Domestic Wastewater Phosphorus Concentration Report

Phosphorus Concentration of Residential Clarified Effluent

State of Idaho
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Acknowledgments

Appreciation is extended to the many health district field personnel who assisted in collecting the data for this study.

The cover photo was taken by Brian Crawford, registered environmental health specialist/registered sanitarian of Southwest District Health. The photo depicts the interior of a trash tank; the red fragments on the scum blanket are red worms.

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Executive Summary

The domestic wastewater phosphorus concentration project was a team effort between the Idaho Department of Environmental Quality (DEQ), and six of Idaho's independent health districts (HDs), with funding from the American Recovery and Reinvestment Act of 2009. The project's team successfully identified acceptable ranges for the average domestic wastewater concentration for the wastewater constituent, phosphorus, at the 90%, 95%, and 99% levels of confidence.

The project focused on residential domestic subsurface sewage disposal (SSD) systems, commonly referred to as septic systems. In Idaho septic systems comprise the majority of SSD systems associated with sites not accessible to municipal sewage collection systems. Through this study, DEQ and the HDs tried to quantify the amount of phosphorus that was being discharged via the drainfield to the environment. No effort was made to determine whether these discharges impact ground water or adjacent surface water. Septic systems were the focus due to the widespread use of this type of system in Idaho. Extended treatment package systems (ETPSs), which are aerobic wastewater treatment systems used in areas of concern, were also considered for sampling. It was concluded that the pretreatment tank, referred to as the trash tank, would be an acceptable source, because it was assumed to provide an anoxic environment similar to a septic tank. This decision was unfortunately based on the faulty assumption that the trash tanks were anoxic environments. Dissolved oxygen from the aerobic treatment section of the ETPS infiltrated the trash tank. This aerobic environment's biological activity sequestered phosphorus at a higher rate than an anoxic environment, which negatively skewed the results. Consequently, data obtained from this environment were excluded from the analysis.

DEQ planned and coordinated all project activities, which included developing a quality assurance project plan, purchasing and providing all expendable field materials used during sample collection, outfitting field sampling kits with suitable equipment (e.g., water quality analyzers, peristaltic pumps, and sampling containers), and providing training on the sample collection protocols and equipment operation. DEQ also administered the contracts with each participating HD. At the project's conclusion, DEQ statistically evaluated the data, and compiled this report.

The participating HDs each provided a field sampling team comprised of two to three personnel. These teams identified suitable sampling locations and obtained permission from the homeowners. This avenue of site selection proved to be problematic; very few homeowners were willing to allow the HDs access to their septic tanks for sample collection. One HD partnered with an ETPS operations and maintenance provider to collect samples from the ETPS's trash tank. While this eased the burden on the HD to identify suitable sites, in the end this practice did not yield suitable samples to support the project, as previously described.

Overall, the statewide sampling activity yielded 118 viable total phosphorus samples and 116 viable soluble reactive phosphorus samples. Statistical analysis identified upper and lower confidence limits at 0.10%, 0.05% and 0.01% significance levels. The range of phosphorus concentrations and mean values identified generally matched the US Environmental Protection Agency's (EPA's) values reported for this constituent in the *Onsite Wastewater Treatment Systems Manual* (EPA 2002). This report recommends that DEQ's Water Quality Division establish 8.6 milligrams of phosphorus per liter as the acceptable upper confidence limit for

average total phosphorus concentrations discharged to the environment from subsurface sewage disposal systems in Idaho. This value can be applied in the nutrient-pathogen evaluations where phosphorus is a constituent of concern due to the proximity and sensitivity of surface waters.

1. Introduction

Idaho's surface waters are detrimentally affected by phosphorus discharges, whether directly, from point sources, or indirectly, from nonpoint sources. Idaho has over 93,000 miles of streams and rivers, and more than 2,000 lakes, many of which are susceptible to phosphorus degradation. Phosphorus enters our surface water bodies through multiple paths, such as fertilizer runoff and municipal wastewater treatment plant discharges.

1.1 Regulatory Considerations

Point source discharges are currently addressed through the US Environmental Protection Agency's (EPA's) National Pollutant Discharge Elimination System permitting program and are limited based on the water body's load-carrying capacity. Nonpoint source flows are composed of storm and agricultural runoff in addition to ground water contributions. Ground water provides the base flow for many streams in Idaho. Nonpoint phosphorus sources in Idaho are predominantly from agricultural fertilizer, natural phosphorus-bearing geological formations, and subsurface sewage disposal (SSD). Nonpoint source phosphorus contributions attributable to SSD systems are currently undefined in Idaho. The first step toward quantifying the nonpoint source phosphorus loads due to SSD is to quantify wastewater systems' effluent phosphorus concentrations.

Human waste, food residues, and consumer products, such as detergents, contribute phosphorus to sewage. Idaho does not regulate the phosphorus content of products. Only Bonner County, in northern Idaho, has established bans on detergent containing phosphorus (USGS 1999). Outside of Idaho, phosphorus concentrations in detergents were beginning to see legislative restrictions in the 1970s; these limitations did not apply to automatic dishwashing detergents or commercial cleaning products. The market for dishwashing detergents containing phosphorus is driven by local regulations, which are initiating bans or restrictions on dishwashing detergent phosphorus content. Regionally, Spokane County, Washington, banned the sale of dishwashing detergent with phosphorus concentrations exceeding 0.5%. This ban was imposed on July 1, 2008.

Currently, Idaho has two prominent phosphorus-limited watersheds: the middle and lower Snake River in Idaho's south central and southwest regions, and the Spokane River, which drains Coeur d'Alene Lake in Idaho's panhandle. While most surface water phosphorus degradation results from past agricultural practices, the northern regions of Idaho have limited agriculture. In the early 2000s, most regions in Idaho were experiencing an increase in residential construction, particularly at sites that provided views of or actual access to surface water. Frequently, the Idaho Department of Environmental Quality (DEQ) was asked to determine or estimate the total phosphorus (TP) concentration of septic tank effluent. Literature values were suggested based on studies across the United States. Protecting Idaho's water from degradation involves understanding the actual impacts from SSD systems situated near surface water.

1.2 Phosphorus in Septic Systems

Phosphorus, as it commonly occurs in effluent, is a solid at standard temperature and pressure. It will typically concentrate in the sludge accumulated in the bottom of residential septic tanks. EPA's *Onsite Wastewater Treatment Systems Manual* (EPA 2002, Table 4-15) lists the average TP concentration in septage as 210 milligrams per liter (mg/L). Septage is considered the entire contents of a septic tank and is composed of three layers within the tank: (1) scum blanket, (2) clear zone, and (3) sludge layer. EPA (2002, Table 3-7) also provides domestic wastewater constituent concentrations and lists a range of TP loads in residential wastewater, as published in Sedlak (1991), as 1–2 grams per person per day (gram/day/capita). Furthermore, based on an anticipated wastewater generation rate of 60 gallons per day per person (227 liters per person per day), the resulting concentration range is listed as 6–12 mg/L in EPA 2002.

Further characterization of septic system effluent is found in EPA (2002), Table 3-18. Table 3-18 depicts data extracted from Anderson et al (1994) on multiple constituents in effluent and percolate extracted at 2 foot (0.6 m) and 4 foot (1.2 m) depths below the drainfield-soil interface. The range of phosphorus concentrations in effluent, based on 11 samples and reported as TP, is 7.2–17.0 mg/L, with an average of 8.6 mg/L. TP ranges in lysimeter samples varied between 0.01 mg/L and 3.8 mg/L at the 2 foot depth, and 0.02 mg/L and 1.8 mg/L at the 4 foot depth. The amount of phosphorus discharged to a residential SSD system is variable and depends on residents' consumer product selections, water use habits, and occupancy rate. Additionally, a septic tank's phosphorus removal efficiency is affected by the tank size and rate at which the residents create wastewater.

The phosphorus load is composed of both inorganic and organic forms. Organic phosphorus is bound to plant or animal tissue and is formed by biological processes. Inorganic phosphorus is not associated with organic materials and includes orthophosphate (ortho-P) and polyphosphates. Ortho-P is the most stable form and is also referred to as soluble reactive phosphorus (SRP). SRP is the inorganic phosphorus form used by algae and other aquatic plants. SRP has been identified as a main concern in septic tank effluent (Green 2001). Consequently, analysis of septic tank effluent for SRP has been conducted along with TP analysis in this study. It has been reported that a septic tank's anaerobic environment is conducive to conversion of the influent's organic phosphorus and polyphosphates to the more mobile SRP (Gill et al. 2009).

1.3 Purpose of the Study

The purpose of this study was to determine statistically significant values for both TP and SRP in septic system effluent. The phosphorus concentration will be used to evaluate the impact that subsurface discharge of clarified effluent has on the environment, particularly, impacts on the ground water beneath residential subsurface sewage drainfields and any adjacent surface waters.

2. Study Description

DEQ compiled protocols for sampling septic tanks. The media collected and analyzed was clarified effluent rather than raw wastewater. Clarified effluent has undergone primary clarification, which removes particulate matter containing phosphorus. This particulate phosphorus settles out in the septic tank and is not discharged to the environment through the drainfield. These phosphorus-bearing particulates are only removed from the septic tank when the tank is pumped. The clarified effluent is discharged to the drainfield where it may infiltrate to ground water and possibly migrate to surface water.

Samples were collected from residential systems' primary clarifier tanks, referred to as septic tanks. Residential systems serve individual residences, and community systems serve residential subdivisions that do not receive wastewater from commercial, industrial, or institutional facilities. Examples of commercial facilities include, but are not limited to, stores, beauty salons, offices, and restaurants. Examples of industrial facilities include, but are not limited to, food processing operations, manufacturing facilities, and raw materials refineries. Examples of institutional facilities include, but are not limited to, hospitals, doctor and veterinary clinics, nursing homes, and schools. Samples were collected at the septic tank's discharge point, through the outlet tee or baffle, or from the system's dosing chamber or distribution box.

Currently, DEQ has a memorandum of understanding (MOU) with Idaho's seven independent health districts (HDs): Panhandle Health District (PHD), Southwest District Health (SWDH), Central District Health Department (CDHD), South Central Public Health District (SCPHD), Southeastern Idaho Public Health (SIPH), Eastern Idaho Public Health District (EIPHD), and North Central Health District (NCHD). This MOU authorizes the HDs to execute the individual / subsurface sewage disposal program within their respective districts. Due to the HD's responsibility for siting and permitting residential subsurface sewage systems, DEQ solicited their participation in identifying sites and collecting samples. Six of Idaho's seven HD's agreed to participate in this project. This participation provided good statewide coverage. NCHD chose to not participate because it covers the vast, sparsely populated central section of the state, and it would have been difficult to transport samples from remote communities to a courier capable of delivering the samples to the laboratory within the required sample holding time.

The remaining HDs were able to collect samples from across the southern section of the state, from Oregon to Wyoming, and from northern Idaho's panhandle region. The broad source of samples was critical in establishing an applicable statistic for use statewide. The broad coverage also increased the probability that the resulting statistical phosphorus concentration value would represent phosphorus contributions to ground water due to discharges to on-site SSD systems, regardless of the homeowner's water use and product selection habits.

DEQ provided training for this project and all the necessary sampling equipment in a kit for each HD to use. Funding limitations and equipment availability restrictions limited the number of kits to two. These kits were routed around to the HDs on a proposed schedule that took into account the onset of winter and availability of wintertime sampling activity.

2.1 Equipment

DEQ developed two kits to outfit two HDs concurrently. DEQ's objective was to collect all field data in three rounds of field sampling. Each kit contained a water quality meter, a peristaltic pump, silicone peristaltic pump tubing, polytetrafluoroethylene (PTFE) tubing, 0.45 micrometer (µm) high-capacity disposable filters, sample bottles, and all necessary tools and safety equipment.

The water quality meter was used to sample the clarified effluent for the following parameters: temperature (°C), pH, specific conductivity (millisiemen per centimeter [mS/cm]), turbidity (nephelometric turbidity unit [NTU]), salinity (%), and dissolved oxygen (DO in mg/L) content. The intent of this data collection was to provide data that may correlate with effluent phosphorus concentrations. Additionally, the DO reading helped identify samples from anoxic environments, such as those found in septic tanks. Since trash tanks preceding extended treatment package systems (ETPSs) were allowed sampling sites, the data needed to show that aerobic bacteria were not present. The presence of aerobic bacteria would reduce the available phosphorus in the effluent, negatively skewing the results.

