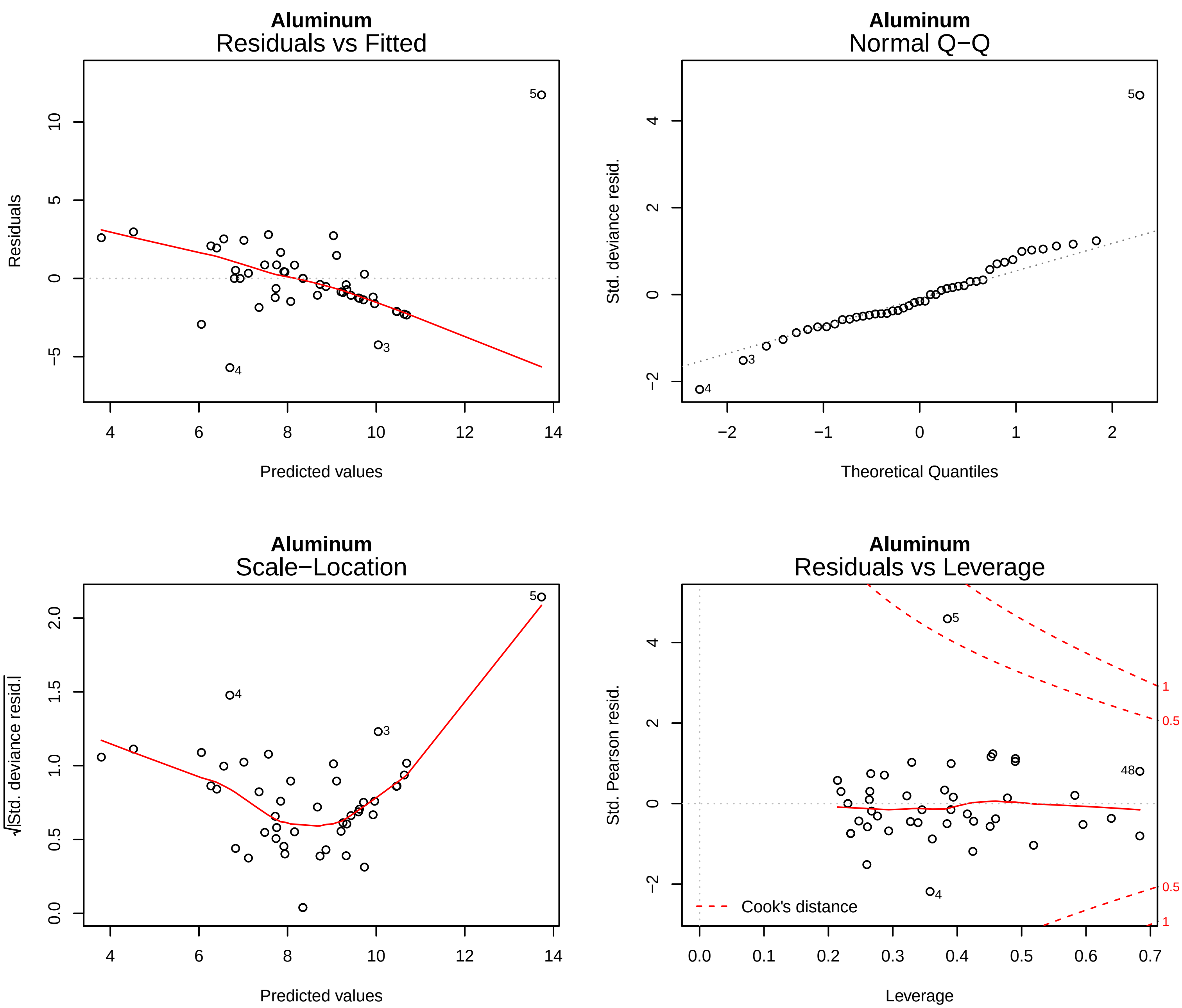






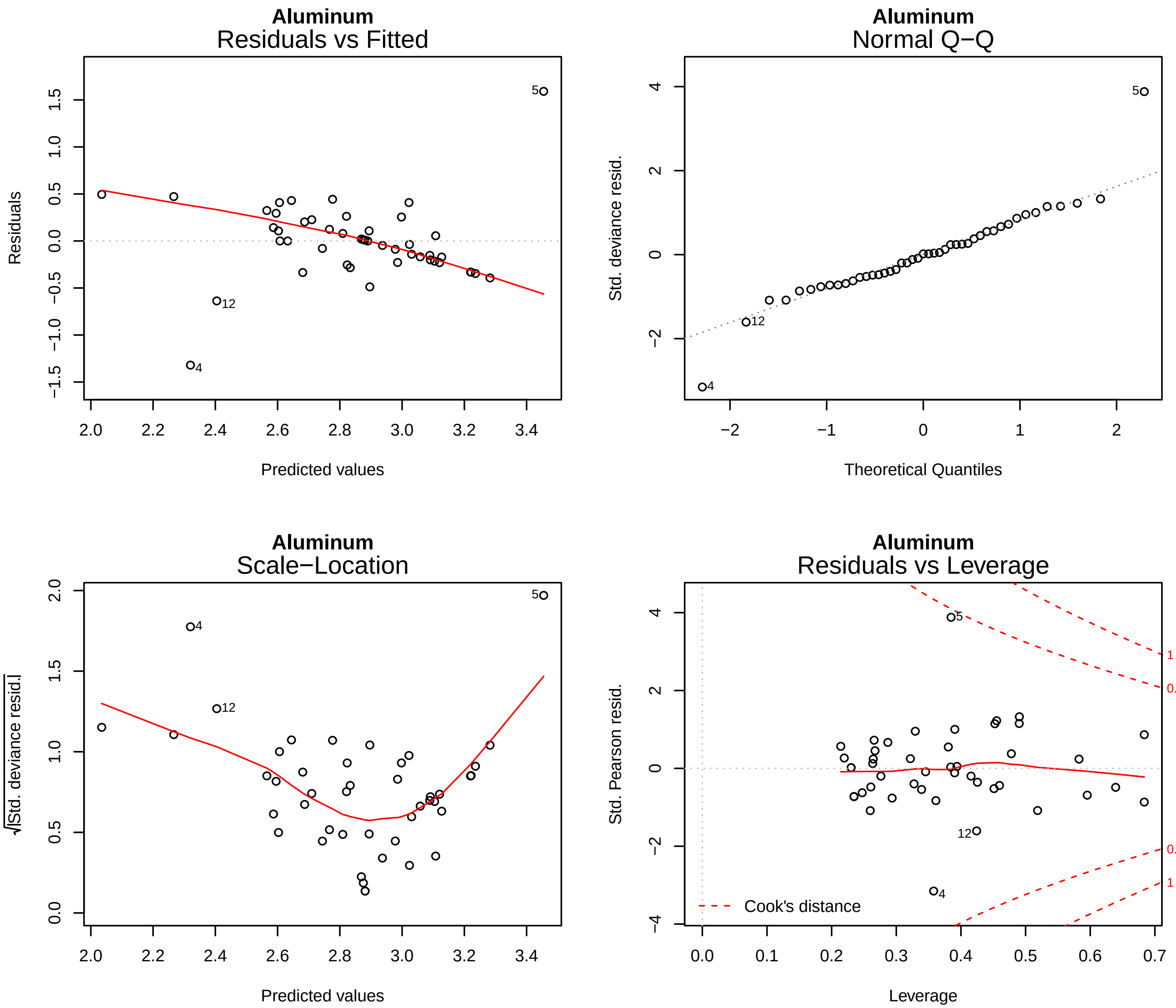
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

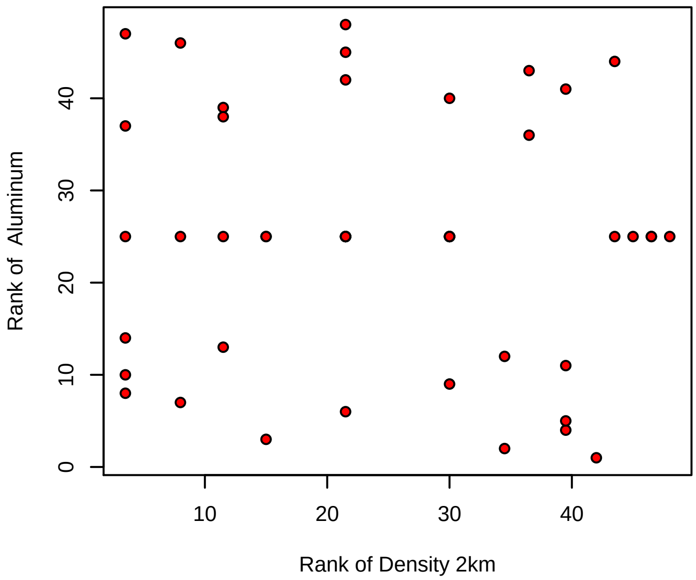
Original
Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



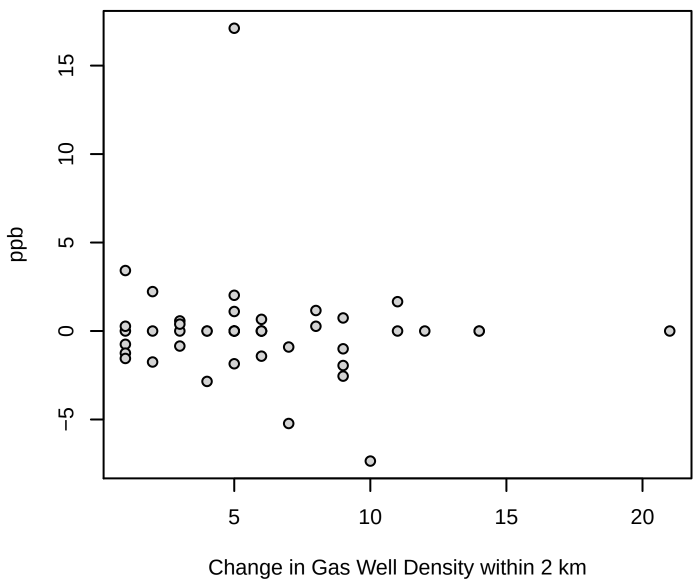


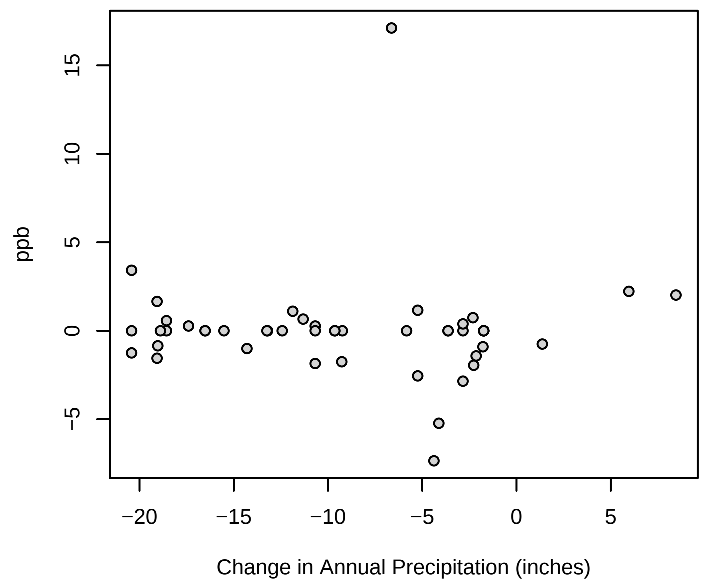
Aluminum

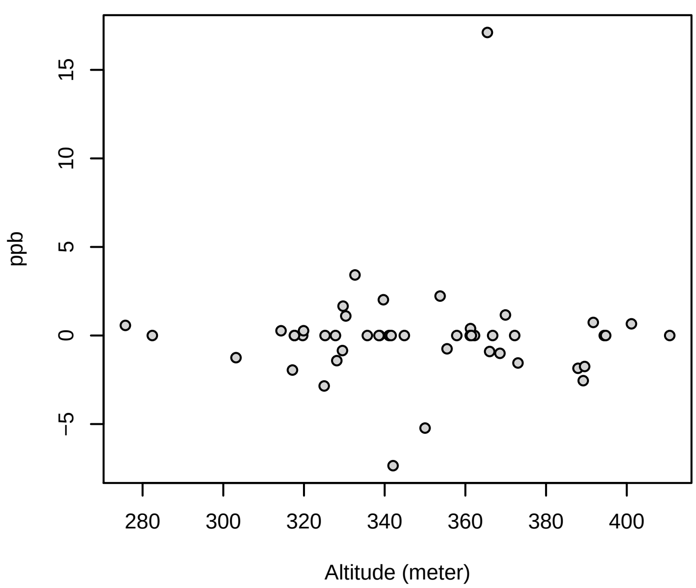
Kendalls Tau Rank Correlation

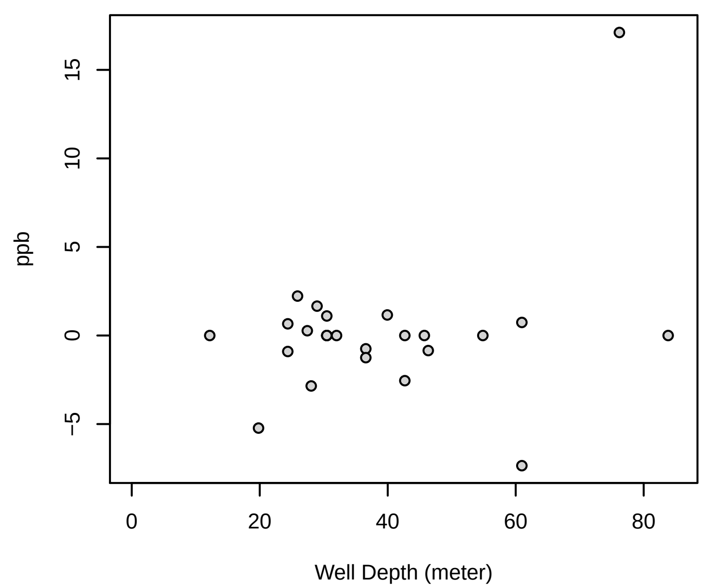
p−value: 0.599

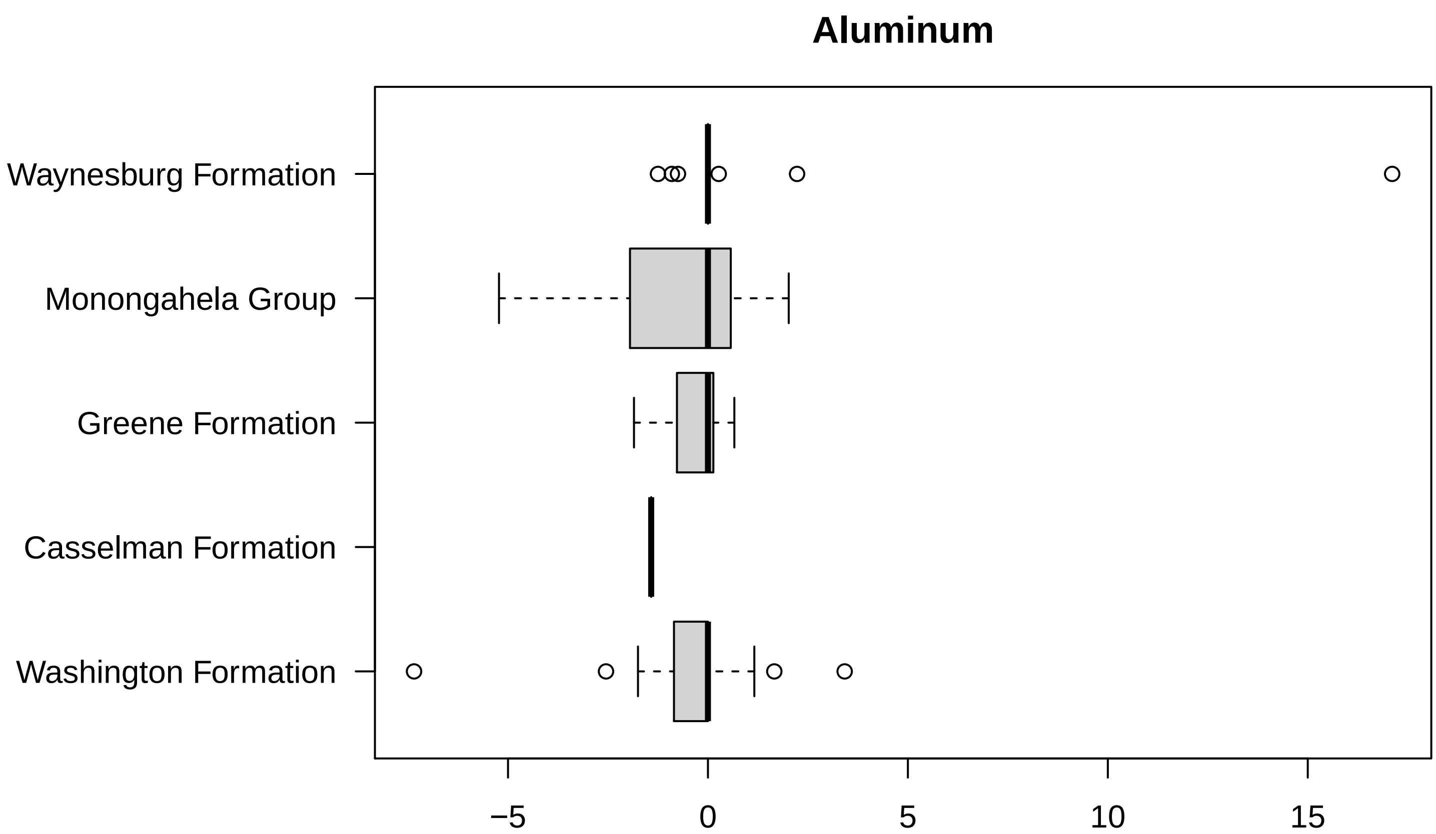
Tau: −0.0577

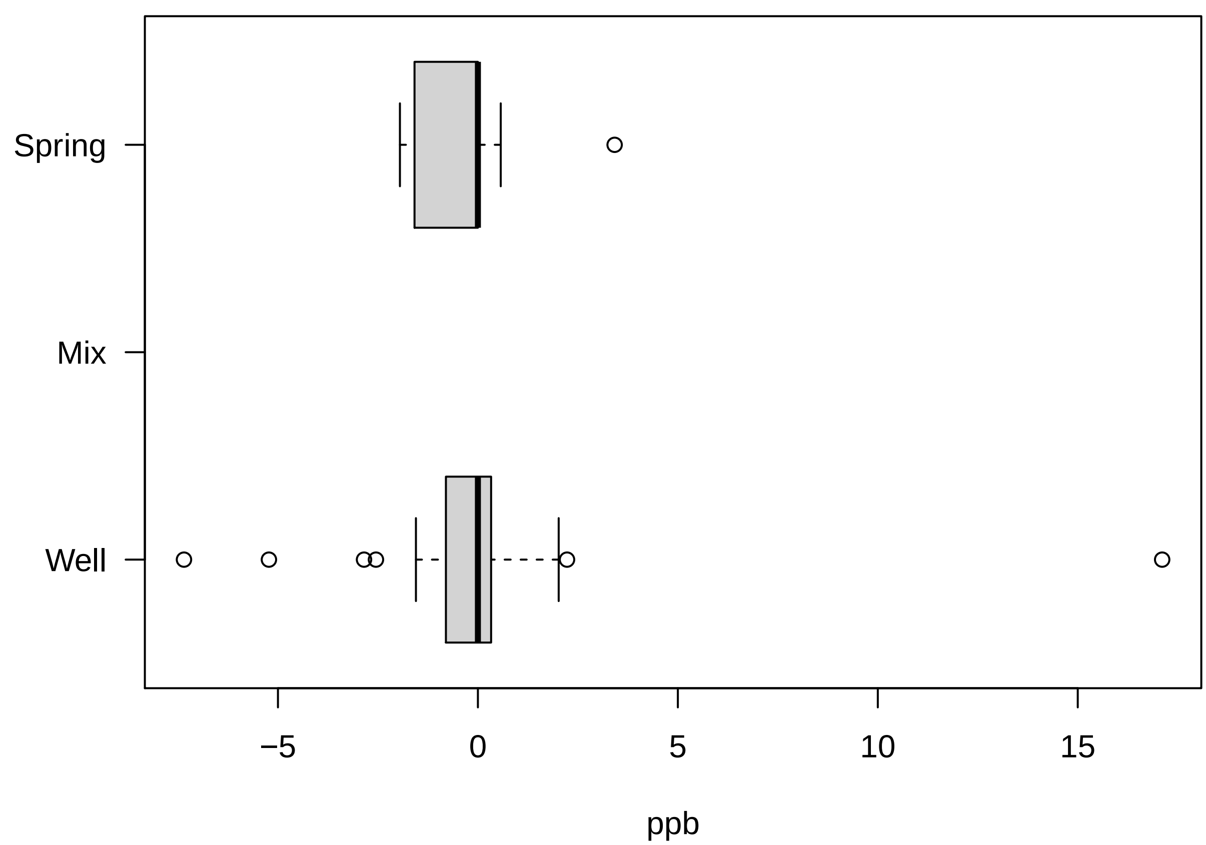


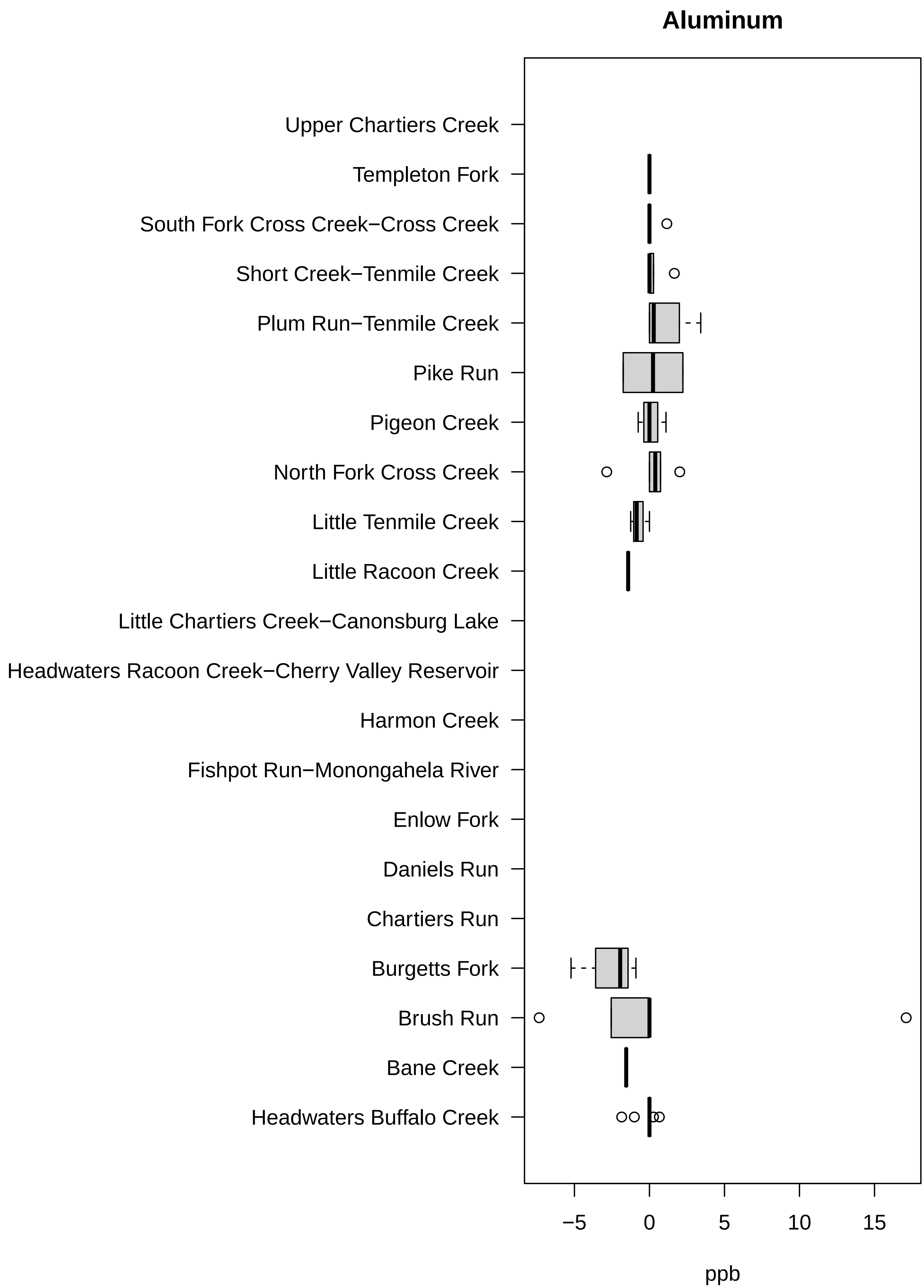







Aluminum
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−5
0
5
10
15


Spring
Mix
Well
−5
0
5
10
15
ppb


Aluminum
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−5
0
5
10
15
ppb

```
[1] "ORIGINAL MODEL - Aluminum"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-5.6976  -1.2563  -0.1913   0.8647  11.7296

Coefficients: (1 not defined because of singularities)
                                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                               -17.28745   12.94263  -1.336   0.1924
dat$GWellDensity_2kmDiff                   -0.14758    0.20051  -0.736   0.4678
dat$Altitude_meter                          0.06689    0.03502   1.910   0.0664 .
dat$WatershedBane Creek                    -0.64138    4.03316  -0.159   0.8748
dat$WatershedBrush Run                      2.33680    2.34524   0.996   0.3276
dat$WatershedBurgetts Fork                 -3.75315    2.97165  -1.263   0.2170
dat$WatershedLittle Racoon Creek            2.69791    4.25802   0.634   0.5315
dat$WatershedLittle Tenmile Creek          -0.83717    3.04430  -0.275   0.7853
dat$WatershedNorth Fork Cross Creek        -1.15239    3.20257  -0.360   0.7217
dat$WatershedPigeon Creek                  -2.20170    2.84017  -0.775   0.4447
dat$WatershedPike Run                      -1.25326    3.48364  -0.360   0.7217
dat$WatershedPlum Run-Tenmile Creek         2.75811    3.08280   0.895   0.3786
dat$WatershedShort Creek-Tenmile Creek      5.54176    3.17436   1.746   0.0918 .
dat$WatershedSouth Fork Cross Creek-Cross Creek   1.27795    2.53129   0.505   0.6176
dat$WatershedTempleton Fork                 2.79706    3.90543   0.716   0.4798
dat$FormationCasselman Formation                 NA         NA      NA       NA
dat$FormationGreene Formation              -1.12726    2.13184  -0.529   0.6011
dat$FormationMonongahela Group              4.48946    2.52517   1.778   0.0863 .
dat$FormationWaynesburg Formation           4.60817    1.73489   2.656   0.0129 *
dat$HHWSourceSpring                         0.33727    1.51174   0.223   0.8251
dat$Precip_inchDiff                        -0.05504    0.17195  -0.320   0.7513
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 10.61286)

    Null deviance: 435.76  on 47  degrees of freedom
Residual deviance: 297.16  on 28  degrees of freedom
AIC: 265.73

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Aluminum"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.3201  -0.2183   0.0000   0.2086   1.5911

Coefficients: (1 not defined because of singularities)
                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                 -1.512438   2.076560  -0.728   0.4725
dat$GWellDensity_2kmDiff                    -0.025205   0.032171  -0.783   0.4399
dat$Altitude_meter                           0.011612   0.005618   2.067   0.0481 *
dat$WatershedBane Creek                     -0.119705   0.647093  -0.185   0.8546
dat$WatershedBrush Run                       0.093254   0.376278   0.248   0.8061
dat$WatershedBurgetts Fork                  -0.709760   0.476782  -1.489   0.1478
dat$WatershedLittle Racoon Creek             0.405962   0.683171   0.594   0.5571
dat$WatershedLittle Tenmile Creek           -0.055162   0.488438  -0.113   0.9109
dat$WatershedNorth Fork Cross Creek         -0.213053   0.513831  -0.415   0.6816
dat$WatershedPigeon Creek                   -0.325720   0.455687  -0.715   0.4807
dat$WatershedPike Run                       -0.248221   0.558927  -0.444   0.6604
dat$WatershedPlum Run-Tenmile Creek          0.537324   0.494615   1.086   0.2866
dat$WatershedShort Creek-Tenmile Creek       0.985923   0.509305   1.936   0.0630 .
dat$WatershedSouth Fork Cross Creek-Cross Creek  0.216974   0.406129   0.534   0.5974
dat$WatershedTempleton Fork                  0.503731   0.626600   0.804   0.4282
dat$FormationCasselman Formation                   NA         NA      NA       NA
dat$FormationGreene Formation               -0.149967   0.342039  -0.438   0.6644
dat$FormationMonongahela Group               0.720862   0.405146   1.779   0.0861 .
dat$FormationWaynesburg Formation            0.727414   0.278352   2.613   0.0143 *
dat$HHWSourceSpring                          0.070641   0.242549   0.291   0.7730
dat$Precip_inchDiff                         -0.004370   0.027588  -0.158   0.8753
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.2731971)

    Null deviance: 11.3007  on 47  degrees of freedom
Residual deviance:  7.6495  on 28  degrees of freedom
AIC: 90.063

Number of Fisher Scoring iterations: 2
```

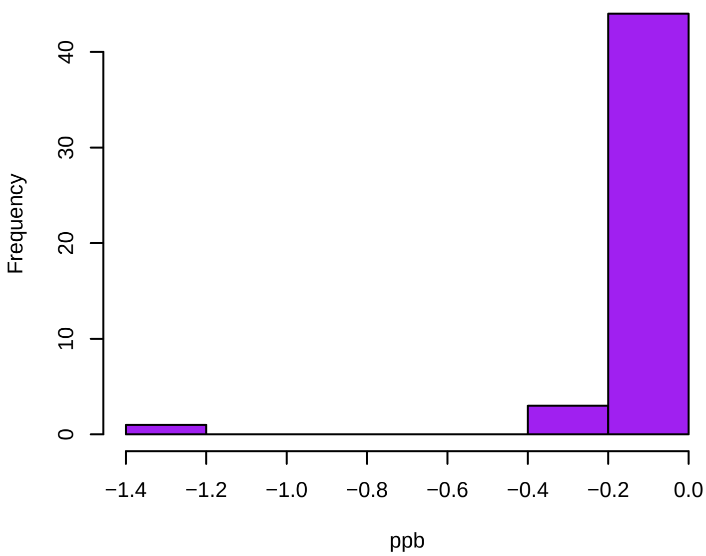
Arsenic

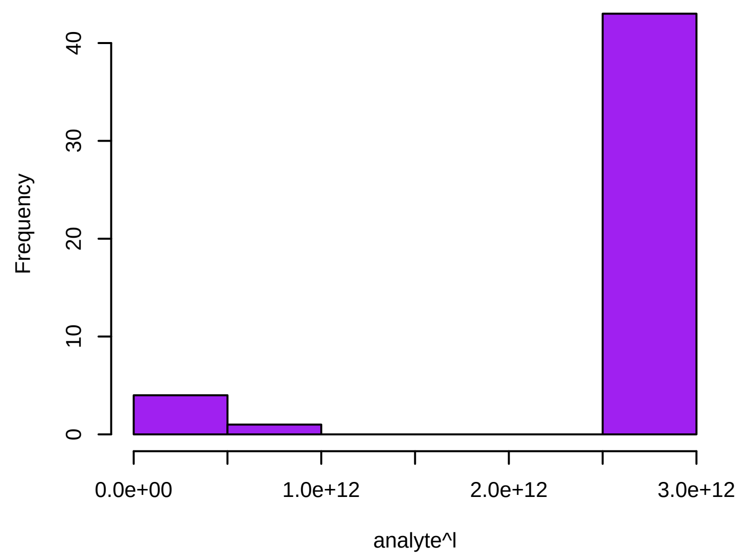
Skewness: −5.7261
Kurtosis: 36.6874

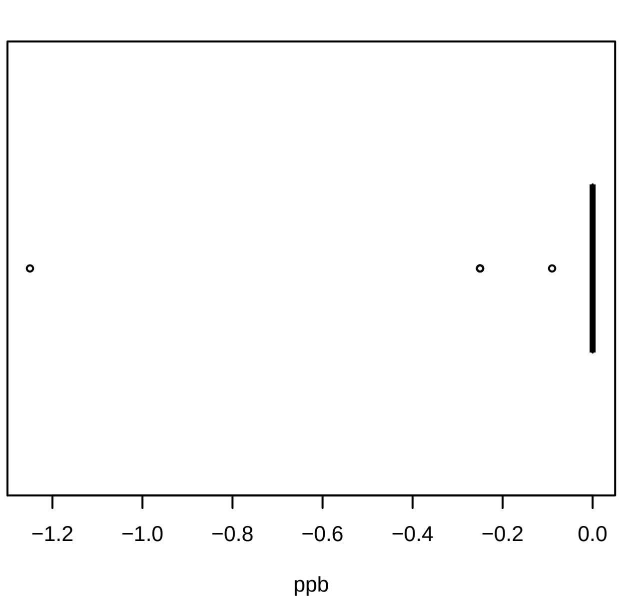
Arsenic Box−Cox

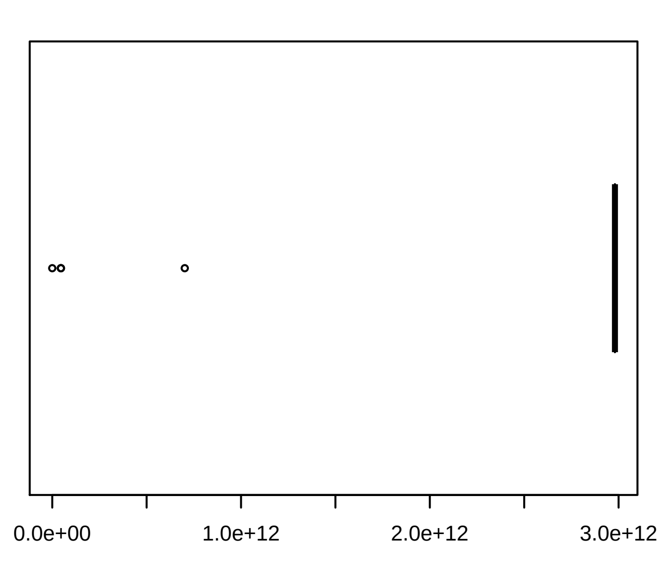
Skewness: −2.6358
Kurtosis: 8.0232

Optimal lambda: 35.42



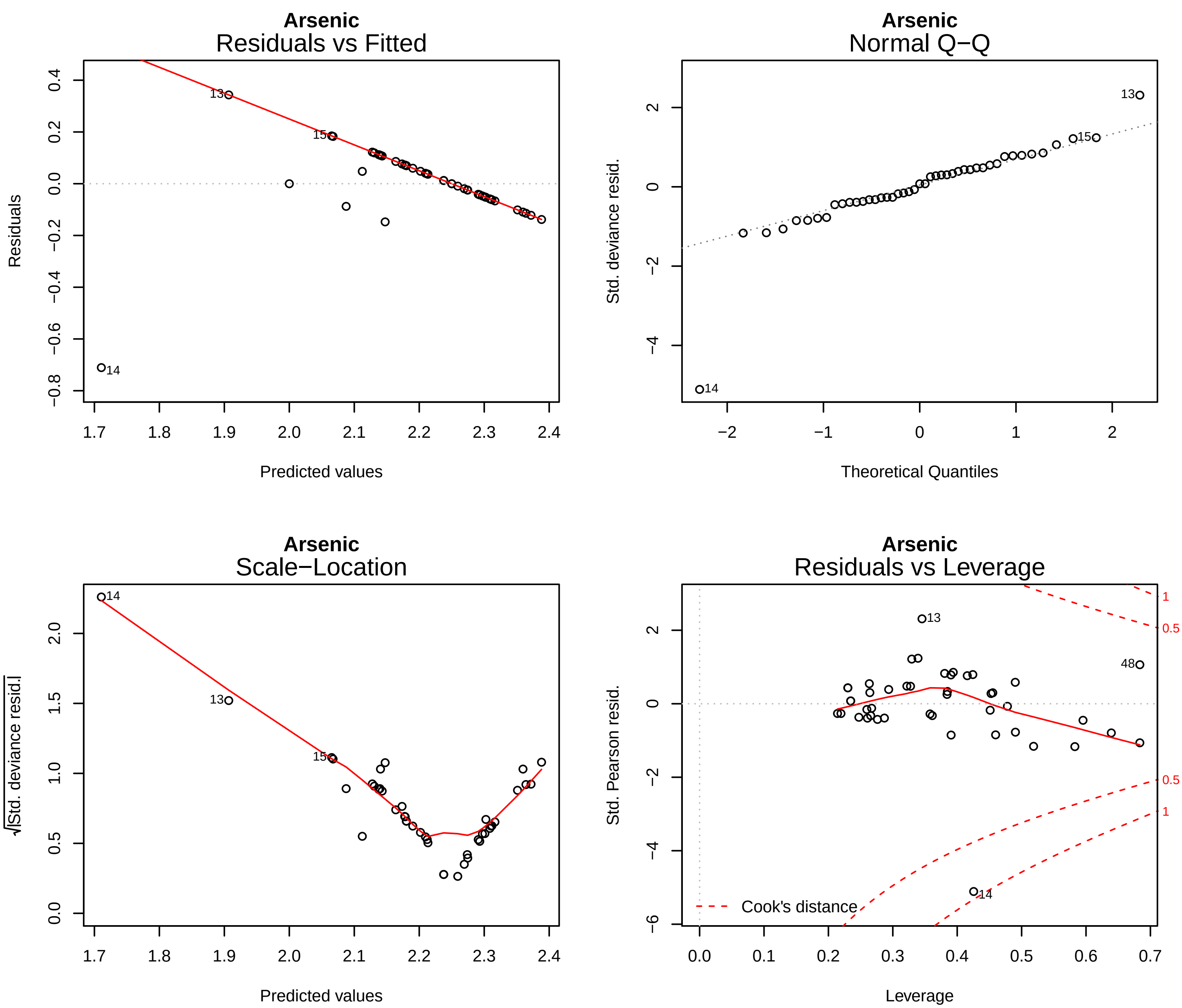






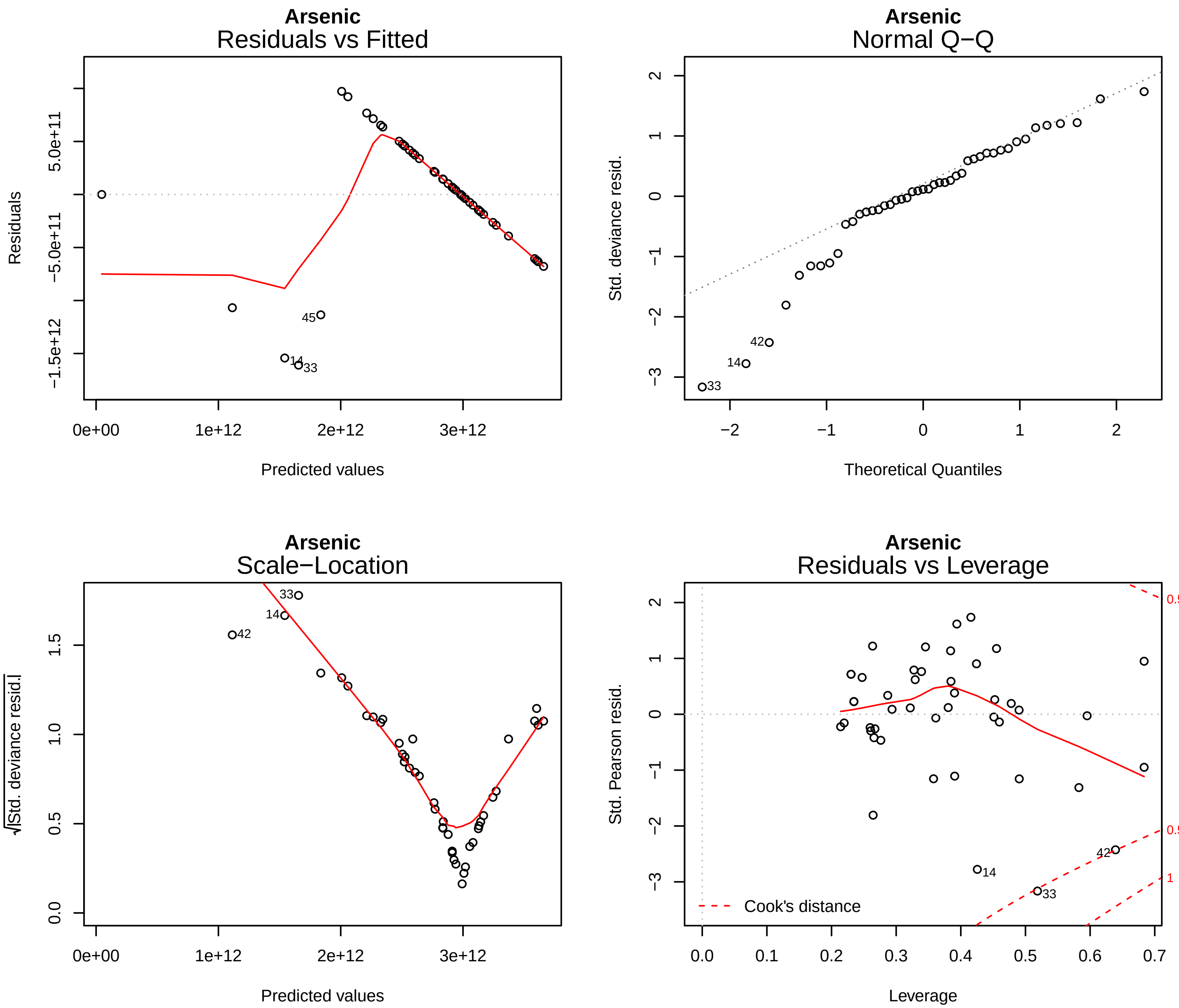
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

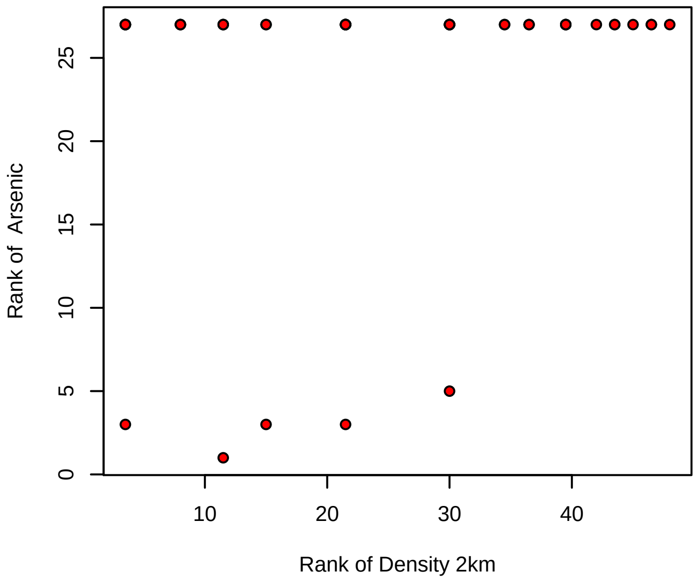
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox
Model



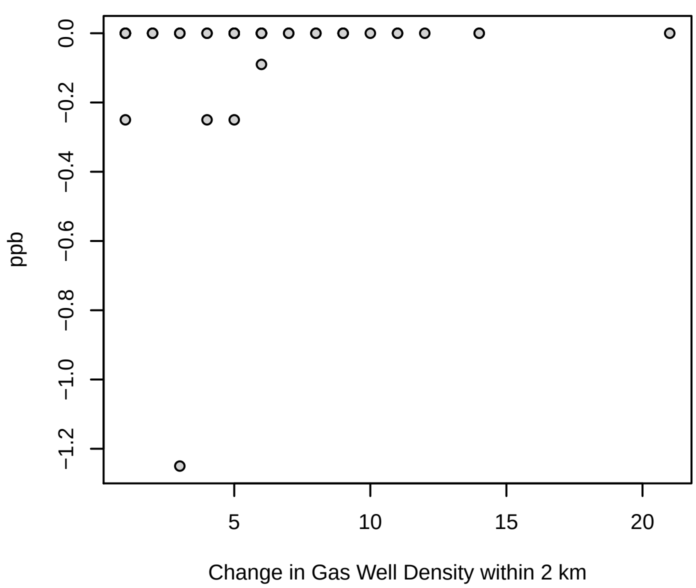


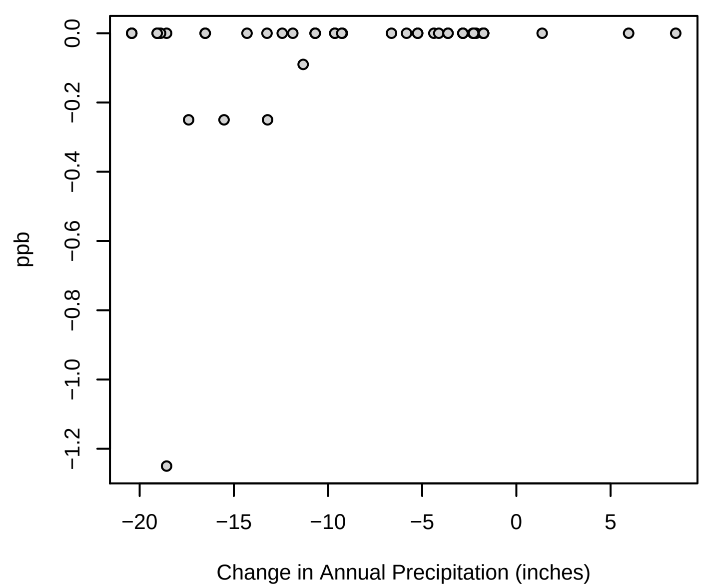
Arsenic

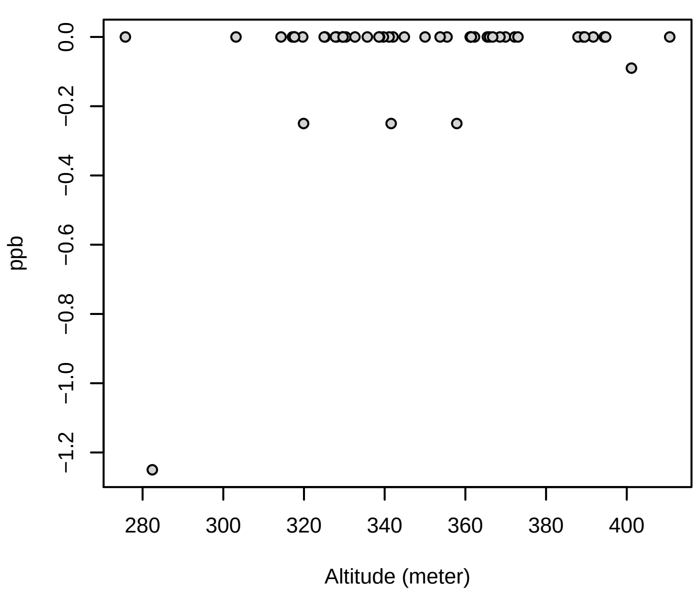
Kendalls Tau Rank Correlation

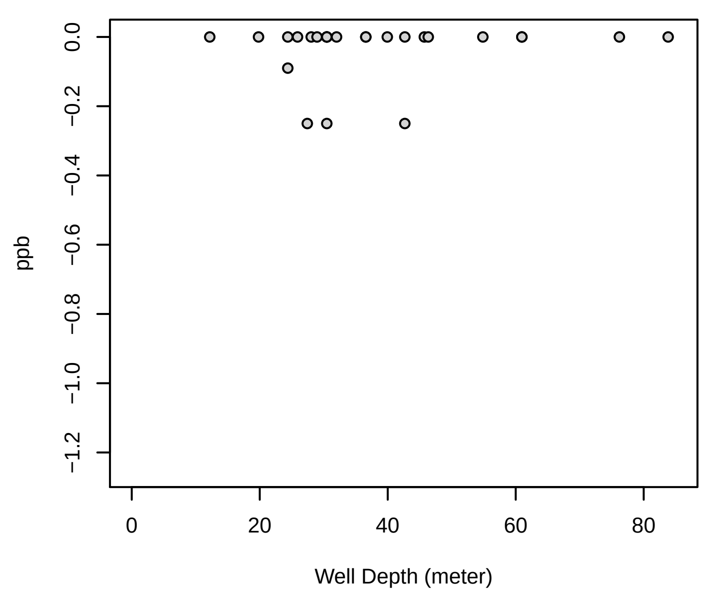
p−value: 0.14

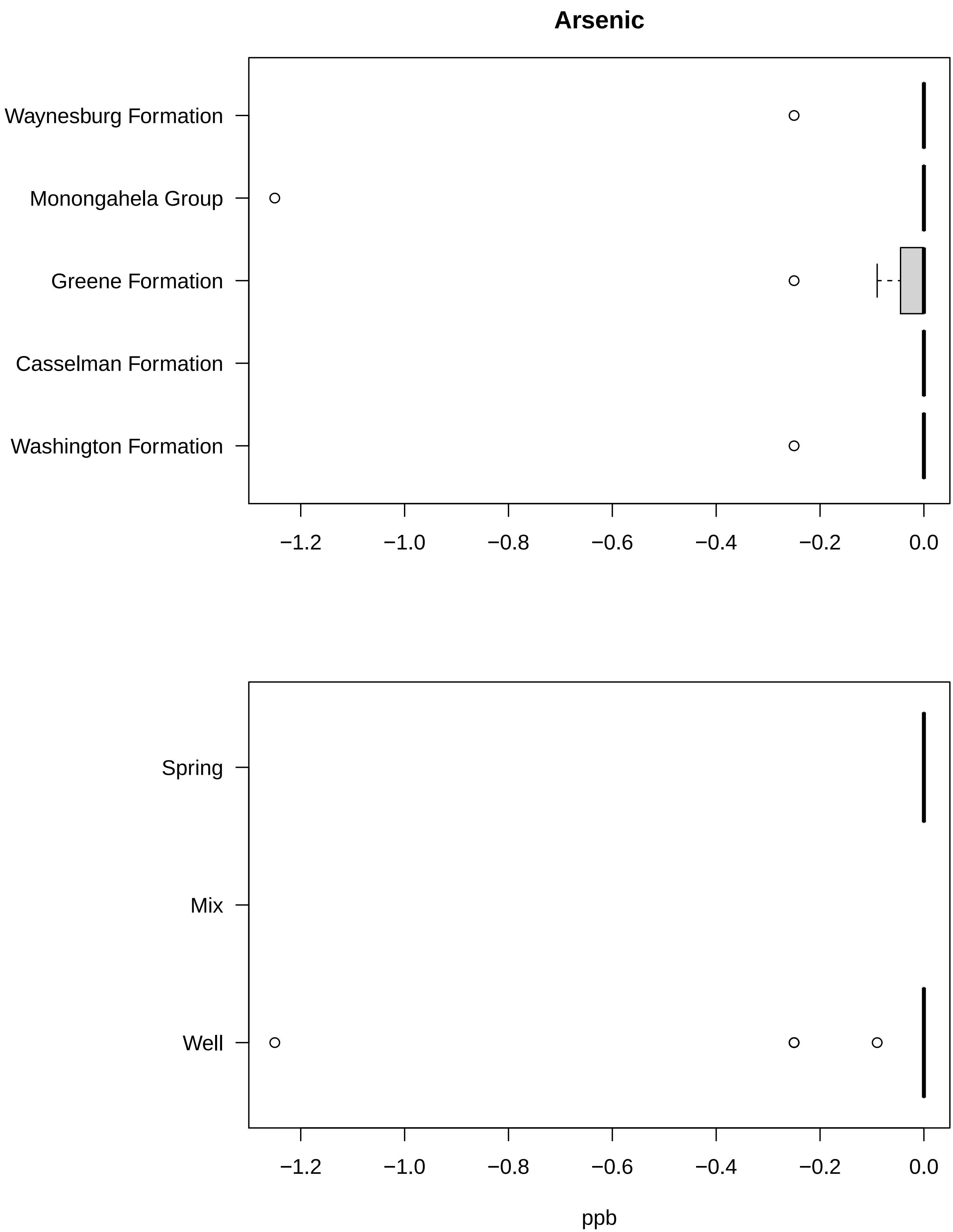
Tau: 0.182

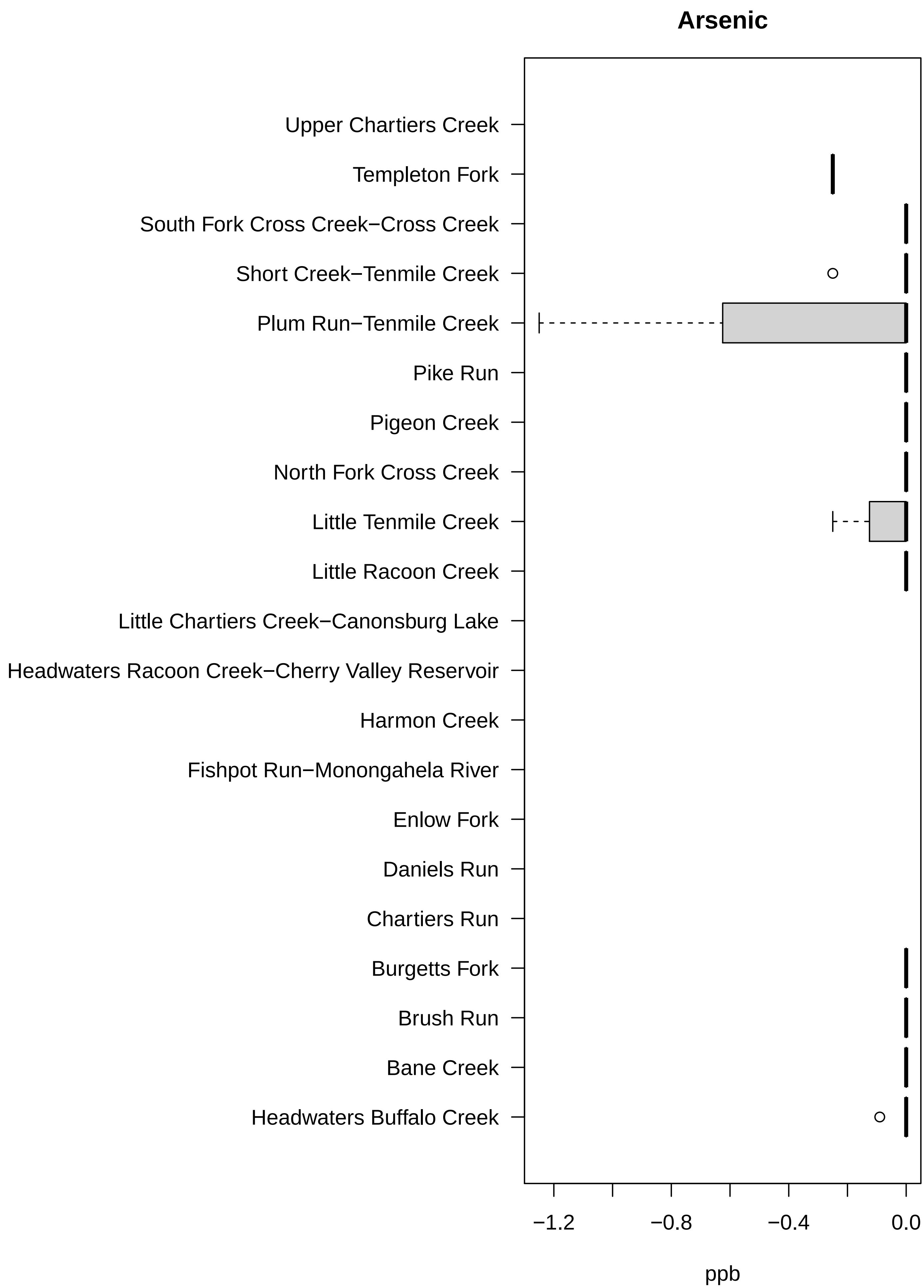









Arsenic
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−1.2
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
Spring
Mix
Well
−1.2
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
ppb



Arsenic
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−1.2
−0.8
−0.4
0.0
ppb

```
[1] "ORIGINAL MODEL - Arsenic"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.71067  -0.05407   0.00000   0.07184   0.34324  

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                  2.2737934  0.7290139   3.119  0.00418 **
dat$GWellDensity_2kmDiff                     0.0027109  0.0112940   0.240  0.81206   
dat$Altitude_meter                          -0.0002478  0.0019724  -0.126  0.90091   
dat$WatershedBane Creek                      0.1601076  0.2271738   0.705  0.48677   
dat$WatershedBrush Run                       0.0836336  0.1320991   0.633  0.53180   
dat$WatershedBurgetts Fork                   0.1257728  0.1673831   0.751  0.45868   
dat$WatershedLittle Racoon Creek            -0.1487942  0.2398396  -0.620  0.54002   
dat$WatershedLittle Tenmile Creek            0.0482767  0.1714749   0.282  0.78037   
dat$WatershedNorth Fork Cross Creek          0.1756570  0.1803896   0.974  0.33851   
dat$WatershedPigeon Creek                    0.1762566  0.1599772   1.102  0.27995   
dat$WatershedPike Run                        0.0015268  0.1962215   0.008  0.99385   
dat$WatershedPlum Run-Tenmile Creek         -0.2793630  0.1736435  -1.609  0.11887   
dat$WatershedShort Creek-Tenmile Creek      -0.0190039  0.1788007  -0.106  0.91611   
dat$WatershedSouth Fork Cross Creek-Cross Creek  0.0999913  0.1425789   0.701  0.48890   
dat$WatershedTempleton Fork                 -0.1756465  0.2199794  -0.798  0.43132   
dat$FormationCasselman Formation                    NA         NA      NA       NA   
dat$FormationGreene Formation               -0.0551231  0.1200790  -0.459  0.64974   
dat$FormationMonongahela Group              -0.1838886  0.1422339  -1.293  0.20663   
dat$FormationWaynesburg Formation           -0.0649376  0.0977204  -0.665  0.51179   
dat$HHWSourceSpring                          0.1944341  0.0851511   2.283  0.03020 * 
dat$Precip_inchDiff                          0.0020473  0.0096852   0.211  0.83412   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.03367123)

    Null deviance: 1.66710  on 47  degrees of freedom
Residual deviance: 0.94279  on 28  degrees of freedom
AIC: -10.427

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Arsenic"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
       Min          1Q      Median          3Q         Max  
-1.609e+12  -1.694e+11   4.687e+10   3.983e+11   9.727e+11  

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                  5.972e+12  2.912e+12   2.051  0.04974 * 
dat$GWellDensity_2kmDiff                     6.328e+10  4.511e+10   1.403  0.17164   
dat$Altitude_meter                          -9.868e+09  7.878e+09  -1.253  0.22072   
dat$WatershedBane Creek                      1.178e+12  9.073e+11   1.299  0.20469   
dat$WatershedBrush Run                       4.276e+11  5.276e+11   0.810  0.42451   
dat$WatershedBurgetts Fork                   5.451e+11  6.685e+11   0.815  0.42174   
dat$WatershedLittle Racoon Creek            -7.915e+11  9.579e+11  -0.826  0.41564   
dat$WatershedLittle Tenmile Creek           -5.758e+11  6.849e+11  -0.841  0.40762   
dat$WatershedNorth Fork Cross Creek          9.369e+11  7.205e+11   1.300  0.20407   
dat$WatershedPigeon Creek                    9.370e+11  6.390e+11   1.466  0.15367   
dat$WatershedPike Run                        4.554e+11  7.837e+11   0.581  0.56583   
dat$WatershedPlum Run-Tenmile Creek         -8.124e+11  6.935e+11  -1.171  0.25134   
dat$WatershedShort Creek-Tenmile Creek      -1.212e+12  7.141e+11  -1.697  0.10077   
dat$WatershedSouth Fork Cross Creek-Cross Creek  2.952e+11  5.695e+11   0.518  0.60824   
dat$WatershedTempleton Fork                 -2.878e+12  8.786e+11  -3.276  0.00281 **
dat$FormationCasselman Formation                    NA         NA      NA       NA   
dat$FormationGreene Formation               -5.616e+11  4.796e+11  -1.171  0.25146   
dat$FormationMonongahela Group              -1.030e+12  5.681e+11  -1.813  0.08055 . 
dat$FormationWaynesburg Formation           -4.706e+11  3.903e+11  -1.206  0.23804   
dat$HHWSourceSpring                          6.576e+11  3.401e+11   1.934  0.06332 . 
dat$Precip_inchDiff                         -5.356e+08  3.868e+10  -0.014  0.98905   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 5.371349e+23)

    Null deviance: 3.5792e+25  on 47  degrees of freedom
Residual deviance: 1.5040e+25  on 28  degrees of freedom
AIC: 2775.1

Number of Fisher Scoring iterations: 2
```

Barium

Skewness: −5.1767

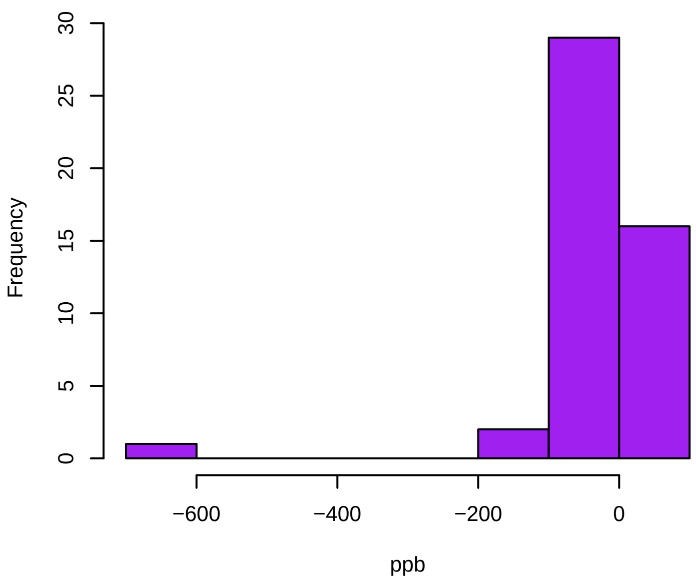
Kurtosis: 32.6905

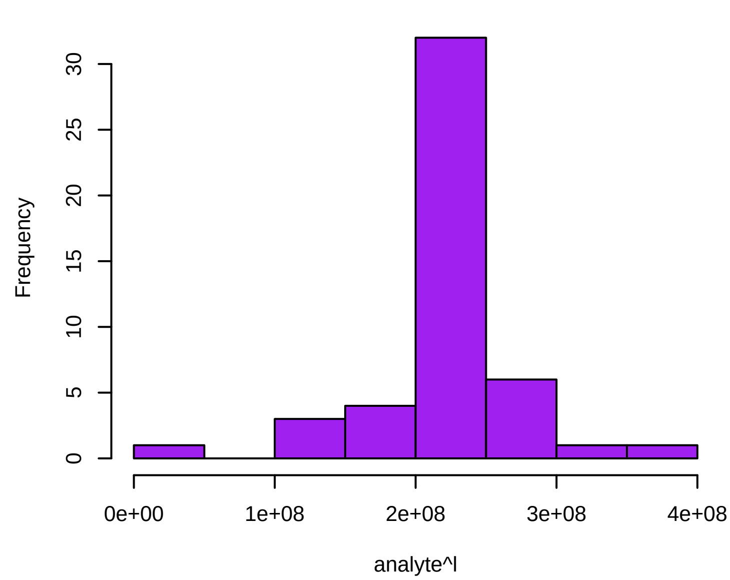
Barium Box−Cox

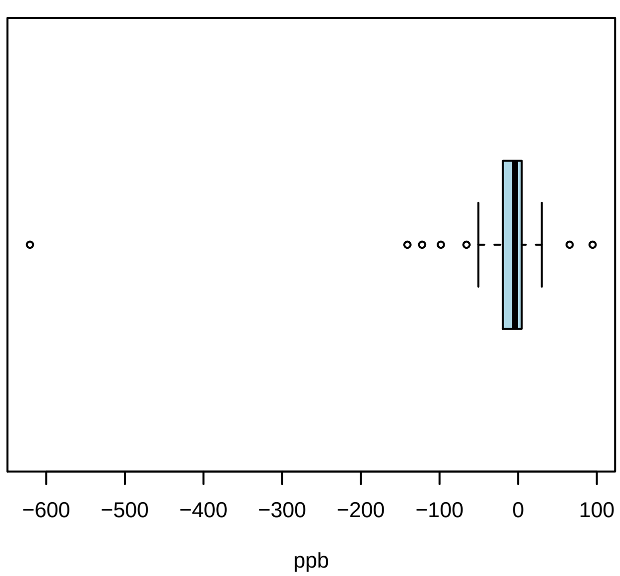
Skewness: −1.5794

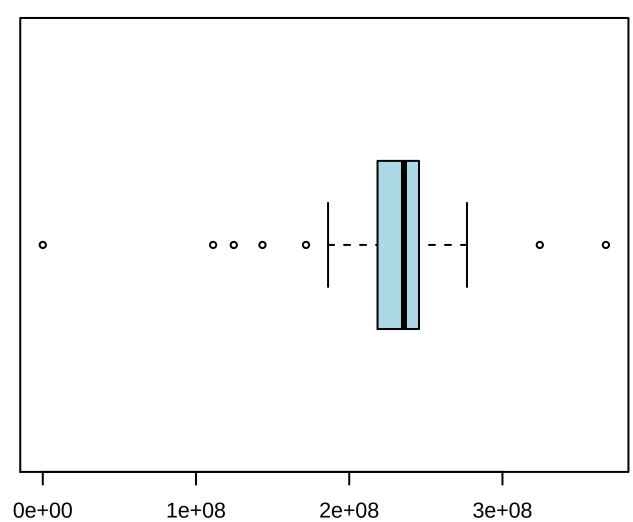
Kurtosis: 9.7297

Optimal lambda: 3



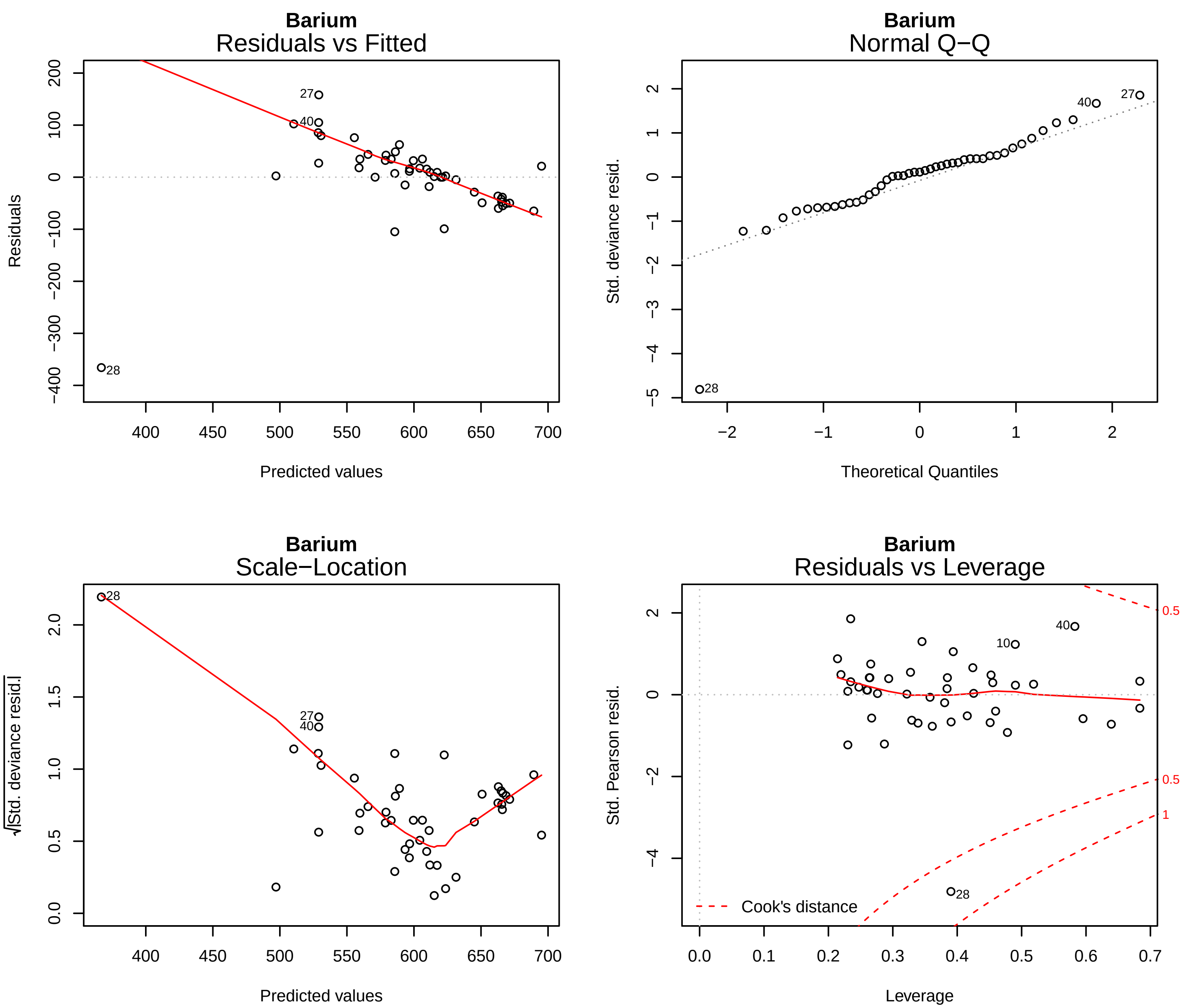






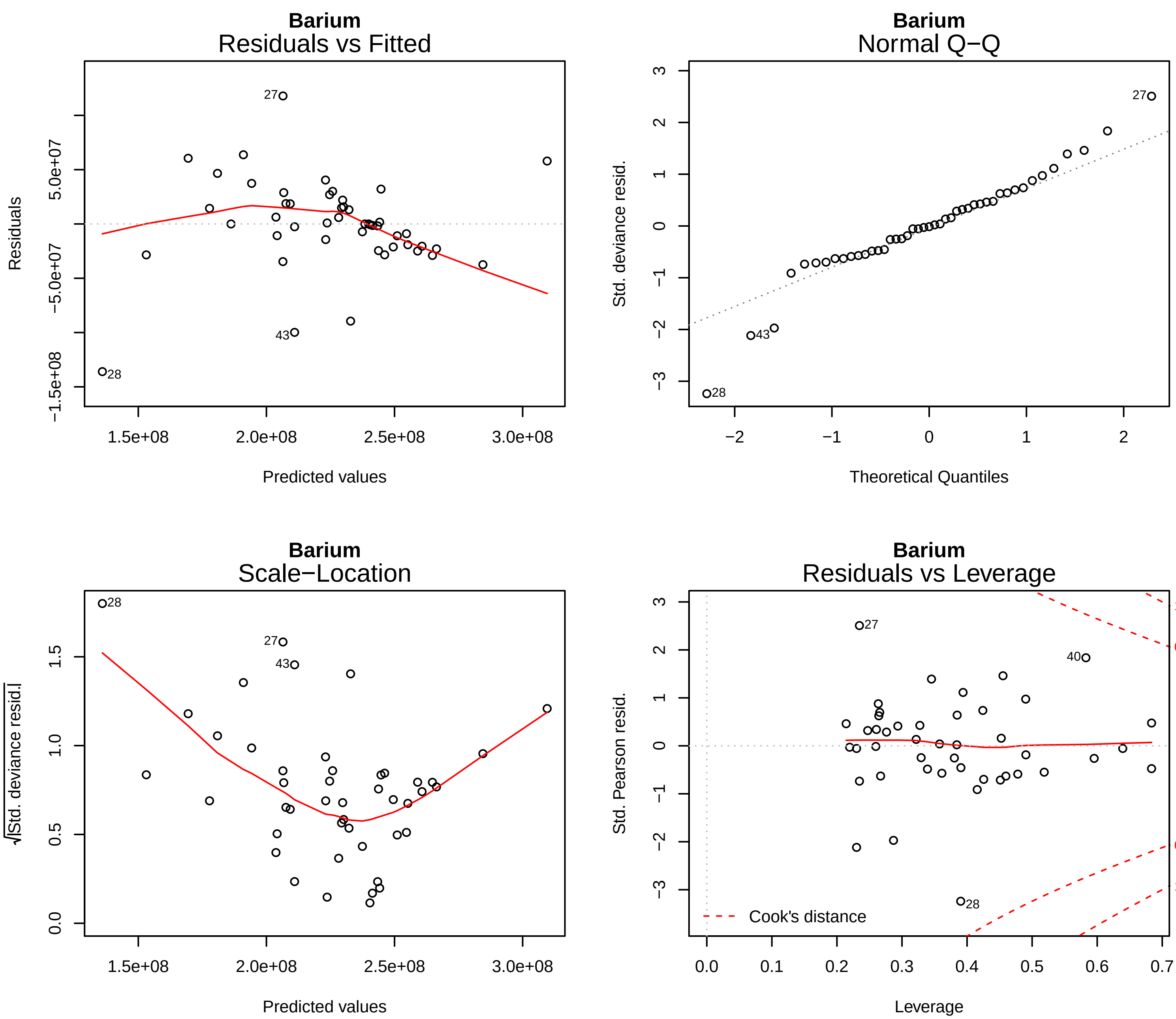
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

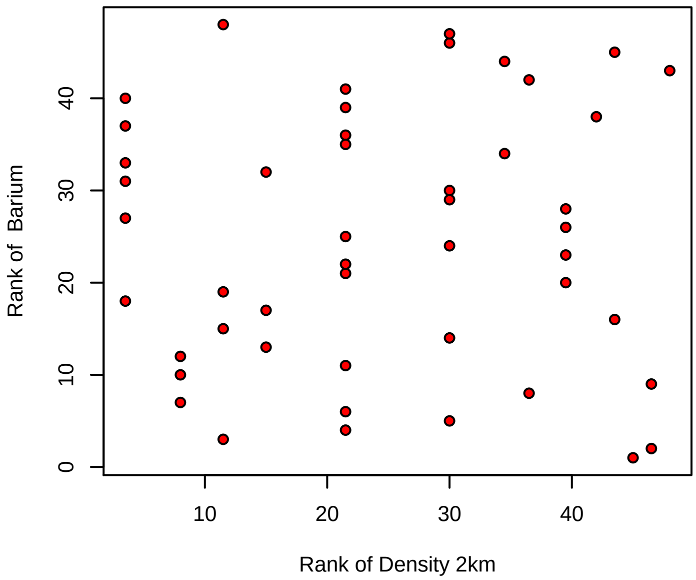
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



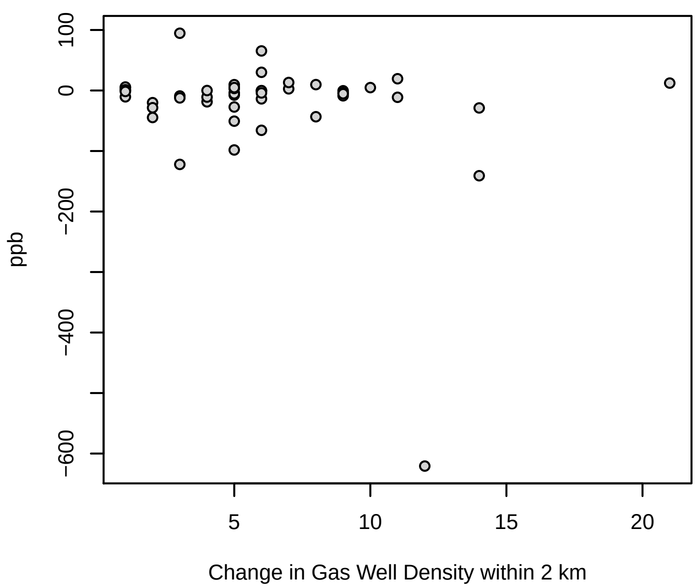


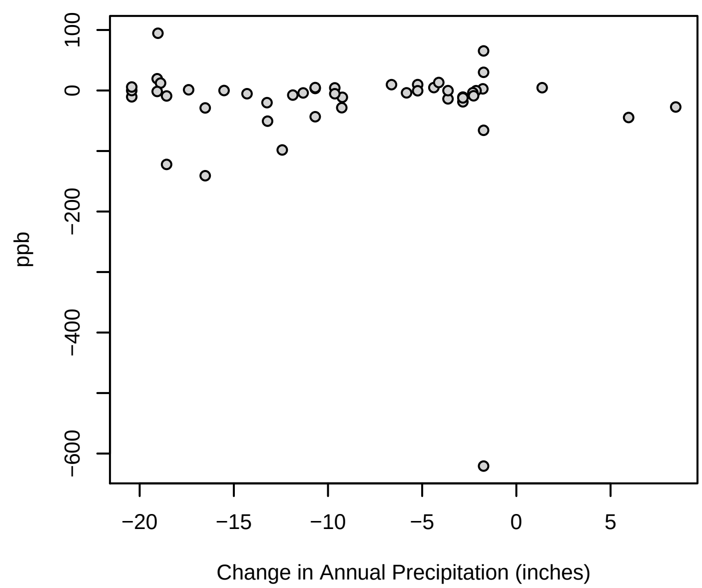
Barium

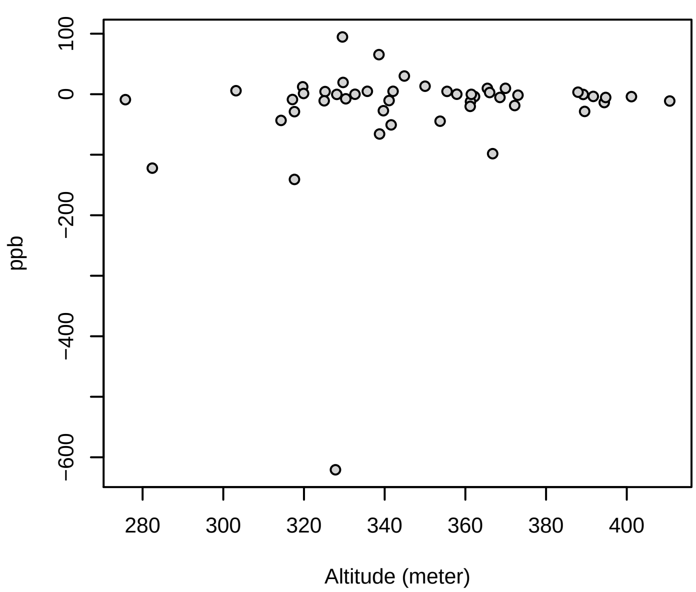
Kendalls Tau Rank Correlation

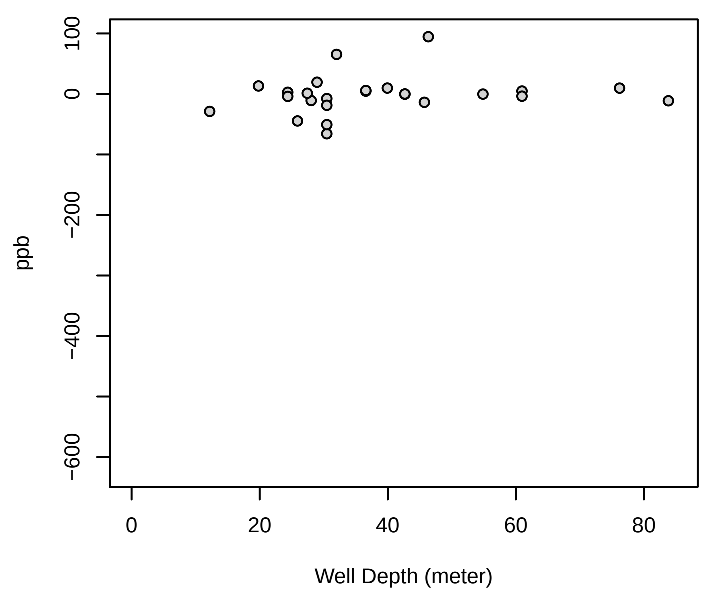
p−value: 0.865

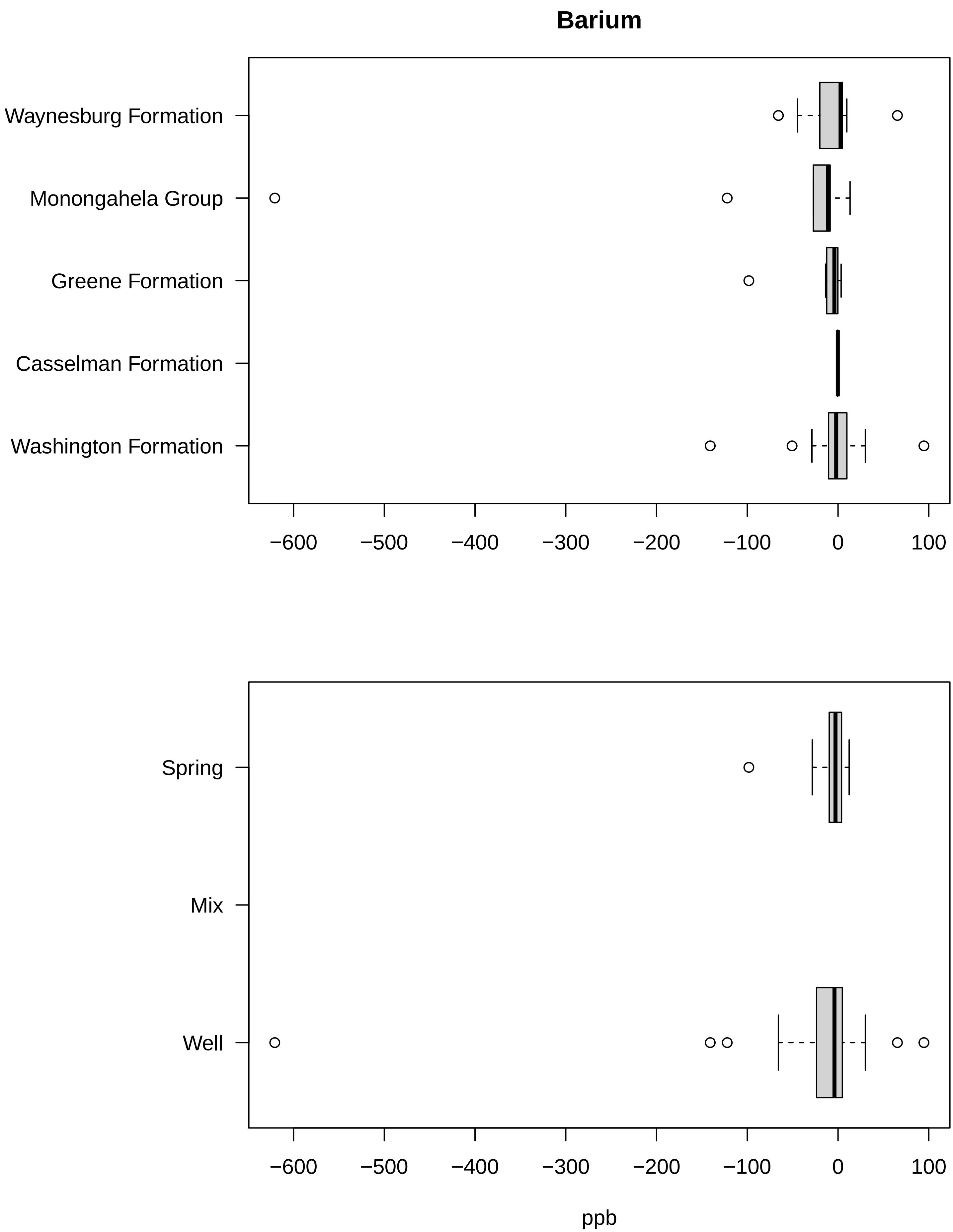
Tau: 0.0177











Barium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−600
−500
−400
−300
−200
−100
0
100
Spring
Mix
Well
−600
−500
−400
−300
−200
−100
0
100
ppb


Barium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−600
−400
−200
0
100
ppb

```
[1] "ORIGINAL MODEL - Barium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-365.83   -36.83     8.22    34.70   158.07

Coefficients: (1 not defined because of singularities)
                                                  Estimate Std. Error t value Pr(>|t|)
(Intercept)                                      923.03078  386.83218   2.386   0.0240 *
dat$GWellDensity_2kmDiff                          -9.26696    5.99289  -1.546   0.1333
dat$Altitude_meter                                -0.61170    1.04660  -0.584   0.5636
dat$WatershedBane Creek                          -26.93161  120.54386  -0.223   0.8248
dat$WatershedBrush Run                             9.96128   70.09492   0.142   0.8880
dat$WatershedBurgetts Fork                       118.96690   88.81747   1.339   0.1912
dat$WatershedLittle Racoon Creek                 -54.67350  127.26461  -0.430   0.6708
dat$WatershedLittle Tenmile Creek                  0.24458   90.98866   0.003   0.9979
dat$WatershedNorth Fork Cross Creek               68.48145   95.71904   0.715   0.4803
dat$WatershedPigeon Creek                         30.36984   84.88773   0.358   0.7232
dat$WatershedPike Run                            -64.72214  104.11982  -0.622   0.5392
dat$WatershedPlum Run-Tenmile Creek              -49.45098   92.13937  -0.537   0.5957
dat$WatershedShort Creek-Tenmile Creek           -14.39395   94.87592  -0.152   0.8805
dat$WatershedSouth Fork Cross Creek-Cross Creek  -67.42218   75.65578  -0.891   0.3804
dat$WatershedTempleton Fork                      -97.59640  116.72632  -0.836   0.4102
dat$FormationCasselman Formation                        NA         NA      NA       NA
dat$FormationGreene Formation                    -39.81527   63.71679  -0.625   0.5371
dat$FormationMonongahela Group                  -177.17481   75.47272  -2.348   0.0262 *
dat$FormationWaynesburg Formation                -63.99226   51.85279  -1.234   0.2274
dat$HHWSourceSpring                                9.19000   45.18320   0.203   0.8403
dat$Precip_inchDiff                               -0.06577    5.13921  -0.013   0.9899
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 9480.528)

    Null deviance: 433019  on 47  degrees of freedom
Residual deviance: 265455  on 28  degrees of freedom
AIC: 591.88

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Barium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
       Min          1Q      Median          3Q         Max
-135974718   -20658533           0    19565914   117903550

Coefficients: (1 not defined because of singularities)
                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                              341684137  213522819   1.600   0.1208
dat$GWellDensity_2kmDiff                  -4903115    3307943  -1.482   0.1494
dat$Altitude_meter                         -181332     577701  -0.314   0.7559
dat$WatershedBane Creek                    3411093   66537546   0.051   0.9595
dat$WatershedBrush Run                    14341262   38690849   0.371   0.7137
dat$WatershedBurgetts Fork                65096979   49025281   1.328   0.1950
dat$WatershedLittle Racoon Creek         -27606207   70247252  -0.393   0.6973
dat$WatershedLittle Tenmile Creek         45693634   50223731   0.910   0.3707
dat$WatershedNorth Fork Cross Creek       29074815   52834797   0.550   0.5865
dat$WatershedPigeon Creek                 21487542   46856152   0.459   0.6501
dat$WatershedPike Run                    -51591648   57471841  -0.898   0.3770
dat$WatershedPlum Run-Tenmile Creek      -36944028   50858898  -0.726   0.4736
dat$WatershedShort Creek-Tenmile Creek    -1535898   52369410  -0.029   0.9768
dat$WatershedSouth Fork Cross Creek-Cross Creek  -4696691   41760319  -0.112   0.9113
dat$WatershedTempleton Fork              -66711809   64430351  -1.035   0.3093
dat$FormationCasselman Formation                NA         NA      NA       NA
dat$FormationGreene Formation            -30754332   35170260  -0.874   0.3893
dat$FormationMonongahela Group           -82427266   41659276  -1.979   0.0578 .
dat$FormationWaynesburg Formation        -39401802   28621594  -1.377   0.1795
dat$HHWSourceSpring                       15130560   24940129   0.607   0.5490
dat$Precip_inchDiff                         176617    2836732   0.062   0.9508
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 2.888524e+15)

    Null deviance: 1.3031e+17  on 47  degrees of freedom
Residual deviance: 8.0879e+16  on 28  degrees of freedom
AIC: 1861.1

Number of Fisher Scoring iterations: 2
```

