APPENDICES

Appendix A

Nitrogen: Focus group members are Bill Holder, P.E., and Dick Martindale, R.E.H.S.

For the most part, Nitrogen (N) is a non-reactive, highly soluble and mobile nutrient. With respect to wastewater, N becomes a concern to water quality when it is discharged to the soil, and is converted to the nitrate (NO_3^-) form. Once it enters groundwater, it will move to the eventual discharge to surface water, or other point of use, with very little change to its chemistry. Some dilution due to advective groundwater flow and dispersion occurs, but denitrification by chemical or biological reactions is generally very limited in Idaho aquifers. Some limited denitrification may occur where saturated, anaerobic conditions exist.

The concern of nitrates and water quality is generally directed at groundwater. The greatest health concern is for infants less than one year old and for young or pregnant people/animals. High levels of nitrates can be toxic to newborns, causing anoxia, or internal suffocation. The current Maximum Contaminant Level (MCL) for nitrate in drinking water is set at 10 mg/l. Total nitrogen (TN) reductions are modeled and groundwater dilution impacts accounted for in Idaho's current nutrient-pathogen (N-P) study requirements.

Few articles were available that addressed nitrate impacts to surface water, and those that were available focused on salt water environments or amphibians that were detrimentally impacted. Idaho has no numeric criteria for nitrates in surface water. DEQ Surface Water program staff stated that typically Idaho does not have Total Maximum Daily Loads (TMDLs) for nitrates. The program is not seeing cold water life impacts from nitrates but in the future may see TMDLs for total N or ammonia.

Many articles reviewed dealt with individual technology's nutrient removal efficiency. Several systems that reduce N are already approved in Idaho, but again the primary benefit is protection of groundwater.

Based on input from the professional community, review of literature, and discussions during subcommittee meetings, consensus was reached that N was not a constituent of concern that would potentially alter the existing setbacks for drainfields from surface water.

Literature reviewed includes:

Marjorie E. Bedessem, Thomas V. Edgar, and Robert Roll. *Nitrogen Removal in Laboratory Model Leachfields with Organic-Rich Layers*. April 20, 2005

Rebecca A. Efroymson; Daniel S. Jones; Arthur J. Gold, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN. *An Ecological Risk Assessment Framework for Effects of Onsite Wastewater Treatment Systems and Other Localized Sources of Nutrients on Aquatic Ecosystems*. June 25, 2008

P.M. Geary. *On-Site Domestic System Effluent Tracing in a Costal Catchment***.** On-Site Wastewater Treatment X, Conference Proceedings, 21-24 March 2004 Sacramento, California USA

George Huefelder, M.S., R.S., Susan Rask, M.S., R.S., Christopher Burt. Barnstable County Department of Health and Environment. *Performance of Innovative Alternative Onsite Septic Systems for the Removal of Nitrogen in Barnstable County*, Massachusetts 1999-2007.

A. E. Morey, A. Amoozegar. *Use of Septic Systems in Sandy Soils with a Shallow Water Table*. On-Site Wastewater Treatment X, Conference Proceedings, 21-24 March 2004 Sacramento, California USA

W. D. Robertson and J.A. Cherry. *In Situ Denitrification of Septic System Nitrate Using Reactive Porouos Media Barriers: Field Trials*. Vol. 33, No. 1 – Ground Water – January-February 1995

H. L. Leverenz, G. Tchobanoglous, J. L. Darby. *Comparison of Pretreatment Systems for the Onsite Management of Wastewater*. On-Site Wastewater Treatment X, Conference Proceedings, 21-24 March 2004 Sacramento, California USA

Michael McIntyre, Tonia Mitchell, IDEQ Water Quality Division. Personal communications during Subcommittee meeting. January 27, 2010

Appendix B

EMERGING ENVIRONMENTAL CONTAMINANTS (PPCP'S AND EDC'S)

Focus group members are Nathan Taylor, R.E.H.S., John Corcoran, Realtor Association, and Brett Skidmore, Building Contractors Association.

Domestic waste water contains many environmental contaminants. Pathogens (viruses, bacteria, protozoa, etc.) and nutrients (phosphorous, nitrates, ammonia, etc.) are well known contaminants and have been studied quite extensively over the years. Recently, we have become aware of a new group of potential environmental contaminants called pharmaceutical and personal care products, and endocrine disrupting compounds (PPCP's and EDC's).

PPCPs comprise a very broad, diverse collection of thousands of chemical substances, including prescription and over-the-counter therapeutic drugs, fragrances, cosmetics, sun-screen agents, as well as many others. EDC's are chemicals that alter the endocrine system and have hormonal effects on humans and animals. Potential EDC's could be personal care products, pharmaceuticals, pesticides, herbicides, metals, or many others.

Through our waste streams, these chemicals end up at the municipal wastewater treatment plant or in our onsite septic systems. Municipal wastewater treatment plants are not designed to remove these chemicals; therefore most of them are being discharged into surface waters throughout the country.

How efficient are onsite septic systems at removing PPCP's? Are these chemicals passing through septic systems and into the groundwater? How efficient is the soil at removing these contaminants, and how close to surface waters should we allow septic system drainfields? How quickly will these chemicals end up in our drinking water, and ultimately, how will ingesting these chemicals effect our health and well being. How will these chemicals affect all forms of life?

Currently, the answers to these questions are being researched. Little hard evidence is known. Many ongoing studies are being conducted nationwide, but it will be years before we understand the fate, transport, and treatment of some of these chemicals through septic systems. In the interim, maintaining a conservative separation distance between septic system drainfields and surface or ground water is of vital importance. Failure to do so could have devastating consequences.

Appendix C

IDEQ Surface Water Separation Committee
Pathogens Sub-Committee Publication Review Whitepaper
Research By: J. D. Canning, PE/PLS, & Allen Worst
Date: July 13th, 2010

Introduction:

According to the USEPA Onsite Wastewater Treatment Systems Manual, pathogenic microorganisms found in domestic wastewater include a number of different bacteria, viruses, protozoa, and parasites that cause a wide range of diseases. These pathogens pass from the human body, through the plumbing system, to the septic treatment system and eventually out to the subsurface infiltration/leach field system. The goal of any effective subsurface disposal system is to filter or deactivate the pathogens before they reach surface or ground water.

Bacteria of various types are typical and widespread in domestic wastewater. Because of their ability to multiply outside of a host and widespread availability, bacteria are of primary concern in the protection of human health. The removal of bacteria in soils is affected by many conditions including, but not limited to: initial numbers, types of organisms, temperature, humidity, amount of sunlight, and soil texture. Improvements in bacteria reductions at the drainfield system have been attributed to unsaturated conditions, uniform distribution, fine soil textures, to name a few.

Viruses are not a normal septic waste component and appear in septic systems intermittently. Viruses only occur in the waste of humans who have been infected. It is estimated that less than 1 to 2 percent of stools excreted in the United States contain enteric viruses.

A reduction in virus counts of nearly one log is recognized as viruses pass through a typical septic tank with, up to, an additional 2 – 3 log reduction is achieved in some types of secondary treatment package systems. Like bacteria, virus removal rates are heavily dependent on soil conditions at the drainfield site. Viruses tend to be less affected by filtration and more resistant to inactivation by disinfection.