The HDs supplied their own digital cameras. The HDs used Global Positioning System equipment if available; otherwise, tank locations were approximated using Google Earth.

2.2 Site Selection

The HDs maintained records on all permitted systems. Consequently, these records were the prime source for information on sites that were suitable for sampling. Some HDs solicited the help of the ETPS service providers to identify suitable systems to sample while other HDs focused on contacting individual homeowners with septic systems. Each HD was expected to sample 25 sites, which would yield a total of 150 samples for this project.

The HDs had to obtain permission from all homeowners to draw samples for analysis. Significant effort was expended to identify suitable sites and obtain permission to sample. Accessing ETPSs was less problematic because service provider’s need to access systems to provide maintenance; Idaho requires that ETPSs are monitored and effluent quality reported annually; and the systems are already placed in established access easements.

During the second round of sampling, the participating HDs solicited the help of licensed septage pumpers. The pumpers’ participation provided access to septic tanks, which met one of the project’s criteria, namely, that the septic tanks must not have been pumped within the past 6 months. This criterion was established to ensure that data would be obtained from a mature septic tank (i.e., a septic tank in equilibrium with particulate phosphorus settled out into the sludge). An economic benefit of this course of action was that it allowed DEQ to distribute the American Recovery and Reinvestment Act of 2009 funds to the pumpers for their assistance in identifying the sites and for their additional effort in exposing the outlet manhole cover, where the samples were extracted versus the inlet manhole cover, where the pumper typically gains access to clean the septic tank.

2.3 Sample Collection

Sample collection required a team of at least two people. The practice of dirty hands/clean hands was employed to minimize the potential for cross-contamination and sample degradation. The HDs discovered after their first round of sampling that a third pair of hands was helpful to record the data. The teams mobilized early in the morning to collect multiple samples and allow time to deliver the samples to the courier for overnight delivery to the Idaho Bureau of Laboratories (state laboratory) in Boise.

The quiescent nature of septic tanks allowed the teams to extract samples through the outlet tee or baffle, which provided direct access to the clear zone. The teams extracted effluent samples using a peristaltic pump. PTFE tubing was attached to a 48-inch steel sprinkler key, which was used to position the tubing through the outlet baffle into the clarified effluent without disturbing the scum layer. The PTFE tubing was secured to the silicone peristaltic pump tubing at the other end.

Sampling consisted of three phases. The first sample collected, approximately 2 quarts in volume, was placed in a clear, plastic container for the water quality meter to assess field parameters. Next a 1-liter Cubitainer was filled with unfiltered effluent for analysis to assess TP concentrations. Finally, a 0.45 µm filter was placed on the outlet end of the silicone tubing. A second 1-liter Cubitainer was filled with filtered effluent for analysis to assess SRP concentrations. Total volume extracted was typically 1 gallon. Given that the typical home septic tank is approximately 1,000 gallons, extraction-induced disturbances were kept to a minimum.

2.4 Sample Handling and Custody

Samples were packed in ice-filled coolers and chilled to approximately 4 ºC. The chain-of-custody sheet was filled out for each sampling event and placed inside the cooler in a large waterproof bag. The samples were then transported either directly to the state laboratory, or to a courier who delivered the samples overnight. The coolers also contained the necessary field blanks, created at the sampling site, trip blanks, and spike samples as specified in the quality assurance project plan (QAPP) (DEQ 2009). The chain-of-custody sheet was signed and dated as required at each handoff.

2.5 Laboratory Procedures

The Idaho Bureau of Laboratories was the sole laboratory selected to perform the analyses. TP was analyzed using EPA method 365.1, while SRP was analyzed using Standard Methods (SM) 4500-PE. The state laboratory adhered to their internal quality assurance protocols.

3. Discussion

The project's purpose was to establish statistically supported values for TP and SRP in domestic effluent. The following sections present the findings of this study in addition to discussing significant events and issues that occurred during the study.

3.1 Equipment

The supplied materials and equipment list is provided in the project's QAPP. DEQ had sufficient equipment to outfit two complete field kits. The kit's limiting equipment were Geotech peristaltic pumps and Horiba U-10 multiparameter meters (Horiba multimeter). DEQ only had two of each of the equipment. The remaining equipment was either inexpensive (e.g., sprinkler key and screw driver) or consumable (e.g., tubing and filters).

The Geotech peristaltic pumps performed flawlessly, as long as an airtight seal could be created where the PTFE tubing interfaced with the silicone peristaltic tubing. Initially, an airtight seal was obtained by placing about 4 inches of the silicone peristaltic pump tubing over the PTFE tubing. It was only after a second lot of PTFE and silicone tubing was purchased that a lack of sealing at this interface occurred. The field teams overcame this leak by running more of the PTFE tubing into the silicone tubing and then zip-tying them together with between two and four zip ties. The cause of the leak was most likely due to manufacturing tolerances. If the PTFE tubing was near its minimum outside diameter, and the silicone tubing's inside diameter was near its maximum, then a leak was more likely to occur.

The Horiba multimeter was capable of measuring the following water quality parameters:

- Temperature
- pH
- DO
- Specific conductivity
- Turbidity

The Horiba multimeter calculated the solution's salinity from the temperature and conductivity readings.

The DO data were collected to verify that the sampling environment was truly an anoxic septic tank environment. Phosphorus data corresponding to an environment that exhibited DO concentrations of 3.0 mg/L or greater were removed from the data set. The data set was removed to limit the impact an aerobic environment's more active aerobic bacteria would have on the wastewater's phosphorus concentration. Similarly, temperature and pH were collected to evaluate the sample's validity. Excessively hot samples, above 26 °C (79 °F), and excessively cold samples, below 2 °C (36 °F), were removed from the data set. Additionally, pH was monitored to obtain assurances that the samples were between 6.0 and 9.0 standard units.

The specific conductivity, turbidity, and salinity data were collected to assess their suitability for use as a surrogate measurement in place of sending an actual sample to the state laboratory for TP and SRP analysis. This activity was not documented in the project's QAPP, and did not yield any acceptable correlation between the wastewater attribute (e.g., pH, turbidity, or salinity) and either the TP or SRP concentration.

Prior to delivering the kits to begin sample collection, it was discovered that one of the Horiba multimeter's nephelometer tube was cracked. This equipment had recently been calibrated and undergone periodic maintenance at a manufacturer's designated facility. Returning the Horiba multimeter to be repaired would have delayed one HD by approximately 6 weeks. Fortunately, DEQ was able to identify a replacement water quality meter of another make and model, an YSI Environmental 556 multiprobe system (YSI MPS). While the YSI MPS could measure temperature, pH, DO, and specific conductivity, just like the Horiba multimeter, the YSI MPS did not measure turbidity or calculate salinity. The YSI MPS was capable of calculating the solution's total dissolved solids (TDS) from the conductivity and temperature readings. Additionally, the YSI MPS was capable of measuring the solution's oxidation-reduction potential (ORP).

The YSI MPS was able to assess the critical environmental parameters (pH, temperature, DO, and specific conductivity) needed to verify the environment was truly anoxic. The addition of ORP was interesting but also failed to yield any useable correlation between the wastewater's ORP and either TP or SRP.

During the first round of data collection, the YSI MPS provided intermittent performance. The YSI MPS failed to provide stable readings after approximately 30 days of use. It was determined that the unit suffered multiple sensor failures. The YSI MPS was pulled from the kits after the first round of data collection, reducing the number of operational kits to one. The second round of data collection was completed using the remaining Horiba multimeter. The Horiba multimeter also had difficulties providing stable readings. The DO and nephelometer were periodically unstable, limiting the septic tank environment qualifying data collected. The causes of this instability were varied. Typically, instability in the DO reading indicated that the field personnel had failed to remove the rubber boot that protected the sensor. Turbidity fluctuations were most likely due to wastewater that contained large quantities of floc.

3.2 Expendable Materials

The list of expendable materials is identified in the project's QAPP and consisted of the PTFE tubing that connected the peristaltic pump to the septic tank, peristaltic pump tubing, and 0.45 µm filters. During the pilot test field efforts, when the first two HDs were trained, samples were collected at two sites in southwest Idaho. During these sample collection efforts, deionized (DI) water was drawn through the tubing and filters to assess the expendable material's potential phosphorus contribution to the samples. The first sample was drawn through the silicone tubing; the second sample was drawn through the silicone tubing and PTFE tubing; and the third and fourth samples were drawn through the tubing and each of the different filters. This sampling method allowed DEQ to assess each component's contribution of phosphorus to a sample if phosphorus was detected. The samples collected from DI water flow through the tubing alone were analyzed for TP, while the samples through the tubing and filters were analyzed for SRP.

The laboratory analyses of these samples indicated that the expendable equipment did not contribute phosphorus above the method detection limit (MDL) of the methods employed (EPA method 365.1 for TP, and SM 4500-P-E for SRP). This activity verified the integrity of the sample collection materials selected.

The disposable filters were good for a single use. During the project's pilot test phase, the project manager and field teams from the first two HDs evaluated two potential 0.45 µm filters. The filters evaluated were products from Geotech and Millipore. Both filters performed satisfactorily, so the least expensive filter was chosen for the project. The volume of filterable sample collected was directly affected by the solids content of the tank being sampled. When the suspended solids volume was high, the sample volume collected was reduced. In one instance, the team was only able to collect approximately 200 milliliters (mL), far short of the specified 500 mL minimum specified in the QAPP. The state laboratory was still able to analyze this small sample and report a valid SRP concentration.

3.3 Equipment Disinfection Protocol Verification

After the pilot test samples were collected and equipment cleanup commenced, the water quality meter underwent a cleaning protocol. This decontamination protocol is documented in the project's QAPP. The water quality meter's sensor head, the part that contacted the clarified effluent, was rinsed with DI water, sprayed with a 10% chlorine solution, and allowed to stand a few minutes. The sensor head was sprayed again and then rinsed with DI water. A sample from this final rinse was collected and analyzed for total coliform. The laboratory analyses indicated that the total coliform levels were below 1.0 most probable number/100 mL. This result verified the efficacy of the disinfection protocol required to safeguard the field personnel from pathogens.

3.4 Site Selection

In the 2010 initial phase of sample collection, the HDs contacted permit holders seeking access to their septic systems. Records were not kept on their success rate, but the HDs did report that they were having trouble gaining access to systems. While most HDs were successful in obtaining the minimum number of samples specified in the QAPP, 25, one HD was only able to obtain permission to sample 11 septic systems.

The QAPP allowed the HDs to sample trash tanks that precede ETPS. The reasons for allowing this were twofold. First, in Idaho ETPS are required to be maintained by a service provider who has access to the units to perform periodic maintenance, sampling, and annual reporting. This was expected to provide easy identification of and access to suitable sampling sites. Second, the trash tanks were expected to provide an anoxic environment equivalent to a septic tank.

Accepting ETPS as suitable sampling sites did ease the site identification problem. Unfortunately, the expectation that the trash tank would be an anoxic environment was not met. Trash tanks are expected to supply a quiescent environment, necessary for gravity settling of small particles. The field data indicate that the vast majority of the ETPS sampled have aerobic trash tanks, indicating a significant link between the trash tank and agitated aerobic compartment. ETPSs oxygenate the mixed liquor typically using diffusers or similar components. The oxygen-rich bubbles rising through the mixed liquor agitate the mixed liquor and increase the DO concentration. This agitation apparently assists migration of the DO into the hydraulically linked trash tanks, creating an aerobic environment.

The high DO concentrations in the trash tanks support aerobic bacteria, which consume nutrients at a more rapid rate than the septic tank's anaerobic bacteria. Consequently, this undocumented, biologically based reduction of phosphorus is not accountable in this project's structure, resulting in the rejection of all data from tanks with DO concentrations exceeding 3.0 mg/L (3 parts per million [ppm]).

During the second phase of sample collection, the participating HDs asked whether they could solicit their regional septage pumpers. This alternative was considered and accepted. Since the pumpers would need to expose the outlet manhole in addition to the inlet manhole, which they need for access to perform their contracted work, the decision was made to compensate them for their time and labor. This course of action allowed 22 more samples to be obtained in an 8-week period in one HD, a marked improvement over the initial HD site identification efforts.