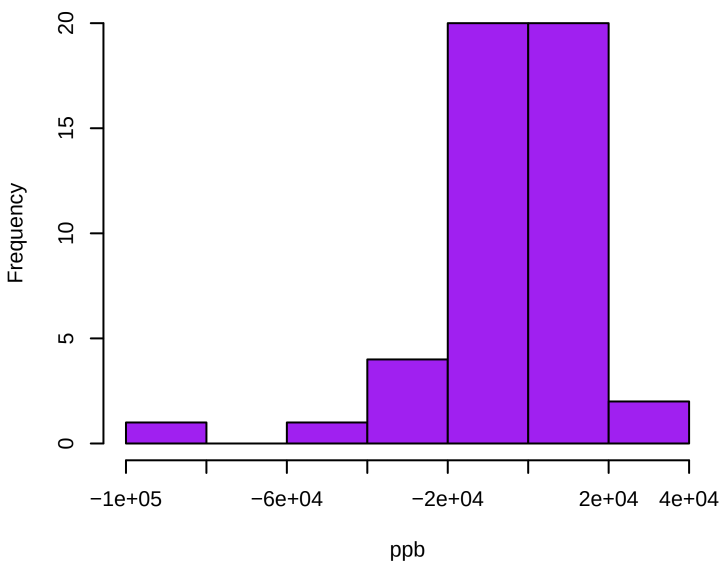
Calcium

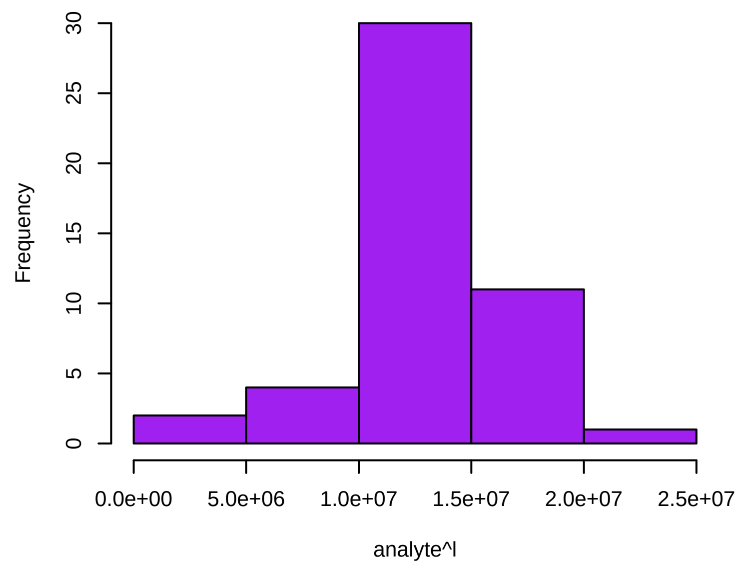
Skewness: −2.1605
Kurtosis: 11.1763

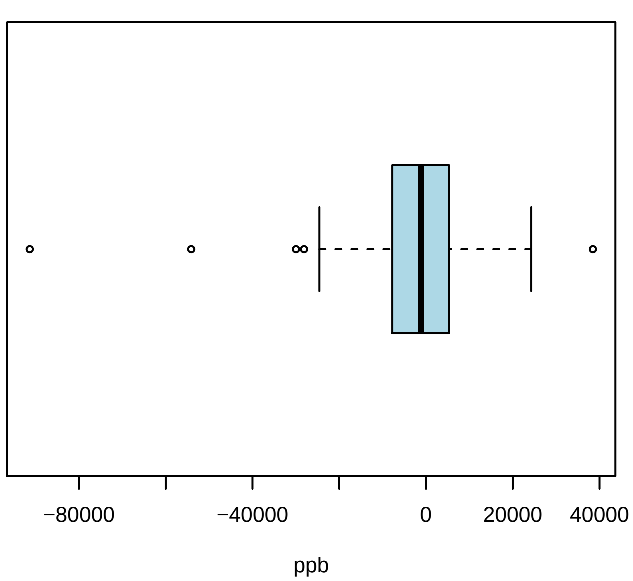
Calcium Box−Cox

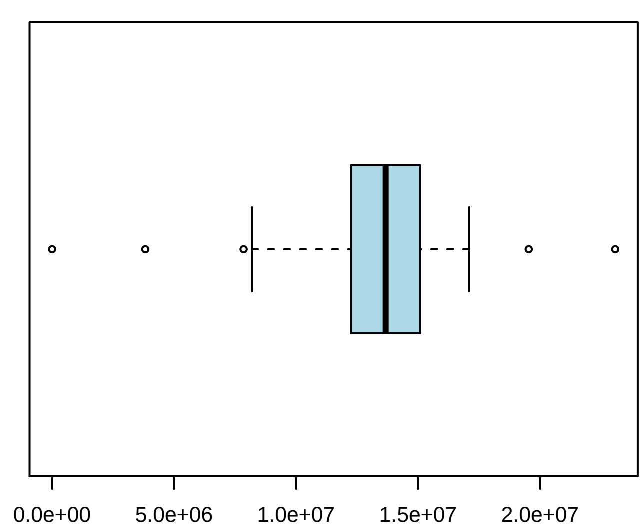
Skewness: −1.0333
Kurtosis: 6.9910

Optimal lambda: 1.44



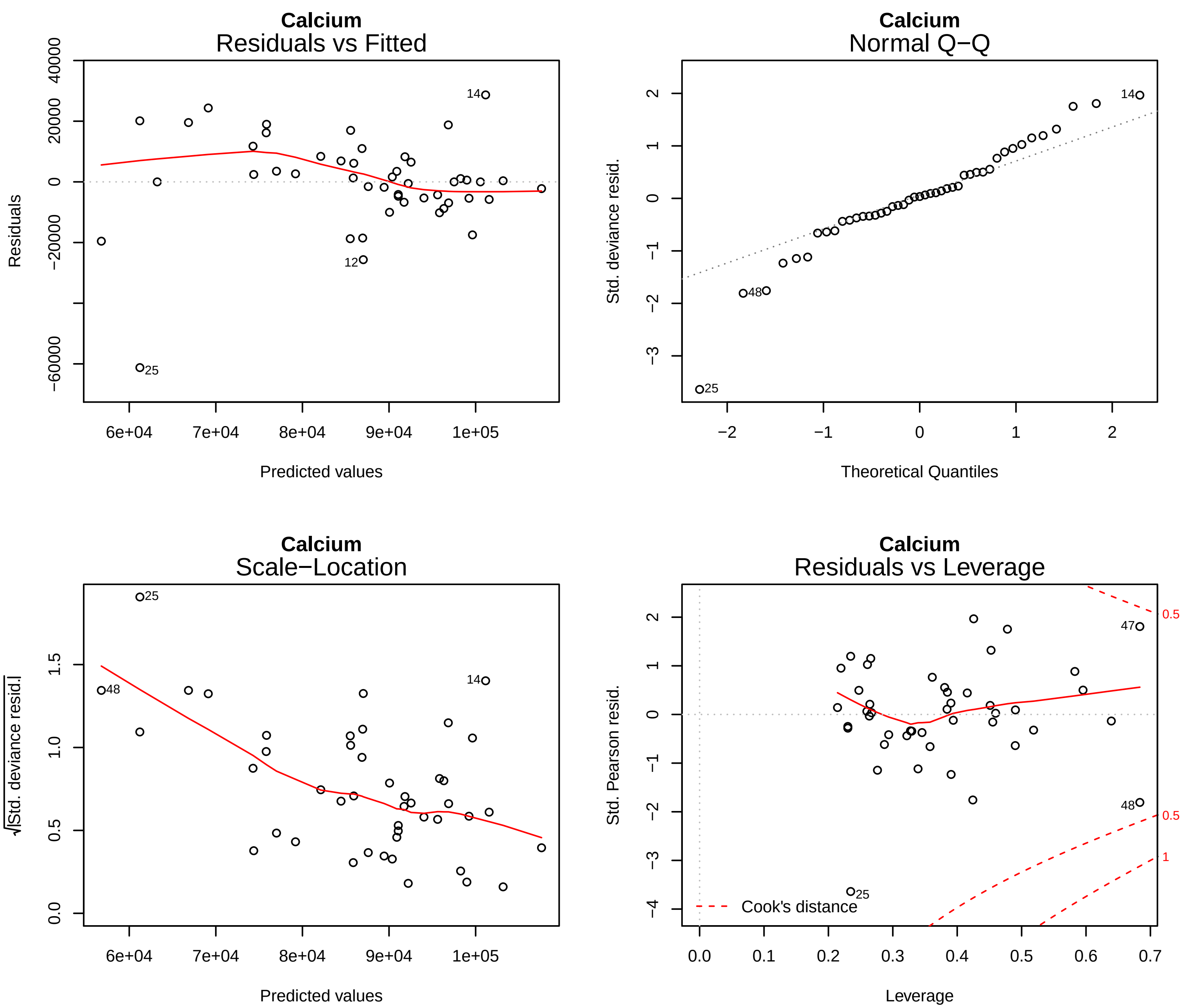






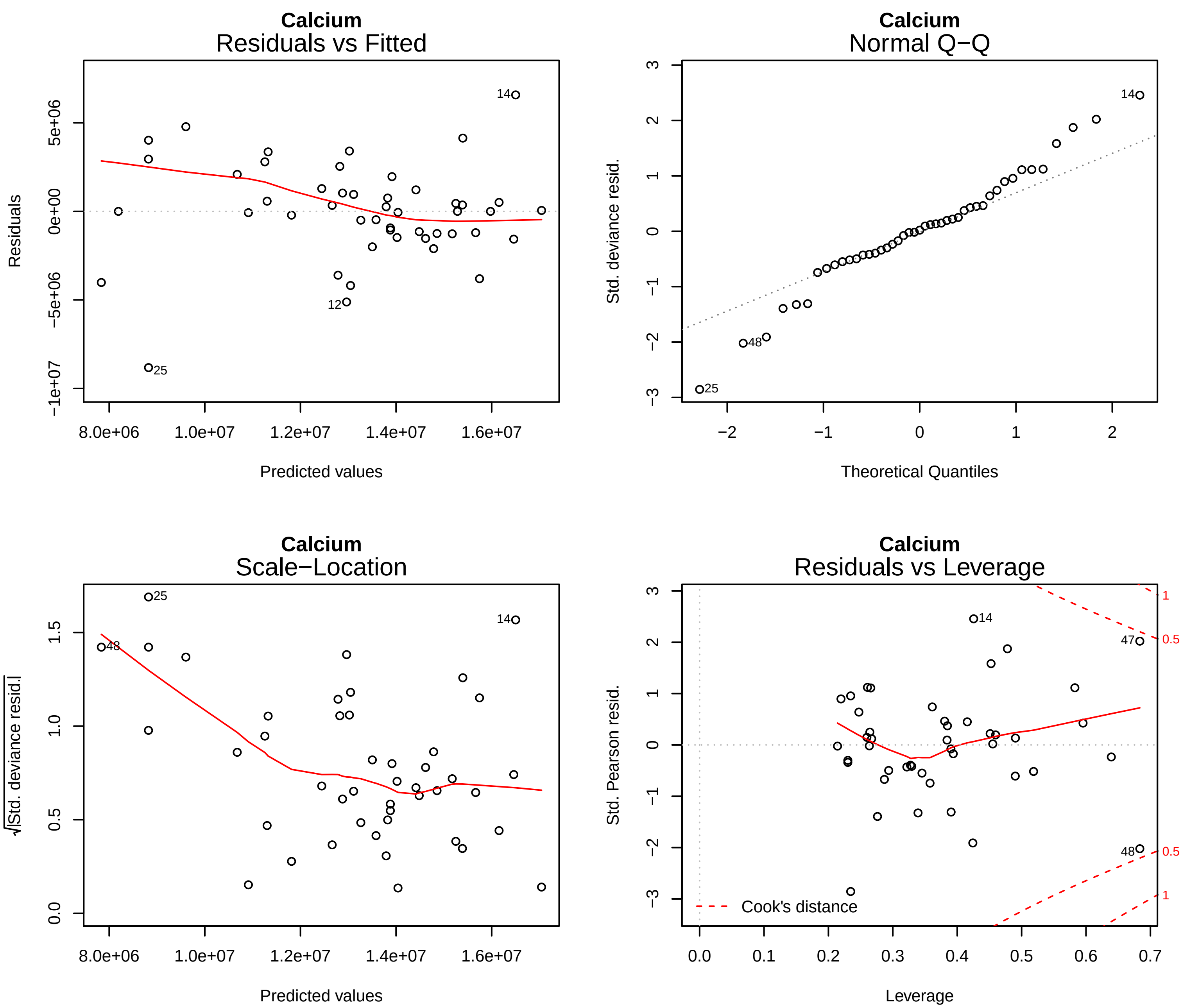
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

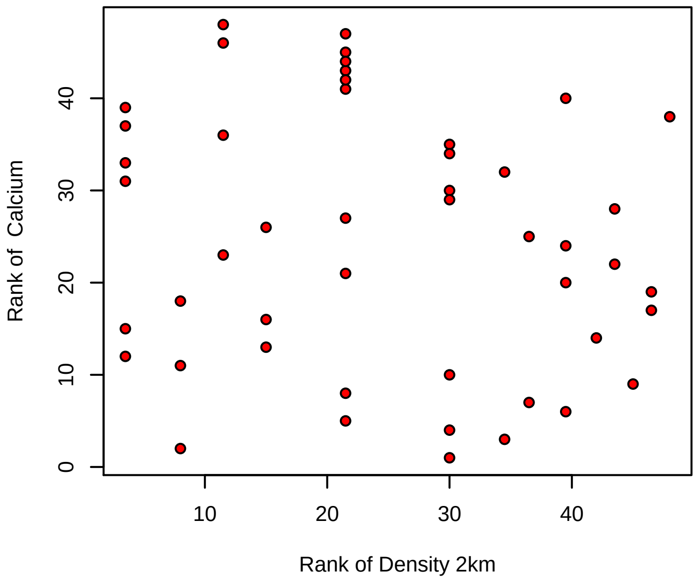
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



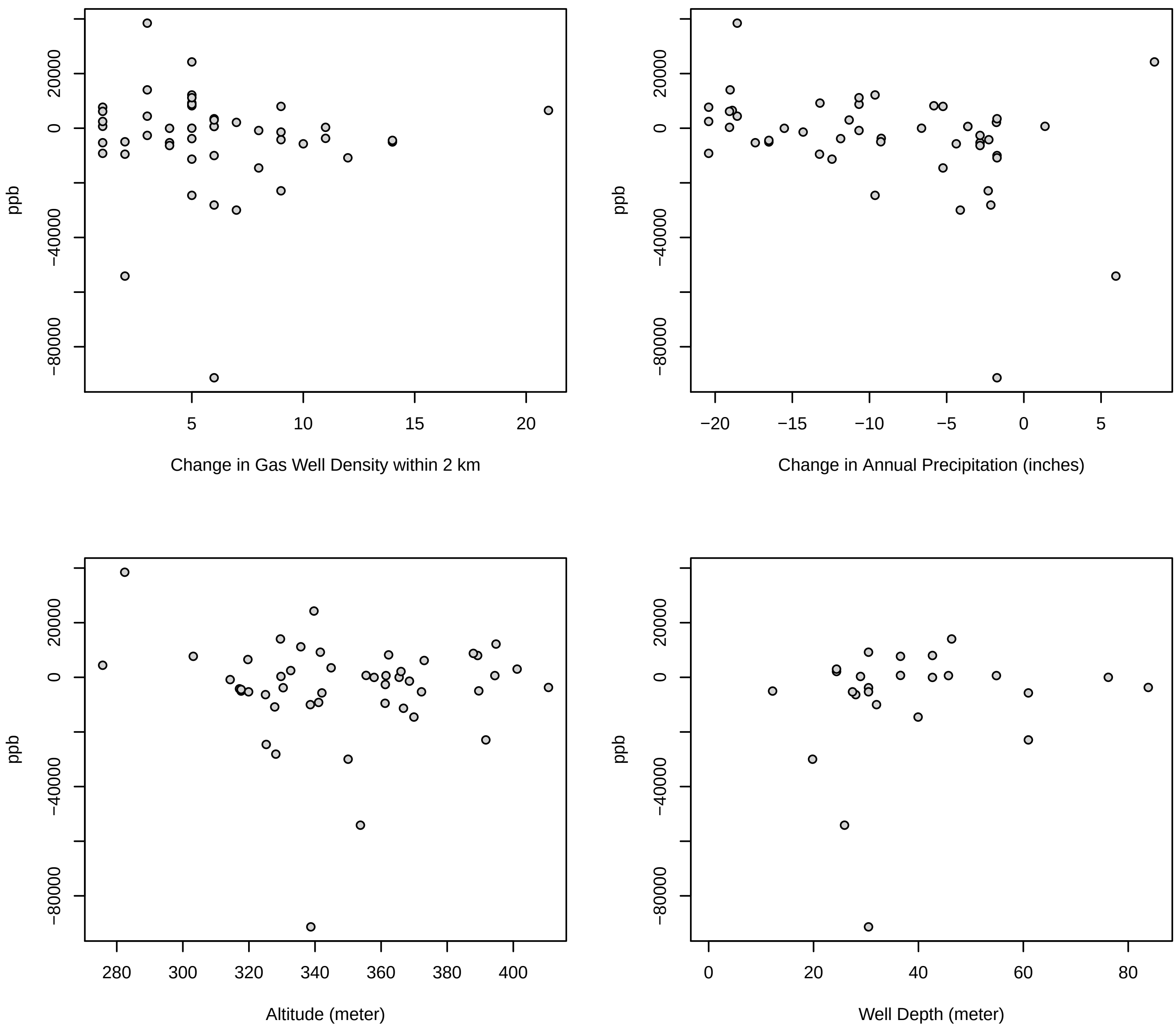


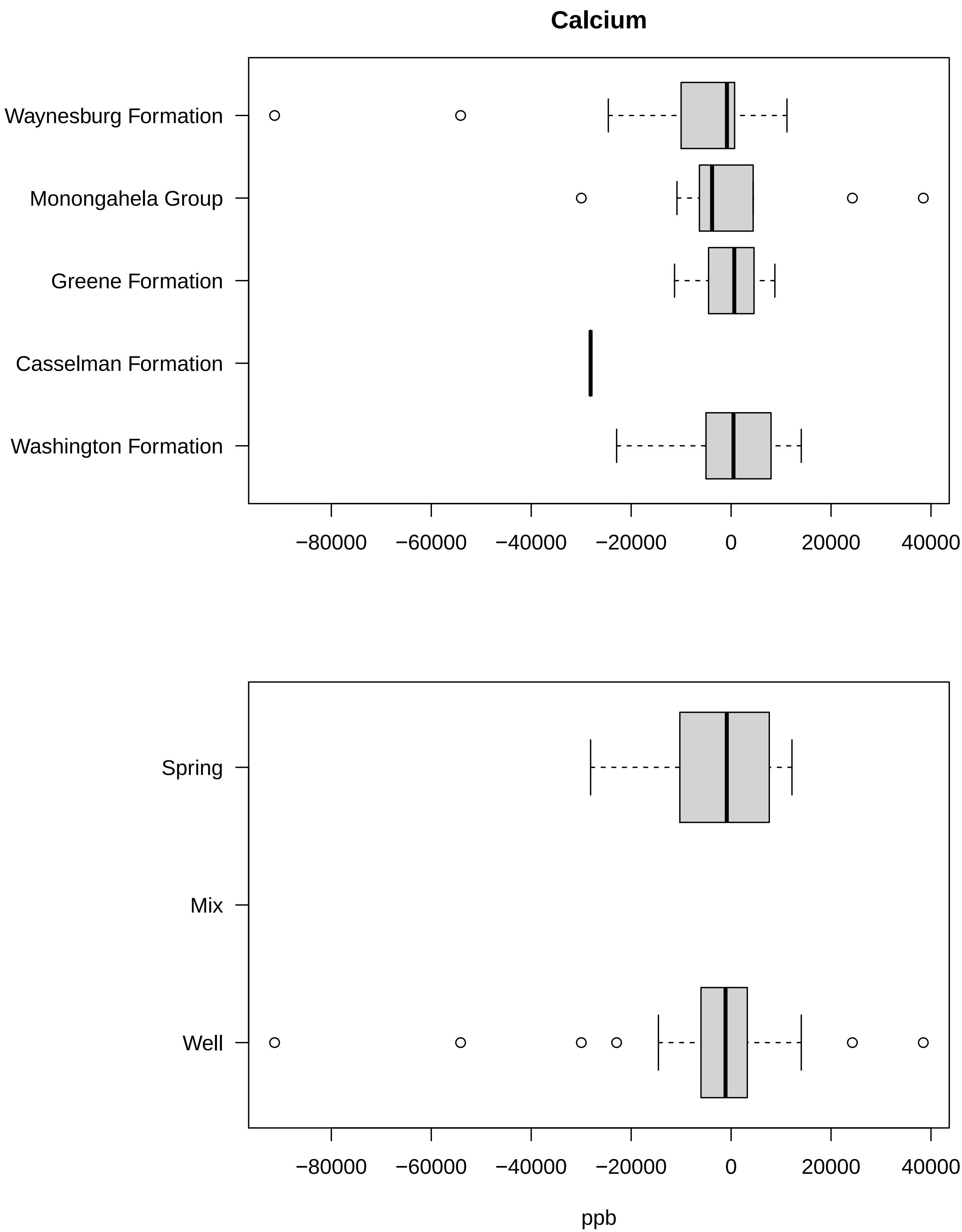
Calcium

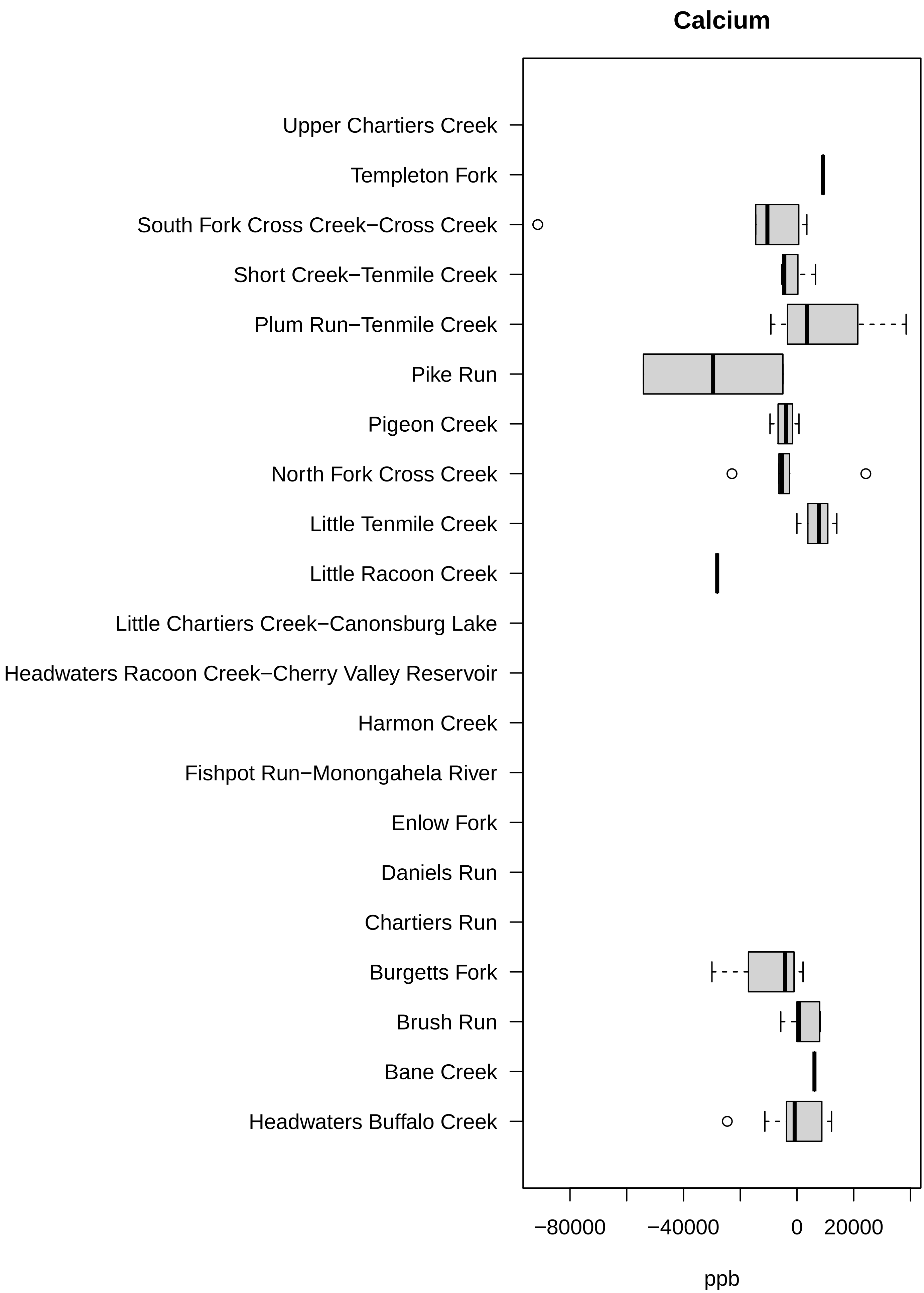
Kendalls Tau Rank Correlation

p−value: 0.219

Tau: −0.127




Calcium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−80000
−60000
−40000
−20000
0
20000
40000
Spring
Mix
Well
−80000
−60000
−40000
−20000
0
20000
40000
ppb


Calcium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−80000
−40000
0
20000
ppb

```
[1] "ORIGINAL MODEL - Calcium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
   Min      1Q  Median      3Q     Max  
-61228   -5498     180    7244   28666  

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                   90672.66   76406.84   1.187   0.2453  
dat$GWellDensity_2kmDiff                       -566.38    1183.71  -0.478   0.6360  
dat$Altitude_meter                               47.75     206.72   0.231   0.8190  
dat$WatershedBane Creek                        8540.12   23809.74   0.359   0.7225  
dat$WatershedBrush Run                        -3586.61   13845.10  -0.259   0.7975  
dat$WatershedBurgetts Fork                   -19944.97   17543.17  -1.137   0.2652  
dat$WatershedLittle Racoon Creek             -39488.61   25137.22  -1.571   0.1274  
dat$WatershedLittle Tenmile Creek             11281.40   17972.02   0.628   0.5353  
dat$WatershedNorth Fork Cross Creek          -16306.53   18906.36  -0.862   0.3957  
dat$WatershedPigeon Creek                     -7426.34   16766.97  -0.443   0.6612  
dat$WatershedPike Run                        -37945.94   20565.68  -1.845   0.0756 .
dat$WatershedPlum Run-Tenmile Creek            1505.82   18199.31   0.083   0.9346  
dat$WatershedShort Creek-Tenmile Creek          426.75   18739.83   0.023   0.9820  
dat$WatershedSouth Fork Cross Creek-Cross Creek -27122.76   14943.48  -1.815   0.0802 .
dat$WatershedTempleton Fork                    2217.40   23055.71   0.096   0.9241  
dat$FormationCasselman Formation                    NA         NA      NA       NA  
dat$FormationGreene Formation                -10549.41   12585.30  -0.838   0.4090  
dat$FormationMonongahela Group                 5363.82   14907.32   0.360   0.7217  
dat$FormationWaynesburg Formation            -14331.38   10241.93  -1.399   0.1727  
dat$HHWSourceSpring                             726.09    8924.56   0.081   0.9357  
dat$Precip_inchDiff                             440.26    1015.09   0.434   0.6678  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 369872257)

    Null deviance: 1.7289e+10  on 47  degrees of freedom
Residual deviance: 1.0356e+10  on 28  degrees of freedom
AIC: 1099.3

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Calcium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
     Min       1Q   Median       3Q      Max
-8822972 -1253292        0  1232894  6576724

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                   14094597   14031251   1.005   0.3237
dat$GWellDensity_2kmDiff                       -116607     217375  -0.536   0.5959
dat$Altitude_meter                                9555      37963   0.252   0.8031
dat$WatershedBane Creek                        2072223    4372390   0.474   0.6392
dat$WatershedBrush Run                         -887399    2542496  -0.349   0.7297
dat$WatershedBurgetts Fork                    -4516951    3221604  -1.402   0.1719
dat$WatershedLittle Racoon Creek              -8105935    4616166  -1.756   0.0900 .
dat$WatershedLittle Tenmile Creek              2425452    3300358   0.735   0.4685
dat$WatershedNorth Fork Cross Creek           -3725380    3471939  -1.073   0.2924
dat$WatershedPigeon Creek                     -1983939    3079064  -0.644   0.5246
dat$WatershedPike Run                         -7676230    3776654  -2.033   0.0517 .
dat$WatershedPlum Run-Tenmile Creek             926615    3342097   0.277   0.7836
dat$WatershedShort Creek-Tenmile Creek          358625    3441357   0.104   0.9177
dat$WatershedSouth Fork Cross Creek-Cross Creek -5158383  2744201  -1.880   0.0706 .
dat$WatershedTempleton Fork                     779673    4233919   0.184   0.8552
dat$FormationCasselman Formation                    NA         NA      NA       NA
dat$FormationGreene Formation                 -2049399    2311148  -0.887   0.3828
dat$FormationMonongahela Group                 1352667    2737561   0.494   0.6251
dat$FormationWaynesburg Formation             -2442198    1880814  -1.298   0.2047
dat$HHWSourceSpring                              23936    1638894   0.015   0.9885
dat$Precip_inchDiff                             119588     186411   0.642   0.5264
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1.247326e+13)

    Null deviance: 6.0077e+14  on 47  degrees of freedom
Residual deviance: 3.4925e+14  on 28  degrees of freedom
AIC: 1599.8

Number of Fisher Scoring iterations: 2
```

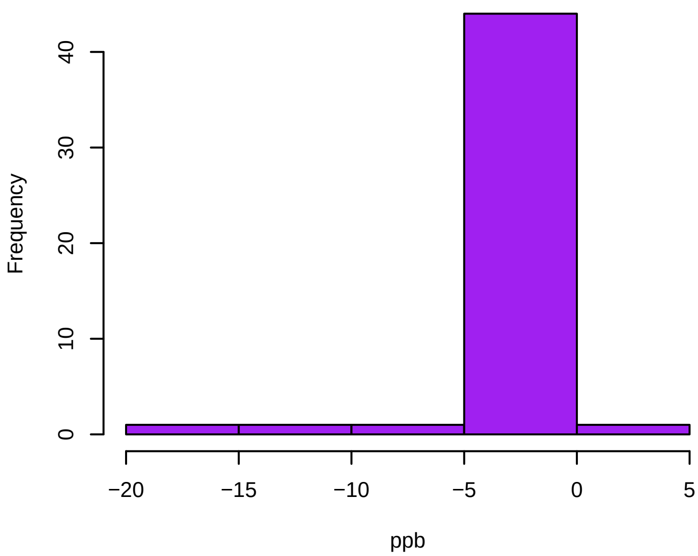
Chromium

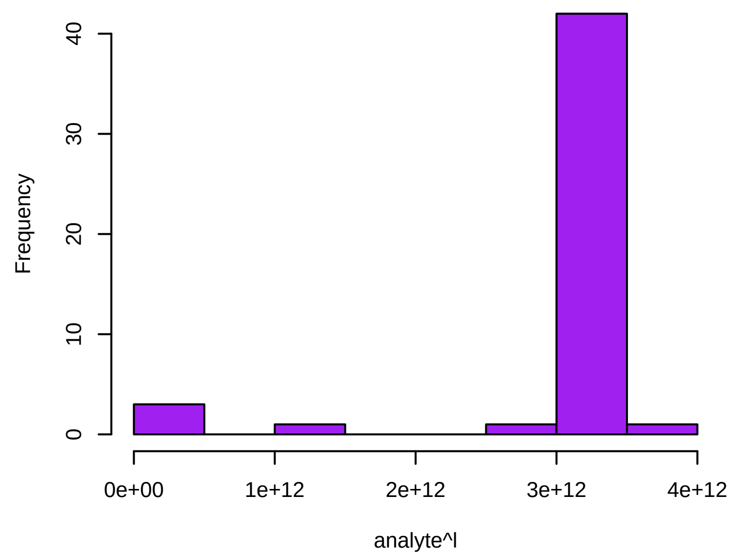
Skewness: −4.6767
Kurtosis: 24.7925

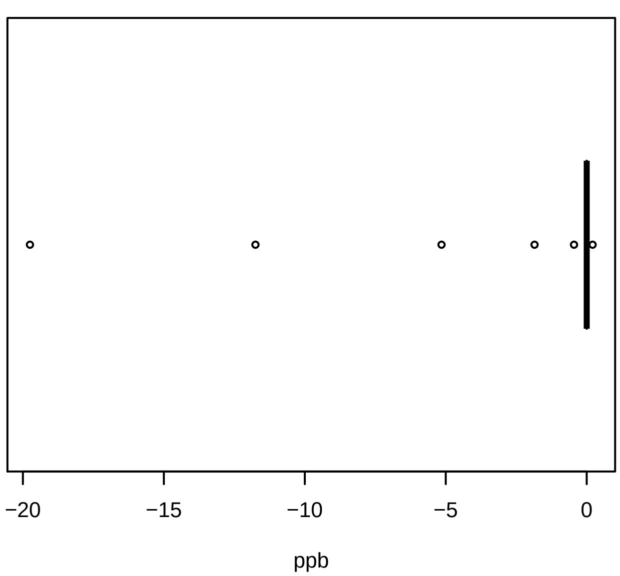
Chromium Box−Cox

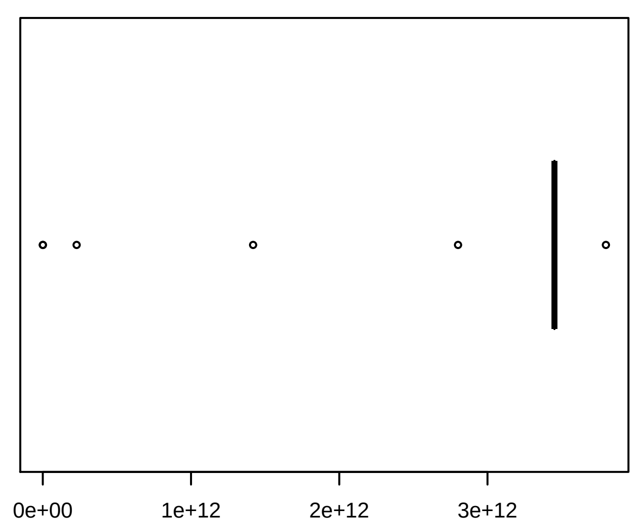
Skewness: −3.1156
Kurtosis: 11.1365

Optimal lambda: 9.52



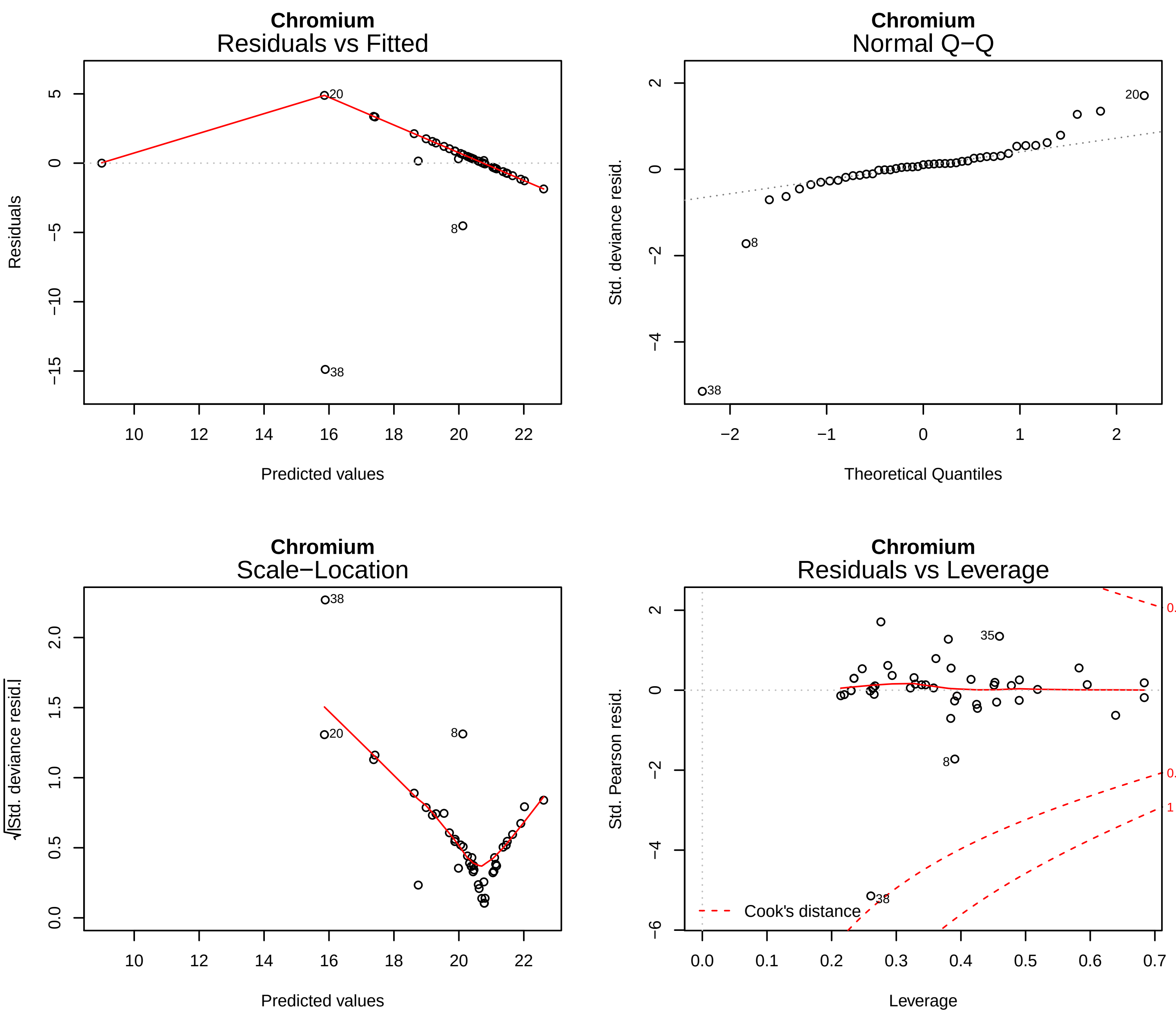






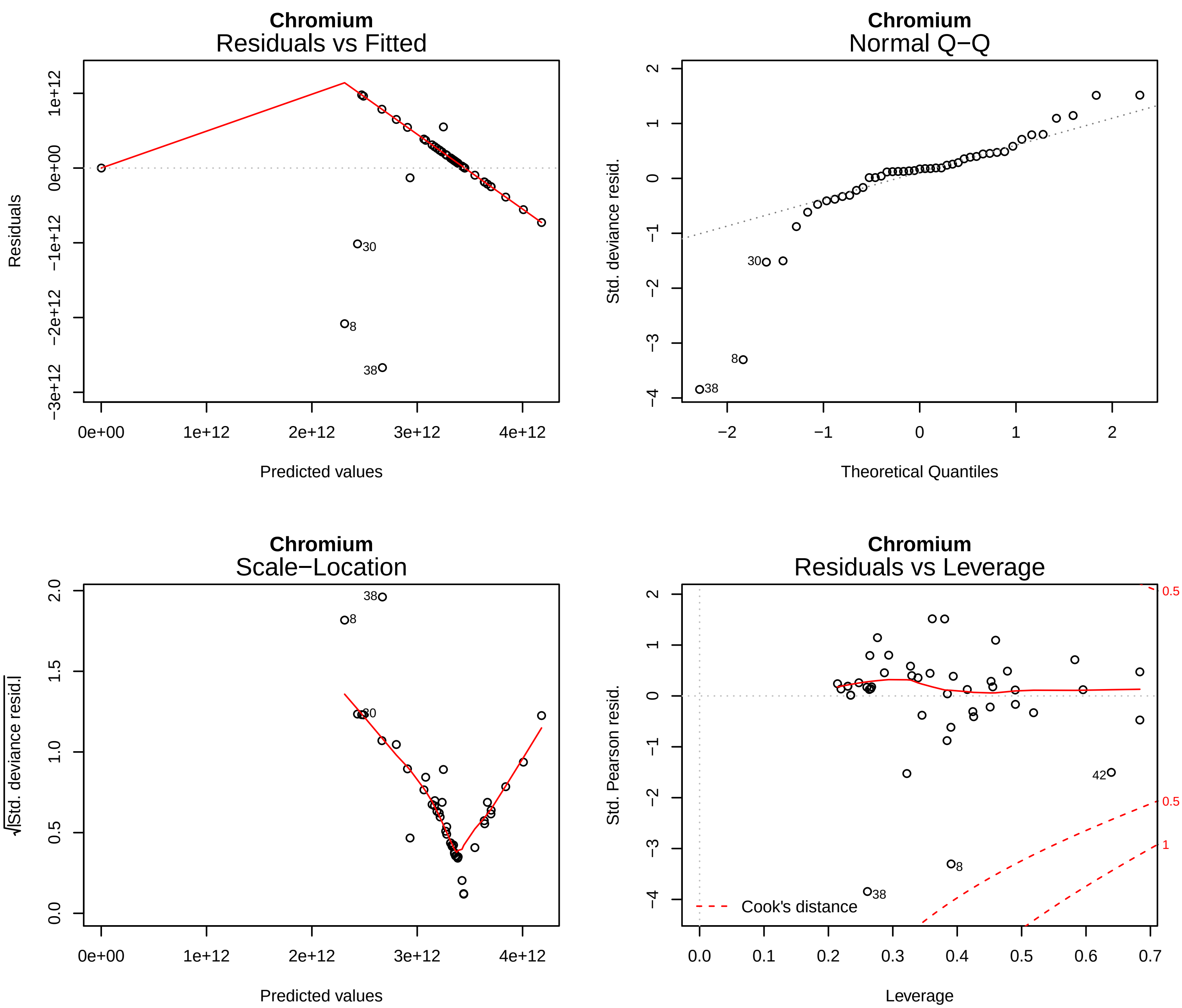
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

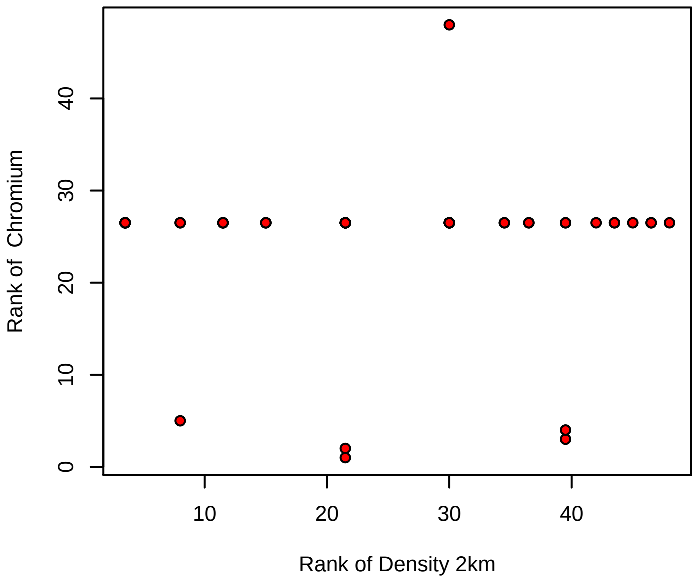
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



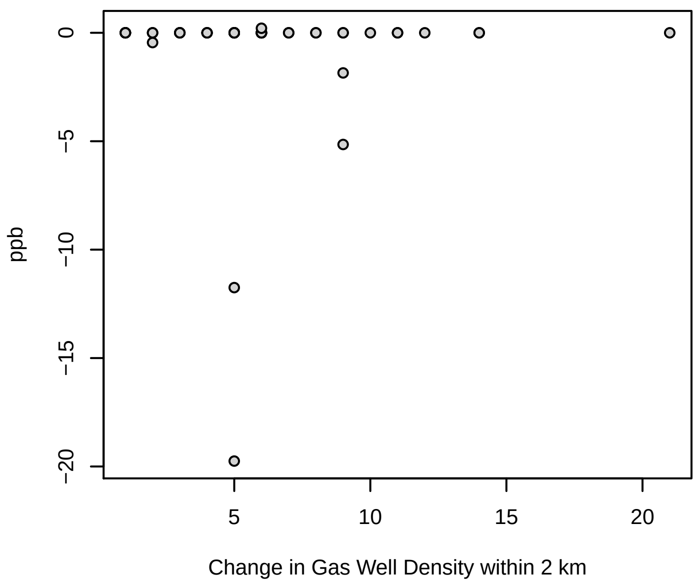


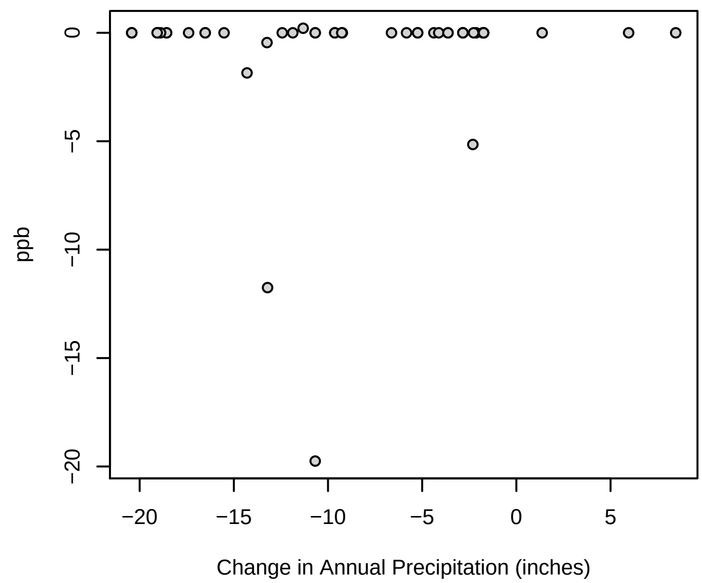
Chromium

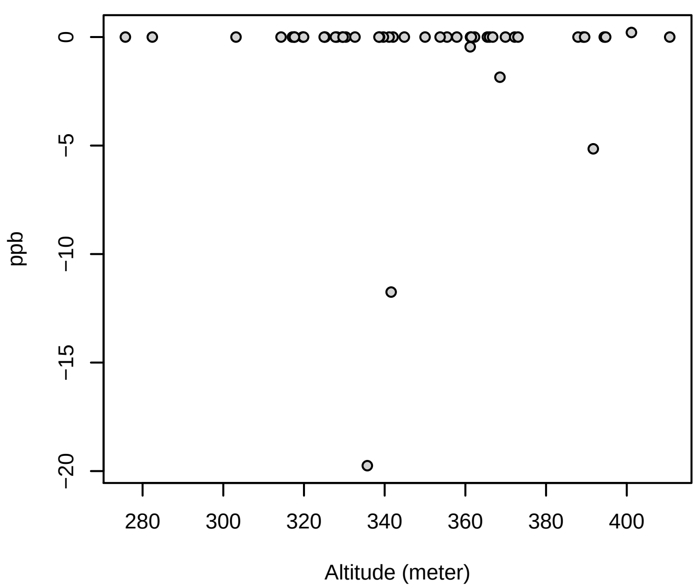
Kendalls Tau Rank Correlation

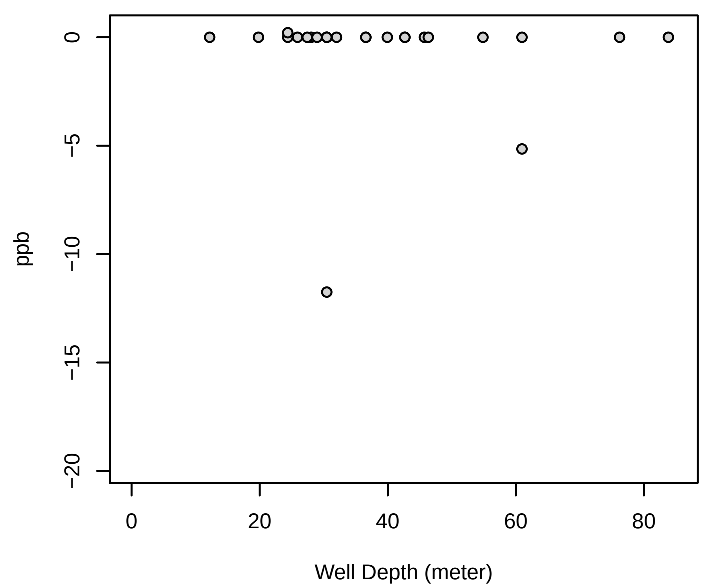
p−value: 0.938

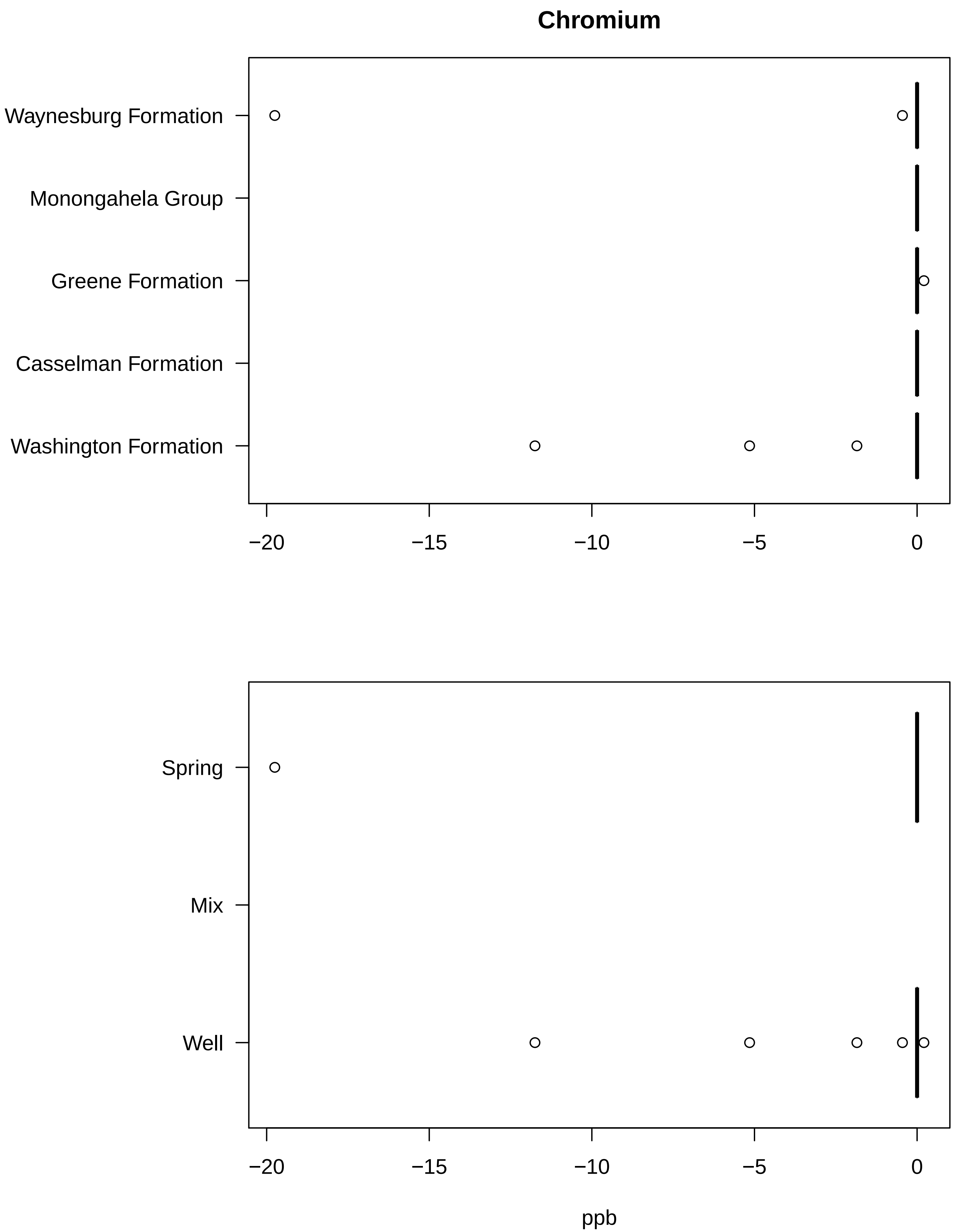
Tau: −0.00956

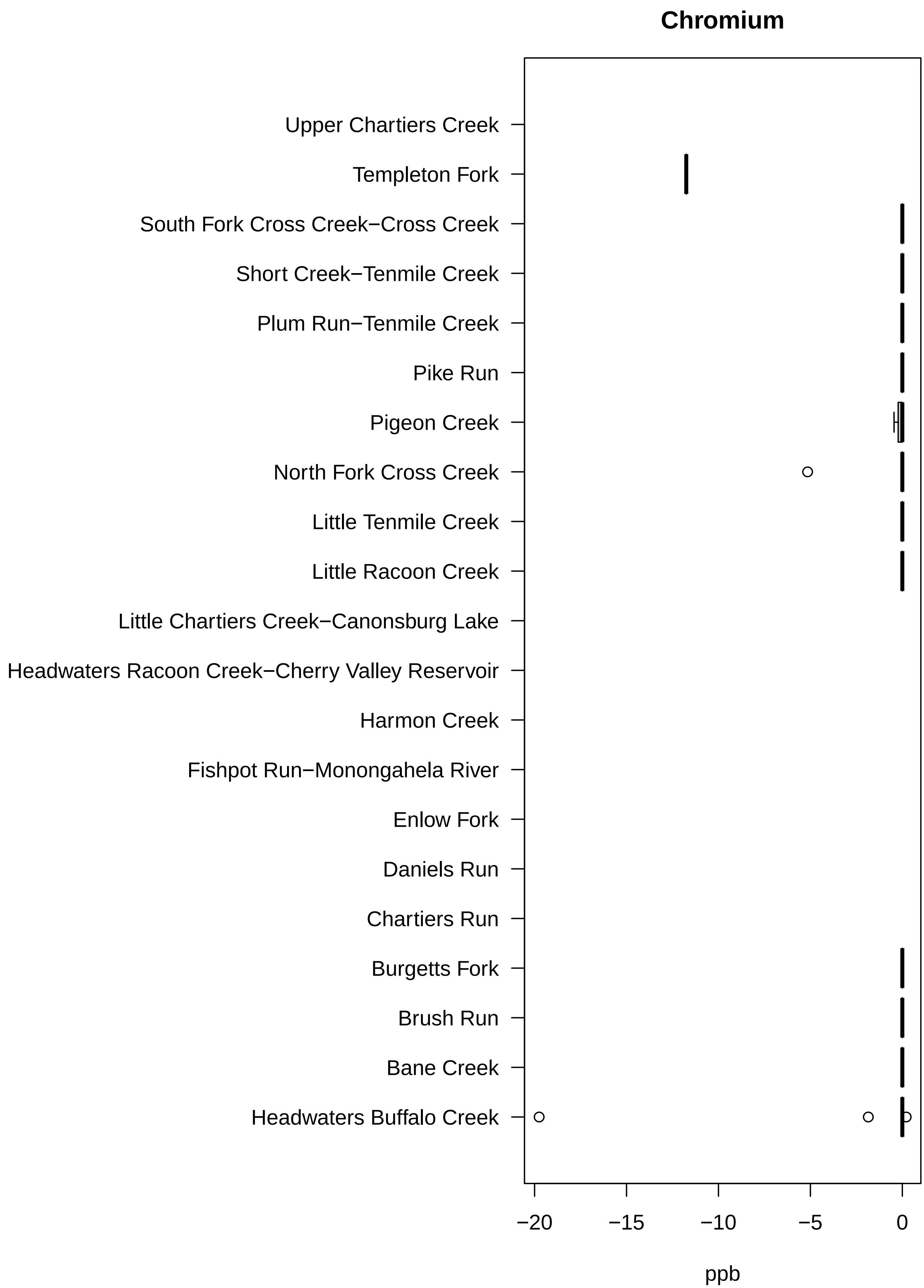









Chromium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−20
−15
−10
−5
0
Spring
Mix
Well
−20
−15
−10
−5
0
ppb


Chromium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−20
−15
−10
−5
0
ppb

```
[1] "ORIGINAL MODEL - Chromium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-14.8840   -0.3342    0.1708    0.7389    4.8908

Coefficients: (1 not defined because of singularities)
                                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                               16.636208  13.364877   1.245   0.2235
dat$GWellDensity_2kmDiff                   0.045589   0.207052   0.220   0.8273
dat$Altitude_meter                         0.006064   0.036160   0.168   0.8680
dat$WatershedBane Creek                    0.667308   4.164736   0.160   0.8739
dat$WatershedBrush Run                     1.595426   2.421748   0.659   0.5154
dat$WatershedBurgetts Fork                 2.490799   3.068603   0.812   0.4238
dat$WatershedLittle Racoon Creek           3.413739   4.396935   0.776   0.4440
dat$WatershedLittle Tenmile Creek          3.429176   3.143617   1.091   0.2846
dat$WatershedNorth Fork Cross Creek        0.786329   3.307050   0.238   0.8138
dat$WatershedPigeon Creek                  2.697436   2.932833   0.920   0.3656
dat$WatershedPike Run                      3.139519   3.597293   0.873   0.3902
dat$WatershedPlum Run-Tenmile Creek        3.875006   3.183374   1.217   0.2337
dat$WatershedShort Creek-Tenmile Creek     2.197424   3.277920   0.670   0.5081
dat$WatershedSouth Fork Cross Creek-Cross Creek  2.112508   2.613873   0.808   0.4258
dat$WatershedTempleton Fork               -9.443220   4.032842  -2.342   0.0265 *
dat$FormationCasselman Formation                 NA         NA      NA       NA
dat$FormationGreene Formation              1.849642   2.201386   0.840   0.4079
dat$FormationMonongahela Group             0.238794   2.607548   0.092   0.9277
dat$FormationWaynesburg Formation         -1.134283   1.791490  -0.633   0.5318
dat$HHWSourceSpring                       -1.483494   1.561059  -0.950   0.3501
dat$Precip_inchDiff                        0.037276   0.177558   0.210   0.8352
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 11.31663)

    Null deviance: 527.05  on 47  degrees of freedom
Residual deviance: 316.87  on 28  degrees of freedom
AIC: 268.81

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Chromium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
       Min          1Q      Median          3Q         Max
-2.670e+12  -1.043e+11   9.797e+10   2.482e+11   9.787e+11

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                  1.811e+12  3.209e+12   0.564   0.5771
dat$GWellDensity_2kmDiff                    -2.750e+10  4.971e+10  -0.553   0.5845
dat$Altitude_meter                           3.555e+09  8.681e+09   0.409   0.6853
dat$WatershedBane Creek                      4.042e+11  9.999e+11   0.404   0.6891
dat$WatershedBrush Run                       5.468e+11  5.814e+11   0.940   0.3550
dat$WatershedBurgetts Fork                   1.923e+11  7.367e+11   0.261   0.7960
dat$WatershedLittle Racoon Creek             6.836e+11  1.056e+12   0.648   0.5225
dat$WatershedLittle Tenmile Creek            1.031e+12  7.547e+11   1.366   0.1828
dat$WatershedNorth Fork Cross Creek         -5.738e+11  7.940e+11  -0.723   0.4758
dat$WatershedPigeon Creek                    1.894e+11  7.041e+11   0.269   0.7900
dat$WatershedPike Run                        3.597e+11  8.637e+11   0.416   0.6802
dat$WatershedPlum Run-Tenmile Creek          8.286e+11  7.643e+11   1.084   0.2875
dat$WatershedShort Creek-Tenmile Creek       1.270e+12  7.870e+11   1.614   0.1177
dat$WatershedSouth Fork Cross Creek-Cross Creek  5.350e+11  6.276e+11   0.853   0.4011
dat$WatershedTempleton Fork                 -2.480e+12  9.682e+11  -2.561   0.0161 *
dat$FormationCasselman Formation                    NA         NA      NA       NA
dat$FormationGreene Formation                5.251e+11  5.285e+11   0.993   0.3290
dat$FormationMonongahela Group               7.125e+11  6.260e+11   1.138   0.2647
dat$FormationWaynesburg Formation            1.102e+11  4.301e+11   0.256   0.7996
dat$HHWSourceSpring                          2.165e+10  3.748e+11   0.058   0.9543
dat$Precip_inchDiff                          3.078e+10  4.263e+10   0.722   0.4763
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 6.523136e+23)

    Null deviance: 3.5648e+25  on 47  degrees of freedom
Residual deviance: 1.8265e+25  on 28  degrees of freedom
AIC: 2784.4

Number of Fisher Scoring iterations: 2
```

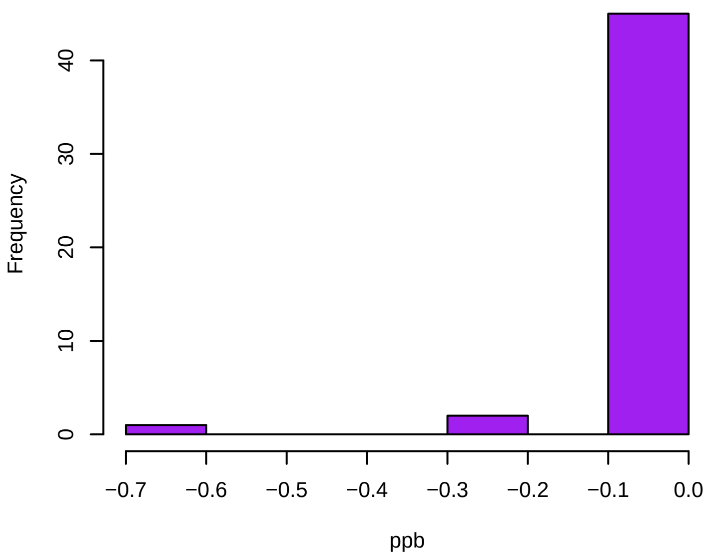
Cobalt

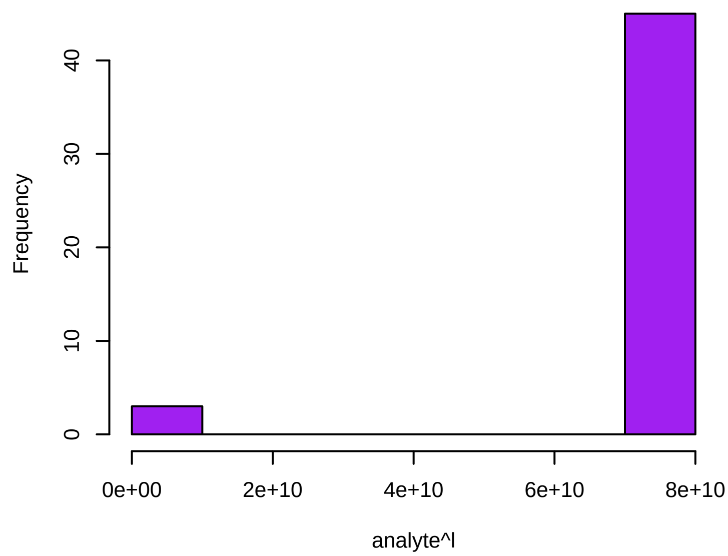
Skewness: −4.9495
Kurtosis: 28.2028

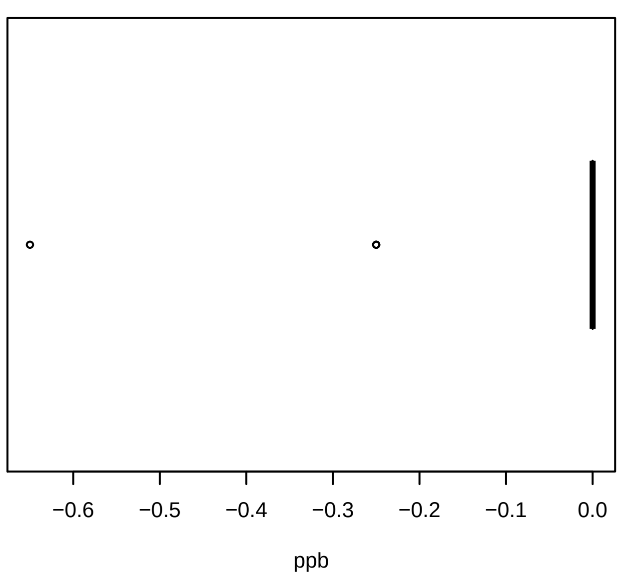
Cobalt Box−Cox

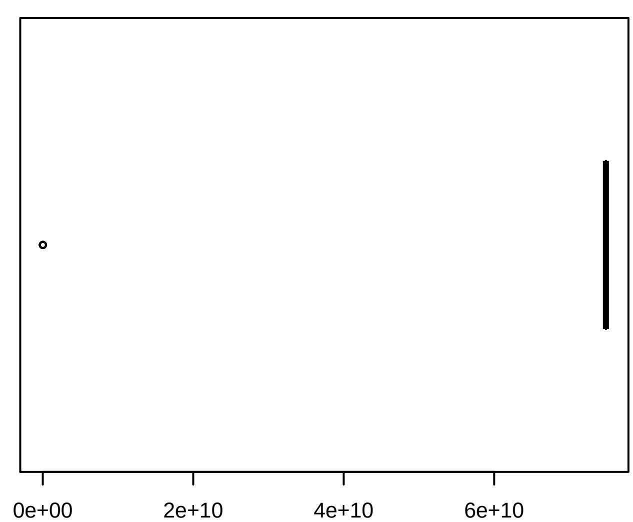
Skewness: −3.6148
Kurtosis: 14.0667

Optimal lambda: 50



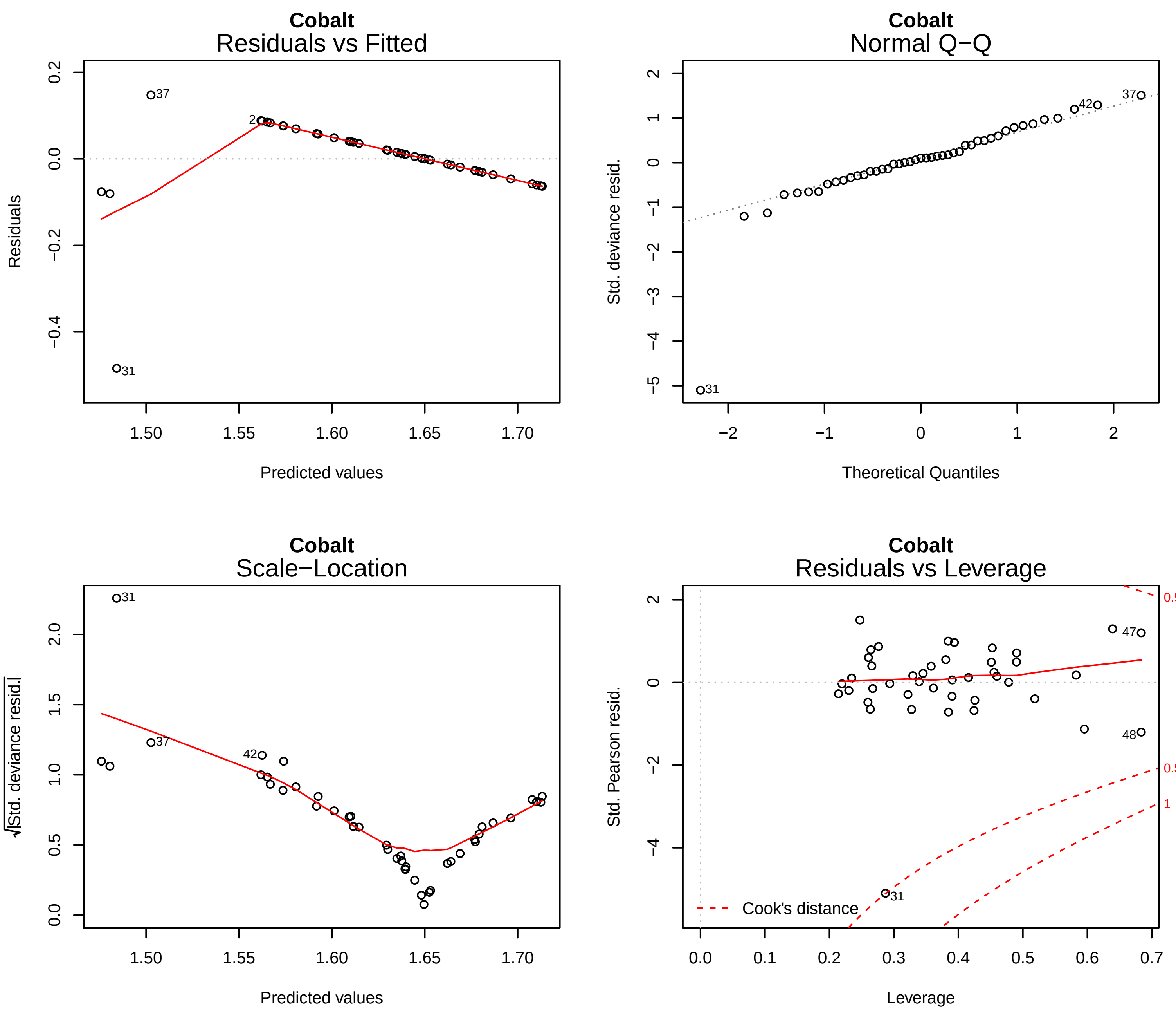






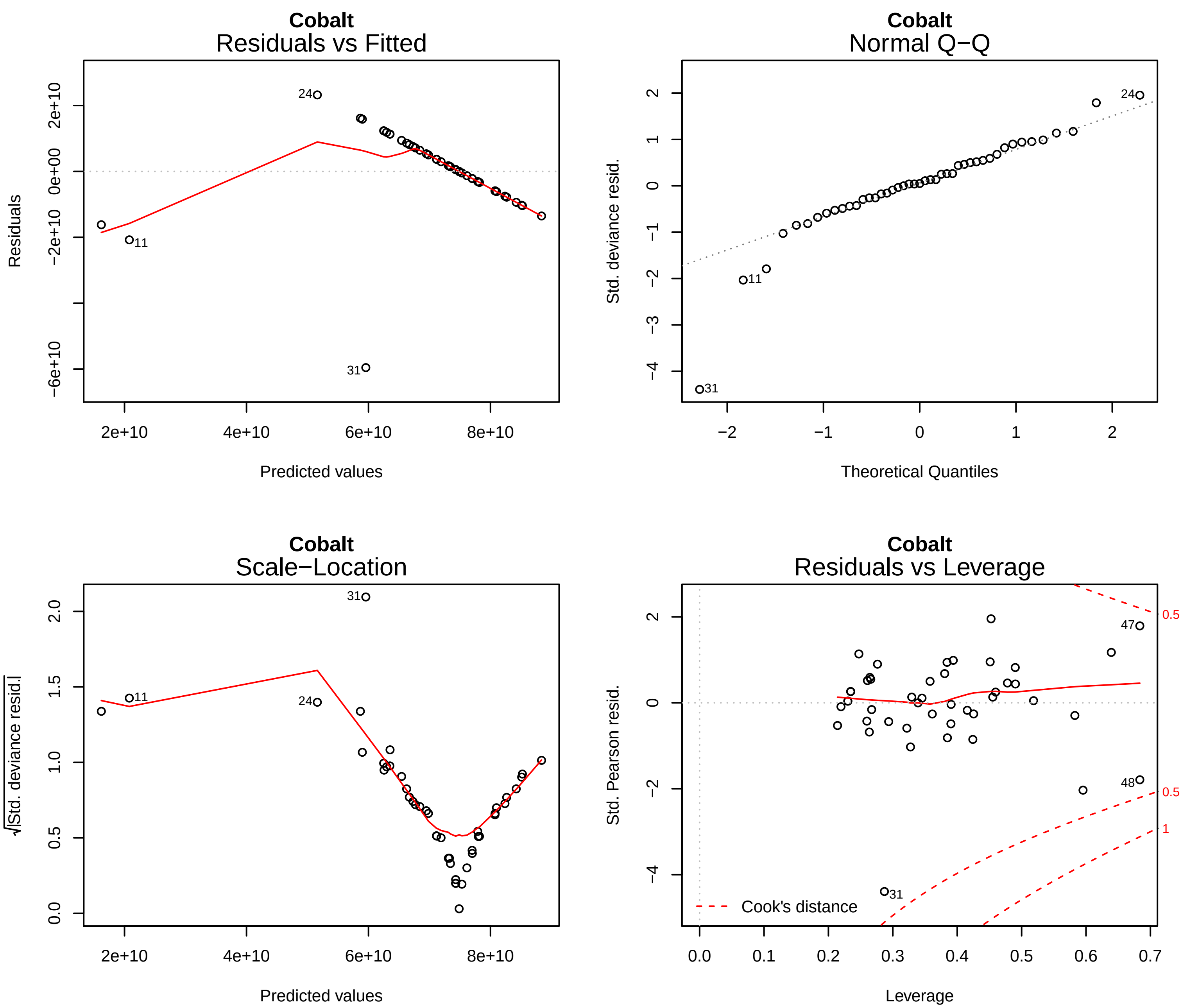
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

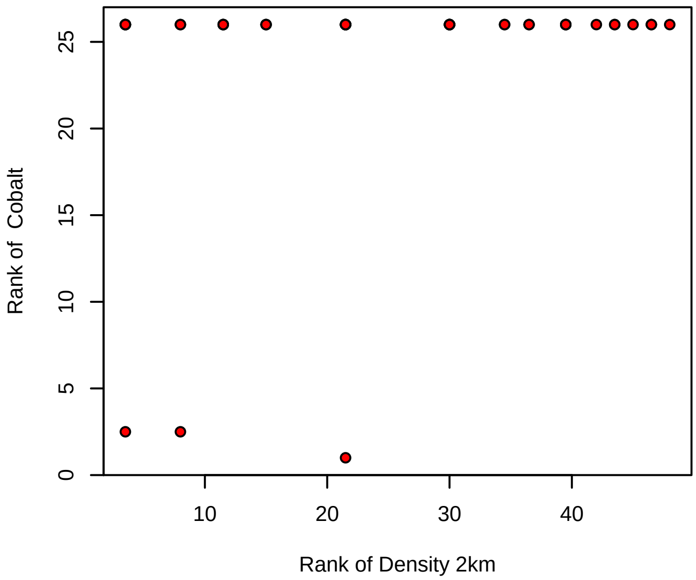
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



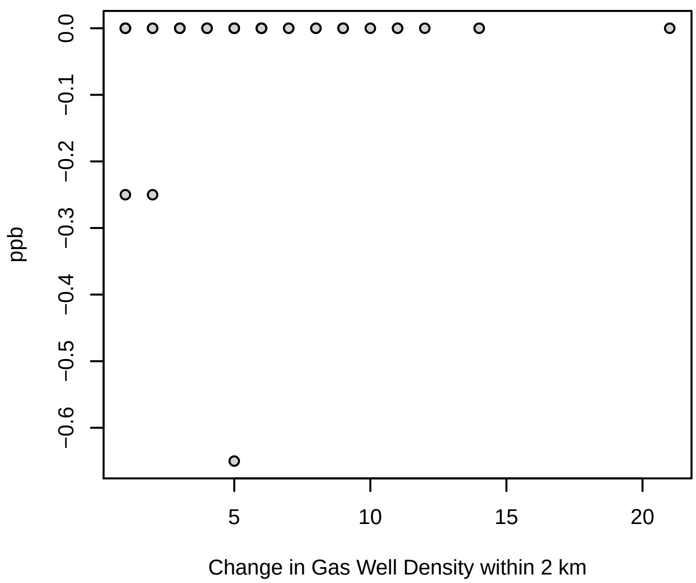


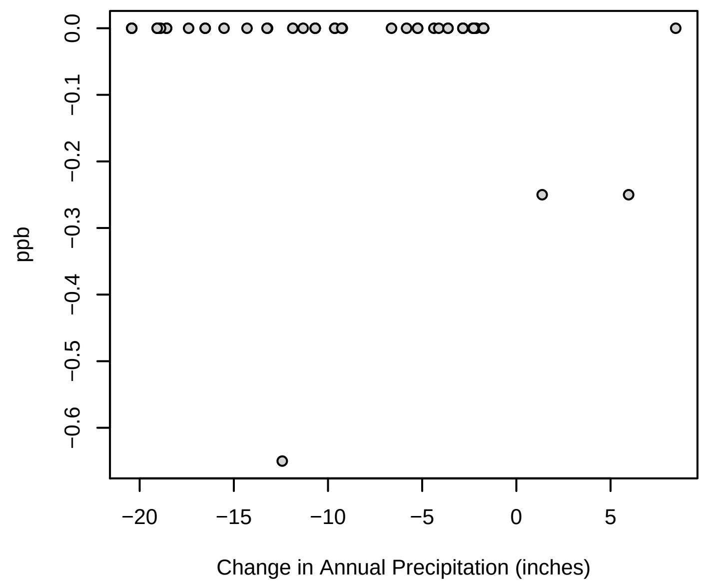
Cobalt

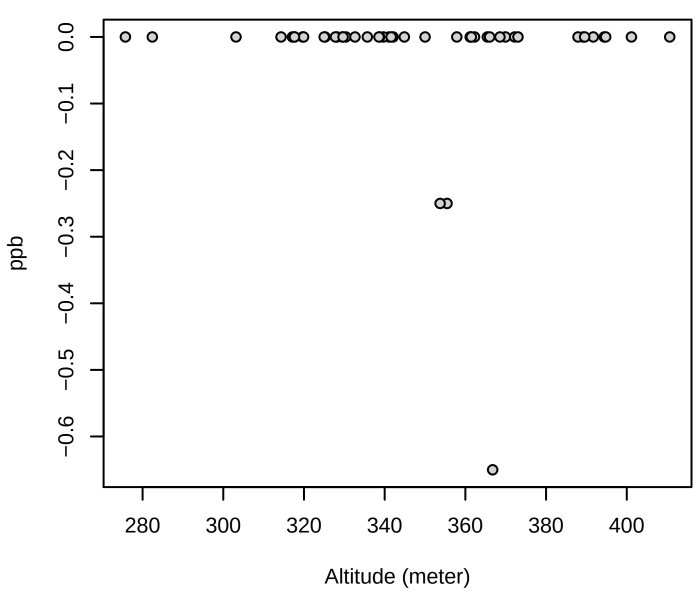
Kendalls Tau Rank Correlation

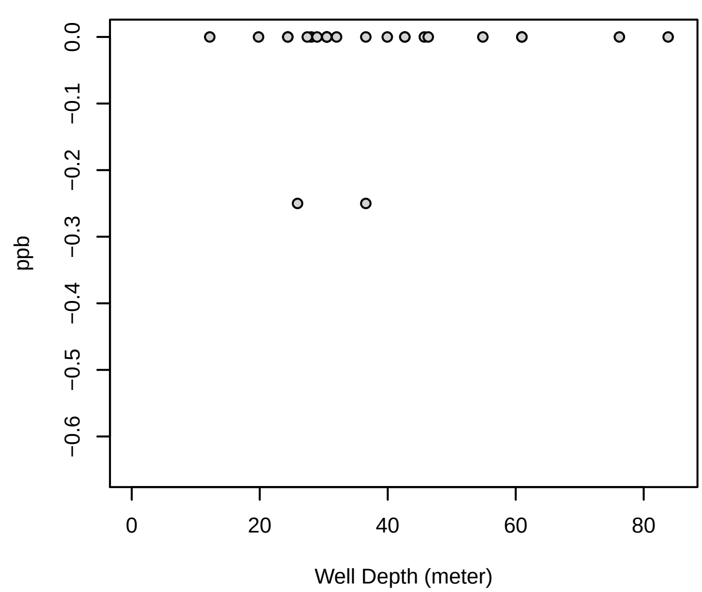
p−value: 0.0901

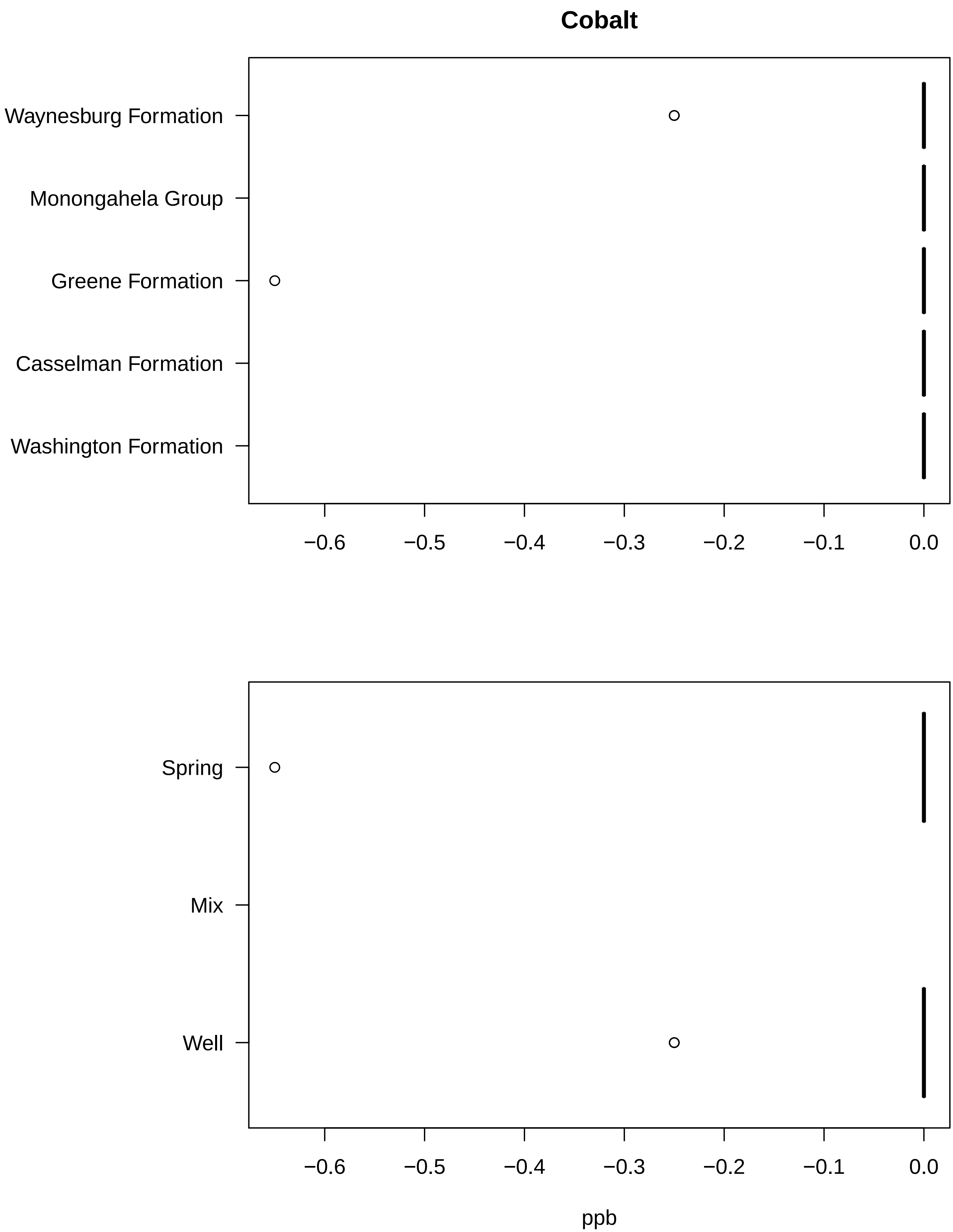
Tau: 0.211

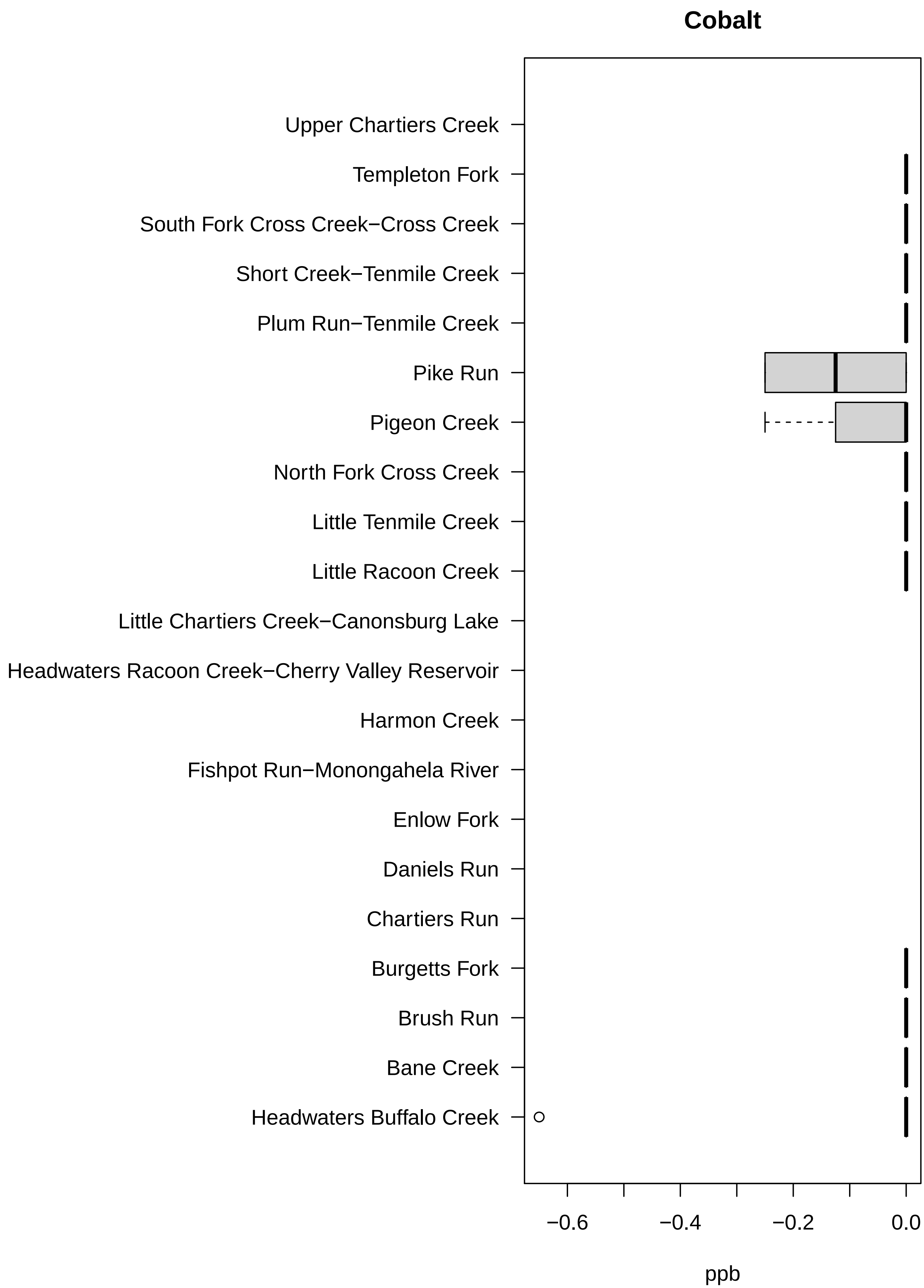









Cobalt
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
Spring
Mix
Well
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
ppb

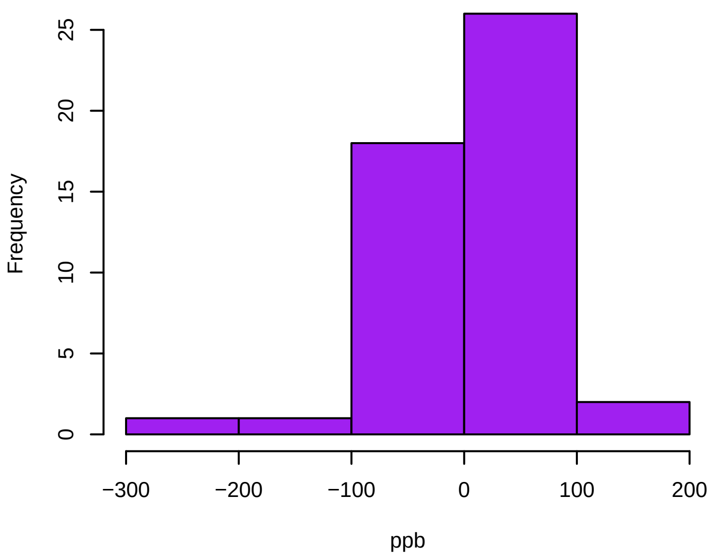

Cobalt
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−0.6
−0.4
−0.2
0.0
ppb

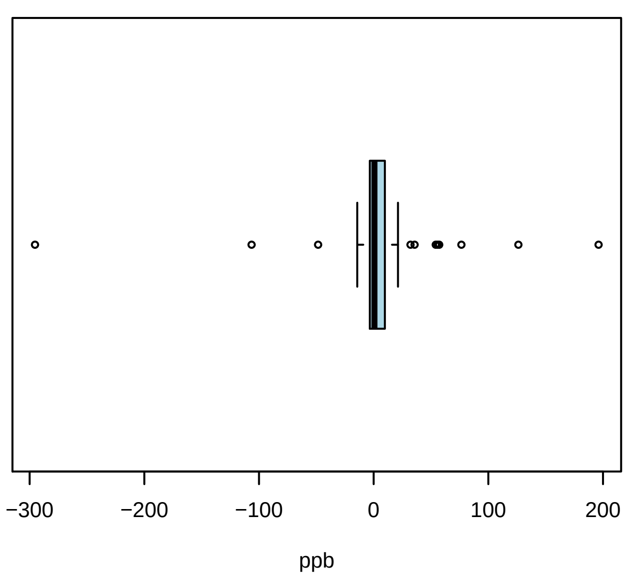
```
[1] "ORIGINAL MODEL - Cobalt"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.48417  -0.02697   0.00364   0.04005   0.14737  

Coefficients: (1 not defined because of singularities)
                                                Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                    0.9950513  0.4466133   2.228   0.0341 *
dat$GWellDensity_2kmDiff                      -0.0011976  0.0069190  -0.173   0.8638  
dat$Altitude_meter                             0.0015579  0.0012083   1.289   0.2078  
dat$WatershedBane Creek                        0.0499694  0.1391727   0.359   0.7223  
dat$WatershedBrush Run                         0.0623146  0.0809274   0.770   0.4477  
dat$WatershedBurgetts Fork                     0.0403176  0.1025433   0.393   0.6972  
dat$WatershedLittle Racoon Creek               0.1795124  0.1469321   1.222   0.2320  
dat$WatershedLittle Tenmile Creek             -0.0330443  0.1050501  -0.315   0.7554  
dat$WatershedNorth Fork Cross Creek            0.0309236  0.1105115   0.280   0.7817  
dat$WatershedPigeon Creek                     -0.0933064  0.0980063  -0.952   0.3492  
dat$WatershedPike Run                         -0.0559970  0.1202105  -0.466   0.6449  
dat$WatershedPlum Run-Tenmile Creek            0.0001174  0.1063786   0.001   0.9991  
dat$WatershedShort Creek-Tenmile Creek         0.0590438  0.1095381   0.539   0.5941  
dat$WatershedSouth Fork Cross Creek-Cross Creek  0.0720038  0.0873476   0.824   0.4167  
dat$WatershedTempleton Fork                    0.0193532  0.1347652   0.144   0.8868  
dat$FormationCasselman Formation                      NA         NA      NA       NA  
dat$FormationGreene Formation                 -0.1329058  0.0735636  -1.807   0.0816 .
dat$FormationMonongahela Group                 0.1014520  0.0871363   1.164   0.2541  
dat$FormationWaynesburg Formation              0.0375700  0.0598661   0.628   0.5354  
dat$HHWSourceSpring                           -0.0463043  0.0521658  -0.888   0.3823  
dat$Precip_inchDiff                           -0.0082807  0.0059334  -1.396   0.1738  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.01263719)

    Null deviance: 0.51995  on 47  degrees of freedom
Residual deviance: 0.35384  on 28  degrees of freedom
AIC: -57.467

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Cobalt"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
       Min          1Q      Median          3Q         Max
-5.956e+10  -3.976e+09   5.567e+08   7.253e+09   2.324e+10

Coefficients: (1 not defined because of singularities)
                                               Estimate Std. Error t value Pr(>|t|)
(Intercept)                                  -3.439e+10  6.381e+10  -0.539  0.59422
dat$GWellDensity_2kmDiff                     -5.367e+07  9.886e+08  -0.054  0.95709
dat$Altitude_meter                            2.085e+08  1.726e+08   1.208  0.23732
dat$WatershedBane Creek                      -8.307e+09  1.988e+10  -0.418  0.67931
dat$WatershedBrush Run                        1.956e+10  1.156e+10   1.692  0.10183
dat$WatershedBurgetts Fork                    1.773e+10  1.465e+10   1.210  0.23631
dat$WatershedLittle Racoon Creek              3.824e+10  2.099e+10   1.822  0.07921 .
dat$WatershedLittle Tenmile Creek            -1.503e+10  1.501e+10  -1.001  0.32523
dat$WatershedNorth Fork Cross Creek           2.196e+10  1.579e+10   1.391  0.17533
dat$WatershedPigeon Creek                    -2.013e+10  1.400e+10  -1.438  0.16161
dat$WatershedPike Run                        -1.125e+10  1.718e+10  -0.655  0.51790
dat$WatershedPlum Run-Tenmile Creek          -1.673e+10  1.520e+10  -1.101  0.28036
dat$WatershedShort Creek-Tenmile Creek       -3.793e+09  1.565e+10  -0.242  0.81025
dat$WatershedSouth Fork Cross Creek-Cross Creek  2.516e+10  1.248e+10   2.016  0.05351 .
dat$WatershedTempleton Fork                   7.028e+08  1.925e+10   0.036  0.97114
dat$FormationCasselman Formation                     NA         NA      NA       NA
dat$FormationGreene Formation                -1.443e+10  1.051e+10  -1.373  0.18061
dat$FormationMonongahela Group                1.757e+10  1.245e+10   1.411  0.16919
dat$FormationWaynesburg Formation             5.157e+09  8.554e+09   0.603  0.55145
dat$HHWSourceSpring                          -3.178e+09  7.453e+09  -0.426  0.67306
dat$Precip_inchDiff                          -2.845e+09  8.478e+08  -3.356  0.00228 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 2.579746e+20)

    Null deviance: 1.5752e+22  on 47  degrees of freedom
Residual deviance: 7.2233e+21  on 28  degrees of freedom
AIC: 2408.3

Number of Fisher Scoring iterations: 2
```