Protozoa and parasites can be found in human waste. Due to their rather large relative size compared to viruses and bacteria, physical filtration in the soil is considered the primary removal mechanism. Little research has been discovered on protozoa and/or parasite removal in soils.

Summary of Research

1. Source: EPA Design Manual – On-site Wastewater Treatment and Disposal Systems – Date: October 1980

   Information: Page 207 - Section 7.2.1 – Introduction – Effluent "travel through two to four feet of unsaturated soil is necessary to provide adequate removals of pathogenic organisms and other pollutants from the wastewater before it reaches the groundwater."

2. Source: EPA Design Manual – On-site Wastewater Treatment and Disposal Systems – Date: February 2002

   Information: Page 3-33: "Normal operation of septic tank/subsurface infiltration systems results in retention and die-off of most, if not all, observed pathogenic bacteria indicators within 2 to 3 feet (60 – 90 centimeters) of the infiltrative surface (Andreson et al., 1994; Ayres associates, 1993a, c;

Bouma et al., 1972; McGauhey and Krone, 1967)." Furthermore, "With a mature biomat at the infiltrative surface or coarser soils, most bacteria are removed within the first 1 foot (30 centimeters) vertically or horizontally from the trench-soil interface (University of Wisconsin, 1978). Hydraulic loading rates of less than 2 inches/day (5 centimeters/day or 1.2 gallons/ft^2/day) have been found to promote better removal of bacteria in septic tank effluent (Ziebell et al., 1975). Biomat formation and lower hydraulic loading rates promote unsaturated flow, which is one key to soil-based removal of bacteria from wastewater the retention behavior of actual pathogens in unsaturated soil might be different from that of the indicators (e.g., fecal coliforms) that have been measured in most studies.

3. Source: "Effects of Soil Permeability on Virus Removal Through Soil Columns" – Published in "Applied and Environmental Microbiology" – Date: July 1981 – Authors: De-Shin Wang, Charles P. Gerba and J. Clarence Lance

   Information: This article used four different soil types with wastewater applied at varying application rates from 33 cm/day (13 in/day – 8 gals per square foot per day) to 1,352 cm/day (530 in/day – 330 gals per square foot per day) over a soil column that was 100 cm (39 inches) long. The soils were sands or sandy loams ranging in sand content from 92 to 77 percent, silt content from 8 to 10 percent and clay content from 3 to 13 percent. Not surprisingly the columns performed best at the lower loading rates (33 cm/day), with the sandy loam material removing 99% of seeded poliovirus within the first 7 cm (3 inches) of the soil column. Even at flow rates of 300 cm/day (120 in/day – 14 gals per square foot per day) the poorest soil (one with highest sand content) removed 90% of the seeded viruses within the 100 cm (39 inch) soil column.
   It should be noted that the loading rates used in this study were substantially higher than the loading rates prescribed in Idaho Rule and the Idaho Technical Guidance Manual. The loading rates ranged between 8 to 330 gallons per ft^2/day in the study to 1.2 to .2 gallons per ft^2/day in Idaho's rule and guidance. It is unlikely that unsaturated conditions existed in the column tests performed. Unsaturated soil/sand condition testing was not a focus of this study.

4. Source: "The Potential for Ground Water Contamination from Septic Effluents" – Published in "Journal of Environmental Quality" – Date: January-March 1981 – Authors: C. Hagedorn, E. L. McCoy and T. M. Rahe

   Information: "Septic systems which exhibit proper hydraulic functioning also served to purify septic effluent." "The large population of total coliforms, fecal coliforms and enterococci present in septic tank effluent were reduced to levels associated with control samples within 61 cm (24 inches) below the percolation trench. In addition, the most abrupt population declines occurred in the 'biological mat or clogged zone' located at the interface of the drainfield trench and the soil." "Approximately 30-90 cm (12-35 inches) of soil beneath the base of the drainfield trench was adequate for complete bacterial removal of septic effluents provided the soil has both a layer permeable to effluent flow and another region adequately restricted to form a clogged zone". "Coliforms and other microorganisms move only a few dozen centimeters with the percolating waters in unsaturated soil layers although much greater distances are possible under saturated flow conditions." This article contains Table 1 that shows maximum travel distances for a variety of pollution sources and travel medium.

5. Source: "Virus Movement in Soil During Saturated and Unsaturated Flow" – Published in "Applied and Environmental Microbiology" – Date: February 1984- Authors: J. C. Lance and C. P. Gerba

   Information: "Viruses did not move below the 40 cm (16 inches) level when sewage water was applied at less than the maximum infiltration rate; virus penetration in columns flooded with sewage was at least 160 cm (65 inches)." The soil column was loamy sand. Application rates ranged from 32.5 cm/day (13 inches/day – 8 gals per square foot per day) to 100 cm/day (39 inches/day – 25 gals per square foot per day). Based on this study, it appears that unsaturated flow conditions are favorable when vertical virus movement is a concern. It should be noted that the

applications rates of wastewater in the studied columns were substantially higher than the loading rates prescribed in Idaho's Guidance and Rule.

5. Source: "Performance of Engineered Treatment Units and Their Effects on Biozone Formation in Soil and System Purification Efficiency" – Submitted by the Colorado School of Mines – Date: September 2005 – Authors: Van Cuyk, S., R. L. Siegrist, K. Lowe, J. Drewes, J. Munakata-Marr, and L. Figueroa

   Information: "The ability of an Ascalon sandy loam soil to remove virus was quite high by 60 cm (24 inches). At that depth it was insensitive to whether the natural soil had received septic tank effluent, textile filter unit effluent or membrane bioreactor effluent at experimental design hydraulic loading rates of either 2 (0.8 inches/day – 0.5 gallons per square foot per day) or 8 cm/day (3 inches/day – 2 gallons per square foot per day)."

6. Source: "In-Situ Lysimeter Investigation of Pollutant Attenuation in the Vadose Zone of Fine Sand" – Funded by the Florida Department of Health and Rehabilitative Services - Authors: D. L. Anderson, R. J. Otis, J. I. McNeillie and R. A. Apfel

   Information: Regarding delivery of septic tank effluent to the infiltration system, "The vadose zone thicknesses investigated were 0.6 and 1.2 meters (2 and 4 feet) for each experimental condition. The hydraulic loading rates investigated were 3.1 and 6.1 cm/day (0.75 and 1.5 gdp/SF)." "No positive sample results were obtained for fecal coliform or fecal streptocouccus bacteria below the infiltration systems at any of the variable levels, indicating that significant attenuation of these fecal indicators also occurred in the sandy soil."