3.5 Sample Collection

Sample collection generally proceeded without problems. Certain difficulties arose during sample collection, but they were corrected. The first issue involved extracting samples from the tank. From the initial batch of tubing purchased, variations in the diameter of the PTFE tubing, when inserted into the silicon peristaltic pump tubing, allowed a tight seal. Subsequent batches of PTFE tubing were smaller in outside diameter, allowing air to leak in. The leaking problem was corrected in the field by using multiple zip ties to seal the silicon tubing to the PTFE tubing.

Another issue was the high concentration of particulate matter during the first flush of effluent extracted from the tank. The HD’s field teams addressed this issue by placing the first flush into the collection container that was used to obtain the secondary data: pH, temperature, specific conductivity, salinity, ORP, DO, and turbidity. Difficulties with collecting the secondary data are addressed in section 3.6. Placing the first liter or two into this secondary container allowed the area in the tank around the extraction probe to be vacated before collecting the TP sample. The high particulates usually occurred due to the probe contacting the outlet tee or baffle, dislodging biomat from the surface.

While the TP sample collection was only hindered intermittently by excessive particulates in the sample, the SRP sample collection was slightly more problematic. The 0.45 µm filters had a tendency to plug if the samples were being collected from a poorly maintained septic tank, or from a tank with high concentrations of suspended solids. In essence, the filters were performing their expected function; however, the volume of samples collected and supplied to the state laboratory was limited. In every instance where high particulates limited the SRP sample volume collected, the state laboratory still successfully established the sample’s SRP concentration.

3.6 Water Quality Data Collection

Data collection using the water quality meters proved to be the most problematic aspect of this project. As stated in section 3.1, the second Horiba multimeter was discovered to have a cracked nephelometer tube soon after its return from being calibrated. Luckily, DEQ had another model of water quality meter available to collect the secondary data—an YSI Environmental 556 MPS. The YSI MPS did not provide salinity monitoring or turbidity, but it did monitor the solution’s ORP and calculate TDS. The water quality attributes monitored by each meter are listed in Table 1, along with the range and accuracy.

The purpose behind collecting this additional data was primarily to verify that the environment the sample was being extracted from was anoxic, neither too acidic nor basic, and of an acceptable temperature. A secondary purpose, not documented in the QAPP, was to investigate whether an easily monitored water quality attribute could be found that would correlate with the effluent’s TP concentration. This would provide an inexpensive, alternative means of assessing an effluent’s TP concentration.

After the laboratory analyses and water quality meter-collected data were quality-assured, the appropriate data sets were compiled and the data plotted. Various curves were then fitted to these data to identify an acceptable relationship between the phosphorus concentration and a water quality attribute. The various parameters that were plotted versus TP and SRP included the following:

- pH
- Turbidity
- Temperature
- TDS
- Salinity
- DO
- ORP
- Specific conductivity

No acceptable correlations between these parameters and either TP or SRP were identified. The best correlation involved the TDS and TP. The second degree polynomial fit between TDS and TP yielded a correlation coefficient (R^2) of 0.36, which still indicates a poor fit. This fit is based on only 19 data points obtained from a single HD's field data. The YSI MPS was the only water quality meter that provided TDS readings. The majority of R^2 values associated with the other attributes yielded correlation coefficients (R^2) approximating zero. This effort was terminated.

Table 1. Secondary data meter parameters, range, and accuracy.

Meter	Parameter	Range	Accuracy
Horiba U-10, multiparameter meter	Specific conductivity	0–1 mS/cm 1–10 mS/cm 10–100 mS/cm	0.01 mS/cm 0.1 mS/cm 1.0 mS/cm
	pH	0–14 units	0.1 units
	Turbidity	0–800 NTU	10 NTU
	Dissolve oxygen	0–19.9 mg/L	0.1 mg/L
	Temperature	0–50 °C	1 °C
	Salinity	0–4%	0.1%
YSI Environmental 556 multiprobe system (MPS)	Specific conductivity	0–200 mS/cm	±0.5% of reading or ±0.001 mS/cm, whichever is more
	pH	0–14 units	±0.2 units
	Total dissolved solids	0–100 g/L	Calculated from specific. conductivity
	Dissolved oxygen	0–20 mg/L	±2% of reading or 0.2 mg/L; whichever is more
		20–50 mg/L	±6% of reading
	Temperature	-5 to 45 °C	±0.15 °C
	Oxidation-reduction potential	-999 to +999 mV	±20 mV

Notes: millisiemen per centimeter (mS/cm); nephelometric turbidity unit (NTU); milligram per liter (mg/L); gram per liter (g/L); millivolt (mV)

3.7 Sample Handling

Sample handling addresses the packaging, shipping, and documentation associated with delivering the collected samples to the Idaho Bureau of Laboratories in Boise. The HDs packaged the samples, along with any duplicates, trip blanks, field blanks, and spiked samples in ice-filled coolers. These samples were then delivered with the chain-of-custody documents to the overnight courier. The courier delivered the samples to the state laboratory the next day, meeting the 48-hour holding time limit.

All remote HDs used this scheme. The HDs nearest Boise used one of their field personnel to deliver the iced sample container directly to the state laboratory. The only reported shipping error occurred when two blank samples were not included in the cooler during shipping from northern Idaho.

3.8 Laboratory Analysis

The Idaho Bureau of Laboratories' analyses adhered to their internal quality assurance plan. Various observations were clearly reported in the accompanying quality assurance summary for each laboratory analysis. An example of responses included identifying a sample that did not undergo analysis until 53 minutes after its holding time had expired. Other responses included noting excessive particulates in some samples, or unexpected responses, such as excessive foaming during the chemical oxidation processes required by EPA method 365.1.

3.9 Data Quality

This section presents the data quality attributes of accuracy, representativeness, comparability, and completeness. Each section presents how the data set complied or deviated from these requirements.

3.9.1 Data Accuracy

Data accuracy was evaluated as specified in the QAPP, section VII.A. Due to the non-normal characteristic of the data, the accuracy is reported as a relative standard deviation (RSD).

Analysis of the spike sample laboratory results yielded an accuracy value of RSD = 1.94%. The acceptable accuracy value specified in Table 5 of the QAPP establishes acceptable precision at 5%, and bias at 1%, for a total accuracy RSD of 6%. Data analyses placed the precision at 1.00%, and the bias at 0.94%.

3.9.2 Data Representativeness

Representativeness is a qualitative term that "addresses the extent to which measurements actually reflect the sampling unit from which they were taken, as well as the degree to which samples actually represent the target population" (EPA 2006). Data representativeness is ensured by properly executing sample collection and transportation protocols, by following the state laboratory's quality control program for sample analyses and data interpretation, and through selective use of field replicates.

All 52 of the trip and field blanks yielded analysis results below the MDL as reported on the laboratory analyses reports. This metric provides assurances that the resulting sample collection and handling were not sources of phosphorus contamination.

The sampling teams were trained and provided with a field example on how to safely and properly collect domestic effluent samples. The sampling teams followed the protocol documented in the QAPP and demonstrated to them during the training. The training, coupled with the laboratory results of the trip and field blanks, provides some assurance that the data reported in the laboratory analyses represents the actual phosphorus concentrations being discharged to the environment.

One HD collected replicated samples. These replicates were collected under comparable conditions. Each pair was collected sequentially in time, one immediately following the other. This method should have provided samples yielding approximately equal phosphorus concentrations since each sample was 1 liter or less collected from tanks typically 3,785 liters (1,000 gallons) or larger. Barring inclusion of biological floc or other organic matter into one of the replicates, the analysis should yield approximately equivalent values.

There were 21 pairs of samples and replicates provided. Evaluation of the paired laboratory analyses yielded 17 pairs of samples meeting the requirement that the analysis yield values within 30% of each other. Two pairs of replicate samples were rejected due to either sample-marking error or laboratory error. Two other pairs exceeded the 30% difference criteria for unknown reasons. The average deviation among the valid replicates was 7.5%. Five replicates yielded no difference; eight replicates differed by less than 5%; three replicates differed by less than 10%; and one replicate differed by 13.3%.

Two of the 21 replicated pairs were rejected due to discrepancies in the data package. While the field data sheets and the laboratory reports indicated appropriate laboratory testing, the results for TP samples 8988-7 and 8988-8 yielded values lower than the SRP sample (8988-9); 6.4, 7.3, and 7.84 milligrams phosphorus per liter (mg-P/L), respectively. A plausible, but unsubstantiated, explanation is that one of the replicated TP samples was labeled as the filtered SRP sample, and the filtered SRP sample was labeled as a replicated TP sample. If the posited analyses occurred, it may explain the low TP value for the filtered sample (6.4 mg-P/L), and a comparable SRP value for the unfiltered TP sample (7.84 mg-P/L).

A plausible, but unsubstantiated, explanation for the other rejected data, samples 8989-10, 8989-11, and 8989-12, is that the samples were tested using the alternate test method. The laboratory analyses yielded TP values of 6.2 mg-P/L for both 8989-10 and 8989-11, and a SRP value of 10.9 mg-P/L for sample 8989-12. Considering the SRP sample is filtered, removing particulate phosphorus, and the TP samples are chemically oxidized using sulfuric acid hydrolysis and persulfate digestion, it is possible that the filtered SRP sample, after undergoing chemical oxidation, would yield a marginally elevated phosphorus value. Conversely, the unfiltered TP samples undergoing the SRP test (SM 4500-PE) would yield low phosphorus concentrations due to the presence of unoxidized phosphorus.

Two pairs of samples exceeded 30%; one at 34.6% and the second at 40%. The replicates that yielded the 34.6% difference were analyzed yielding 7.8 mg-P/L and 5.1 mg-P/L, respectively. The site's SRP sample yielded 3.42 mg-P/L. No explanation is evident from the documentation package for this distribution of sample results.

The last set of replicates yielded the 40% difference. The laboratory analyses for samples 8983-1 and 8983-2 yielded 9.0 mg-P/L and 15.0 mg-P/L, respectively. The SRP sample, 8983-3, yielded 8.68 mg-P/L. A plausible, but unsubstantiated, explanation would require swapping the SRP sample with a TP sample. Analyzing the filtered SRP sample with EPA method 365.1 chemical oxidation would yield a lower TP value than the unfiltered replicate, due to the lack of particulates. Analyzing the unfiltered TP sample with the SRP method, SM 4500-PE, which would not chemically oxidize the unfiltered sample, would yield a lower value than the sample actually contains. This explanation is more plausible than collecting two SRP samples. Collecting two SRP samples is extremely unlikely since the SRP sampling effort required using a 0.45 µm filter. Each filter was typically capable of filtering 1 liter before it became clogged and unusable, thereby restricting one filter for every SRP sample collected.

3.9.3 Data Comparability

Comparability is a data quality indicator that expresses the measure of confidence that one data set is fundamentally equivalent to another. Comparability ensures that the project can combine analytical results from each HD without introducing error. Comparability was initially assessed using box plots of each HD's previously qualified data (Figure 1).

During this project's sample collection effort, one HD was allowed to collect samples from the trash tanks that precede aerobic treatment units, known ETPS in Idaho. A typical ETPS configuration has the trash tank contiguous with the aerobic unit, although some older ETPS have hydraulically isolated tanks (i.e., a preceding septic tank). This contiguous configuration did not provide thorough hydraulic isolation, evident by the increased DO reading. The presence of high DO in the trash tank changes the environment from an anoxic to an aerobic environment. This environment allows more active aerobic bacteria to propagate and consume nutrients, one of which is phosphorus. Consequently, DEQ rejected those samples that were identified as coming from the trash tank of an aerobic unit and exhibiting DO concentrations in excess of 3.0 milligrams dissolved oxygen per liter (mg-DO/L) (3 ppm). The qualified data set was reduced for this HD from 70 to 3. The box plot for this HD's three data points appears as Group 6 in Figure 1. The three data points were not considered to be a sufficiently large sample to retain in this study. Removing this HD's data reduced the qualified data set from 188 to 118 for TP and 116 for SRP.

The remaining five data sets were subsequently evaluated to determine whether they could be combined into one larger data set. To accomplish this, DEQ used Levene's test, as specified in the QAPP. Levene's test assesses the homogeneity of variance (homoscedasticity) between multiple data sets to determine whether the data represent a larger population. Levene's test is robust and does not require that these data sets be normally distributed. Normality of the individual data sets was assessed and is presented in section 3.10.

Levene's test assesses whether the variances of the data sets are sufficiently similar to assert that there is an equality of variance. The test's null and alternative hypotheses are presented in Equation 1.

$$Null\ Hypothesis.H_0: \sigma_1^2 = \sigma_2^2 = \sigma_3^2 = \cdots = \sigma_i^2;\ Alternative\ Hypothesis.H_a: \sigma_1^2 \neq \sigma_i^2$$

Equation 1. Levene's test hypothesis.