Copper

Skewness: −1.7832
Kurtosis: 15.5447

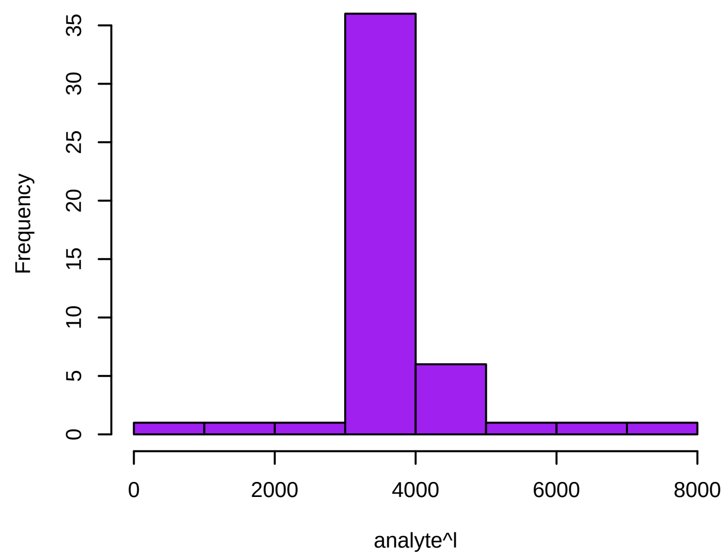


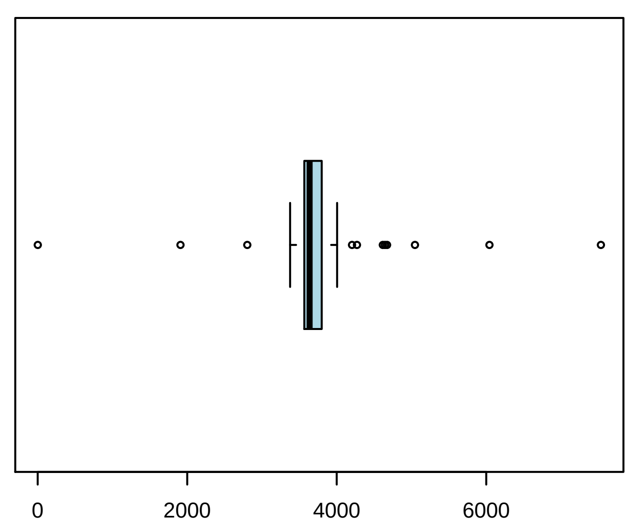


Copper Box−Cox

Skewness: 0.2342
Kurtosis: 11.2260

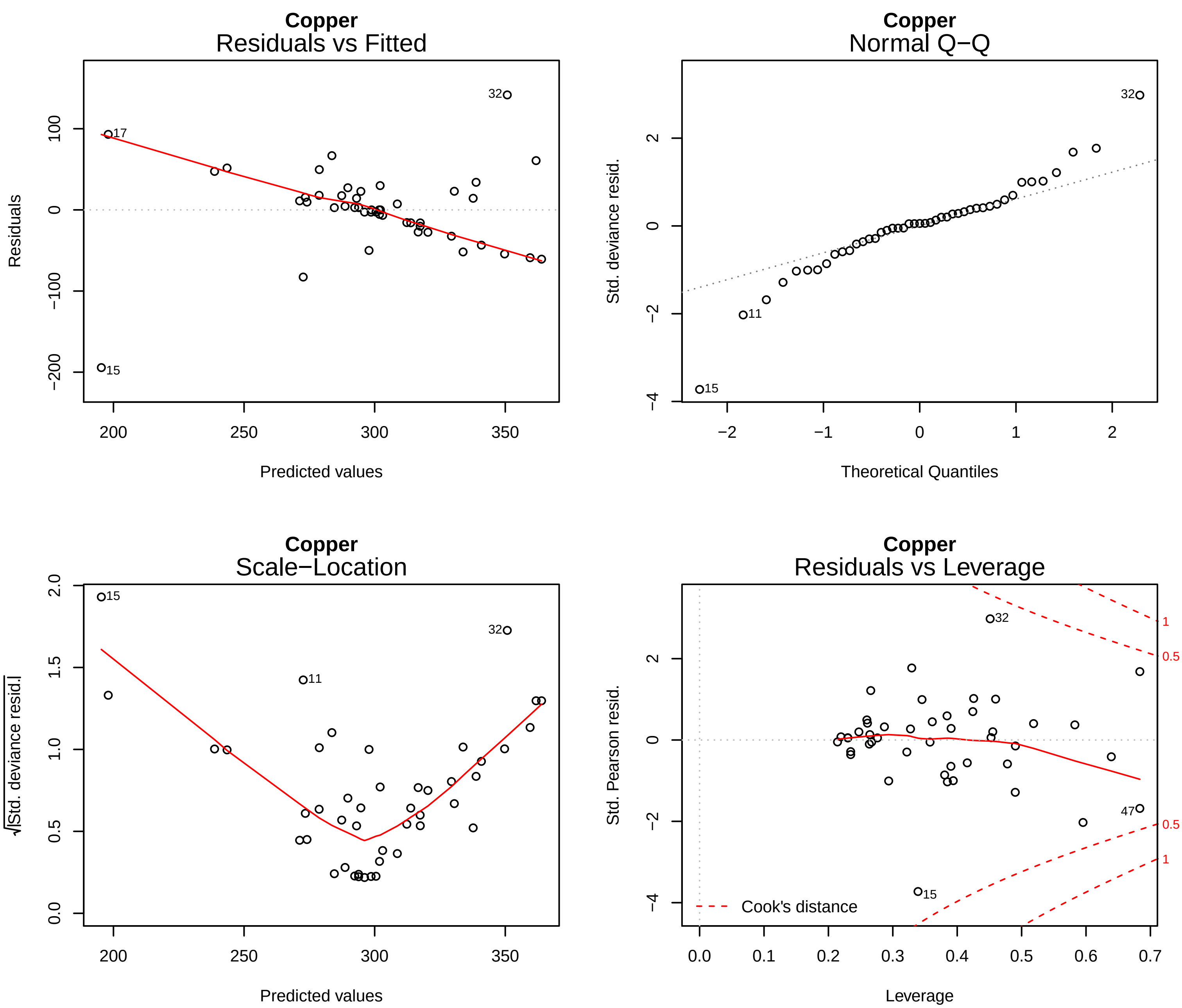
Optimal lambda: 1.44





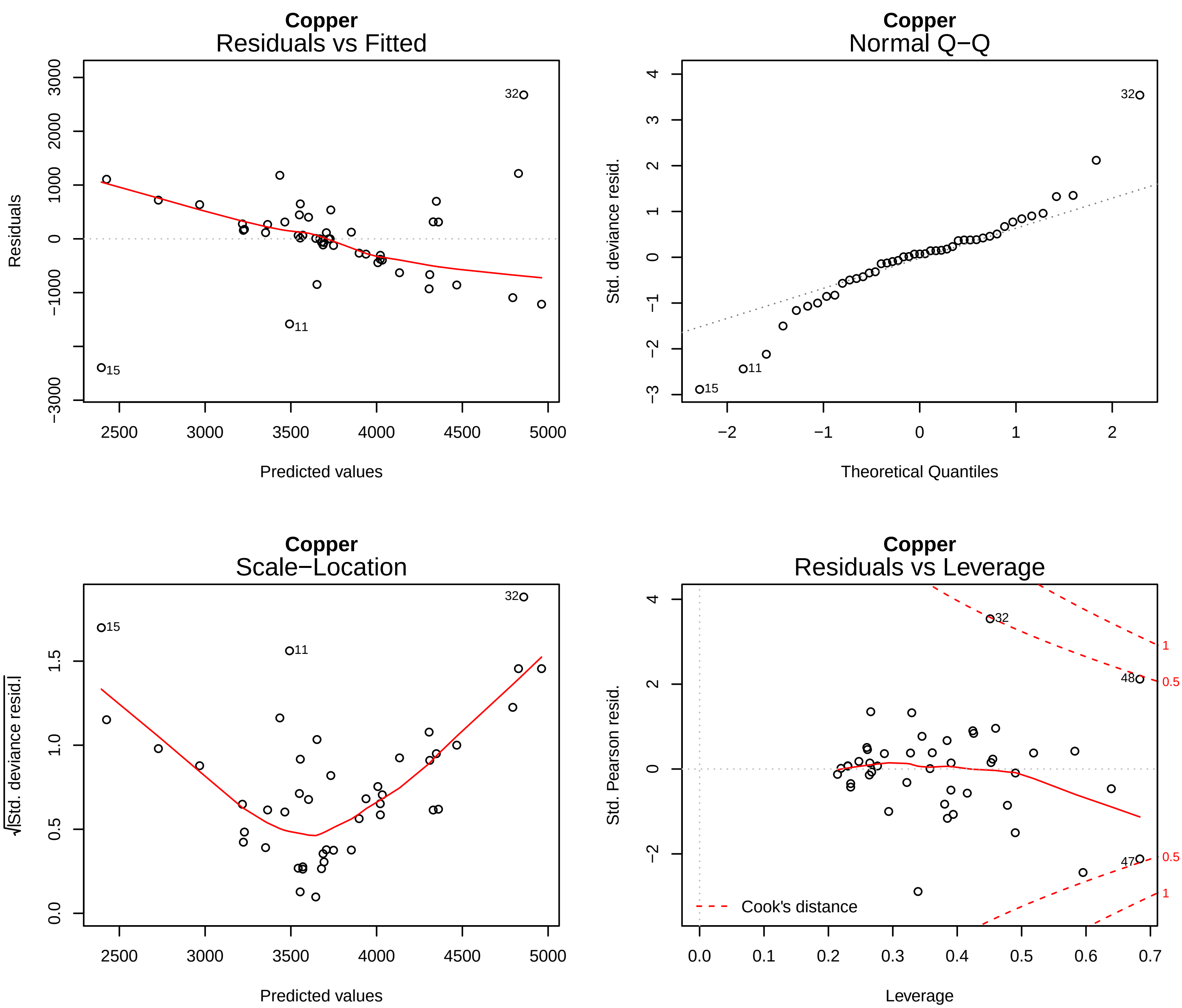
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

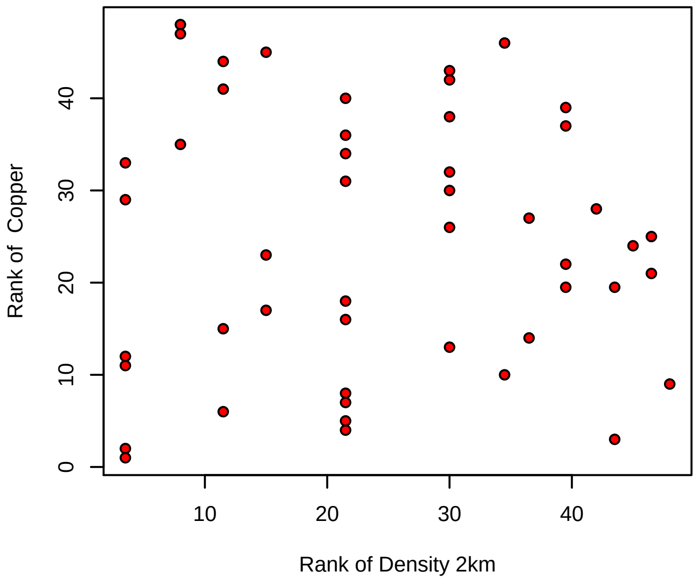
Original
Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



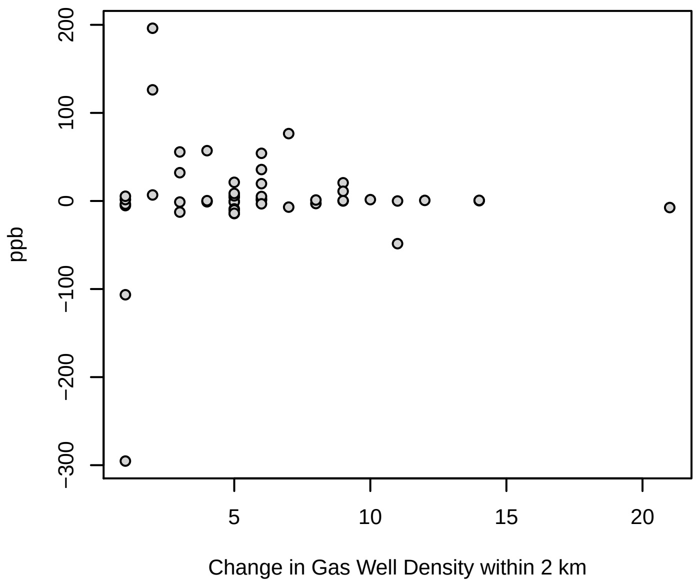


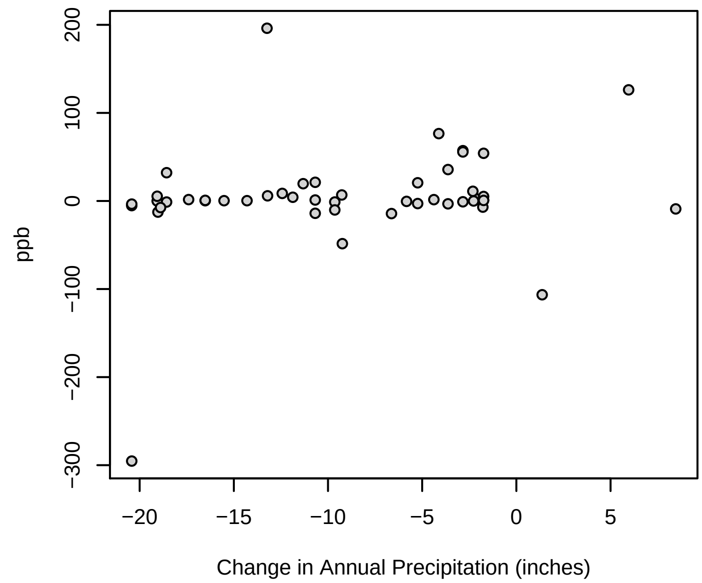
Copper

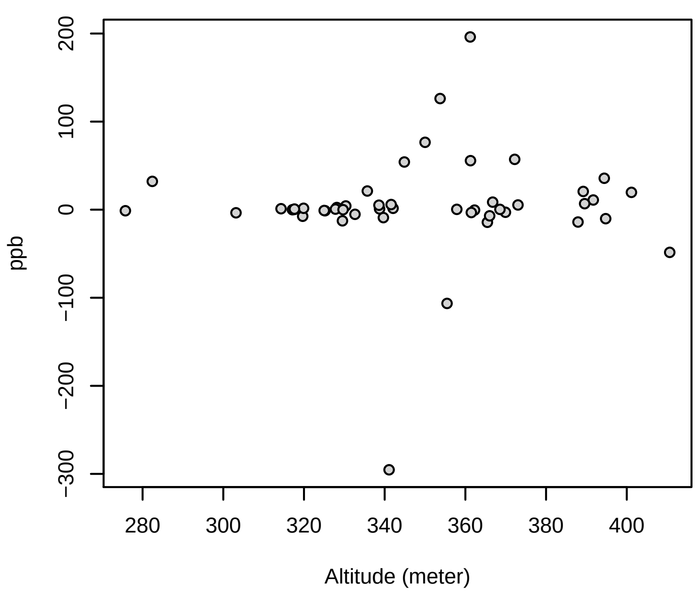
Kendalls Tau Rank Correlation

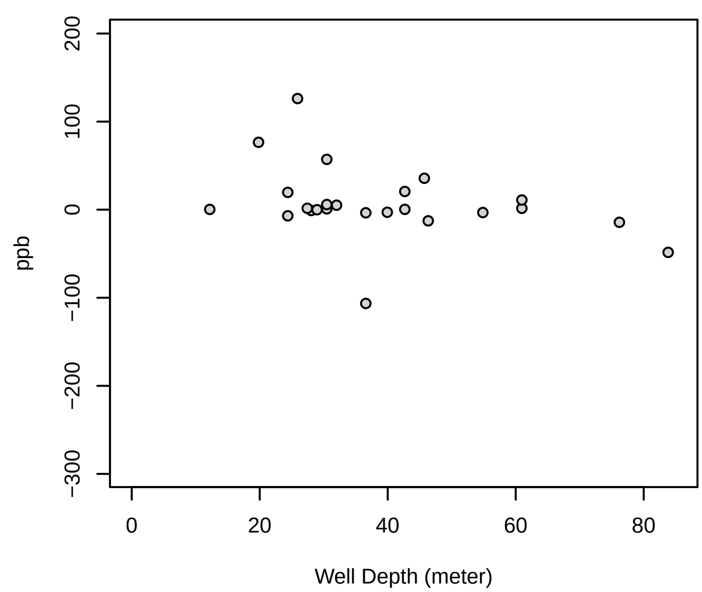
p−value: 0.9

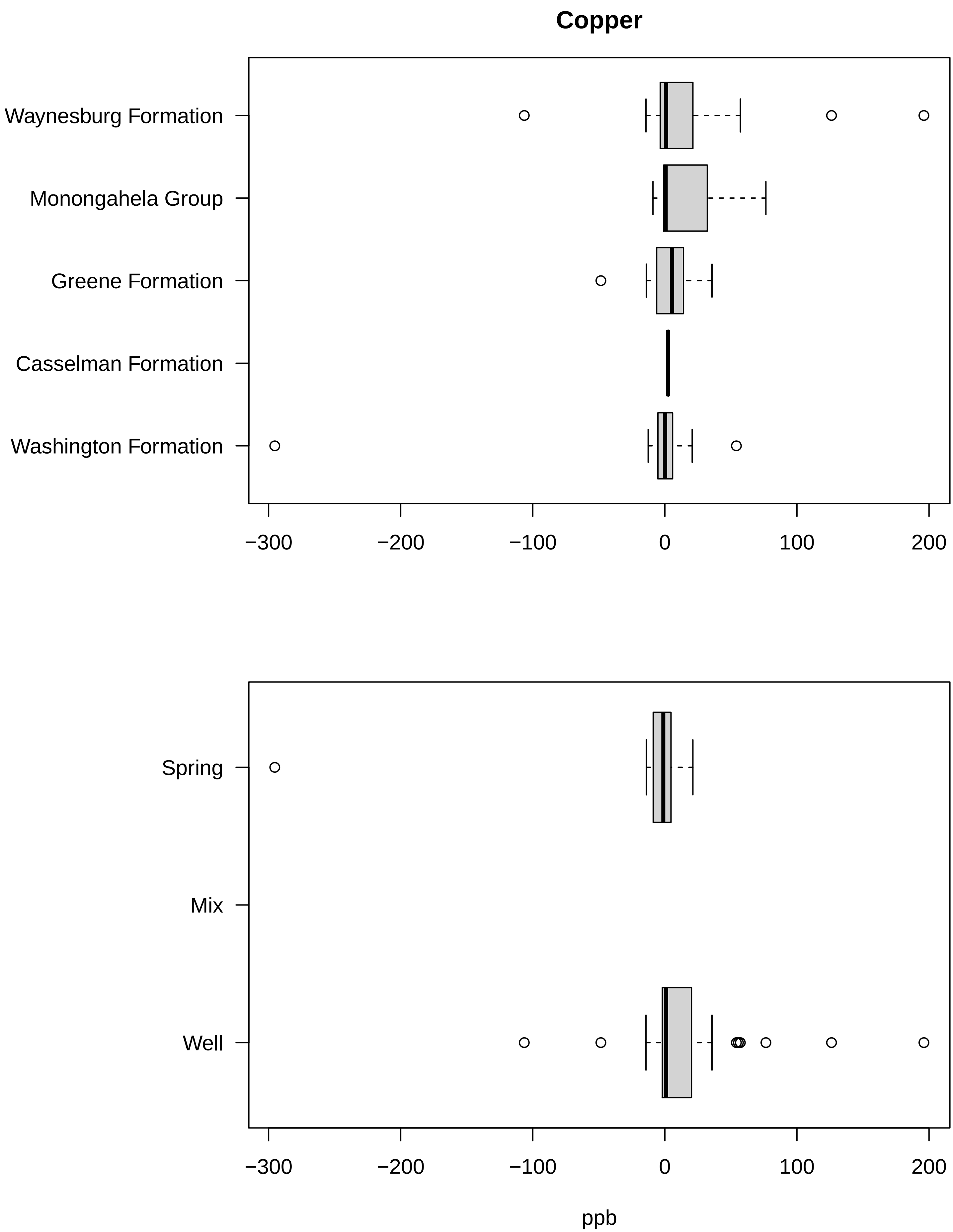
Tau: −0.013



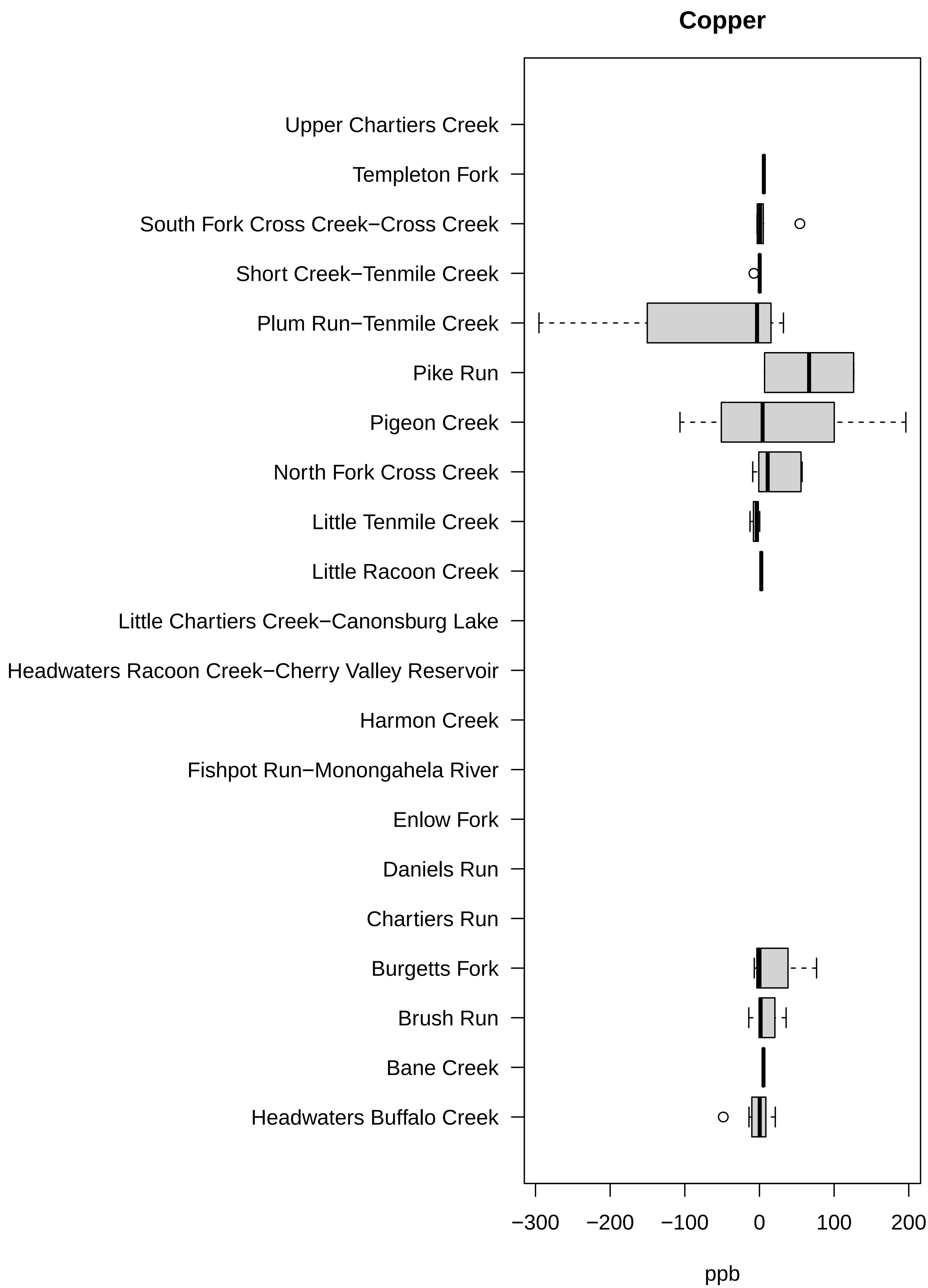








Copper
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−300
−200
−100
0
100
200
Spring
Mix
Well
−300
−200
−100
0
100
200
ppb


Copper
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−300
−200
−100
0
100
200
ppb

```
[1] "ORIGINAL MODEL - Copper"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-194.36   -17.06     2.79    19.18   141.70

Coefficients: (1 not defined because of singularities)
                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                  344.0260   254.9897   1.349   0.1881
dat$GWellDensity_2kmDiff                       0.6834     3.9504   0.173   0.8639
dat$Altitude_meter                            -0.3131     0.6899  -0.454   0.6534
dat$WatershedBane Creek                      -54.3765    79.4594  -0.684   0.4994
dat$WatershedBrush Run                        33.0132    46.2048   0.714   0.4808
dat$WatershedBurgetts Fork                    40.9343    58.5462   0.699   0.4902
dat$WatershedLittle Racoon Creek              79.2053    83.8895   0.944   0.3532
dat$WatershedLittle Tenmile Creek            -71.9945    59.9774  -1.200   0.2401
dat$WatershedNorth Fork Cross Creek           53.0146    63.0955   0.840   0.4079
dat$WatershedPigeon Creek                     14.7999    55.9558   0.264   0.7933
dat$WatershedPike Run                        127.6071    68.6331   1.859   0.0735 .
dat$WatershedPlum Run-Tenmile Creek         -115.8800    60.7359  -1.908   0.0667 .
dat$WatershedShort Creek-Tenmile Creek       -49.8584    62.5397  -0.797   0.4320
dat$WatershedSouth Fork Cross Creek-Cross Creek   34.0449    49.8703   0.683   0.5004
dat$WatershedTempleton Fork                   -9.9077    76.9430  -0.129   0.8985
dat$FormationCasselman Formation                   NA         NA      NA       NA
dat$FormationGreene Formation                 24.7750    42.0005   0.590   0.5600
dat$FormationMonongahela Group                36.3367    49.7497   0.730   0.4712
dat$FormationWaynesburg Formation             31.8712    34.1800   0.932   0.3591
dat$HHWSourceSpring                          -37.3957    29.7836  -1.256   0.2196
dat$Precip_inchDiff                           -5.4226     3.3876  -1.601   0.1207
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 4119.389)

    Null deviance: 174380  on 47  degrees of freedom
Residual deviance: 115343  on 28  degrees of freedom
AIC: 551.87

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Copper"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-2393.83   -324.60     38.22    313.62   2675.98

Coefficients: (1 not defined because of singularities)
                                               Estimate Std. Error t value Pr(>|t|)
(Intercept)                                    3826.631   4053.181   0.944   0.3532
dat$GWellDensity_2kmDiff                          6.077     62.793   0.097   0.9236
dat$Altitude_meter                               -3.620     10.966  -0.330   0.7437
dat$WatershedBane Creek                        -935.780   1263.044  -0.741   0.4649
dat$WatershedBrush Run                          582.330    734.446   0.793   0.4345
dat$WatershedBurgetts Fork                      857.920    930.619   0.922   0.3645
dat$WatershedLittle Racoon Creek               1402.781   1333.463   1.052   0.3018
dat$WatershedLittle Tenmile Creek             -1220.712    953.368  -1.280   0.2109
dat$WatershedNorth Fork Cross Creek            1025.495   1002.933   1.022   0.3153
dat$WatershedPigeon Creek                       512.415    889.443   0.576   0.5691
dat$WatershedPike Run                          2268.697   1090.955   2.080   0.0468 *
dat$WatershedPlum Run-Tenmile Creek           -1521.109    965.425  -1.576   0.1264
dat$WatershedShort Creek-Tenmile Creek         -752.986    994.098  -0.757   0.4551
dat$WatershedSouth Fork Cross Creek-Cross Creek  656.770    792.712   0.829   0.4144
dat$WatershedTempleton Fork                    -138.991   1223.044  -0.114   0.9103
dat$FormationCasselman Formation                     NA         NA      NA       NA
dat$FormationGreene Formation                   372.476    667.617   0.558   0.5813
dat$FormationMonongahela Group                  499.145    790.794   0.631   0.5330
dat$FormationWaynesburg Formation               563.478    543.307   1.037   0.3086
dat$HHWSourceSpring                            -611.153    473.424  -1.291   0.2073
dat$Precip_inchDiff                             -94.481     53.848  -1.755   0.0903 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1040829)

    Null deviance: 43722596  on 47  degrees of freedom
Residual deviance: 29143206  on 28  degrees of freedom
AIC: 817.41

Number of Fisher Scoring iterations: 2
```

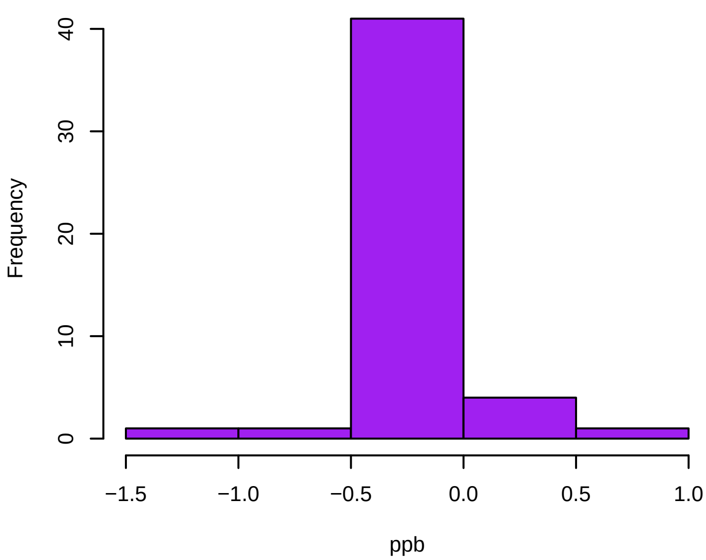
Lead

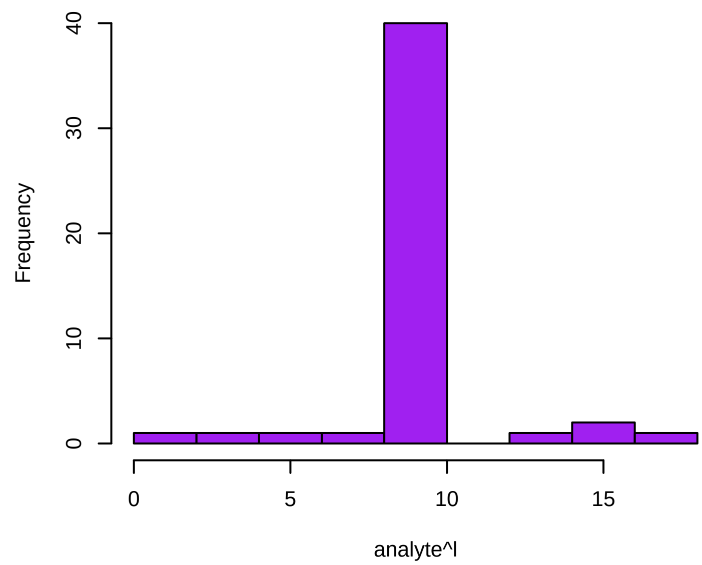
Skewness: −1.7991
Kurtosis: 12.7801

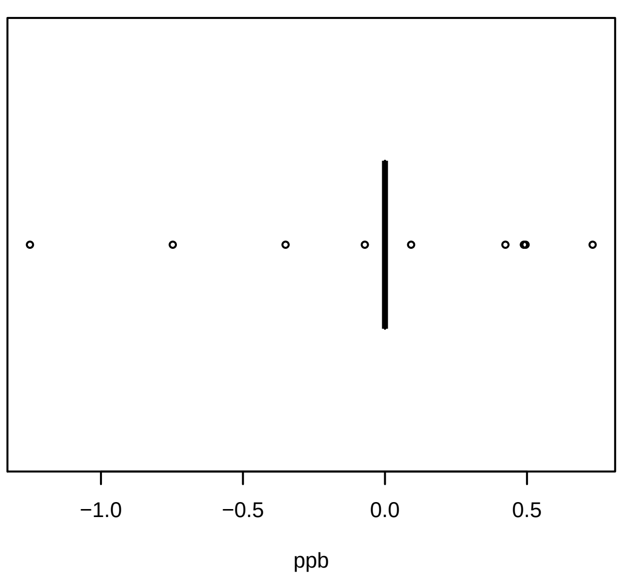
Lead Box−Cox

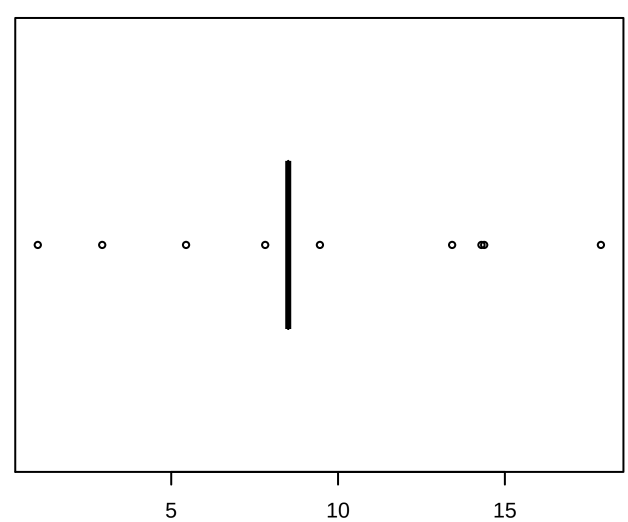
Skewness: 0.8152
Kurtosis: 9.0159

Optimal lambda: 2.64



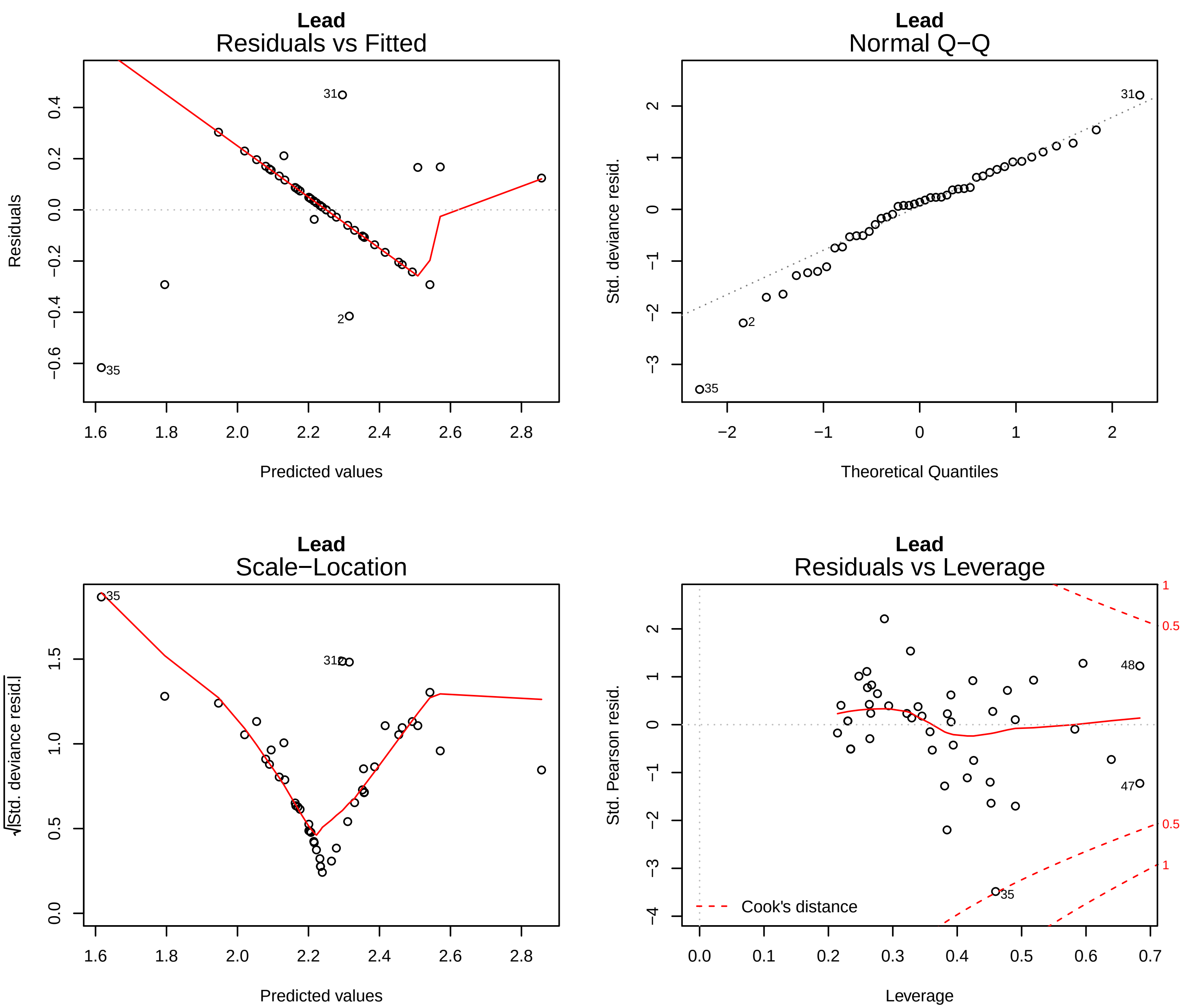






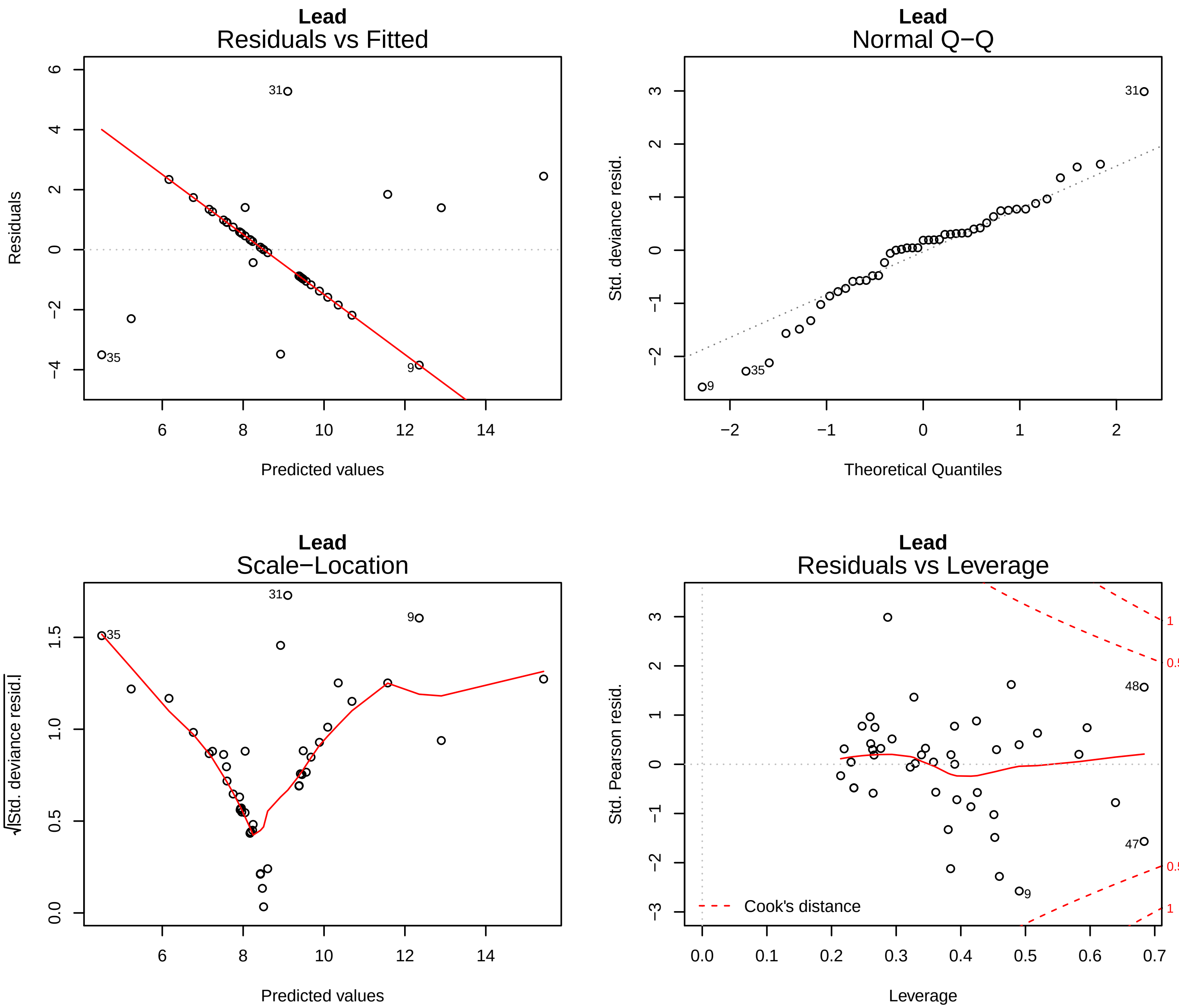
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

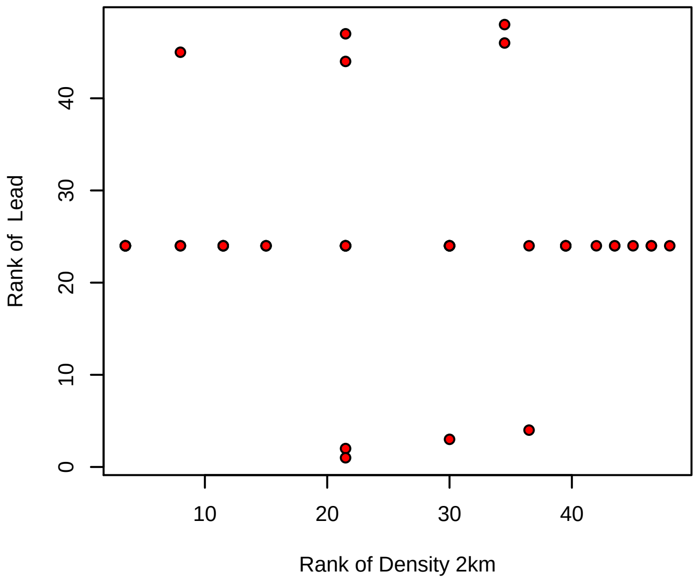
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



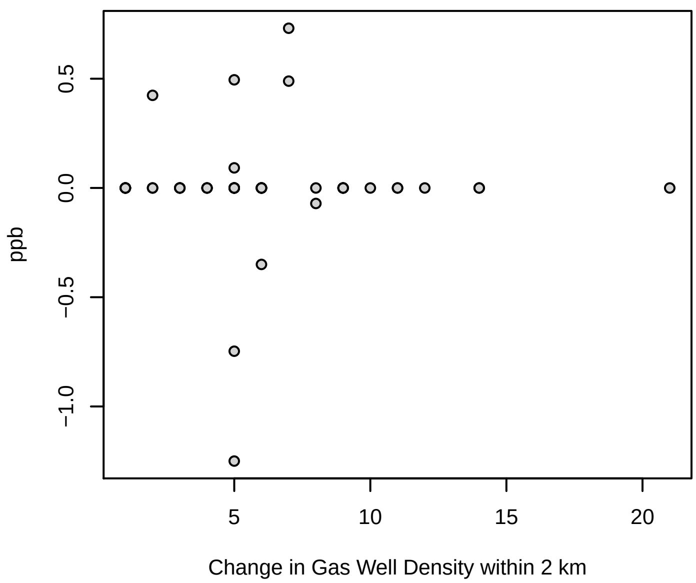


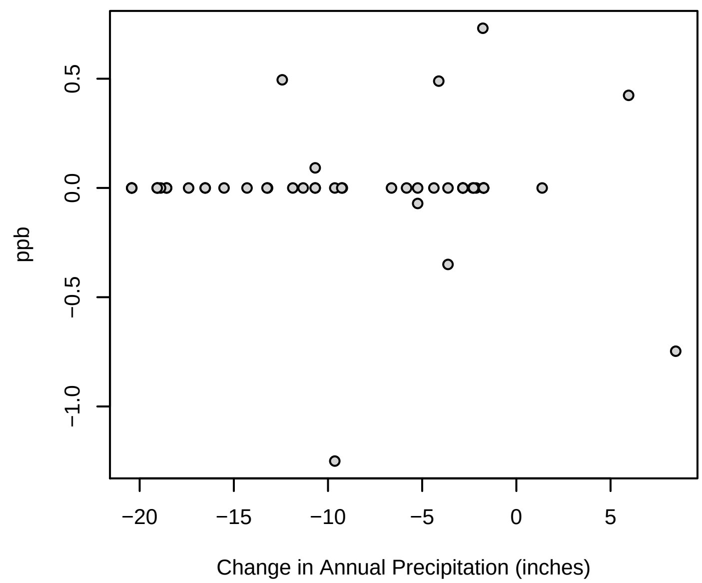
Lead

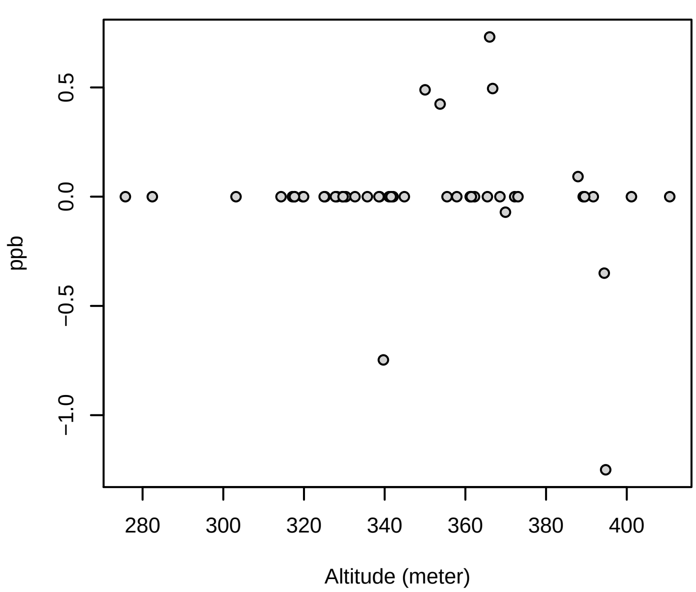
Kendalls Tau Rank Correlation

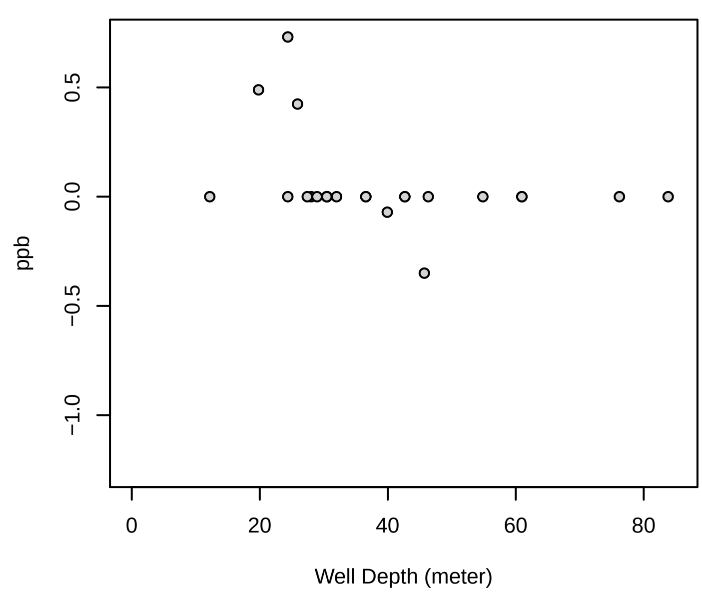
p−value: 0.843

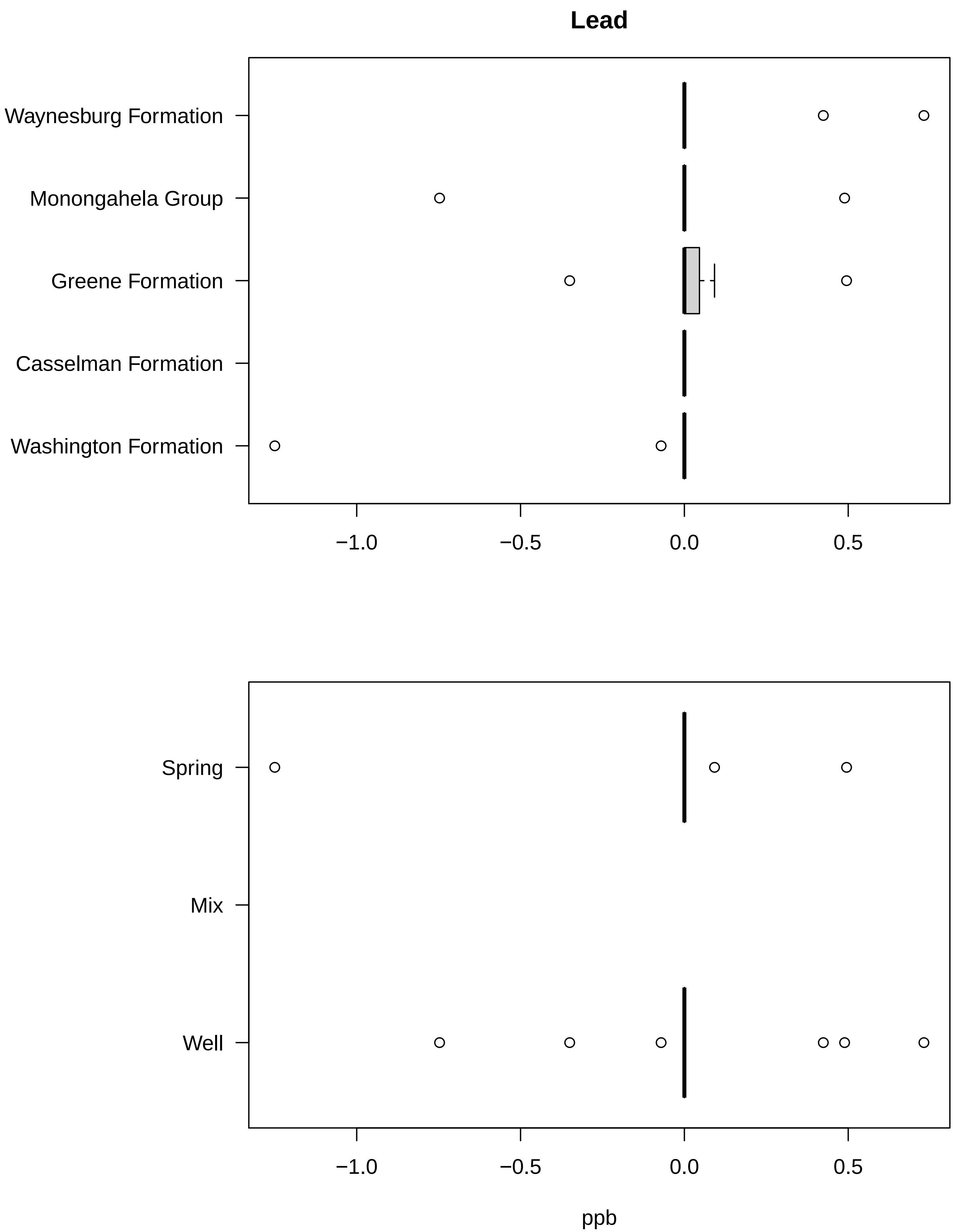
Tau: −0.0238

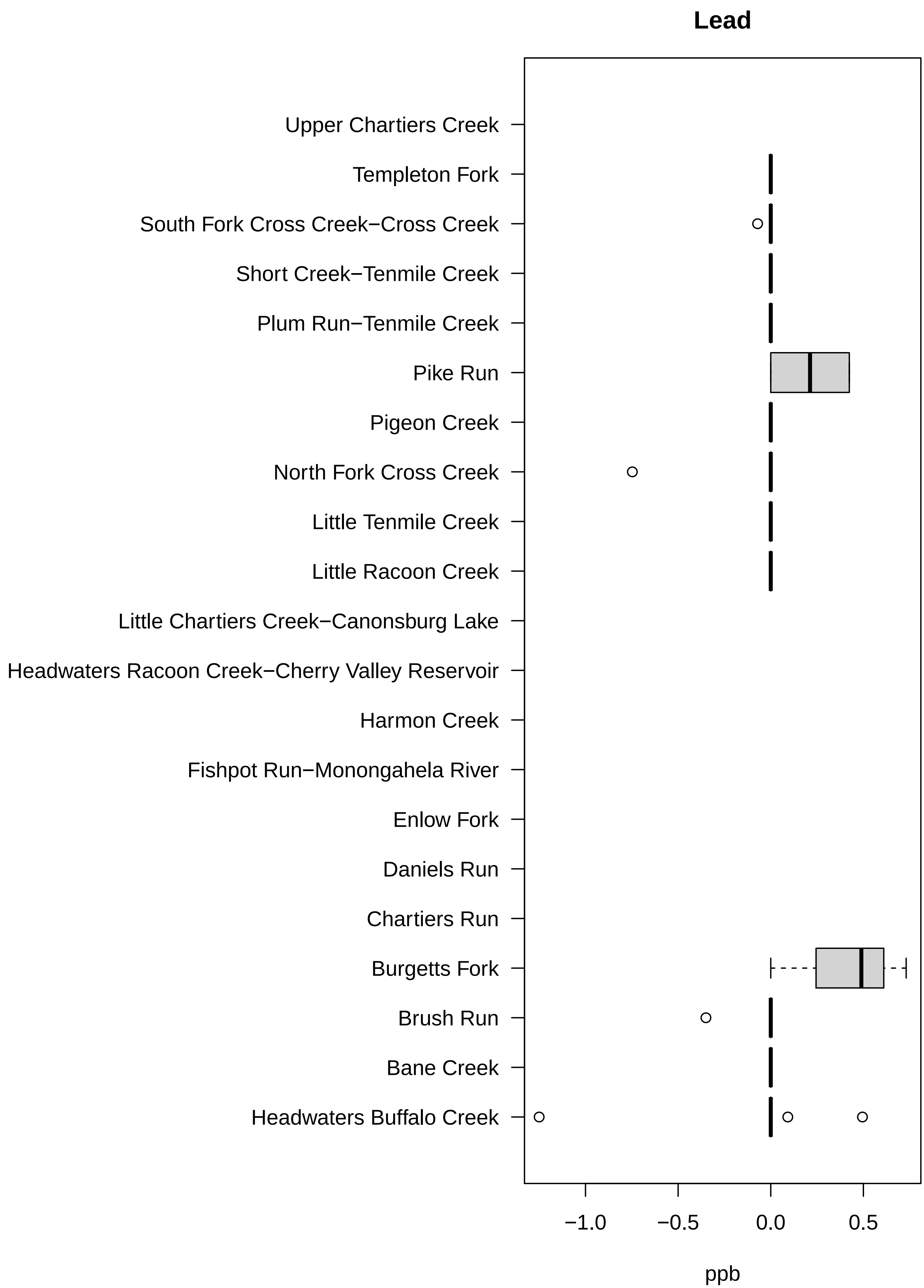









Lead
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−1.0
−0.5
0.0
0.5
Spring
Mix
Well
−1.0
−0.5
0.0
0.5
ppb


Lead
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−1.0
−0.5
0.0
0.5
ppb

```
[1] "ORIGINAL MODEL - Lead"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.61635  -0.10287   0.01704   0.11856   0.44925  

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)    
(Intercept)                                   3.571582   0.956124   3.735 0.000850 ***
dat$GWellDensity_2kmDiff                      0.026058   0.014812   1.759 0.089473 .  
dat$Altitude_meter                           -0.005451   0.002587  -2.107 0.044187 *  
dat$WatershedBane Creek                      -0.303831   0.297945  -1.020 0.316576    
dat$WatershedBrush Run                        0.186507   0.173252   1.077 0.290889    
dat$WatershedBurgetts Fork                    0.925074   0.219528   4.214 0.000236 ***
dat$WatershedLittle Racoon Creek              0.457578   0.314557   1.455 0.156879    
dat$WatershedLittle Tenmile Creek            -0.193662   0.224895  -0.861 0.396483    
dat$WatershedNorth Fork Cross Creek           0.502386   0.236586   2.123 0.042685 *  
dat$WatershedPigeon Creek                     0.310605   0.209815   1.480 0.149938    
dat$WatershedPike Run                         0.859885   0.257350   3.341 0.002375 ** 
dat$WatershedPlum Run-Tenmile Creek           0.065054   0.227739   0.286 0.777246    
dat$WatershedShort Creek-Tenmile Creek       -0.440868   0.234503  -1.880 0.070548 .  
dat$WatershedSouth Fork Cross Creek-Cross Creek  0.303562   0.186997   1.623 0.115720    
dat$WatershedTempleton Fork                   0.034583   0.288510   0.120 0.905444    
dat$FormationCasselman Formation                    NA         NA      NA       NA    
dat$FormationGreene Formation                 0.447372   0.157487   2.841 0.008298 ** 
dat$FormationMonongahela Group               -0.317105   0.186544  -1.700 0.100236    
dat$FormationWaynesburg Formation             0.122134   0.128163   0.953 0.348766    
dat$HHWSourceSpring                          -0.207724   0.111678  -1.860 0.073417 .  
dat$Precip_inchDiff                          -0.028434   0.012702  -2.238 0.033321 *  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.05791828)

    Null deviance: 3.4542  on 47  degrees of freedom
Residual deviance: 1.6217  on 28  degrees of freedom
AIC: 15.608

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Lead"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.8466  -0.9193   0.0818   0.7919   5.2772

Coefficients: (1 not defined because of singularities)
                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                  17.47584    8.31017   2.103 0.044585 *
dat$GWellDensity_2kmDiff                      0.16445    0.12874   1.277 0.211957
dat$Altitude_meter                           -0.03501    0.02248  -1.557 0.130625
dat$WatershedBane Creek                      -2.60027    2.58960  -1.004 0.323920
dat$WatershedBrush Run                        0.50431    1.50582   0.335 0.740191
dat$WatershedBurgetts Fork                    8.30369    1.90803   4.352 0.000163 ***
dat$WatershedLittle Racoon Creek              2.84628    2.73398   1.041 0.306747
dat$WatershedLittle Tenmile Creek            -1.78508    1.95468  -0.913 0.368915
dat$WatershedNorth Fork Cross Creek           2.85130    2.05630   1.387 0.176500
dat$WatershedPigeon Creek                     1.57164    1.82361   0.862 0.396102
dat$WatershedPike Run                         6.22488    2.23677   2.783 0.009538 **
dat$WatershedPlum Run-Tenmile Creek           0.52866    1.97940   0.267 0.791365
dat$WatershedShort Creek-Tenmile Creek       -3.18384    2.03818  -1.562 0.129498
dat$WatershedSouth Fork Cross Creek-Cross Creek  1.47154    1.62528   0.905 0.372978
dat$WatershedTempleton Fork                  -0.19130    2.50759  -0.076 0.939733
dat$FormationCasselman Formation                   NA         NA      NA       NA
dat$FormationGreene Formation                 3.12015    1.36880   2.279 0.030460 *
dat$FormationMonongahela Group               -2.51214    1.62135  -1.549 0.132513
dat$FormationWaynesburg Formation             0.99585    1.11393   0.894 0.378946
dat$HHWSourceSpring                          -1.69529    0.97065  -1.747 0.091679 .
dat$Precip_inchDiff                          -0.17872    0.11040  -1.619 0.116697
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 4.375294)

    Null deviance: 276.05  on 47  degrees of freedom
Residual deviance: 122.51  on 28  degrees of freedom
AIC: 223.19

Number of Fisher Scoring iterations: 2
```

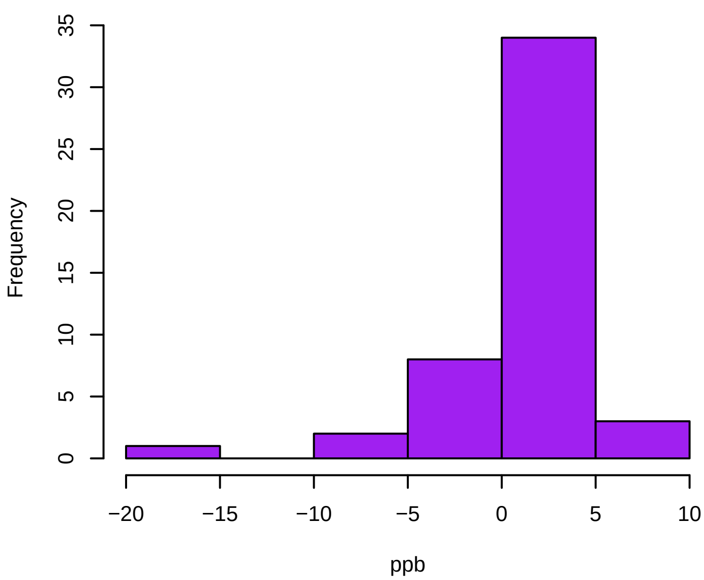
Lithium

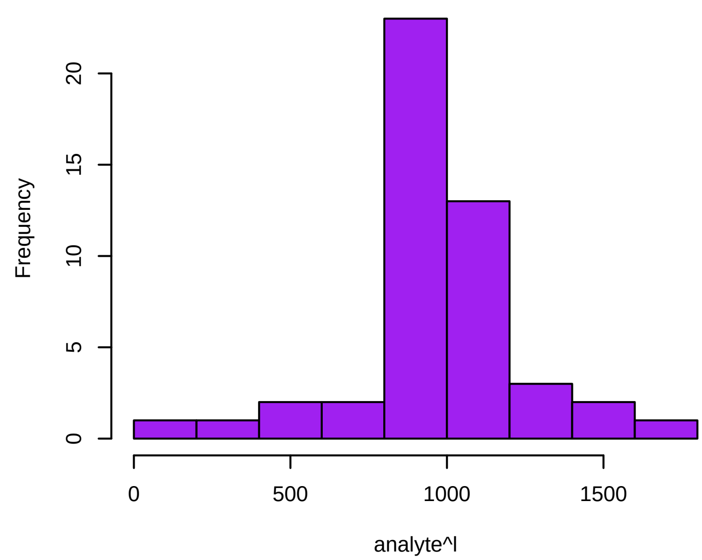
Skewness: −3.1099
Kurtosis: 17.5882

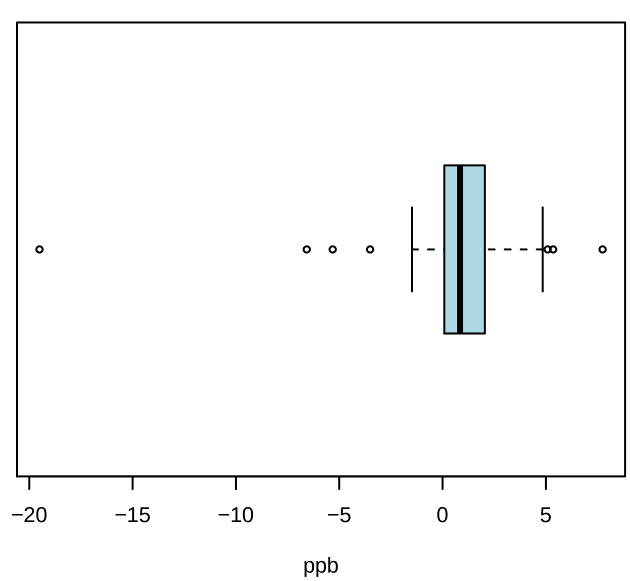
Lithium Box−Cox

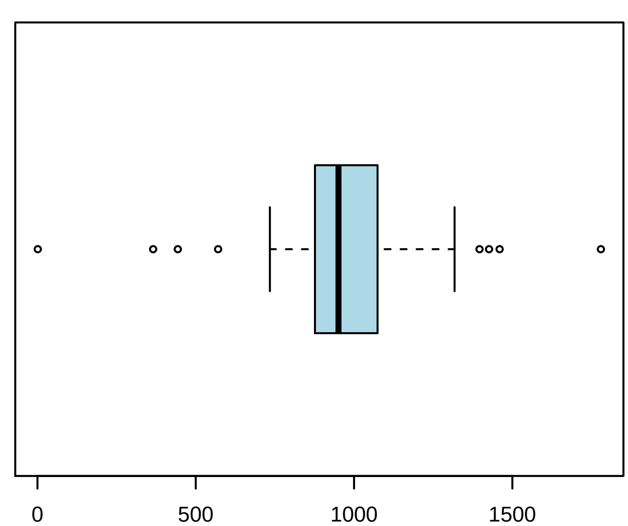
Skewness: −0.4302
Kurtosis: 6.1921

Optimal lambda: 2.24



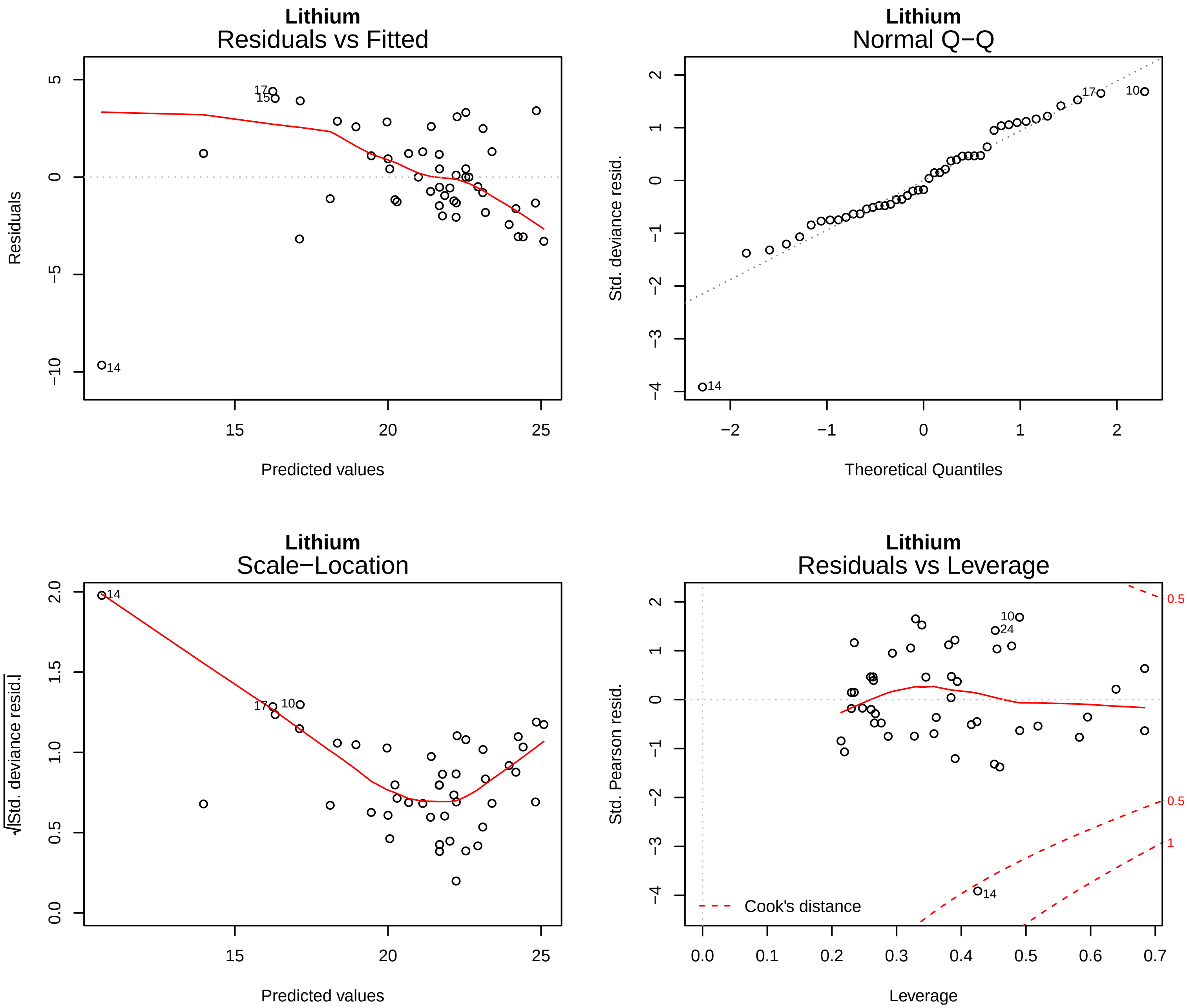






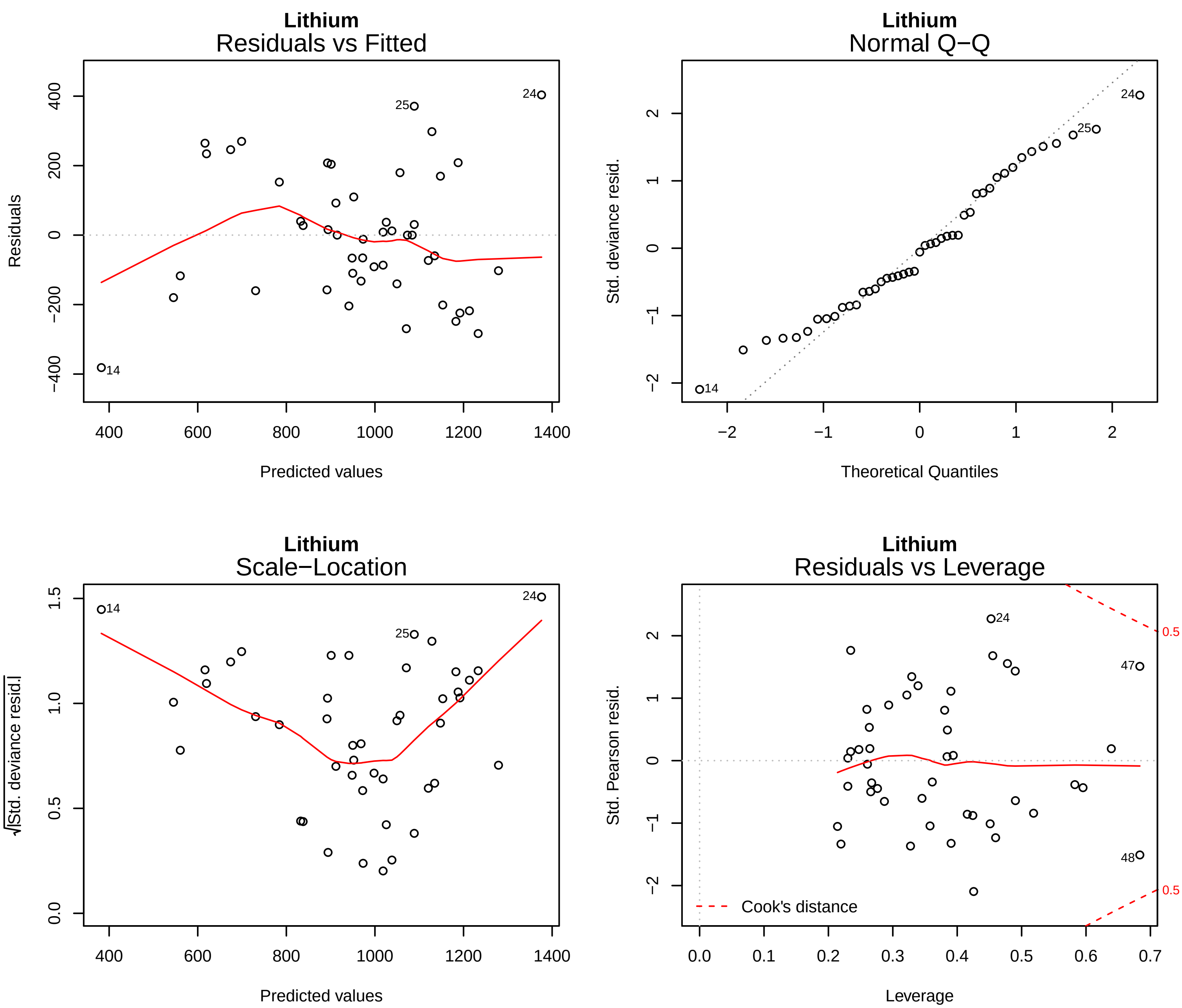
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

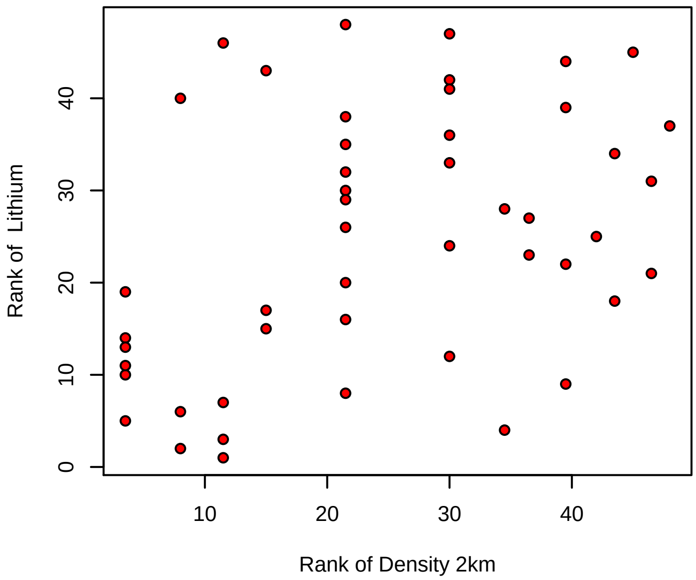
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



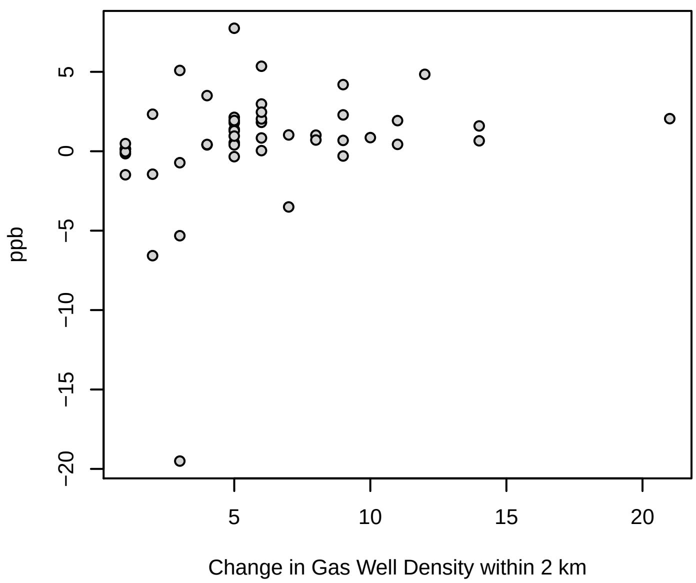


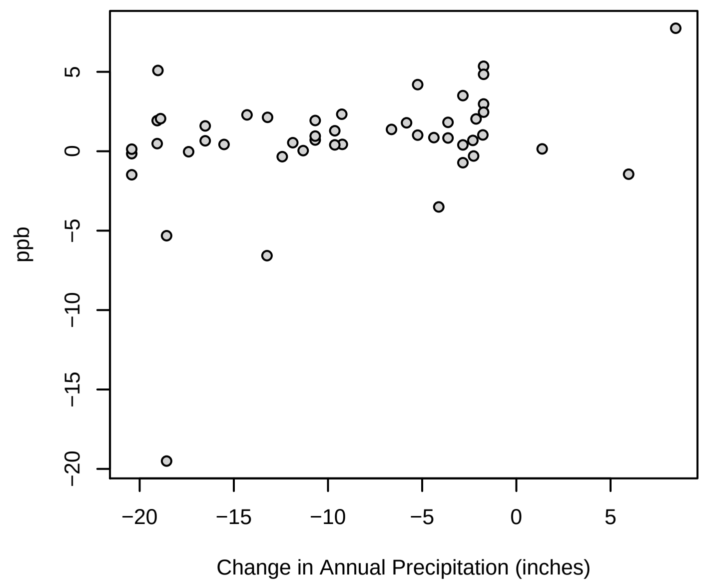
Lithium

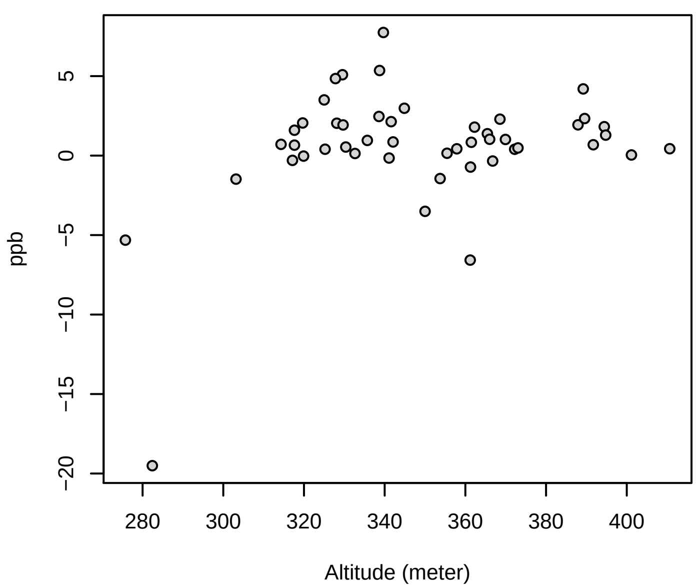
Kendalls Tau Rank Correlation

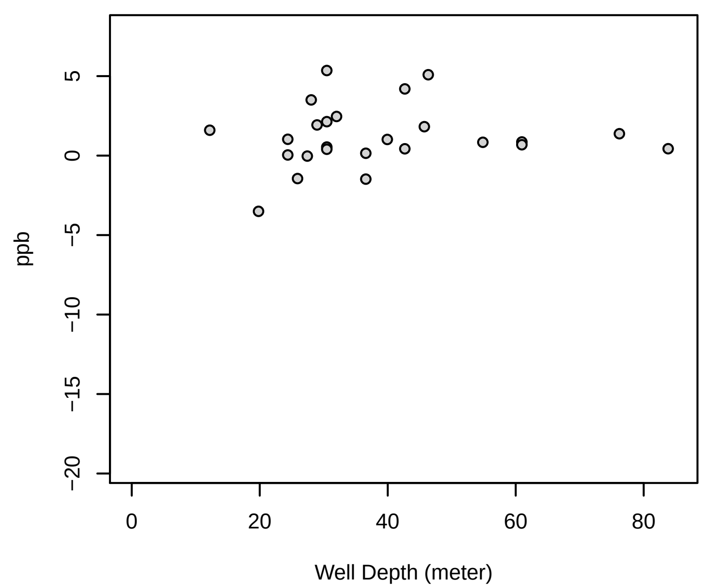
p−value: 0.00906

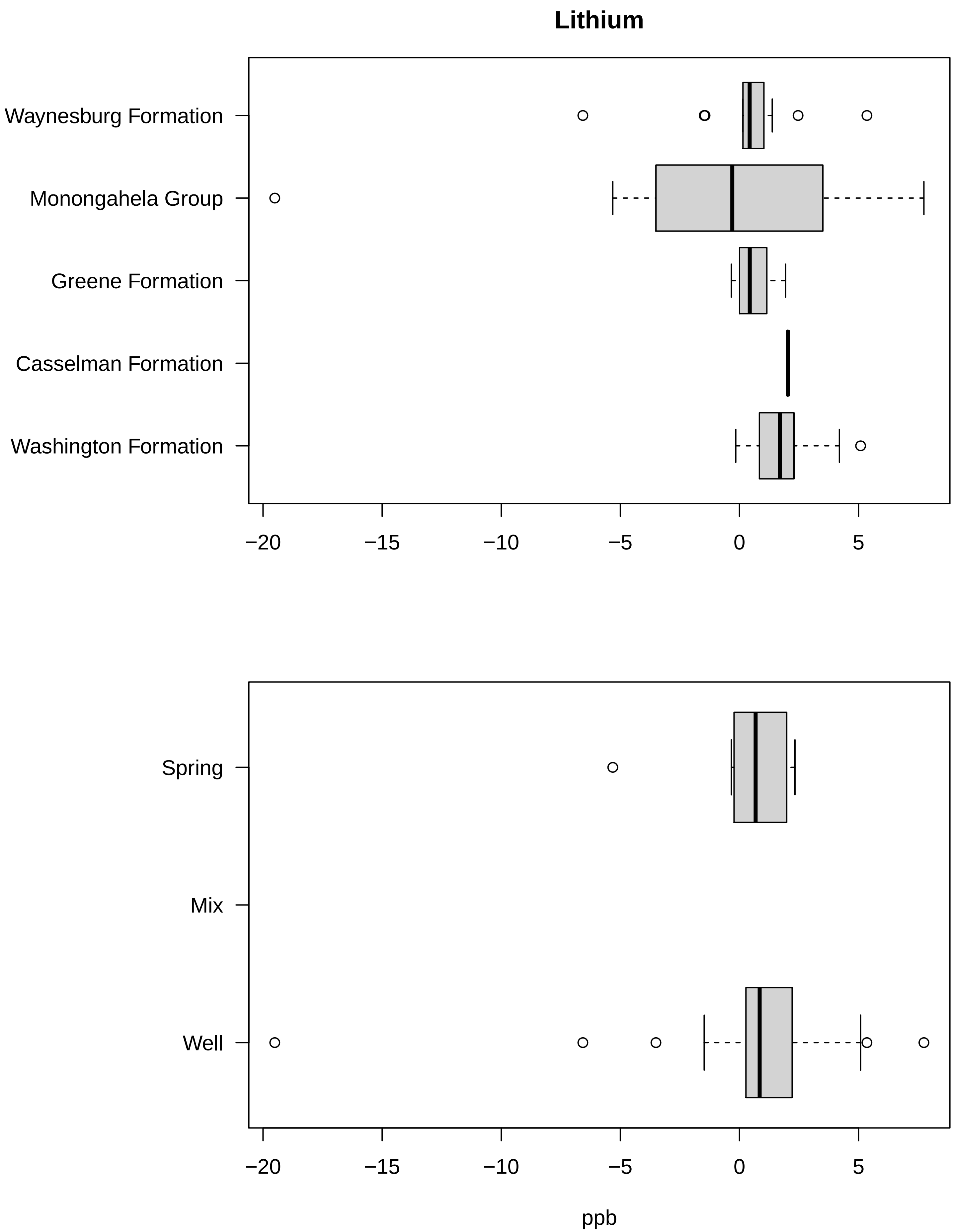
Tau: 0.271

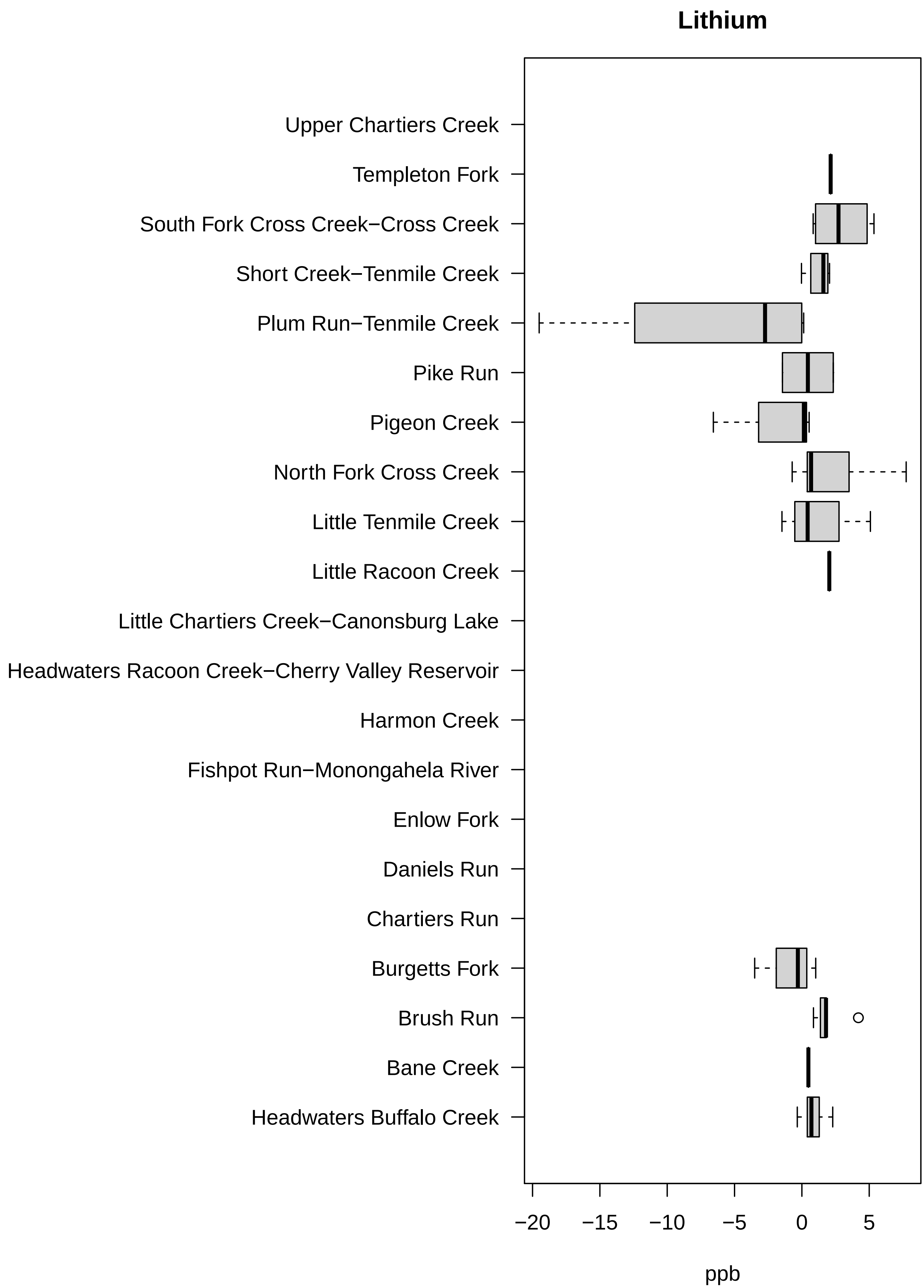









Lithium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−20
−15
−10
−5
0
5
Spring
Mix
Well
−20
−15
−10
−5
0
5
ppb


Lithium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−20
−15
−10
−5
0
5
ppb

```
[1] "ORIGINAL MODEL - Lithium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-9.652  -1.325   0.000   1.301   4.401

Coefficients: (1 not defined because of singularities)
                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                 21.046793  12.928937   1.628   0.1148
dat$GWellDensity_2kmDiff                    -0.030595   0.200298  -0.153   0.8797
dat$Altitude_meter                           0.009248   0.034980   0.264   0.7934
dat$WatershedBane Creek                      3.925879   4.028889   0.974   0.3382
dat$WatershedBrush Run                       0.569639   2.342755   0.243   0.8097
dat$WatershedBurgetts Fork                  -2.523385   2.968511  -0.850   0.4025
dat$WatershedLittle Racoon Creek            -4.110316   4.253514  -0.966   0.3421
dat$WatershedLittle Tenmile Creek            4.707264   3.041078   1.548   0.1329
dat$WatershedNorth Fork Cross Creek          0.539934   3.199179   0.169   0.8672
dat$WatershedPigeon Creek                   -1.099953   2.837169  -0.388   0.7012
dat$WatershedPike Run                       -3.569165   3.479955  -1.026   0.3138
dat$WatershedPlum Run-Tenmile Creek         -5.225453   3.079537  -1.697   0.1008
dat$WatershedShort Creek-Tenmile Creek       2.993995   3.171000   0.944   0.3532
dat$WatershedSouth Fork Cross Creek-Cross Creek  1.277003   2.528613   0.505   0.6175
dat$WatershedTempleton Fork                  2.480428   3.901297   0.636   0.5301
dat$FormationCasselman Formation                   NA         NA      NA       NA
dat$FormationGreene Formation               -1.785699   2.129581  -0.839   0.4088
dat$FormationMonongahela Group              -2.220114   2.522495  -0.880   0.3863
dat$FormationWaynesburg Formation           -2.216030   1.733055  -1.279   0.2115
dat$HHWSourceSpring                          3.385658   1.510140   2.242   0.0331 *
dat$Precip_inchDiff                          0.294515   0.171766   1.715   0.0975 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 10.59042)

    Null deviance: 685.24  on 47  degrees of freedom
Residual deviance: 296.53  on 28  degrees of freedom
AIC: 265.62

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Lithium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-381.4  -134.3     0.0   156.9   403.6

Coefficients: (1 not defined because of singularities)
                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                             1143.27766  954.22251   1.198   0.2409
dat$GWellDensity_2kmDiff                   0.06924   14.78303   0.005   0.9963
dat$Altitude_meter                         0.39621    2.58172   0.153   0.8791
dat$WatershedBane Creek                  309.08601  297.35287   1.039   0.3075
dat$WatershedBrush Run                    -4.78890  172.90741  -0.028   0.9781
dat$WatershedBurgetts Fork              -352.67342  219.09146  -1.610   0.1187
dat$WatershedLittle Racoon Creek        -321.78540  313.93136  -1.025   0.3141
dat$WatershedLittle Tenmile Creek        382.84396  224.44727   1.706   0.0991 .
dat$WatershedNorth Fork Cross Creek      -52.17073  236.11599  -0.221   0.8267
dat$WatershedPigeon Creek               -186.01965  209.39773  -0.888   0.3819
dat$WatershedPike Run                   -320.06848  256.83871  -1.246   0.2230
dat$WatershedPlum Run-Tenmile Creek     -272.75265  227.28580  -1.200   0.2402
dat$WatershedShort Creek-Tenmile Creek   206.89435  234.03620   0.884   0.3842
dat$WatershedSouth Fork Cross Creek-Cross Creek   46.88017  186.62472   0.251   0.8035
dat$WatershedTempleton Fork              171.78924  287.93593   0.597   0.5556
dat$FormationCasselman Formation                NA         NA      NA       NA
dat$FormationGreene Formation           -156.09946  157.17409  -0.993   0.3291
dat$FormationMonongahela Group           -84.76294  186.17316  -0.455   0.6524
dat$FormationWaynesburg Formation       -187.70223  127.90843  -1.467   0.1534
dat$HHWSourceSpring                      180.85064  111.45615   1.623   0.1159
dat$Precip_inchDiff                       27.75952   12.67721   2.190   0.0370 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 57688.15)

    Null deviance: 3635546  on 47  degrees of freedom
Residual deviance: 1615268  on 28  degrees of freedom
AIC: 678.56

Number of Fisher Scoring iterations: 2
```