7. Source: "Wastewater: Emergent Environmental and Health Issues" – Small Scale Waste Management Project #6.10, University of Wisconsin, Madison – Date: October 1981 - Author: Dean O. Cliver

   Information: This article summarizes data from other studies and discusses the public's perception of wastewater. However it does provide some points gleaned from other studies that are of interest. Although not quantitative in nature, the points are important. The points are: 1) "Media courser than sand are unlikely to be effective in removing viruses from septic tank effluent, and saturation of the medium appears to allow viruses to persist and be transported over considerable distances in an infectious condition." 2) "Virus that is retained either by absorption or adhesive will gradually lose its infectivity as a result of physical and chemical effects of the environment. The rate of loss is especially dependant on the temperature of soil" 3) "Bacteria do not appear to travel as far as viruses through saturated of unsaturated soil; however, a properly operated, unsaturated soil treatment system should be able to contain both viral and bacterial pathogens."

8. Source: "The Effects of Effluents on Groundwater: Bacterial Aspects" – Small Scale Waste Management Project #6.6, University of Wisconsin, Madison – Date: November 1975 - Author: E. McCoy, W. A. Ziebell

   Information: The article notes that "while it has been shown that remarkable purification can be achieved in non-aggregated soil under conditions of established (partial) clogging and proper flow regime, it must be remembered that many soil conditions are less efficient in providing bacterial removal. During initial periods of operation (prior to clogging) conventional soil absorption systems do not provide ideal removal. Similarly channeling, effected by voids between soil aggregates, can result in movement of bacteria to depths of 2 or more feet in aggregated soils, especially under dry conditions. Under such conditions a deep soil profile (or further treatment of effluent) must be present to insure adequate purification. It is impossible to state with certainty the precise number of feet of soil which will retain contaminants. Three types of soil conditions which would prevent safe soil disposal are: 1) shallow soils over creviced bedrock, 2) shallow soil over

high groundwater tables, and 3) impermeable soils. In recognition of the retention capabilities of soil, our Small Scale Waste Management Project has written guidelines to be used on an experimental basis in some problem areas of Wisconsin. These guidelines delineate procedures for installing sand-fill systems (mounds), 2 feet in depth, over 2-5 feet minimum of naturally occurring soil. Such systems employ pressurized distribution to insure proper loadings and flow conditions."

9. Source: "Removal of Virus from Septic Tank Effluent by Sand Columns" – Small Scale Waste Management Project #6.3, University of Wisconsin, Madison – Date: 1975 - Author: K. M. Green, D. O. Cliver

Information: This article, as many, discusses sand as a treatment media. It states, "Sand has been shown to be effective in removing poliovirus, a presumably typical human intestinal virus, from septic tank effluent. A properly operating sand filtration system should produce effluents that present no hazards from human enteric viruses. However, there are factors which must be taken into account in the design of such systems. The longer the path through the sand, the better, although we have not always found a direct relationship between column length and virus removal, and there may be a point of diminishing returns. The temperature of operation is important: at low temperatures the sand is less retentive and the virus is inactivated more slowly, if at all. Conditioning (nutrients in the waste stream) must also be taken into consideration. (Higher loading of nutrients may reduce the sand's ability to properly attenuate virus.) The retentiveness of the fill decreases markedly after a few weeks of operation. Finally, dose rate is critical; if the pores between the sand grains are continuously saturated with fluid, a significant proportion of the virus will not absorb to the sand."

10. Source: "Soil Treatment Performance and Cold Weather Operations of Drip Distribution Systems" – R. M. Bohrer and J. C. Converse.

Information: This article examined six drip distribution sites in Wisconsin. Three of the sites received septic tank effluent, one received recirculating gravel filter (RGF) effluent and two sites received effluent treated by aerobic treatment units. The soils at these sites ranged from coarse sand to clay loam. The depth of the drip-lines ranged from 4-20 inches below ground surface. The findings of this study are as follows:

> The systems receiving STE showed very low fecal coliforms at 45-60 cm (18-24 in.) below the dripline with no detects below 60 cm (24 in.). The system with pretreatment showed even better results, both for the RGF, which was very heavily loaded, and the ATU systems. This could probably allow for a reduction in the separation distance to 45 cm (18 in.) for systems receiving STE and 30 cm (12 in.) if the effluent is aerobically pretreated to a fecal coliform livel of <100 colonies/100ml.

11. Source: "Virus, Phosphorus, and nitrogen removal in onsite wastewater treatment processes" – J. L. Darby and H Leverenz

Information: Research done at the UC Davis wastewater treatment facility examined various treatment mechanisms including: a standard septic tank systems followed by sand trenches, three high porosity, high surface area multi-pass biofilm reactors, two submerged aerated biofilm reactors, and soil basins which were used to evaluate the fate of contaminates after discharge to the soil disposal system. Total coliform counts, fecal coliform counts, and coliphage counts were used to determine the effectiveness of the above treatment mechanisms in removing viruses. It was determined that 16.5 and 25.3 percent virus removal was achieved in the septic tank alone, 82 percent in the aerobic biofilter, 84.97 percent in textile biofilters, 87.5 percent with septic tanks combined with aeration, 97.28 percent with sand beds, 99.88 percent with sand beds and aerated tanks, 100% with textile biofilters and 18" of loam soil, and 100% in all systems after passing through 30" of Yolo loam soil.

12. Title: Research Needs in Decenteralized Wastewater Treatment and Management – Fate and Transport of Pathogens - Dean O. Cliver, Ph. D.

Information: The study primarily looked at available research and determined needs for additional research in determining the effectiveness of alternate wastewater treatment systems to prevent the transmission of pathogens by the water route. The study discussed bacteria, viruses, and parasites. It was suggested that a 74% reduction in viruses occurs in the septic tank alone. The soil vadose zone was determined to be an important mode of wastewater purification. Often small-scale systems are at a relative disadvantage from the standpoints of cost and maintenance with regard to disinfection. Even saturated flow can be expected to accomplish some purification, but it is clear from column studies that the greatest removal of viruses occurs in the vadose zone or unsaturated soils layers. The research on distribution systems was examined and the following is quoted directly from this paper:

> The effectiveness of soil as a treatment medium also depends on how the wastewater is applied. The existence of an adequate vadose zone is moot if the wastewater enters the soil in a concentrated plume that displaces the air along its path. This may occur early in the life of a gravity distribution system, in that the wastewater arrives at a small portion of the constructed infiltrative surface and enters, rather than being widely distributed over the surface of the bed. Pressure distribution systems are designed to attain uniform distribution from the start-up, but conventional, gravity system may eventually perform well after some period in service.

General Comments:

#1: As long as flows in drainfields and the underlying soil infiltration area remain <u>unsaturated</u>, reasonable vertical separation distances to groundwater for sandy soils appear to be 60 cm (24 inches) or even as shallow as 40 cm (16 inches).

#2: As the soils become finer, the separation distances may be less.

#3: Experimental testing of pathogen removal in soil columns was typically completed at extremely high loading rates.

#4: Once saturated conditions occur, pathogens in septic tank effluent can travel horizontal distances in fine sands of as much as two or three hundred feet. But the information regarding this horizontal travel of pathogens in saturated conditions, was not specific testing, but more informational. Also most of the situations observed were not septic system drainfields, but more intense operations (i.e. rapid infiltration basins, etc.).