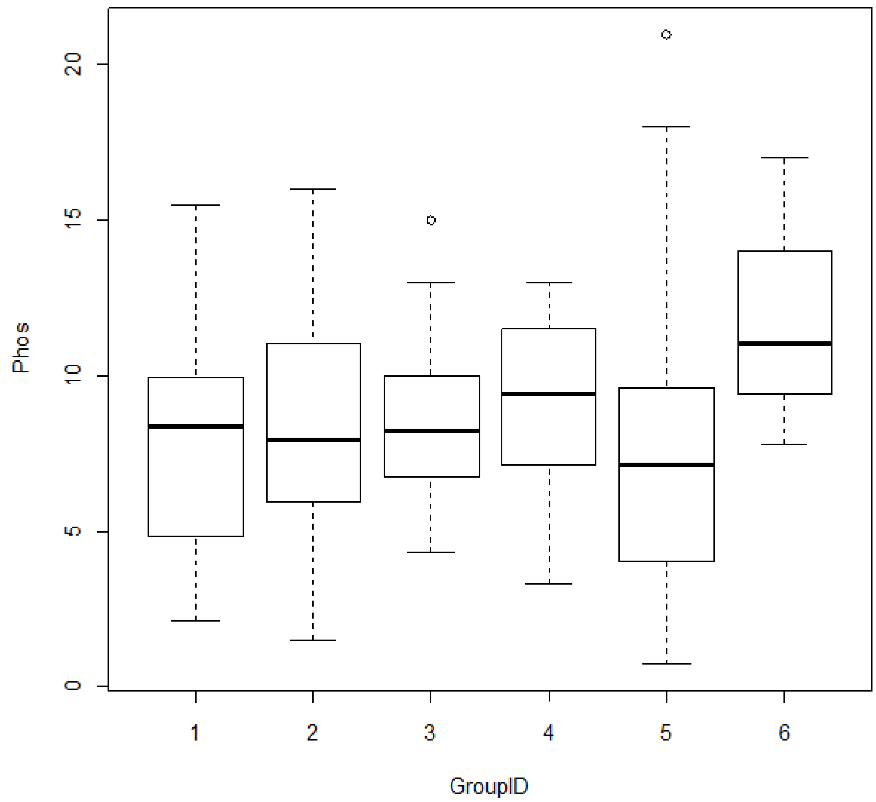

Figure 1. Box plots of each health district's data: Group 1—SWDH; Group 2—SCPHD; Group 3—SIPH; Group 4—PHD; Group 5—EIPHD; Group 6—CDHD.

The test was performed on the qualified TP data set. The data were found to exhibit homoscedasticity. Levene's test results are presented in Figure 2.

Since Levene's statistic is 1.669, which is smaller than the critical value of 2.452 at the 5% probability level ($\alpha = 0.05$), evidence does not support rejecting the hypothesis. As a result, at a 95% confidence level, the variances of the HD's data sets are equal. This homoscedasticity supports combining the data sets into a single data set so that a suitable statistic can be calculated and an acceptable confidence interval can be defined that represents domestic effluent's phosphorus concentrations statewide.

Levene's Test	
# of Groups (<=6)	5

Group (i)	n_i	Sum(n)
1	34	34
2	25	59
3	25	84
4	23	107
5	11	118

	SS	df
Between Group	37.00534	4
Within Group	626.2396	113
Levene's Statistic	1.66933	
Critical Value (a=0.05)	2.451988	
P-value	0.162017	

Figure 2. Levene's test results.

3.9.4 Data Completeness

Completeness is a measure of the amount of valid data obtained with respect to the total amount of samples collected and analyzed during project execution. The QAPP established the acceptable data completeness level at 90% for both TP and SRP data.

3.9.4.1 Data Qualifiers

Data disqualification criteria included the following:

- Data that were identified as a statistical outlier (assessed using Rosner's test) (1 data point)
- Samples analyzed using incorrect testing procedure as documented on the laboratory analysis sheet (EPA method 365.1 instead of SM 4500-PE) (21 data points)
- Site analyses where the SRP results exceeded the TP results (4 data points)
- Sites with qualified DO readings exceeding 3.0 mg/L (3.0 ppm) (65 data points)
- Sample holding time violations (1 data point)

3.9.4.2 Outliers

After the data were qualified, histograms of each HD's data were plotted in an initial attempt to identify potential outliers. One HD was identified as having a sample with a particularly large phosphorus concentration (Figure 3 and Figure 4). Additionally, probability plots were generated for these data (Appendix A). The probability plots of SCPHD's data substantiated the need to apply an outlier test.

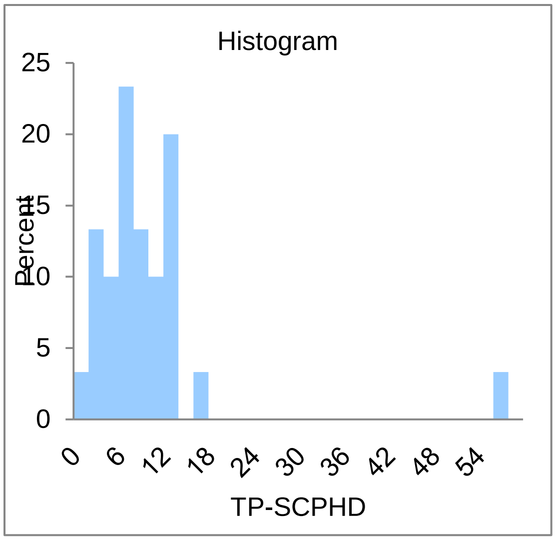

Figure 3. SCPHD total phosphorus outlier histogram.

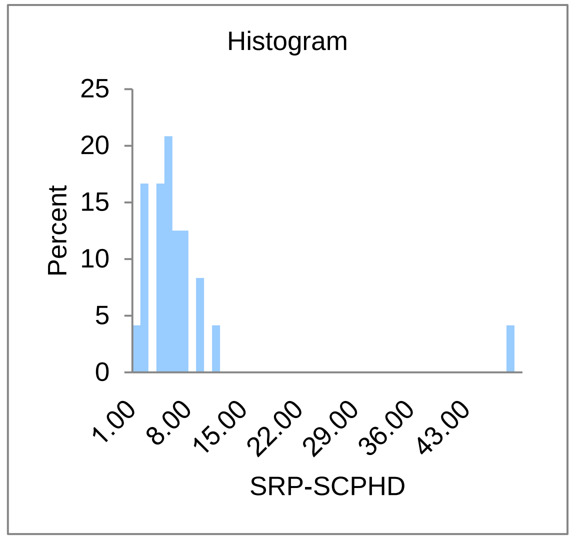

Figure 4. SCPHD soluble reactive phosphorus outlier histogram.

Prior to applying the outlier test, the records were consulted to determine whether any uncharacteristic situations may have occurred at this site that might explain the high phosphorus concentrations. DEQ discovered that this home had been vacant for a month or more and hypothesized that during this extended quiescent period, anaerobic digestion would have occurred. The buildup of anaerobic gasses, methane and hydrogen sulfide, in the septage could have recently disturbed the solids layer, by gas buildup agitating the solids layer as it escaped in mass, suspending phosphorus-bearing solids and liberating SRP.

All data points that appeared to be outliers were assessed using Rosner's test. Rosner's test identified the TP and SRP data shown in Figure 3 and Figure 4 as true outliers. These data points were removed from the valid set of data. Appendix B provides the Rosner's test results.

3.9.4.3 Qualified Data

A total of 202 sites were sampled across the state. After applying the data qualifiers, the data were reduced to 118 samples suitable for TP analysis and 116 samples suitable for SRP analysis. These data yield a 60% data completeness for the TP analysis, and 58% data completeness for the SRP analysis. While the data fall short of the selected target of 90% stated in the QAPP, the resulting data set is of sufficient size to yield valid population statistics for TP and SRP concentrations.

3.10 Data Normality

Initial data plotting in a histogram indicated that the data are positively skewed, resulting in a long tail to the right as indicated in Figure 5. The skew for the TP data is 0.582, and for the SRP data is 0.487. These values are close to zero indicating a possibility that the data could be evaluated using statistical tools applicable to normally distributed data. Even if the data set was determined to be skewed beyond normality, skewed data may be transformed, yielding normally distributed transformed data. Consequently, data assessment was performed in two phases:

1. The normality of the raw, qualified data was assessed, and, depending on the results
2. Either
    a. Data evaluated using statistical tools applicable for normal distributions, or
    b. A transformation was selected, applied, and the transformed data were statistically evaluated.

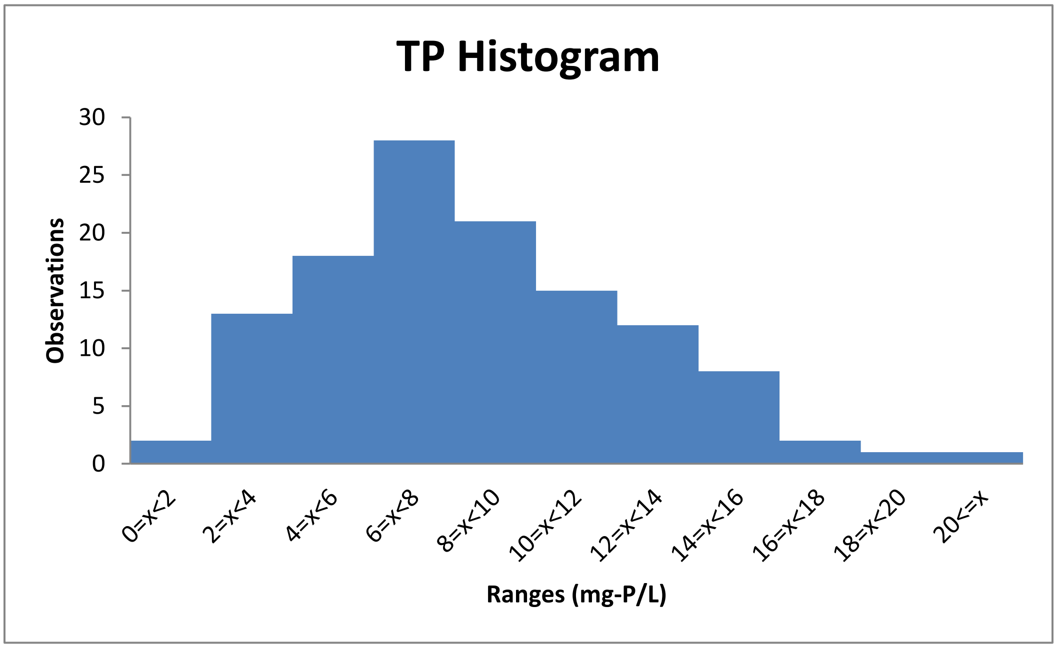

Figure 5. Total phosphorus data histogram.

Each HD's data were tested for normality by plotting the data on normal quantile plots. The results are provided in Appendix A. Some HD's data were found to be normal (EIPHD, SCPHD, and SIPH) at the three probability levels tested, (α=0.1, α=0.05, and α=0.01), while others were found to be normal at only some probability levels (SWDH and PHD). One HD's data was not found to be normal at any probability level (CDHD). Various transformations were tried, ending in the selection of a square root transformation. This transformation normalized the data, at all probability levels, for all but one HD. The HD that remained non-normal was the one whose data had been disqualified (CDHD) as presented in section 3.9.3.

The combined TP data were plotted on a normal quantile plot to determine at various probability (significance) levels (α=0.01, 0.05, and 0.10), whether the data were normal or non-normal. The test determined that the combined TP data did not provide sufficient evidence to reject normality at α = 0.01 probability level (99% confidence level). Figure 6 presents the graph of the untransformed TP data.

The combined TP data were transformed using the square root transformation and tested again. The transformed data were found to be normal at all probability levels tested (Figure 7).

Sample Size	Critical Value Using α = .01	Critical Value Using α = .05	Critical Value Using α = .10
118	0.982631668	0.989355244	0.991414458
r Correlation Coefficient	Conclusion Using α=.01	Conclusion Using α=.05	Conclusion Using α=.10
0.98691461	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not support the claim that these values come from a normal population.	Sample data do not support the claim that these values come from a normal population.