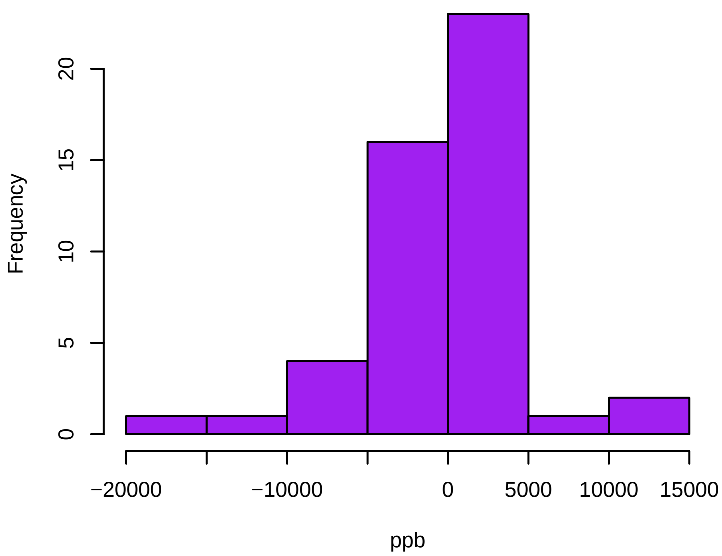
Magnesium

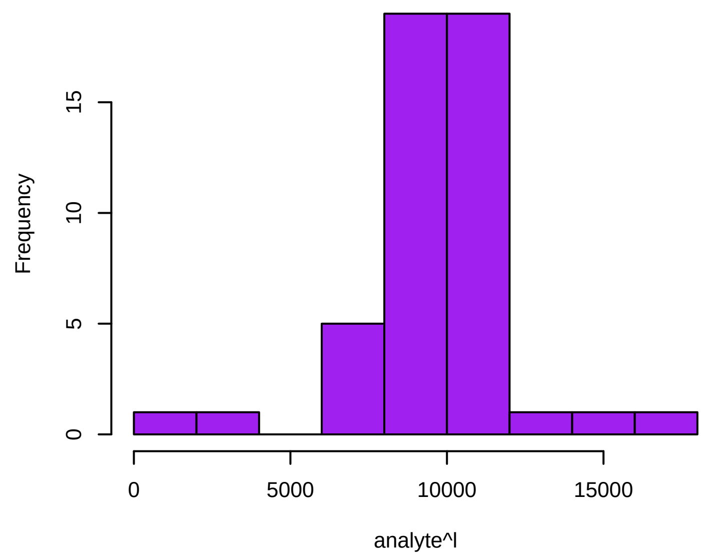
Skewness: −0.7807
Kurtosis: 7.3822

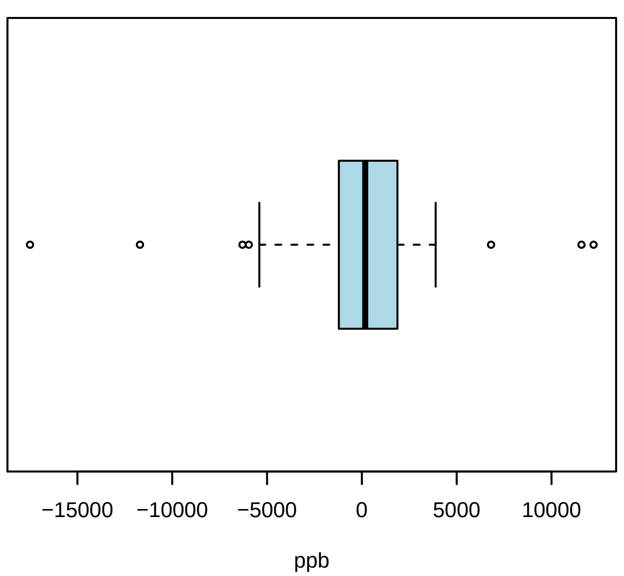
Magnesium Box−Cox

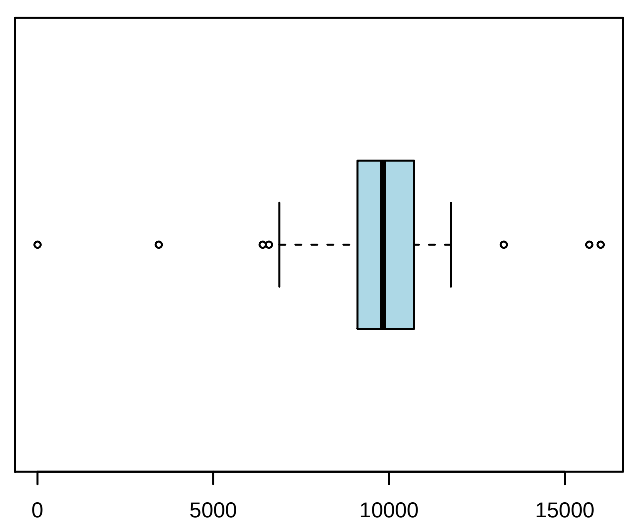
Skewness: −0.9933
Kurtosis: 7.8885

Optimal lambda: 0.94



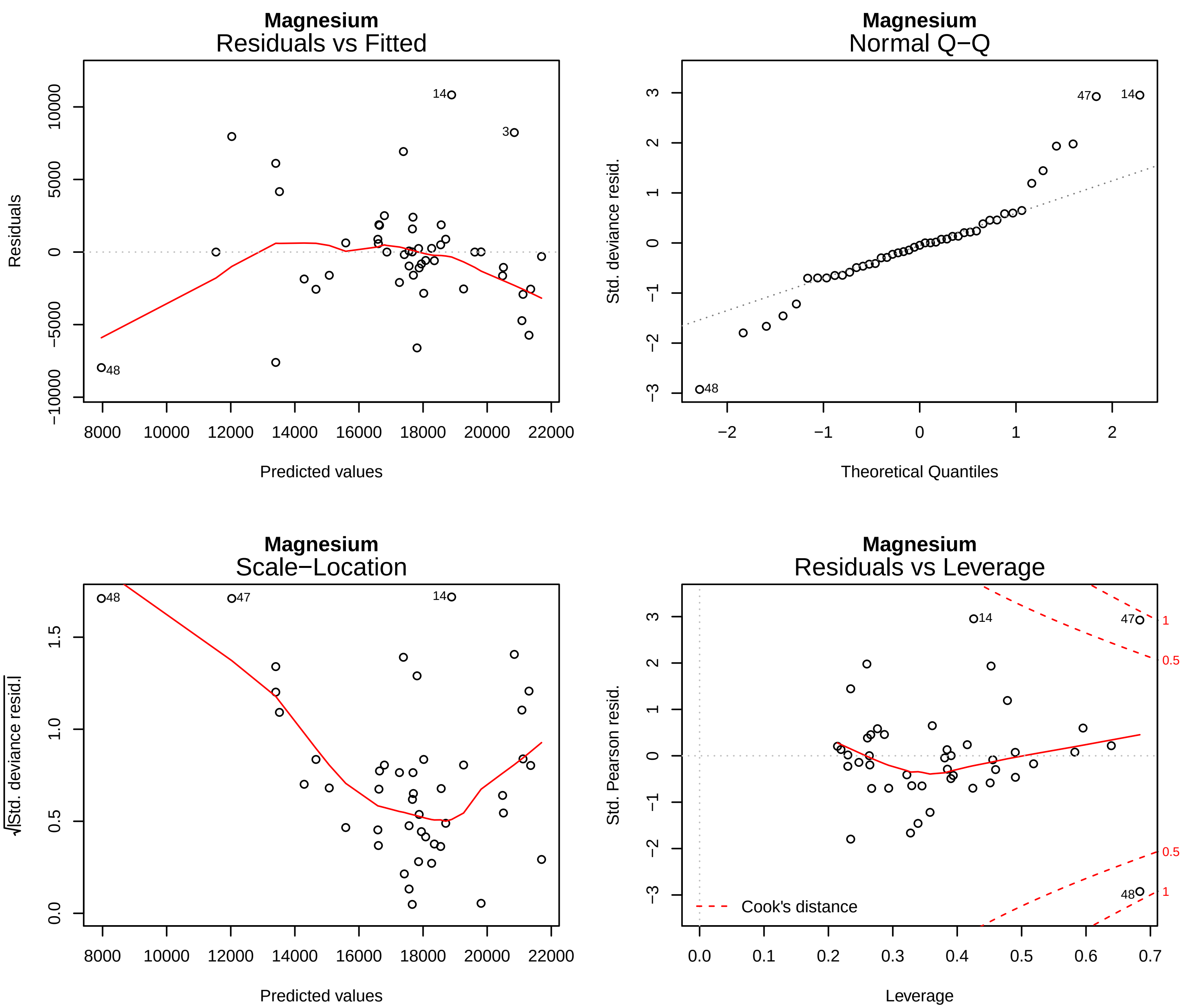






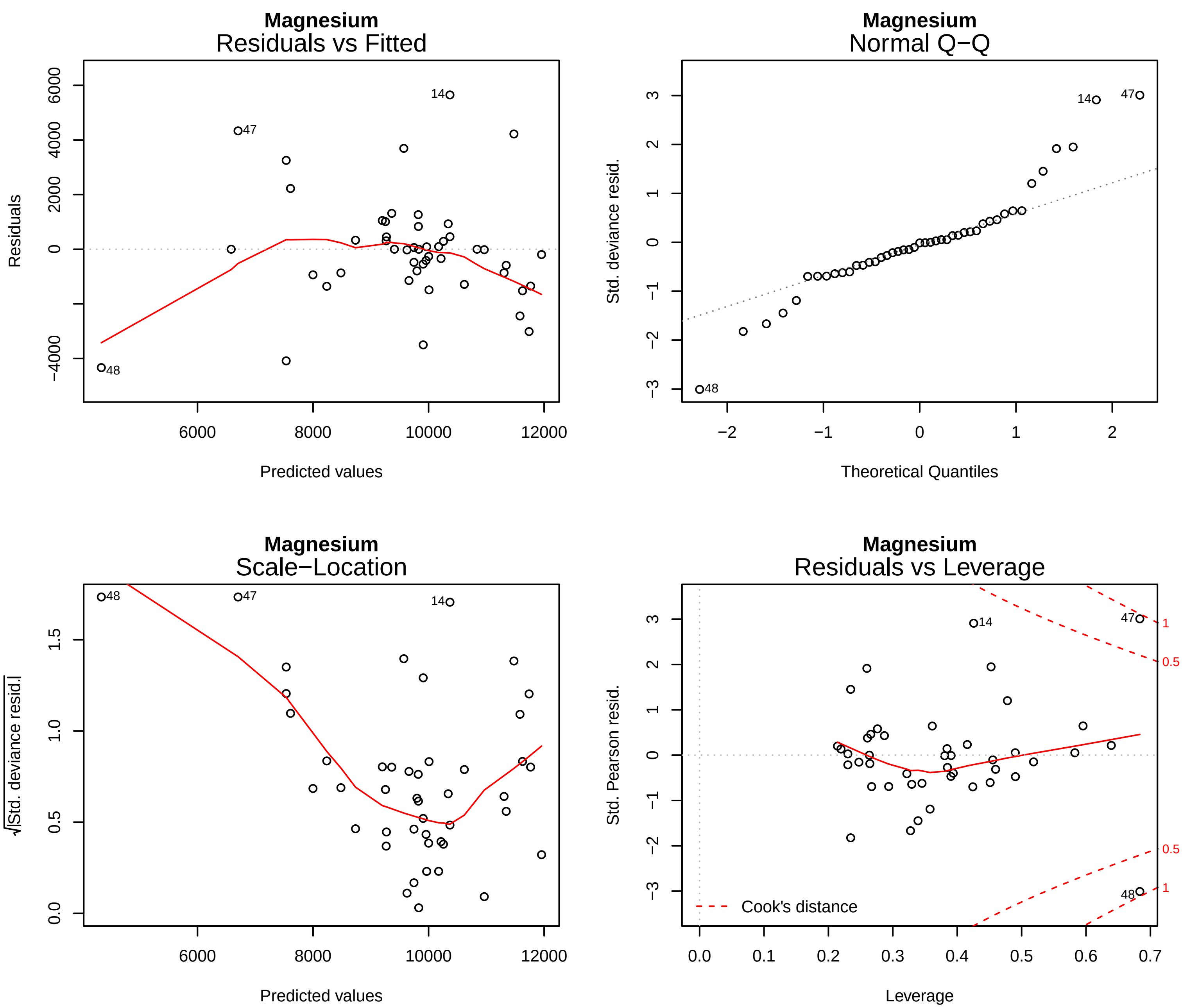
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

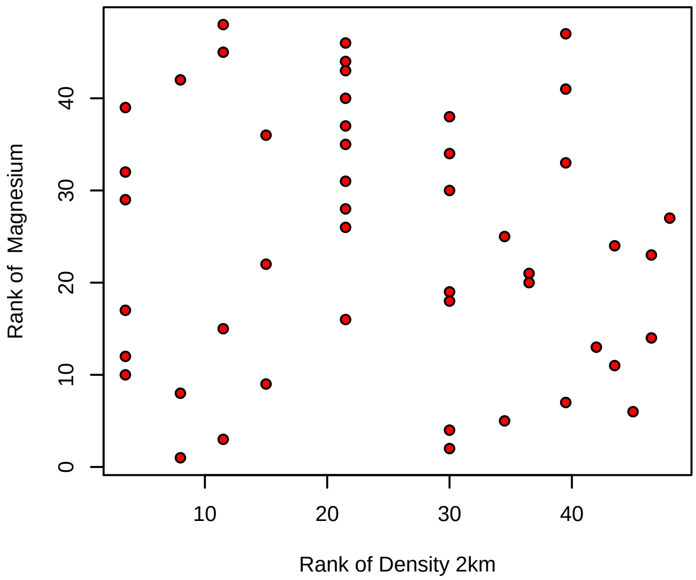
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox
Model



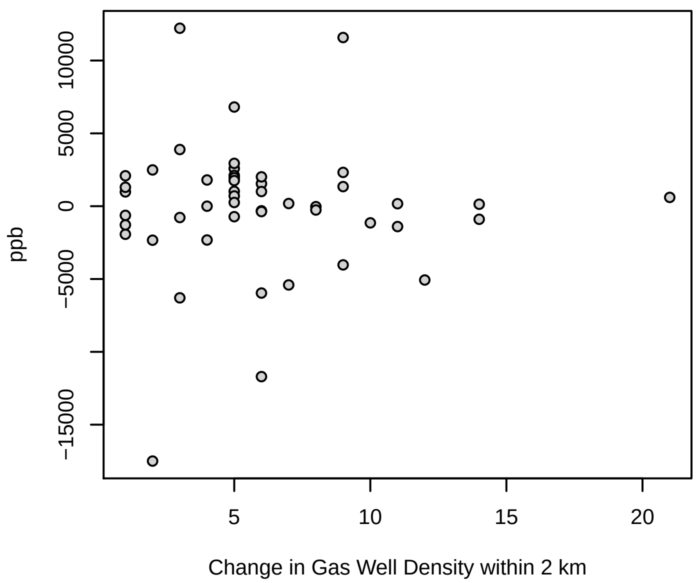


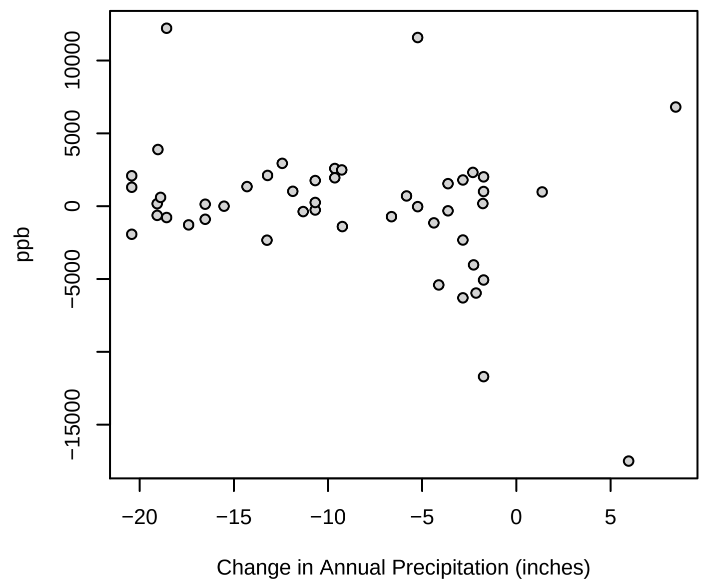
Magnesium

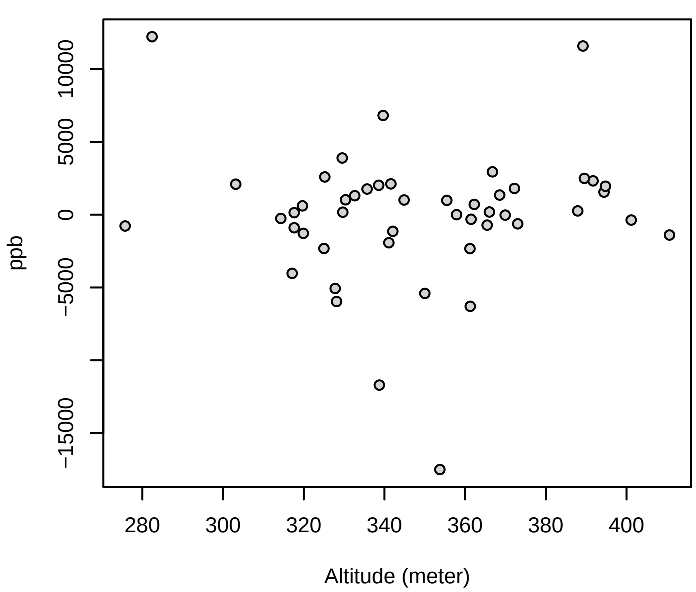
Kendalls Tau Rank Correlation

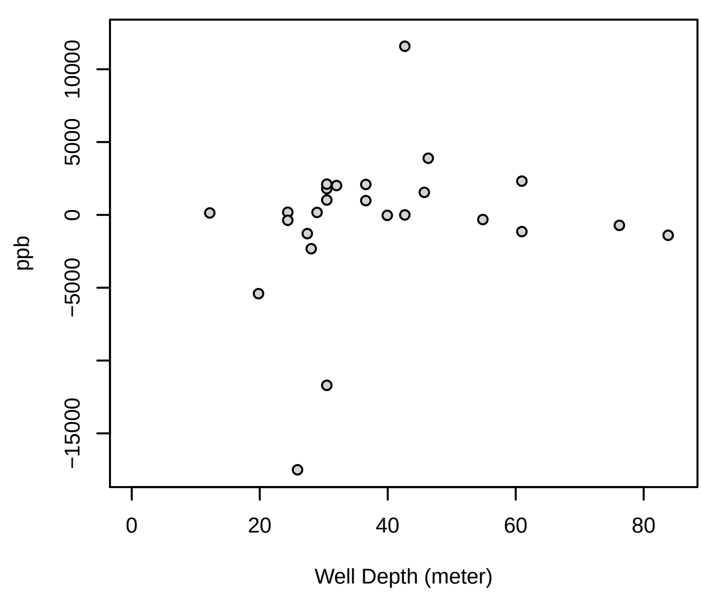
p−value: 0.49

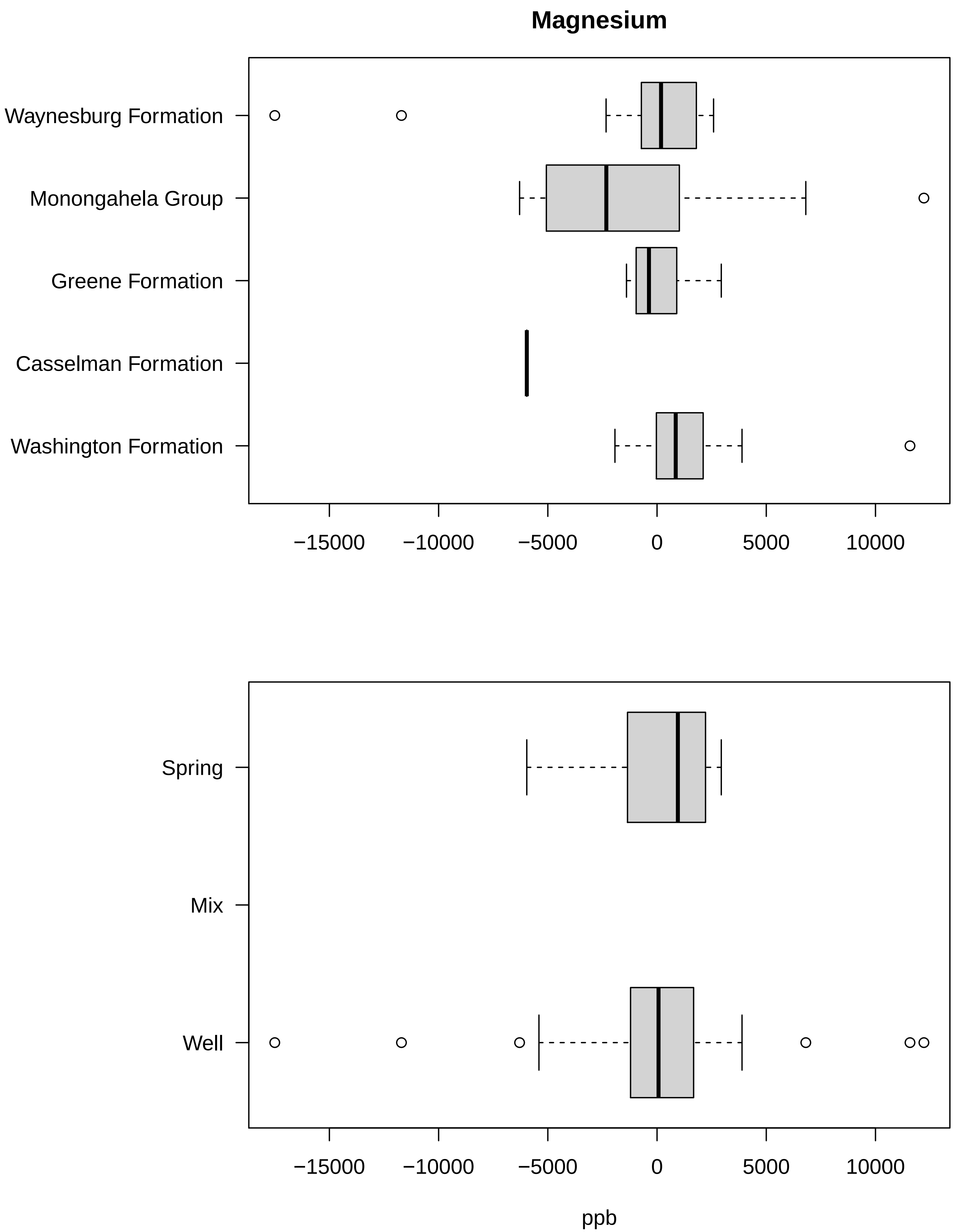
Tau: −0.0716

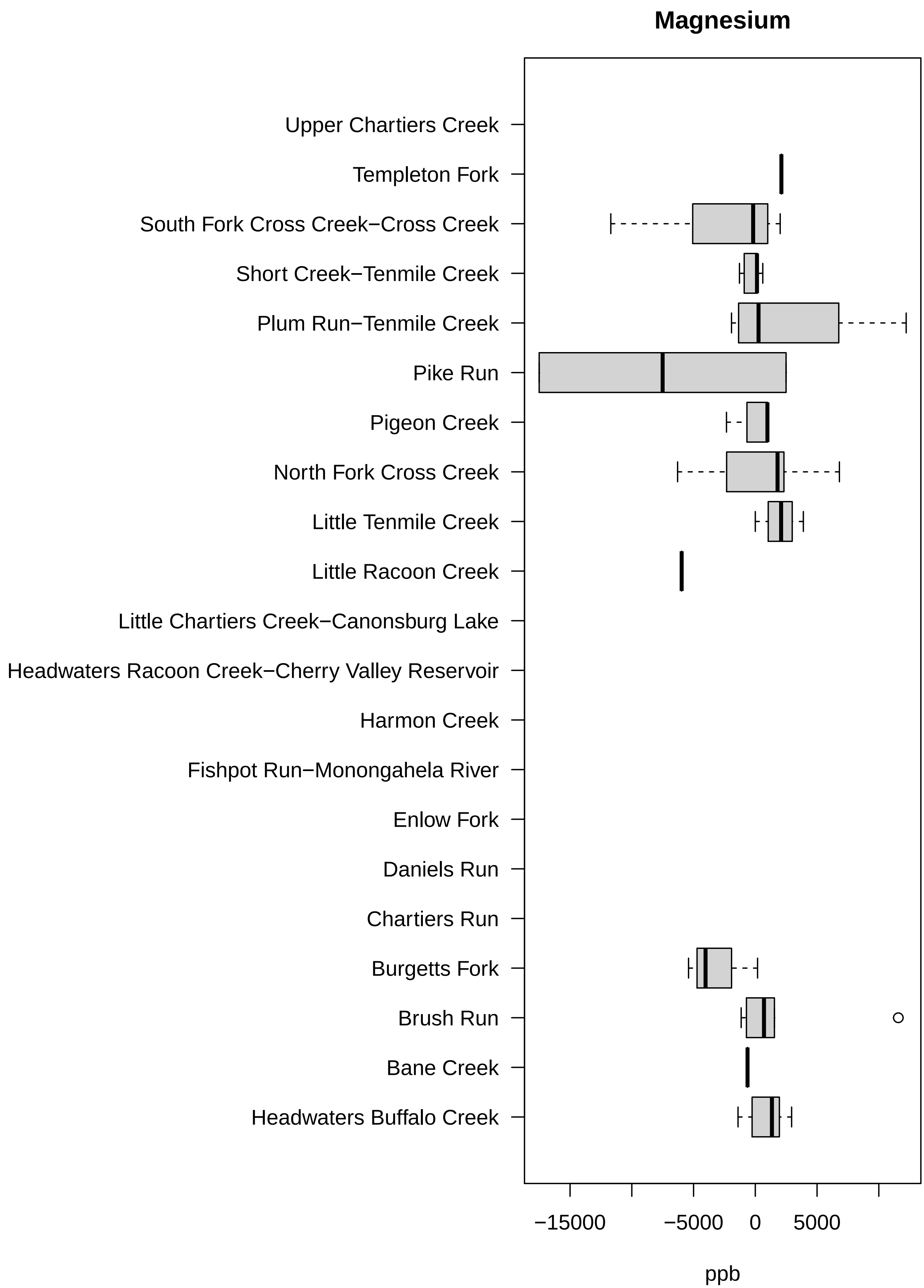









Magnesium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−15000
−10000
−5000
0
5000
10000
Spring
Mix
Well
−15000
−10000
−5000
0
5000
10000
ppb


Magnesium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−15000
−5000
0
5000
ppb

```
[1] "ORIGINAL MODEL - Magnesium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
   Min      1Q  Median      3Q     Max  
 -7960   -1690       0    1062   10827  

Coefficients: (1 not defined because of singularities)
                                               Estimate Std. Error t value Pr(>|t|)
(Intercept)                                    22298.74   19218.41   1.160    0.256
dat$GWellDensity_2kmDiff                         -18.80     297.74  -0.063    0.950
dat$Altitude_meter                                -6.27      52.00  -0.121    0.905
dat$WatershedBane Creek                        -1705.79    5988.80  -0.285    0.778
dat$WatershedBrush Run                           914.52    3482.42   0.263    0.795
dat$WatershedBurgetts Fork                     -3178.34    4412.59  -0.720    0.477
dat$WatershedLittle Racoon Creek               -9021.14    6322.70  -1.427    0.165
dat$WatershedLittle Tenmile Creek                639.41    4520.45   0.141    0.889
dat$WatershedNorth Fork Cross Creek               29.16    4755.47   0.006    0.995
dat$WatershedPigeon Creek                        -89.30    4217.35  -0.021    0.983
dat$WatershedPike Run                          -8548.57    5172.83  -1.653    0.110
dat$WatershedPlum Run-Tenmile Creek             -113.73    4577.62  -0.025    0.980
dat$WatershedShort Creek-Tenmile Creek         -3245.74    4713.58  -0.689    0.497
dat$WatershedSouth Fork Cross Creek-Cross Creek -3482.47    3758.69  -0.927    0.362
dat$WatershedTempleton Fork                    -1061.52    5799.14  -0.183    0.856
dat$FormationCasselman Formation                     NA         NA      NA       NA
dat$FormationGreene Formation                  -2247.08    3165.55  -0.710    0.484
dat$FormationMonongahela Group                 -2326.64    3749.60  -0.621    0.540
dat$FormationWaynesburg Formation              -3257.58    2576.12  -1.265    0.216
dat$HHWSourceSpring                              331.36    2244.77   0.148    0.884
dat$Precip_inchDiff                              -46.29     255.32  -0.181    0.857

(Dispersion parameter for gaussian family taken to be 23400343)

    Null deviance: 1015874362  on 47  degrees of freedom
Residual deviance:  655209616  on 28  degrees of freedom
AIC: 966.82

Number of Fisher Scoring iterations: 2




[1] "BOX-COX MODEL - Magnesium"
```

```
Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4333.8   -884.5     -9.4    551.8   5649.7

Coefficients: (1 not defined because of singularities)
                                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                                12068.423  10174.265   1.186   0.2455
dat$GWellDensity_2kmDiff                     -11.581    157.622  -0.073   0.9420
dat$Altitude_meter                            -3.088     27.527  -0.112   0.9115
dat$WatershedBane Creek                     -952.524   3170.484  -0.300   0.7661
dat$WatershedBrush Run                       538.759   1843.601   0.292   0.7723
dat$WatershedBurgetts Fork                 -1569.351   2336.032  -0.672   0.5072
dat$WatershedLittle Racoon Creek           -4703.109   3347.250  -1.405   0.1710
dat$WatershedLittle Tenmile Creek            300.473   2393.138   0.126   0.9010
dat$WatershedNorth Fork Cross Creek          131.754   2517.554   0.052   0.9586
dat$WatershedPigeon Creek                     23.512   2232.674   0.011   0.9917
dat$WatershedPike Run                      -4680.340   2738.507  -1.709   0.0985 .
dat$WatershedPlum Run-Tenmile Creek         -177.752   2423.403  -0.073   0.9421
dat$WatershedShort Creek-Tenmile Creek     -1733.848   2495.379  -0.695   0.4929
dat$WatershedSouth Fork Cross Creek-Cross Creek -1738.983   1989.860  -0.874   0.3896
dat$WatershedTempleton Fork                 -560.124   3070.077  -0.182   0.8565
dat$FormationCasselman Formation                  NA         NA      NA       NA
dat$FormationGreene Formation              -1184.385   1675.847  -0.707   0.4856
dat$FormationMonongahela Group             -1238.010   1985.046  -0.624   0.5379
dat$FormationWaynesburg Formation          -1737.458   1363.806  -1.274   0.2131
dat$HHWSourceSpring                          228.390   1188.386   0.192   0.8490
dat$Precip_inchDiff                          -33.587    135.169  -0.248   0.8056
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 6558332)

    Null deviance: 288819110  on 47  degrees of freedom
Residual deviance: 183633308  on 28  degrees of freedom
AIC: 905.77

Number of Fisher Scoring iterations: 2
```

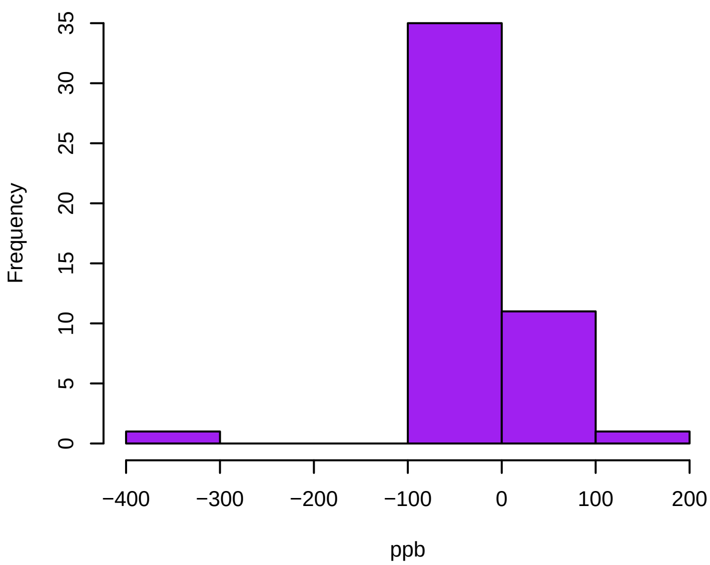
Manganese

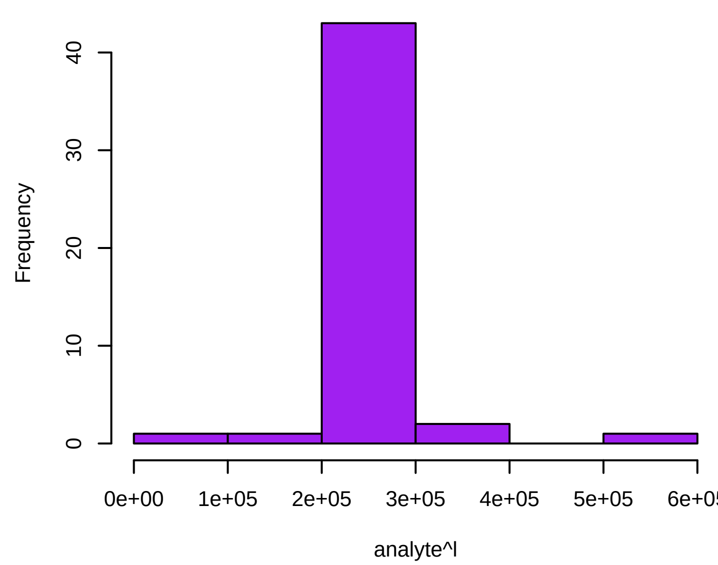
Skewness: −4.2355
Kurtosis: 28.7558

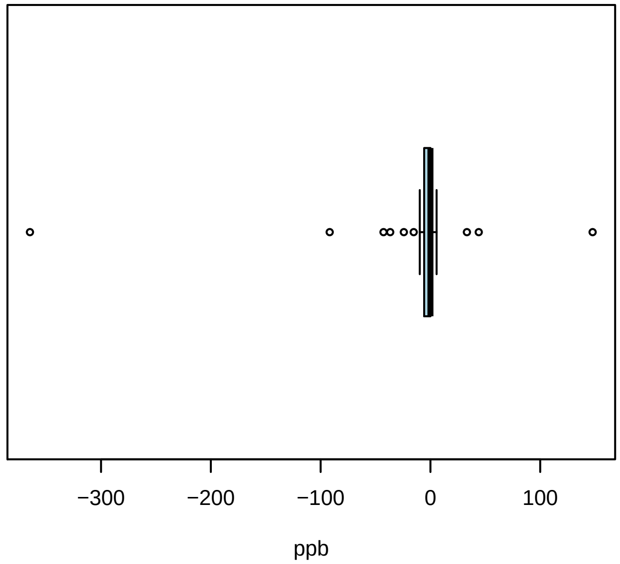
Manganese Box−Cox

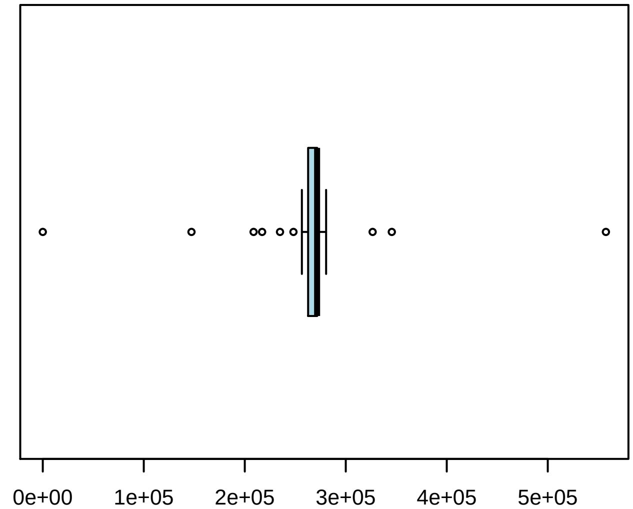
Skewness: 0.3681
Kurtosis: 16.9303

Optimal lambda: 2.12



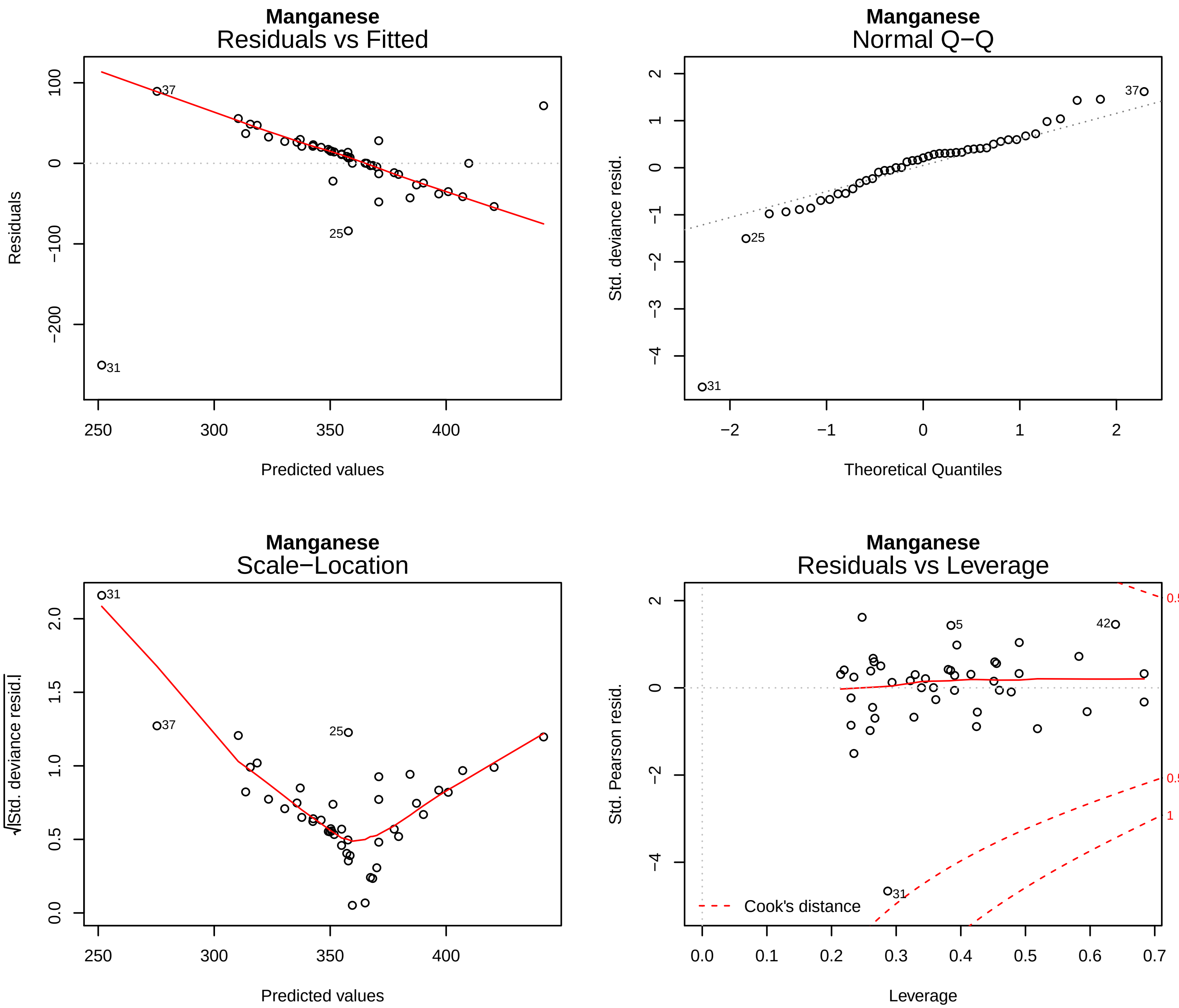






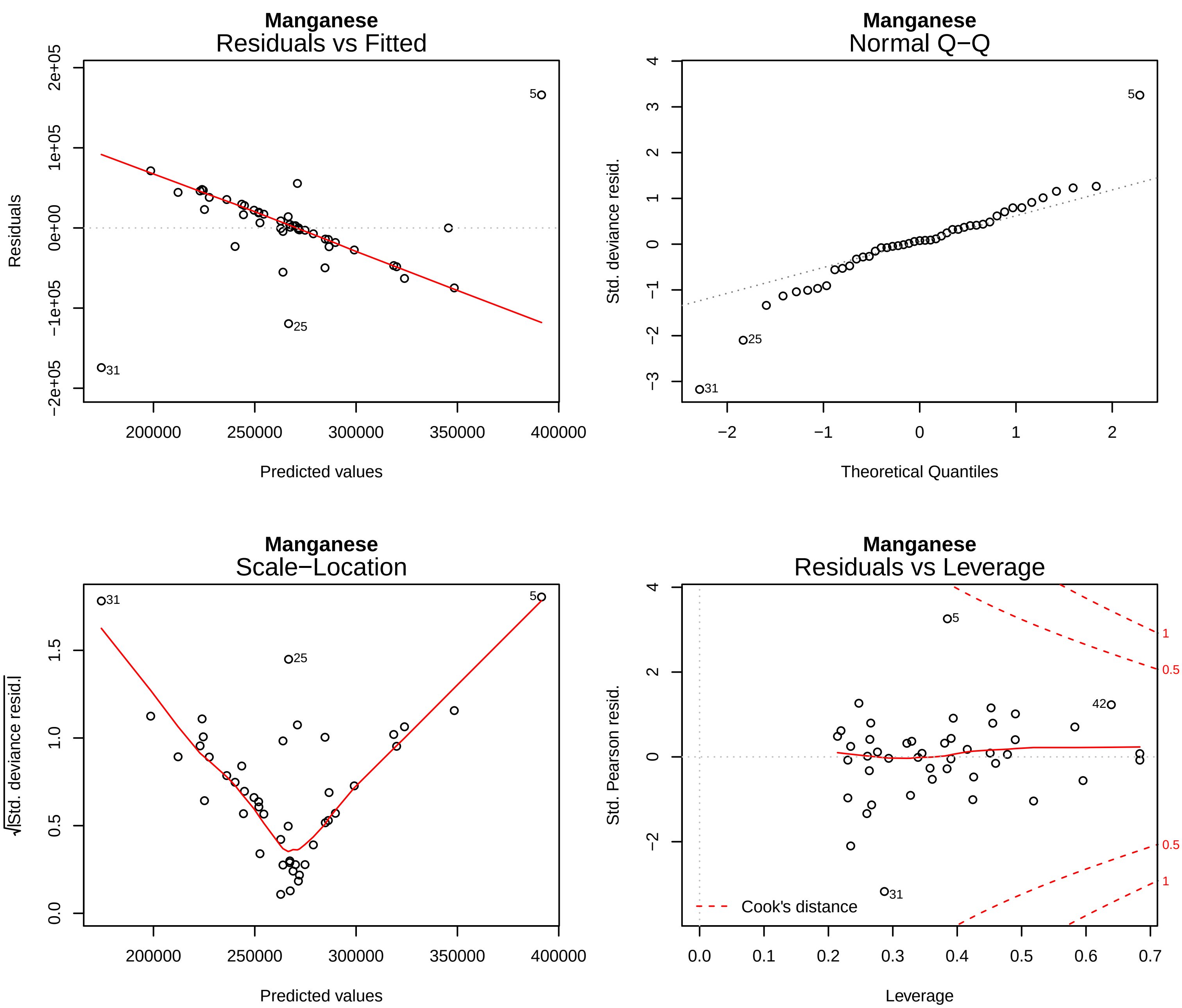
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

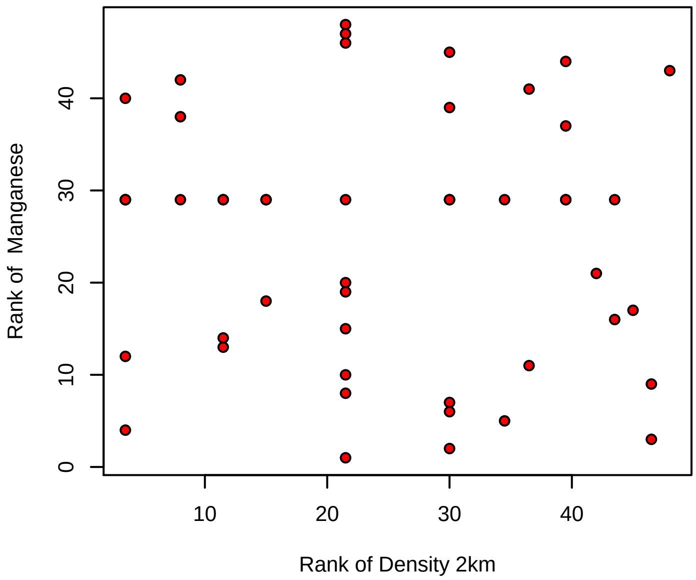
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



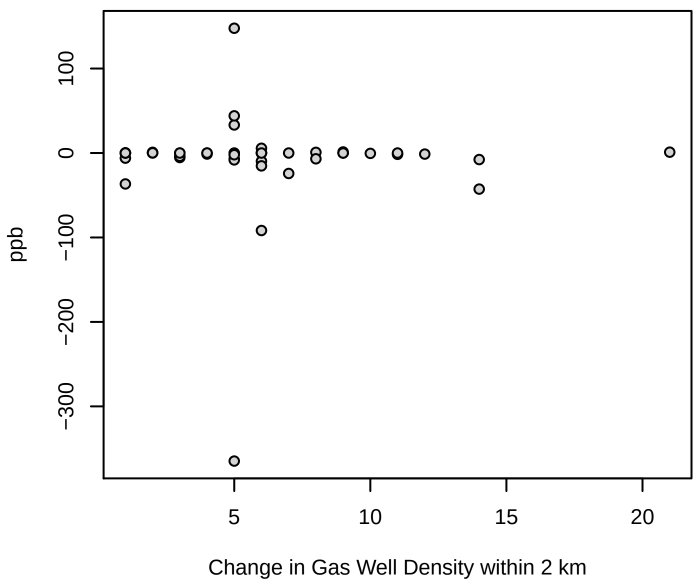


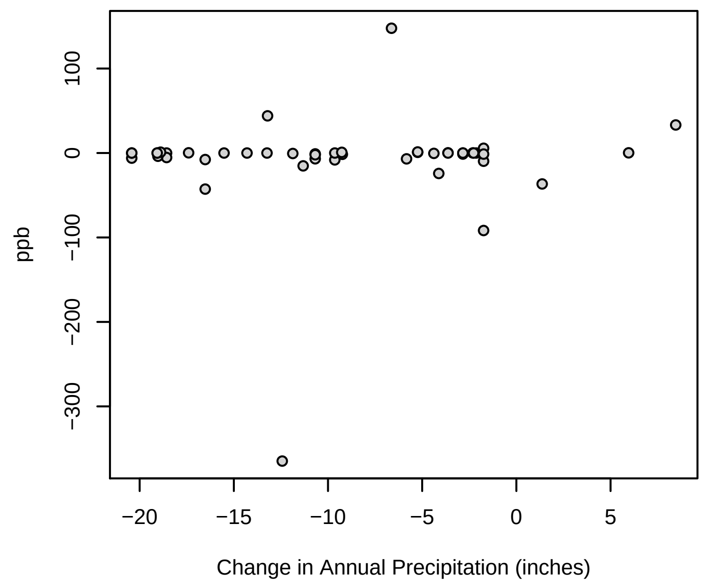
Manganese

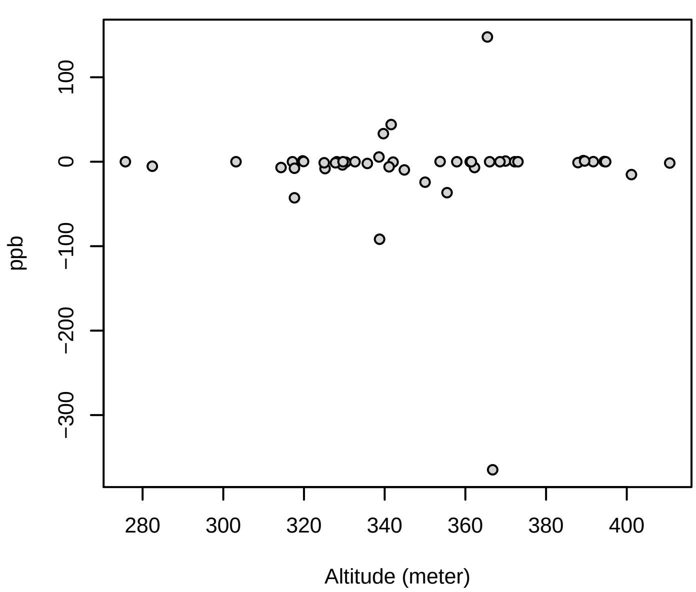
Kendalls Tau Rank Correlation

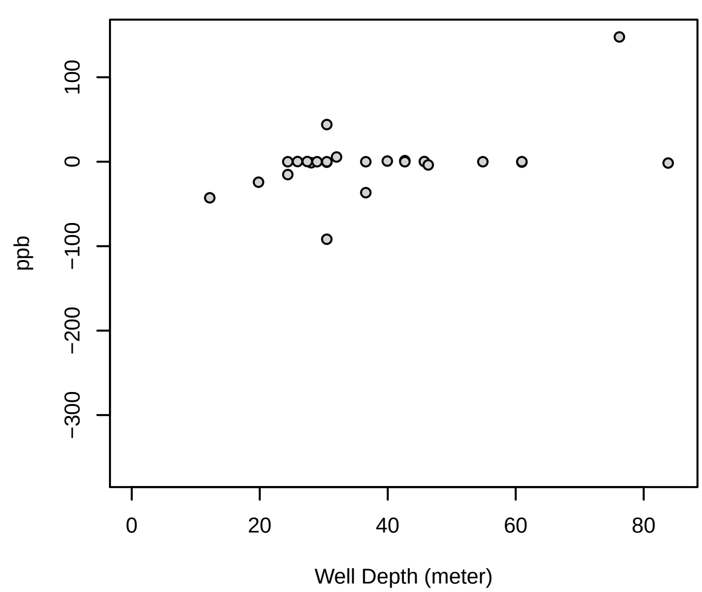
p−value: 0.566

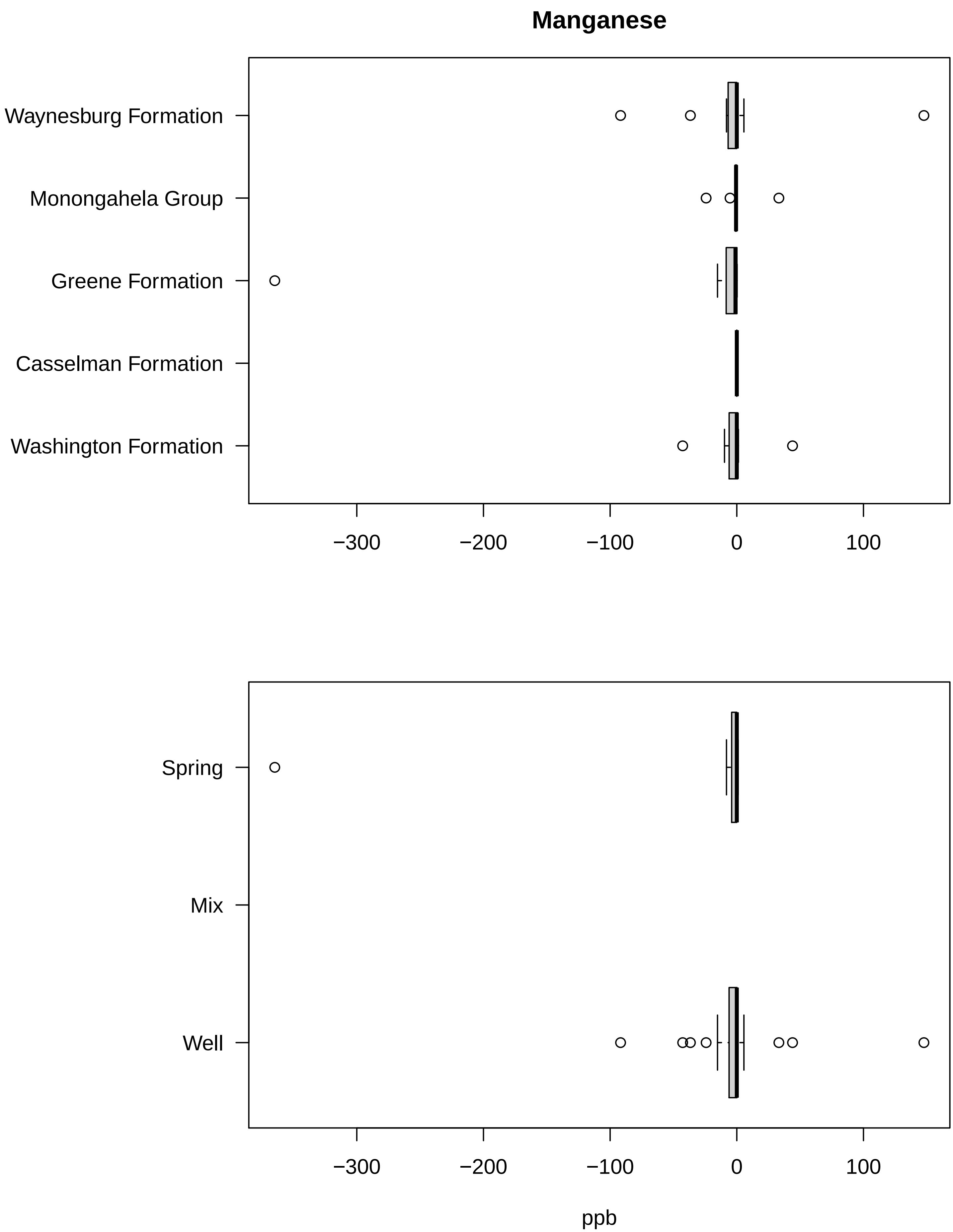
Tau: −0.0615

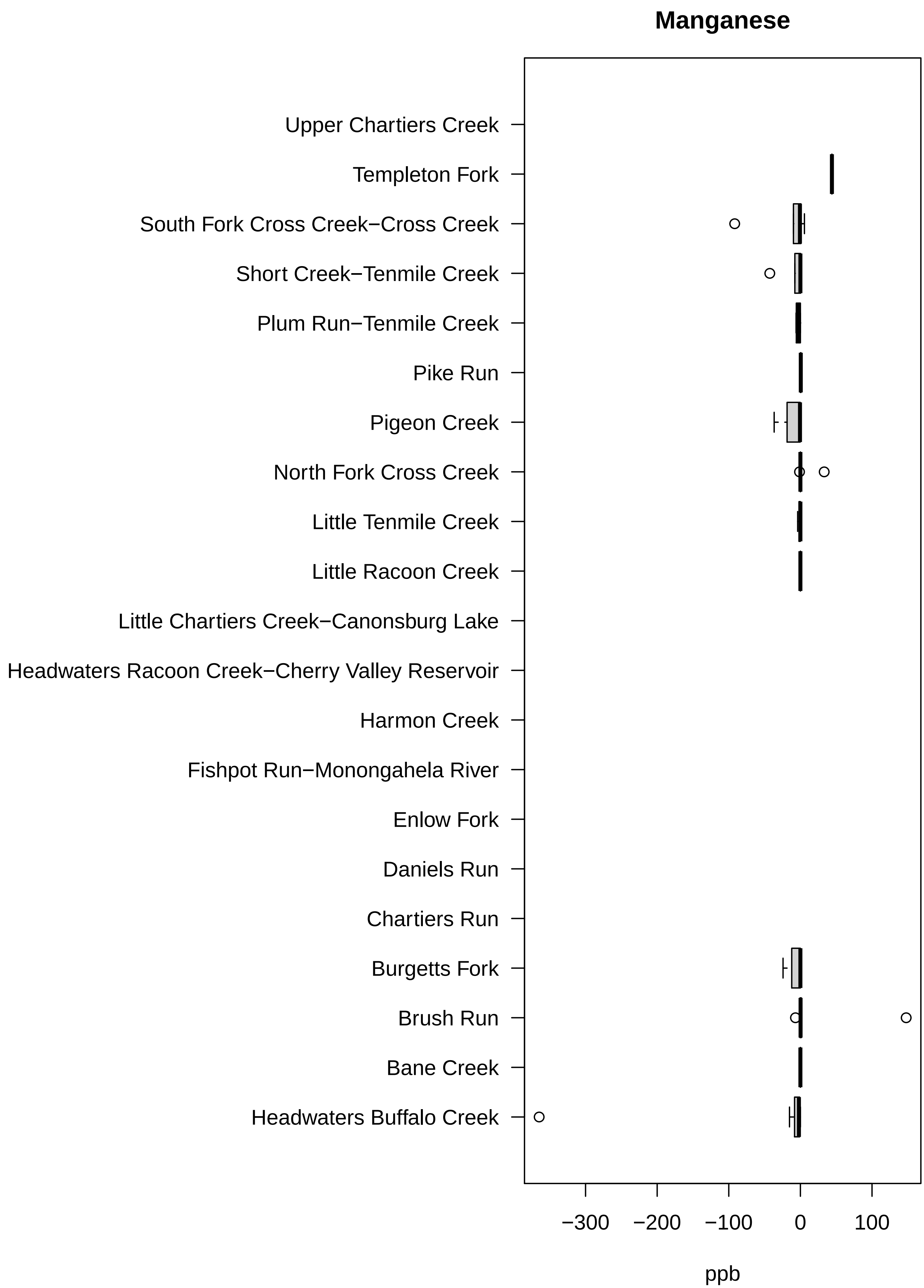









Manganese
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−300
−200
−100
0
100
Spring
Mix
Well
−300
−200
−100
0
100
ppb


Manganese
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−300
−200
−100
0
100
ppb

```
[1] "ORIGINAL MODEL - Manganese"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-250.507   -13.132     7.891    21.641    89.369

Coefficients: (1 not defined because of singularities)
                                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                                -50.4214   252.9002  -0.199    0.843
dat$GWellDensity_2kmDiff                    -1.6964     3.9180  -0.433    0.668
dat$Altitude_meter                           1.1406     0.6842   1.667    0.107
dat$WatershedBane Creek                     74.4535    78.8082   0.945    0.353
dat$WatershedBrush Run                      41.5182    45.8261   0.906    0.373
dat$WatershedBurgetts Fork                 -26.8125    58.0664  -0.462    0.648
dat$WatershedLittle Racoon Creek            76.4195    83.2021   0.918    0.366
dat$WatershedLittle Tenmile Creek           12.0689    59.4859   0.203    0.841
dat$WatershedNorth Fork Cross Creek        -29.7644    62.5785  -0.476    0.638
dat$WatershedPigeon Creek                  -43.2800    55.4972  -0.780    0.442
dat$WatershedPike Run                      -12.4609    68.0707  -0.183    0.856
dat$WatershedPlum Run-Tenmile Creek         43.8356    60.2382   0.728    0.473
dat$WatershedShort Creek-Tenmile Creek      79.9805    62.0272   1.289    0.208
dat$WatershedSouth Fork Cross Creek-Cross Creek  -9.6461    49.4617  -0.195    0.847
dat$WatershedTempleton Fork                 76.7593    76.3124   1.006    0.323
dat$FormationCasselman Formation                 NA         NA      NA       NA
dat$FormationGreene Formation              -85.3429    41.6563  -2.049    0.050 *
dat$FormationMonongahela Group              73.5969    49.3420   1.492    0.147
dat$FormationWaynesburg Formation           41.4068    33.8999   1.221    0.232
dat$HHWSourceSpring                        -24.7077    29.5395  -0.836    0.410
dat$Precip_inchDiff                         -0.1711     3.3599  -0.051    0.960
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 4052.15)

    Null deviance: 167370  on 47  degrees of freedom
Residual deviance: 113460  on 28  degrees of freedom
AIC: 551.08

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Manganese"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-174267   -15272     1822    22364   166042

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                 -217149.25  258302.16  -0.841   0.4076
dat$GWellDensity_2kmDiff                      -2227.93    4001.67  -0.557   0.5821
dat$Altitude_meter                             1275.71     698.85   1.825   0.0786 .
dat$WatershedBane Creek                       59547.20   80491.59   0.740   0.4656
dat$WatershedBrush Run                        81265.73   46804.97   1.736   0.0935 .
dat$WatershedBurgetts Fork                   -30343.86   59306.71  -0.512   0.6129
dat$WatershedLittle Racoon Creek              91224.68   84979.29   1.073   0.2922
dat$WatershedLittle Tenmile Creek              2398.53   60756.50   0.039   0.9688
dat$WatershedNorth Fork Cross Creek          -16342.98   63915.15  -0.256   0.8001
dat$WatershedPigeon Creek                    -54122.71   56682.68  -0.955   0.3478
dat$WatershedPike Run                         -8300.94   69524.66  -0.119   0.9058
dat$WatershedPlum Run-Tenmile Creek           27279.41   61524.87   0.443   0.6609
dat$WatershedShort Creek-Tenmile Creek        82224.20   63352.16   1.298   0.2049
dat$WatershedSouth Fork Cross Creek-Cross Creek      82.74   50518.16   0.002   0.9987
dat$WatershedTempleton Fork                  118249.27   77942.48   1.517   0.1404
dat$FormationCasselman Formation                    NA         NA      NA       NA
dat$FormationGreene Formation                -73080.12   42546.06  -1.718   0.0969 .
dat$FormationMonongahela Group                95038.41   50395.93   1.886   0.0697 .
dat$FormationWaynesburg Formation             62373.29   34624.03   1.801   0.0824 .
dat$HHWSourceSpring                          -10906.98   30170.50  -0.362   0.7204
dat$Precip_inchDiff                           -1501.58    3431.64  -0.438   0.6651
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 4227108604)

    Null deviance: 1.8819e+11  on 47  degrees of freedom
Residual deviance: 1.1836e+11  on 28  degrees of freedom
AIC: 1216.3

Number of Fisher Scoring iterations: 2
```

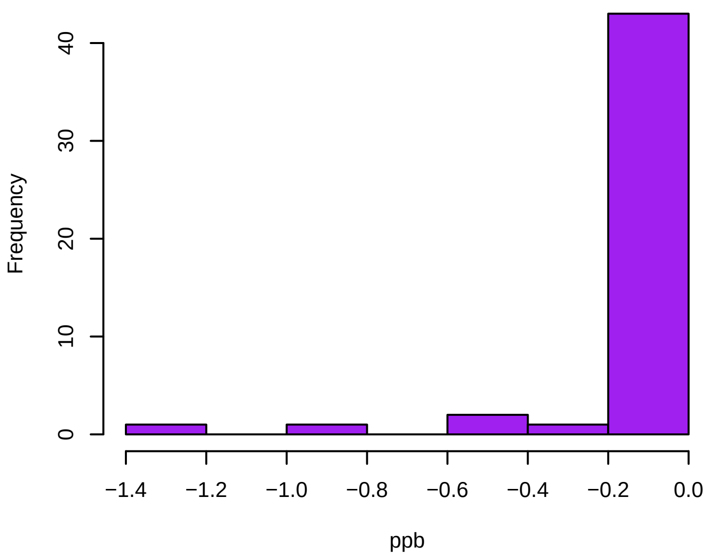
Mercury

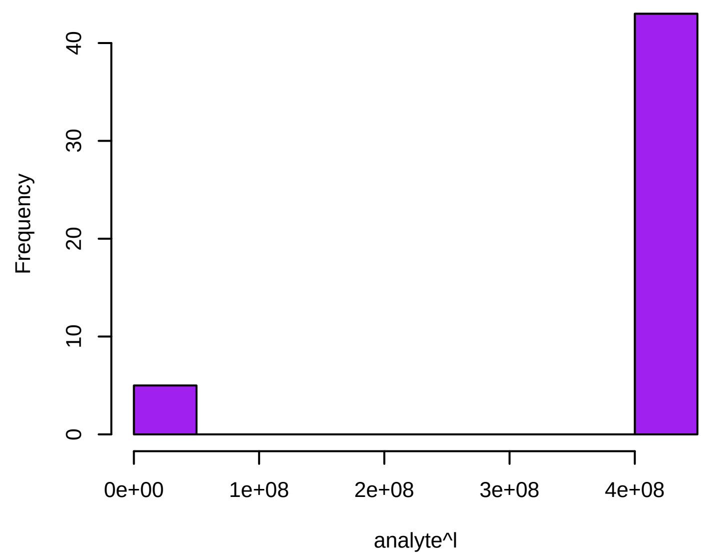
Skewness: −3.7207
Kurtosis: 16.7068

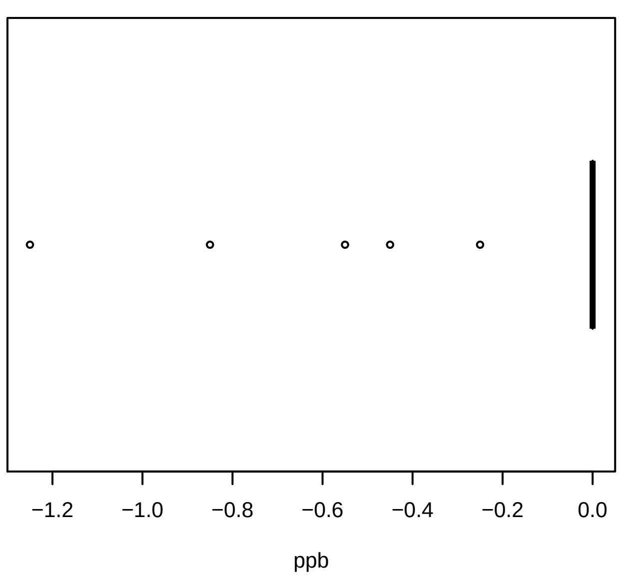
Mercury Box−Cox

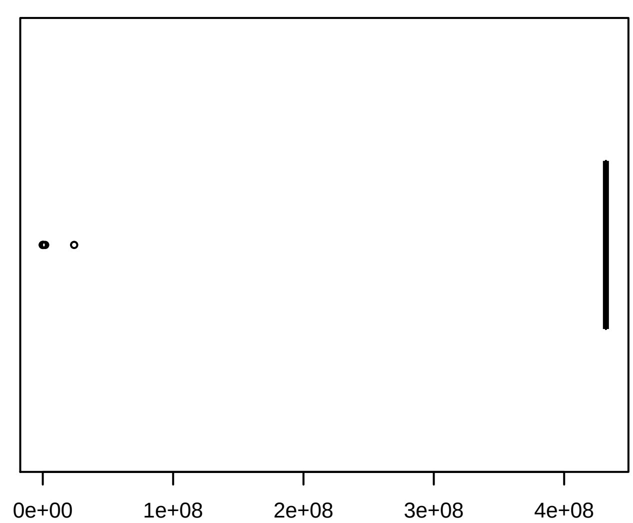
Skewness: −2.5942
Kurtosis: 7.7353

Optimal lambda: 24.52



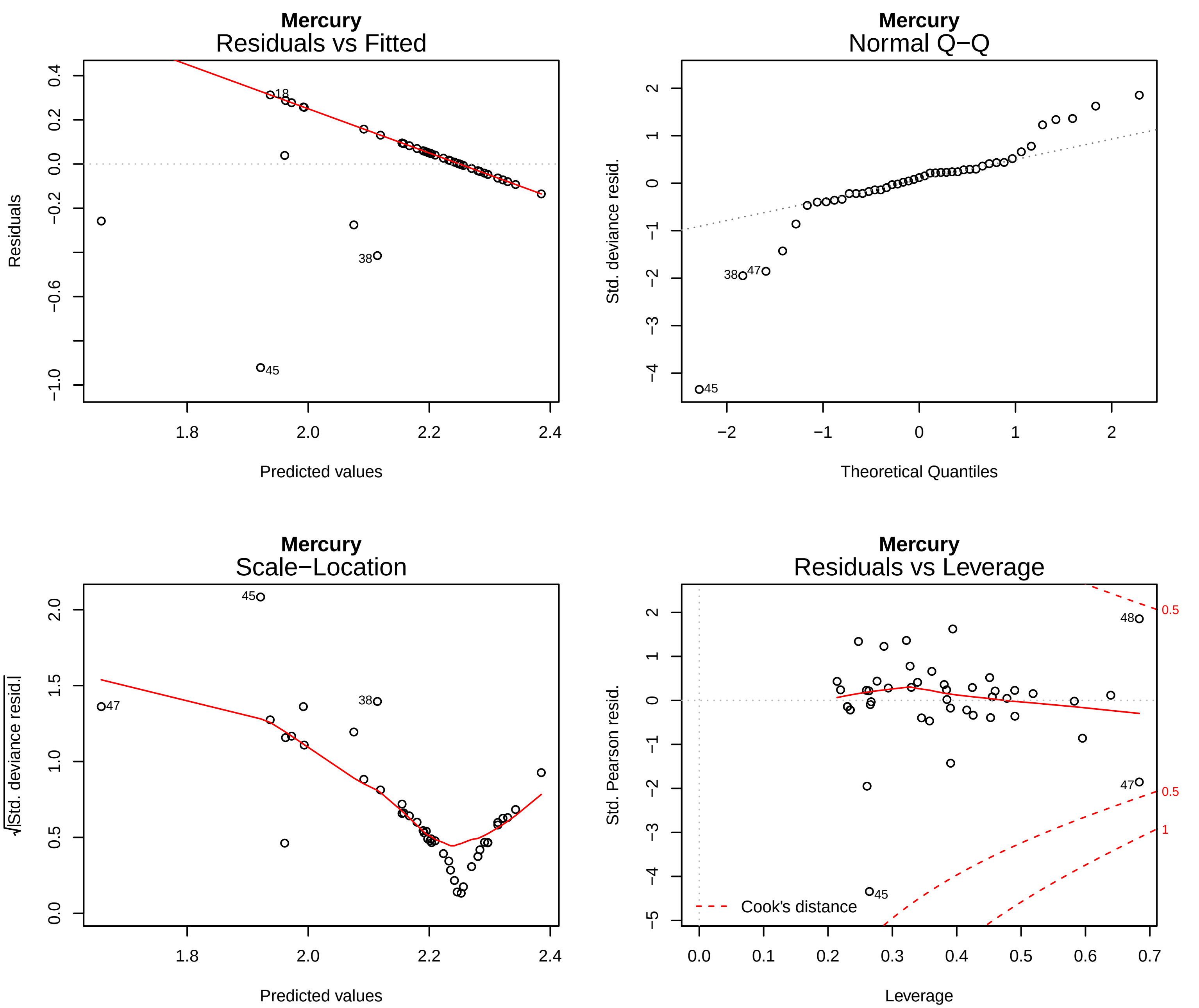






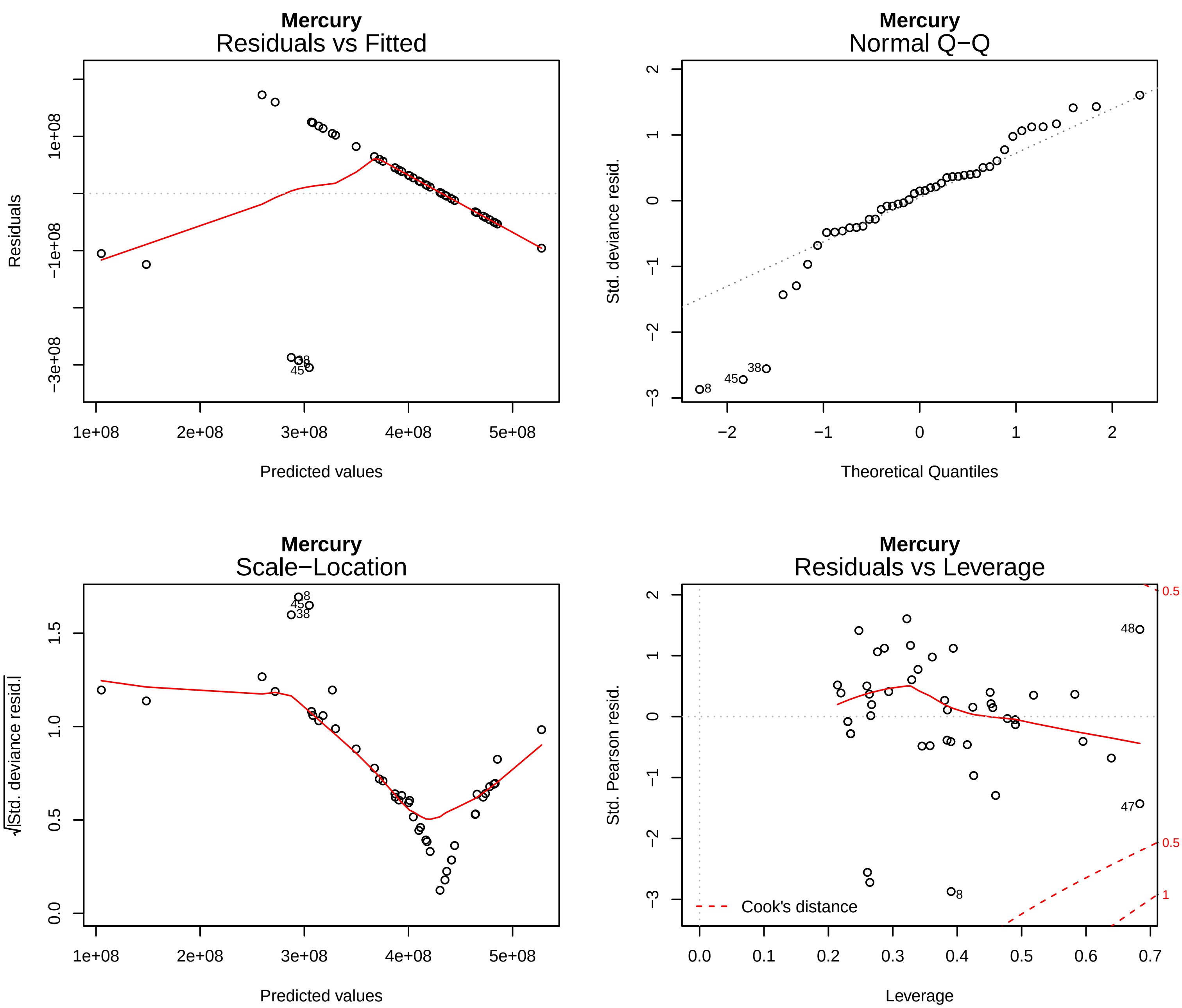
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

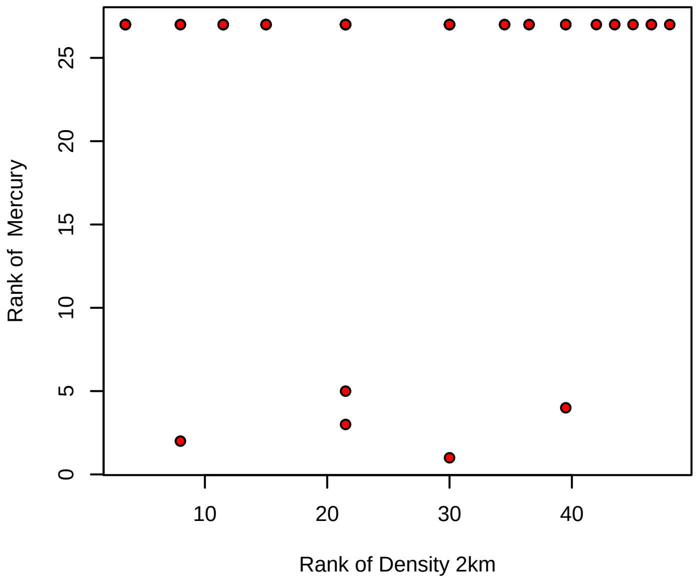
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



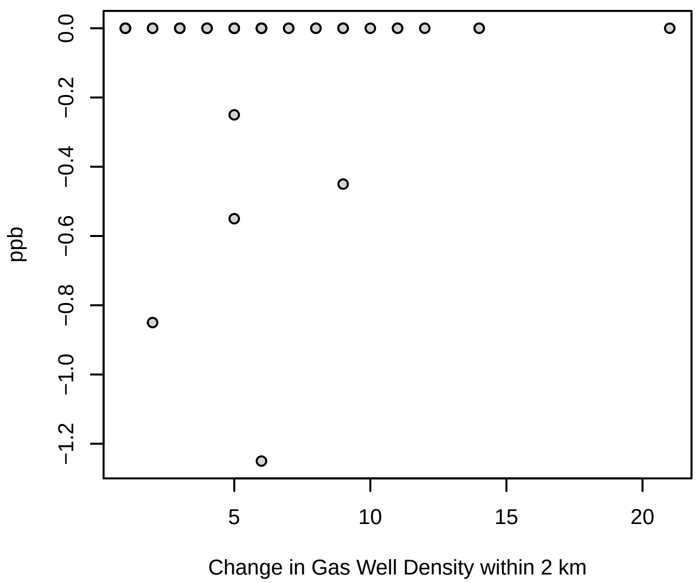


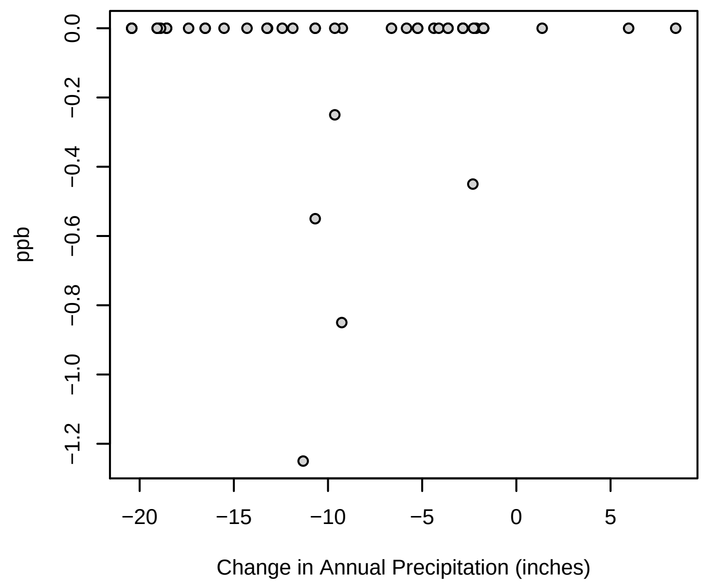
Mercury

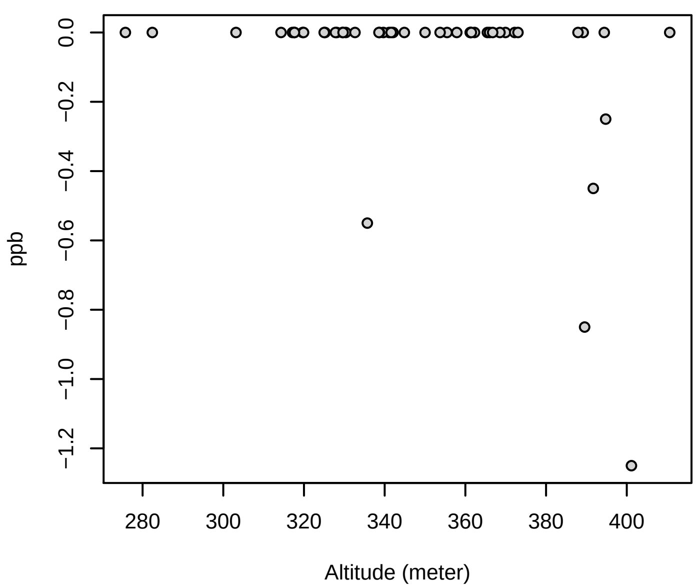
Kendalls Tau Rank Correlation

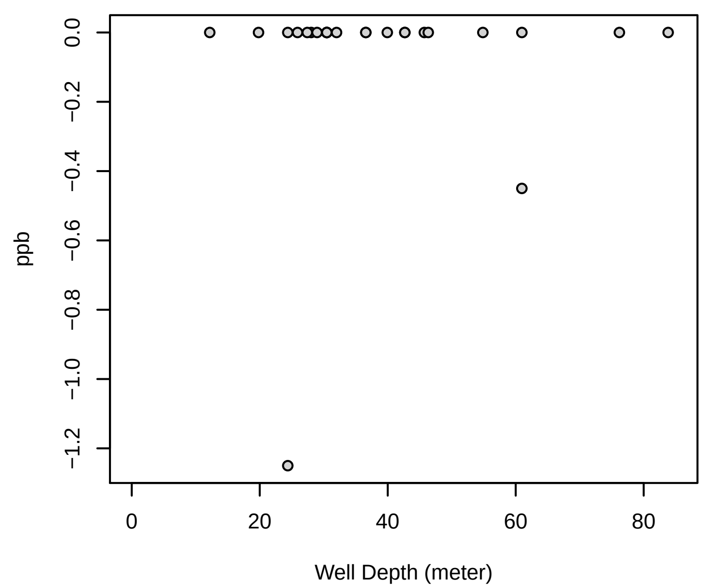
p−value: 0.932

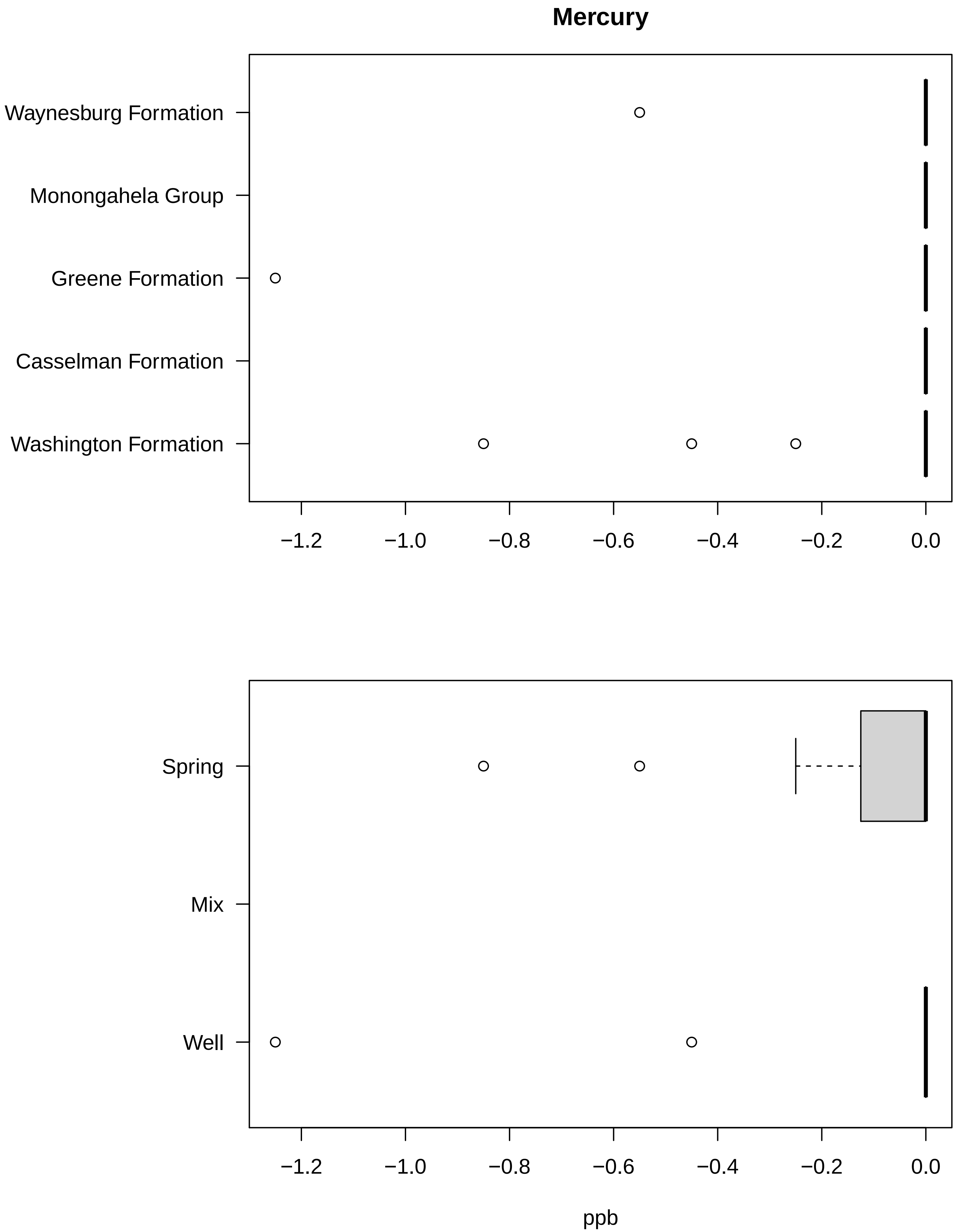
Tau: 0.0104

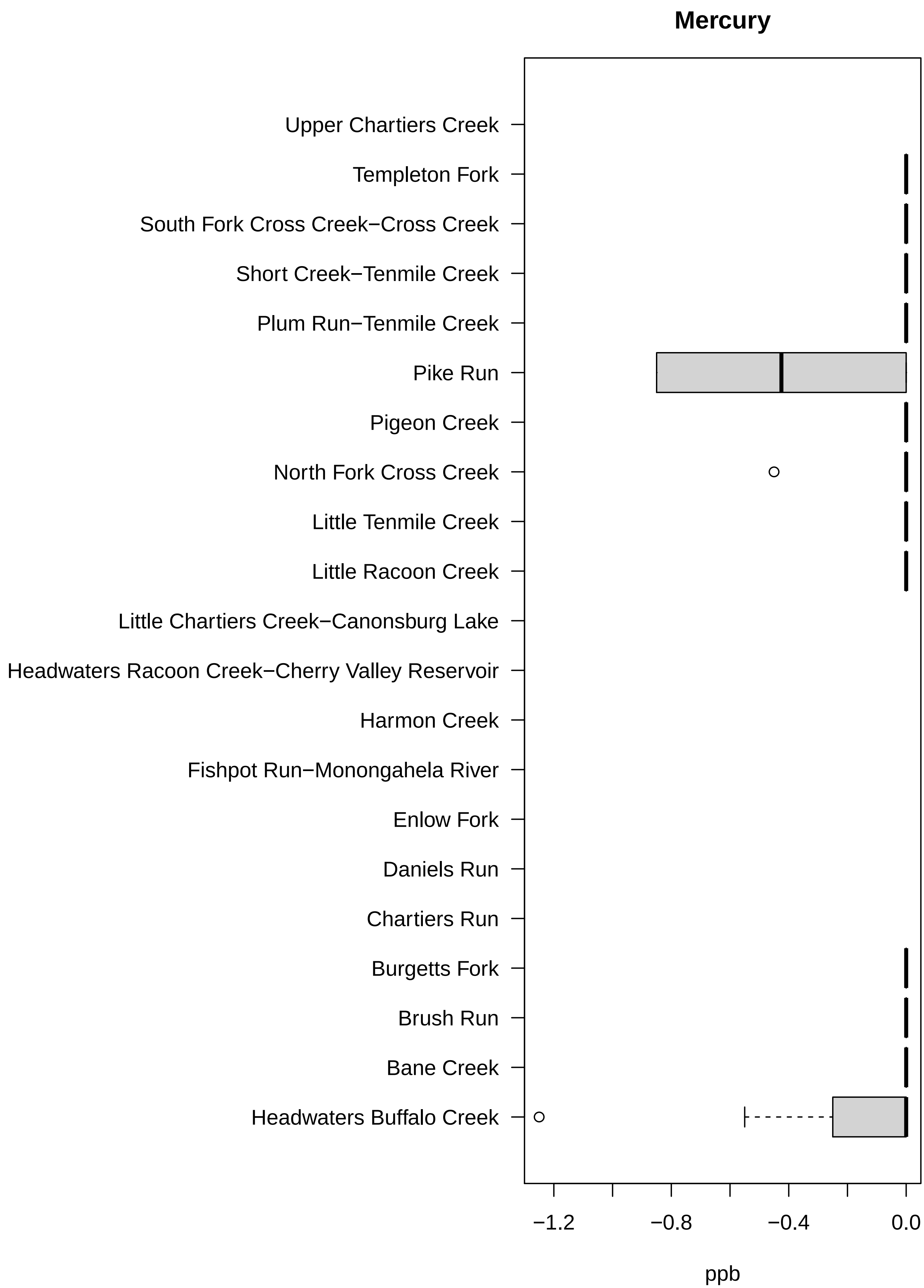









Mercury
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−1.2
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
Spring
Mix
Well
ppb


Mercury
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−1.2
−0.8
−0.4
0.0
ppb

```
[1] "ORIGINAL MODEL - Mercury"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.92128  -0.04264   0.01157   0.06265   0.31281  

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                   3.154972   0.982682   3.211  0.00332 **
dat$GWellDensity_2kmDiff                      0.002103   0.015224   0.138  0.89113   
dat$Altitude_meter                           -0.002684   0.002659  -1.010  0.32136   
dat$WatershedBane Creek                       0.378746   0.306221   1.237  0.22642   
dat$WatershedBrush Run                        0.149855   0.178064   0.842  0.40715   
dat$WatershedBurgetts Fork                    0.070665   0.225626   0.313  0.75645   
dat$WatershedLittle Racoon Creek             -0.003397   0.323294  -0.011  0.99169   
dat$WatershedLittle Tenmile Creek             0.240797   0.231141   1.042  0.30643   
dat$WatershedNorth Fork Cross Creek          -0.012838   0.243158  -0.053  0.95827   
dat$WatershedPigeon Creek                     0.151733   0.215643   0.704  0.48747   
dat$WatershedPike Run                        -0.316288   0.264499  -1.196  0.24180   
dat$WatershedPlum Run-Tenmile Creek           0.230306   0.234065   0.984  0.33357   
dat$WatershedShort Creek-Tenmile Creek        0.193707   0.241016   0.804  0.42834   
dat$WatershedSouth Fork Cross Creek-Cross Creek  0.053938   0.192191   0.281  0.78104   
dat$WatershedTempleton Fork                   0.197406   0.296524   0.666  0.51103   
dat$FormationCasselman Formation                    NA         NA      NA       NA   
dat$FormationGreene Formation                -0.001607   0.161862  -0.010  0.99215   
dat$FormationMonongahela Group               -0.044666   0.191726  -0.233  0.81748   
dat$FormationWaynesburg Formation             0.010112   0.131723   0.077  0.93935   
dat$HHWSourceSpring                          -0.001709   0.114780  -0.015  0.98822   
dat$Precip_inchDiff                           0.014837   0.013055   1.136  0.26538   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.06118057)

    Null deviance: 2.6187  on 47  degrees of freedom
Residual deviance: 1.7131  on 28  degrees of freedom
AIC: 18.238

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Mercury"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-304815215  -35287249    6470734   47889033  172624122

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                 1047100028  518851696   2.018   0.0533 .
dat$GWellDensity_2kmDiff                       4724000    8038166   0.588   0.5614
dat$Altitude_meter                            -2079597    1403790  -1.481   0.1497
dat$WatershedBane Creek                      126903364  161683508   0.785   0.4391
dat$WatershedBrush Run                       118649405   94017176   1.262   0.2174
dat$WatershedBurgetts Fork                   103000349  119129422   0.865   0.3946
dat$WatershedLittle Racoon Creek             106990351  170697942   0.627   0.5359
dat$WatershedLittle Tenmile Creek            126674916  122041606   1.038   0.3082
dat$WatershedNorth Fork Cross Creek           29736456  128386391   0.232   0.8185
dat$WatershedPigeon Creek                    126129537  113858528   1.108   0.2774
dat$WatershedPike Run                        -41523149  139654218  -0.297   0.7684
dat$WatershedPlum Run-Tenmile Creek          156783676  123585036   1.269   0.2150
dat$WatershedShort Creek-Tenmile Creek        62346309  127255519   0.490   0.6280
dat$WatershedSouth Fork Cross Creek-Cross Creek   79830352  101475863   0.787   0.4381
dat$WatershedTempleton Fork                  130588199  156563112   0.834   0.4113
dat$FormationCasselman Formation                    NA         NA      NA       NA
dat$FormationGreene Formation                114073184   85462290   1.335   0.1927
dat$FormationMonongahela Group               -20178094  101230331  -0.199   0.8434
dat$FormationWaynesburg Formation             20979865   69549299   0.302   0.7651
dat$HHWSourceSpring                          -58486476   60603490  -0.965   0.3428
dat$Precip_inchDiff                            4457339    6893143   0.647   0.5231
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1.705587e+16)

    Null deviance: 8.1623e+17  on 47  degrees of freedom
Residual deviance: 4.7756e+17  on 28  degrees of freedom
AIC: 1946.4

Number of Fisher Scoring iterations: 2
```