#5: Articles noted the importance of pathogen attenuation in the drainfield bio-mat. It also should be noted that the presence of a bio-mat contributes to the creation of unsaturated conditions in the soil below the bio-matted area. Properly distributed and dosed effluent can create the same unsaturated conditions without the presence of biomatted soils.

#6: It would appear that very small setbacks from surface waters are needed for pathogen removal, if flows remain unsaturated. From my perspective, one suggestion is that systems be properly distributed and dosed (pressurized systems or drip disposal) to help assure unsaturated flow conditions, if reduced horizontal separation to surface waters is proposed.

#7: Highly aggregated soils must be discounted for their ability to effectively treat septic tank effluent for pathogens. Current practices in Idaho conform to this recommendation.

1989 challenge to 1985 Rules

Hearing examiner's comments to HCR 53

Setback distances:

reiterated the wishes of one commenter.
"He also requested that distance set-backs from surface water be limited to 100', regardless of soil type, citing testimony given during the 1985 hearings, (exhibit 70). He stated that the contiguous states of WA. OR, MT, UT, and NV have only 100' requirements; and that lagoons are not required to be more than 100' from surface waters. In a letter, (exhibit 8), he claims IDHW has no scientific study proof that more than 100' set-backs are needed. He asked to delete the set-back part of the regulation, (16.01.3008,02.d.), unless the IDHW can provide scientific study proof that 200 and 300' set-backs are required."

recommendations

3. Change the distance set-back, (separation distance), requirements from surface waters, (16.01.3008,02.d.), to 100' for all soils unless the IDHW staff can provide convincing, scientifically based authority to prove the need for greater set-backs. (Compelling arguments have been made that 100' set-backs are safe, [page 3 of report, plus exhibits 8 and 70]. An allegation has been raised that IDHW cannot provide convincing, scientifically based authority to prove the need for greater set-backs. IDHW staff should be allowed to answer those allegations.)

IDHW response

Change the distance separation requirement from septic systems to surface water to 100' for all soils. The Division does not support this recommendation. The technical justification for requiring a separation distance increase from 100 ' incrementally to 300' based on soil texture, is well documented in the 1985 Administrator's Responses to individual testimony. This section of the rules, more than any other, addresses the concern stated in HCR 53 that the regulations are not site specific enough in that each site is arrived at and a particular type of individual sewage treatment system is designed. In addition to the literature cited in the 1985 report, the justification for variable separation distances is also supported by the following:

a. Hagadorn (1983) "...bacteria can migrate considerable distances in the subsurface given proper conditions. In fractured rocks and coarse sand grain soils bacteria can move quite rapidly. For example, in a sand and gravel aquifer coliform bacteria have been isolated 100' from the source just 35 hours after sewage was introduced."

b. Bingham county 208 study found bacteria travelling up to 2,000' under saturated conditions in coarse gravel and bedrock.

c. Keswich and Gerba (1980) have found viruses moving up to 220' in depth and as far as 1310 feet horizontally in sandy soil.

d. Vaughn et. al., (1983) directly studied the movement of viruses from a septic tank to a ground water well and found viruses could move as far as 213' and live up to 131 days in ground water.

e. Stramer (1984) found polio virus in lake water 152 feet from the septic tank 71 days after it was injected.

f. Hagadorn (1984) found that many bacteria are filtered out depending on soils and soil pore size if the soils are unsaturated.

The literature actually supports having greater separation distances to surface water. However, the Division believes that the distances as proposed and used since 1985 protect the public health and the environment in the majority of cases.
No change recommended.

Leachate

"Since the character of soil and rock, quantity of rain, rate of ground water flow, amount of pollution, bacteria growth media, and other factors beyond control are variable, one cannot say with certainty through what thickness or distance sewage must pass to be purified" (Salvato, 1972).

"Septic systems are designed to work best under a specified set of environmental conditions and may not function properly under other conditions. More specifically, because conventional septic systems depend on the soil for wastewater treatment and disposal, consideration of soil and site conditions is critical to designing and siting an effective septic system. Ground water contamination occurs when the hazardous constituents in septic system effluent enter the ground water without being adequately treated or retained in the soil. This may be caused by soil or geologic characteristics such as highly permeable gravel layers, creviced limestone, clay layers with major macropores caused by shrinking and swelling, or other formations that allow partially treated effluent to by pass soil layers and enter the ground water" (EPA, 1986, p.8).

"Septic Tank leachate is the most frequently reported cause of ground water contamination" (EPA, 1977).

"As the septic tank effluent percolates through the soil, its bacteriological quality changes depending upon the characteristics of the subsurface environment." "Many bacteria are large enough to be filtered out as the water moves through the soil pores, thus limiting the depth of penetration. Another limitation on the distances bacteria can travel is the moisture content of the soil; bacteria can move greater distances in saturated soil than in unsaturated soil ((Hagadorn, 1984). in EPA June 1987, p.9).

"One common reason for degradation is that the capacity of the soils to absorb effluent from the tank has been exceeded, and the waste added to the system moves to the soil surface above the lateral lines. In addition many soils with high hydraulic absorptive capacity (permeability) can be rapidly overloaded with organic and inorganic chemicals and microorganisms, thus permitting rapid movement of contaminant from the lateral field to the ground water zone" (Cantor and Knox, 1984).

"Many environmental factors can influence transport rate, including rainfall, soil moisture, temperature, pH and availability of organic matter" (Cantor and Knox, 1984).

Bacteria

"...Bacteria can migrate considerable distances in the subsurface given the proper conditions. In fractured rocks and coarse grained soils, bacteria can move quite rapidly." (EPA, June 1987)

"Under saturated conditions, bacteria can travel up to 2,000 feet in coarse gravel and bedrock." (Bingham Co. 208 study)

"Removal by filtration and inactivation notwithstanding, bacteria can migrate considerable distances in the subsurface given the proper conditions. In fractured rock and coarse grain soils bacteria can move quite rapidly. For example, in a sand and gravel aquifer coliform bacteria have been isolated 100 feet from the source just 35 hours after sewage was introduced" (Hagadorn, 1983).

Bacteria can move considerable distances in the soil; Kudryavtseva (1974) reports that bacteria were transported 1,000 meters through a weathered limestone aquifer.

Viruses

"Most people have at least one virus infection every year, so it is likely that a septic tank system will receive virus-laden waste water at some time over the course of a year (Sobsey, 1983)

"Viruses can travel considerable distances in the subsurface; depths as great as 67 m (220 feet) and horizontal migration as far a 400 m (1,310 feet) have been reported" (Keswich and Gerba, 1980).

"Viruses can penetrate 60 feet of sand and gravel and can move horizontally up to 600 feet." (Schuab et al., 19)

"Viruses have been found to migrate in soils to distances greater than 600 feet from their source" (Allen, 1978)

"Viruses in particular, due to their small size (20 to 200 nm) and long survival times, can migrate very large distances in soil and ground water; as much as 1,600 m (5,250') have been reported for certain viruses in karst terrain (Gerba, 1984b) and up to 400 meters (1,312') in sandy soil (Keswich and Gerba, 1980)" (Yates and Yates, 1989).