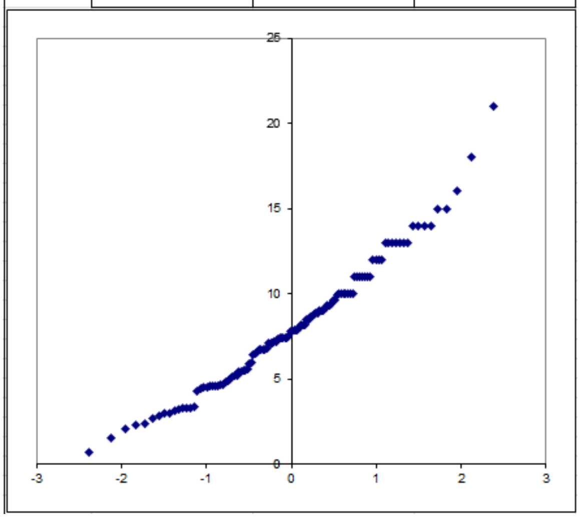

Figure 6. Total phosphorus data normal quantile plot.

Sample Size	Critical Value Using α = .01	Critical Value Using α = .05	Critical Value Using α = .10
118	0.982631668	0.989355244	0.991414458
r Correlation Coefficient	Conclusion Using α=.01	Conclusion Using α=.05	Conclusion Using α=.10
0.99602726	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.

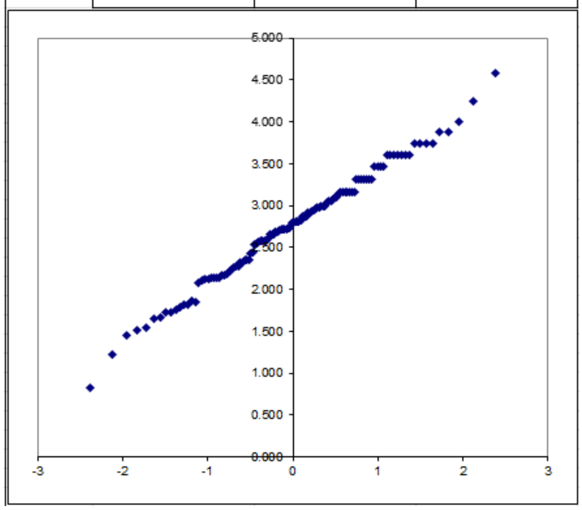

Figure 7. Total phosphorus transformed data normal quantile plot.

The combined SRP data were plotted on a normal quantile plot to determine at various probability (significance) levels, (α=0.01, 0.05, and 0.10), whether the data were normal or non-normal. The SRP data test was not as definitive as the TP data test. At the 0.01 and 0.05 significance levels, the data did not provide sufficient evidence to reject normality, while at the 0.10 significance level, the data did not support the claim of normality. Figure 8 provides the results for the SRP data normal quantile plot.

The SRP data were also transformed using the square root function. These transformed data were then checked for normality using a normal quantile plot. The transformed SRP data were also found to be normally distributed at the three probability levels previously mentioned. Figure 9 presents the normal quantile plot of the square root transformed SRP data.

Sample Size	Critical Value Using α = .01	Critical Value Using α = .05	Critical Value Using α = .10
118	0.982631668	0.989355244	0.991414458
r Correlation Coefficient	Conclusion Using α=.01	Conclusion Using α=.05	Conclusion Using α=.10
0.99104381	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not support the claim that these values come from a normal population.

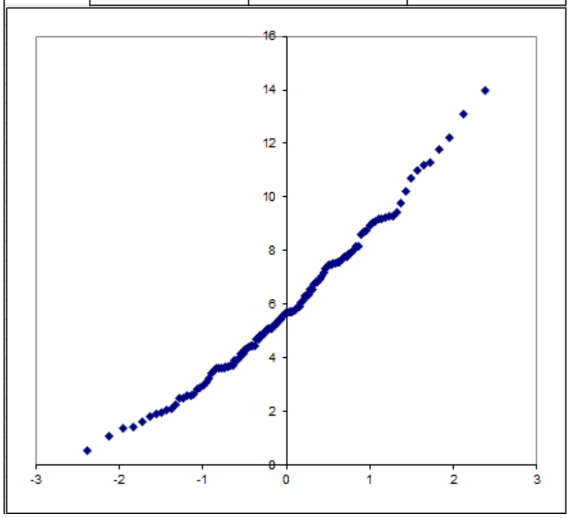

Figure 8. Soluble reactive phosphorus data normal quantile plot.

Sample Size	Critical Value Using α = .01	Critical Value Using α = .05	Critical Value Using α = .10
116	0.982416828	0.989167446	0.991254265
r Correlation Coefficient	Conclusion Using α=.01	Conclusion Using α=.05	Conclusion Using α=.10
0.9983362	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.

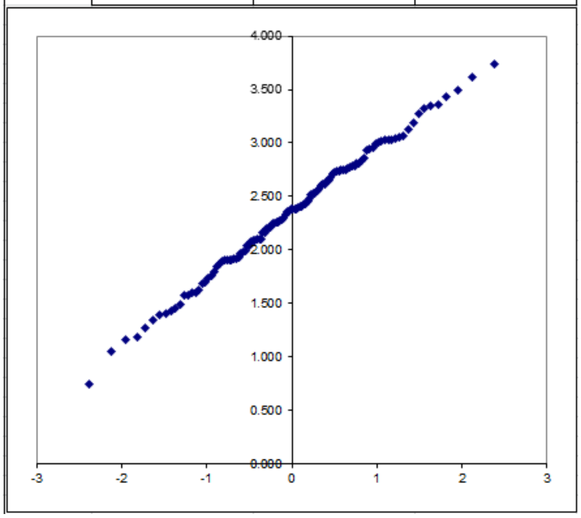

Figure 9. Soluble reactive phosphorus transformed data normal quantile plot.

An alternative assessment of the complete data set compiled from the five HDs using EPA's ProUCL software (ProUCL 4.1 2010), indicated that the TP and SRP data were normally distributed at the 5% significance level (95% confidence level). The ProUCL evaluation deviated from the assessment presented above only in assessing the TP data at the 5% significance level as exhibiting a normal distribution. The ProUCL output tables are provided in Appendix C.

3.11 Residential Effluent Phosphorus Statistics

Transformed data evaluation yielded the statistics presented in Table 2, Table 3, and Table 4. Care was taken to calculate the confidence intervals using the transformed data prior to back-transforming, squaring the LCL and UCL values, to the original data domain.

Table 2. Total phosphorus and soluble reactive phosphorus statistics.

Statistic	TP (mg/L)	SRP (mg/L)
Dataset size (n)	118	116
Mean	7.60	5.53
UCL at 95% Confidence Interval	8.17	5.97
LCL at 95% Confidence Interval	7.04	5.10
Median	7.80	5.68
Minimum value	0.68	0.552
Maximum value	21	14
Skew	0.582	0.487

Notes: number of data points (n); total phosphorus (TP); soluble reactive phosphorus (SRP); milligram per liter (mg/L); (n); upper confidence level (UCL); lower confidence level (LCL)

Table 3. Total phosphorus concentration ranges at specified level of confidence.

Level of Confidence (%)	Lower Confidence Limit (mg-P/L)	Upper Confidence Limit (mg-P/L)
99	6.8	8.4
95	7.0	8.2
90	7.2	8.0

Notes: milligram phosphorus per liter (mg-P/L)

Table 4. SRP concentration ranges at specified level of confidence for normal data.

Level of Confidence (%)	Lower Confidence Limit (mg-P/L)	Upper Confidence Limit (mg-P/L)
99	4.9	6.2
95	5.1	6.0
90	5.2	5.9

Notes: milligram phosphorus per liter (mg-P/L)

Additionally, the complete data set was subjected to statistical analysis using EPA's ProUCL software (ProUCL 4.1 2010). The ProUCL analysis yielded comparable values for the UCL affiliated with the 5% probability level. Table 5 presents the ProUCL results for both TP and SRP.

Table 5. ProUCL results for total phosphorus and soluble reactive phosphorus upper confidence level at 5% significance level.

Constituent	Test Statistical Methodology	Upper Confidence Limit (mg-P/L)
TP	95% student's–t UCL	8.605
	Adjusted For Skewness	
	95% adjusted–CLT UCL[a]	8.620
	95% modified–t UCL[b]	8.608
SRP	95% student's–t UCL	6.313
	Adjusted For Skewness	
	95% adjusted–CLT UCL[a]	6.323
	95% modified–t UCL[b]	6.315

Notes: upper confidence level (UCL); milligram phosphorus per liter (mg-P/L); central limit theorem (CLT)
a. Chen 1995
b. Johnson 1978

4. Conclusion

The discovery that ETPSs with integral trash tanks do not hydraulically isolate their trash tank from the aerobic chamber resulted in excluding a significant amount of data from this project (70 sites providing 140 samples). The aerobic nature of the trash tank resulted in a significantly different environment, as evident by the lack of homoscedasticity of this HD's data set. The type of ETPS sampled does not represent all ETPSs, but the possibility of an aerobic trash tank being present should be assessed before any future data collection.

Removing a significant amount of data from this study was unfortunate, but it did not prevent DEQ from determining statistically significant TP and SRP concentrations for domestic clarified effluent discharged to a subsurface sewage disposal drainfield. The uncertainty in the data has yielded a range for the true mean of the phosphorus concentration, with a higher confidence level encompassing a wider range of values as is evident in the reported values appearing in Table 3, Table 4, and Table 5.

DEQ is selecting a 95% level of confidence, as the level of acceptable risk, to safeguard the ground and surface water resources for future beneficial use. DEQ is also selecting to use the UCL values, at the specified confidence level. The more conservative approach supports selecting the UCL as the compliance and assessment value. The reason for selecting this value stems from uncertainty in the data and the uncertainty in the data quality of any future monitoring efforts.

Since phosphorus' impact to the environment is the issue of concern, and the phosphorus concentrations that sample analyses established lie between the LCL and UCL and cannot be distinguished from a true population average, DEQ selects an UCL associated with the 95% level of confidence as the value recommended for use in nutrient-pathogen evaluations. The UCL value established using EPA's ProUCL software at the 95% confidence level is 8.6 mg-P/L. This value is slightly lower than the value currently accepted for nutrient-pathogen evaluations (9.0 mg-P/L) of phosphorus impacts to adjacent surface waters.

In conclusion, DEQ supports the use of the following value as a suitable limit for analyzing impacts to ground and surface waters in Idaho. A 95% confidence level UCL of 8.6 mg-P/L should be used.

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Appendix A—Data Normality Tests

Appendix A provides the individual health district (HD) data set’s normality test results, including the qualified data from each HD and associated normal quantile lot.

Panhandle Health District (PHD)

The qualified total phosphorus (TP) data appears in Table A-1, and the corresponding normal quantile plot appears in Figure A-1.

Table A-1. PHD square root of total phosphorus qualified data.

Sample Count	PHD Square Root (TP)
1	0.825
2	1.500
3	1.549
4	1.673
5	1.732
6	1.732
7	2.236
8	2.258
9	2.280
10	2.280
11	2.588
12	2.665
13	2.720
14	2.739
15	2.811
16	2.950
17	3.033
18	3.162
19	3.317
20	3.606
21	3.742
22	4.243
23	4.583

Sample Size	Critical Value Using α = .01	Critical Value Using α = .05	Critical Value Using α = .10
23	0.936579552	0.955396274	0.963974678
r Correlation Coefficient	Conclusion Using α=.01	Conclusion Using α=.05	Conclusion Using α=.10
0.98956036	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.

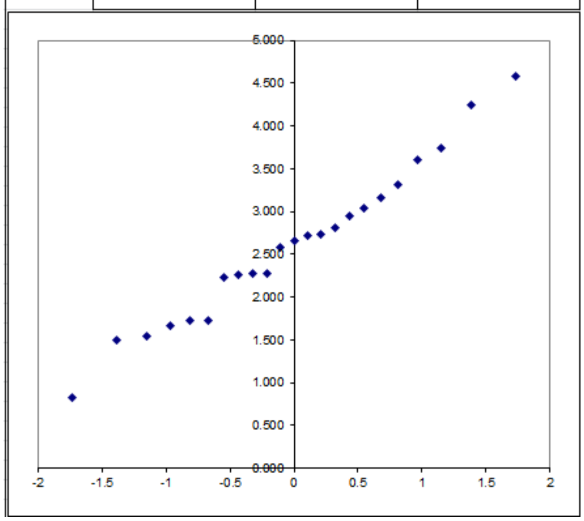

Figure A-1. PHD normal quantile plot of square root transformed data—non-normality test.