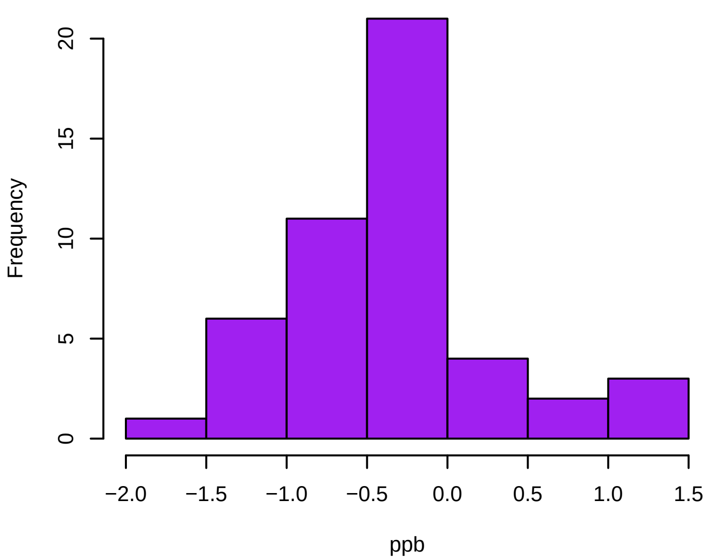
Nickel

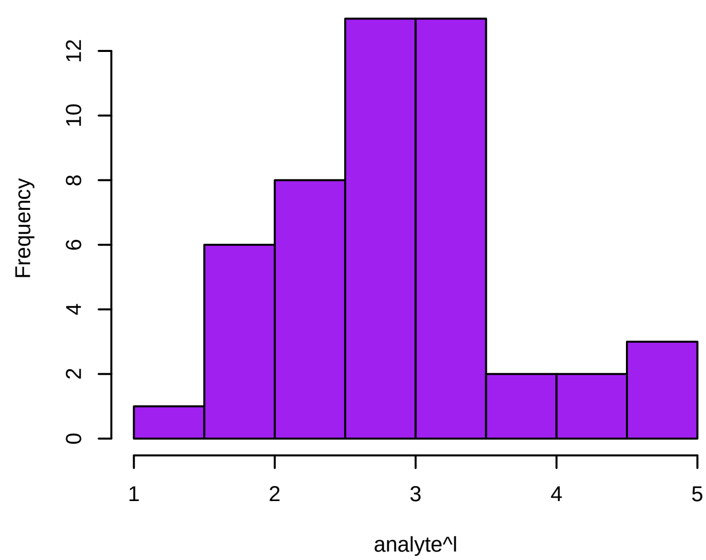
Skewness: 0.2937
Kurtosis: 3.3590

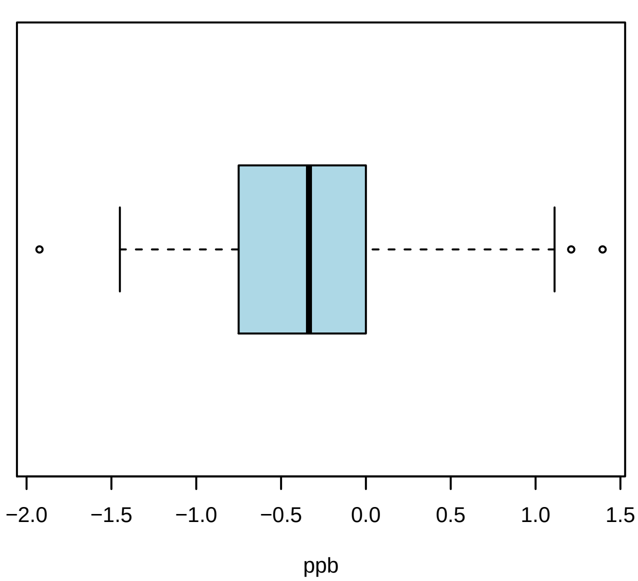
Nickel Box−Cox

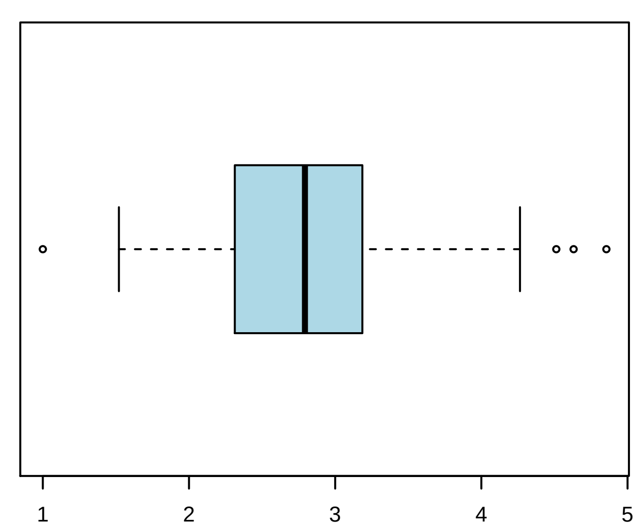
Skewness: 0.3667
Kurtosis: 3.3873

Optimal lambda: 1.08



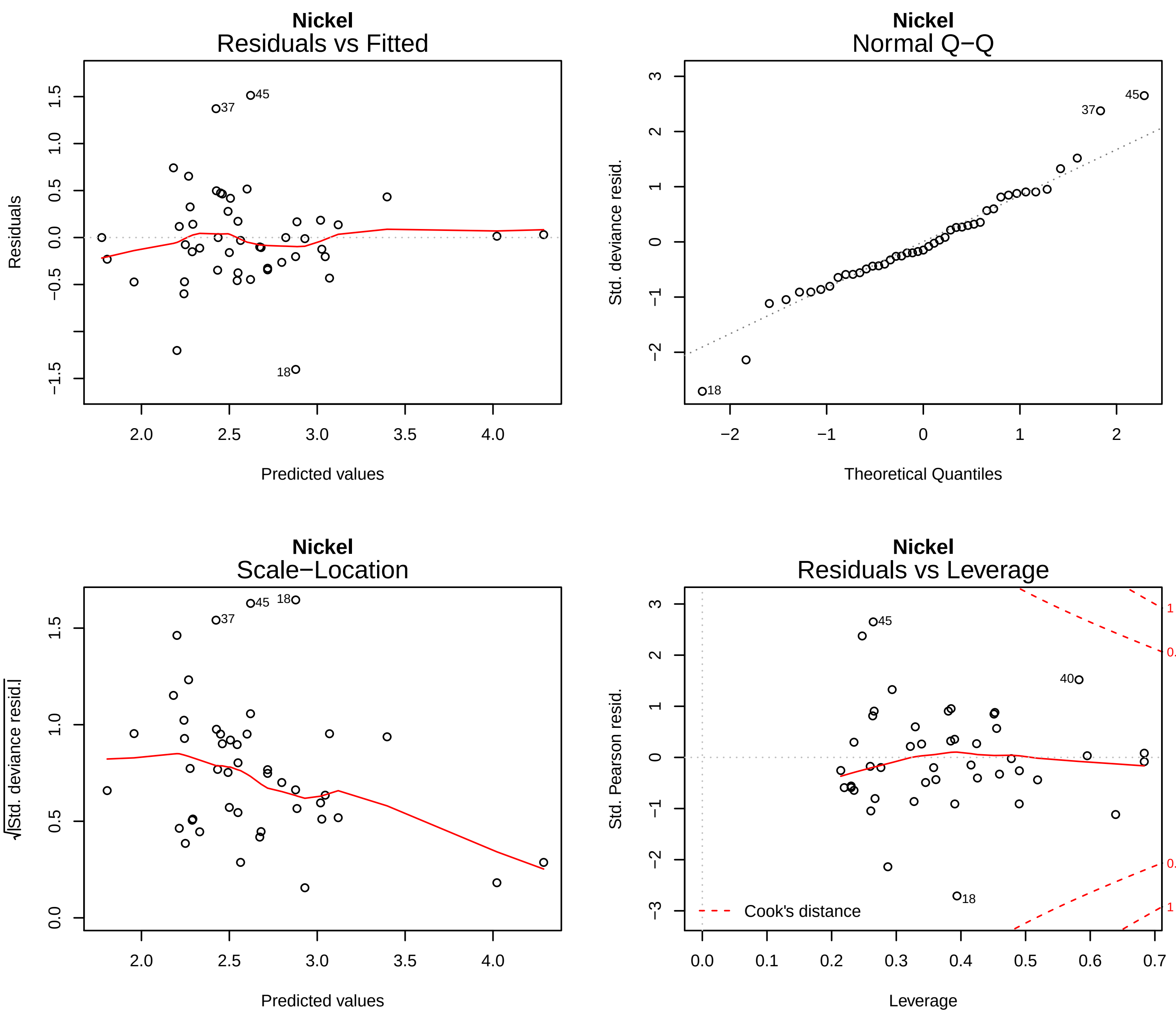






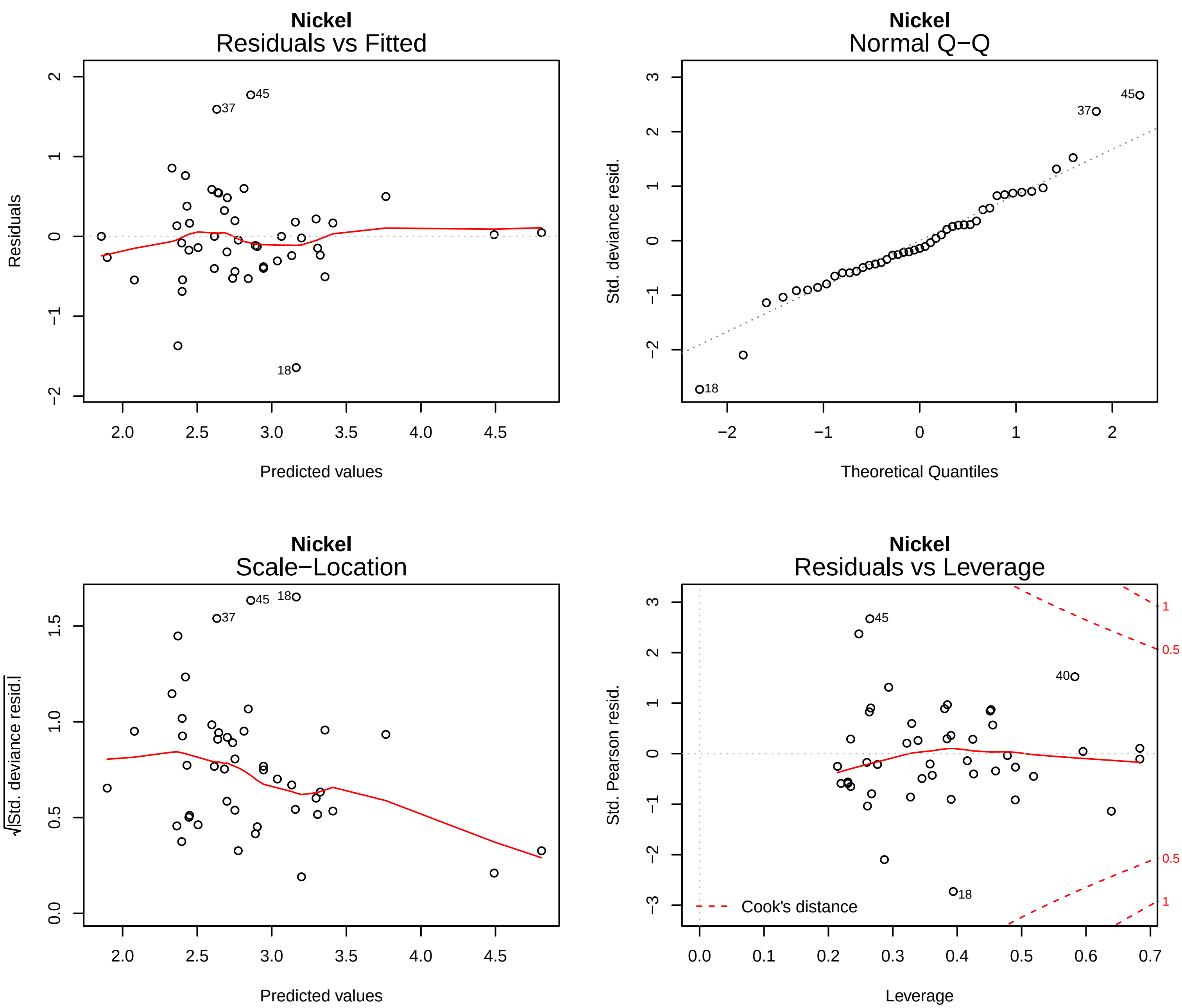
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

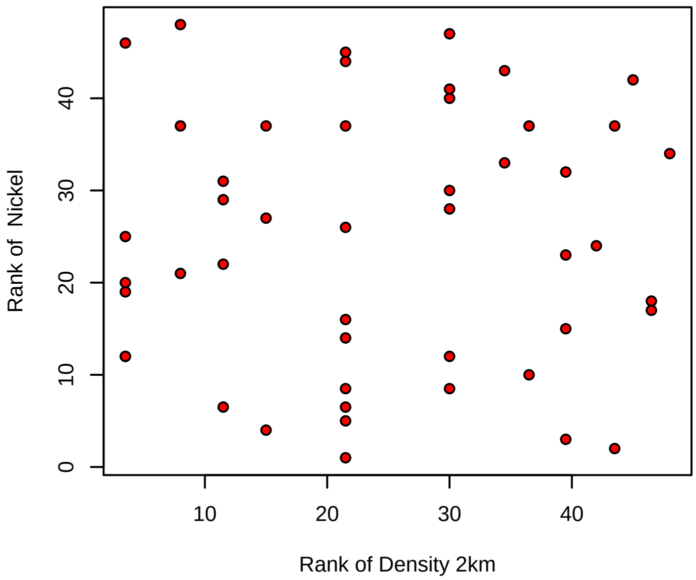
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox
Model



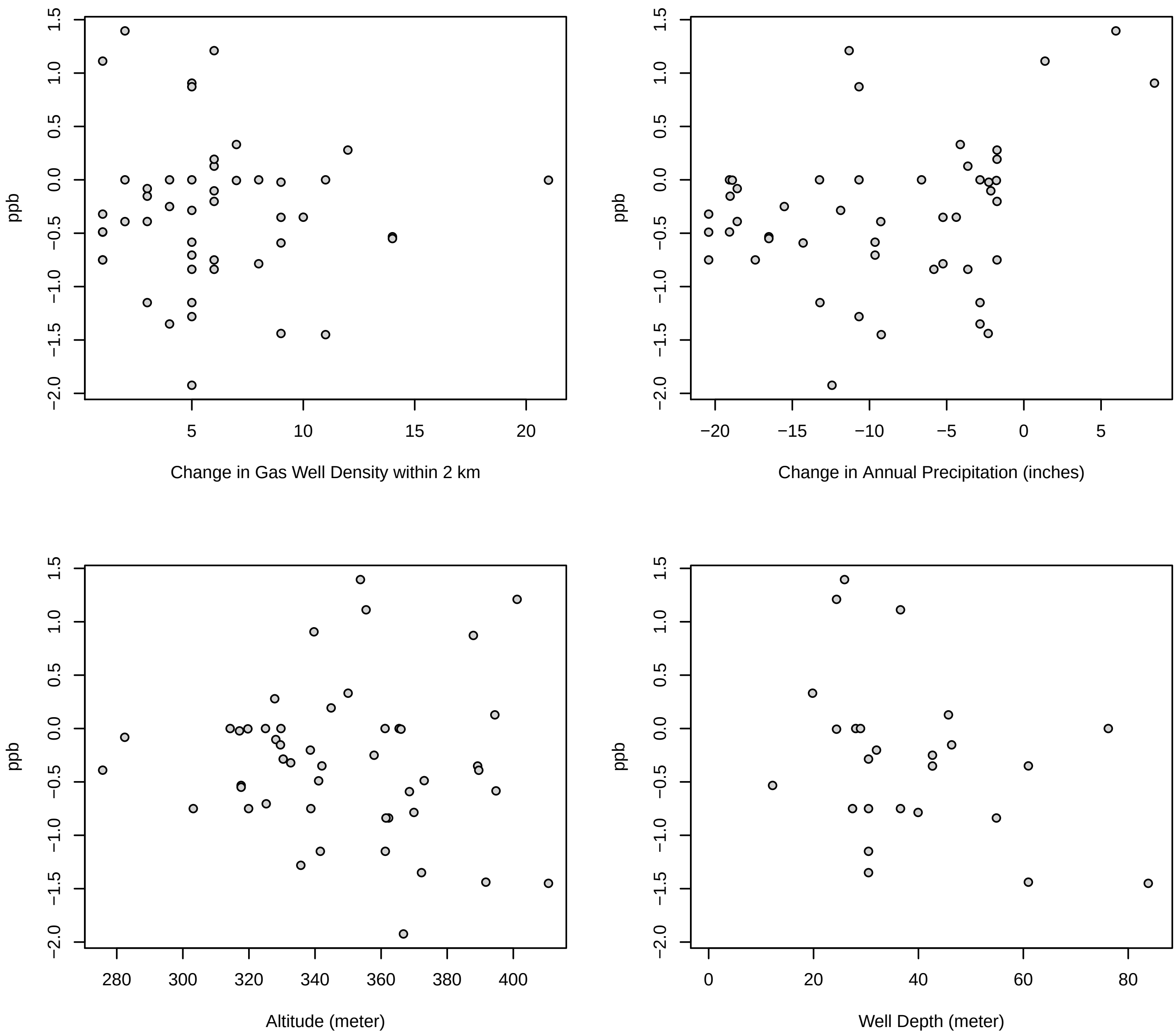


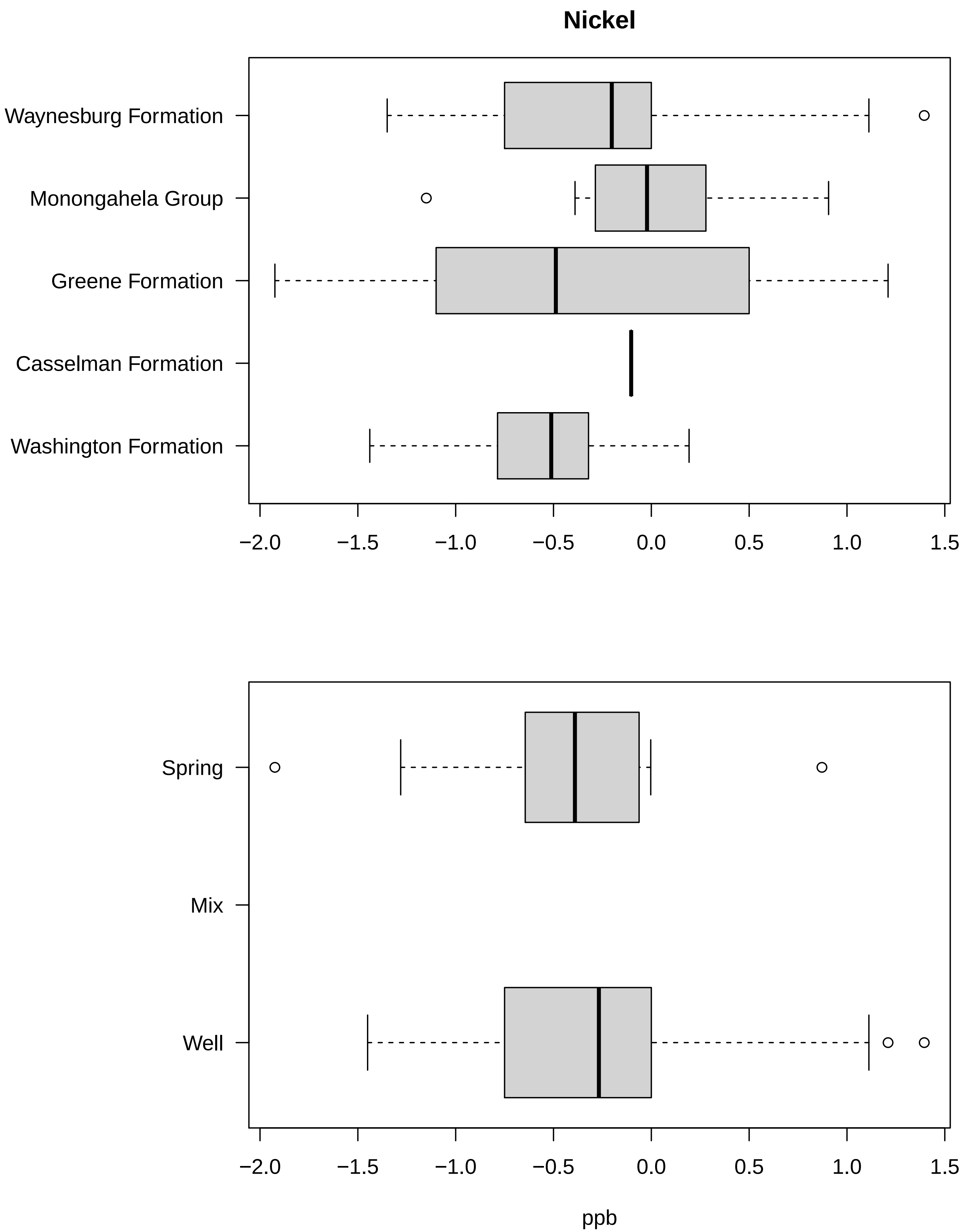
Nickel

Kendalls Tau Rank Correlation

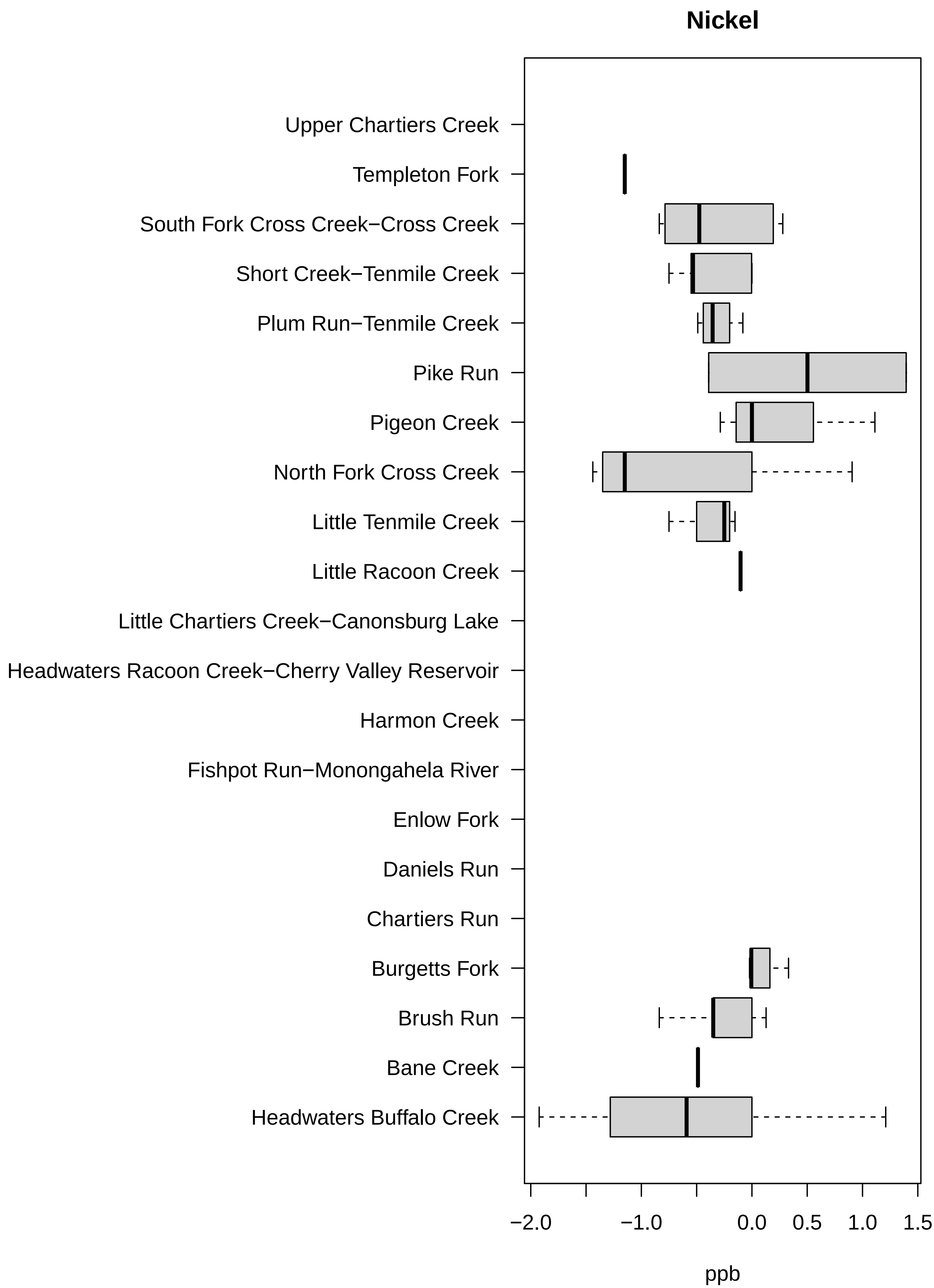
p−value: 0.85

Tau: 0.0197





Nickel
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
Spring
Mix
Well
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
ppb


Nickel
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−2.0
−1.0
0.0
0.5
1.0
1.5
ppb

```
[1] "ORIGINAL MODEL - Nickel"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-1.40362  -0.27989  -0.02127   0.20767   1.51311  

Coefficients: (1 not defined because of singularities)
                                             Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                  2.994566   2.644275   1.132  0.26704   
dat$GWellDensity_2kmDiff                     0.004255   0.040966   0.104  0.91801   
dat$Altitude_meter                           0.001846   0.007154   0.258  0.79822   
dat$WatershedBane Creek                      0.700284   0.824004   0.850  0.40261   
dat$WatershedBrush Run                      -0.529469   0.479149  -1.105  0.27856   
dat$WatershedBurgetts Fork                  -0.543895   0.607131  -0.896  0.37797   
dat$WatershedLittle Racoon Creek            -0.345914   0.869945  -0.398  0.69392   
dat$WatershedLittle Tenmile Creek            0.870593   0.621973   1.400  0.17258   
dat$WatershedNorth Fork Cross Creek         -1.556255   0.654308  -2.378  0.02444 * 
dat$WatershedPigeon Creek                    0.263450   0.580268   0.454  0.65332   
dat$WatershedPike Run                        0.047576   0.711734   0.067  0.94718   
dat$WatershedPlum Run-Tenmile Creek          1.038091   0.629839   1.648  0.11049   
dat$WatershedShort Creek-Tenmile Creek       0.807889   0.648545   1.246  0.22320   
dat$WatershedSouth Fork Cross Creek-Cross Creek -0.873876   0.517161  -1.690  0.10218   
dat$WatershedTempleton Fork                 -0.488568   0.797908  -0.612  0.54527   
dat$FormationCasselman Formation                   NA         NA      NA       NA   
dat$FormationGreene Formation                0.046087   0.435550   0.106  0.91649   
dat$FormationMonongahela Group               0.424182   0.515910   0.822  0.41791   
dat$FormationWaynesburg Formation           -0.040130   0.354451  -0.113  0.91067   
dat$HHWSourceSpring                         -0.234854   0.308860  -0.760  0.45338   
dat$Precip_inchDiff                          0.104772   0.035130   2.982  0.00587 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.4429968)

    Null deviance: 22.681  on 47  degrees of freedom
Residual deviance: 12.404  on 28  degrees of freedom
AIC: 113.27

Number of Fisher Scoring iterations: 2
```

[1] "BOX-COX MODEL - Nickel"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:

Min	1Q	Median	3Q	Max
-1.64360	-0.32607	-0.03338	0.24482	1.77208

Coefficients: (1 not defined because of singularities)

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	3.307542	3.073768	1.076	0.29109	
dat$GWellDensity_2kmDiff	0.005588	0.047619	0.117	0.90743	
dat$Altitude_meter	0.002101	0.008316	0.253	0.80239	
dat$WatershedBane Creek	0.802258	0.957841	0.838	0.40937	
dat$WatershedBrush Run	-0.637719	0.556974	-1.145	0.26191	
dat$WatershedBurgetts Fork	-0.648593	0.705743	-0.919	0.36593	
dat$WatershedLittle Racoon Creek	-0.427421	1.011244	-0.423	0.67577	
dat$WatershedLittle Tenmile Creek	1.019034	0.722996	1.409	0.16971	
dat$WatershedNorth Fork Cross Creek	-1.816467	0.760583	-2.388	0.02391	*
dat$WatershedPigeon Creek	0.309190	0.674518	0.458	0.65021	
dat$WatershedPike Run	0.057517	0.827336	0.070	0.94507	
dat$WatershedPlum Run-Tenmile Creek	1.217835	0.732139	1.663	0.10739	
dat$WatershedShort Creek-Tenmile Creek	0.934005	0.753884	1.239	0.22566	
dat$WatershedSouth Fork Cross Creek-Cross Creek	-1.036845	0.601161	-1.725	0.09560	.
dat$WatershedTempleton Fork	-0.562390	0.927507	-0.606	0.54917	
dat$FormationCasselman Formation	NA	NA	NA	NA	
dat$FormationGreene Formation	0.074904	0.506294	0.148	0.88345	
dat$FormationMonongahela Group	0.485883	0.599706	0.810	0.42466	
dat$FormationWaynesburg Formation	-0.047664	0.412022	-0.116	0.90873	
dat$HHWSourceSpring	-0.273394	0.359026	-0.761	0.45273	
dat$Precip_inchDiff	0.123661	0.040836	3.028	0.00524	**

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.59859)

    Null deviance: 30.873 on 47 degrees of freedom
Residual deviance: 16.761 on 28 degrees of freedom
AIC: 127.71

Number of Fisher Scoring iterations: 2

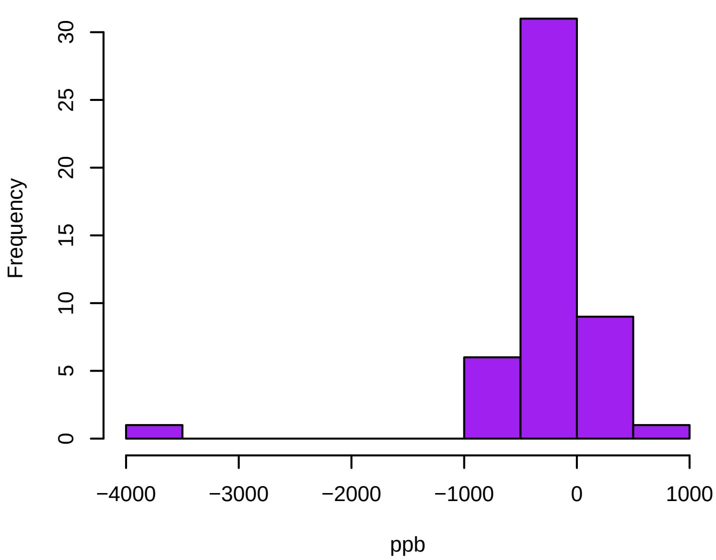
Potassium

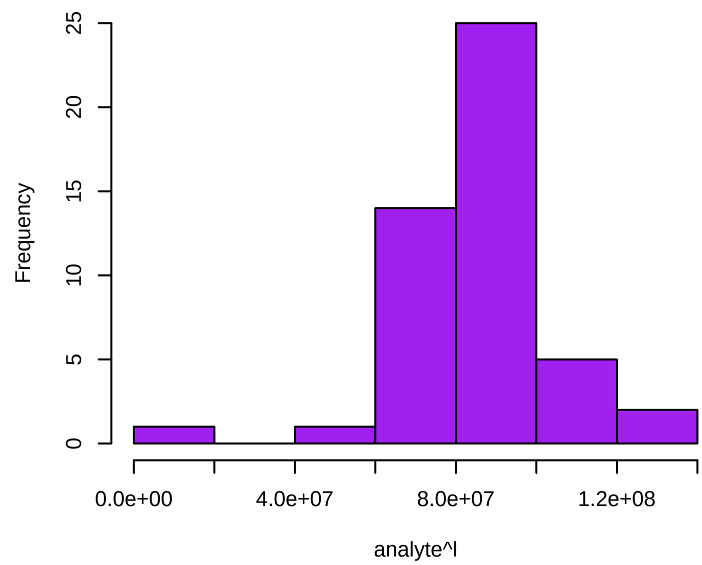
Skewness: −4.2366
Kurtosis: 26.0432

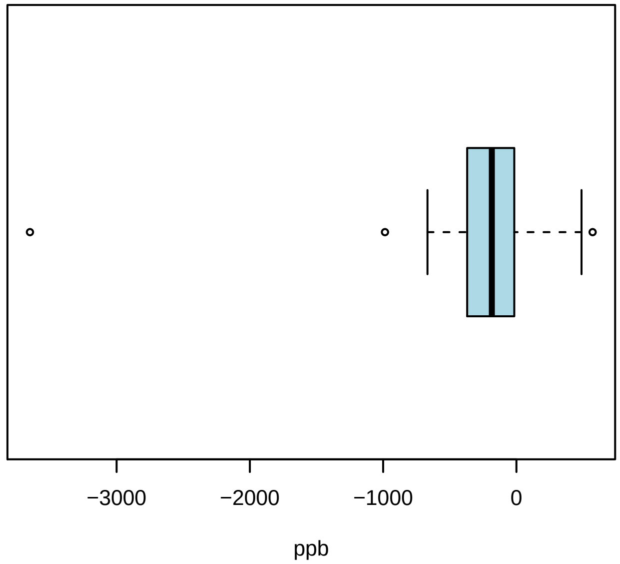
Potassium Box−Cox

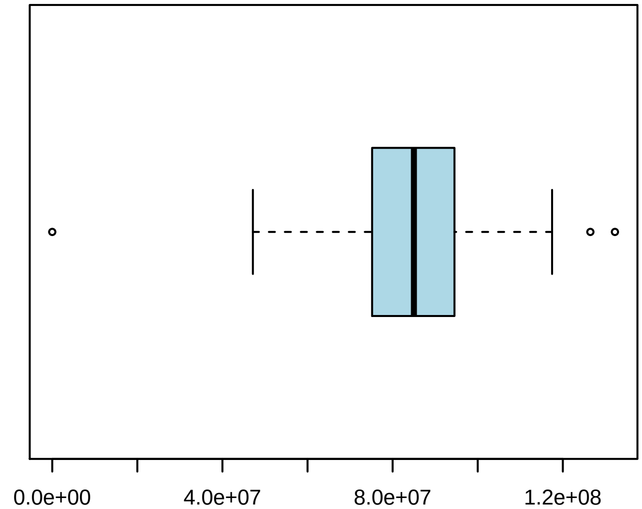
Skewness: −1.0988
Kurtosis: 8.0733

Optimal lambda: 2.24



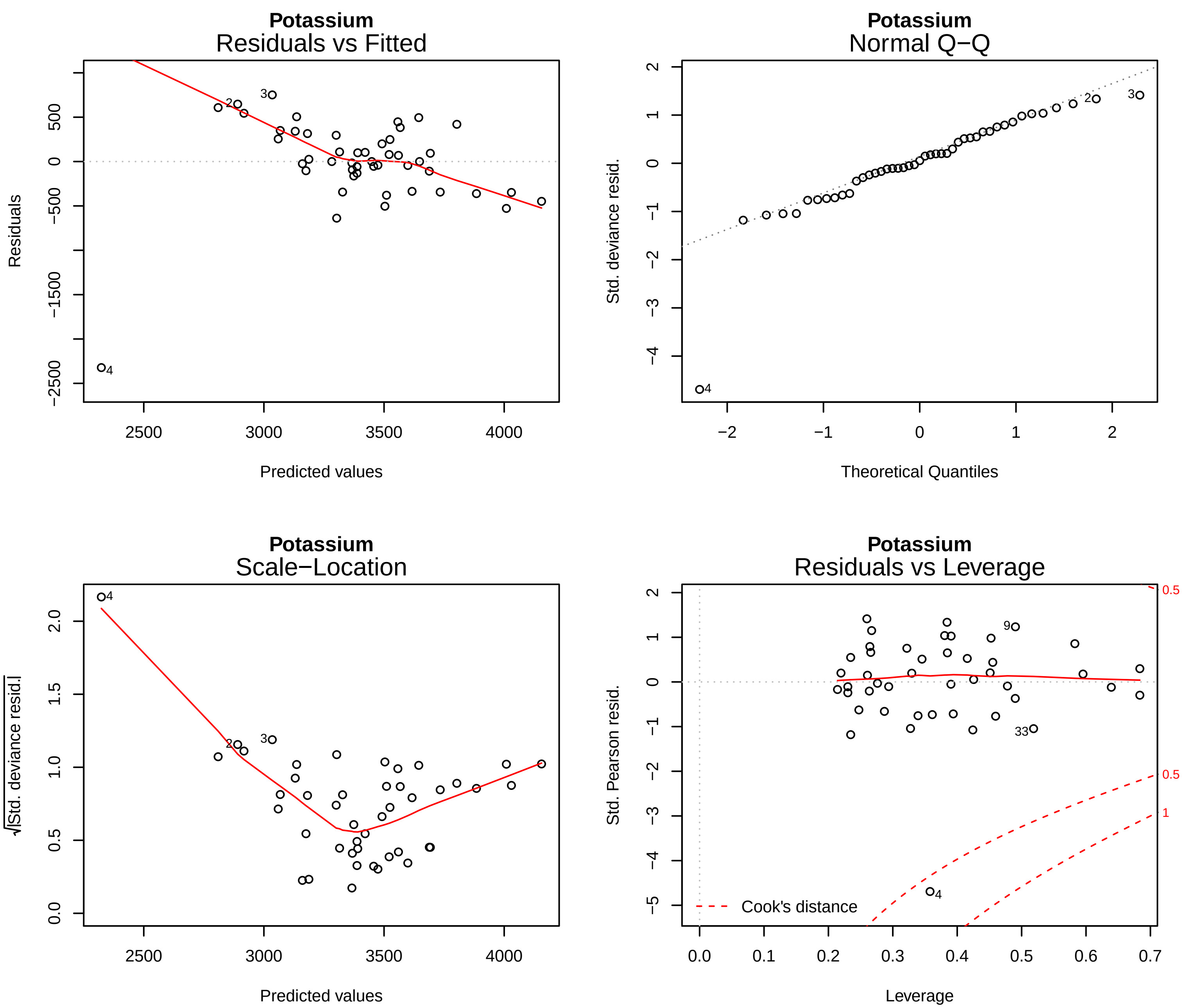






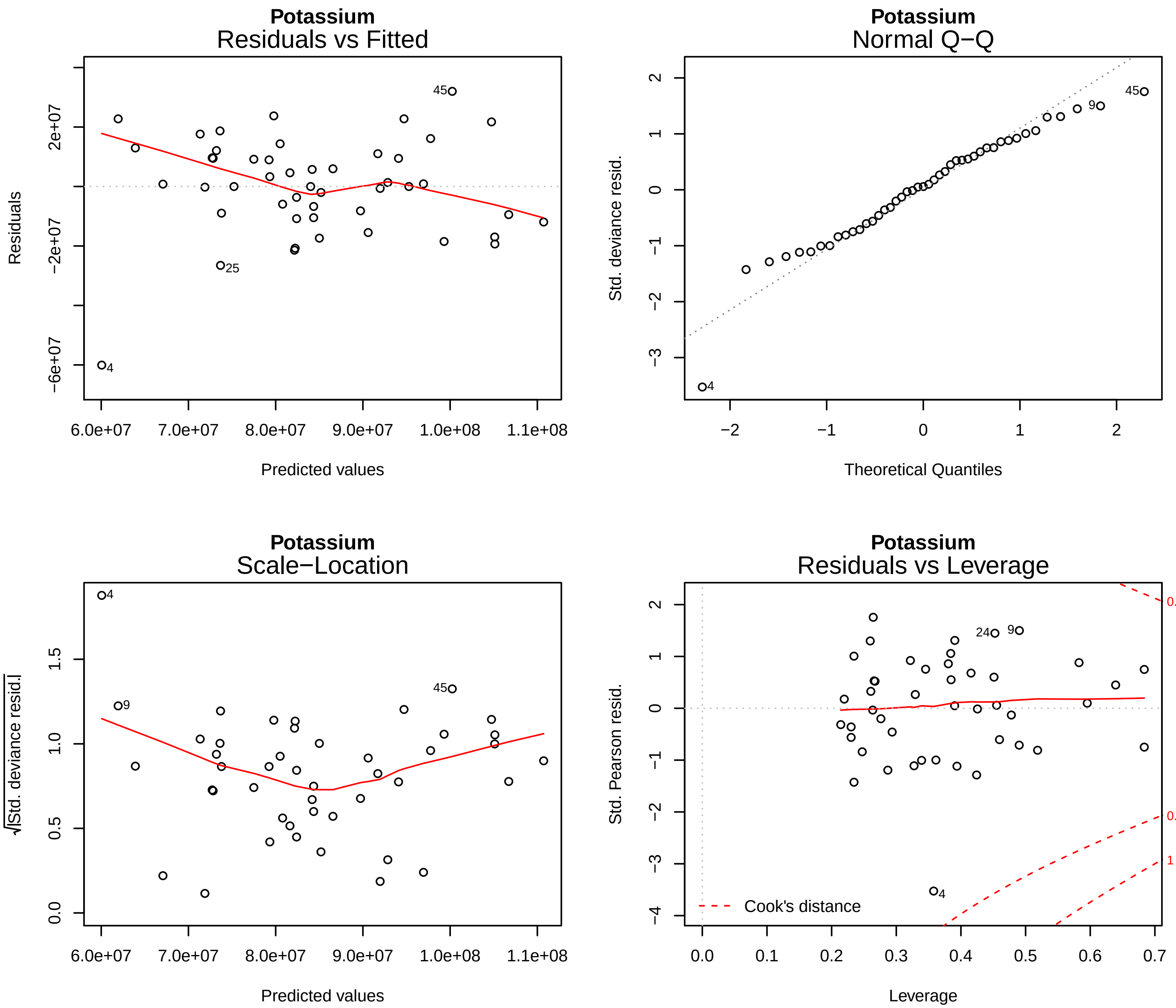
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

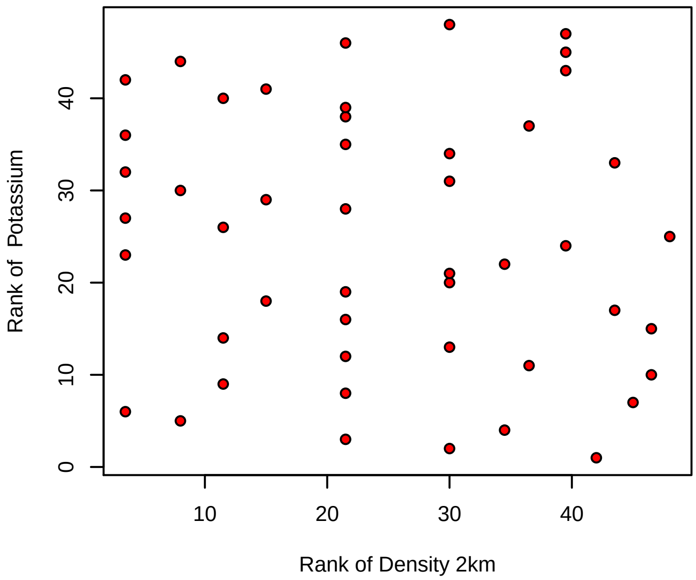
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



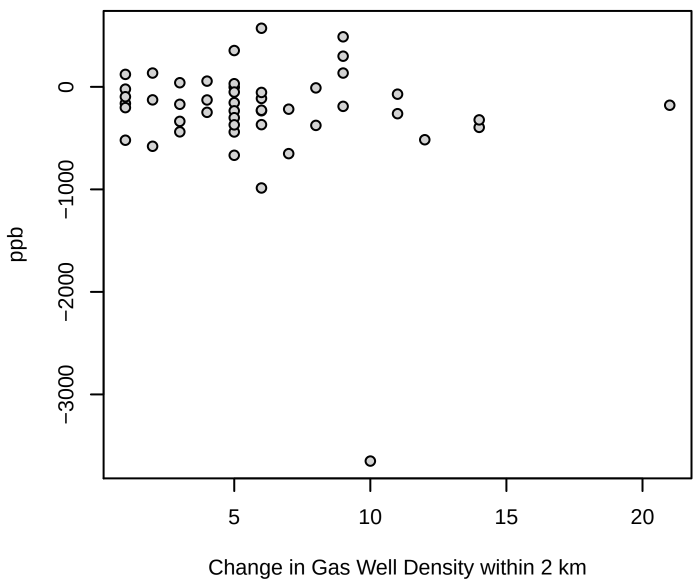


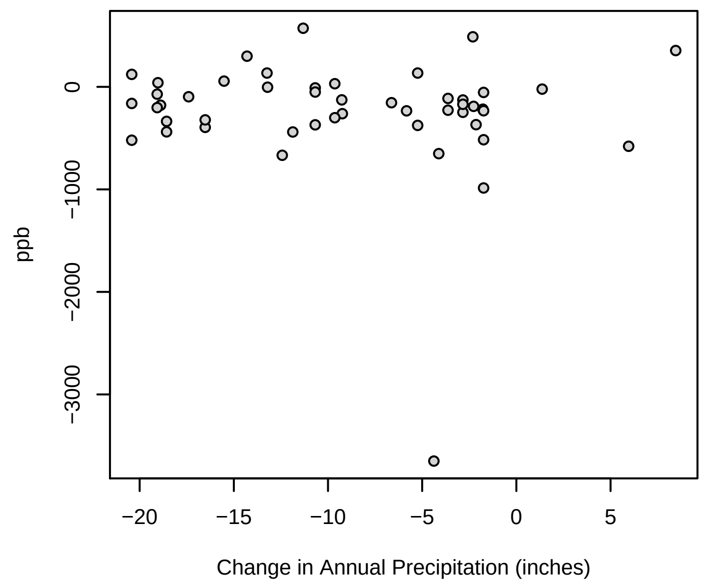
Potassium

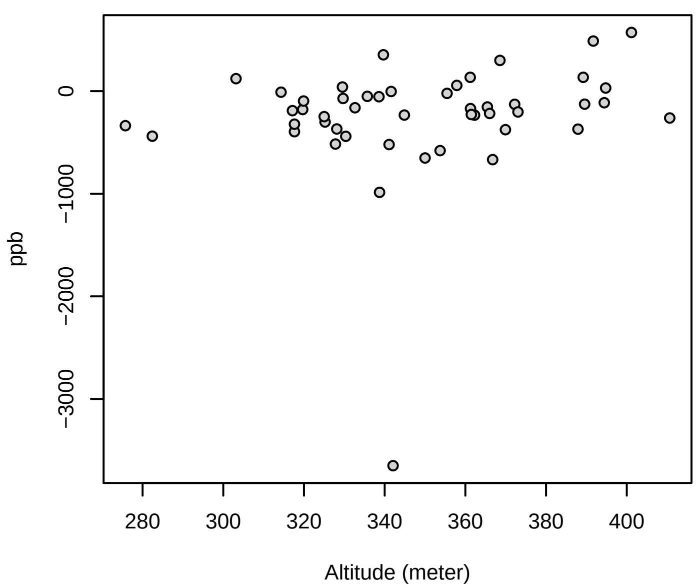
Kendalls Tau Rank Correlation

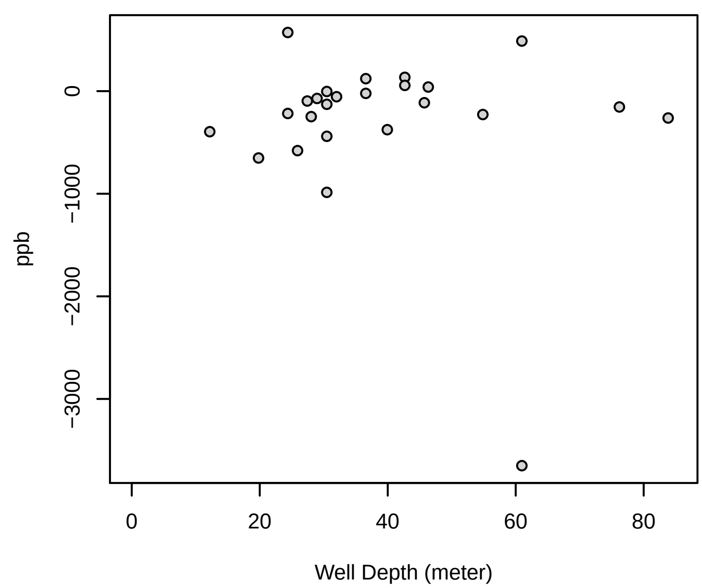
p−value: 0.425

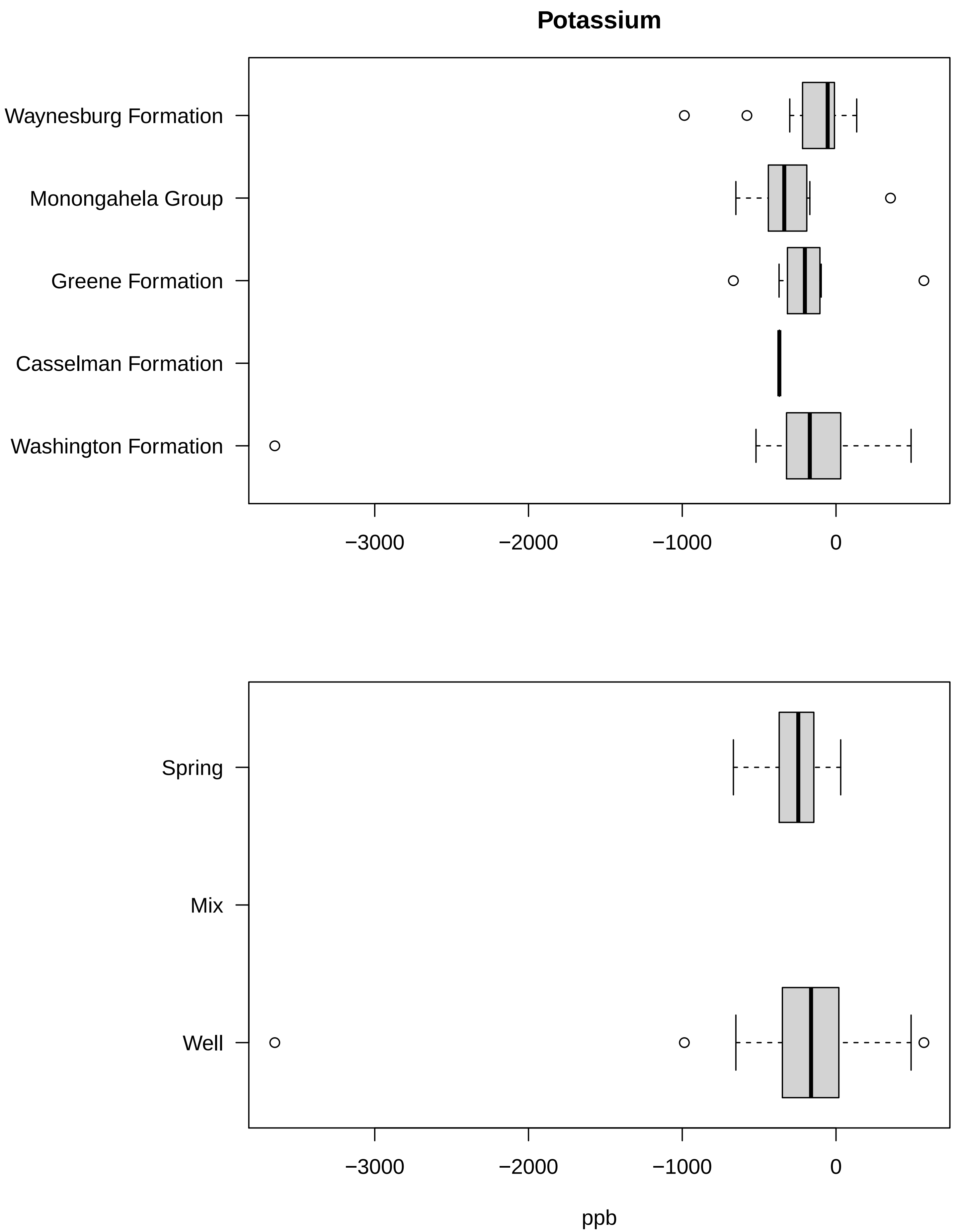
Tau: −0.0828

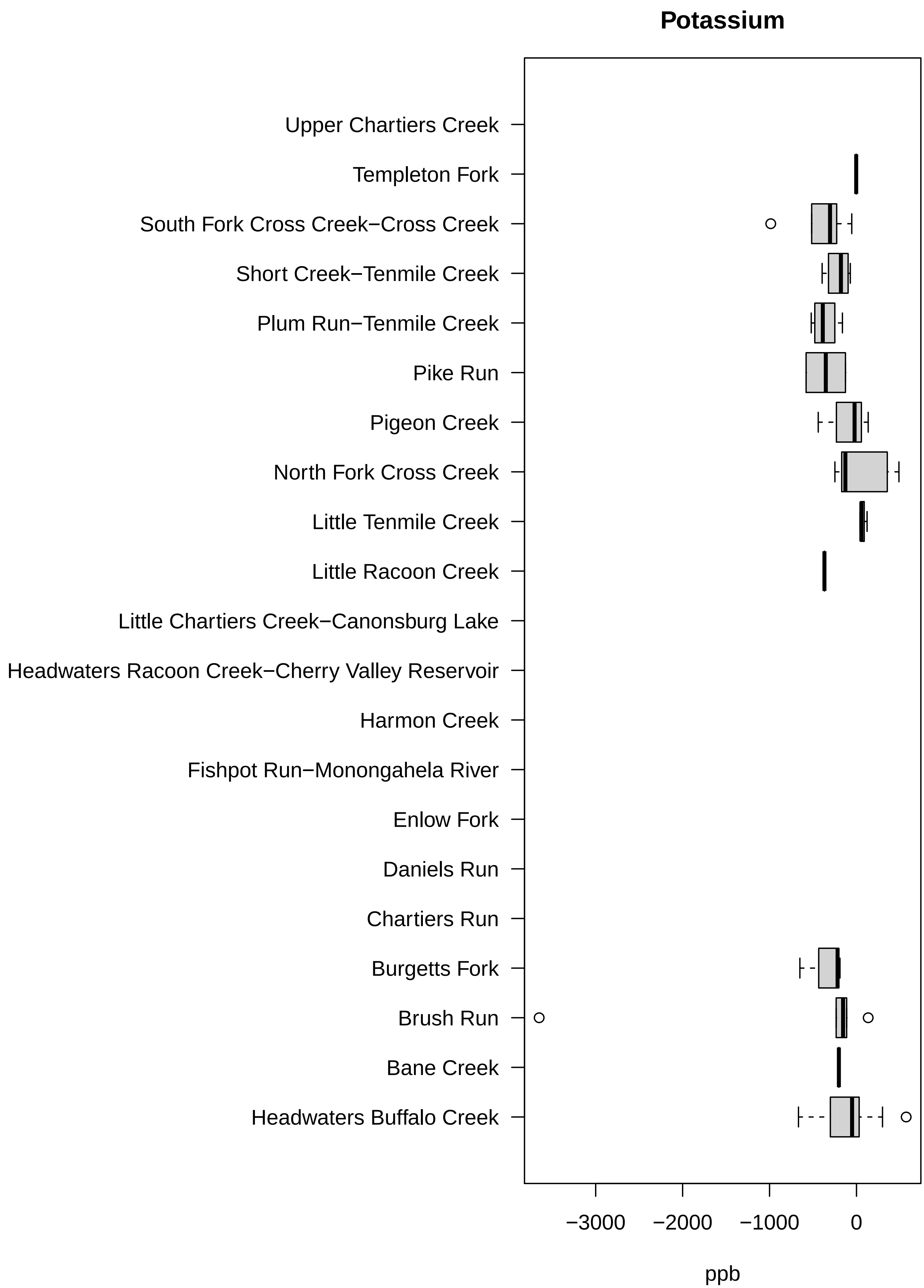









Potassium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−3000
−2000
−1000
0
Spring
Mix
Well
−3000
−2000
−1000
0
ppb



Potassium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−3000
−2000
−1000
0
ppb

```
[1] "ORIGINAL MODEL - Potassium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-2322.3   -139.1      0.0    301.1    751.2  

Coefficients: (1 not defined because of singularities)
                                            Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                -1400.193   2454.095  -0.571   0.5729  
dat$GWellDensity_2kmDiff                     -38.214     38.019  -1.005   0.3234  
dat$Altitude_meter                            14.173      6.640   2.135   0.0417 *
dat$WatershedBane Creek                     -194.291    764.740  -0.254   0.8013  
dat$WatershedBrush Run                      -769.607    444.688  -1.731   0.0945 .
dat$WatershedBurgetts Fork                  -378.351    563.465  -0.671   0.5074  
dat$WatershedLittle Racoon Creek             281.194    807.377   0.348   0.7302  
dat$WatershedLittle Tenmile Creek            219.364    577.239   0.380   0.7068  
dat$WatershedNorth Fork Cross Creek         -177.320    607.249  -0.292   0.7724  
dat$WatershedPigeon Creek                   -353.172    538.535  -0.656   0.5173  
dat$WatershedPike Run                       -647.398    660.545  -0.980   0.3354  
dat$WatershedPlum Run-Tenmile Creek           22.103    584.540   0.038   0.9701  
dat$WatershedShort Creek-Tenmile Creek       719.385    601.900   1.195   0.2420  
dat$WatershedSouth Fork Cross Creek-Cross Creek  -201.214    479.966  -0.419   0.6783  
dat$WatershedTempleton Fork                  316.519    740.521   0.427   0.6723  
dat$FormationCasselman Formation                  NA         NA      NA       NA  
dat$FormationGreene Formation               -322.658    404.224  -0.798   0.4315  
dat$FormationMonongahela Group               563.418    478.805   1.177   0.2492  
dat$FormationWaynesburg Formation            321.864    328.958   0.978   0.3362  
dat$HHWSourceSpring                          -32.962    286.646  -0.115   0.9093  
dat$Precip_inchDiff                           -6.124     32.604  -0.188   0.8524  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 381566.2)

    Null deviance: 15810682  on 47  degrees of freedom
Residual deviance: 10683855  on 28  degrees of freedom
AIC: 769.24

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Potassium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-60058700   -9703042    402934   9985806   32001540

Coefficients: (1 not defined because of singularities)
                                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                                -40528313   84442066  -0.480    0.635
dat$GWellDensity_2kmDiff                      -946719    1308195  -0.724    0.475
dat$Altitude_meter                            398621     228464   1.745    0.092 .
dat$WatershedBane Creek                      -9697872   26313664  -0.369    0.715
dat$WatershedBrush Run                      -26272067   15301106  -1.717    0.097 .
dat$WatershedBurgetts Fork                  -16937057   19388073  -0.874    0.390
dat$WatershedLittle Racoon Creek             -4044490   27780746  -0.146    0.885
dat$WatershedLittle Tenmile Creek             9099359   19862025   0.458    0.650
dat$WatershedNorth Fork Cross Creek          -2329638   20894626  -0.111    0.912
dat$WatershedPigeon Creek                   -10774115   18530246  -0.581    0.566
dat$WatershedPike Run                       -28242307   22728442  -1.243    0.224
dat$WatershedPlum Run-Tenmile Creek          -4017132   20113215  -0.200    0.843
dat$WatershedShort Creek-Tenmile Creek       11643099   20710579   0.562    0.578
dat$WatershedSouth Fork Cross Creek-Cross Creek -18525566   16514992  -1.122    0.272
dat$WatershedTempleton Fork                   4463574   25480330   0.175    0.862
dat$FormationCasselman Formation                   NA         NA      NA       NA
dat$FormationGreene Formation               -13371499   13908815  -0.961    0.345
dat$FormationMonongahela Group                6836902   16475032   0.415    0.681
dat$FormationWaynesburg Formation             3399752   11319008   0.300    0.766
dat$HHWSourceSpring                          -5310940    9863096  -0.538    0.595
dat$Precip_inchDiff                              7584    1121845   0.007    0.995
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 4.517571e+14)

    Null deviance: 1.9635e+16  on 47  degrees of freedom
Residual deviance: 1.2649e+16  on 28  degrees of freedom
AIC: 1772.1

Number of Fisher Scoring iterations: 2
```

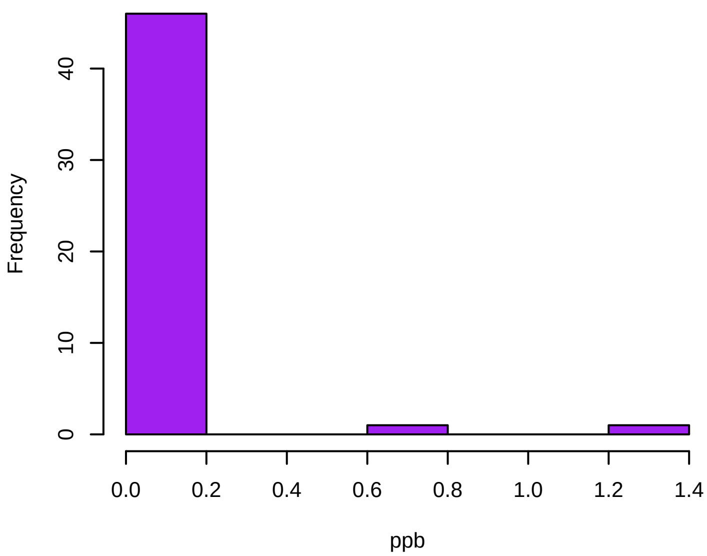
Selenium

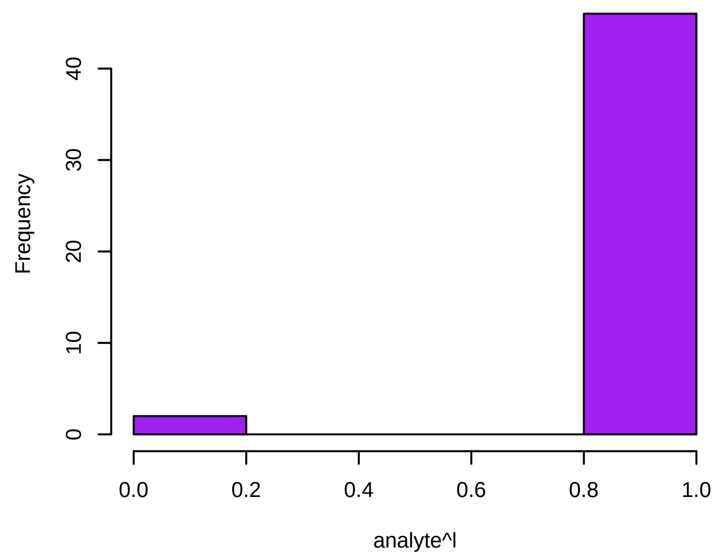
Skewness: 4.9756
Kurtosis: 26.8356

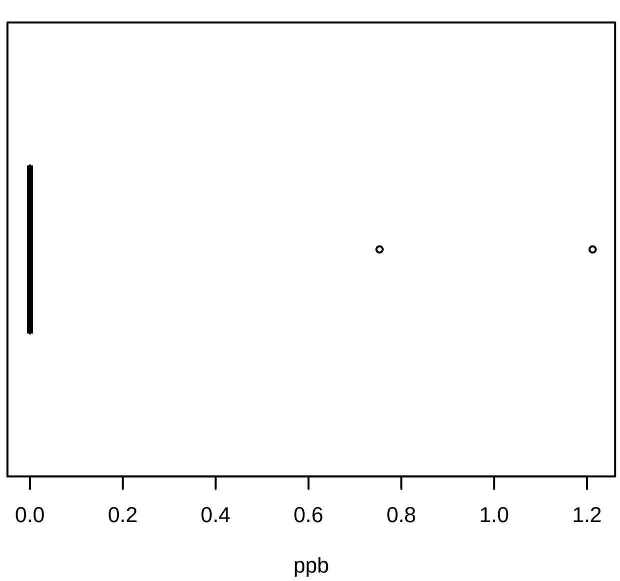
Selenium Box−Cox

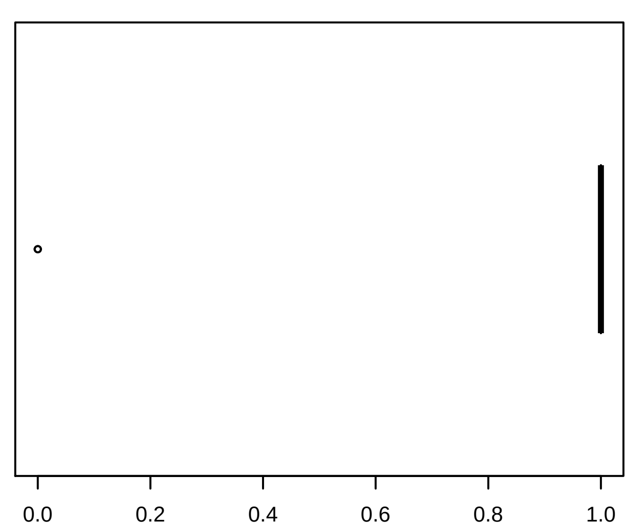
Skewness: −4.5873
Kurtosis: 22.0435

Optimal lambda: −35.42



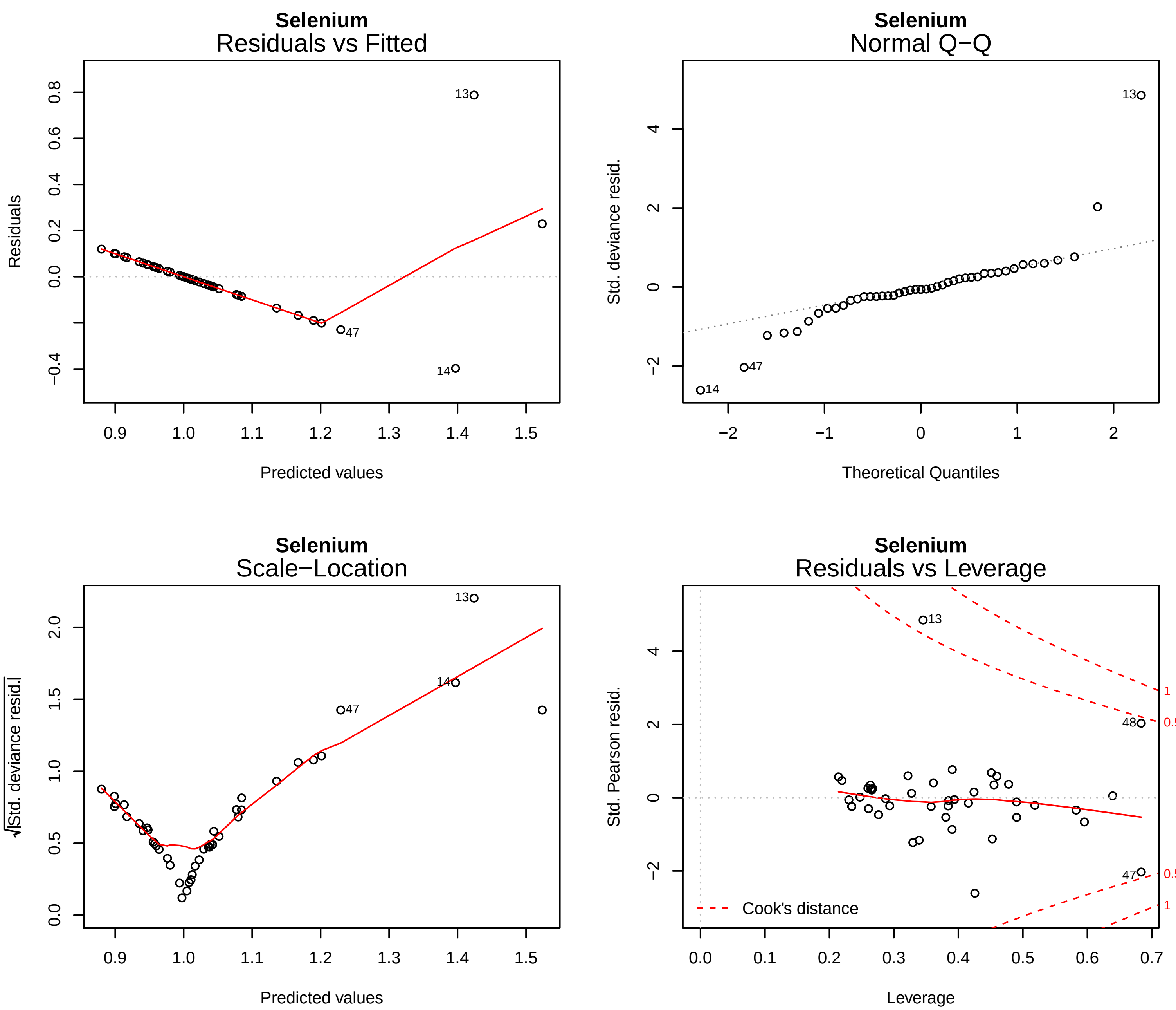






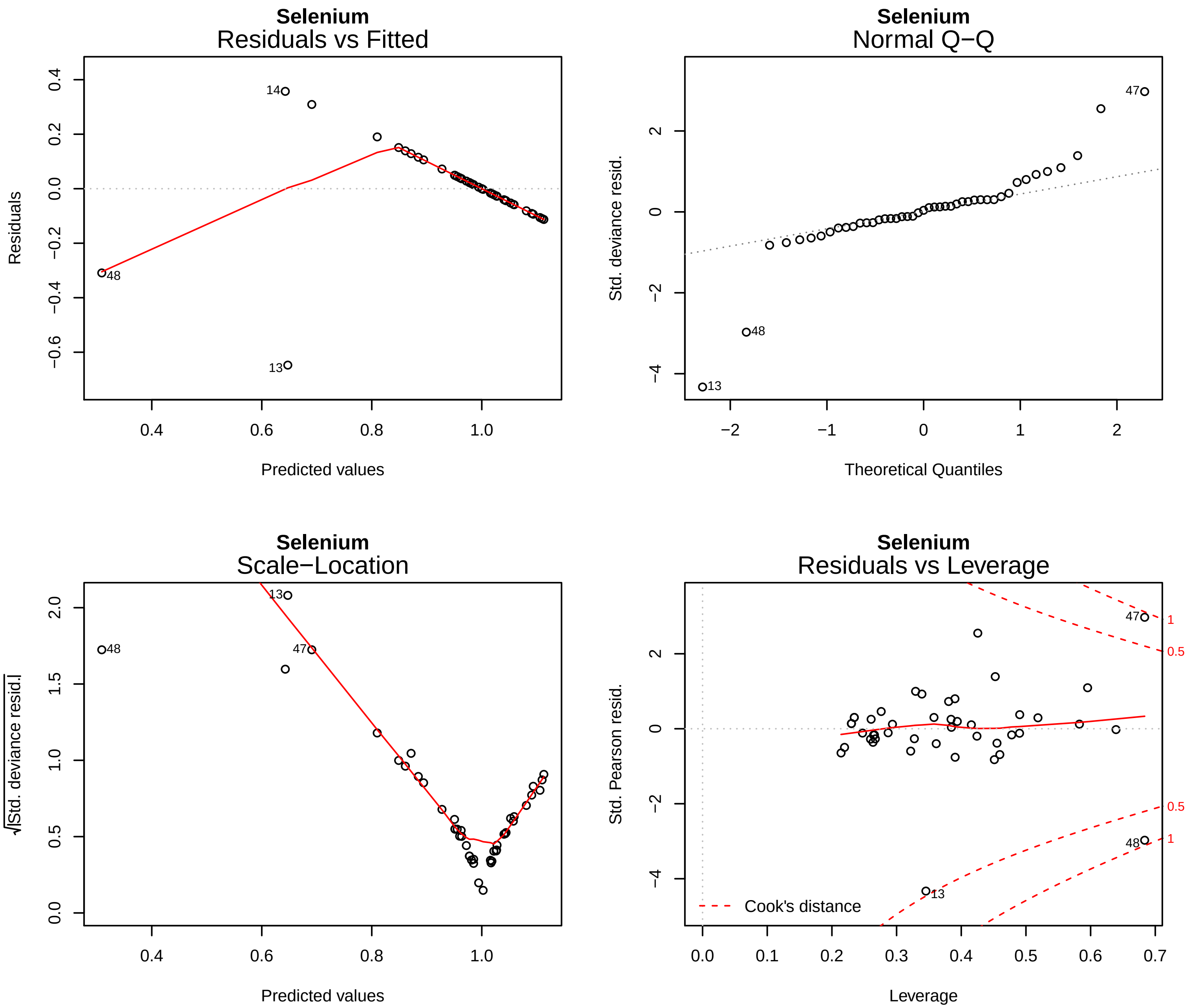
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

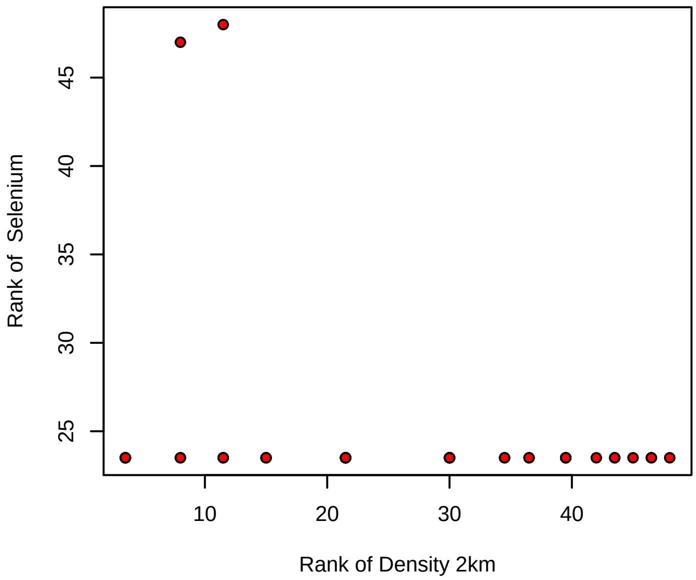
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



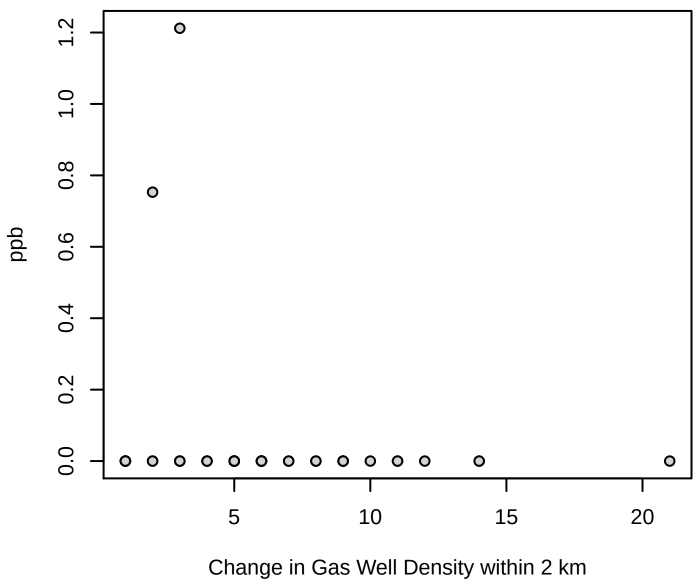


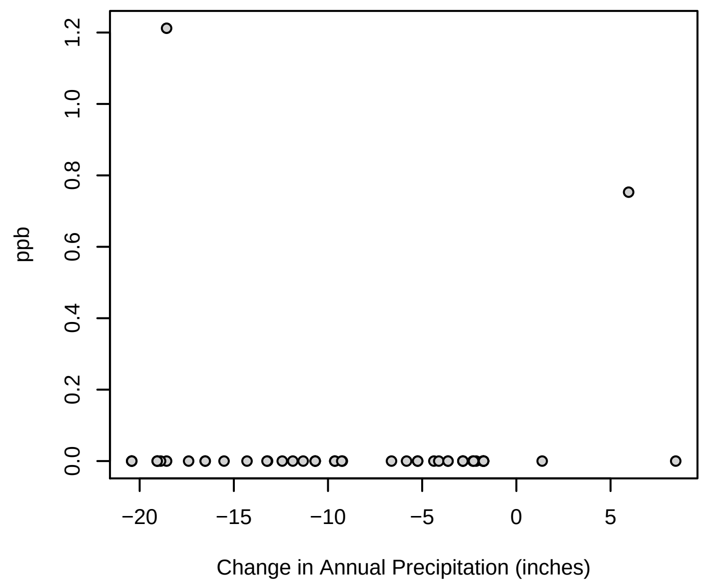
Selenium

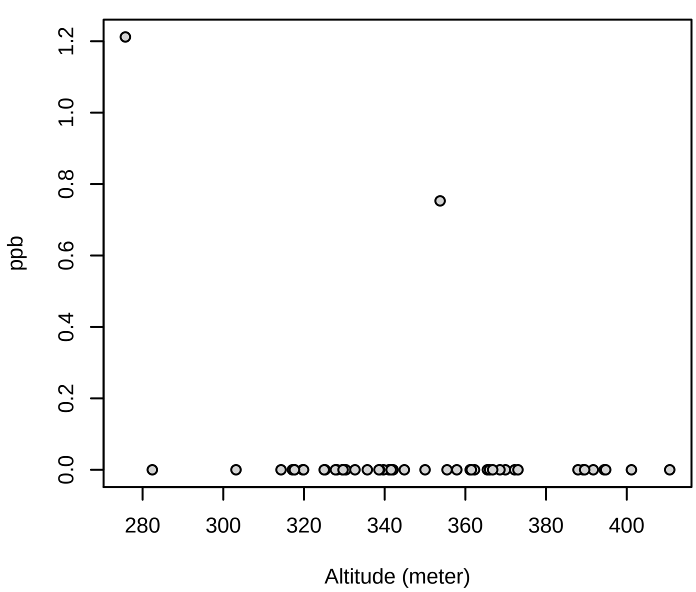
Kendalls Tau Rank Correlation

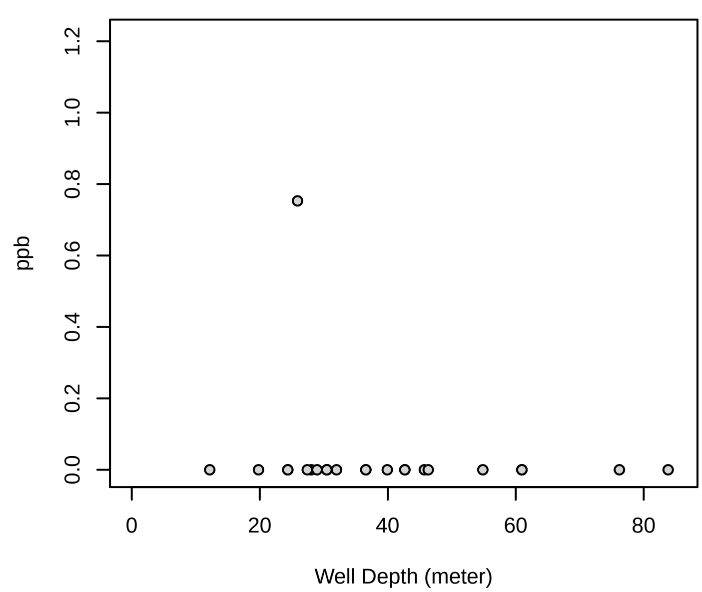
p−value: 0.132

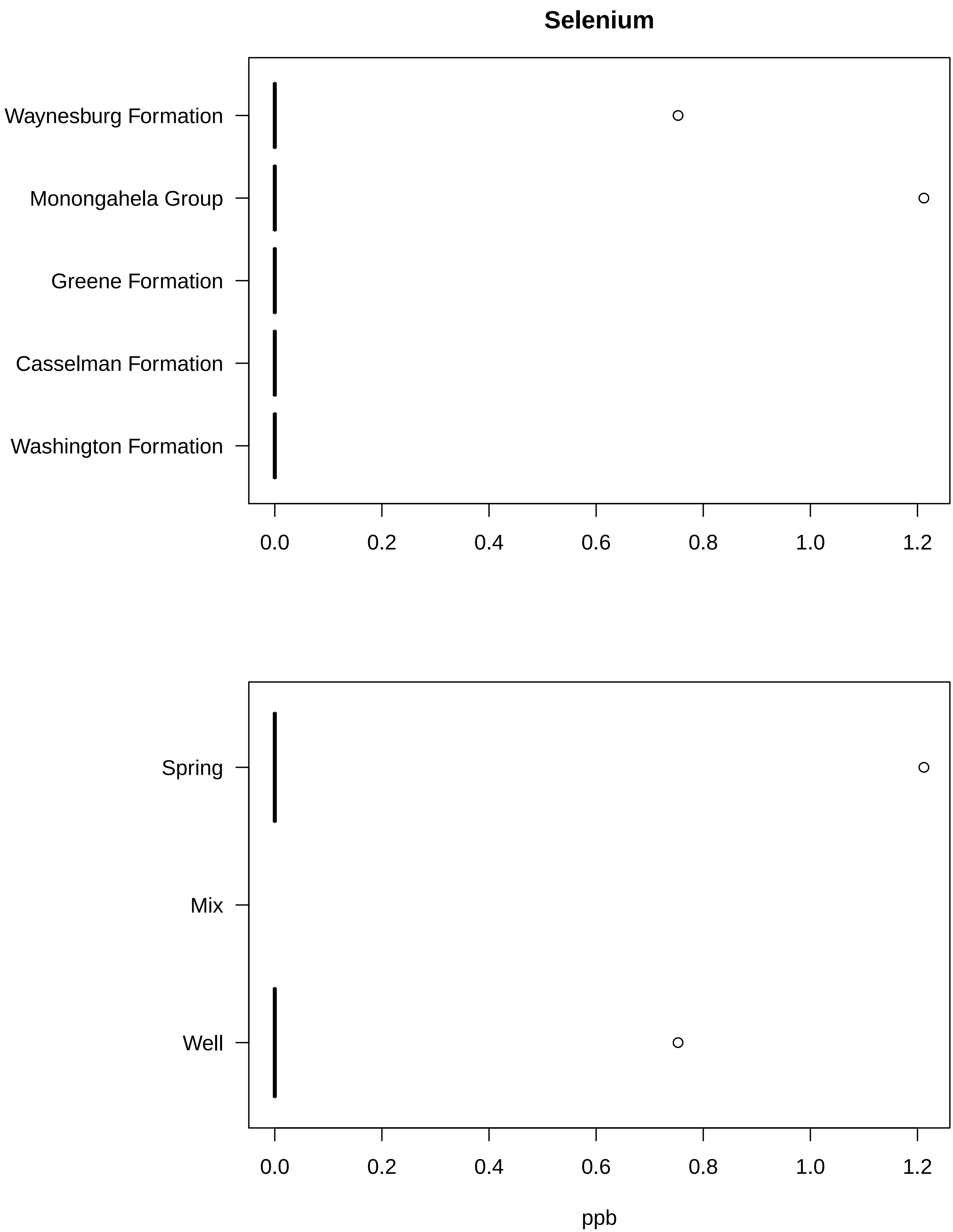
Tau: −0.188

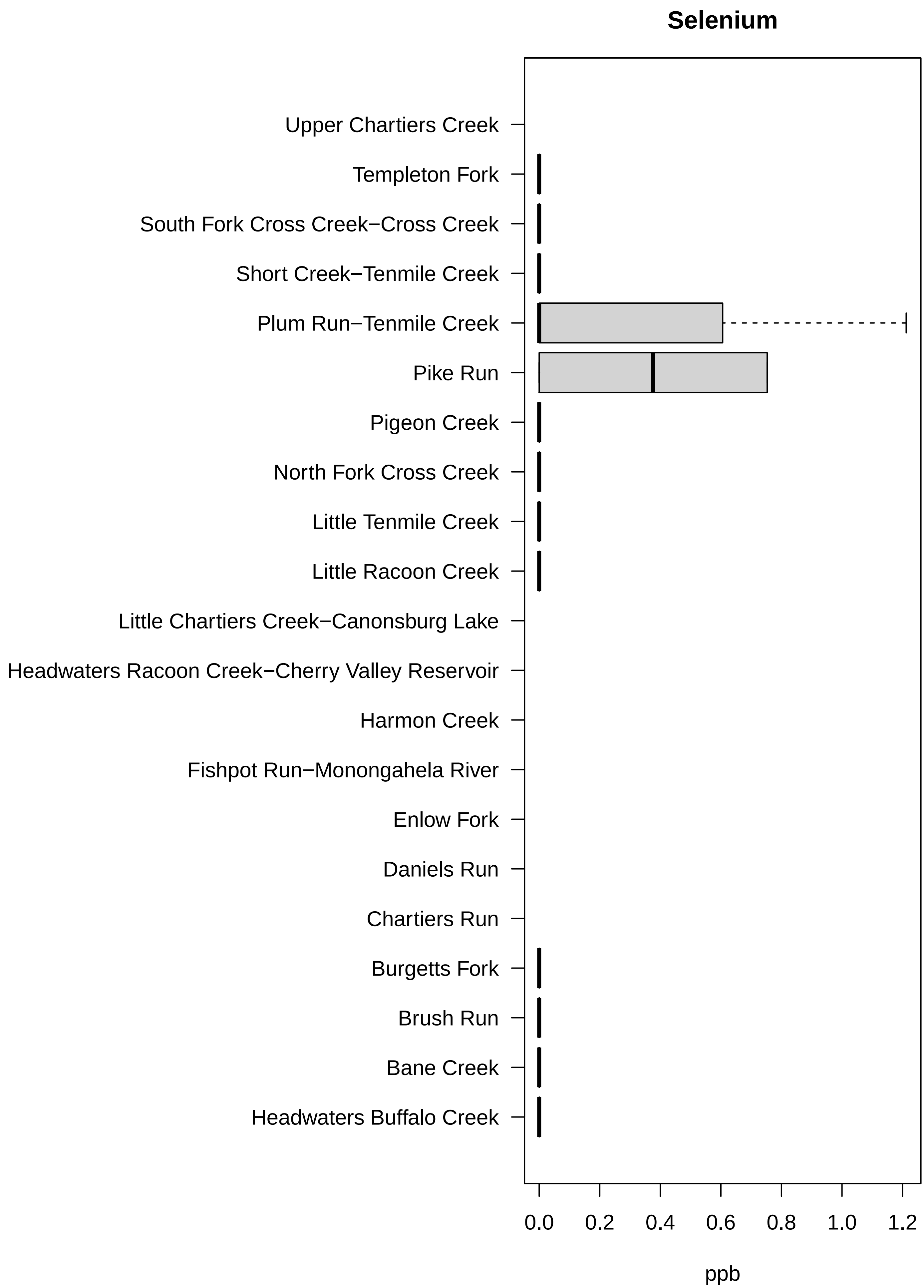









Selenium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Spring
Mix
Well
0.0
0.2
0.4
0.6
0.8
1.0
1.2
ppb


Selenium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0.0
0.2
0.4
0.6
0.8
1.0
1.2
ppb

```
[1] "ORIGINAL MODEL - Selenium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.39707  -0.04268  -0.00637   0.04644   0.78791  

Coefficients: (1 not defined because of singularities)
                                                Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                     1.532443   0.797286   1.922   0.0648 .
dat$GWellDensity_2kmDiff                        0.006935   0.012352   0.561   0.5789  
dat$Altitude_meter                             -0.001392   0.002157  -0.645   0.5239  
dat$WatershedBane Creek                         0.133476   0.248449   0.537   0.5953  
dat$WatershedBrush Run                         -0.031294   0.144470  -0.217   0.8301  
dat$WatershedBurgetts Fork                     -0.171581   0.183058  -0.937   0.3566  
dat$WatershedLittle Racoon Creek               -0.107890   0.262300  -0.411   0.6840  
dat$WatershedLittle Tenmile Creek               0.094435   0.187533   0.504   0.6185  
dat$WatershedNorth Fork Cross Creek            -0.140402   0.197283  -0.712   0.4826  
dat$WatershedPigeon Creek                      -0.046571   0.174959  -0.266   0.7920  
dat$WatershedPike Run                           0.324981   0.214598   1.514   0.1411  
dat$WatershedPlum Run-Tenmile Creek             0.365762   0.189905   1.926   0.0643 .
dat$WatershedShort Creek-Tenmile Creek          0.032380   0.195545   0.166   0.8697  
dat$WatershedSouth Fork Cross Creek-Cross Creek -0.107800   0.155931  -0.691   0.4951  
dat$WatershedTempleton Fork                     0.075663   0.240580   0.315   0.7555  
dat$FormationCasselman Formation                      NA         NA      NA       NA  
dat$FormationGreene Formation                   0.087869   0.131324   0.669   0.5089  
dat$FormationMonongahela Group                  0.106282   0.155554   0.683   0.5001  
dat$FormationWaynesburg Formation               0.069365   0.106872   0.649   0.5216  
dat$HHWSourceSpring                             0.017733   0.093125   0.190   0.8504  
dat$Precip_inchDiff                             0.012658   0.010592   1.195   0.2421  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.04027313)

    Null deviance: 1.9555  on 47  degrees of freedom
Residual deviance: 1.1276  on 28  degrees of freedom
AIC: -1.8331

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Selenium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-0.64730  -0.04303   0.00000   0.04563   0.35725  

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                   0.388480   0.734246   0.529   0.6009  
dat$GWellDensity_2kmDiff                     -0.006892   0.011375  -0.606   0.5495  
dat$Altitude_meter                            0.001436   0.001987   0.723   0.4757  
dat$WatershedBane Creek                      -0.148348   0.228804  -0.648   0.5220  
dat$WatershedBrush Run                        0.072556   0.133047   0.545   0.5898  
dat$WatershedBurgetts Fork                    0.192739   0.168584   1.143   0.2626  
dat$WatershedLittle Racoon Creek              0.132296   0.241561   0.548   0.5883  
dat$WatershedLittle Tenmile Creek            -0.101372   0.172705  -0.587   0.5619  
dat$WatershedNorth Fork Cross Creek           0.182668   0.181684   1.005   0.3233  
dat$WatershedPigeon Creek                     0.067874   0.161125   0.421   0.6768  
dat$WatershedPike Run                        -0.409722   0.197630  -2.073   0.0475 *
dat$WatershedPlum Run-Tenmile Creek          -0.360089   0.174890  -2.059   0.0489 *
dat$WatershedShort Creek-Tenmile Creek       -0.042150   0.180084  -0.234   0.8166  
dat$WatershedSouth Fork Cross Creek-Cross Creek  0.155102   0.143602   1.080   0.2893  
dat$WatershedTempleton Fork                  -0.061695   0.221558  -0.278   0.7827  
dat$FormationCasselman Formation                    NA         NA      NA       NA  
dat$FormationGreene Formation                -0.082348   0.120941  -0.681   0.5015  
dat$FormationMonongahela Group               -0.075688   0.143255  -0.528   0.6014  
dat$FormationWaynesburg Formation            -0.066033   0.098422  -0.671   0.5078  
dat$HHWSourceSpring                           0.014138   0.085762   0.165   0.8702  
dat$Precip_inchDiff                          -0.016431   0.009755  -1.684   0.1032  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.03415624)

    Null deviance: 1.91667  on 47  degrees of freedom
Residual deviance: 0.95637  on 28  degrees of freedom
AIC: -9.7406

Number of Fisher Scoring iterations: 2
```