"There have been studies that directly examined the movement of viruses from a septic tank to a ground water well (Hain and O'Brien, 1979; Stramer, 1984; and Vaughn et al., 1983). These studies showed that viruses could move as far as 65 meters (213') from the septic tank (Vaughn et al., 1983) and persist up to 131 days in the ground water (Stramer, 1984). Based on the results of these studies, it becomes clear that a setback distance of 15 to 30 m (50 to 100')may not be adequate to prevent viral contamination of ground water, and possibly waterborne disease outbreaks, under certain environmental conditions" (Yates and Yates, 1989).

"In a septic system on a lake shore which received intermittent use, mainly on weekends, virus were isolated in groundwater wells 40.5 feet (12.3 m) and 67.5 (20.6 m) from the septic tank after eight days. One week later viruses were detected in a well 94.5 feet (28.8 m) from the septic tank. On days 43 and

71 after virus introduction poliovirus was isolated from the lake water 152 feet (46.2 m) from the septic tank and from lake sediment on day 109. (Stramer, 1984)

"Yates et al. (1986) and Yates and Yates (1987) demonstrated the variability in setback distances over a city-wide area that resulted when hydrogeologic variables and virus inactivation rates at each well were used in the setback calculations" (Yates and Yates, 1989).

C-TLO's

C-TLO's are chromatographable trace-level organics; several classes of C-TLO's together account for most C-TLO's that persist in ground water are chlorinated hydrocarbons, plasticizers, antioxidants, and aromatic solvents.

1) Many domestic septic tank effluents contain more than 100 C-TLO's in the ug/L range with potential impact on groundwater. Many of these can be accounted by products used in a normal household.

2) In sandy soils, significant C-TlO compounds may be detected up to 61 m (200 feet) away from the leach field, even though removals for the initial concentrations added to the leach field were greater than 90%. A short distance in the leach field (about 15 m) is probably not sufficient for significant C-TLO removal. (Tomson et al., 1984)

Following is a brief comparison of the existing "1985 Rules and Regulations for Individual and Subsurface Sewage Disposal Disposal Systems" and the previous 1978 Regulations.

1978 Regulations	1985 Regulations
1. Unclear as to who is responsible for compliance with regulations.	1. Clearifies responsible party as the owner or anyone receiving compensation for materials, design or construction of the system.
2. Limited definition of terms (5)	2. Expanded definitions section, greatly clarifying regulations (36)
3. Does not define "failing system".	3. Defines "failing system" as failing to accept wastewater or discharging wastewater to surface water or groundwater.
4. Requires 4 feet separation from absorption system bottom to maximum seasonal groundwater.	4. Allows 6 feet to 3 feet separation to normal seasonal (6 week average high). Separation dependent on soil type. (Alternative systems approvable to within 1 foot of groundwater.
5. Allows absorption trenches, deep absorption trenches, absorption beds and seepage pits as standard systems.	5. Allows absorption trenches and absorption beds as standard systems.
6. Allows alternative systems on a case by case basis after approval of the Director with no guidance.	6. Allows alternative systems (22, including seepage pits) with guidance from a Technical Guidance Manual which is maintained by a Technical Guidance Committee composed of State, District, and private professional people.
7. Uses percolation tests to size systems. (found to be unreliable).	7. Uses soil texture and classification to size systems. (Found to be more reliable).
8. Requires a 300 foot separation from surface water to system.	8. Allows 300', 200' or 100' separation to surface water depending on soil.

1978 Regulations	1985 Regulations
9. No site specific field variance from the regulations is allowed.	9. Allows up to 10% variance from reg- by decision in the field that the variance would not violate the intent of the regulations.
10. No specific variance procedure provided by regulations.	10. Specific variance procedure outlined by the regulations.
11. Allows steel septic tanks (susceptable to corrosion).	11. Prohibits steel septic tanks.

The above regulations comparison does not list every change from the 1978 to the 1985 regulations. Rather it is a brief outline of major differences.

Prepared by: Rick Mallory - March 31, 1989

Appendix D

Summary of Soil and Groundwater P Dynamics

Focus group members are Jim Ippolito, Ph.D, A.J. Maupin, P.E., and George Miles, P.E.

Note: Most of this information was taken from the "Phosphorus geochemistry in septic tanks, soil adsorption systems, and groundwater" document prepared by Lombardo Associates, Inc. The document outlines P reactions that are similarly outlined and discussed in numerous journal articles which target P reactions in the environment.

Soil P Dynamics:

Phosphorus chemistry in wastewater treatment systems is governed by physical, chemical, and/or biological processes.

Approximately 20-30% of wastewater P is removed in septic tanks.

Phosphorus removal in soil adsorption systems is primarily achieved by adsorption onto mineral phases and mineral precipitation.

Research suggests that the dominant P minerals responsible for P removal are iron and aluminum precipitates.

Phosphate adsorption to mineral surfaces is very complex and a variety of techniques have been used to describe it. In many instances this can be described by the Freundlich isotherm.

In soil adsorption systems, Fe and Al phosphate-precipitate stability is governed by soil pH, redox conditions, and the chemistry of Fe and Al.

As soil pH decreases from ~6.5, the stability of Fe- and Al-phosphate minerals increases (i.e. their solubility decreases); at a pH of ~6.5 Fe- and Al-phosphate mineral solubility is greatest. Above a pH of 6.5, P in soils is typically governed by Ca-phosphates.

- It is important to note that Ca in soils does not sequester P to the extent that Fe and Al species sequester P.

Redox conditions affect Fe-phosphate precipitates, as Fe can be found in the +3 (III; oxidized) or +2 (II; reduced) state (Figure 1). Under oxidizing conditions, the controlling phases can be amorphous hydroxyapatite, beta tricalcium phosphate, strengite or variscite, depending on pH. Iron reduction is typically caused by Fe-reducing bacteria (IRB). When Fe(III)-phosphate species undergo redox conditions, they dissociate and do not always reprecipitate as Fe(II)-phosphate species (vivianite: $Fe_3(PO_4)_2x8H_2O$). Depending on soil pH and reduced conditions, Fe(II) can remain aqueous, precipitate as magnetite (Fe_3O_4; mixed Fe(II/III) species), siderite ($FeCO_3$), or vivianite.

Redox conditions do not directly affect Al-phosphate precipitates, because Al is only found in the +3 state.