Southwest District Health (SWDH)

The square root transformed qualified TP data appears in Table A-2, and the corresponding normal quantile plot is presented in Figure A-2.

Table A-2. SWDH square root of total phosphorus qualified data.

Sample Count	SWDH Square Root (TP)
1	1.449
2	1.817
3	1.844
4	2.110
5	2.121
6	2.145
7	2.145
8	2.168
9	2.191
10	2.345
11	2.356
12	2.449
13	2.540
14	2.665
15	2.683
16	2.729
17	2.864
18	2.915
19	2.915
20	2.933
21	2.966
22	2.983
23	2.983
24	3.000
25	3.050
26	3.154
27	3.464
28	3.674
29	3.742
30	3.742
31	3.742
32	3.742
33	3.873
34	3.937

Sample Size	Critical Value Using α = .01	Critical Value Using α = .05	Critical Value Using α = .10
34	0.953943231	0.967385117	0.973431143
r Correlation Coefficient	Conclusion Using α=.01	Conclusion Using α=.05	Conclusion Using α=.10
0.98432566	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.

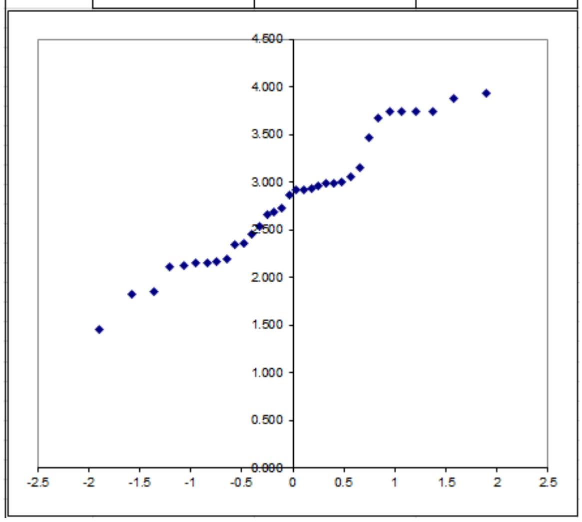

Figure A-2. SWDH normal quantile plot of square root transformed data—non-normality test.

Central District Health Department (CDHD)

The unqualified TP data appears in Table A-3, and the corresponding normal quantile plot appears in Figure A-3.

Table A-3. CDHD total phosphorus unqualified data.

Sample Count	CDHD TP	Sample Count	CDHD TP
1	3.2	36	8.3
2	4.1	37	8.3
3	4.1	38	8.4
4	4.15	39	8.5
5	4.5	40	8.5
6	5.4	41	8.8
7	5.5	42	8.8
8	5.5	43	8.8
9	6.2	44	9
10	6.4	45	9
11	6.5	46	9.1
12	6.5	47	9.1
13	6.6	48	9.1
14	6.7	49	9.2
15	6.7	50	9.4
16	6.8	51	9.6
17	6.8	52	9.7
18	7.2	53	9.7
19	7.3	54	9.7
20	7.3	55	10
21	7.4	56	10
22	7.5	57	10
23	7.6	58	11
24	7.6	59	11
25	7.6	60	12
26	7.6	61	12
27	7.7	62	12
28	7.8	63	12
29	7.8	64	12
30	7.9	65	14
31	7.9	66	14
32	8	67	17
33	8	68	17
34	8.1	69	20
35	8.3	70	34

Sample Size	Critical Value Using α = .01	Critical Value Using α = .05	Critical Value Using α = .10
70	0.974275435	0.982441068	0.985612191
r Correlation Coefficient	Conclusion Using α=.01	Conclusion Using α=.05	Conclusion Using α=.10
0.82309148	Sample data do not support the claim that these values come from a normal population.	Sample data do not support the claim that these values come from a normal population.	Sample data do not support the claim that these values come from a normal population.

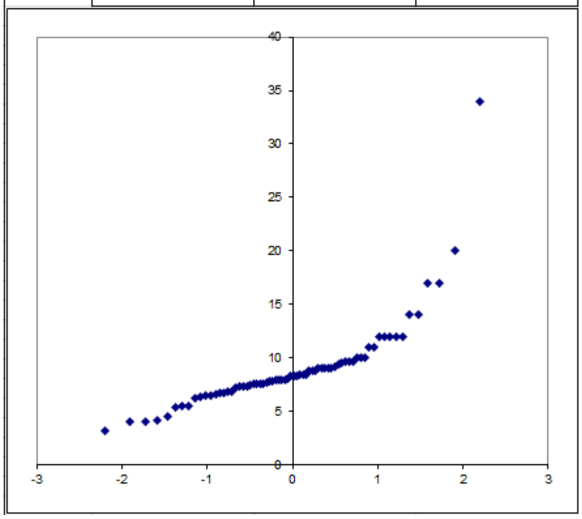

Figure A-3. CDHD normal quantile plot—non-normality test.

South Central Public Health District (SCPHD)

The qualified TP data appears in Table A-4, and the corresponding normal quantile plot appears in Figure A-4.

Table A-4. SCPHD total phosphorus qualified data.

Sample Count	SCPHD TP
1	1.5
2	2.7
3	3.1
4	3.2
5	3.3
6	5.5
7	5.9
8	6.4
9	7.3
10	7.4
11	7.8
12	7.9
13	7.9
14	8
15	9.6
16	9.6
17	10
18	10
19	11
20	12
21	12
22	13
23	13
24	13
25	16

Sample Size	Critical Value Using α = .01	Critical Value Using α = .05	Critical Value Using α = .10
29	0.947520592	0.962891715	0.969869707
r Correlation Coefficient	Conclusion Using α=.01	Conclusion Using α=.05	Conclusion Using α=.10
0.991149	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.

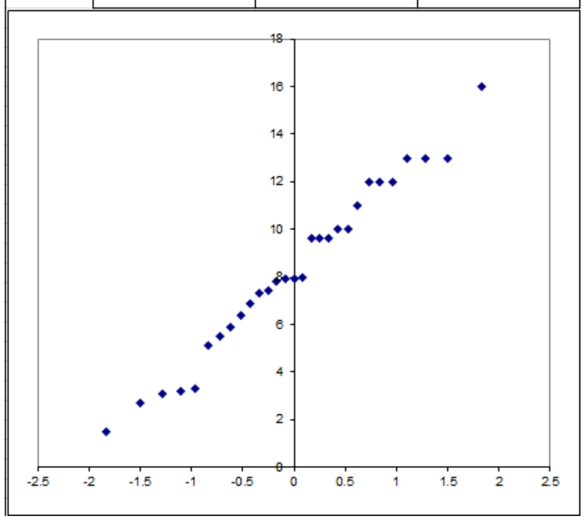

Figure A-4. SCPHD normal quantile plot—non-normality test.

Southeastern Idaho Public Health (SIPH)

The qualified TP data appears in Table A-5, and the corresponding normal quantile plot appears in Figure A-5.

Table A-5. SIPH total phosphorus qualified data.

Sample Count	SIPH TP
1	4.3
2	4.9
3	5.4
4	5.4
5	6.5
6	6.7
7	6.7
8	6.7
9	7.1
10	7.2
11	7.4
12	7.8
13	8.2
14	8.2
15	9
16	9.3
17	10
18	10
19	10
20	11
21	11
22	11
23	11
24	13
25	15

Sample Size	Critical Value Using α = .01	Critical Value Using α = .05	Critical Value Using α = .10
25	0.94074256	0.9582288	0.9661968
r Correlation Coefficient	Conclusion Using α=.01	Conclusion Using α=.05	Conclusion Using α=.10
0.98035734	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.

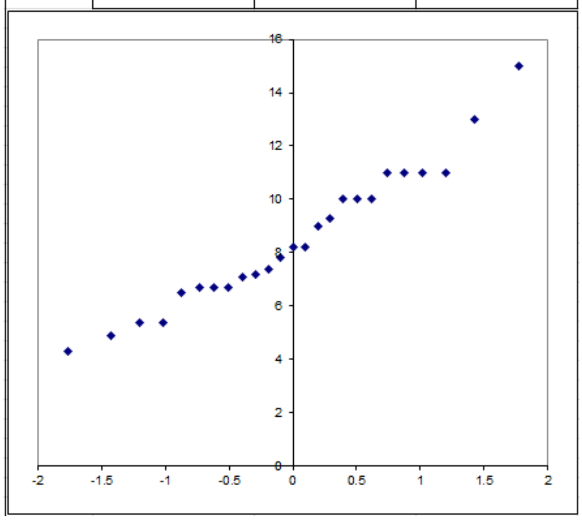

Figure A-5. SIPH normal quantile plot—non-normality test.

Eastern Idaho Public Health District (EIPHD)

The qualified TP data appears in Table A-6, and the corresponding normal quantile plot appears in Figure A-6.

Table A-6. EIPHD total phosphorus qualified data.

Sample Count	EIPHD TP
1	3.3
2	6.6
3	6.8
4	7.4
5	9
6	9.4
7	10
8	11
9	12
10	13
11	13

Sample Size	Critical Value Using α = .01	Critical Value Using α = .05	Critical Value Using α = .10
11	0.887975301	0.923008314	0.938719819
r Correlation Coefficient	Conclusion Using α=.01	Conclusion Using α=.05	Conclusion Using α=.10
0.97962195	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.	Sample data do not give sufficient evidence to warrant rejection of the claim that these values come from a normal population.

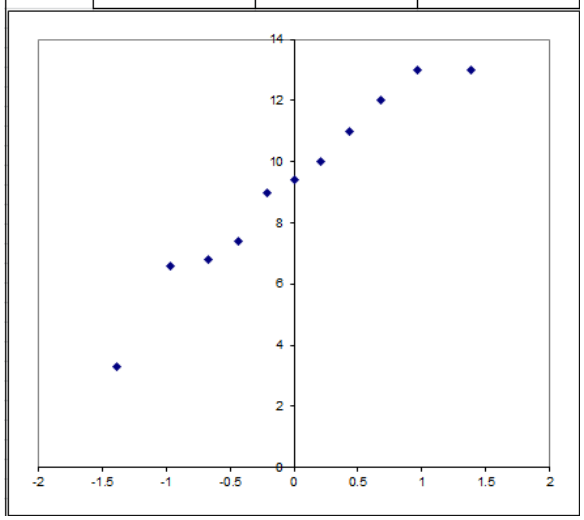

Figure A-6. EIPHD normal quantile plot—non-normality test.

Appendix B—Outlier Test

Table B-1 provides the test results for the South Central Public Health District (SCPHD) total phosphorus (TP) and soluble reactive phosphorus (SRP) data sets.

Table B-1. Rosner's test of data outliers for SCPHD.

Rosner's Test[a]						
Sample Count	**SCPHD TP**	**SCPHD TP**	**SCPHD TP**	**SCPHD SRP**	**SCPHD SRP**	**SCPHD SRP**
1	1.5	1.5	1.5	1.1	1.1	1.1
2	2.7	2.7	2.7	2.24	2.24	2.24
3	3.1	3.1	3.1	2.49	2.49	2.49
4	3.2	3.2	3.2	2.63	2.63	2.63
5	3.3	3.3	3.3	2.9	2.9	2.9
6	5.1	5.1	5.1	4.16	4.16	4.16
7	5.5	5.5	5.5	4.43	4.43	4.43
8	5.9	5.9	5.9	4.89	4.89	4.89
9	6.4	6.4	6.4	4.9	4.9	4.9
10	6.9	6.9	6.9	5.07	5.07	5.07
11	7.3	7.3	7.3	5.11	5.11	5.11
12	7.4	7.4	7.4	5.58	5.58	5.58
13	7.8	7.8	7.8	5.68	5.68	5.68
14	7.9	7.9	7.9	5.7	5.7	5.7
15	7.9	7.9	7.9	6.37	6.37	6.37
16	8	8	8	6.56	6.56	6.56
17	9.6	9.6	9.6	6.85	6.85	6.85
18	9.6	9.6	9.6	7.6	7.6	7.6
19	9.6	9.6	9.6	7.89	7.89	7.89
20	10	10	10	7.9	7.9	7.9
21	10	10	10	9.07	9.07	9.07
22	11	11	11	9.21	9.21	9.21
23	12	12	12	11	11	
24	12	12	12	48.1		
25	12	12	12			
26	13	13	13			
27	13	13	13			
28	13	13	13			
29	16	16				
30	57					
Ave =	9.9	8.3	8.0	7.4	5.6	5.4
STD =	9.6	3.6	3.4	9.0	2.5	2.2
Max =	57.0	16.0	13.0	48.1	11.0	9.2
Rosner's	4.91	2.11	1.47	4.52	2.18	1.72
App D Table 12-2	Outlier	Not an Outlier	Not an Outlier	Outlier	Not an Outlier	Not an Outlier

Notes: Numbers in red are tested outliers that have been verified as outliers.
a. EPA 2009

Appendix C—ProUCL Output

The tables below provide the ProUCL outputs from total phosphorus (TP) and soluble reactive phosphorus (SRP) analysis combined data sets. Full precision was shut off during the statistical analysis, and the confidence coefficient was set at 95% (significant level of 5%).