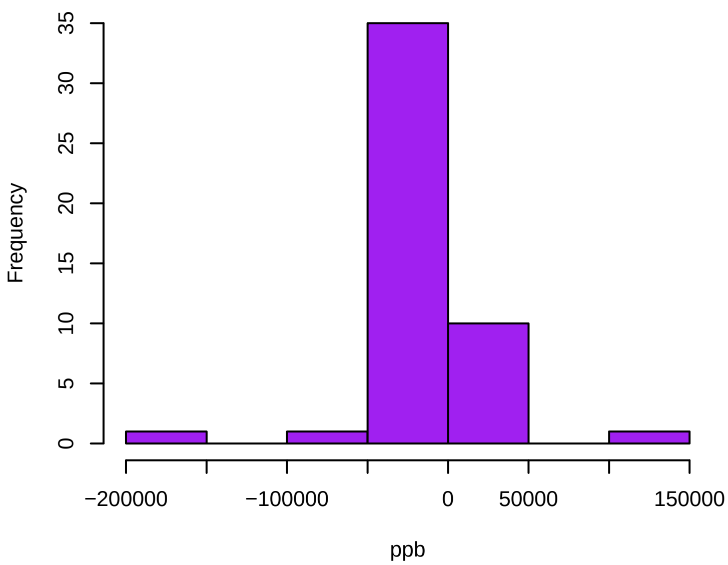
Sodium

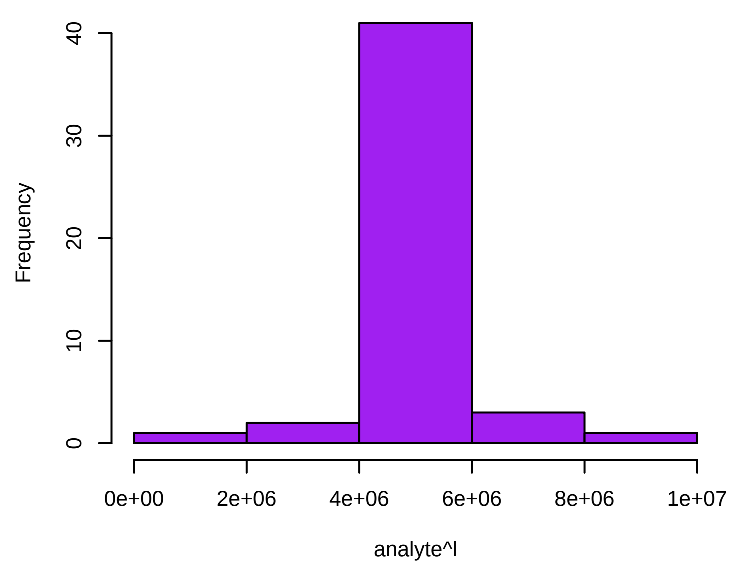
Skewness: −2.8173
Kurtosis: 22.3018

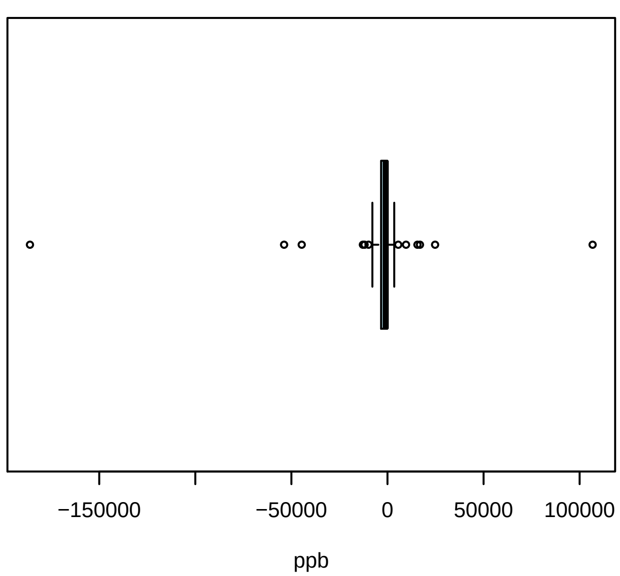
Sodium Box−Cox

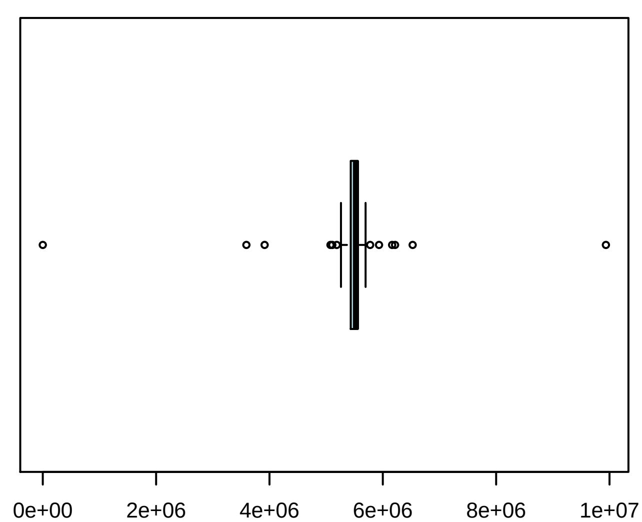
Skewness: −1.2260
Kurtosis: 18.0619

Optimal lambda: 1.28



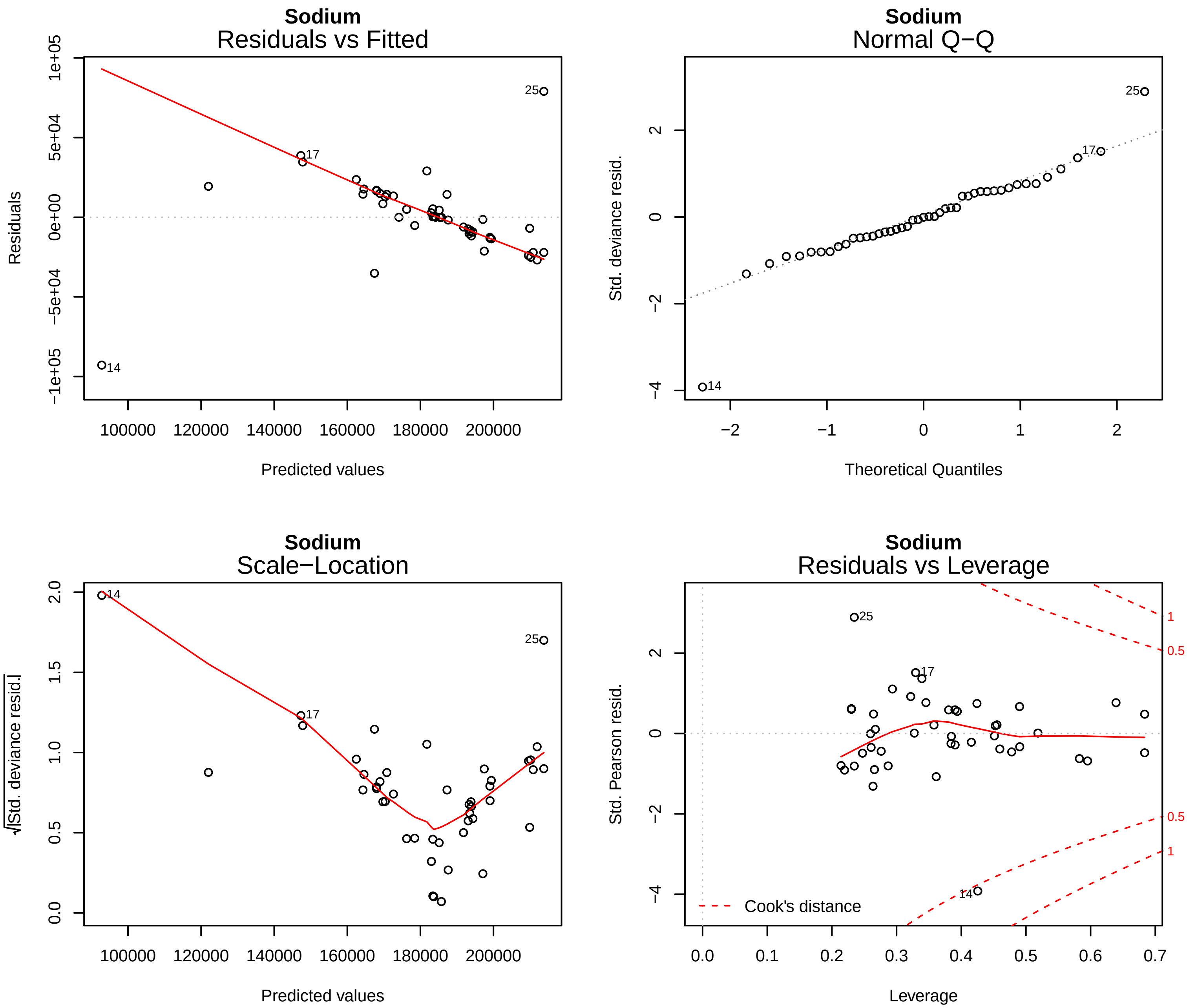






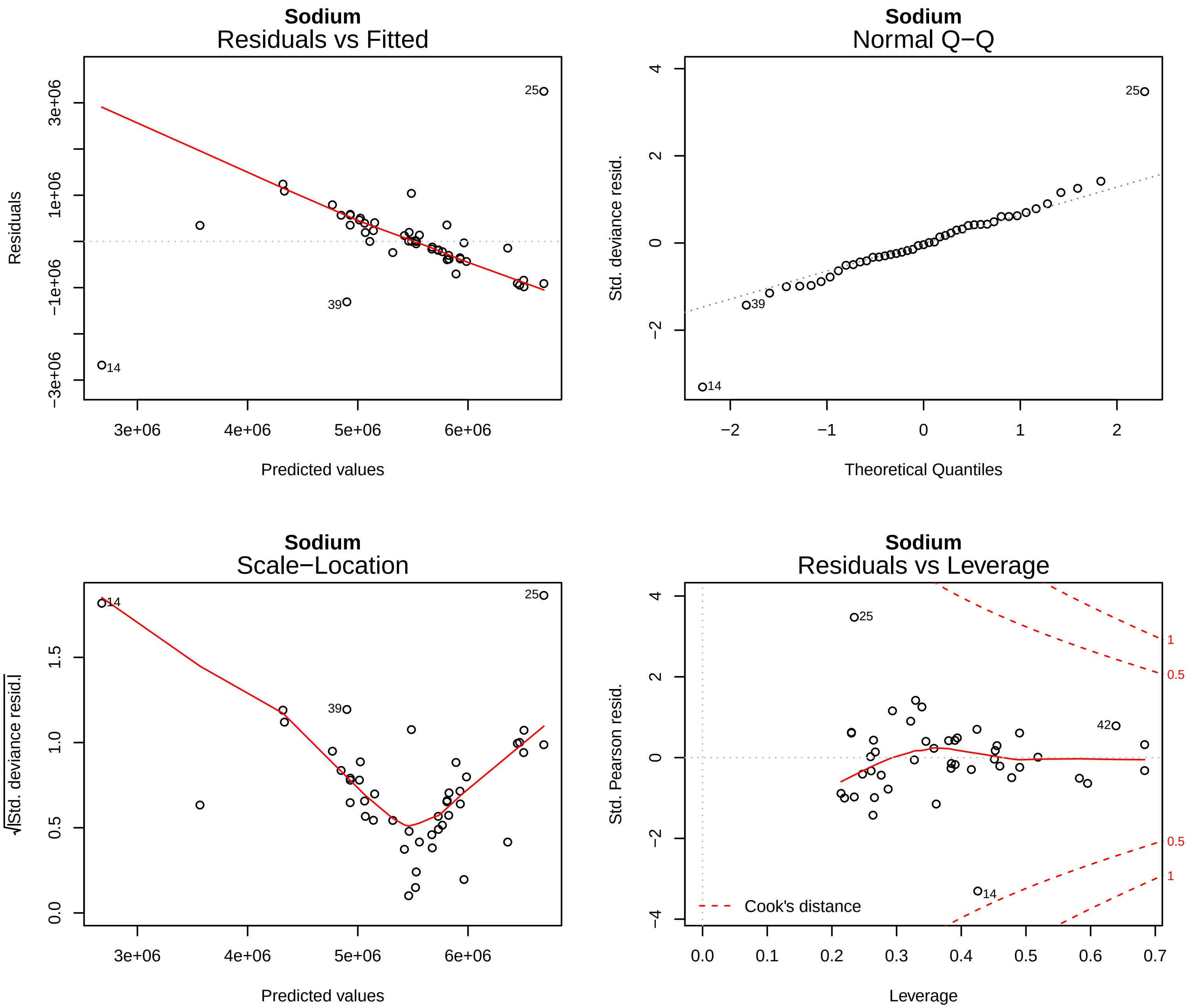
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

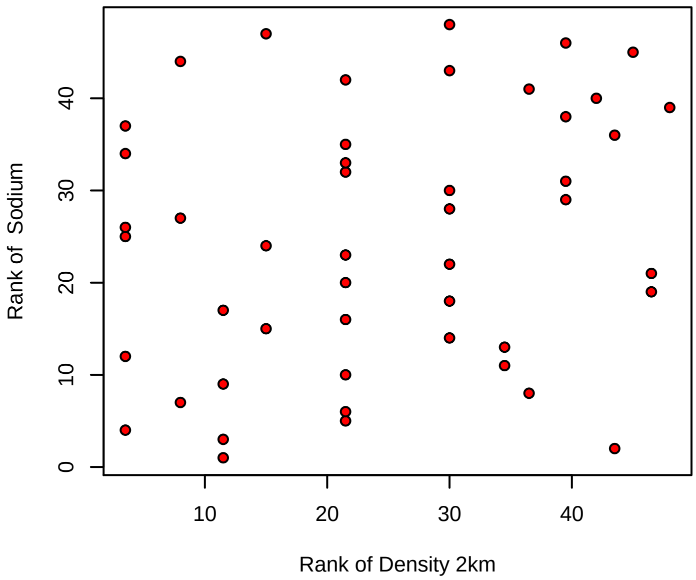
Original
Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



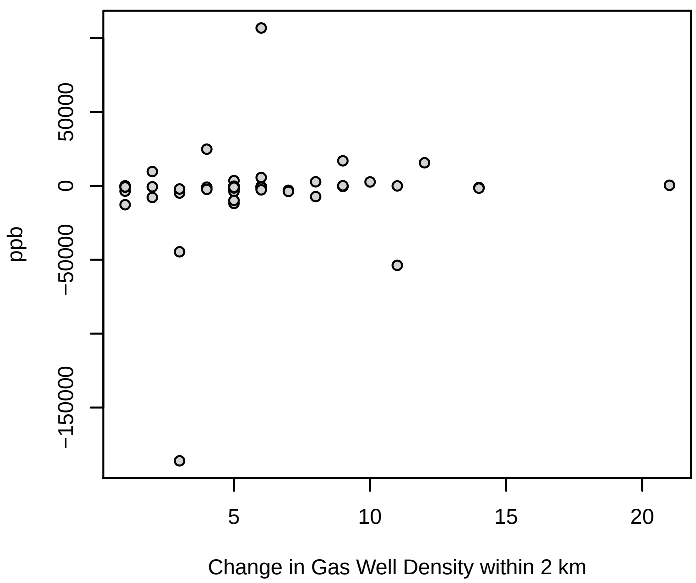


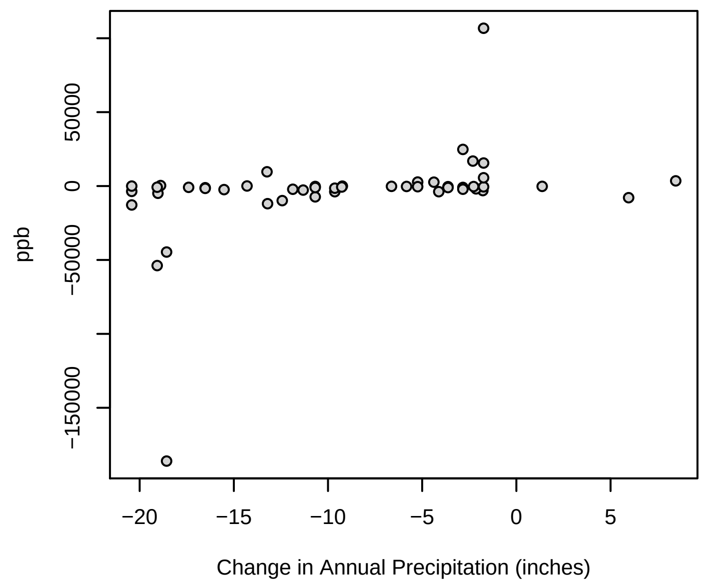
Sodium

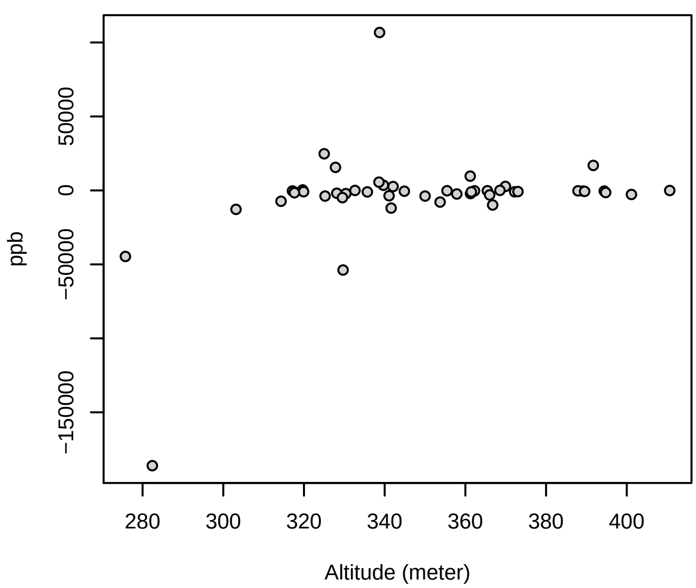
Kendalls Tau Rank Correlation

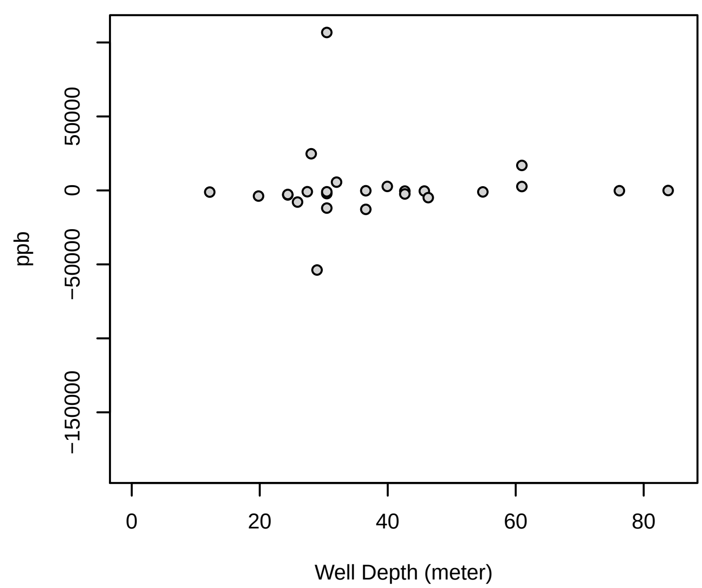
p−value: 0.117

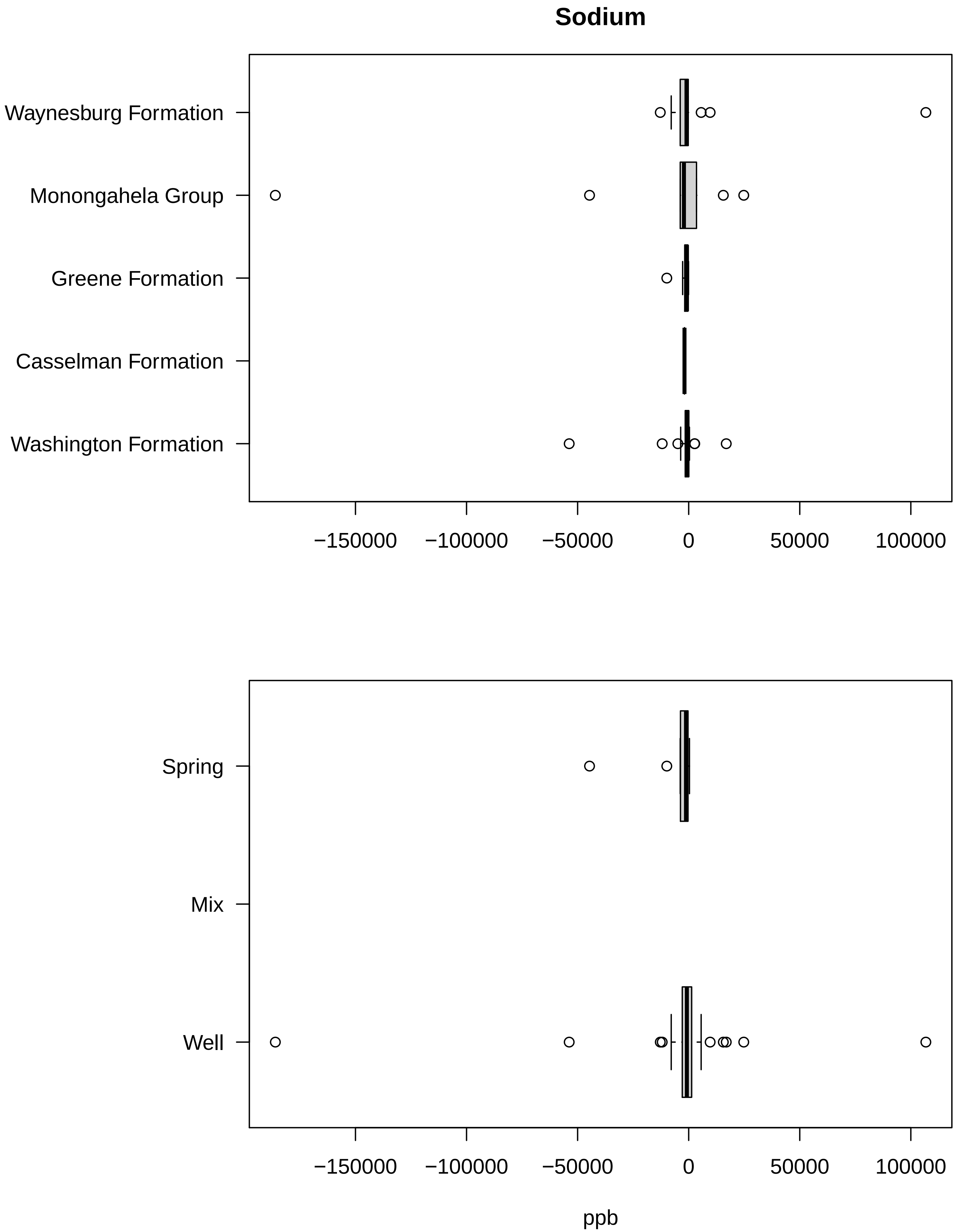
Tau: 0.163

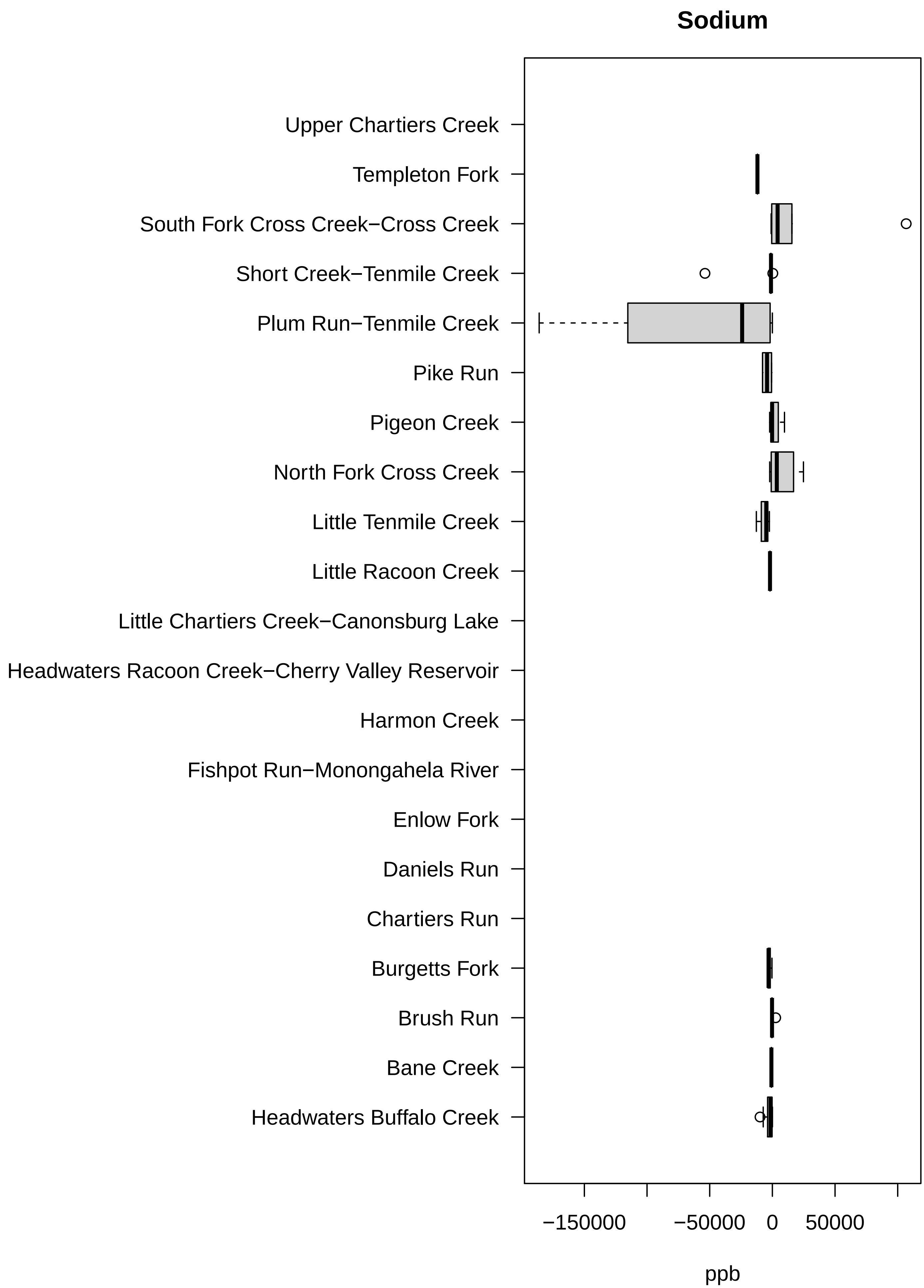









Sodium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−150000
−100000
−50000
0
50000
100000
Spring
Mix
Well
−150000
−100000
−50000
0
50000
100000
ppb



Sodium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−150000
−50000
0
50000
ppb

```
[1] "ORIGINAL MODEL - Sodium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-92824  -10685       0   14357   79030

Coefficients: (1 not defined because of singularities)
                                         Estimate Std. Error t value Pr(>|t|)
(Intercept)                             141314.53  124113.38   1.139   0.2645
dat$GWellDensity_2kmDiff                   255.90    1922.79   0.133   0.8951
dat$Altitude_meter                          58.84     335.80   0.175   0.8622
dat$WatershedBane Creek                  19361.56   38675.96   0.501   0.6206
dat$WatershedBrush Run                   20273.64   22489.64   0.901   0.3750
dat$WatershedBurgetts Fork               24490.11   28496.69   0.859   0.3974
dat$WatershedLittle Racoon Creek         -7143.78   40832.28  -0.175   0.8624
dat$WatershedLittle Tenmile Creek        18539.54   29193.31   0.635   0.5305
dat$WatershedNorth Fork Cross Creek      43706.41   30711.03   1.423   0.1657
dat$WatershedPigeon Creek                32089.77   27235.85   1.178   0.2486
dat$WatershedPike Run                     1369.76   33406.38   0.041   0.9676
dat$WatershedPlum Run-Tenmile Creek     -39365.37   29562.51  -1.332   0.1937
dat$WatershedShort Creek-Tenmile Creek    7698.61   30440.51   0.253   0.8022
dat$WatershedSouth Fork Cross Creek-Cross Creek  46787.10   24273.82   1.927   0.0641 .
dat$WatershedTempleton Fork              14065.23   37451.12   0.376   0.7101
dat$FormationCasselman Formation               NA         NA      NA       NA
dat$FormationGreene Formation             6183.40   20443.25   0.302   0.7645
dat$FormationMonongahela Group          -22821.43   24215.09  -0.942   0.3540
dat$FormationWaynesburg Formation         4560.58   16636.74   0.274   0.7860
dat$HHWSourceSpring                      29578.35   14496.83   2.040   0.0508 .
dat$Precip_inchDiff                        198.60    1648.89   0.120   0.9050
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 975943165)

    Null deviance: 5.2087e+10  on 47  degrees of freedom
Residual deviance: 2.7326e+10  on 28  degrees of freedom
AIC: 1145.9

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Sodium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-2676514   -359654         0    365561   3248349

Coefficients: (1 not defined because of singularities)
                                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                                 4102114    4246492   0.966   0.3423
dat$GWellDensity_2kmDiff                      13998      65788   0.213   0.8330
dat$Altitude_meter                             1591      11489   0.138   0.8909
dat$WatershedBane Creek                      608512    1323283   0.460   0.6492
dat$WatershedBrush Run                       692711     769475   0.900   0.3757
dat$WatershedBurgetts Fork                   800727     975003   0.821   0.4184
dat$WatershedLittle Racoon Creek            -114387    1397061  -0.082   0.9353
dat$WatershedLittle Tenmile Creek            532627     998838   0.533   0.5981
dat$WatershedNorth Fork Cross Creek         1516303    1050766   1.443   0.1601
dat$WatershedPigeon Creek                   1050147     931864   1.127   0.2693
dat$WatershedPike Run                        107129    1142986   0.094   0.9260
dat$WatershedPlum Run-Tenmile Creek        -1162659    1011470  -1.149   0.2601
dat$WatershedShort Creek-Tenmile Creek       179806    1041511   0.173   0.8642
dat$WatershedSouth Fork Cross Creek-Cross Creek  1718665     830519   2.069   0.0479 *
dat$WatershedTempleton Fork                  434727    1281376   0.339   0.7369
dat$FormationCasselman Formation                 NA         NA      NA       NA
dat$FormationGreene Formation                272610     699458   0.390   0.6997
dat$FormationMonongahela Group              -696229     828510  -0.840   0.4078
dat$FormationWaynesburg Formation            250055     569220   0.439   0.6638
dat$HHWSourceSpring                          901704     496003   1.818   0.0798 .
dat$Precip_inchDiff                            3121      56416   0.055   0.9563
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1.142478e+12)

    Null deviance: 5.8961e+13  on 47  degrees of freedom
Residual deviance: 3.1989e+13  on 28  degrees of freedom
AIC: 1485

Number of Fisher Scoring iterations: 2
```

Strontium

Skewness: 1.5309

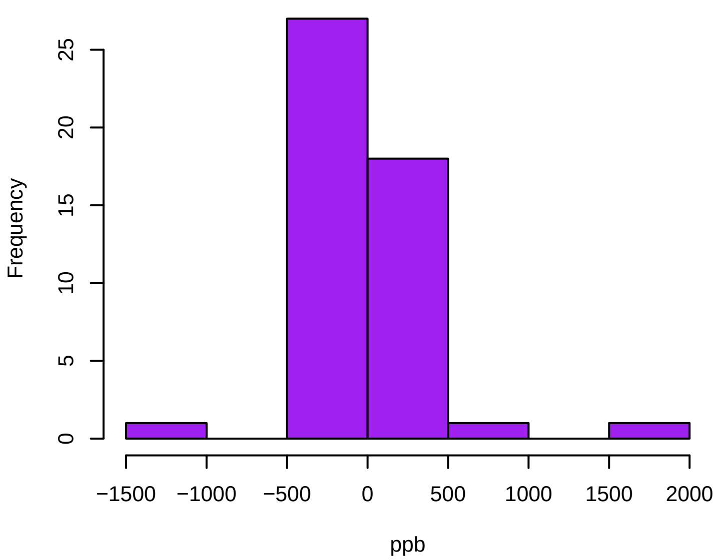
Kurtosis: 17.3994

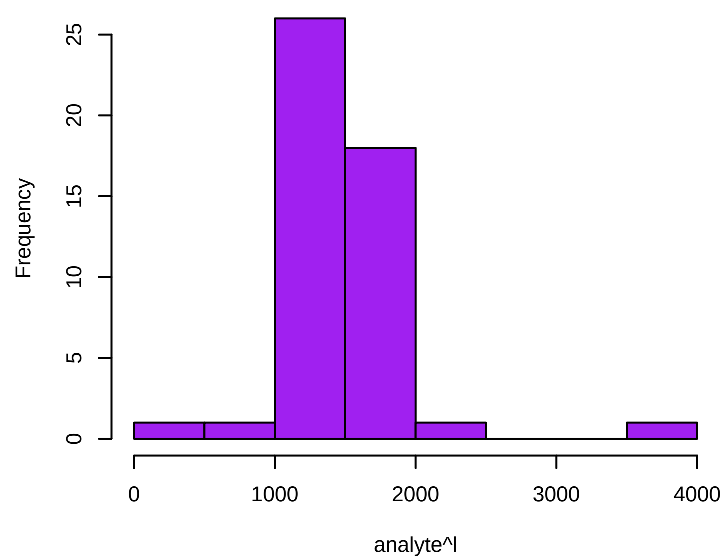
Strontium Box−Cox

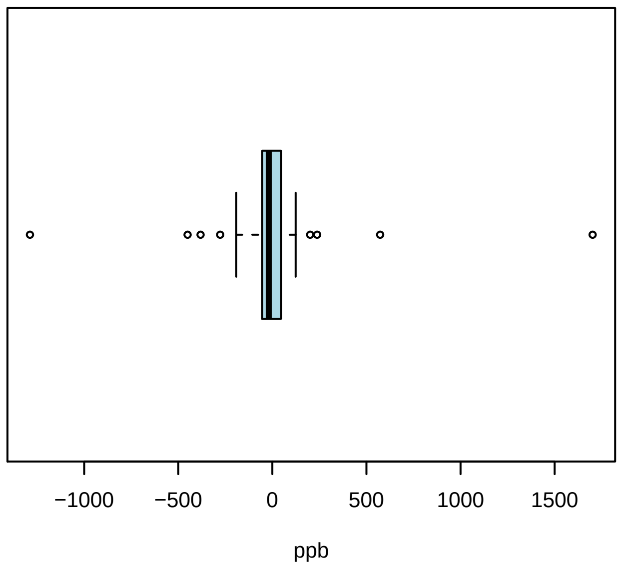
Skewness: 1.6663

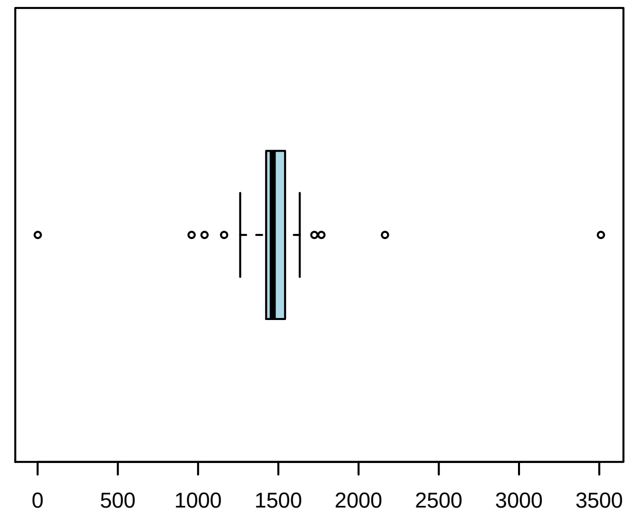
Kurtosis: 17.6225

Optimal lambda: 1.02



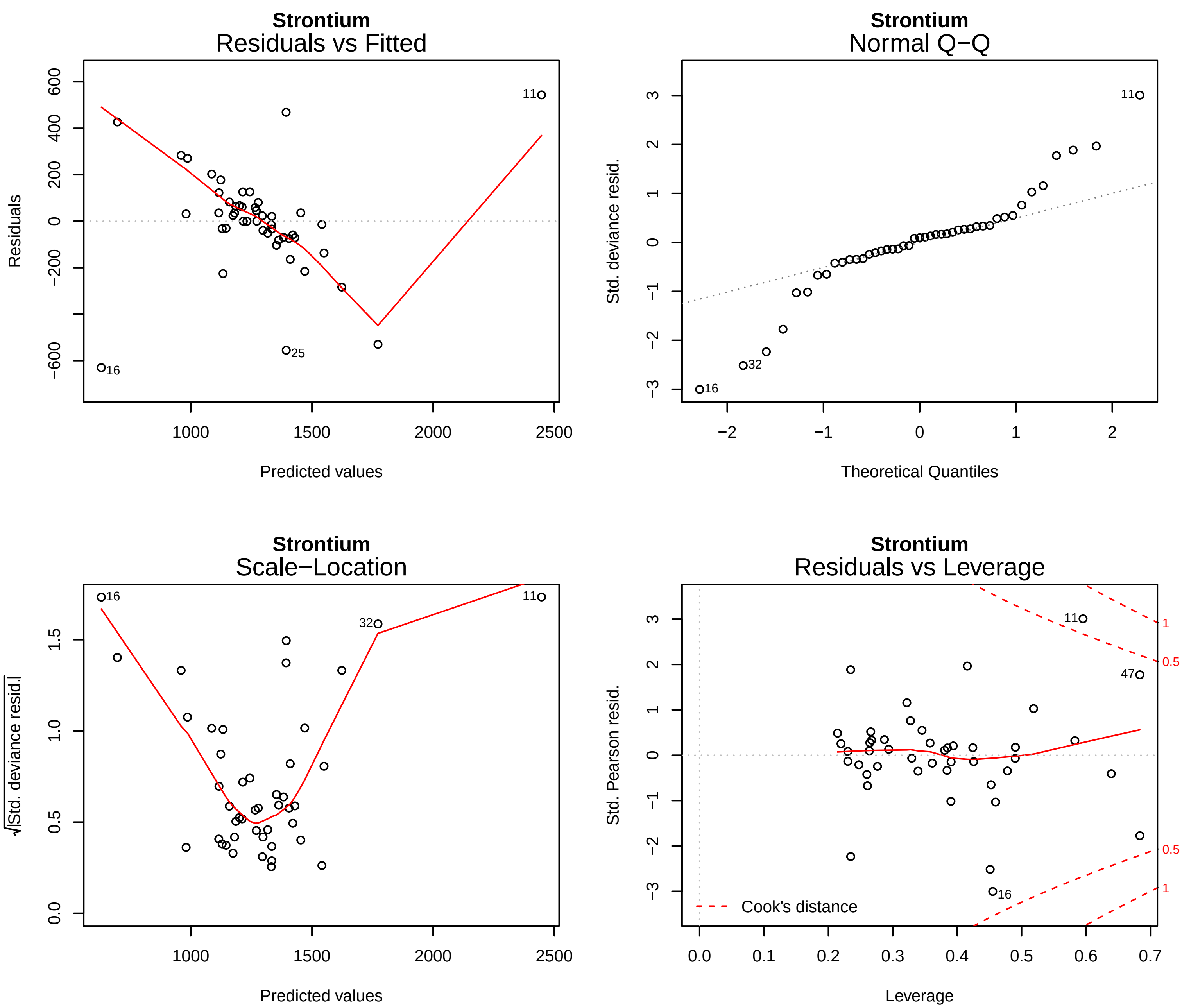






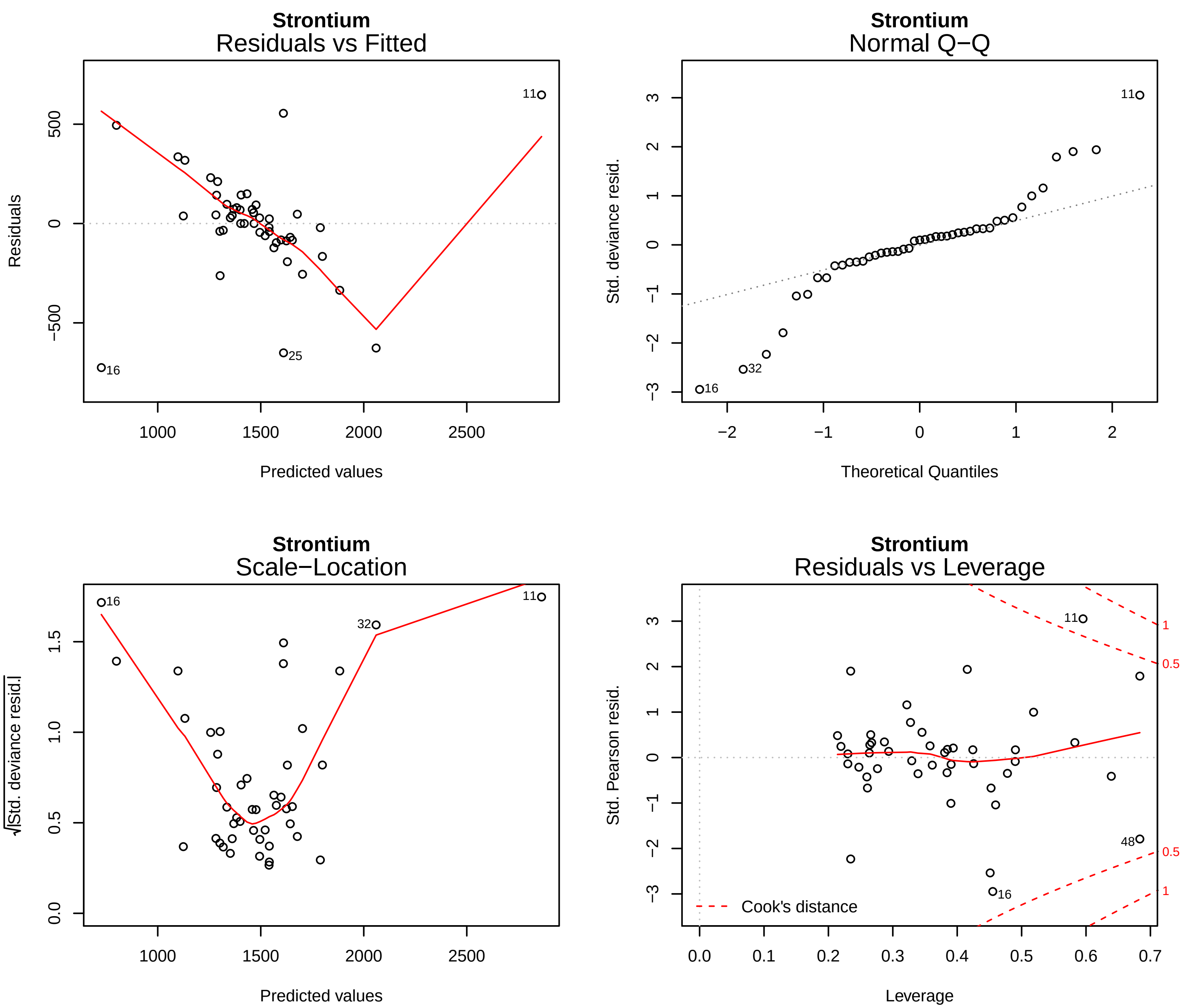
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

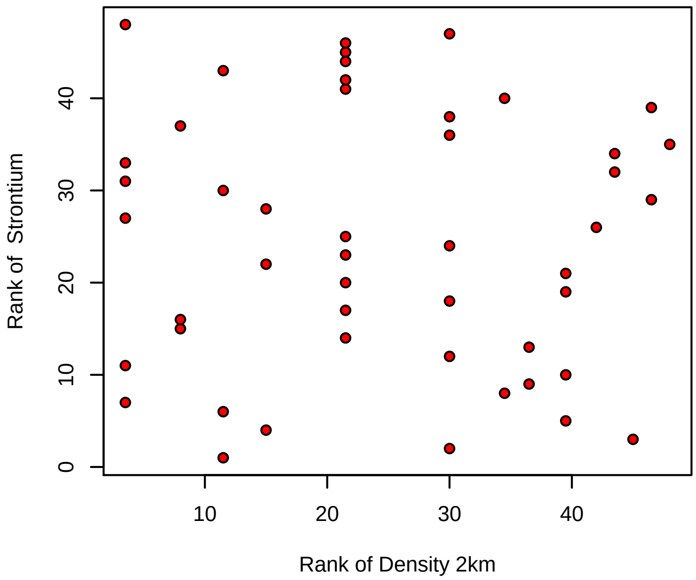
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



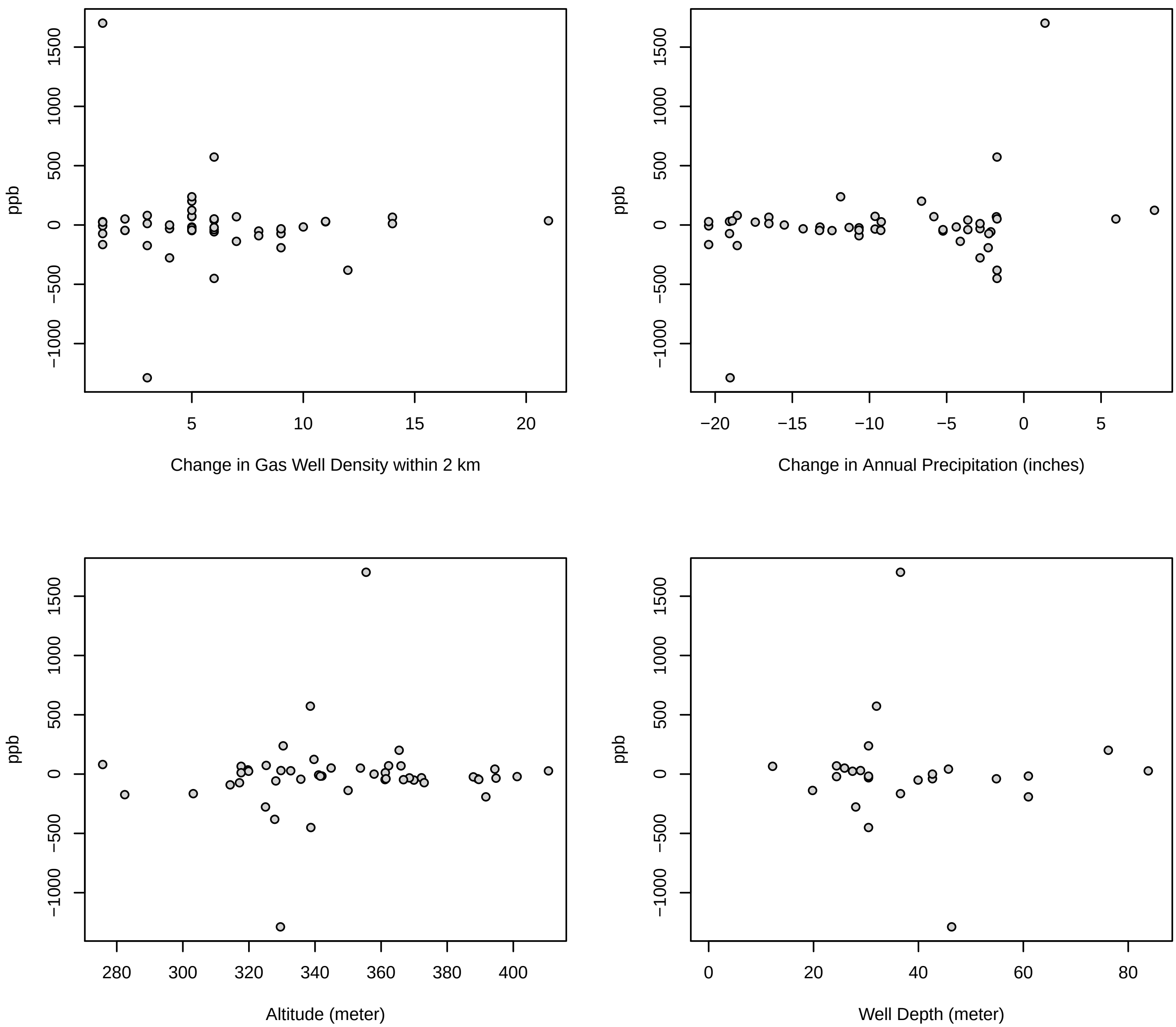


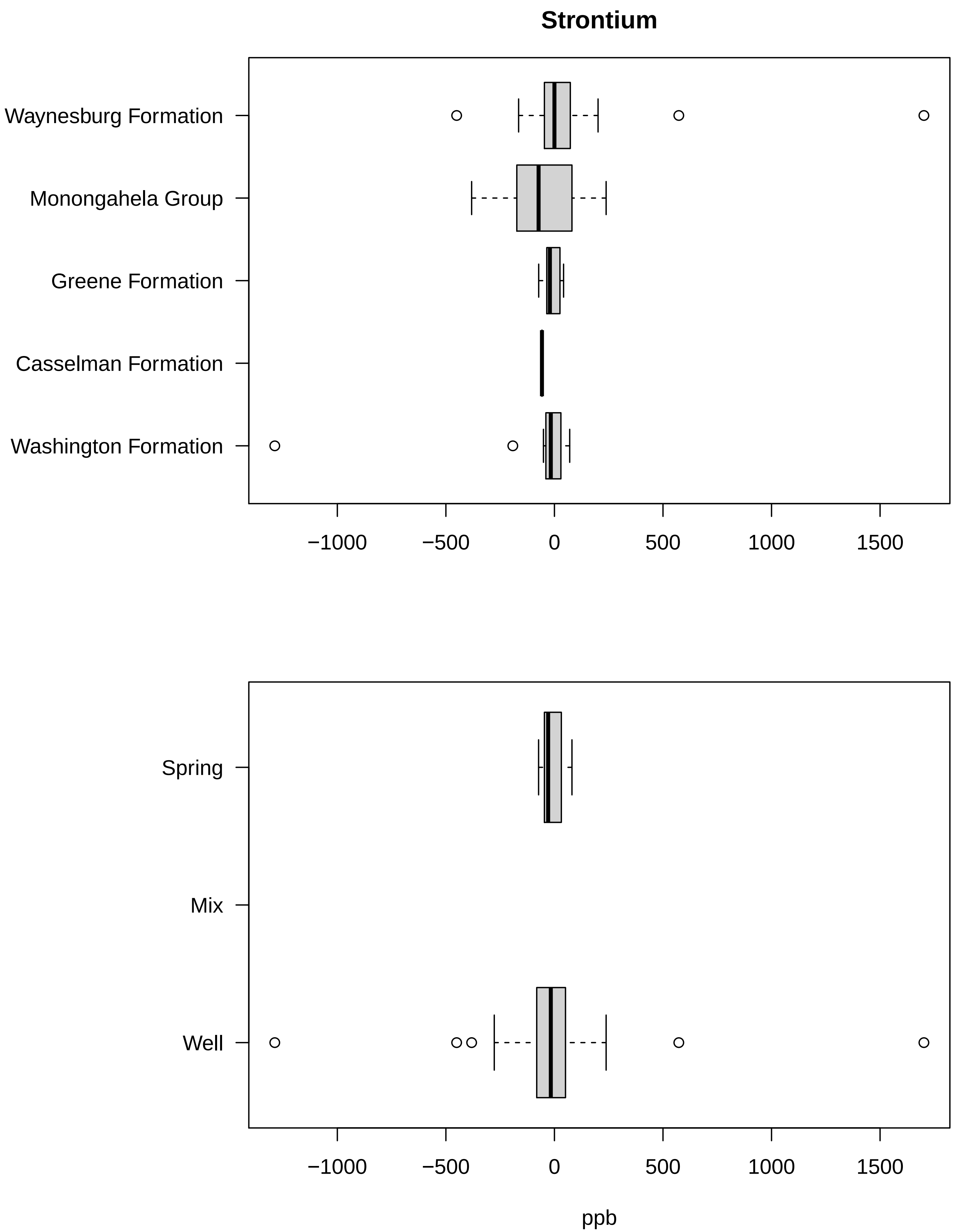
Strontium

Kendalls Tau Rank Correlation

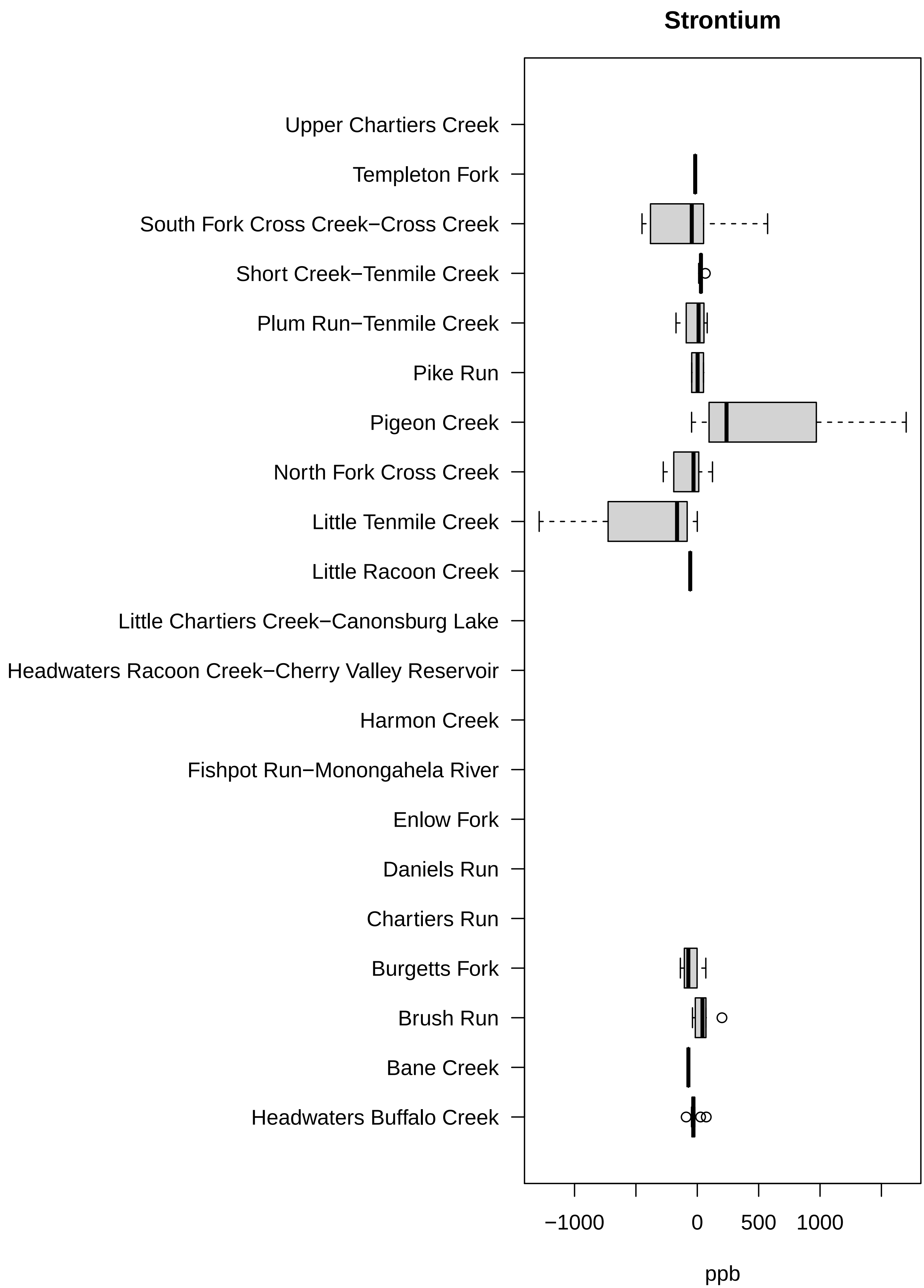
p−value: 0.837

Tau: −0.0214





Strontium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−1000
−500
0
500
1000
1500
Spring
Mix
Well
−1000
−500
0
500
1000
1500
ppb



Strontium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−1000
0
500
1000
ppb

```
[1] "ORIGINAL MODEL - Strontium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-629.90   -69.86    10.33    70.64   543.53  

Coefficients: (1 not defined because of singularities)
                                               Estimate Std. Error t value Pr(>|t|)   
(Intercept)                                     438.801   1128.883   0.389  0.70044   
dat$GWellDensity_2kmDiff                        -12.382     17.489  -0.708  0.48481   
dat$Altitude_meter                                3.603      3.054   1.180  0.24803   
dat$WatershedBane Creek                         417.618    351.780   1.187  0.24514   
dat$WatershedBrush Run                         -130.955    204.556  -0.640  0.52725   
dat$WatershedBurgetts Fork                     -359.433    259.194  -1.387  0.17647   
dat$WatershedLittle Racoon Creek               -336.927    371.393  -0.907  0.37204   
dat$WatershedLittle Tenmile Creek               -67.999    265.530  -0.256  0.79975   
dat$WatershedNorth Fork Cross Creek            -501.186    279.335  -1.794  0.08358 . 
dat$WatershedPigeon Creek                       474.755    247.726   1.916  0.06557 . 
dat$WatershedPike Run                          -545.689    303.850  -1.796  0.08331 . 
dat$WatershedPlum Run-Tenmile Creek             540.804    268.888   2.011  0.05401 . 
dat$WatershedShort Creek-Tenmile Creek          696.900    276.874   2.517  0.01784 * 
dat$WatershedSouth Fork Cross Creek-Cross Creek -311.259    220.784  -1.410  0.16961   
dat$WatershedTempleton Fork                     282.137    340.640   0.828  0.41453   
dat$FormationCasselman Formation                     NA         NA      NA       NA   
dat$FormationGreene Formation                   -79.515    185.943  -0.428  0.67219   
dat$FormationMonongahela Group                   54.402    220.250   0.247  0.80671   
dat$FormationWaynesburg Formation               201.496    151.321   1.332  0.19374   
dat$HHWSourceSpring                             121.843    131.857   0.924  0.36335   
dat$Precip_inchDiff                              46.775     14.998   3.119  0.00418 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 80739.35)

    Null deviance: 5610506  on 47  degrees of freedom
Residual deviance: 2260702  on 28  degrees of freedom
AIC: 694.7

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Strontium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-725.16   -82.79    11.74    83.23   647.39

Coefficients: (1 not defined because of singularities)
                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                   516.598   1324.776   0.390  0.69952
dat$GWellDensity_2kmDiff                      -14.706     20.524  -0.717  0.47961
dat$Altitude_meter                              4.185      3.584   1.168  0.25277
dat$WatershedBane Creek                       494.267    412.824   1.197  0.24124
dat$WatershedBrush Run                       -158.118    240.053  -0.659  0.51548
dat$WatershedBurgetts Fork                   -424.963    304.171  -1.397  0.17335
dat$WatershedLittle Racoon Creek             -405.920    435.841  -0.931  0.35963
dat$WatershedLittle Tenmile Creek             -67.502    311.607  -0.217  0.83007
dat$WatershedNorth Fork Cross Creek          -593.693    327.807  -1.811  0.08087 .
dat$WatershedPigeon Creek                     565.565    290.713   1.945  0.06182 .
dat$WatershedPike Run                        -647.305    356.577  -1.815  0.08020 .
dat$WatershedPlum Run-Tenmile Creek           638.113    315.548   2.022  0.05280 .
dat$WatershedShort Creek-Tenmile Creek        819.841    324.920   2.523  0.01759 *
dat$WatershedSouth Fork Cross Creek-Cross Creek -370.468    259.097  -1.430  0.16383
dat$WatershedTempleton Fork                   329.141    399.750   0.823  0.41726
dat$FormationCasselman Formation                   NA         NA      NA       NA
dat$FormationGreene Formation                 -94.808    218.210  -0.434  0.66727
dat$FormationMonongahela Group                 57.727    258.470   0.223  0.82489
dat$FormationWaynesburg Formation             231.568    177.579   1.304  0.20284
dat$HHWSourceSpring                           143.226    154.738   0.926  0.36256
dat$Precip_inchDiff                            55.598     17.600   3.159  0.00378 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 111191.7)

    Null deviance: 7762869  on 47  degrees of freedom
Residual deviance: 3113369  on 28  degrees of freedom
AIC: 710.06

Number of Fisher Scoring iterations: 2
```

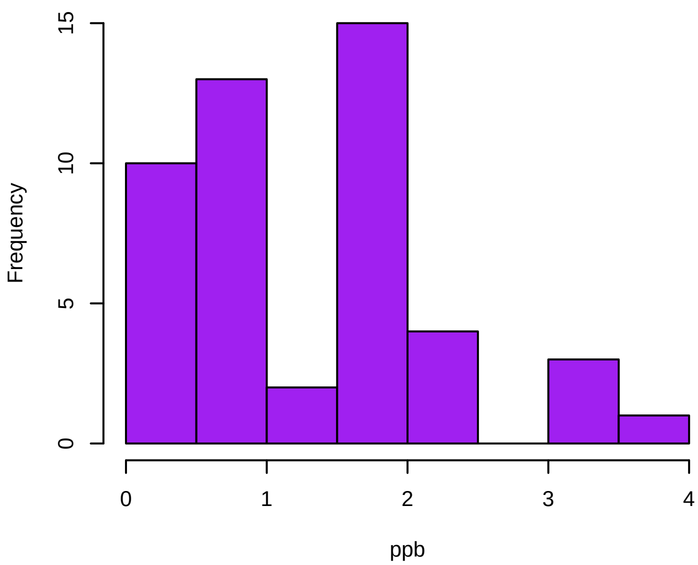
Tin

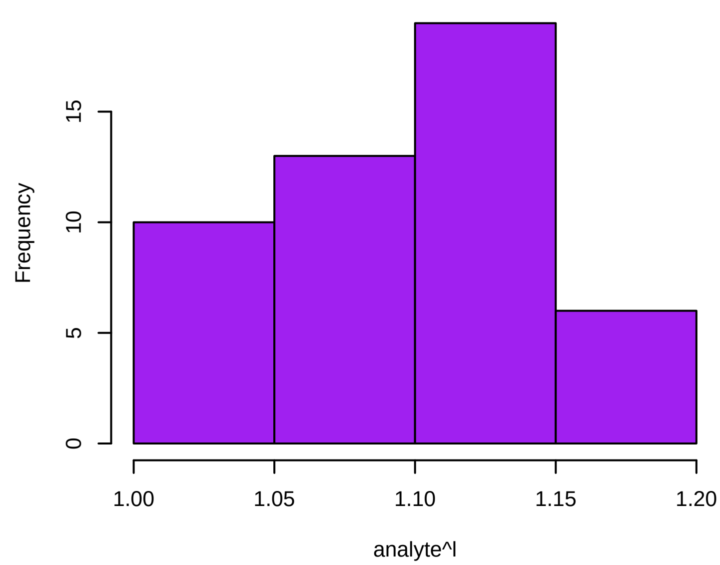
Skewness: 0.7587
Kurtosis: 2.8939

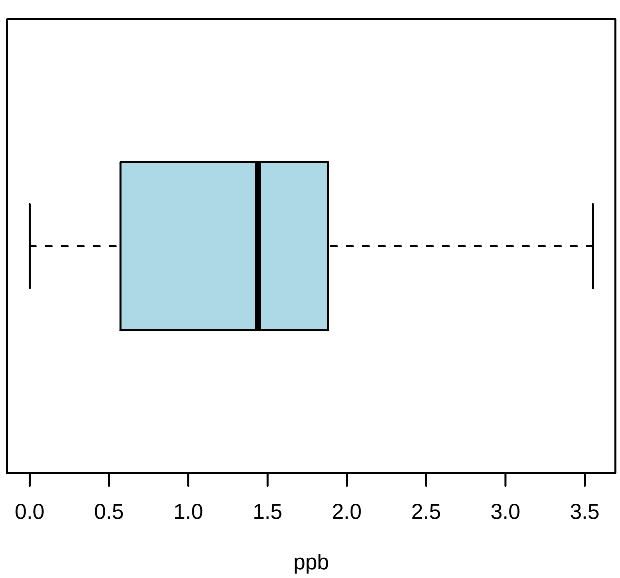
Tin Box−Cox

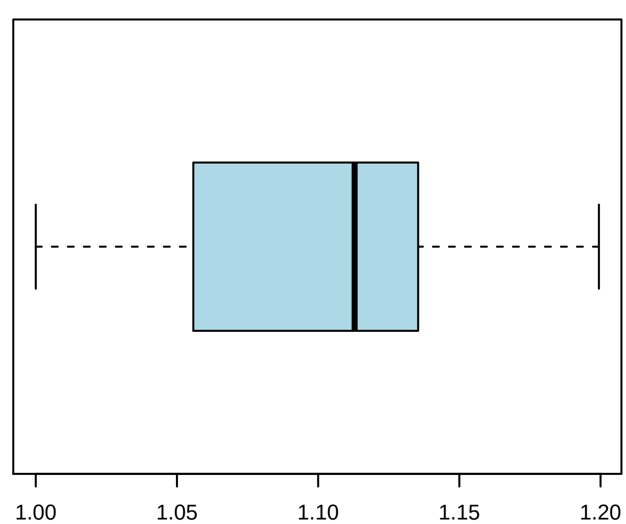
Skewness: 0.2261
Kurtosis: 2.0248

Optimal lambda: 0.12



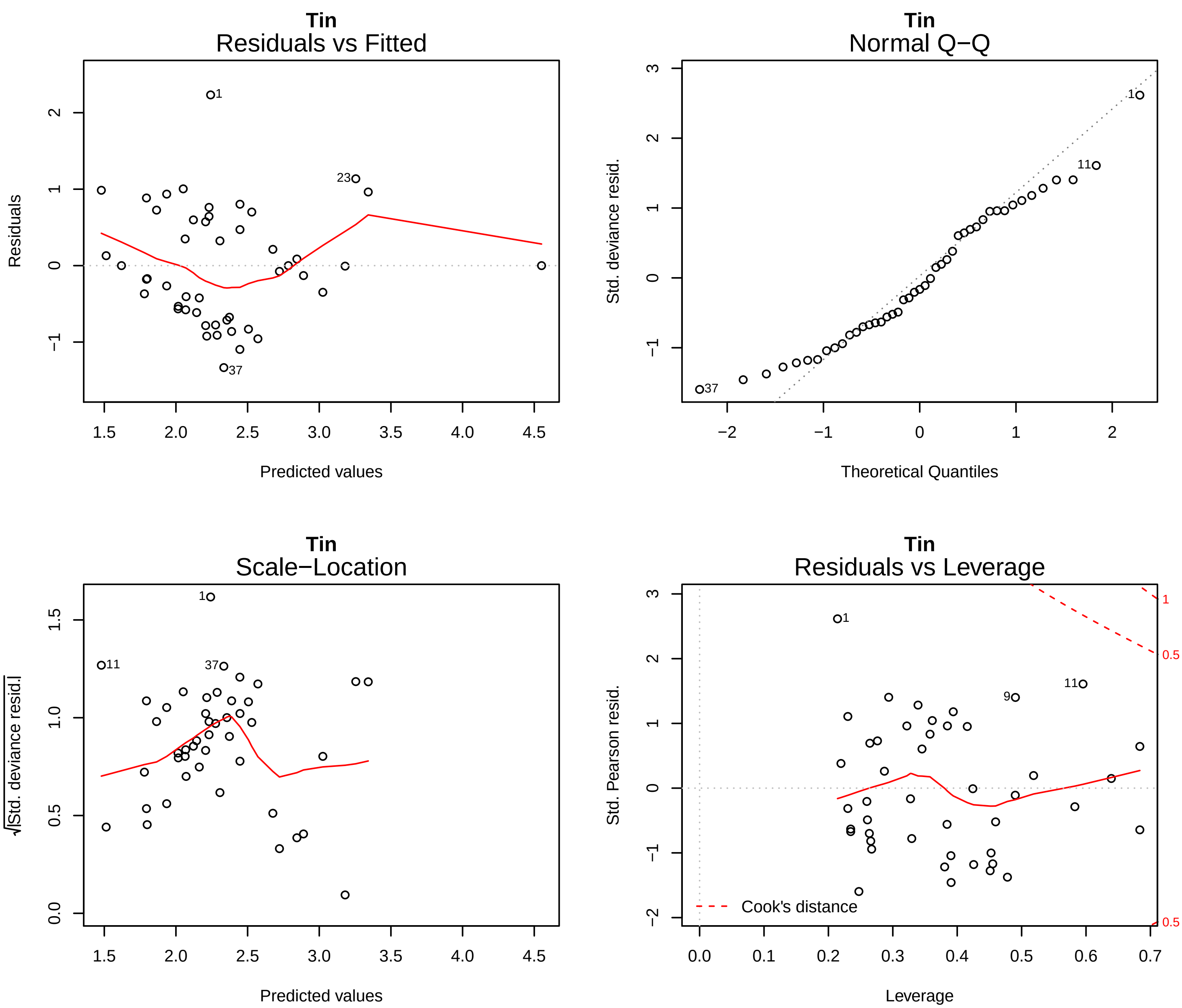






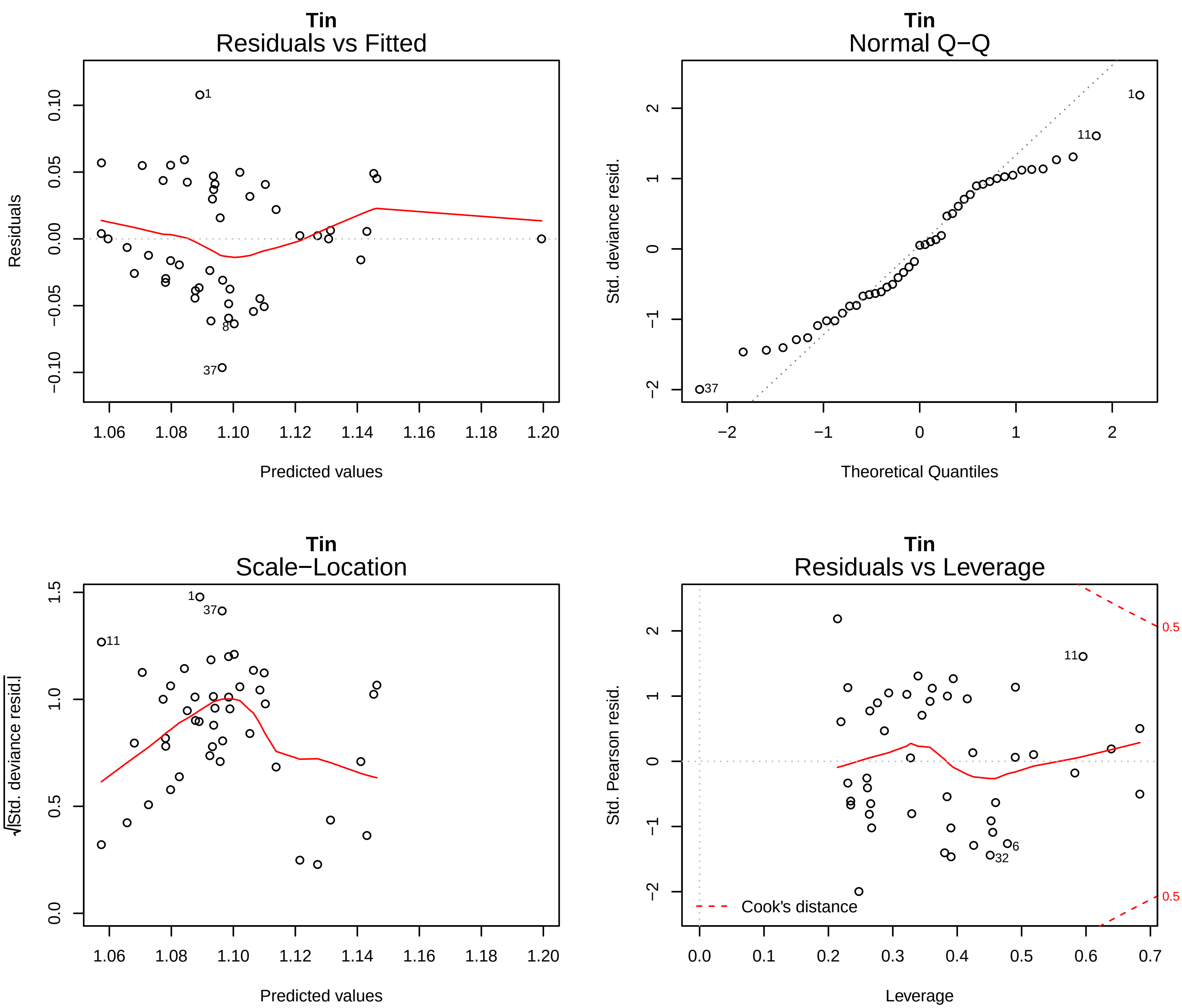
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

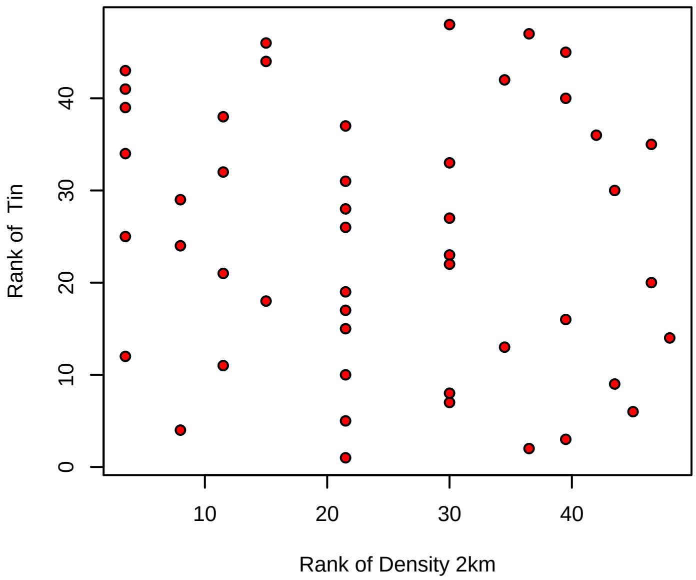
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



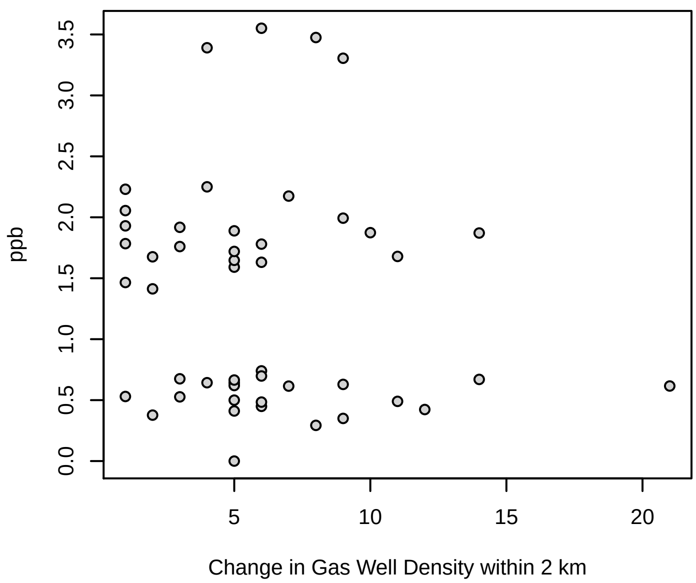


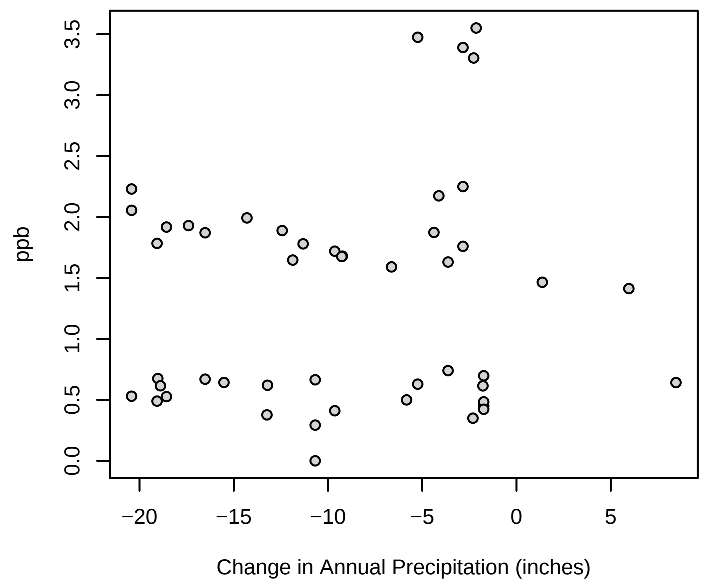
Tin

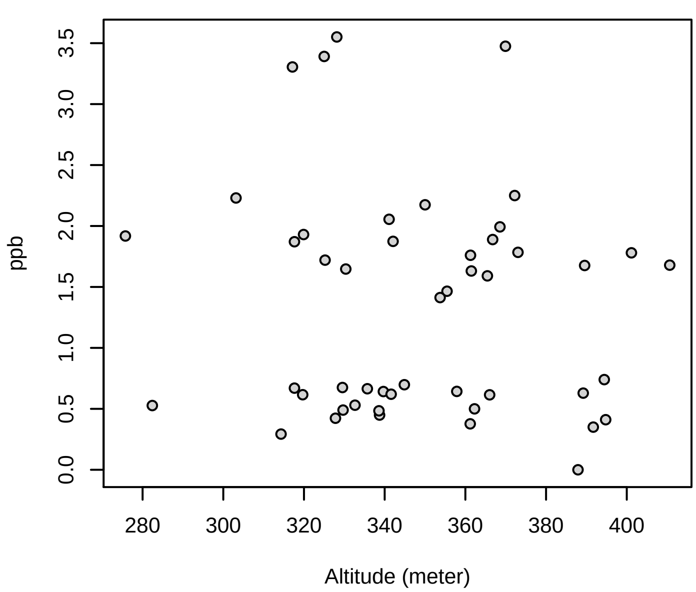
Kendalls Tau Rank Correlation

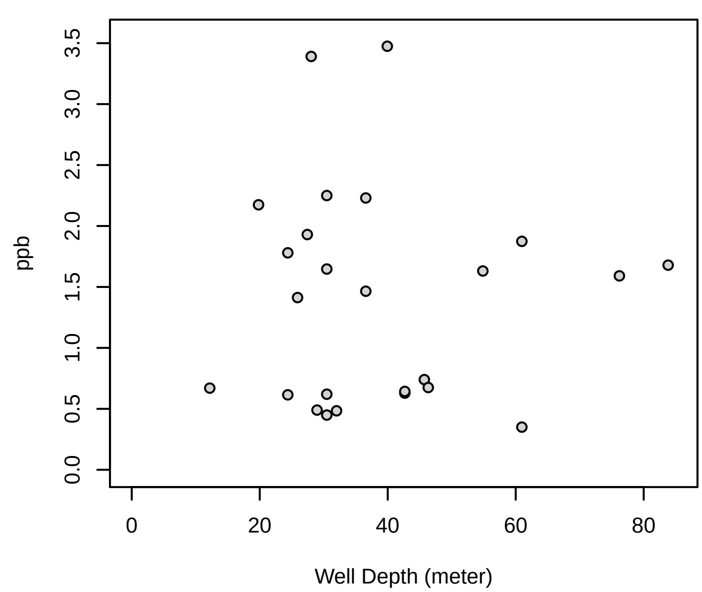
p−value: 0.294

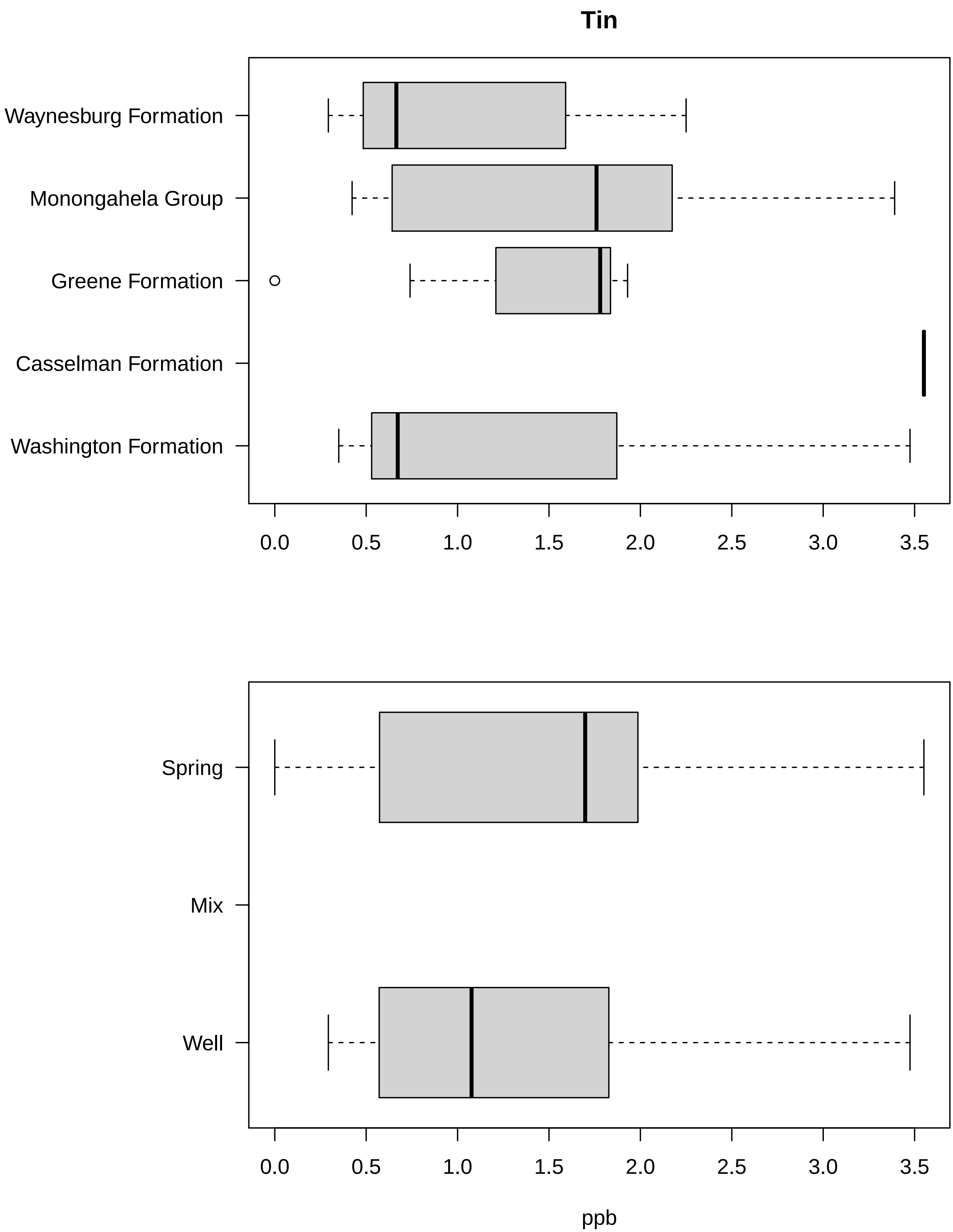
Tau: −0.109

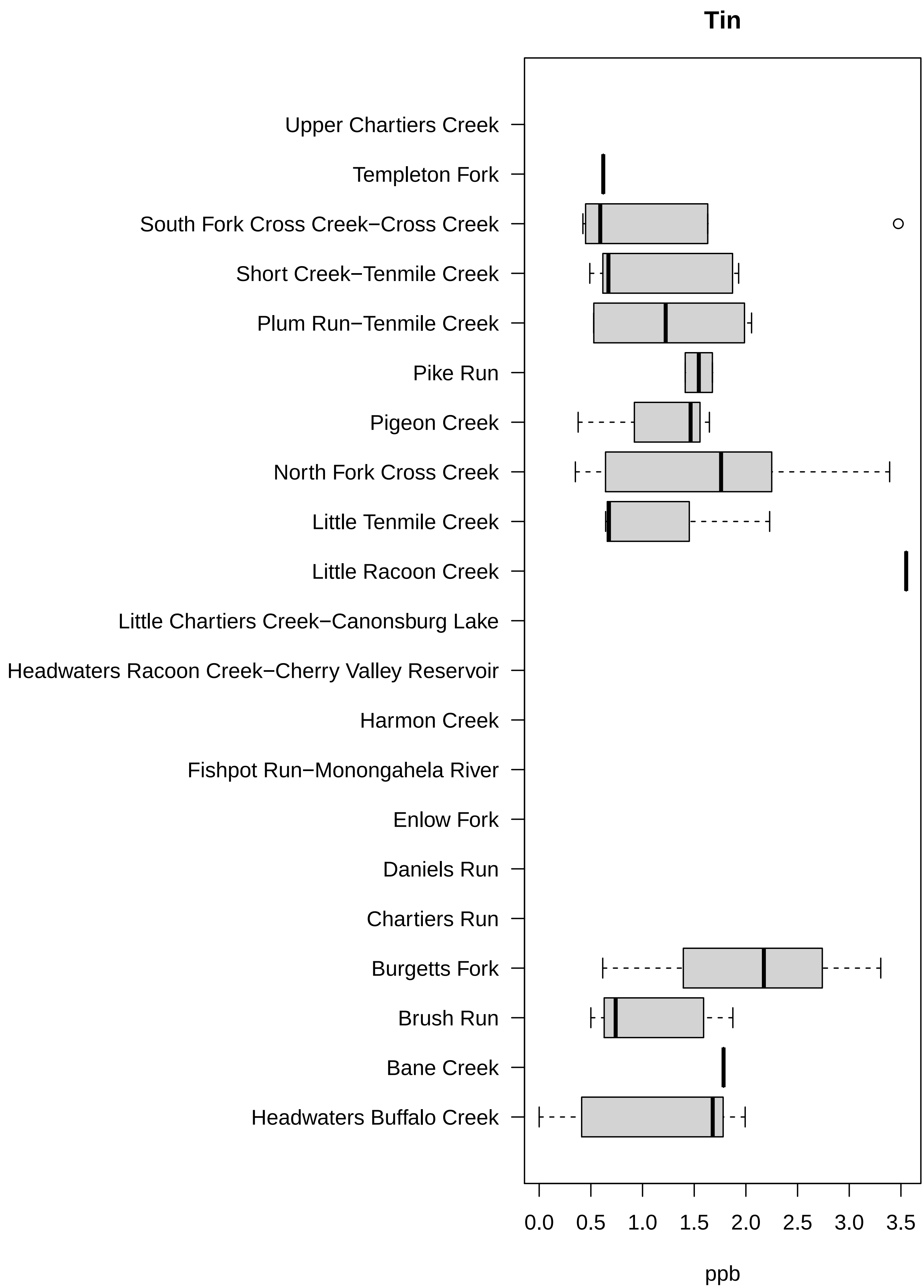









Tin
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Spring
Mix
Well
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
ppb


Tin
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
ppb

```
[1] "ORIGINAL MODEL - Tin"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-1.33395  -0.58703  -0.04084   0.60945   2.23304  

Coefficients: (1 not defined because of singularities)
                                            Estimate Std. Error t value Pr(>|t|)  
(Intercept)                                  5.73585    3.82585   1.499   0.1450  
dat$GWellDensity_2kmDiff                    -0.03576    0.05927  -0.603   0.5511  
dat$Altitude_meter                          -0.01105    0.01035  -1.067   0.2951  
dat$WatershedBane Creek                     -0.39365    1.19220  -0.330   0.7437  
dat$WatershedBrush Run                       0.35879    0.69325   0.518   0.6088  
dat$WatershedBurgetts Fork                   1.44467    0.87842   1.645   0.1112  
dat$WatershedLittle Racoon Creek             2.53655    1.25867   2.015   0.0536 .
dat$WatershedLittle Tenmile Creek           -0.66449    0.89990  -0.738   0.4664  
dat$WatershedNorth Fork Cross Creek          1.21503    0.94668   1.283   0.2099  
dat$WatershedPigeon Creek                    0.21658    0.83956   0.258   0.7983  
dat$WatershedPike Run                        1.10314    1.02977   1.071   0.2932  
dat$WatershedPlum Run-Tenmile Creek         -1.13436    0.91128  -1.245   0.2235  
dat$WatershedShort Creek-Tenmile Creek      -0.81713    0.93834  -0.871   0.3913  
dat$WatershedSouth Fork Cross Creek-Cross Creek  0.55281    0.74825   0.739   0.4662  
dat$WatershedTempleton Fork                 -0.98420    1.15445  -0.853   0.4012  
dat$FormationCasselman Formation                  NA         NA      NA       NA  
dat$FormationGreene Formation                0.41376    0.63017   0.657   0.5168  
dat$FormationMonongahela Group              -0.13958    0.74644  -0.187   0.8530  
dat$FormationWaynesburg Formation           -0.42612    0.51283  -0.831   0.4131  
dat$HHWSourceSpring                         -0.01544    0.44687  -0.035   0.9727  
dat$Precip_inchDiff                         -0.06209    0.05083  -1.222   0.2320  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.9273486)

    Null deviance: 39.461  on 47  degrees of freedom
Residual deviance: 25.966  on 28  degrees of freedom
AIC: 148.73

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Tin"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.09639  -0.03359   0.00000   0.04081   0.10780

Coefficients: (1 not defined because of singularities)
                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                              1.2745851  0.2210337   5.766 3.44e-06 ***
dat$GWellDensity_2kmDiff                -0.0022215  0.0034243  -0.649    0.522
dat$Altitude_meter                      -0.0005603  0.0005980  -0.937    0.357
dat$WatershedBane Creek                 -0.0144352  0.0688781  -0.210    0.836
dat$WatershedBrush Run                   0.0194420  0.0400518   0.485    0.631
dat$WatershedBurgetts Fork               0.0722181  0.0507498   1.423    0.166
dat$WatershedLittle Racoon Creek         0.1200894  0.0727183   1.651    0.110
dat$WatershedLittle Tenmile Creek       -0.0352268  0.0519904  -0.678    0.504
dat$WatershedNorth Fork Cross Creek      0.0578116  0.0546933   1.057    0.300
dat$WatershedPigeon Creek                0.0104928  0.0485044   0.216    0.830
dat$WatershedPike Run                    0.0646447  0.0594935   1.087    0.286
dat$WatershedPlum Run-Tenmile Creek     -0.0570898  0.0526479  -1.084    0.287
dat$WatershedShort Creek-Tenmile Creek  -0.0382857  0.0542116  -0.706    0.486
dat$WatershedSouth Fork Cross Creek-Cross Creek  0.0229944  0.0432293   0.532    0.599
dat$WatershedTempleton Fork             -0.0544905  0.0666967  -0.817    0.421
dat$FormationCasselman Formation                NA         NA      NA       NA
dat$FormationGreene Formation            0.0211710  0.0364074   0.582    0.566
dat$FormationMonongahela Group          -0.0051657  0.0431247  -0.120    0.906
dat$FormationWaynesburg Formation       -0.0218925  0.0296284  -0.739    0.466
dat$HHWSourceSpring                     -0.0048812  0.0258174  -0.189    0.851
dat$Precip_inchDiff                     -0.0031799  0.0029365  -1.083    0.288
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.003095311)

    Null deviance: 0.120868  on 47  degrees of freedom
Residual deviance: 0.086669  on 28  degrees of freedom
AIC: -124.99

Number of Fisher Scoring iterations: 2
```