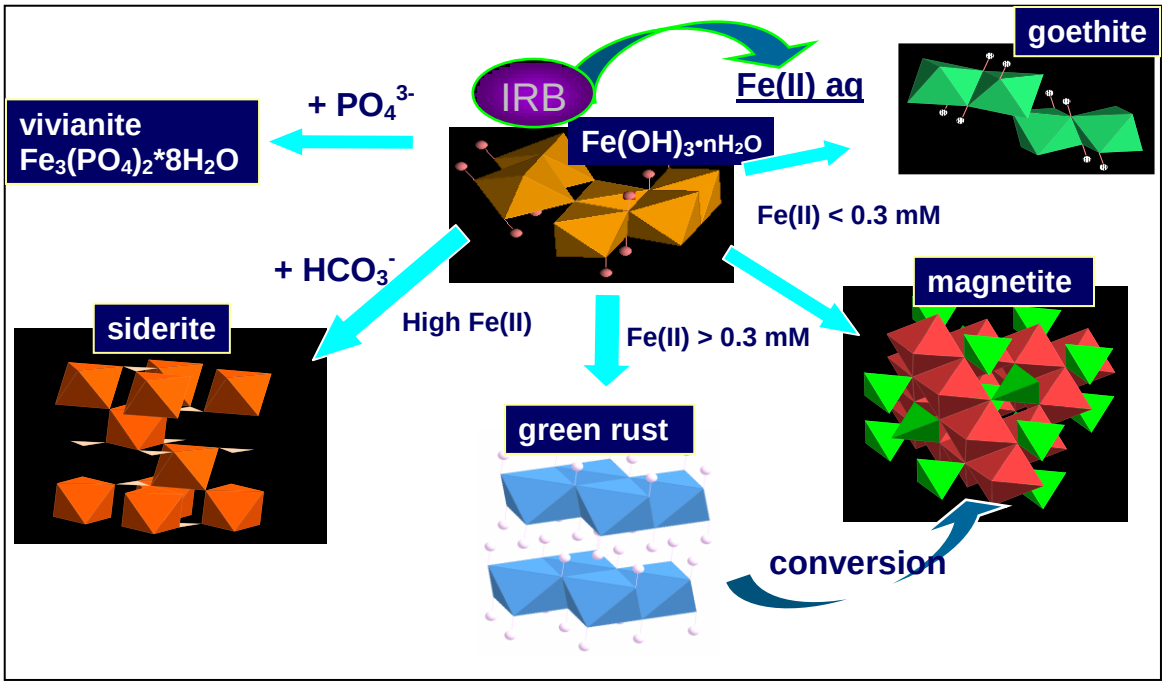

Figure 1. Conceptual model of Fe mineral species as affected by redox conditions.

The vadose zone retains a variable amount of P (23% to 99%).

The vadose zone, also called the unsaturated zone, is generally required to be at least 1 m (39.4 inches) or more in depth to be suitable for drainfield construction. This zone allows oxygen transport to the infiltration zone, and also allows geochemical reactions to occur as a result of soil-water interaction. Most of the phosphorus (and pathogen) removal occurs in the vadose zone.

This zone coincides with the biogeochemically active horizon that underlies the infiltration pipes (e.g., the biomat or infiltration zone).

Electron microscope imaging and electron microprobe analyses suggest that the phosphorus that accumulates in the soil near the infiltration pipes often consists of secondary solids with formula consistent with the minerals strengite ($FePO_4x2H_2O$) and variscite ($AlPO_4x2H_2O$).

The factors that influence phosphorus removal in the vadose zone are:

1. Soil characteristics:
   a. fine-grained, noncalcareous soils remove the most phosphorus, while
   b. coarse-grained, calcareous soils remove the least amount of phosphorus.
2. Wastewater characteristics:
   a. high NH_4^+ concentrations and low alkalinity can enhance removal in noncalcareous soils with gibbsite.
3. Site characteristics:
   a. high hydraulic loading rates and other conditions that may give rise to rapid lateral movement of water will decrease retention in soil absorption systems and thereby increase transport to surface waters.

<u>Groundwater P Dynamics:</u>

Phosphate concentrations in groundwater appear to be strongly affected by attenuation reactions that are focused in the “rapid transformation zone” immediately underlying the soil adsorption system infiltration pipes.

- Soils have been observed to be enriched in phosphorus by a factor of 2 to 4 within 1 m of dispersal systems. Of course, in this zone soil P attenuation is governed by aforementioned reactions with Fe and Al mineral species.

When a septic system plume reaches the ground water zone, and if aerobic conditions are present, concentrations of PO_4^{-3} appear to be consistent; that is, further secondary attenuation reactions do not occur. Migration velocity is strongly retarded, however, likely by sorption reactions that are related to the presence of minerals with positive surface charges (e.g., ferrihydride) at normal pH ranges. These sorption reactions appear to be both fast and slowly reversible.

In most silt and clay rich soils, groundwater velocities are slow enough (<10 m/yr) and phosphate retardation factors are high enough (>30) that phosphate migration (<0.3 m/yr) is not normally of concern.

Phosphate migration from septic systems is normally only a concern in permeable sand and gravel soils where relatively high groundwater velocities are present (20-300 m/yr). At these sites, phosphate migration on the order of 1 m/yr may occur. In most sand aquifers PO_4^{-3} exhibits a retardation factor in the range of 10-100; thus, in sand aquifers which generally have ground water velocities in the range of 10-100 m/yr, PO_4^{-3} plume migration velocity will be in the range of 0.1-10 m/yr.

As with soils, in reducing plumes predicting the mobility and persistence of PO_4^{-3} is less certain because of the complexity of reactions involving Fe (e.g. reductive dissolution of ferric hydroxide minerals may cause increasing concentrations of Fe along the flow path) and the strong interaction of PO_4^{-3} and Fe.

Case Histories:

The Lombardo document outlines 6 case histories rather nicely. Here is a slightly modified Table VI-1 from the Lombardo document:

Table VI-1: Septic System Phosphorus Geochemistry

Subsurface Material	Principal P Geochemical Mechanisms	Capacity/Comments	Case Studies	Additional Comments
Silt	Sorption + ppt.		Killarney	P removal of >99% within 0.5m of tiles.
Calcareous Sands	Sorption + Fe-P ppt.	a. Removal capacity limited b. Retardation factor* of ~30	Cambridge Langton Point Pelee	
Noncalcareous	Precipitation of Al-P mineral variscite due to solubilizing of Al with acidic conditions caused by ammonia nitrification	P concentration <0.1 mg/L possible	Muskoka Ashumet	P removal may not occur without Al solubilization
Reduced Environments (poorly sorted sand with occasional pebble layers).	Reductive iron dissolution mineralization to vivianite and strengite	a. Vivianite produced in reduced environ. b. Strengite produced when oxidized environ. encounter	Point Pelee	P will be released from strengite if anaerobic conditions develop. 2500 L/day gravity fed. Plume has traveled 3.8m/yr. Elevated P in suboxic zone (>3 mg/L) and >0.3 mg/L in reducing zone. P conc's above levels that could cause algal blooms in surface waters.

* Retardation factor is ratio of groundwater velocity to phosphorus plume velocity.