Table C-1 presents the general statistics generated from the TP data set with the ProUCL software. Table C-2 identifies the relevant upper confidence level (UCL) statistics for the TP data set.

Table C-1. Total phosphorus general statistics.

TP mg/L			
	General Statistics		
Number of Valid Observations	118	Number of Distinct Observations	62
Raw Statistics		Log-transformed Statistics	
Minimum	0.68	Minimum of Log Data	-0.386
Maximum	21	Maximum of Log Data	3.045
Mean	8.041	Mean of log Data	1.961
Median	7.8	SD of log Data	0.544
SD	3.692		
Std. Error of Mean	0.34		
Coefficient of Variation	0.459		
Skewness	0.582		

Table C-2. Relevant upper confidence level statistics for the total phosphorus data set.

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.0691	Lilliefors Test Statistic	0.11
Lilliefors Critical Value	0.0816	Lilliefors Critical Value	0.0816
Data appear Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	8.605	95% H-UCL	9.043
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	10.13
95% Adjusted-CLT UCL (Chen-1995)	8.62	97.5% Chebyshev (MVUE) UCL	10.96
95% Modified-t UCL (Johnson-1978)	8.608	99% Chebyshev (MVUE) UCL	12.59

The ProUCL software identified the student's-t UCL as the most appropriate UCL to use for TP. This value is reported to be 8.605 milligrams phosphorus per liter (mg-P/L).

Table C-3 presents the general statistics generated from the SRP data set with the ProUCL software. Table C-4 identifies the relevant UCL statistics for the SRP data set.

Table C-3. Soluble reactive phosphorus general statistics.

SRP mg/L			
General Statistics			
Number of Valid Observations	116	Number of Distinct Observations	108
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.552	Minimum of Log Data	-0.594
Maximum	14	Maximum of Log Data	2.639
Mean	5.882	Mean of log Data	1.637
Median	5.68	SD of log Data	0.566
SD	2.799		
Std. Error of Mean	0.26		
Coefficient of Variation	0.476		
Skewness	0.487		

Table C-4. Relevant upper confidence level statistics for the soluble reactive phosphorus data set.

Relevant UCL Statistics			
Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.0634	Lilliefors Test Statistic	0.0814
Lilliefors Critical Value	0.0823	Lilliefors Critical Value	0.0823
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	6.313	95% H-UCL	6.66
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	7.501
95% Adjusted-CLT UCL (Chen-1995)	6.322	97.5% Chebyshev (MVUE) UCL	8.14
95% Modified-t UCL (Johnson-1978)	6.315	99% Chebyshev (MVUE) UCL	9.396

The ProUCL software identified the student’s-t UCL as the most appropriate UCL to use for SRP. This value is reported to be 6.313 mg-P/L.

Figure C-1 presents the ProUCL software generated multiple Q-Q plot, combining the TP and SRP values (milligram per liter [mg/L]).

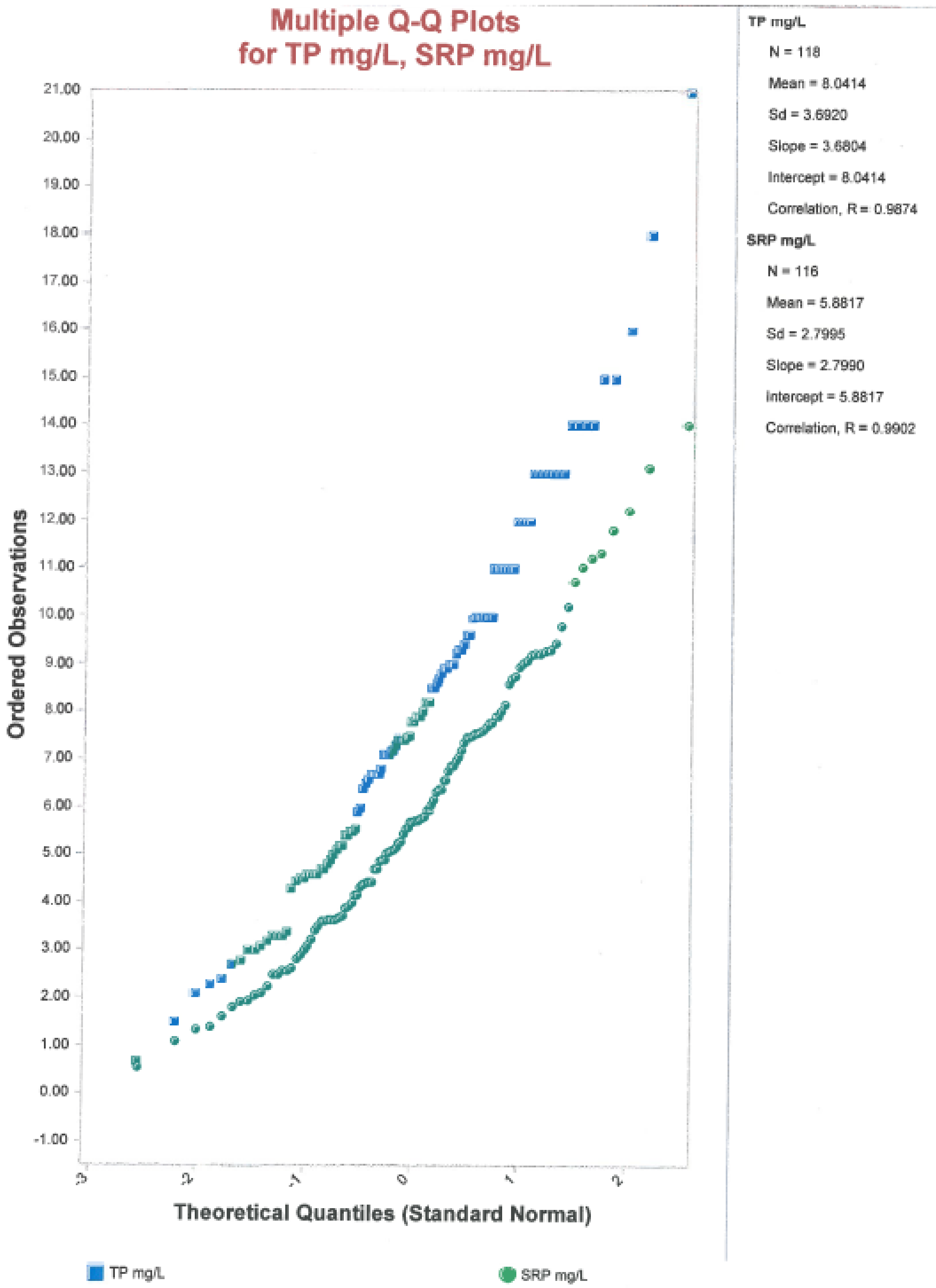

Figure C-1. Multiple Q-Q plot for total phosphorus (mg/L) and soluble reactive phosphorus (mg/L).

Figure C-2 and Figure C-3 present histograms of the data sets for TP and SRP, respectively.

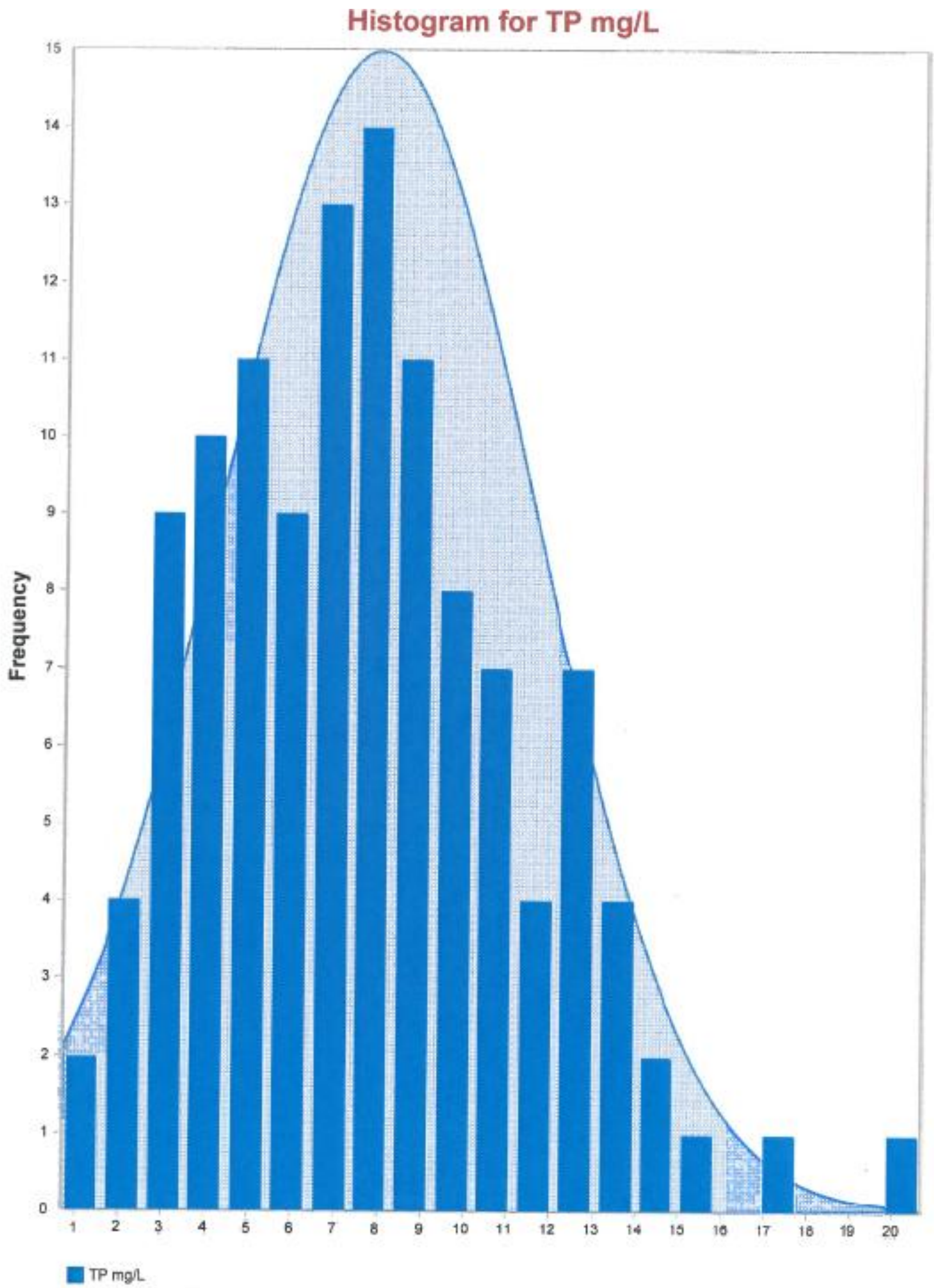

Figure C-2. Histogram of total phosphorus data set.