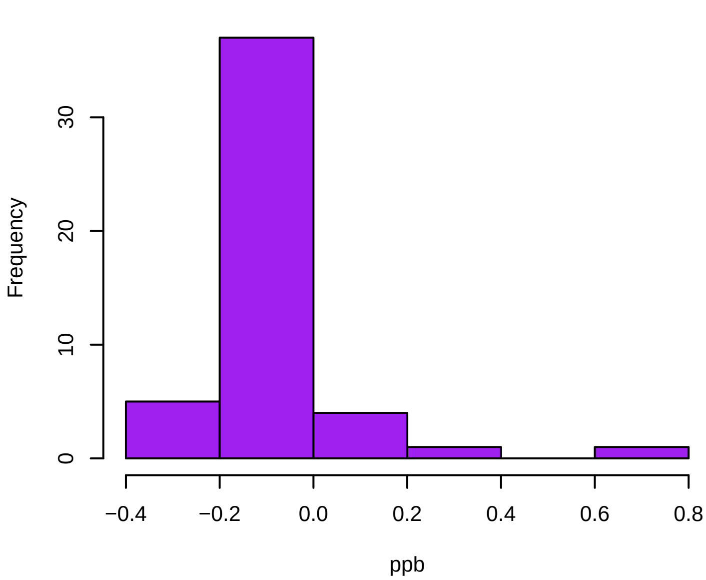
Uranium

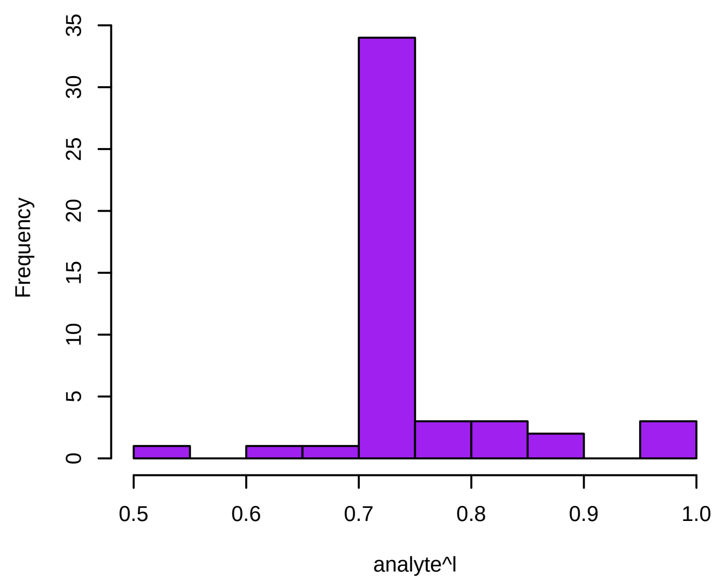
Skewness: 1.4508
Kurtosis: 12.3435

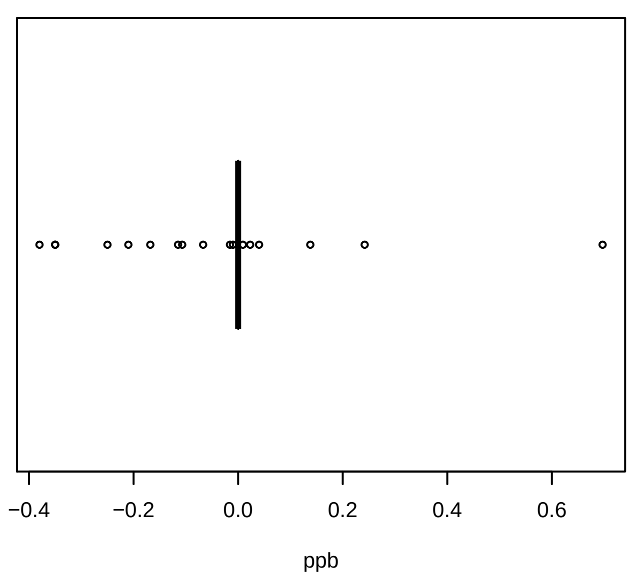
Uranium Box−Cox

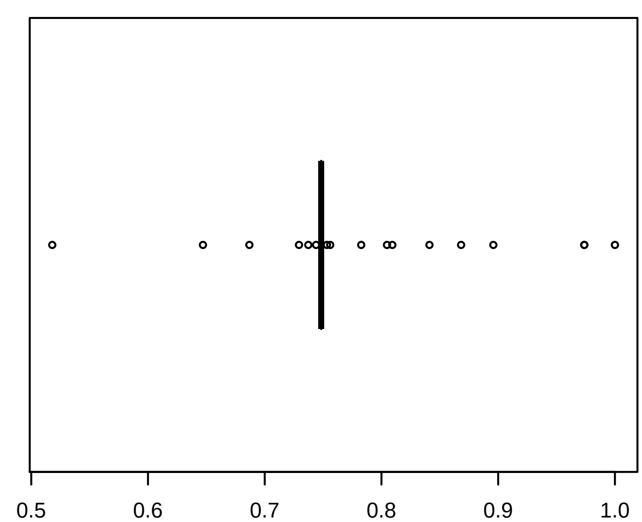
Skewness: 0.8633
Kurtosis: 7.2945

Optimal lambda: −0.9



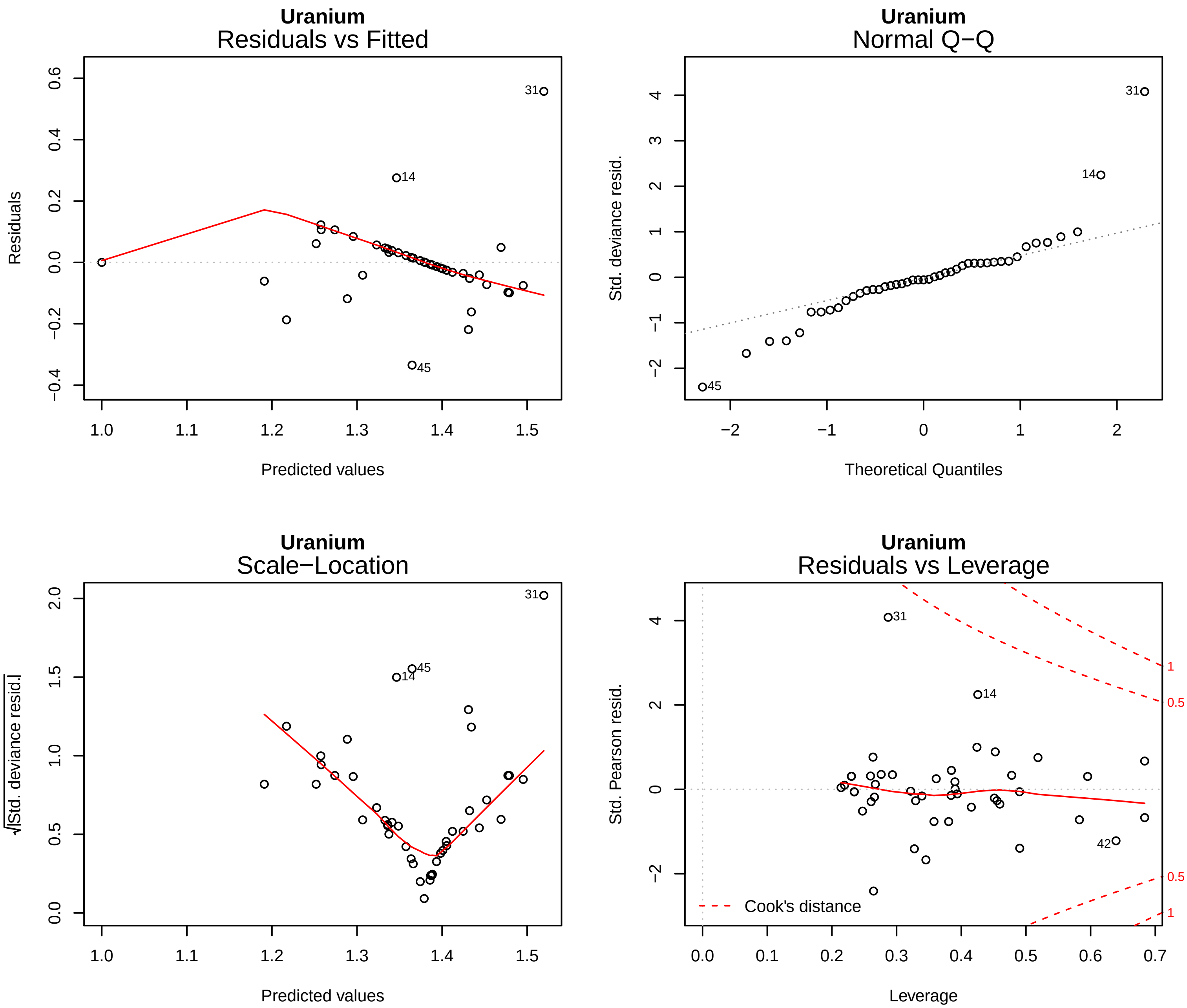






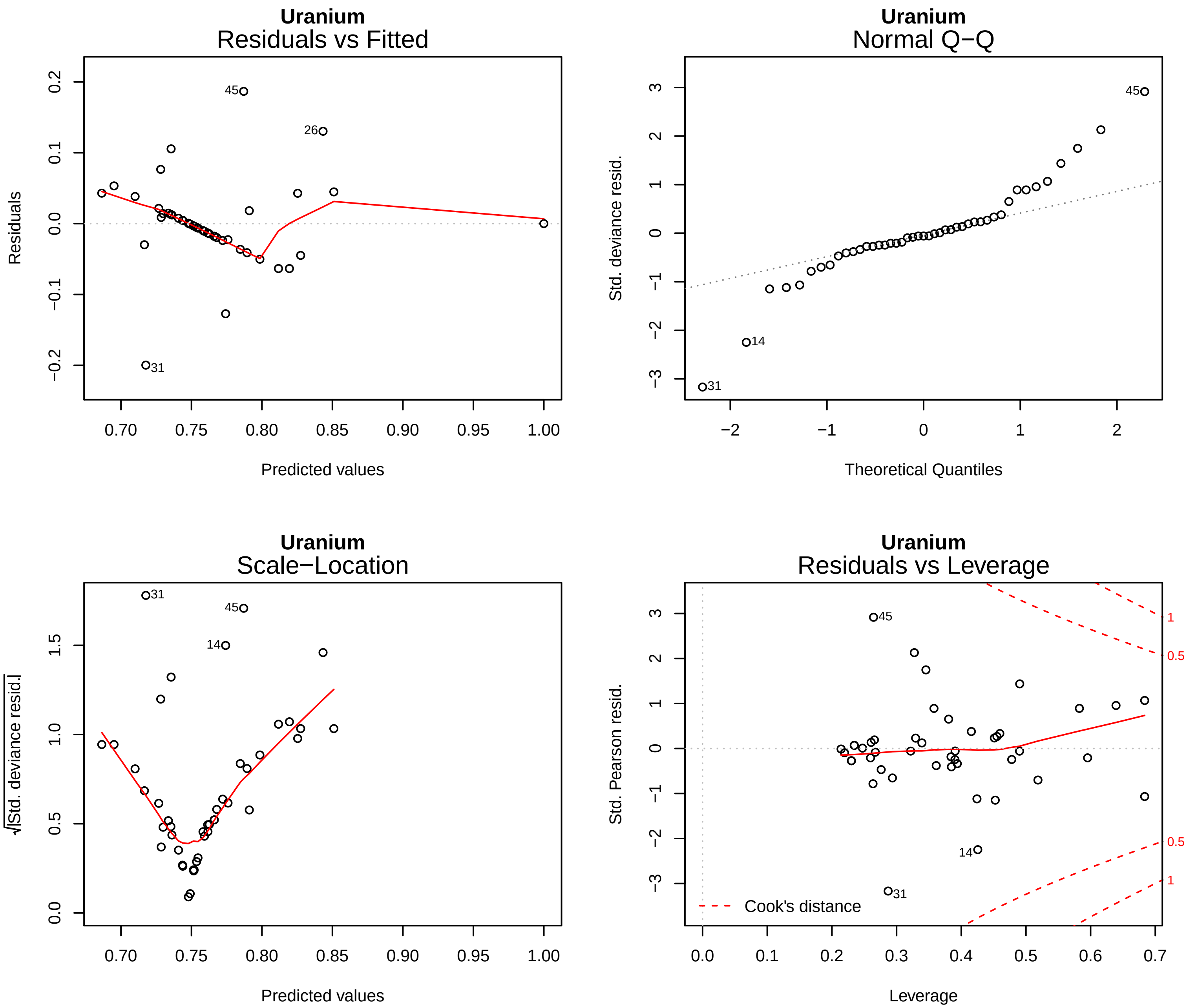
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

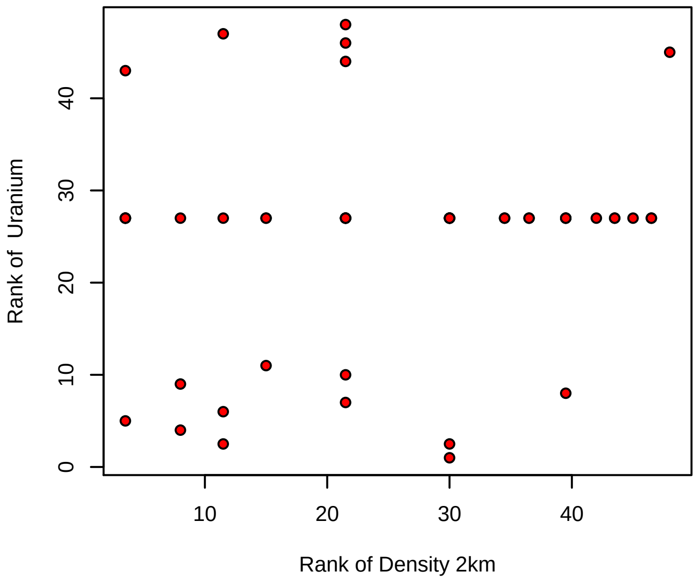
Original
Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox
Model



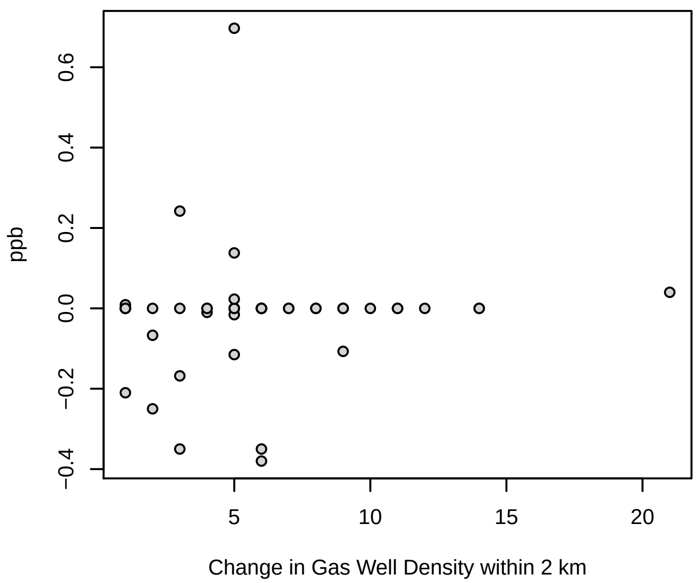


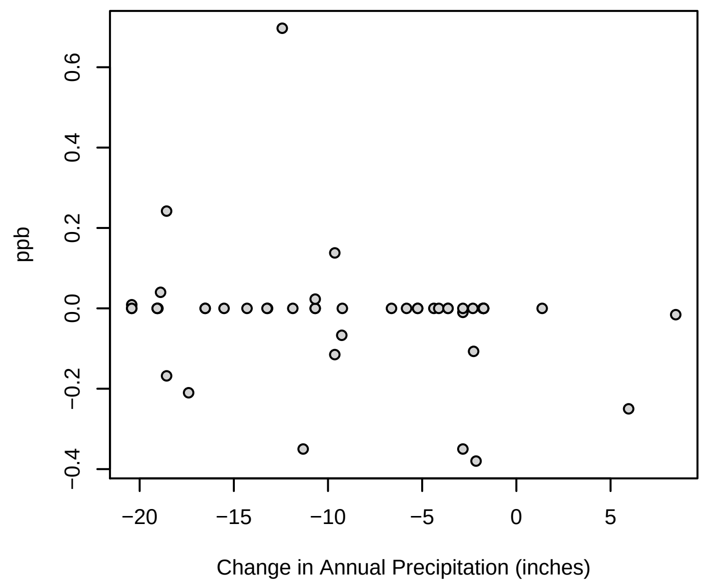
Uranium

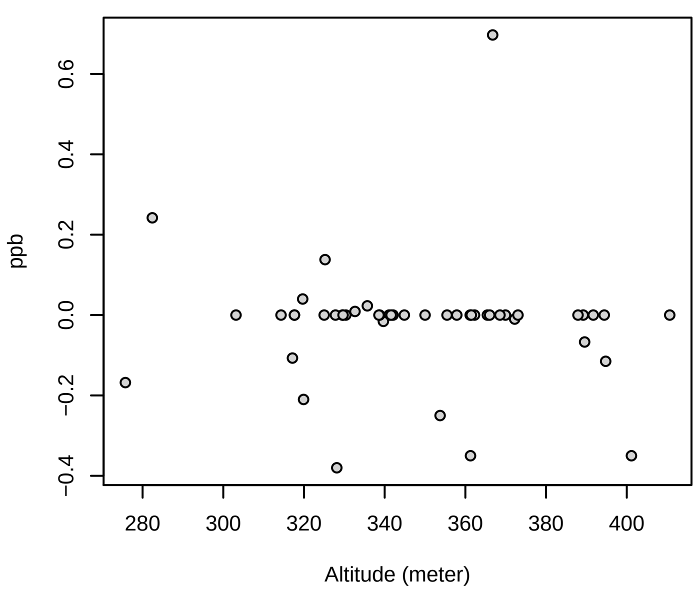
Kendalls Tau Rank Correlation

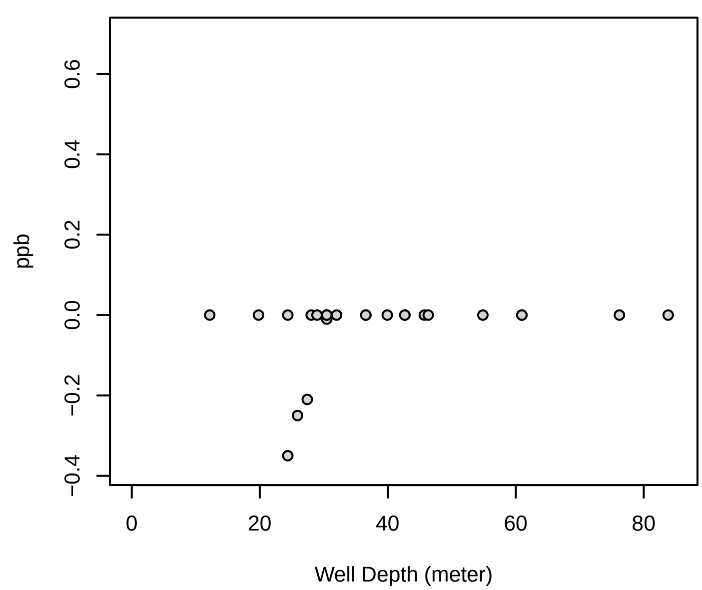
p−value: 0.328

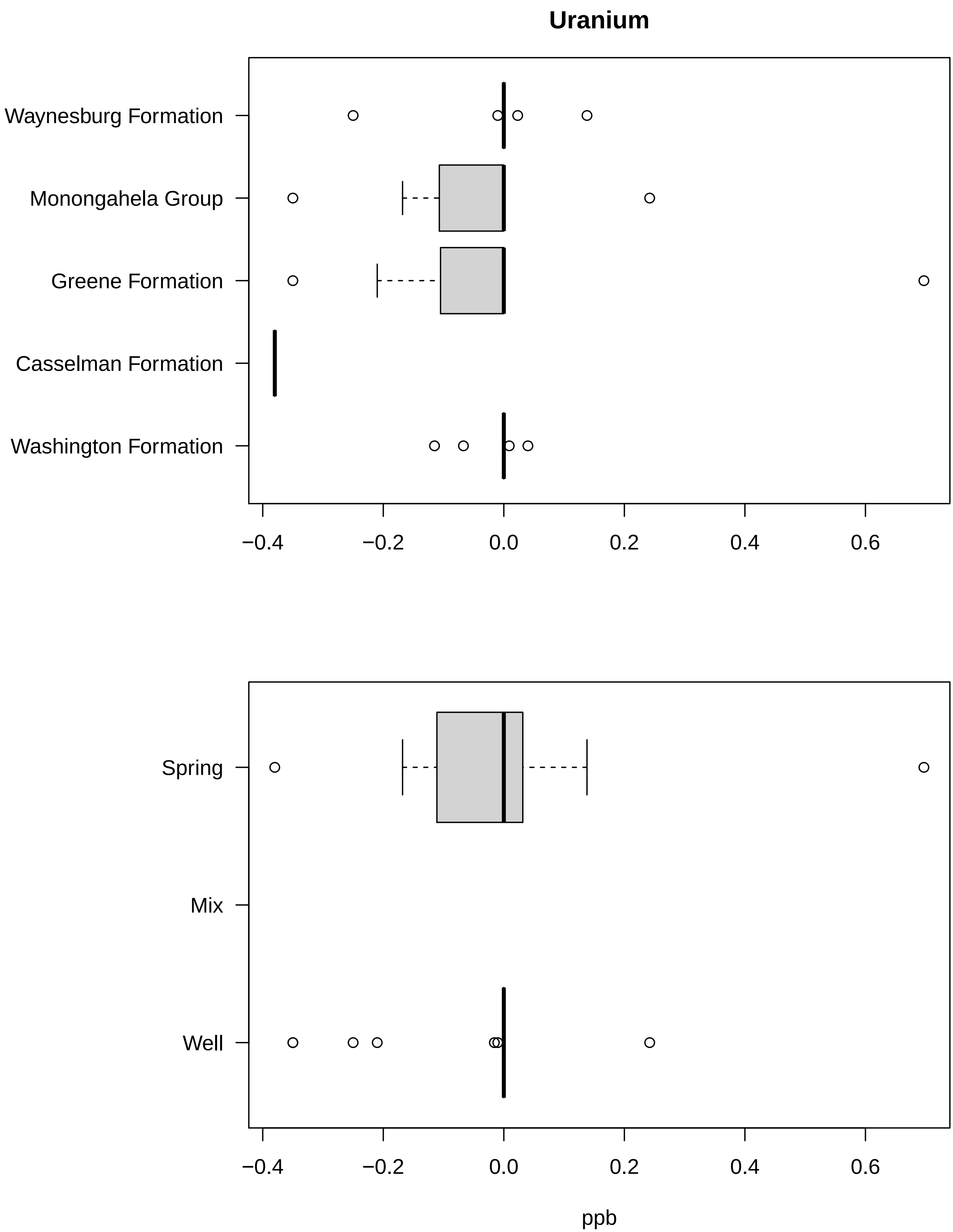
Tau: 0.113

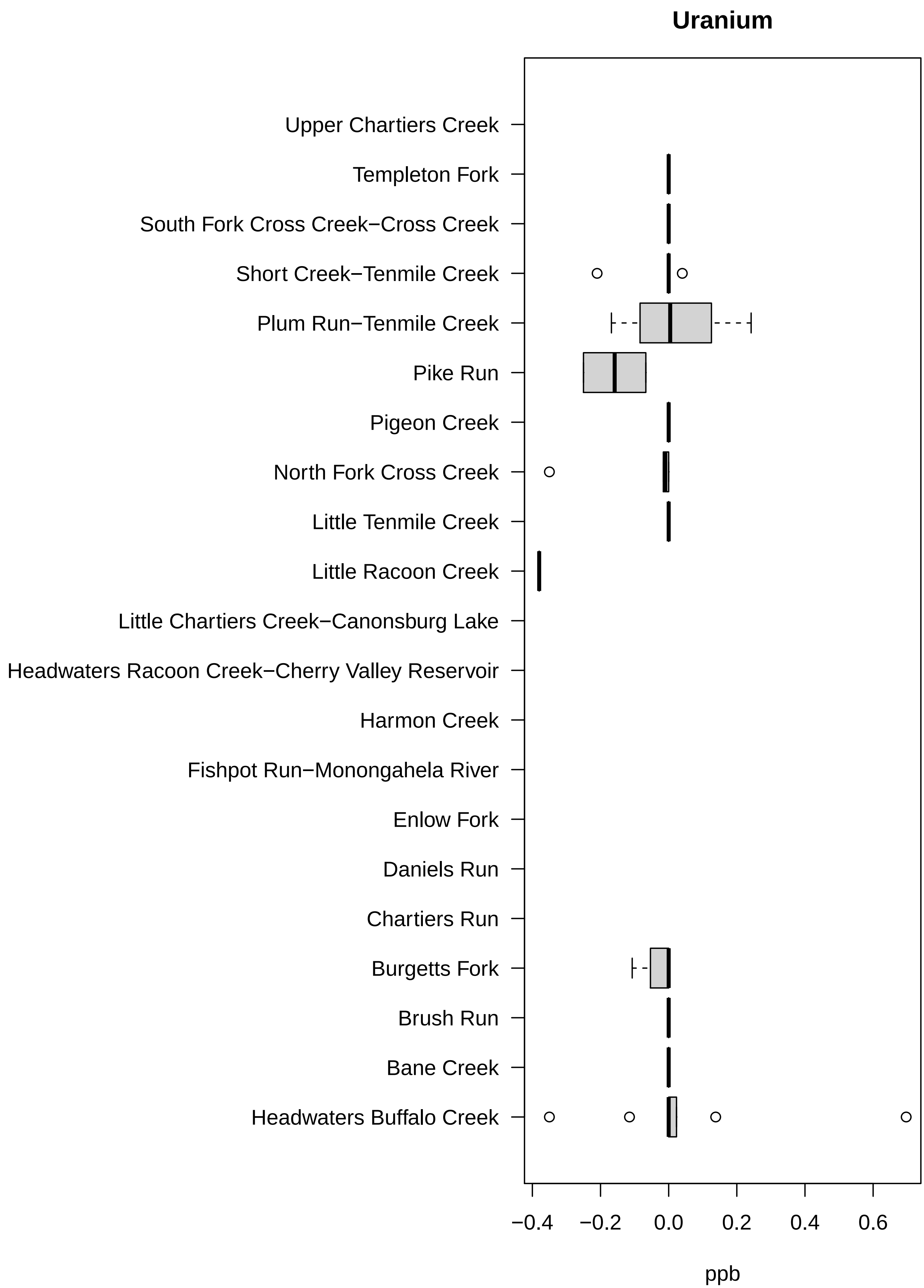









Uranium
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−0.4
−0.2
0.0
0.2
0.4
0.6
Spring
Mix
Well
ppb



Uranium
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−0.4
−0.2
0.0
0.2
0.4
0.6
ppb

```
[1] "ORIGINAL MODEL - Uranium"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.33472  -0.04099  -0.00289   0.04390   0.55741

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                   2.257476   0.642901   3.511  0.00153 **
dat$GWellDensity_2kmDiff                      0.012830   0.009960   1.288  0.20825
dat$Altitude_meter                           -0.002837   0.001739  -1.631  0.11410
dat$WatershedBane Creek                      -0.032010   0.200340  -0.160  0.87420
dat$WatershedBrush Run                        0.045841   0.116495   0.394  0.69693
dat$WatershedBurgetts Fork                    0.059634   0.147612   0.404  0.68929
dat$WatershedLittle Racoon Creek             -0.477908   0.211509  -2.260  0.03182 *
dat$WatershedLittle Tenmile Creek            -0.026703   0.151220  -0.177  0.86111
dat$WatershedNorth Fork Cross Creek           0.107781   0.159082   0.678  0.50364
dat$WatershedPigeon Creek                     0.126986   0.141080   0.900  0.37574
dat$WatershedPike Run                        -0.029499   0.173043  -0.170  0.86586
dat$WatershedPlum Run-Tenmile Creek          -0.050891   0.153132  -0.332  0.74211
dat$WatershedShort Creek-Tenmile Creek       -0.267379   0.157680  -1.696  0.10104
dat$WatershedSouth Fork Cross Creek-Cross Creek  0.042245   0.125737   0.336  0.73939
dat$WatershedTempleton Fork                  -0.026505   0.193995  -0.137  0.89230
dat$FormationCasselman Formation                    NA         NA      NA       NA
dat$FormationGreene Formation                 0.122057   0.105895   1.153  0.25881
dat$FormationMonongahela Group               -0.173322   0.125433  -1.382  0.17796
dat$FormationWaynesburg Formation            -0.034721   0.086178  -0.403  0.69008
dat$HHWSourceSpring                           0.065585   0.075093   0.873  0.38988
dat$Precip_inchDiff                          -0.004086   0.008541  -0.478  0.63609
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.02618642)

    Null deviance: 1.10346  on 47  degrees of freedom
Residual deviance: 0.73322  on 28  degrees of freedom
AIC: -22.494

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Uranium"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-0.199676  -0.018257  -0.001942   0.014268   0.186692

Coefficients: (1 not defined because of singularities)
                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                 0.3598483  0.2965753   1.213  0.23513
dat$GWellDensity_2kmDiff                   -0.0069476  0.0045946  -1.512  0.14171
dat$Altitude_meter                          0.0012952  0.0008024   1.614  0.11770
dat$WatershedBane Creek                    -0.0246663  0.0924182  -0.267  0.79150
dat$WatershedBrush Run                     -0.0313902  0.0537402  -0.584  0.56382
dat$WatershedBurgetts Fork                 -0.0365947  0.0680943  -0.537  0.59523
dat$WatershedLittle Racoon Creek            0.2902777  0.0975709   2.975  0.00597 **
dat$WatershedLittle Tenmile Creek          -0.0018815  0.0697589  -0.027  0.97867
dat$WatershedNorth Fork Cross Creek        -0.0493839  0.0733856  -0.673  0.50650
dat$WatershedPigeon Creek                  -0.0729524  0.0650815  -1.121  0.27184
dat$WatershedPike Run                       0.0217350  0.0798263   0.272  0.78741
dat$WatershedPlum Run-Tenmile Creek         0.0087097  0.0706411   0.123  0.90275
dat$WatershedShort Creek-Tenmile Creek      0.1185045  0.0727392   1.629  0.11448
dat$WatershedSouth Fork Cross Creek-Cross Creek -0.0259332  0.0580035  -0.447  0.65824
dat$WatershedTempleton Fork                 0.0018429  0.0894914   0.021  0.98372
dat$FormationCasselman Formation                   NA         NA      NA       NA
dat$FormationGreene Formation              -0.0326589  0.0488502  -0.669  0.50926
dat$FormationMonongahela Group              0.0903362  0.0578632   1.561  0.12971
dat$FormationWaynesburg Formation           0.0156721  0.0397543   0.394  0.69640
dat$HHWSourceSpring                        -0.0300338  0.0346409  -0.867  0.39331
dat$Precip_inchDiff                         0.0015935  0.0039401   0.404  0.68898
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.005572594)

    Null deviance: 0.27212  on 47  degrees of freedom
Residual deviance: 0.15603  on 28  degrees of freedom
AIC: -96.769

Number of Fisher Scoring iterations: 2
```

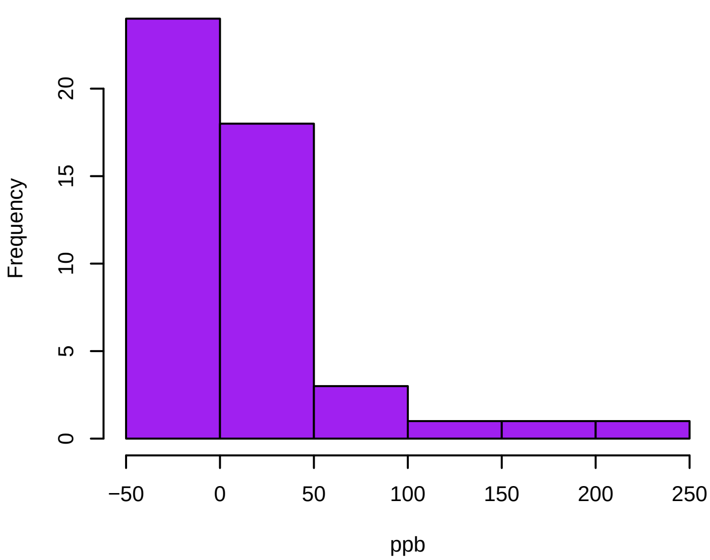
Zinc

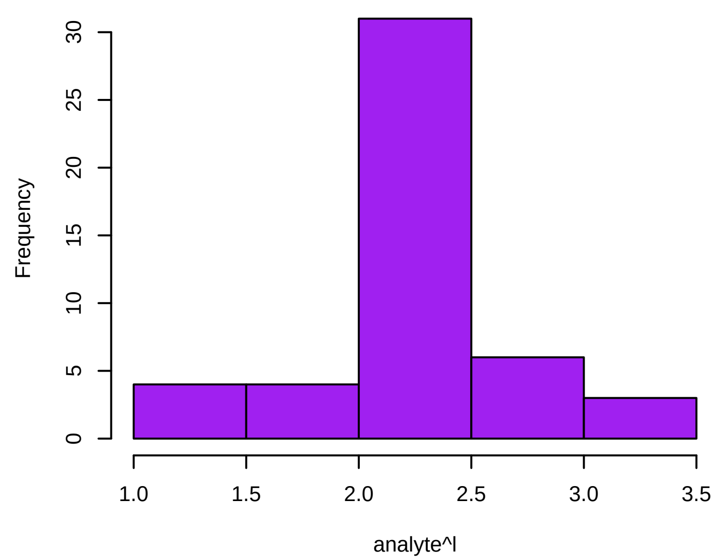
Skewness: 2.4365
Kurtosis: 8.9023

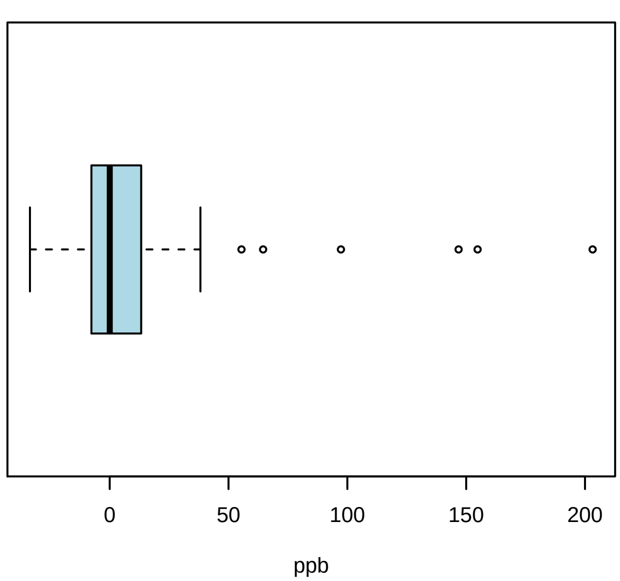
Zinc Box−Cox

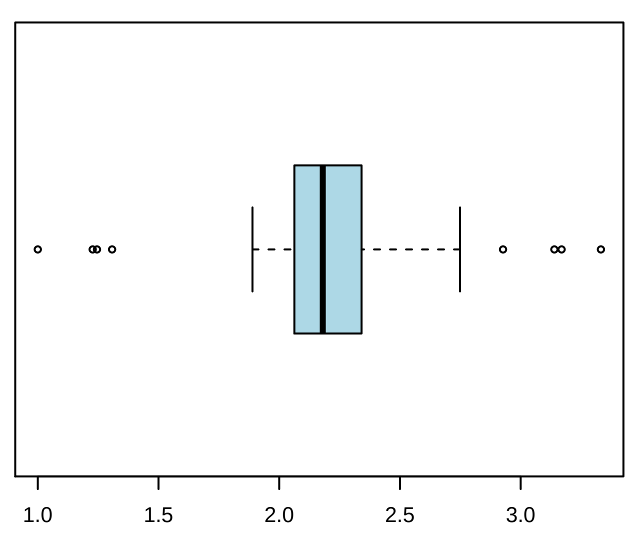
Skewness: −0.1358
Kurtosis: 4.5471

Optimal lambda: 0.22



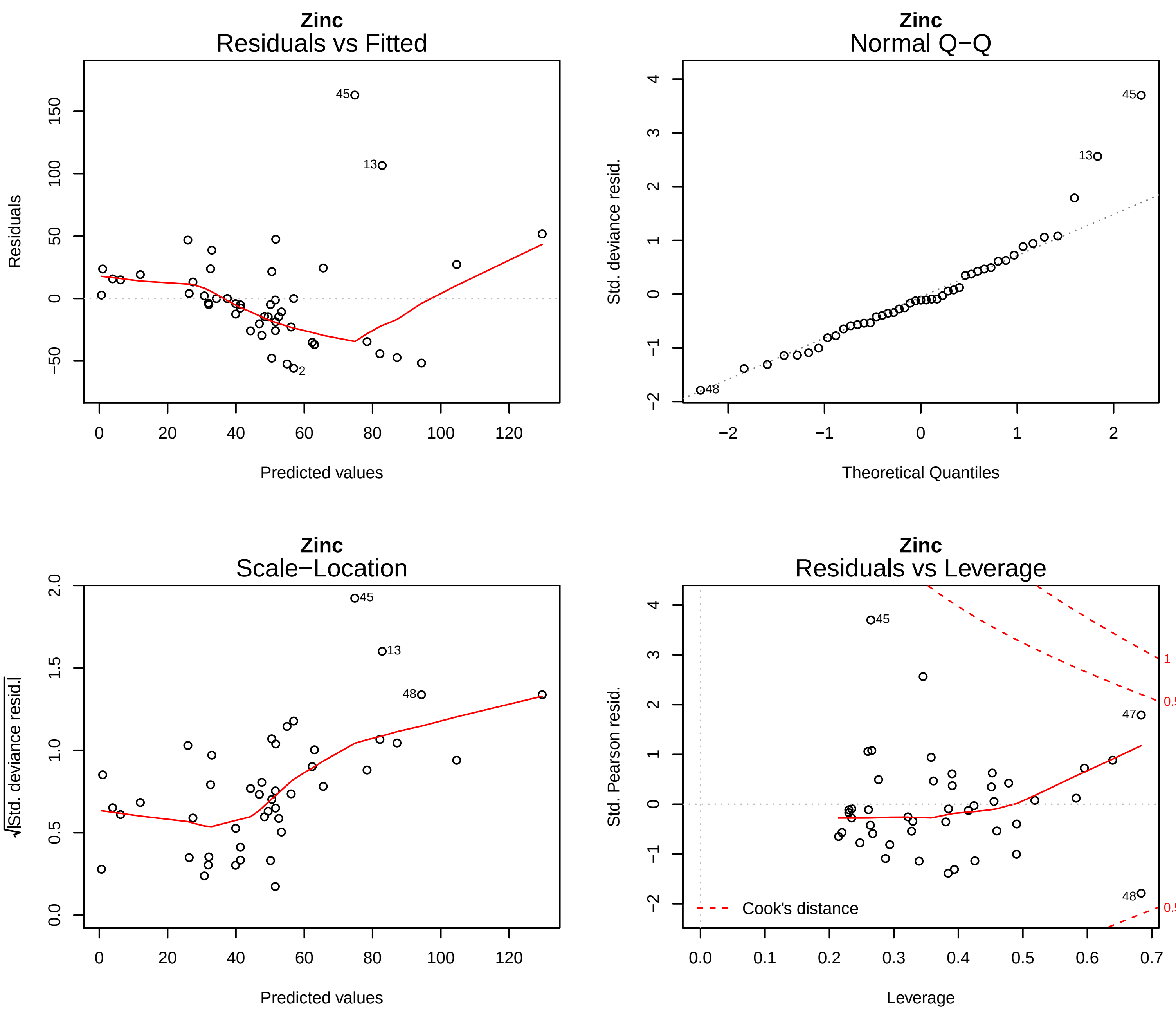






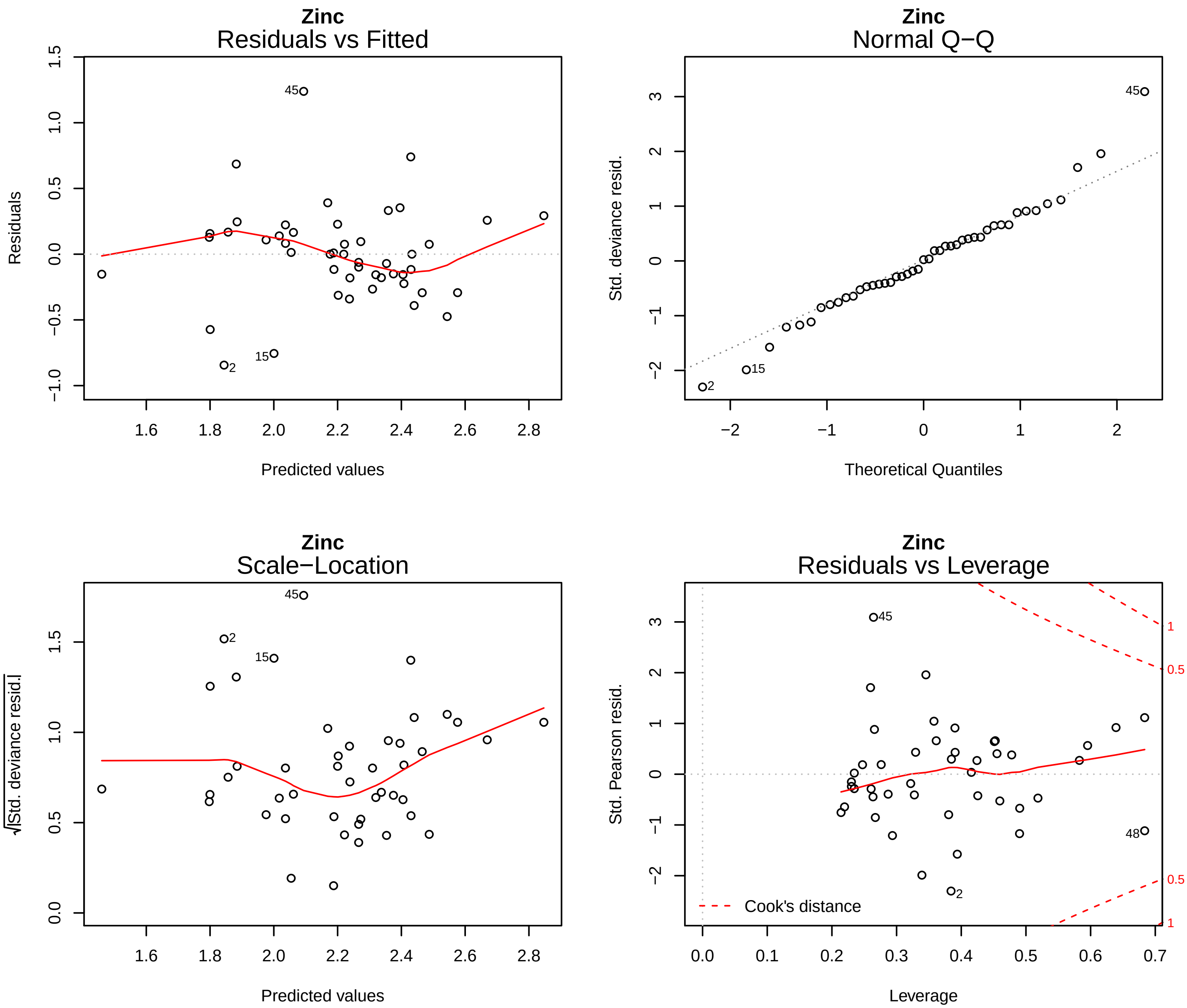
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

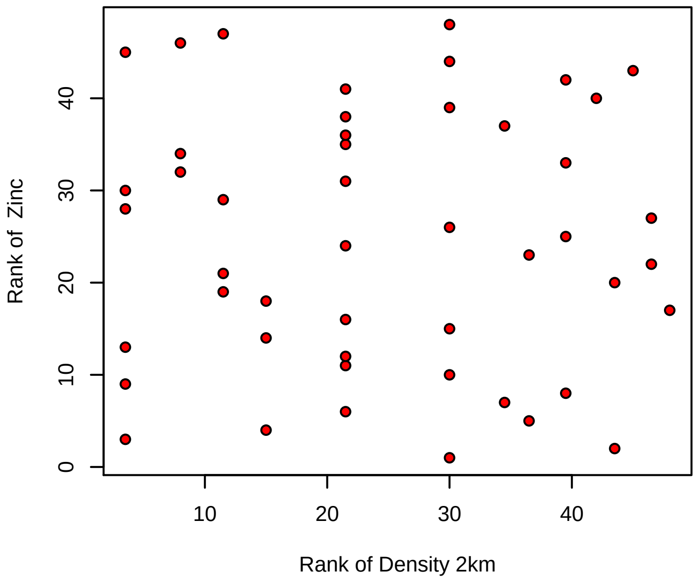
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



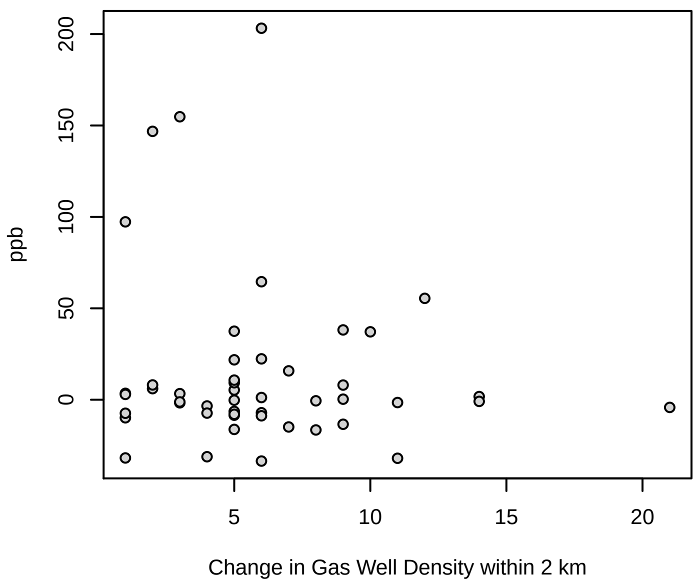


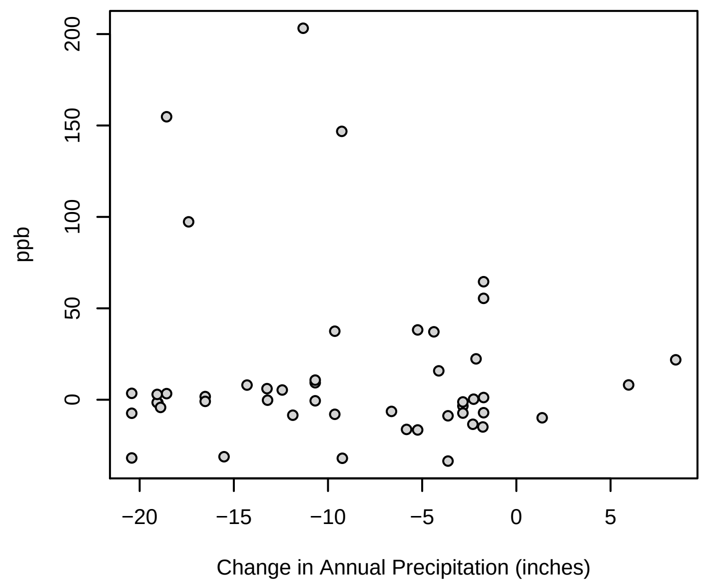
Zinc

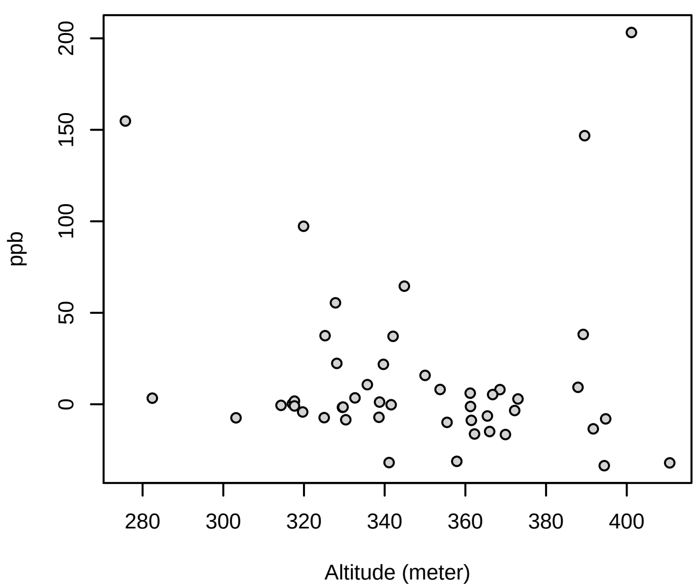
Kendalls Tau Rank Correlation

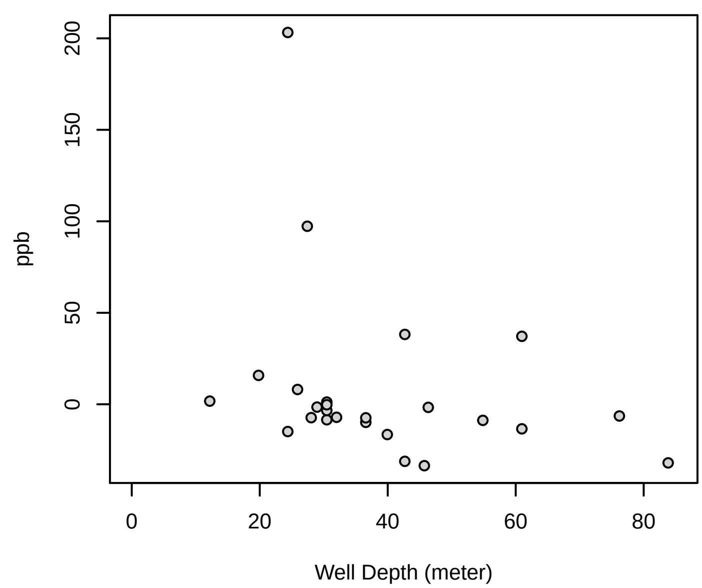
p−value: 0.865

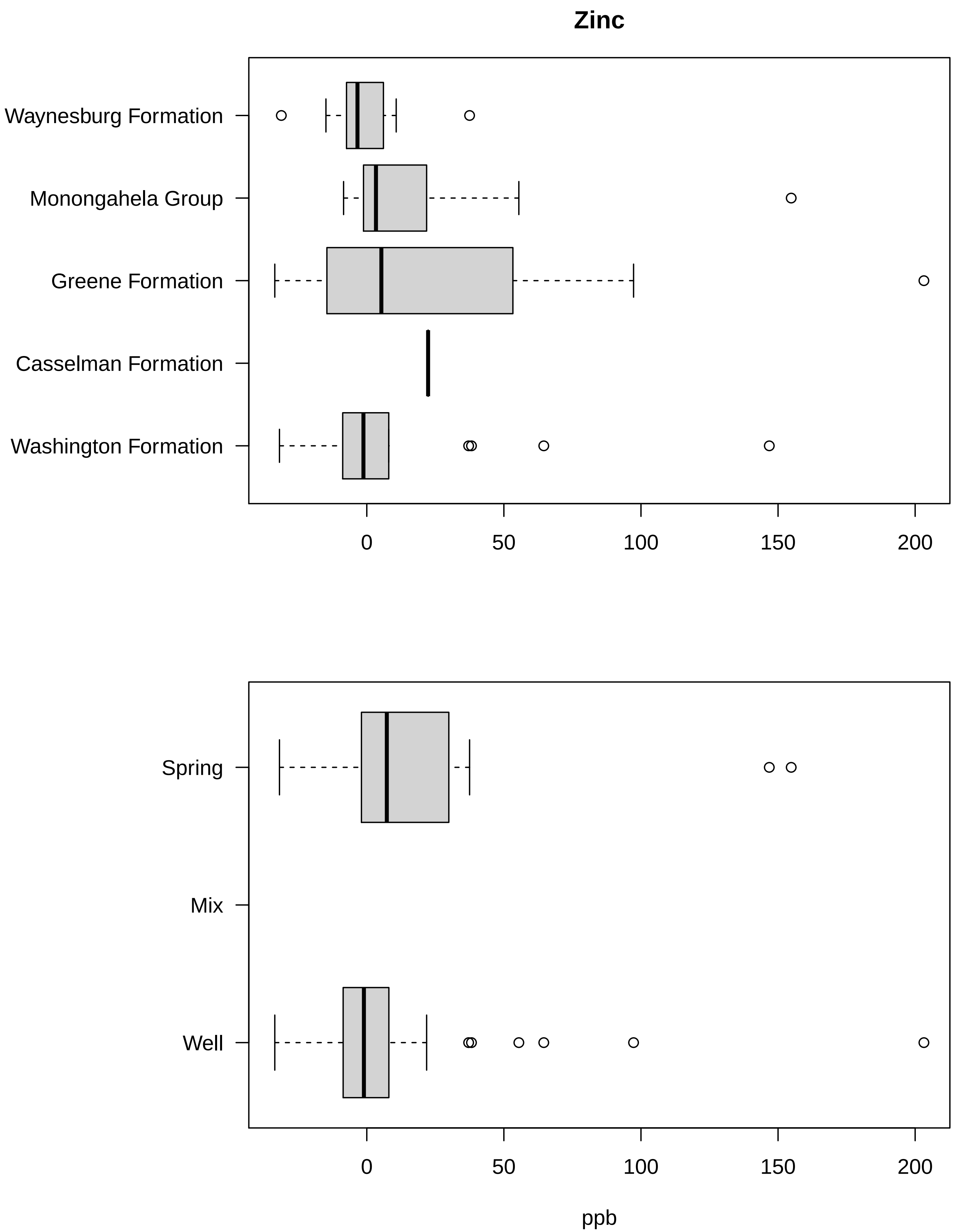
Tau: −0.0177

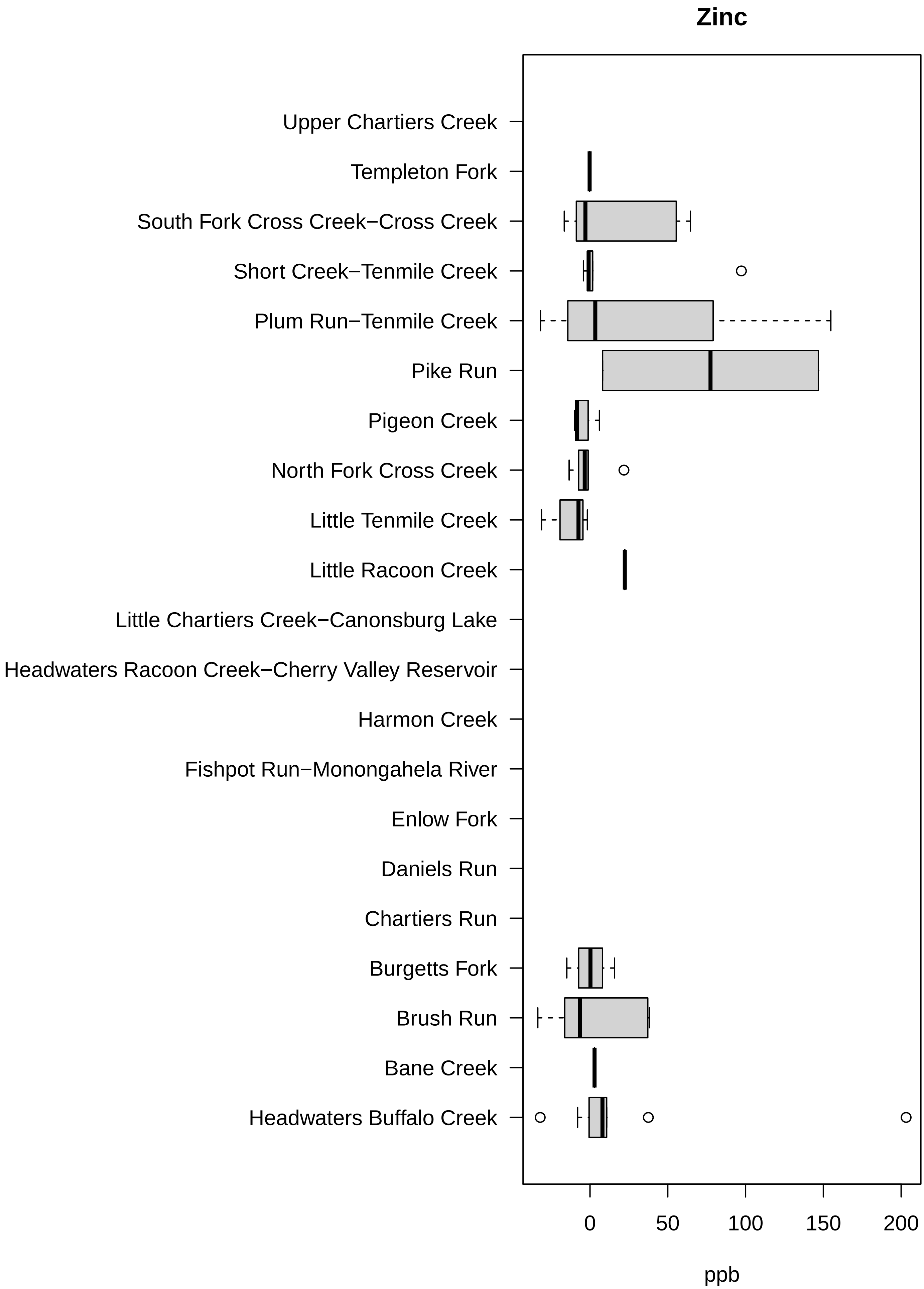









Zinc
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
0
50
100
150
200
Spring
Mix
Well
0
50
100
150
200
ppb



Zinc
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
0
50
100
150
200
ppb

[1] "ORIGINAL MODEL - Zinc"

```
Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-55.916  -23.547   -4.477   16.605  162.950

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                   136.9043   204.0380   0.671    0.508
dat$GWellDensity_2kmDiff                       -2.6411     3.1610  -0.836    0.410
dat$Altitude_meter                             -0.2431     0.5520  -0.440    0.663
dat$WatershedBane Creek                       -73.5280    63.5819  -1.156    0.257
dat$WatershedBrush Run                         -3.5008    36.9722  -0.095    0.925
dat$WatershedBurgetts Fork                    -15.9644    46.8475  -0.341    0.736
dat$WatershedLittle Racoon Creek               12.1344    67.1268   0.181    0.858
dat$WatershedLittle Tenmile Creek             -57.7870    47.9927  -1.204    0.239
dat$WatershedNorth Fork Cross Creek           -16.4920    50.4878  -0.327    0.746
dat$WatershedPigeon Creek                     -30.7201    44.7748  -0.686    0.498
dat$WatershedPike Run                          74.4081    54.9189   1.355    0.186
dat$WatershedPlum Run-Tenmile Creek           -42.4543    48.5997  -0.874    0.390
dat$WatershedShort Creek-Tenmile Creek        -15.8207    50.0431  -0.316    0.754
dat$WatershedSouth Fork Cross Creek-Cross Creek  10.8257    39.9053   0.271    0.788
dat$WatershedTempleton Fork                   -33.8697    61.5683  -0.550    0.587
dat$FormationCasselman Formation                    NA         NA      NA       NA
dat$FormationGreene Formation                  27.6968    33.6080   0.824    0.417
dat$FormationMonongahela Group                 25.5933    39.8087   0.643    0.526
dat$FormationWaynesburg Formation             -13.2609    27.3502  -0.485    0.632
dat$HHWSourceSpring                            -0.9500    23.8323  -0.040    0.968
dat$Precip_inchDiff                            -2.0844     2.7107  -0.769    0.448

(Dispersion parameter for gaussian family taken to be 2637.602)

    Null deviance: 105159  on 47  degrees of freedom
Residual deviance:  73853  on 28  degrees of freedom
AIC: 530.47

Number of Fisher Scoring iterations: 2
```

[1] "BOX-COX MODEL - Zinc"

```
Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-0.8440  -0.1793   0.0000   0.1660   1.2388

Coefficients: (1 not defined because of singularities)
                                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                                   5.094803   1.855937   2.745   0.0104 *
dat$GWellDensity_2kmDiff                     -0.037589   0.028753  -1.307   0.2017
dat$Altitude_meter                           -0.007207   0.005021  -1.435   0.1623
dat$WatershedBane Creek                      -0.402115   0.578343  -0.695   0.4926
dat$WatershedBrush Run                       -0.161927   0.336300  -0.481   0.6339
dat$WatershedBurgetts Fork                   -0.175104   0.426127  -0.411   0.6843
dat$WatershedLittle Racoon Creek             -0.115445   0.610588  -0.189   0.8514
dat$WatershedLittle Tenmile Creek            -0.927033   0.436544  -2.124   0.0427 *
dat$WatershedNorth Fork Cross Creek          -0.174582   0.459239  -0.380   0.7067
dat$WatershedPigeon Creek                    -0.361898   0.407273  -0.889   0.3818
dat$WatershedPike Run                         0.464367   0.499544   0.930   0.3605
dat$WatershedPlum Run-Tenmile Creek          -0.966344   0.442065  -2.186   0.0373 *
dat$WatershedShort Creek-Tenmile Creek       -0.305709   0.455194  -0.672   0.5073
dat$WatershedSouth Fork Cross Creek-Cross Creek -0.018695   0.362980  -0.052   0.9593
dat$WatershedTempleton Fork                  -0.502214   0.560028  -0.897   0.3775
dat$FormationCasselman Formation                    NA         NA      NA       NA
dat$FormationGreene Formation                -0.084902   0.305699  -0.278   0.7833
dat$FormationMonongahela Group                0.065863   0.362102   0.182   0.8570
dat$FormationWaynesburg Formation            -0.252584   0.248779  -1.015   0.3187
dat$HHWSourceSpring                           0.006310   0.216779   0.029   0.9770
dat$Precip_inchDiff                          -0.017714   0.024657  -0.718   0.4785
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.2182298)

    Null deviance: 9.3458  on 47  degrees of freedom
Residual deviance: 6.1104  on 28  degrees of freedom
AIC: 79.28

Number of Fisher Scoring iterations: 2
```

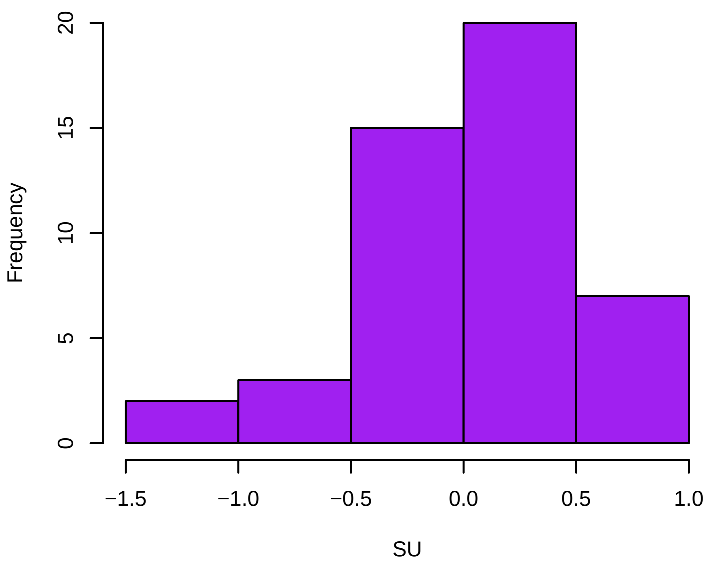
pH

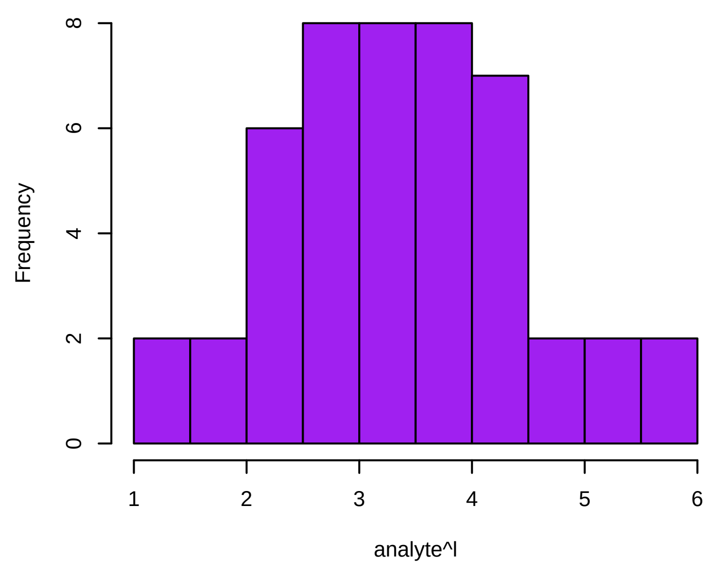
Skewness: −0.2941
Kurtosis: 3.0625

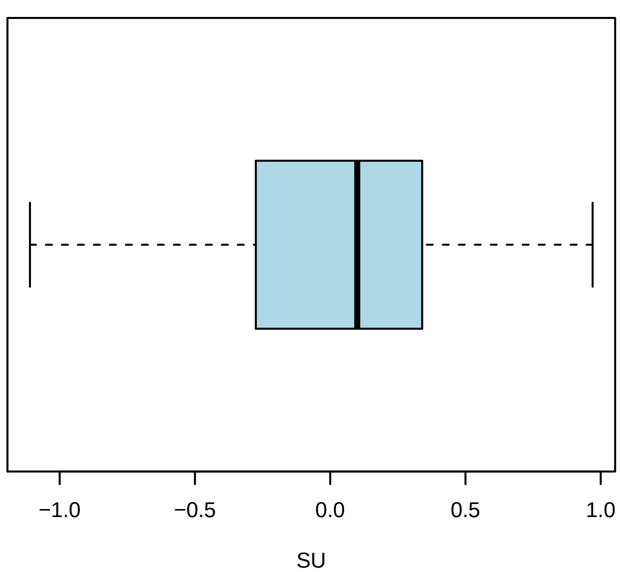
pH Box−Cox

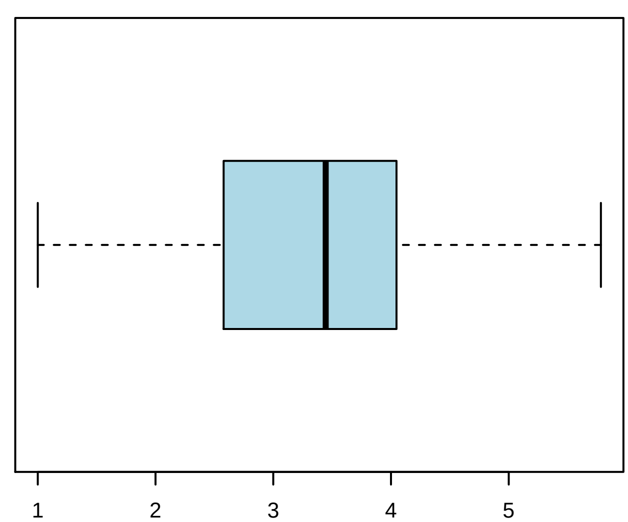
Skewness: 0.0772
Kurtosis: 2.8543

Optimal lambda: 1.56



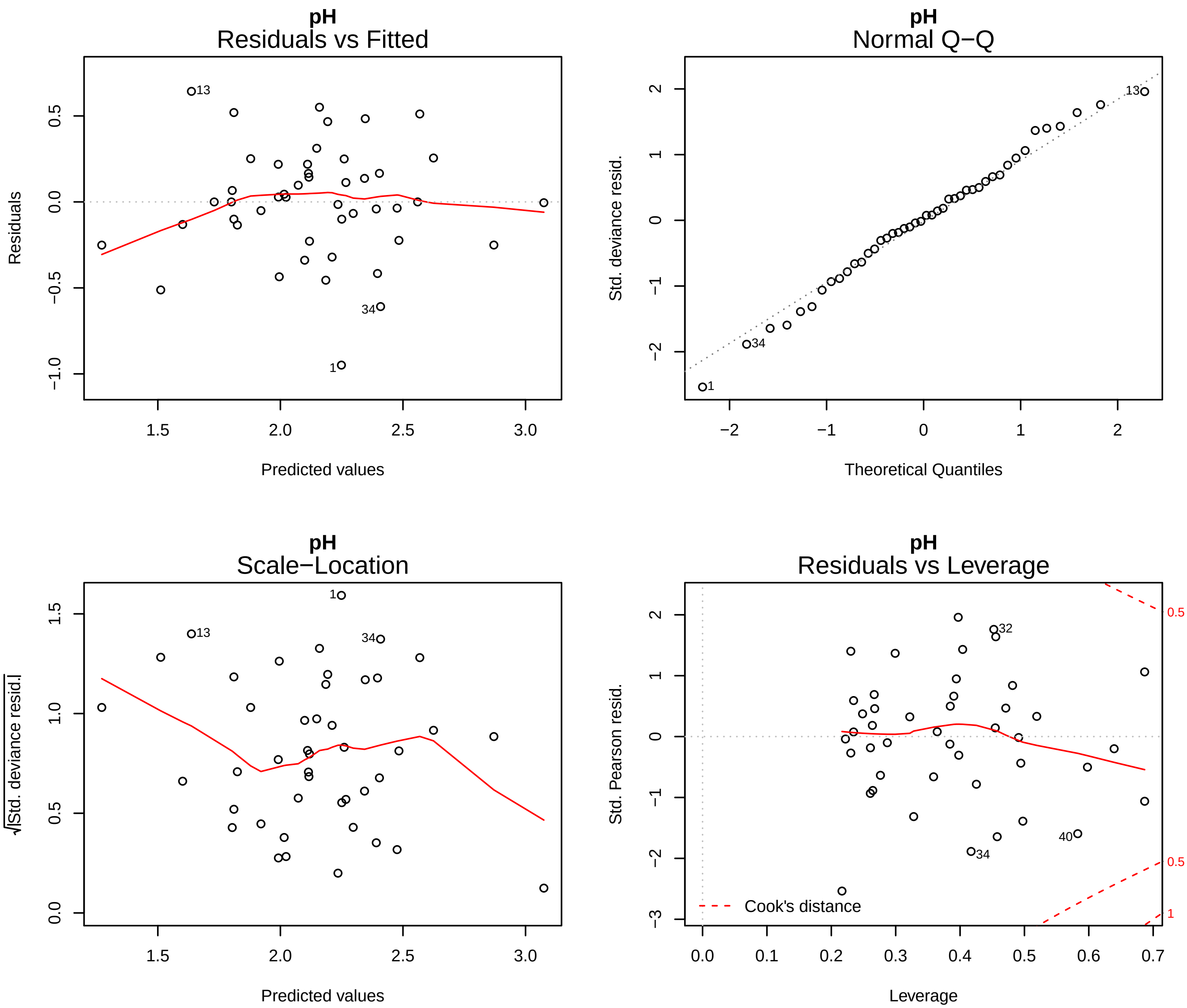






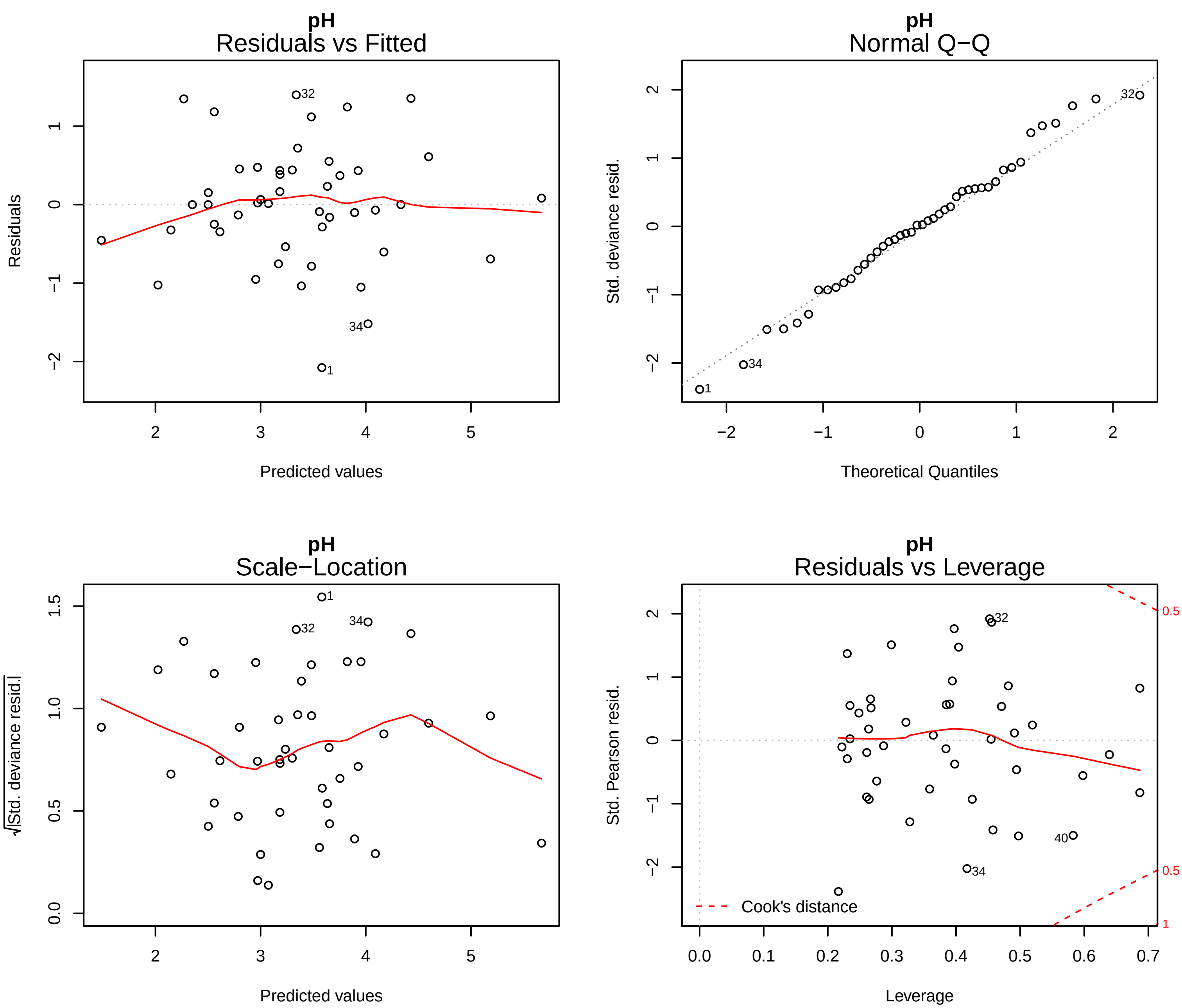
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

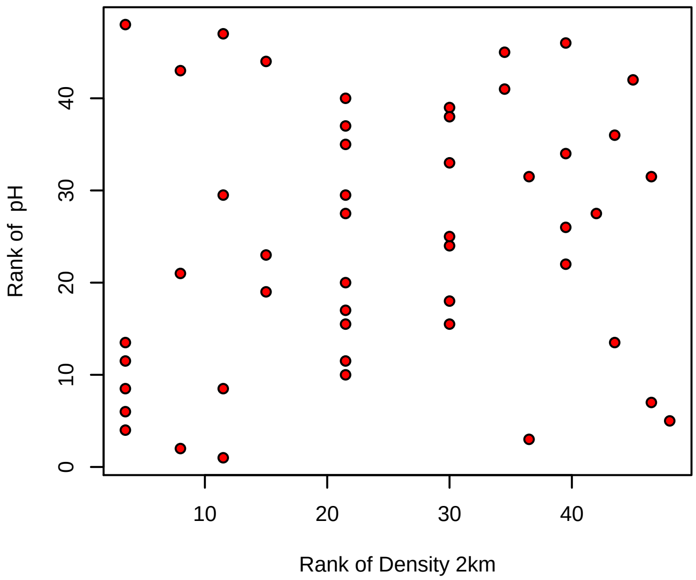
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



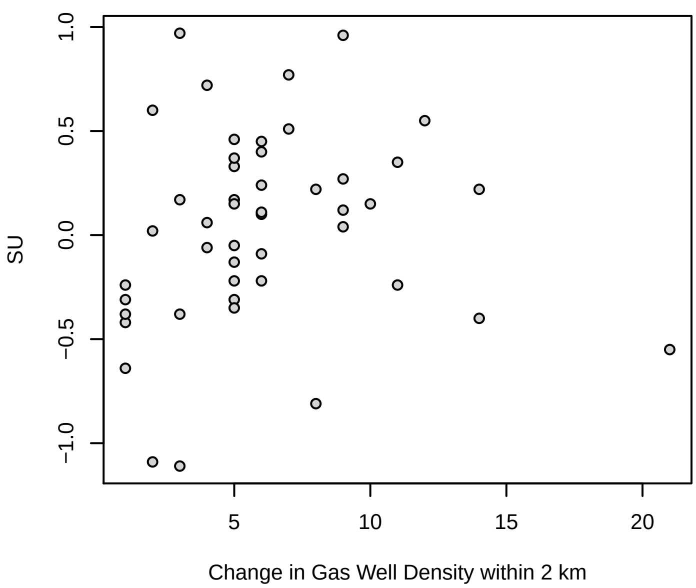


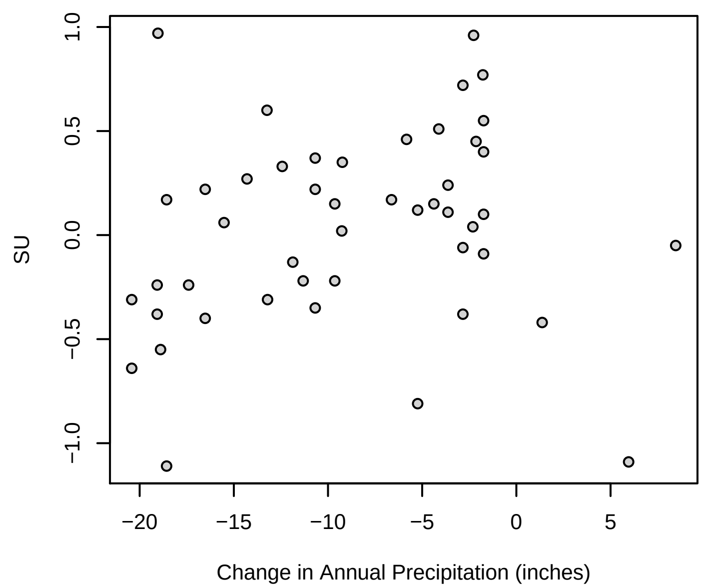
pH

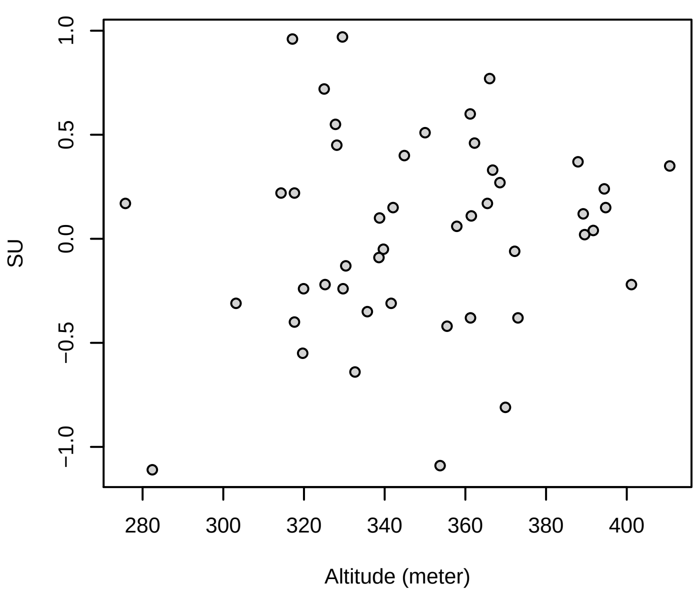
Kendalls Tau Rank Correlation

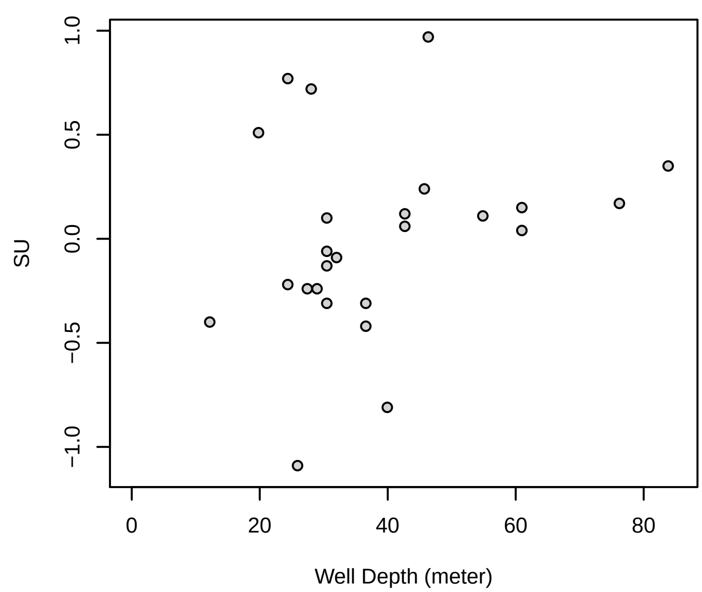
p−value: 0.059

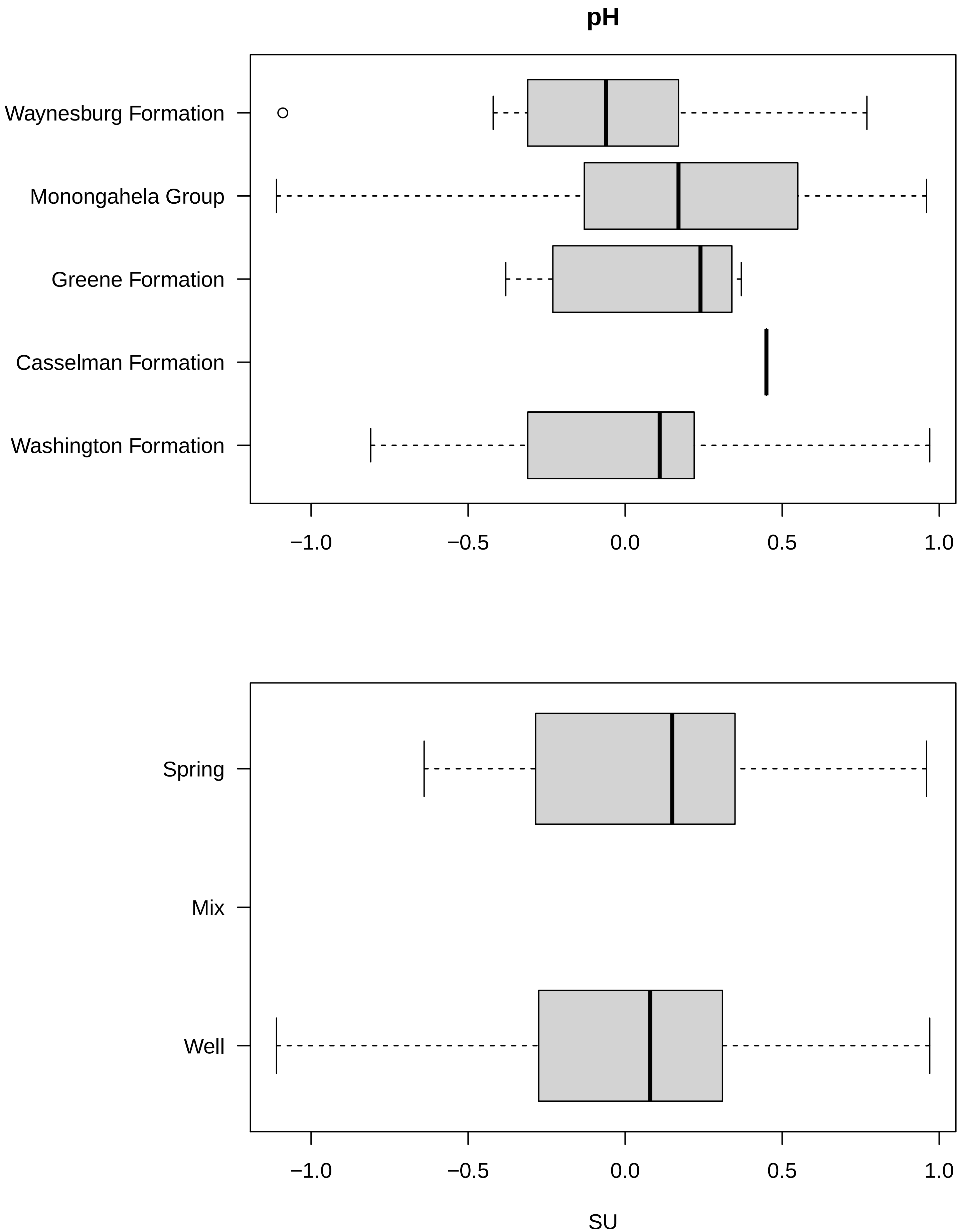
Tau: 0.199

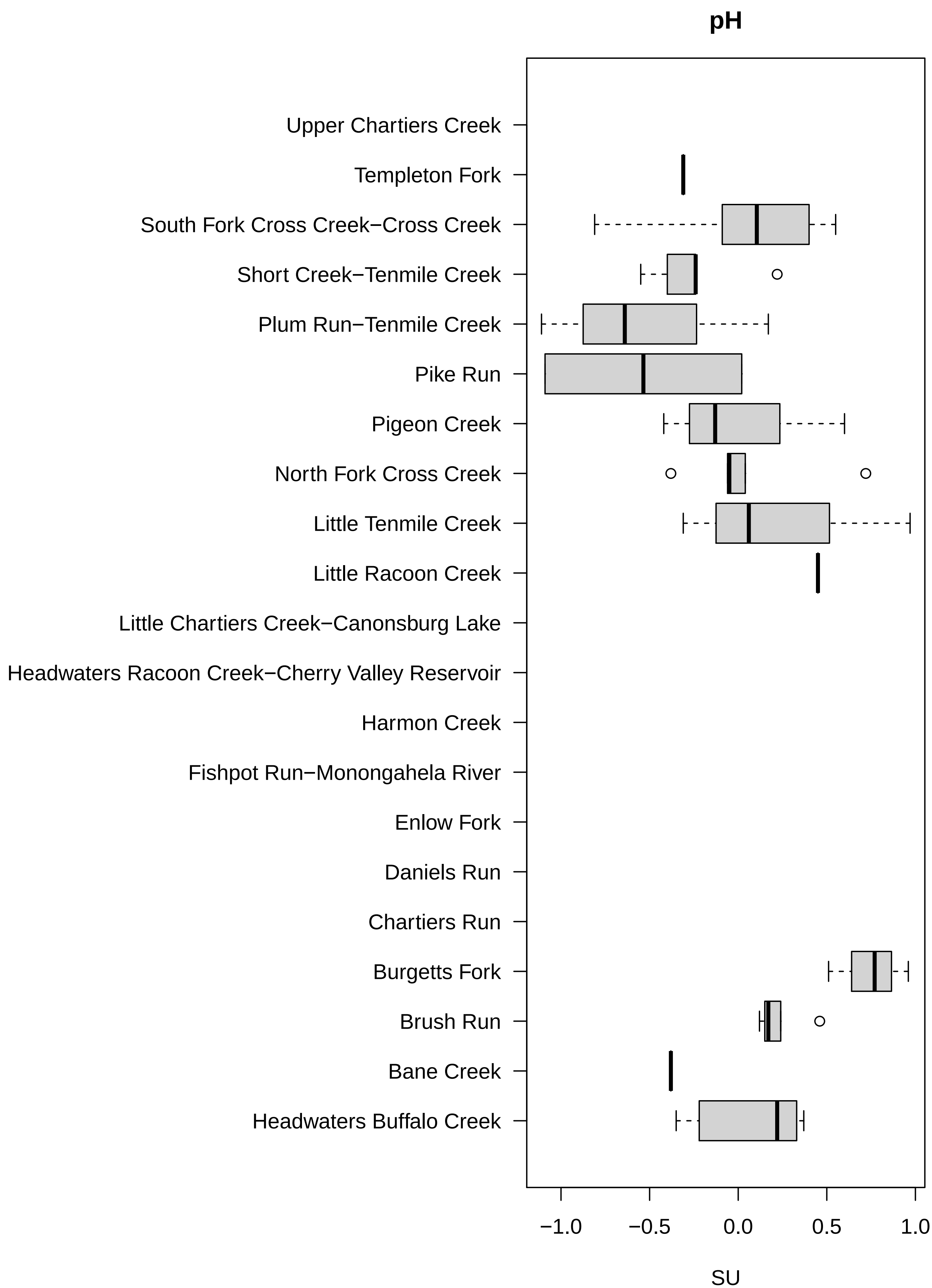









pH
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−1.0
−0.5
0.0
0.5
1.0
Spring
Mix
Well
−1.0
−0.5
0.0
0.5
1.0
SU


pH
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−1.0
−0.5
0.0
0.5
1.0
SU

```
[1] "ORIGINAL MODEL - pH"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-0.9490  -0.1790   0.0000   0.1924   0.6430

Coefficients: (1 not defined because of singularities)
                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                  3.447140   1.689117   2.041   0.0512 .
dat$GWellDensity_2kmDiff                     0.005663   0.026093   0.217   0.8298
dat$Altitude_meter                          -0.004280   0.004577  -0.935   0.3581
dat$WatershedBane Creek                     -0.760587   0.523454  -1.453   0.1577
dat$WatershedBrush Run                       0.337618   0.304285   1.110   0.2770
dat$WatershedBurgetts Fork                   0.956269   0.386872   2.472   0.0200 *
dat$WatershedLittle Racoon Creek             0.334560   0.552545   0.605   0.5499
dat$WatershedLittle Tenmile Creek            0.053847   0.395609   0.136   0.8927
dat$WatershedNorth Fork Cross Creek          0.372589   0.416077   0.895   0.3784
dat$WatershedPigeon Creek                    0.221211   0.369050   0.599   0.5539
dat$WatershedPike Run                       -0.233837   0.452645  -0.517   0.6096
dat$WatershedPlum Run-Tenmile Creek         -1.019337   0.430205  -2.369   0.0252 *
dat$WatershedShort Creek-Tenmile Creek      -0.756889   0.413678  -1.830   0.0784 .
dat$WatershedSouth Fork Cross Creek-Cross Creek  0.212772   0.328879   0.647   0.5231
dat$WatershedTempleton Fork                 -0.533475   0.506811  -1.053   0.3018
dat$FormationCasselman Formation                   NA         NA      NA       NA
dat$FormationGreene Formation                0.172374   0.277786   0.621   0.5401
dat$FormationMonongahela Group              -0.174192   0.330173  -0.528   0.6021
dat$FormationWaynesburg Formation           -0.295199   0.225395  -1.310   0.2013
dat$HHWSourceSpring                          0.096739   0.197614   0.490   0.6284
dat$Precip_inchDiff                         -0.024218   0.022315  -1.085   0.2874
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.1786526)

    Null deviance: 10.1358  on 46  degrees of freedom
Residual deviance:  4.8236  on 27  degrees of freedom
  (1 observation deleted due to missingness)
AIC: 68.379

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - pH"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.0766  -0.4002   0.0000   0.4379   1.3977

Coefficients: (1 not defined because of singularities)
                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                                6.97249    3.92976   1.774   0.0873 .
dat$GWellDensity_2kmDiff                   0.01761    0.06070   0.290   0.7740
dat$Altitude_meter                        -0.01154    0.01065  -1.084   0.2881
dat$WatershedBane Creek                   -1.77980    1.21782  -1.461   0.1554
dat$WatershedBrush Run                     0.73888    0.70792   1.044   0.3059
dat$WatershedBurgetts Fork                 2.38221    0.90006   2.647   0.0134 *
dat$WatershedLittle Racoon Creek           0.75995    1.28550   0.591   0.5593
dat$WatershedLittle Tenmile Creek          0.19879    0.92039   0.216   0.8306
dat$WatershedNorth Fork Cross Creek        0.85265    0.96801   0.881   0.3862
dat$WatershedPigeon Creek                  0.54866    0.85860   0.639   0.5282
dat$WatershedPike Run                     -0.37338    1.05309  -0.355   0.7257
dat$WatershedPlum Run-Tenmile Creek       -2.25453    1.00088  -2.253   0.0326 *
dat$WatershedShort Creek-Tenmile Creek    -1.86894    0.96243  -1.942   0.0627 .
dat$WatershedSouth Fork Cross Creek-Cross Creek  0.46050    0.76514   0.602   0.5523
dat$WatershedTempleton Fork               -1.31642    1.17910  -1.116   0.2741
dat$FormationCasselman Formation                NA         NA      NA       NA
dat$FormationGreene Formation              0.43611    0.64627   0.675   0.5055
dat$FormationMonongahela Group            -0.47124    0.76815  -0.613   0.5447
dat$FormationWaynesburg Formation         -0.75090    0.52439  -1.432   0.1636
dat$HHWSourceSpring                        0.16884    0.45975   0.367   0.7163
dat$Precip_inchDiff                       -0.05296    0.05192  -1.020   0.3167
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.9669868)

    Null deviance: 55.538  on 46  degrees of freedom
Residual deviance: 26.109  on 27  degrees of freedom
  (1 observation deleted due to missingness)
AIC: 147.75

Number of Fisher Scoring iterations: 2
```