Appendix E

Modeling Soil P Sorption Under Drainfields in Idaho
"Model Interpretation"

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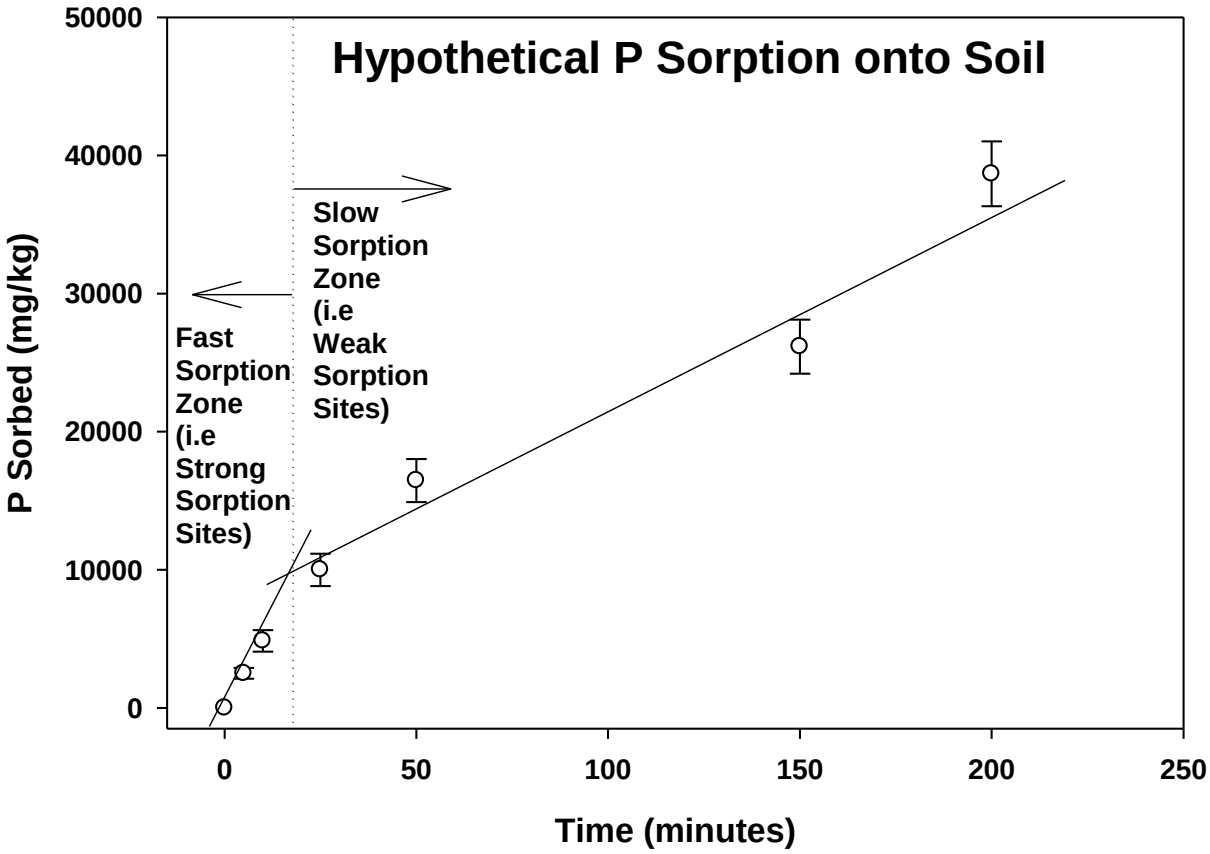
The first task I tackled was to find some real world data from soils in Idaho. Based on my past research experience, as well as research from coworkers in the laboratory I currently work for, we can show that the initial phosphorus (P) sorption in soils is related to the soil amorphous aluminum (Al) and iron (Fe) mineral content. This is interesting especially with regards to the calcareous (i.e. high pH) soils in southern Idaho, where thermodynamics would predict hydroxyapatite dominating the system and little (or no) Fe or Al associated P phases would be present.

Amorphous Al and Fe minerals have no or little crystalline structure and thus are not named minerals. These amorphous materials tend to have a relatively large surface area (as compared to their crystalline mineral counterparts). The large surface area increases their reactivity and thus sorptive capacity for P.

With that said, trying to find the amorphous Al and Fe content of any soil can be a difficult task as it is not a commonly studied component of soils. The NRCS soil survey data typically doesn't include this analysis; most soils research papers don't include the data either. However, some papers do. I tracked down those research papers dealing with Idaho soils, or data collected from the ARS lab here in Kimberly, and used the amorphous Al and Fe content as my model starting point. Now here's where I had to make an assumption: The amorphous Al and Fe content data I found was either from the soil surface at 1 foot depth or down 2 to 3 feet. I had no idea what the amorphous Al and Fe content was below these depths. To make the model work, I assumed the amorphous Al and Fe content, with depth, was equal to those literature values. Taking an educated guess, I would assume that in the real world this is not the case, but without the research to back this up I went with uniform concentrations for sake of the model.

The modeling portion was performed using a program called Visual Minteq, which uses thermodynamics to predict P sorption. The initial input model parameters were pretty simple as I didn't have complete soils analysis for the soils data I found in the literature. I fixed the pH at that found in the literature, and if the soil contained calcium carbonate it was entered as an infinite solid. The literature amorphous Al and Fe concentrations were added together to give one concentration to enter into the model. In Visual Minteq this data was entered into the Surface Complexation section of the model. The sorption model used was called "HFO with DLM" which basically models both strong and weak sorption sites. Using this type of P sorption approach is pretty common, as P sorption onto amorphous minerals tends to occur in two phases or steps. The first step is called the fast step, where P sorption occurs on sites that have a strong affinity for P. The

second step is the slower step, where P sorption occurs on sites that have a weaker affinity for P. The figure below outlines this concept.



The concentration of Al+Fe entered into the model was based on the drainfield depth (1, 2, 3, 4, or 12'), the soil type (silty or loamy were the two soil types encountered), the area required for the drainfield based on state guidelines (for the soils studied it was either based on silty, Type C, or loamy, Type B, soils) and an average volume of 300 gallons of wastewater entering the drainfield every day. Then I determined how much soil volume would "see" this quantity of liquid and calculated how much Al+Fe would "see" the liquid. This final value was entered into the model.

After entering these input values, I entered an initial model PO_4^{-3} concentration of either 1, 2, 3, 4, or 9 mg/L, and entered Na^+ as the balancing cation at the appropriate concentration to balance the PO_4^{-3}. I chose Na^+ instead of other cations such as Ca^{+2} or Mg^{+2} because of the strong thermodynamic association between Ca^{+2} or Mg^{+2} and PO_4^{-3}.

In any event, after inputting the initial parameters, I ran the model and looked at the output PO_4^{-3} concentration. I then ran the model iteratively, adding more and more PO_4^{-3} (and Na^+) to the system until 9 ppm PO_4^{-3} was observed at a given depth. The number of iterations required equaled the number of days until 9 ppm PO_4^{-3} was observed at any given depth. I converted that value to years. This data, for the Idaho soils where

amorphous Al and Fe content were reported in the literature, are presented in Tables 1 through 6 below.

Table 1. Logan Soil: Predicted years until either 1, 2, 3, 4, or 9 mg/L of P is observed at the bottom of the effective soil depth based on 9 mg/L P input into the drainfield. (These values are based on modeling using the chemical speciation model, Visual Minteq).