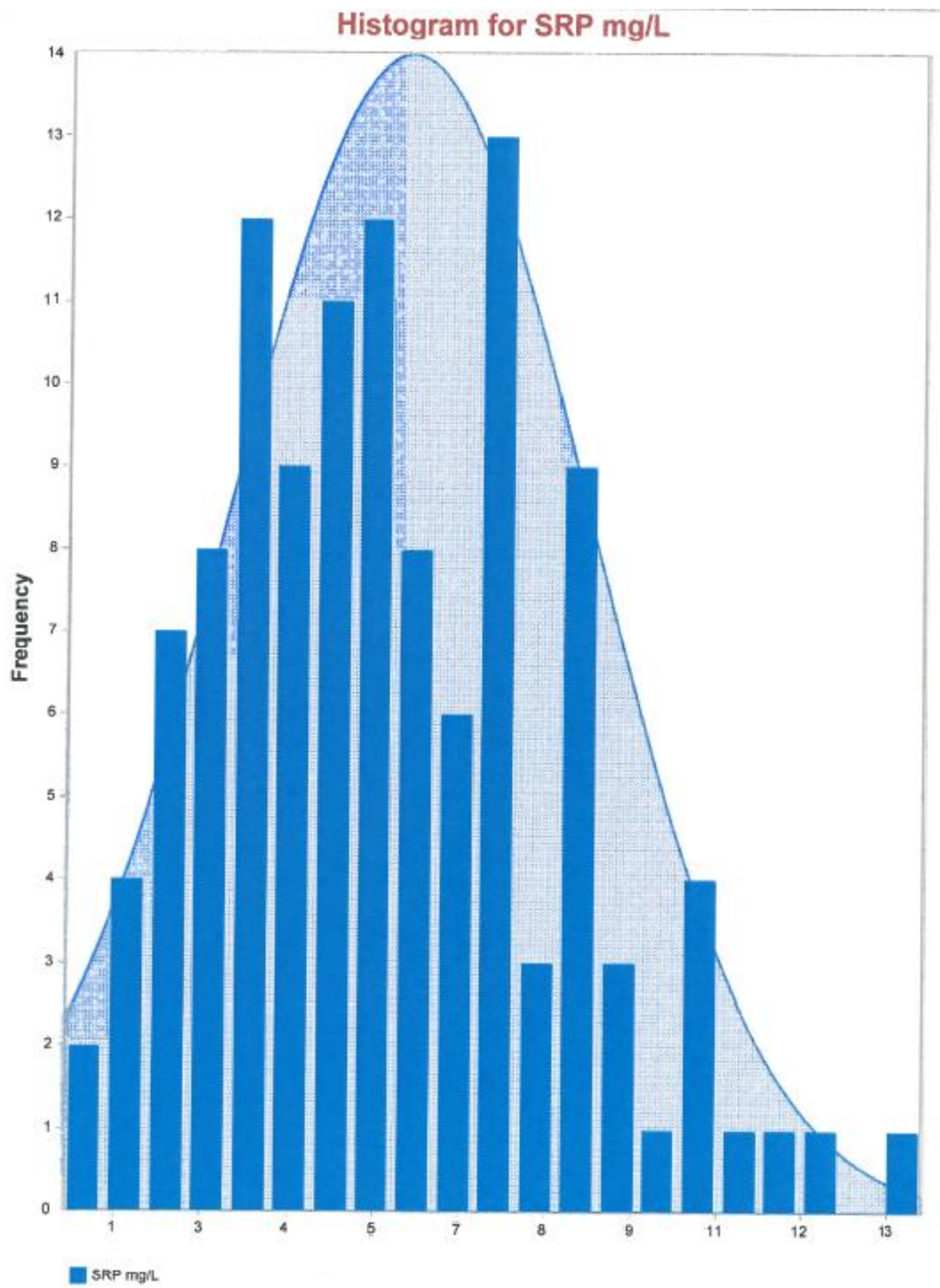

Figure C-3. Histogram of soluble reactive phosphorus data set.

Figure C-4 and Figure C-5 present normal Q-Q plots for the TP and SRP data sets, respectively.

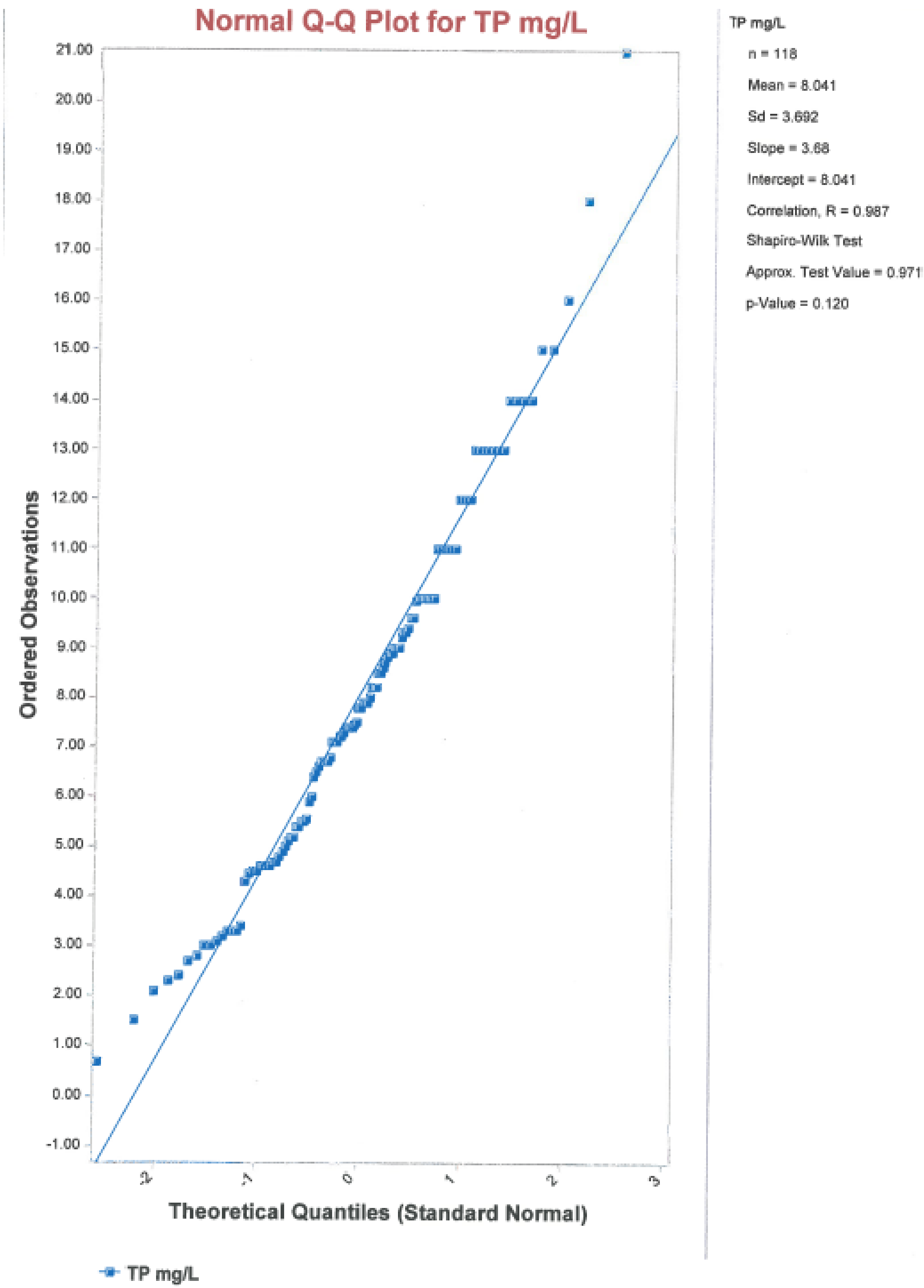

Figure C-4. Normal Q-Q plot for total phosphorus.

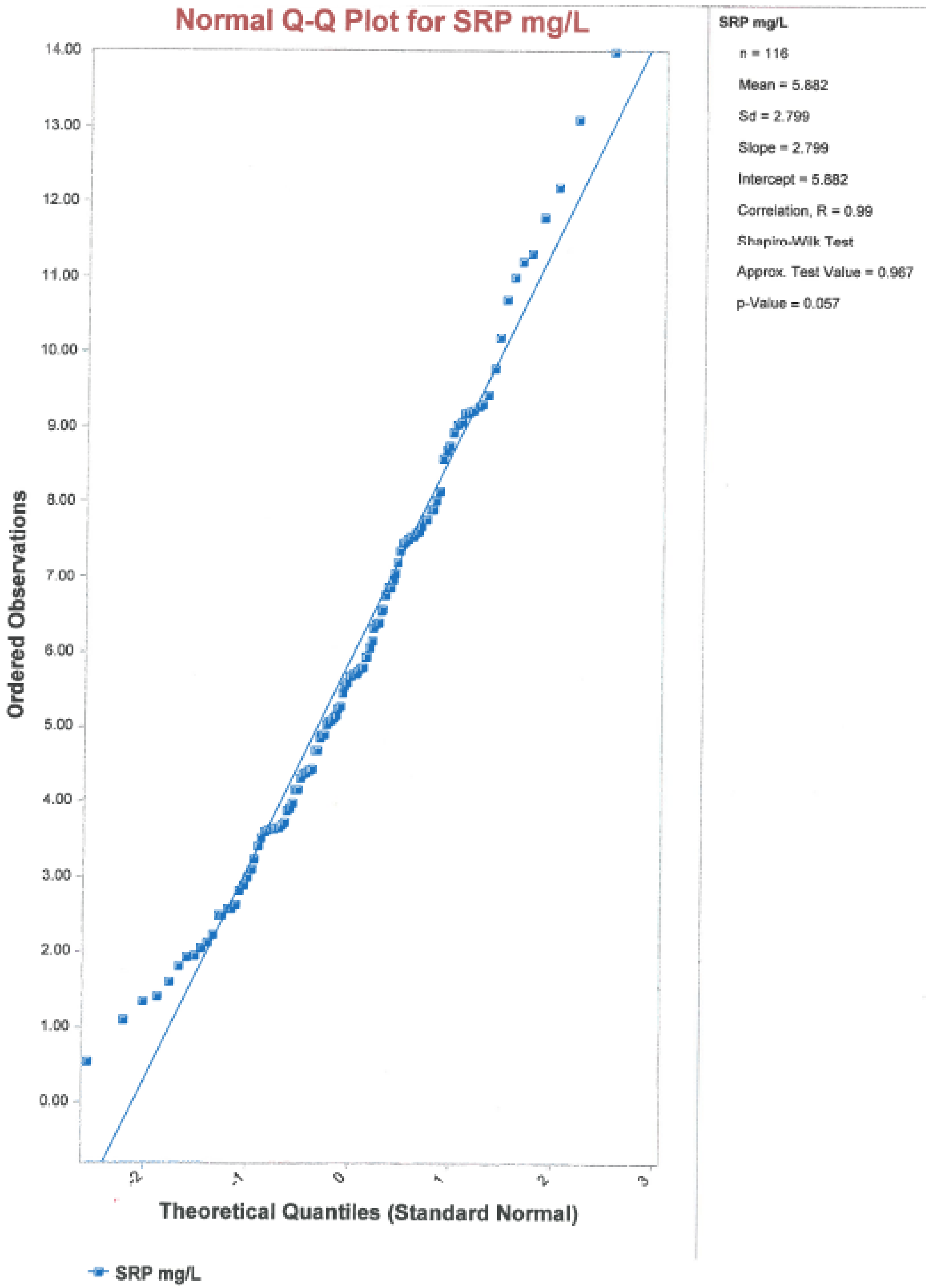

Figure C-5. Normal Q-Q plot for soluble reactive phosphorus.

Table C-5 provides the summary statistics for the raw full data sets for both TP and SRP, and Table C-6 provides the percentiles for the raw full data sets for both TP and SRP.

Table C-5. Total phosphorus and soluble reactive phosphorus data set summary statistics.

Variable	Total Phosphorus (mg/L)	Soluble Reactive Phosphorus (mg/L)
NumObs	118	116
Minimum	0.68	0.552
Maximum	21	14
Mean	8.041	5.882
Median	7.8	5.68
Variance	13.63	7.837
Standard Deviation	3.692	2.799
MAD/0.675	3.558	2.943
Skewness	0.582	0.487
Kurtosis	0.507	-0.107
CV	0.459	0.476

Notes: median absolute deviation (MAD); coefficient of variation (CV)

Table C-6. Total phosphorus and soluble reactive phosphorus raw full data set percentiles.

Variable	Total Phosphorus (mg/L)	Soluble Reactive Phosphorus (mg/L)
NumObs	118	116
5th percentile	2.785	1.903
10th percentile	3.3	2.495
20th percentile	4.7	3.61
25th percentile (Q1)	5.2	3.69
50th percentile (Q2)	7.8	5.68
75th percentile (Q3)	10	7.618
80th percentile	11	8.02
90th percentile	13	9.285
95th percentile	14	11.05
99th percentile	17.66	12.97