Cond at 25C

Skewness: −0.5980

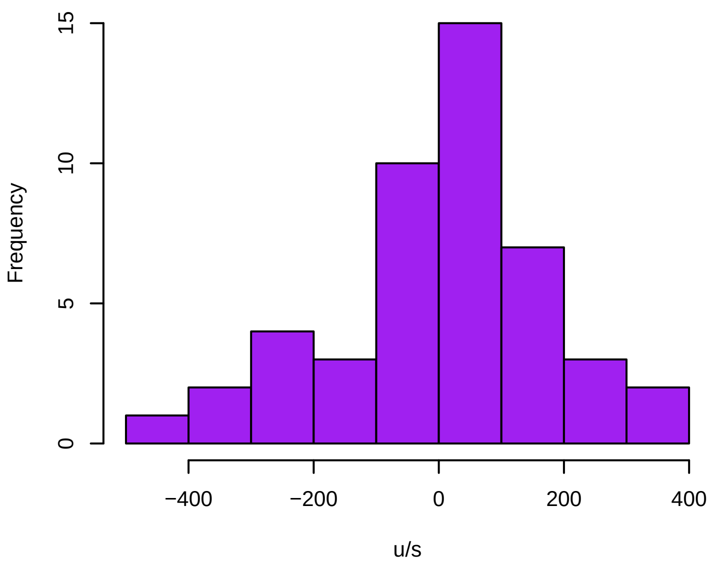
Kurtosis: 3.3727

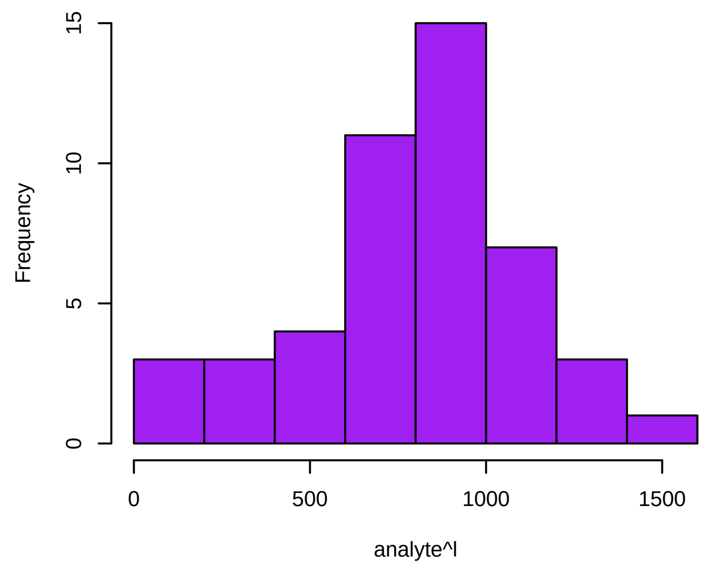
Cond at 25C Box−Cox

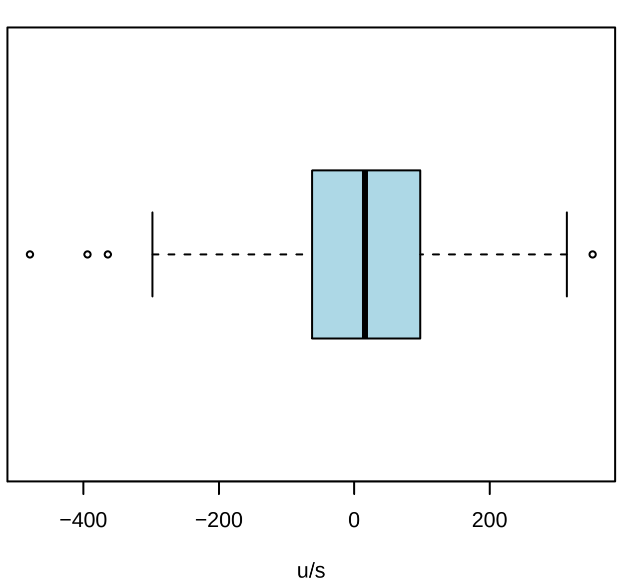
Skewness: −0.4767

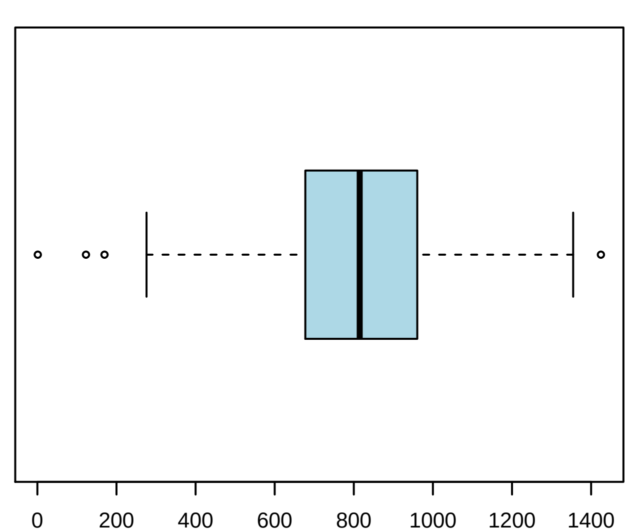
Kurtosis: 3.2022

Optimal lambda: 1.08



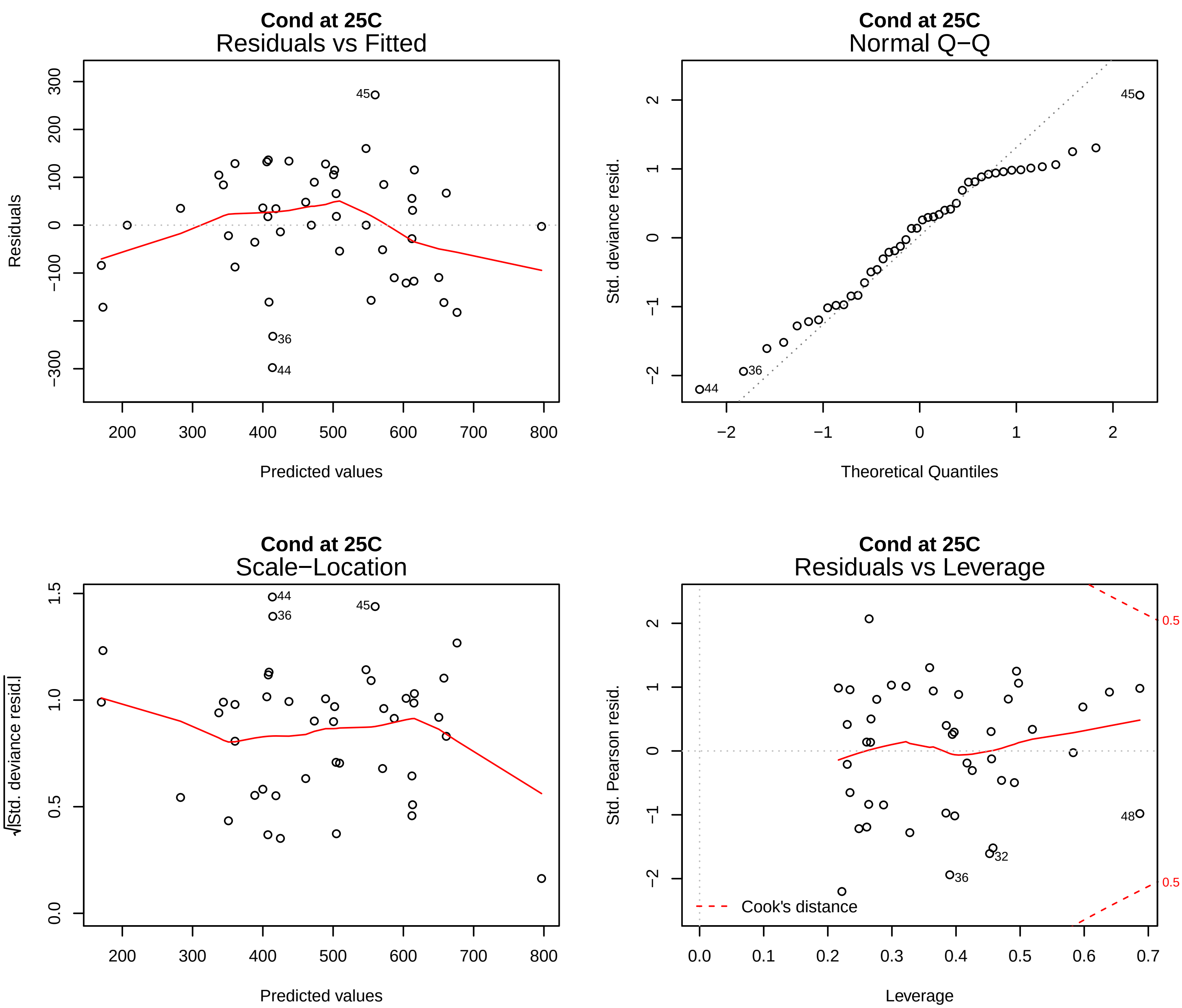






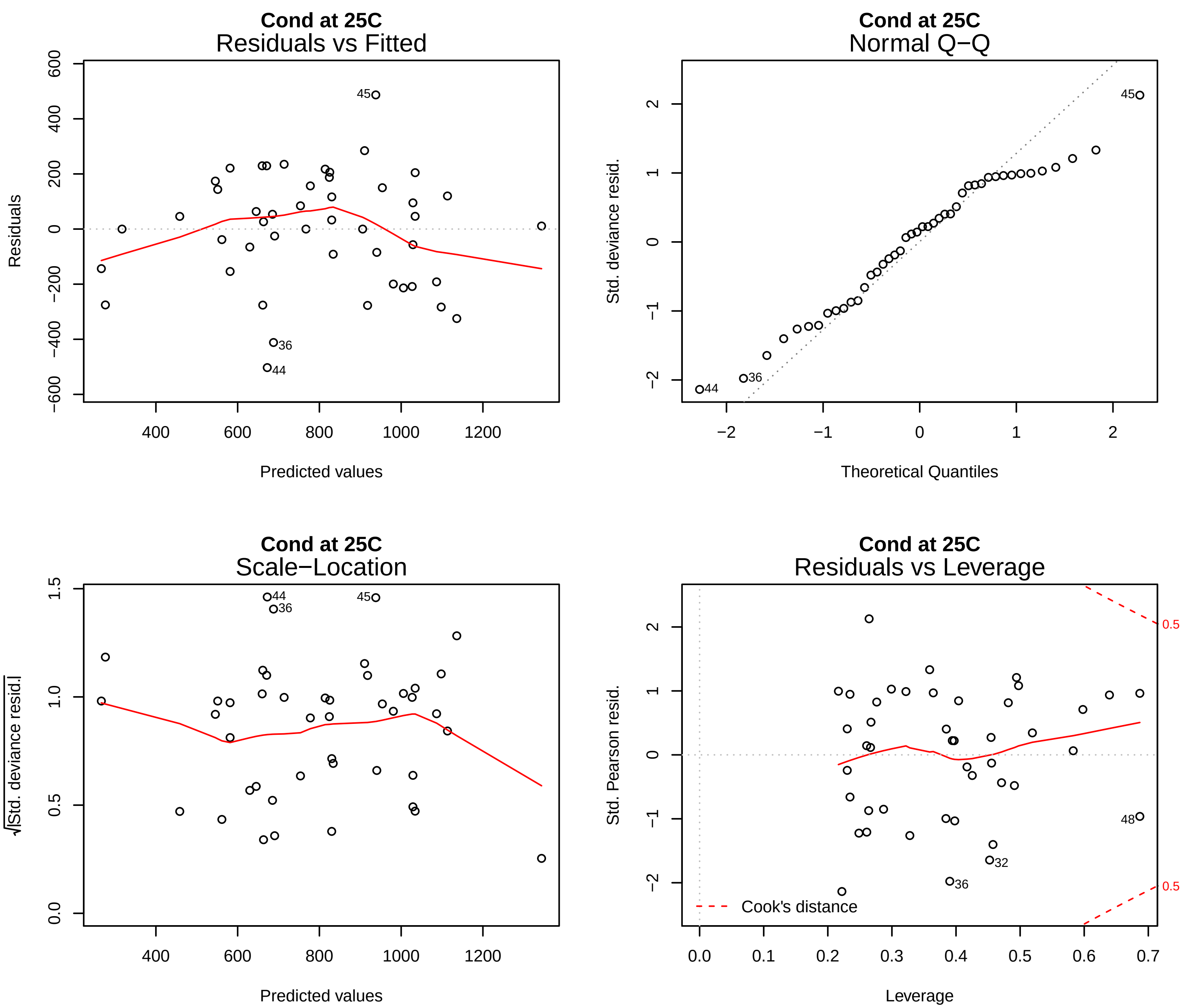
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model

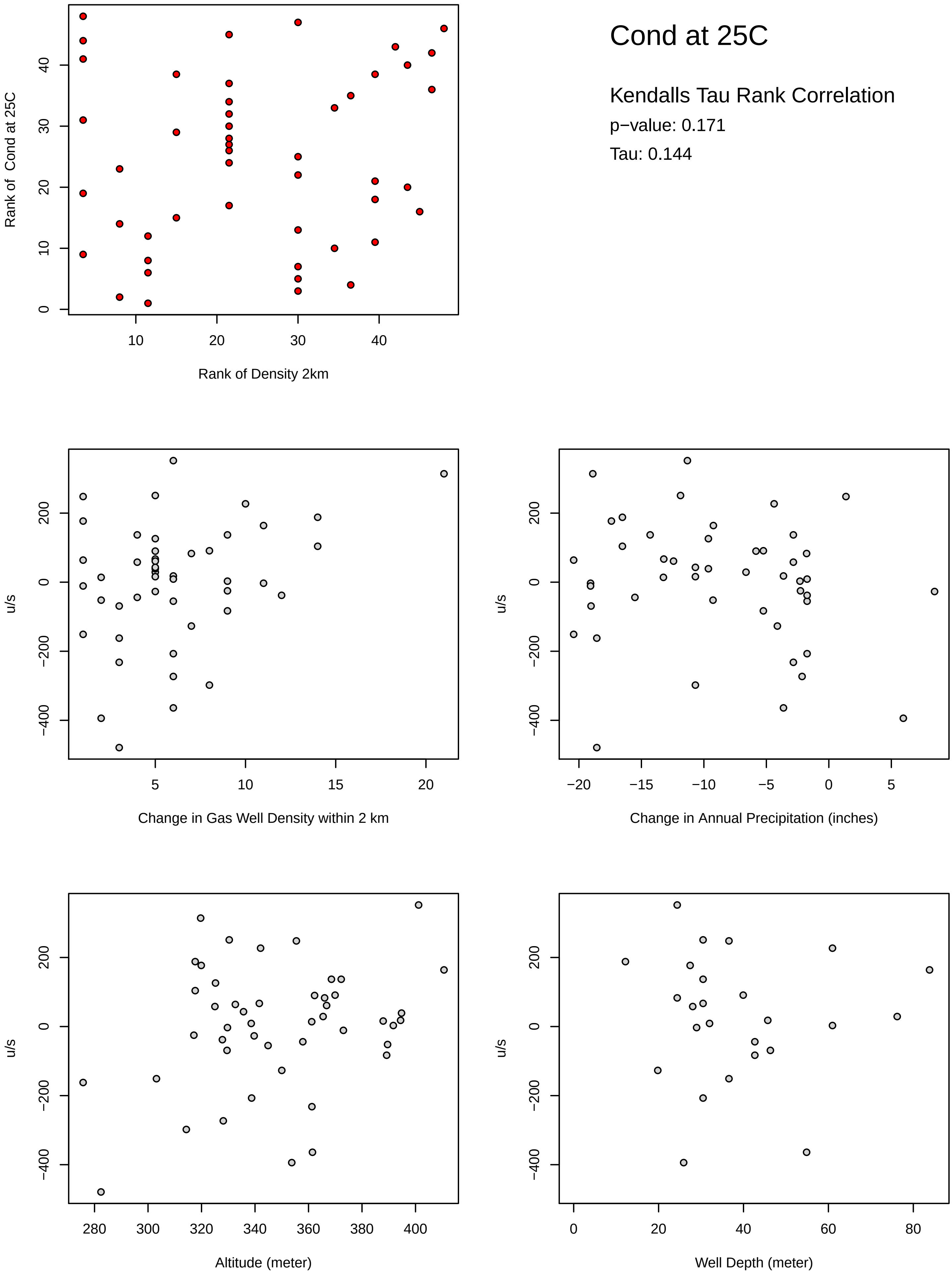


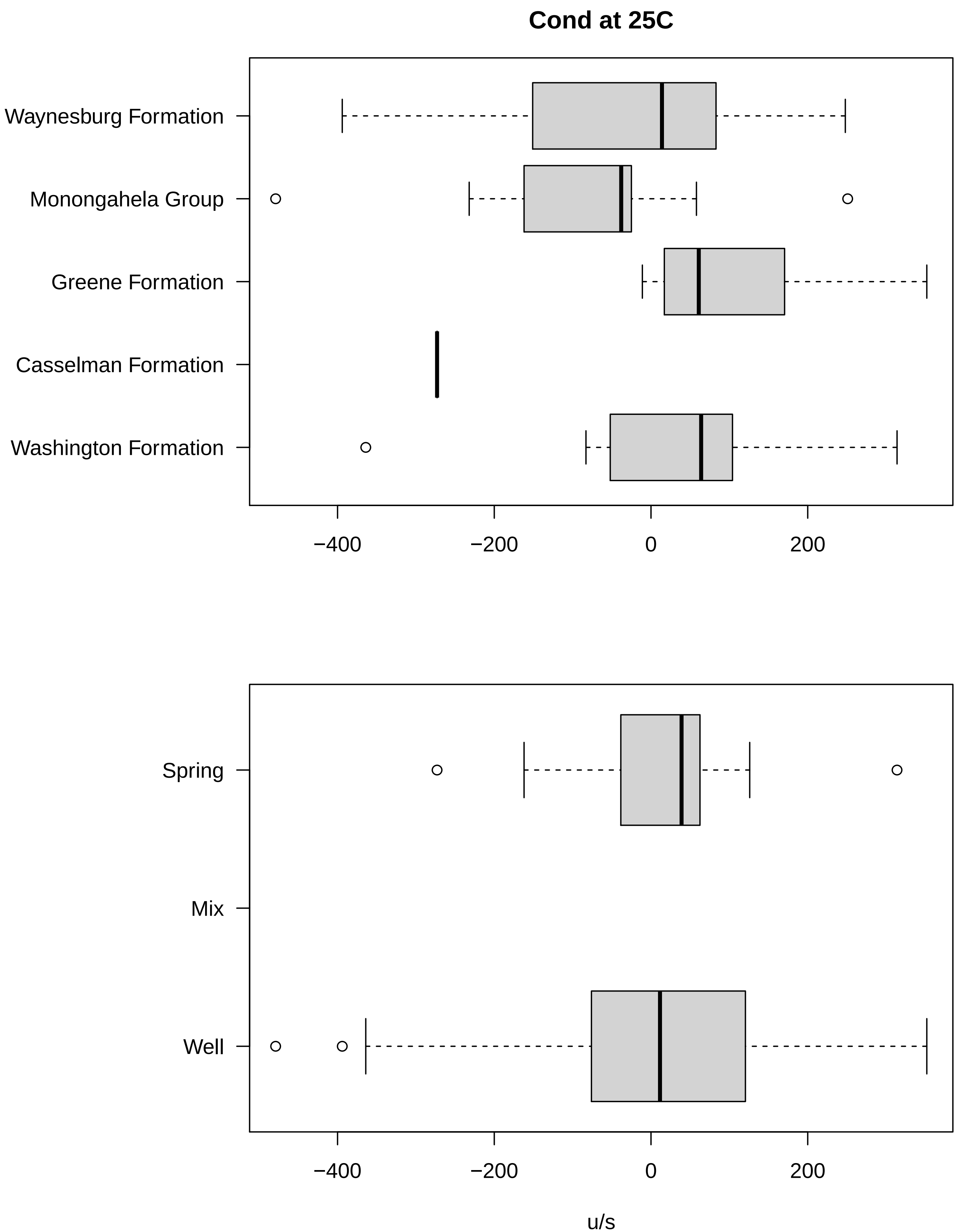
Cond at 25C

Kendalls Tau Rank Correlation

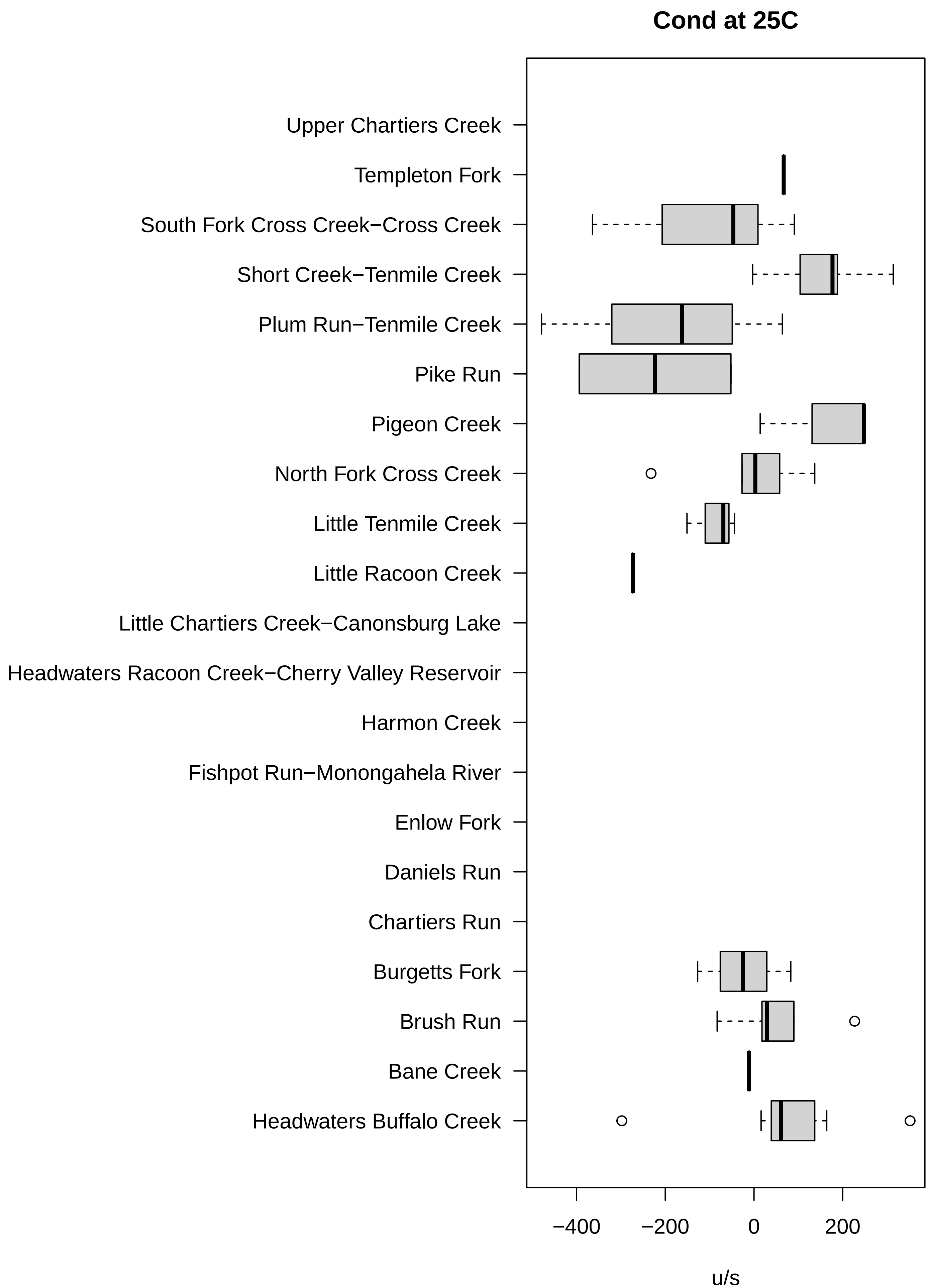
p−value: 0.171

Tau: 0.144





Cond at 25C
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−400
−200
0
200
Spring
Mix
Well
−400
−200
0
200
u/s


Cond at 25C
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−400
−200
0
200
u/s

```
[1] "ORIGINAL MODEL - Cond at 25C"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-297.61   -85.76    17.82    87.35   272.18

Coefficients: (1 not defined because of singularities)
                                               Estimate Std. Error t value Pr(>|t|)
(Intercept)                                    261.9650   612.4996   0.428   0.6723
dat$GWellDensity_2kmDiff                        10.0503     9.4616   1.062   0.2975
dat$Altitude_meter                               0.3628     1.6596   0.219   0.8286
dat$WatershedBane Creek                        -32.0463   189.8123  -0.169   0.8672
dat$WatershedBrush Run                          59.2789   110.3384   0.537   0.5955
dat$WatershedBurgetts Fork                      52.2900   140.2857   0.373   0.7123
dat$WatershedLittle Racoon Creek              -347.6424   200.3610  -1.735   0.0941 .
dat$WatershedLittle Tenmile Creek                9.1641   143.4537   0.064   0.9495
dat$WatershedNorth Fork Cross Creek            108.8681   150.8757   0.722   0.4768
dat$WatershedPigeon Creek                      304.9066   133.8233   2.278   0.0308 *
dat$WatershedPike Run                         -194.4145   164.1360  -1.184   0.2465
dat$WatershedPlum Run-Tenmile Creek           -102.2712   155.9989  -0.656   0.5176
dat$WatershedShort Creek-Tenmile Creek          90.6696   150.0058   0.604   0.5506
dat$WatershedSouth Fork Cross Creek-Cross Creek  -40.5933   119.2565  -0.340   0.7362
dat$WatershedTempleton Fork                    107.9758   183.7774   0.588   0.5617
dat$FormationCasselman Formation                     NA         NA      NA       NA
dat$FormationGreene Formation                   89.5453   100.7293   0.889   0.3819
dat$FormationMonongahela Group                -123.9233   119.7256  -1.035   0.3098
dat$FormationWaynesburg Formation              -44.5595    81.7318  -0.545   0.5901
dat$HHWSourceSpring                            112.8607    71.6580   1.575   0.1269
dat$Precip_inchDiff                             -0.2172     8.0918  -0.027   0.9788
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 23490.98)

    Null deviance: 1464941  on 46  degrees of freedom
Residual deviance:  634256  on 27  degrees of freedom
  (1 observation deleted due to missingness)
AIC: 622.35

Number of Fisher Scoring iterations: 2
```

```
[1] "BOX-COX MODEL - Cond at 25C"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-502.77  -148.80    26.42   153.30   486.82

Coefficients: (1 not defined because of singularities)
                                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                                448.83334 1066.01867   0.421   0.6771
dat$GWellDensity_2kmDiff                    18.25587   16.46733   1.109   0.2774
dat$Altitude_meter                           0.54171    2.88849   0.188   0.8526
dat$WatershedBane Creek                    -64.99103  330.35685  -0.197   0.8455
dat$WatershedBrush Run                      93.39762  192.03731   0.486   0.6306
dat$WatershedBurgetts Fork                  81.20065  244.15878   0.333   0.7420
dat$WatershedLittle Racoon Creek          -604.71270  348.71628  -1.734   0.0943 .
dat$WatershedLittle Tenmile Creek            6.64096  249.67249   0.027   0.9790
dat$WatershedNorth Fork Cross Creek        180.00070  262.59011   0.685   0.4989
dat$WatershedPigeon Creek                  532.24386  232.91139   2.285   0.0304 *
dat$WatershedPike Run                     -331.48826  285.66888  -1.160   0.2560
dat$WatershedPlum Run-Tenmile Creek       -163.76990  271.50669  -0.603   0.5514
dat$WatershedShort Creek-Tenmile Creek     150.82613  261.07607   0.578   0.5682
dat$WatershedSouth Fork Cross Creek-Cross Creek  -82.06915  207.55879  -0.395   0.6957
dat$WatershedTempleton Fork                179.40949  319.85356   0.561   0.5795
dat$FormationCasselman Formation                  NA         NA      NA       NA
dat$FormationGreene Formation              161.19383  175.31329   0.919   0.3660
dat$FormationMonongahela Group            -218.12639  208.37528  -1.047   0.3045
dat$FormationWaynesburg Formation          -78.42436  142.24930  -0.551   0.5860
dat$HHWSourceSpring                        185.53508  124.71643   1.488   0.1484
dat$Precip_inchDiff                         -0.09217   14.08326  -0.007   0.9948
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 71157.25)

    Null deviance: 4421261  on 46  degrees of freedom
Residual deviance: 1921246  on 27  degrees of freedom
  (1 observation deleted due to missingness)
AIC: 674.44

Number of Fisher Scoring iterations: 2
```

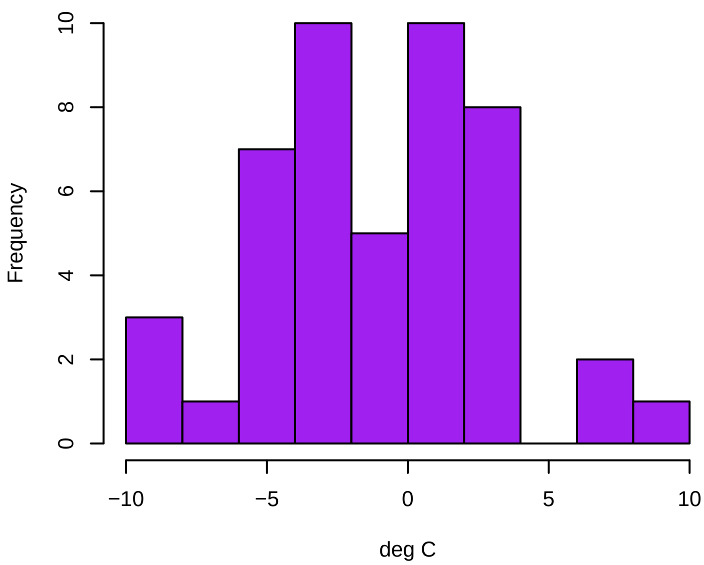
Temperature

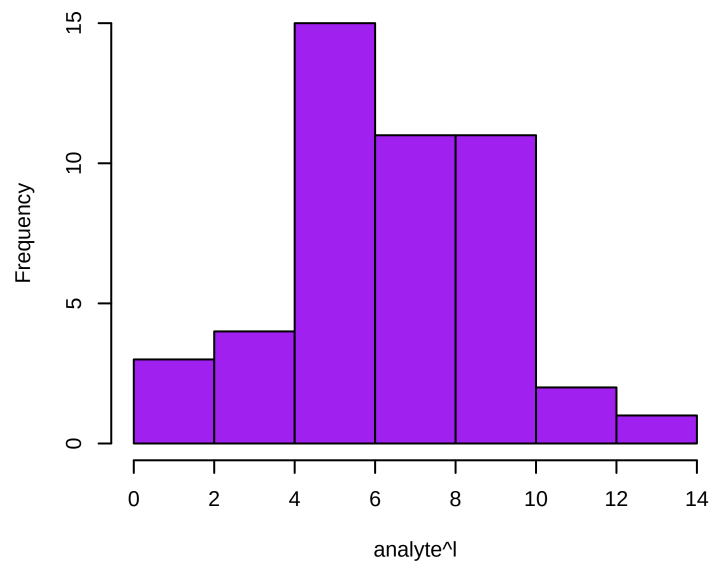
Skewness: 0.2026
Kurtosis: 3.0346

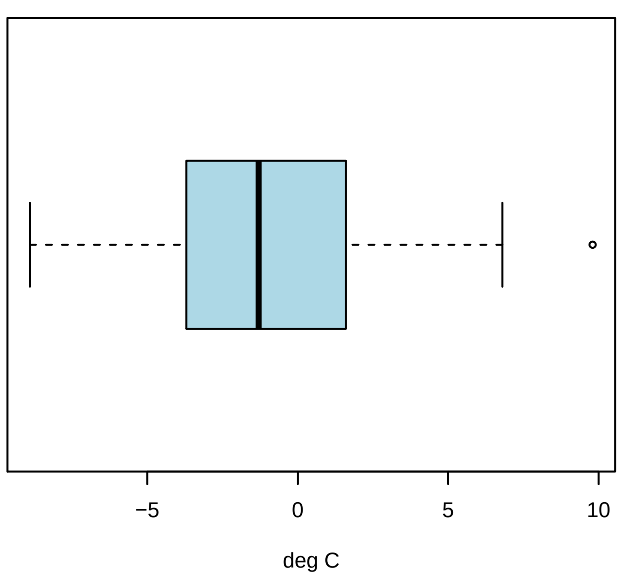
Temperature Box−Cox

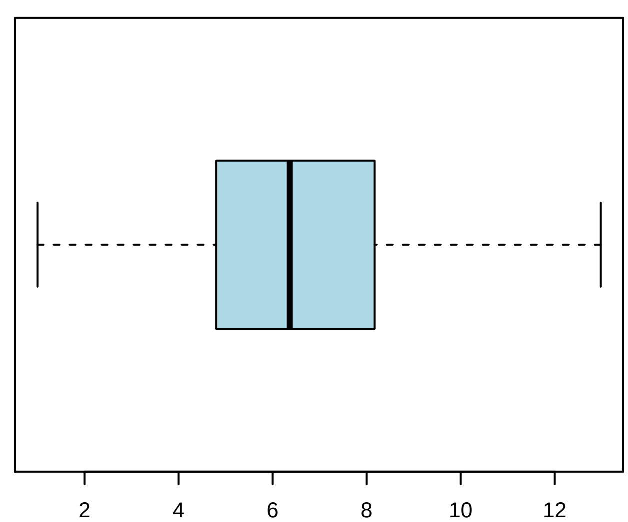
Skewness: −0.0075
Kurtosis: 2.9863

Optimal lambda: 0.86



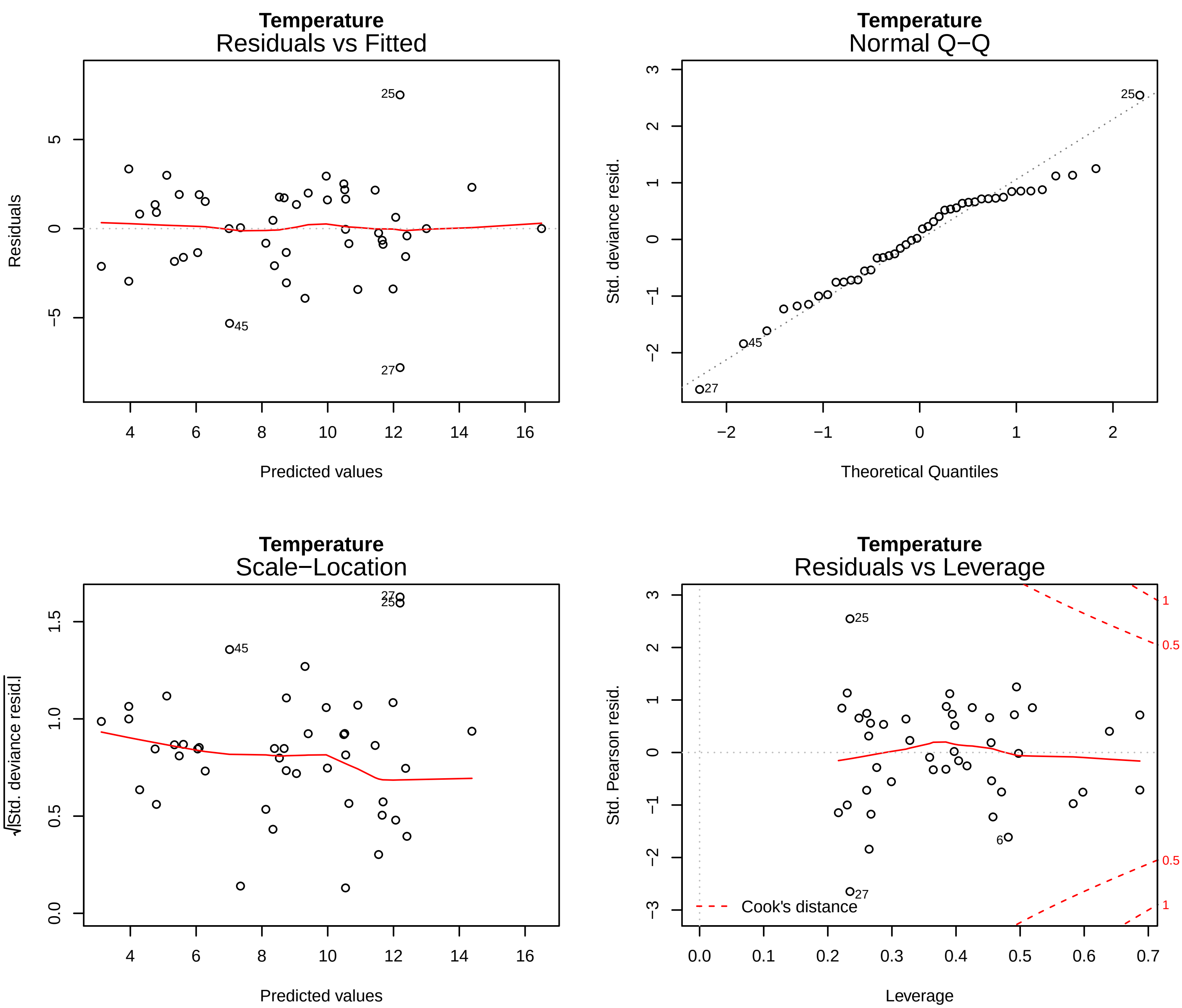






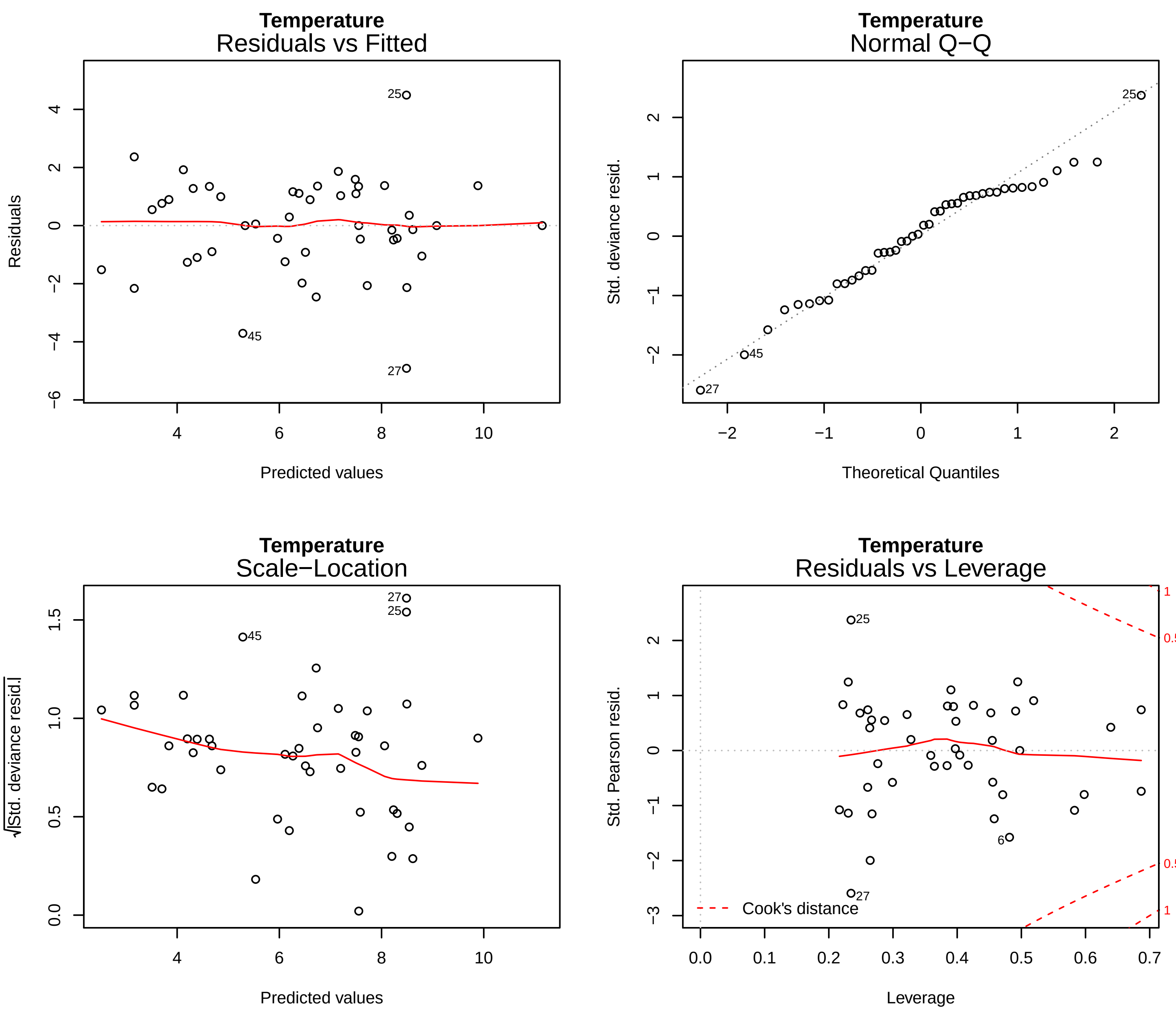
glm(analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watershed ...

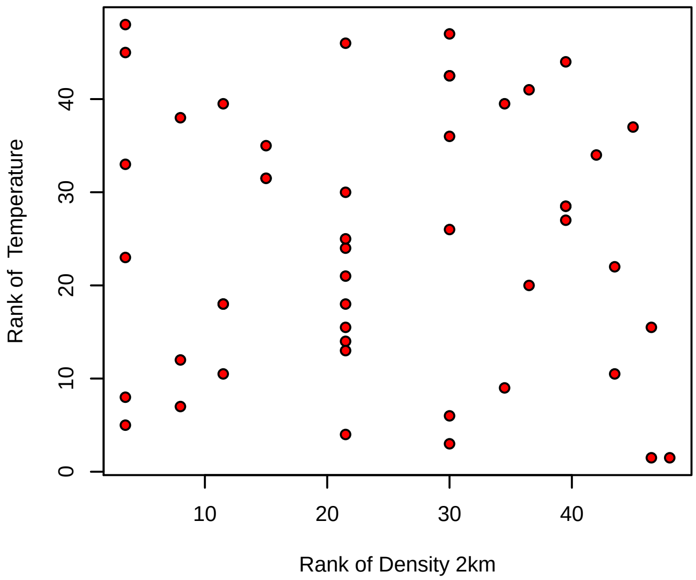
Original Model



glm(analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + dat$Watersh ...

Box−Cox Model



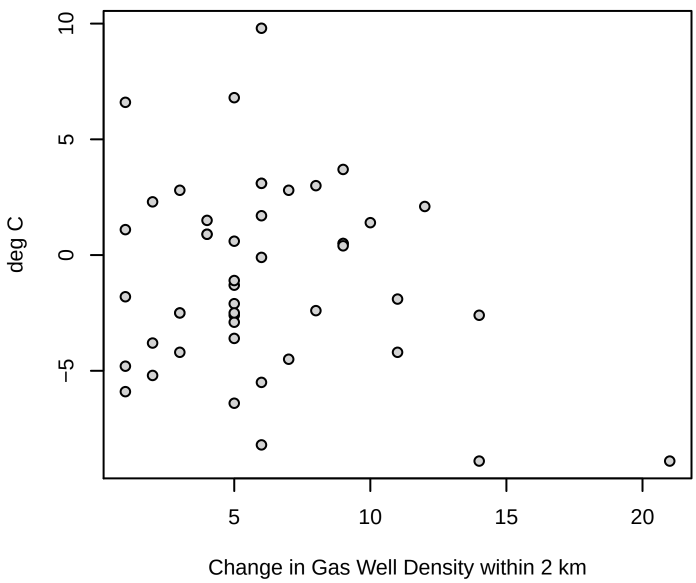


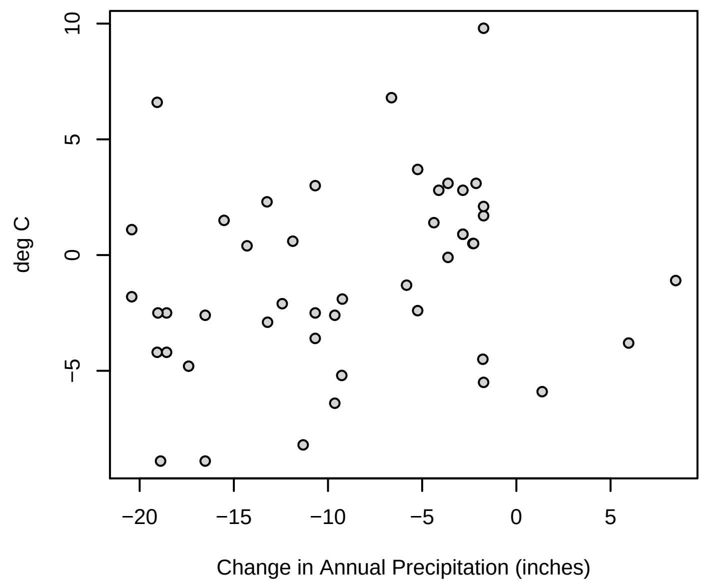
Temperature

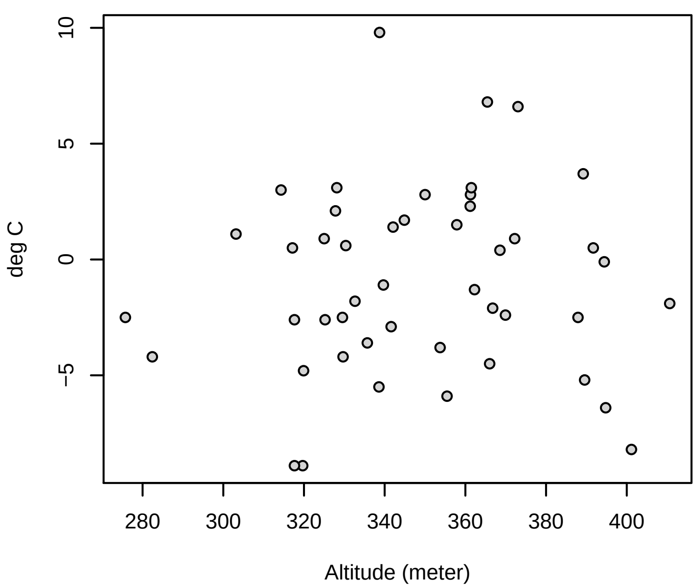
Kendalls Tau Rank Correlation

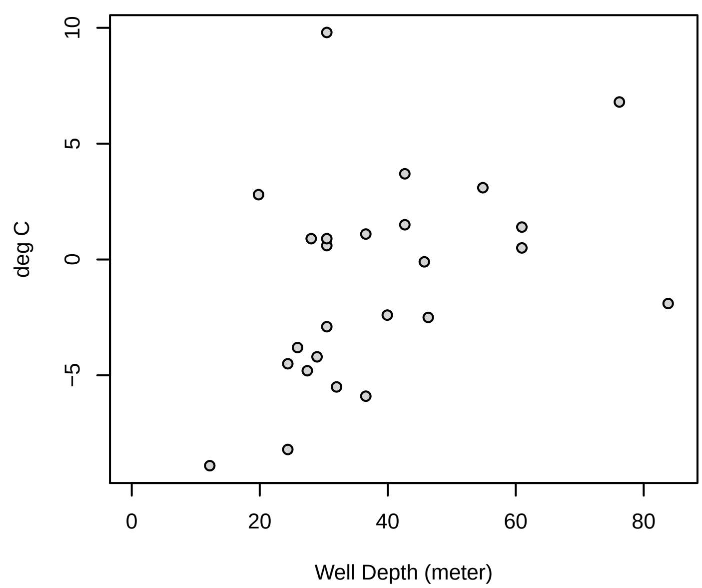
p−value: 0.904

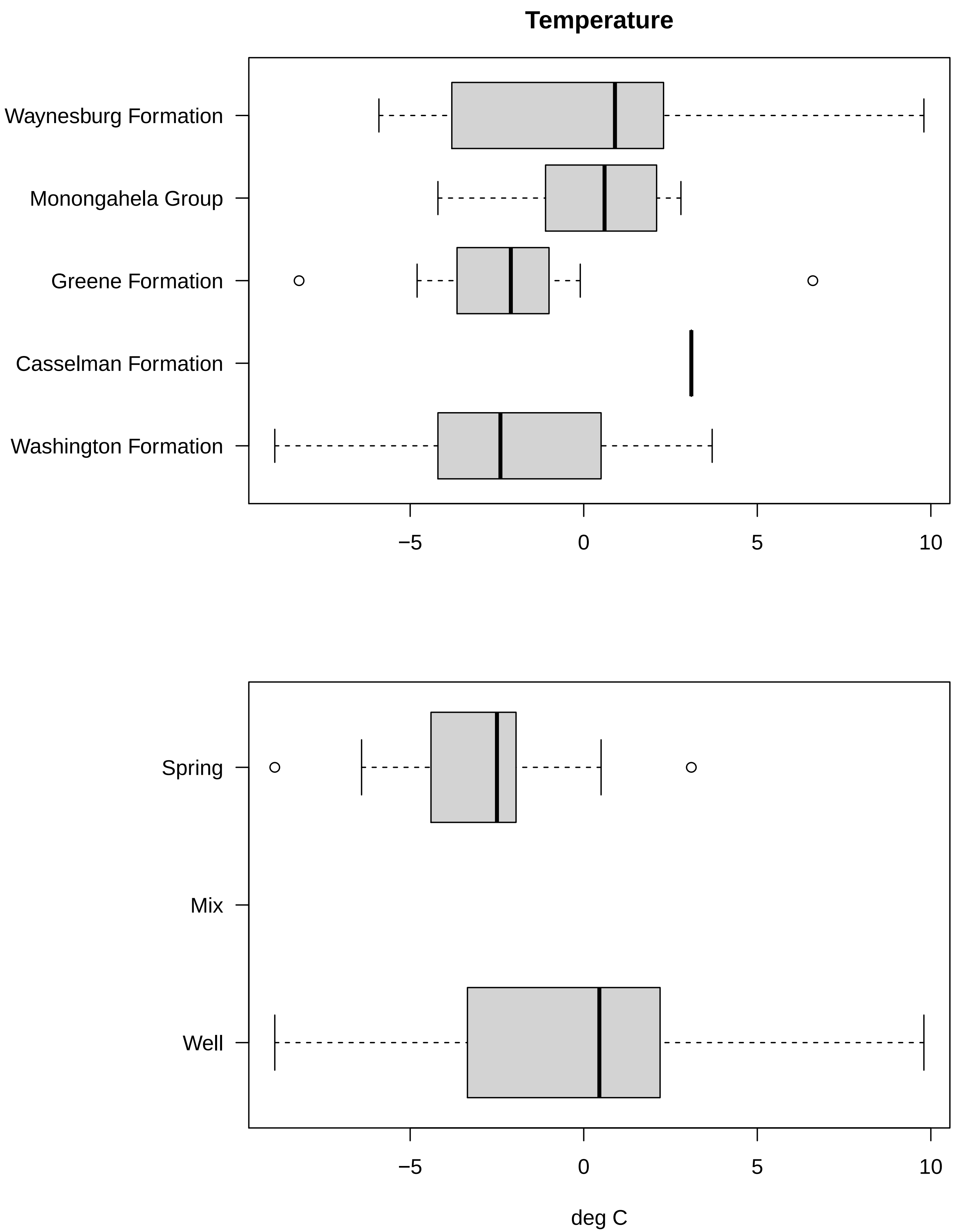
Tau: 0.0127



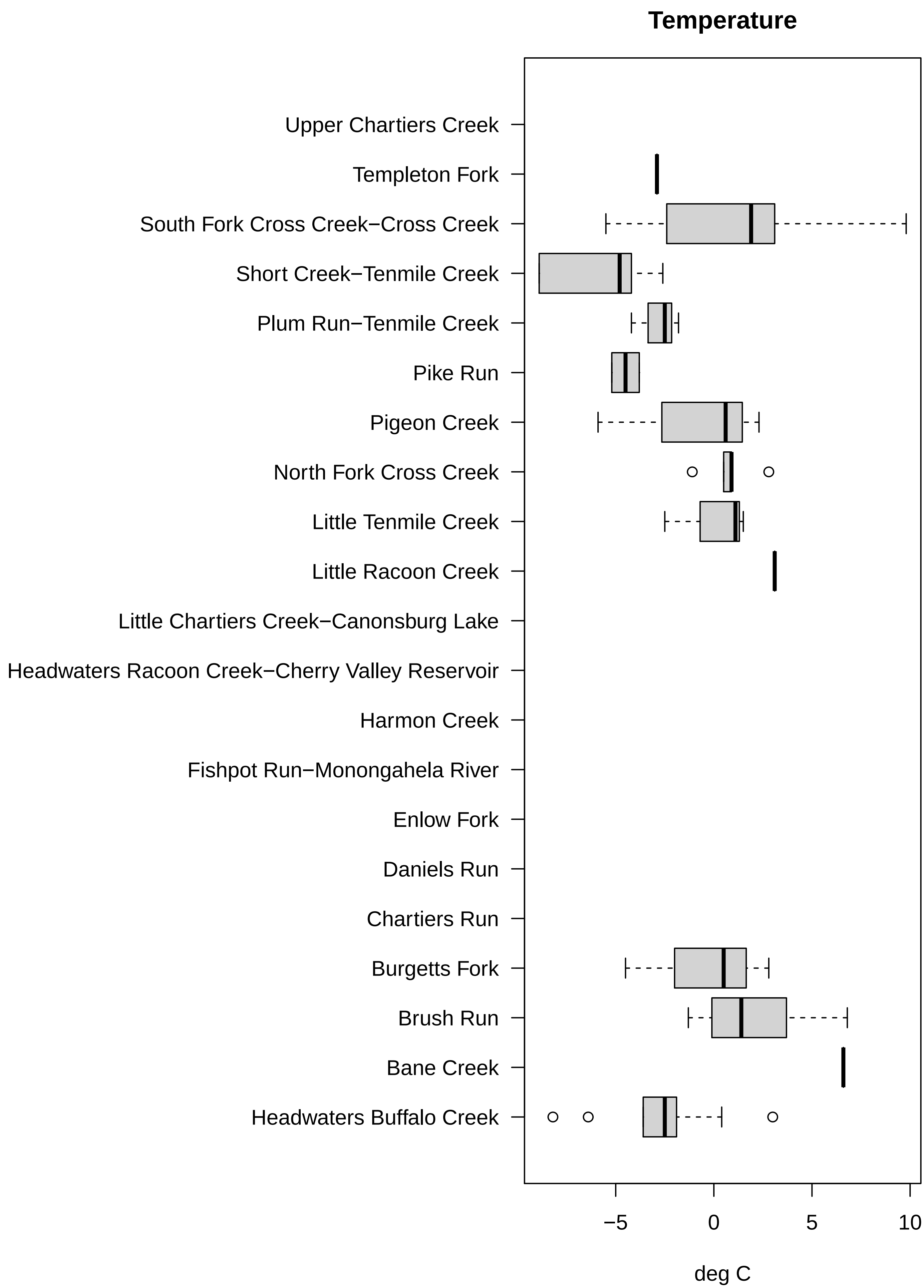








Temperature
Waynesburg Formation
Monongahela Group
Greene Formation
Casselman Formation
Washington Formation
−5
0
5
10
Spring
Mix
Well
−5
0
5
10
deg C



Temperature
Upper Chartiers Creek
Templeton Fork
South Fork Cross Creek−Cross Creek
Short Creek−Tenmile Creek
Plum Run−Tenmile Creek
Pike Run
Pigeon Creek
North Fork Cross Creek
Little Tenmile Creek
Little Racoon Creek
Little Chartiers Creek−Canonsburg Lake
Headwaters Racoon Creek−Cherry Valley Reservoir
Harmon Creek
Fishpot Run−Monongahela River
Enlow Fork
Daniels Run
Chartiers Run
Burgetts Fork
Brush Run
Bane Creek
Headwaters Buffalo Creek
−5
0
5
10
deg C

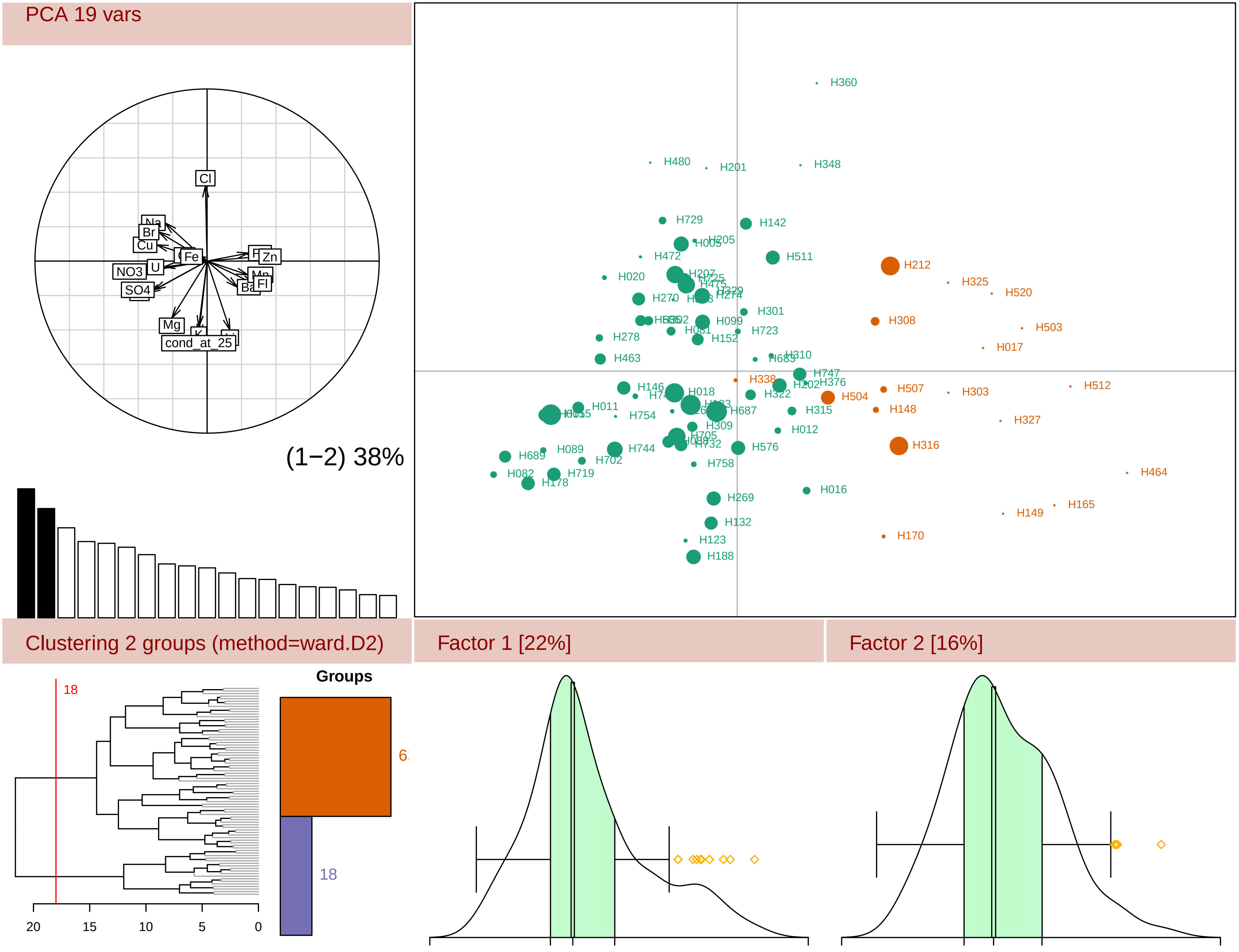
```
[1] "ORIGINAL MODEL - Temperature"

Call:
glm(formula = analyte ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter + 
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals: 
   Min      1Q  Median      3Q     Max  
-7.799  -1.457   0.000   1.748   7.502  

Coefficients: (1 not defined because of singularities)
                                          Estimate Std. Error t value Pr(>|t|)  
(Intercept)                               7.171961  13.457101   0.533   0.5984  
dat$GWellDensity_2kmDiff                 -0.024813   0.207879  -0.119   0.9059  
dat$Altitude_meter                       -0.009014   0.036463  -0.247   0.8066  
dat$WatershedBane Creek                   6.448065   4.170326   1.546   0.1337  
dat$WatershedBrush Run                    6.203748   2.424222   2.559   0.0164 *
dat$WatershedBurgetts Fork                2.848342   3.082187   0.924   0.3636  
dat$WatershedLittle Racoon Creek          9.655641   4.402090   2.193   0.0371 *
dat$WatershedLittle Tenmile Creek        -1.914921   3.151791  -0.608   0.5486  
dat$WatershedNorth Fork Cross Creek       4.838734   3.314859   1.460   0.1559  
dat$WatershedPigeon Creek                -0.012370   2.940204  -0.004   0.9967  
dat$WatershedPike Run                     0.711673   3.606199   0.197   0.8450  
dat$WatershedPlum Run-Tenmile Creek      -4.589280   3.427419  -1.339   0.1917  
dat$WatershedShort Creek-Tenmile Creek   -5.674667   3.295746  -1.722   0.0965 .
dat$WatershedSouth Fork Cross Creek-Cross Creek  5.479468   2.620160   2.091   0.0460 *
dat$WatershedTempleton Fork              -1.499366   4.037736  -0.371   0.7133  
dat$FormationCasselman Formation                NA         NA      NA       NA  
dat$FormationGreene Formation            -0.273111   2.213103  -0.123   0.9027  
dat$FormationMonongahela Group            2.411926   2.630467   0.917   0.3673  
dat$FormationWaynesburg Formation         2.151596   1.795713   1.198   0.2413  
dat$HHWSourceSpring                      -1.455014   1.574383  -0.924   0.3636  
dat$Precip_inchDiff                      -0.342964   0.177783  -1.929   0.0643 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 11.33946)

    Null deviance: 746.68  on 46  degrees of freedom
Residual deviance: 306.17  on 27  degrees of freedom
  (1 observation deleted due to missingness)
AIC: 263.46

Number of Fisher Scoring iterations: 2
```

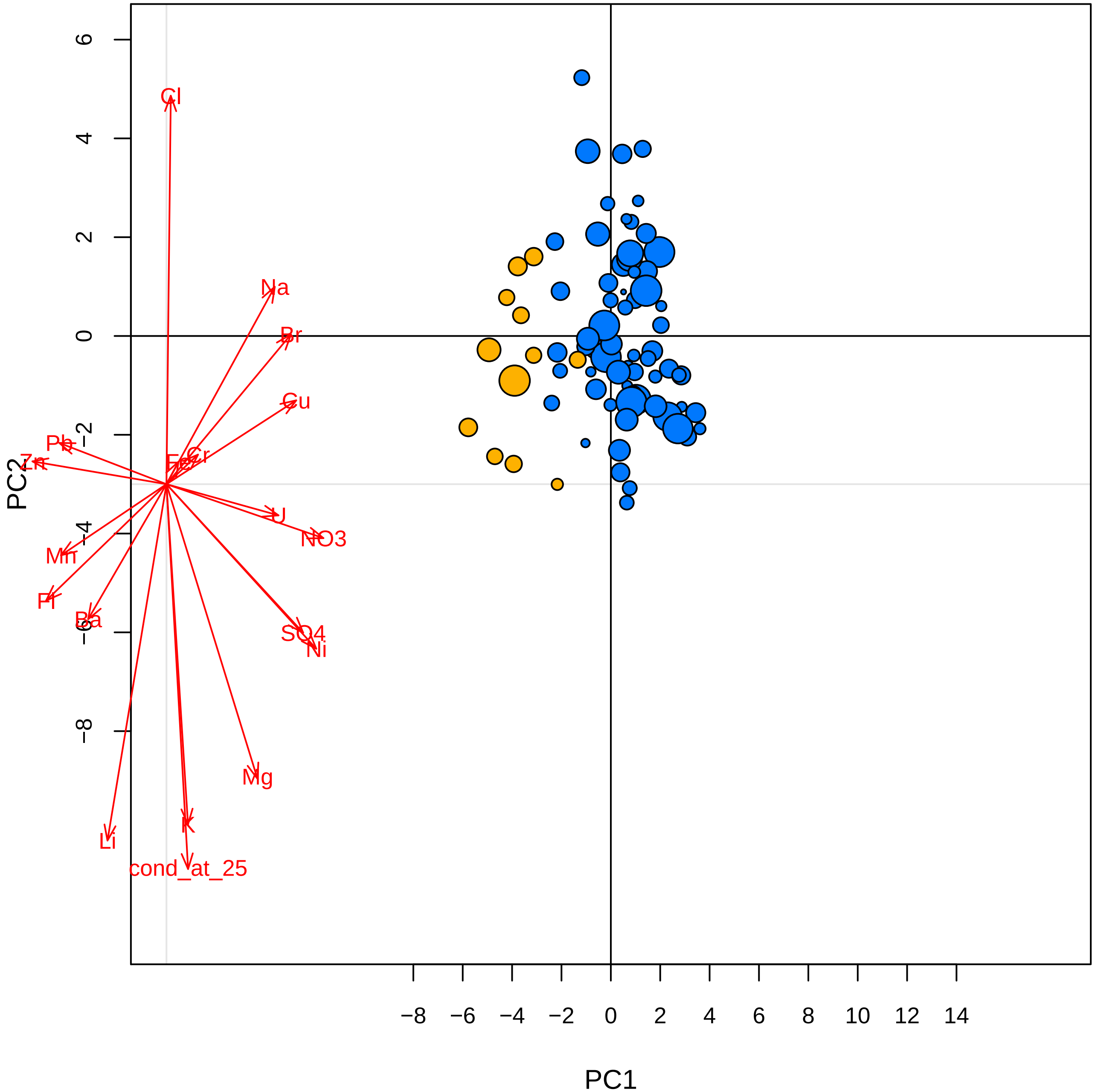
```
[1] "BOX-COX MODEL - Temperature"

Call:
glm(formula = analyte^l ~ dat$GWellDensity_2kmDiff + dat$Altitude_meter +
    dat$Watershed + dat$Formation + dat$HHWSource + dat$Precip_inchDiff)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.9126  -0.9839   0.0006   1.1372   4.4918

Coefficients: (1 not defined because of singularities)
                                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                                  6.168706   8.650615   0.713   0.4819
dat$GWellDensity_2kmDiff                    -0.026123   0.133630  -0.195   0.8465
dat$Altitude_meter                          -0.007536   0.023440  -0.322   0.7503
dat$WatershedBane Creek                      3.830359   2.680807   1.429   0.1645
dat$WatershedBrush Run                       3.919883   1.558360   2.515   0.0181 *
dat$WatershedBurgetts Fork                   1.866134   1.981320   0.942   0.3546
dat$WatershedLittle Racoon Creek             6.032472   2.829791   2.132   0.0423 *
dat$WatershedLittle Tenmile Creek           -1.234198   2.026063  -0.609   0.5475
dat$WatershedNorth Fork Cross Creek          3.116942   2.130888   1.463   0.1551
dat$WatershedPigeon Creek                   -0.014911   1.890048  -0.008   0.9938
dat$WatershedPike Run                        0.443760   2.318169   0.191   0.8496
dat$WatershedPlum Run-Tenmile Creek         -2.994992   2.203245  -1.359   0.1853
dat$WatershedShort Creek-Tenmile Creek      -3.840495   2.118601  -1.813   0.0810 .
dat$WatershedSouth Fork Cross Creek-Cross Creek  3.409120   1.684315   2.024   0.0530 .
dat$WatershedTempleton Fork                 -1.005332   2.595574  -0.387   0.7016
dat$FormationCasselman Formation                   NA         NA      NA       NA
dat$FormationGreene Formation               -0.164312   1.422647  -0.115   0.9089
dat$FormationMonongahela Group               1.439655   1.690941   0.851   0.4020
dat$FormationWaynesburg Formation            1.240609   1.154336   1.075   0.2920
dat$HHWSourceSpring                         -0.958803   1.012059  -0.947   0.3518
dat$Precip_inchDiff                         -0.217443   0.114284  -1.903   0.0678 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 4.685797)

    Null deviance: 307.47  on 46  degrees of freedom
Residual deviance: 126.52  on 27  degrees of freedom
  (1 observation deleted due to missingness)
AIC: 221.92

Number of Fisher Scoring iterations: 2
```

Appendix E

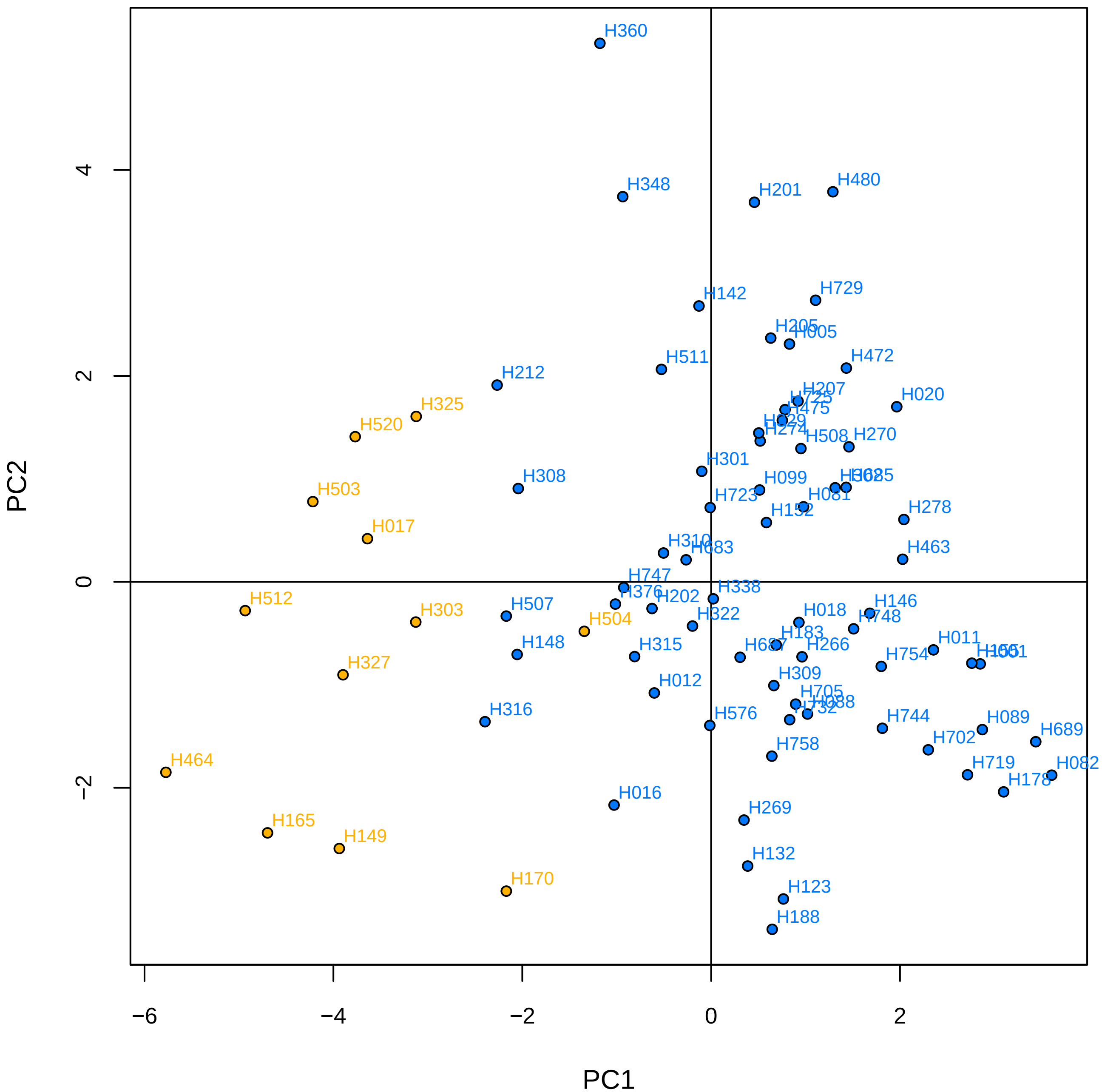
Principal Component Analysis (PCA)

Cross-Sectional PCA Results

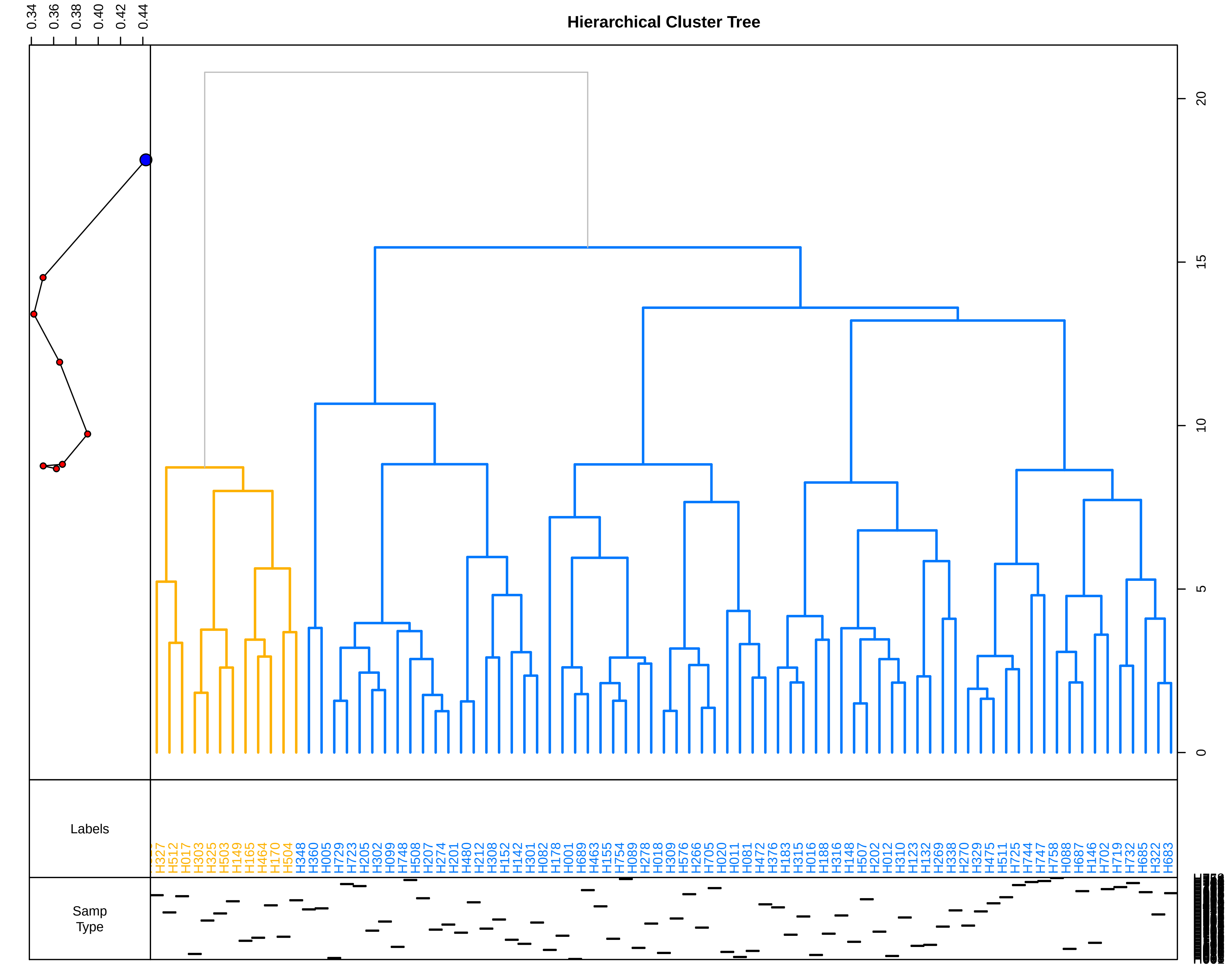

PCA 19 vars
Cl
Br
Cu
Fe
Zn
NO3
U
SO4
Fl
Mg
cond_at_25
(1−2) 38%
Clustering 2 groups (method=ward.D2)
18
20
15
10
5
0
Groups
Factor 1 [22%]
Factor 2 [16%]



Cl
Na
Br
Cu
Pb
Zn
Fe
Cr
U
NO3
Mn
Fl
Ba
SO4
Ni
Mg
K
Li
cond_at_25
PC1
PC2

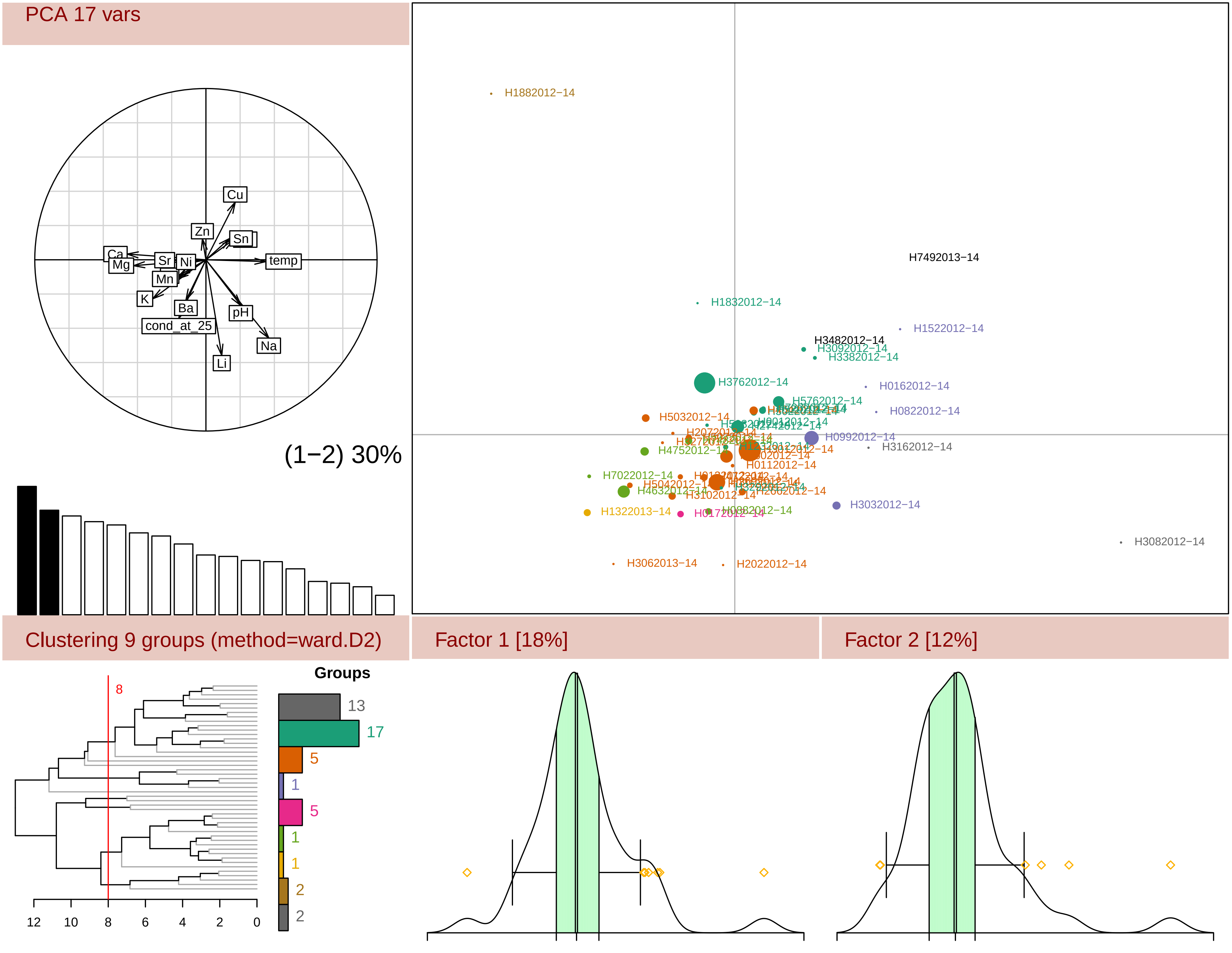


PC1
PC2
−6
−4
−2
0
2
4
H360
H348
H201
H480
H142
H729
H205
H005
H511
H472
H212
H207
H725
H475
H020
H325
H520
H029
H274
H508
H270
H301
H308
H099
H503
H723
H081
H278
H152
H017
H310
H683
H463
H747
H376
H202
H338
H512
H507
H303
H146
H018
H748
H504
H322
H183
H011
H148
H315
H687
H266
H754
H327
H309
H012
H705
H088
H316
H576
H744
H089
H689
H702
H758
H464
H719
H082
H178
H016
H269
H165
H149
H132
H170
H123
H188

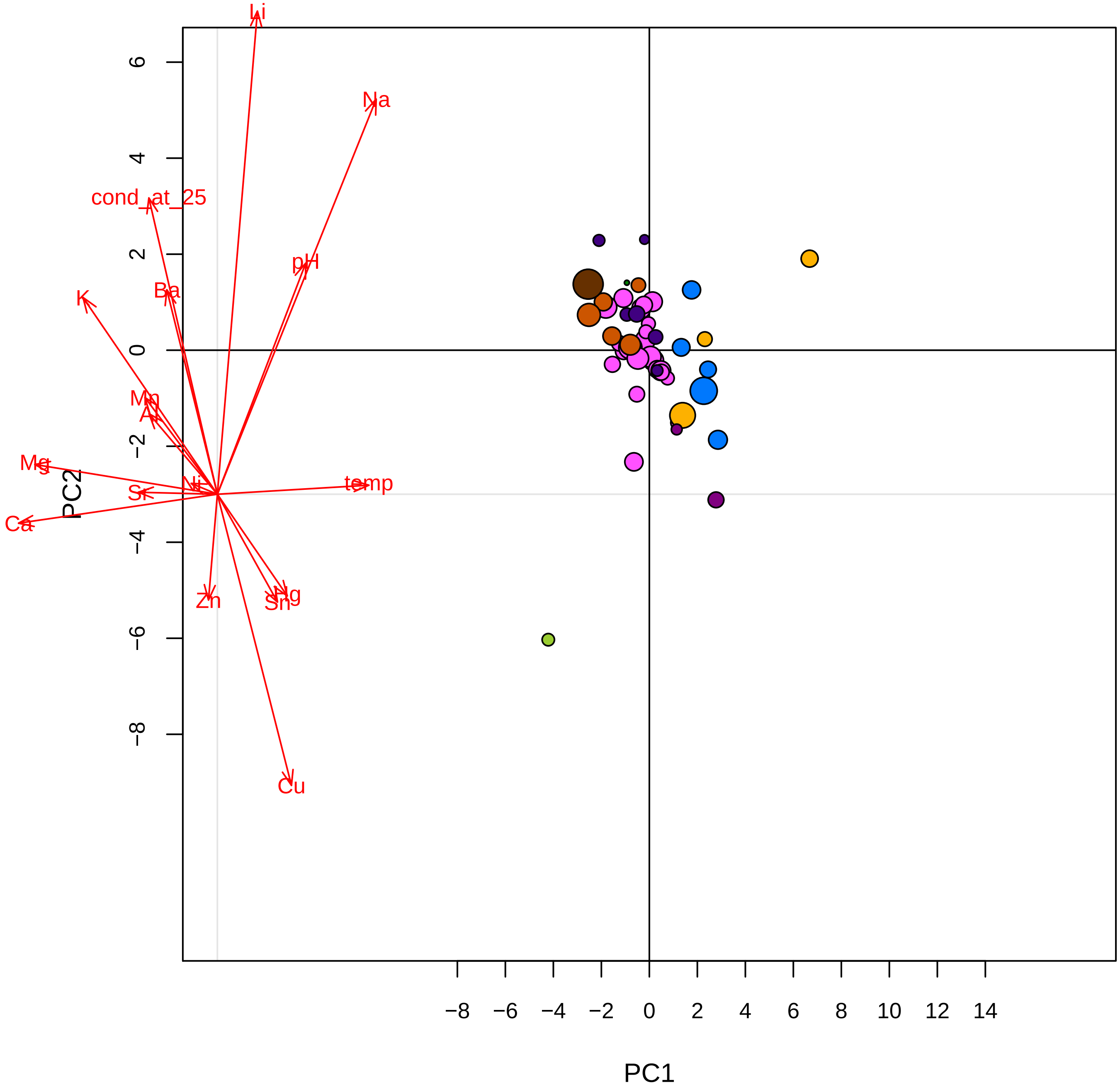


Hierarchical Cluster Tree
Labels
Samp Type
0.34 0.36 0.38 0.40 0.42 0.44
0 5 10 15 20
H327 H512 H017 H303 H325 H503 H149 H165 H464 H170 H504 H348 H360 H005 H729 H723 H205 H302 H099 H748 H508 H207 H274 H201 H480 H212 H308 H152 H142 H301 H082 H178 H001 H689 H463 H155 H754 H089 H278 H018 H309 H576 H266 H705 H020 H011 H081 H472 H376 H183 H315 H016 H188 H316 H148 H507 H202 H012 H310 H123 H132 H269 H338 H270 H329 H475 H511 H725 H744 H747 H758 H088 H687 H146 H702 H719 H732 H685 H322 H683

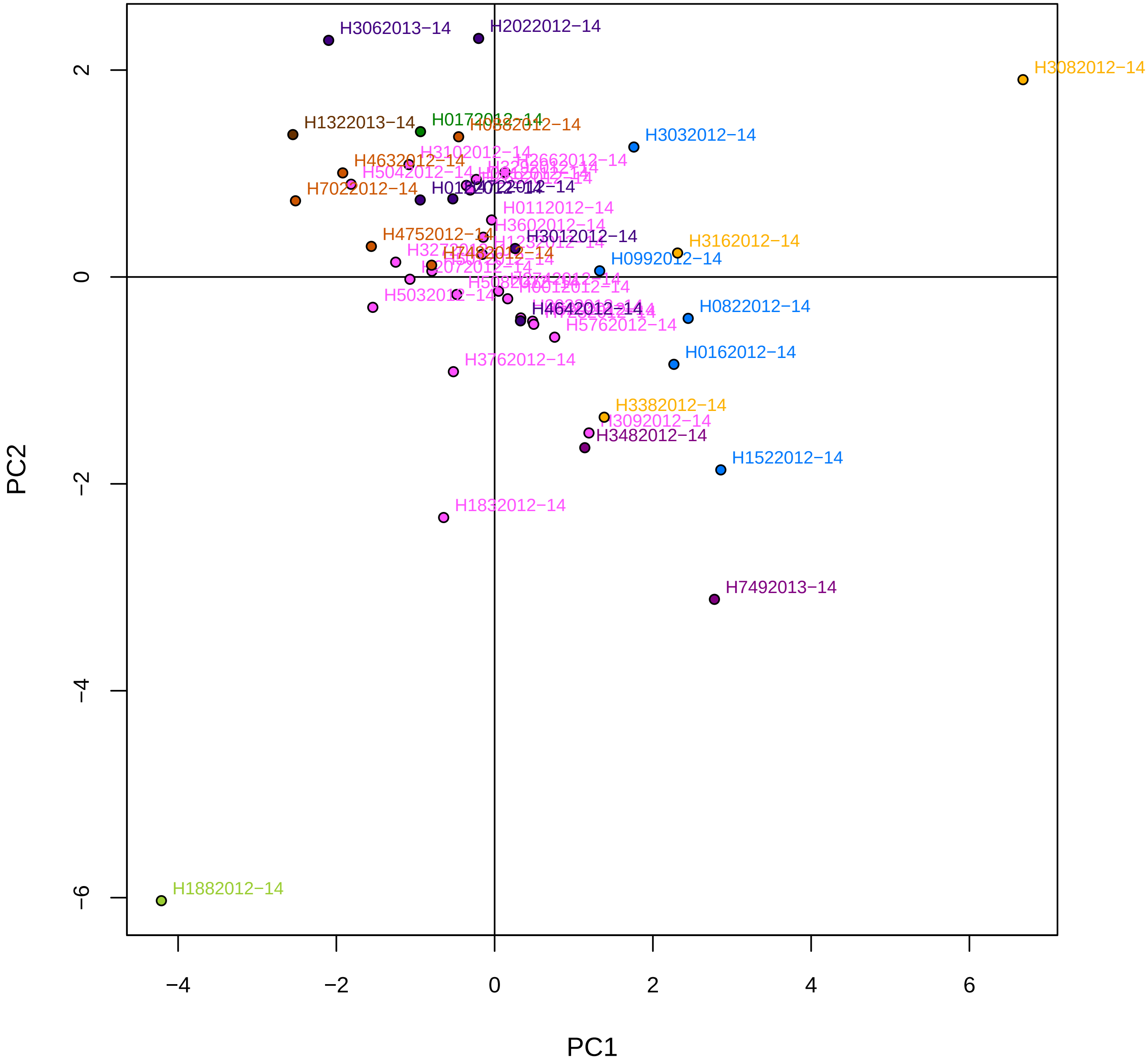
Temporal PCA Results



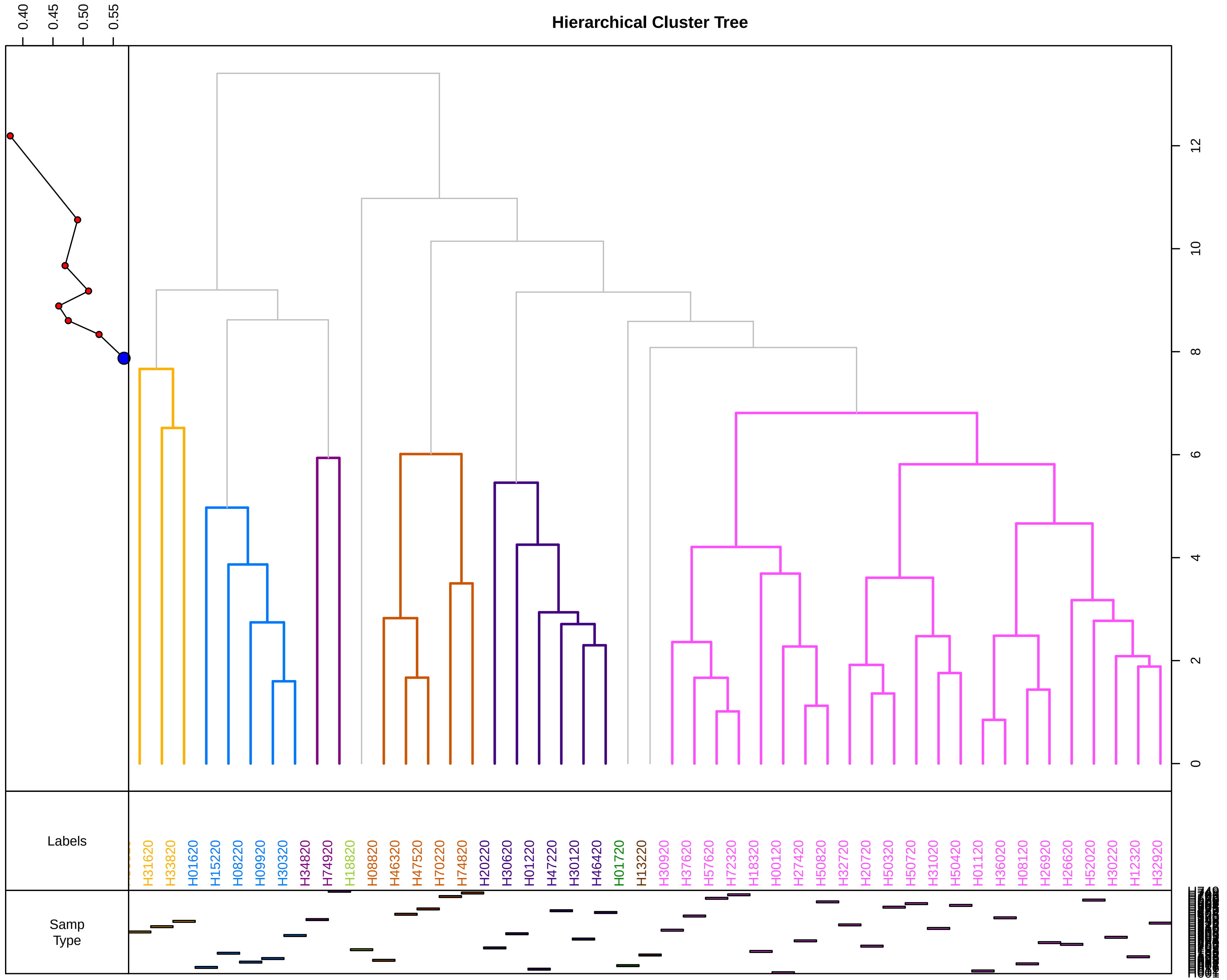
PCA 17 vars
Cu
Zn
Sn
Ca
Mg
Sr
Ni
temp
Mn
K
Ba
pH
cond_at_25
Na
Li
(1−2) 30%
H1882013−14
H7492013−14
H1832012−14
H1522012−14
H3482012−14
H3092012−14
H3382012−14
H3762012−14
H0162012−14
H5762012−14
H0822012−14
H5032012−14
H0992012−14
H3162012−14
H4752012−14
H0112012−14
H7022012−14
H4632012−14
H3102012−14
H2062012−14
H1322013−14
H0172012−14
H0982012−14
H3032012−14
H3082012−14
H3062013−14
H2022012−14
Clustering 9 groups (method=ward.D2)
Groups
8
13
17
5
1
5
1
1
2
2
12
10
8
6
4
2
0
Factor 1 [18%]
Factor 2 [12%]



Li
Na
cond_at_25
pH
K
Ba
Mn
Al
Mg
Ni
temp
Sr
Ca
Zn
Sn
Hg
Cu
6
4
2
0
−2
−4
−6
−8
PC2
−8
−6
−4
−2
0
2
4
6
8
10
12
14
PC1



H3062013−14
H2022012−14
H3082012−14
H1322013−14
H0172012−14
H3032012−14
H4632012−14
H3102012−14
H2662012−14
H5042012−14
H7022012−14
H0112012−14
H3602012−14
H4752012−14
H3012012−14
H3162012−14
H0992012−14
H6012012−14
H5032012−14
H0822012−14
H4642012−14
H5762012−14
H0162012−14
H3762012−14
H3382012−14
H3092012−14
H3482012−14
H1522012−14
H1832012−14
H7492013−14
H1882012−14
PC1
PC2
−4
−2
0
2
4
6
−6



Hierarchical Cluster Tree
0.40
0.45
0.50
0.55
0
2
4
6
8
10
12
Labels
H31620
H33820
H01620
H15220
H08220
H09920
H30320
H34820
H74920
H18820
H08820
H46320
H47520
H70220
H74820
H20220
H30620
H01220
H47220
H30120
H46420
H01720
H13220
H30920
H37620
H57620
H72320
H18320
H00120
H27420
H50820
H32720
H20720
H50320
H50720
H31020
H50420
H01120
H36020
H08120
H26920
H26620
H52020
H30220
H12320
H32920
Samp
Type