Soil Series	**Amorphous Al+ Fe (mg/kg)**	**P out**	**Effective Soil Depth (ft)**				
Logan (Silty)	1732	mg/L	1	2	3	4	12
pH=7.9			Time (Years) Until P Out is Observed				
P in: 9 mg/L		1	8.6	17.2	25.8	34.4	103
D_b = 1.89 g/cc		2	9.1	18.2	27.3	36.4	109
		3	9.4	18.8	28.2	37.6	113
		4	9.6	19.2	28.8	38.4	115
		9	10	21	31	40	123

Table 2. Declo Soil: Predicted years until either 1, 2, 3, 4, or 9 mg/L of P is observed at the bottom of the effective soil depth based on 9 mg/L P input into the drainfield. (These values are based on modeling using the chemical speciation model, Visual Minteq).

Soil Series	**Amorphous Al+ Fe (mg/kg)**	**P out**	**Effective Soil Depth (ft)**				
Declo (loamy)	1115	mg/L	1	2	3	4	12
pH=7.9			Time (Years) Until P Out is Observed				
P in: 9 mg/L		1	2.2	4.4	6.6	8.8	26.4
D_b = 1.89 g/cc		2	2.4	4.8	7.2	9.6	28.8
		3	2.5	5	7.5	10	30
		4	2.6	5.2	7.8	10.4	31.2
		9	3	5	8	11	32

Table 3. Greenleaf Soil: Predicted years until either 1, 2, 3, 4, or 9 mg/L of P is observed at the bottom of the effective soil depth based on 9 mg/L P input into the drainfield. (These values are based on modeling using the chemical speciation model, Visual Minteq).

Soil Series	**Amorphous Al+ Fe (mg/kg)**	**P out**	**Effective Soil Depth (ft)**				
Greenleaf (silty)	1700	mg/L	1	2	3	4	12
pH=7.5			Time (Years) Until P Out is Observed				
P in: 9 mg/L		1	9.1	18.2	27.3	36.4	109
D_b = 1.89 g/cc		2	9.6	19.2	28.8	38.4	115
		3	10	20	30	40	120
		4	10.3	20.6	30.9	41.2	124
		9	11	22	33	44	133

Table 4. Palouse Soil: Predicted years until either 1, 2, 3, 4, or 9 mg/L of P is observed at the bottom of the effective soil depth based on 9 mg/L P input into the drainfield. (These values are based on modeling using the chemical speciation model, Visual Minteq).

Soil Series	**Amorphous Al+ Fe (mg/kg)**	**P out**	**Effective Soil Depth (ft)**				
Palouse (silty)	2490	mg/L	1	2	3	4	12
pH=5.8			Time (Years) Until P Out is Observed				
P in: 9 mg/L		1	21	42	63	84	252
D_b = 1.89 g/cc		2	23.2	46.4	69.6	92.8	278
		3	24.5	49	73.5	98	294
		4	25.5	51	76.5	102	306
		9	28	56	84	112	336

Table 5. Santa Soil: Predicted years until either 1, 2, 3, 4, or 9 mg/L of P is observed at the bottom of the effective soil depth based on 9 mg/L P input into the drainfield. (These values are based on modeling using the chemical speciation model, Visual Minteq).

Soil Series	**Amorphous Al+ Fe (mg/kg)**	**P out**	**Effective Soil Depth (ft)**				
Santa (silty)	2490	mg/L	1	2	3	4	12
pH=6.1			Time (Years) Until P Out is Observed				
P in: 9 mg/L		1	19	38	57	76	228
D_b = 1.89 g/cc		2	21	42	63	84	252
		3	23	46	69	92	276
		4	24	48	72	96	288
		9	27	52	79	105	315

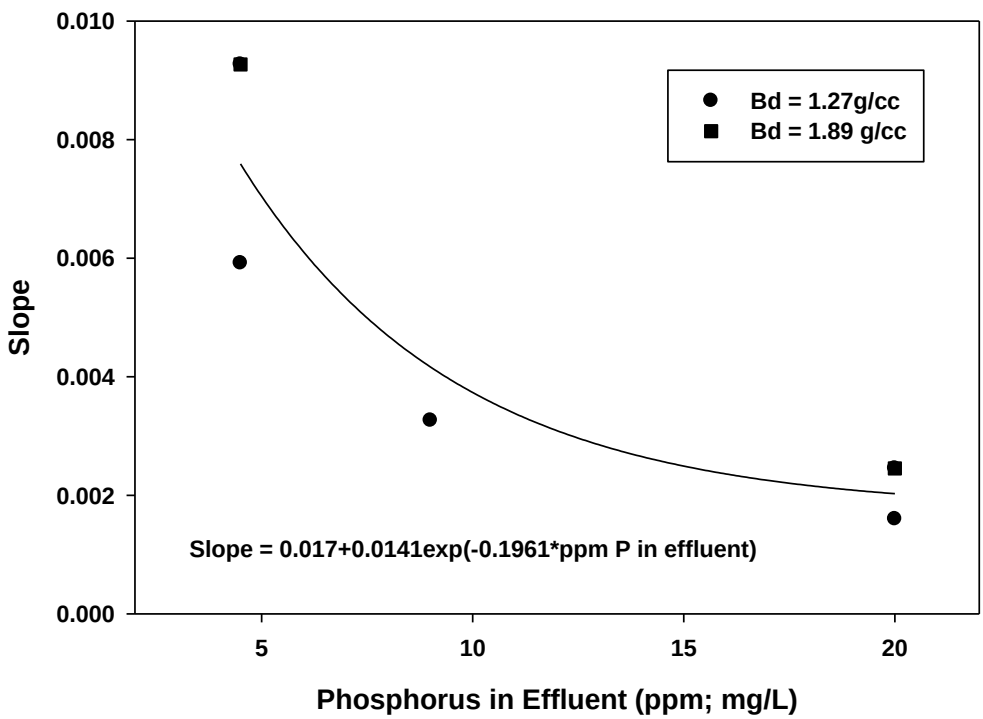
Table 6. Threebear Soil: Predicted years until either 1, 2, 3, 4, or 9 mg/L of P is observed at the bottom of the effective soil depth based on 9 mg/L P input into the drainfield. (These values are based on modeling using the chemical speciation model, Visual Minteq).

Soil Series	**Amorphous Al+ Fe (mg/kg)**	**P out**	**Effective Soil Depth (ft)**				
Threebear (loamy)	27000	mg/L	1	2	3	4	12
pH=6.2			Time (Years) Until P Out is Observed				
P in: 9 mg/L		1	96	192	288	384	1152
D_b = 1.89 g/cc		2	107	214	321	428	1284
		3	115	230	345	460	1380
		4	120	240	360	480	1440
		9	134	268	403	537	1611

Table 7. Years until 9 mg/L of P is observed at the bottom of the effective soil depth based on 9 mg/L P input into the drainfield. (These values are based on modeling using the chemical speciation model, Visual Minteq).

Soil Series	Amorphous Al+ Fe (mg/kg)	Bulk Density (g/cc)	Effective Soil Depth (ft)				
			1	2	3	4	12
			Time Until 9 mg P/L is Observed (years)				
Logan	1732	1.27	7	14	20	27	82
	1732	1.89	10	21	31	40	123
Declo	1115	1.27	2	3.5	5	7	21
	1115	1.89	3	5	8	11	32
Greenleaf	1700	1.27	7	15	22	30	89
	1700	1.89	11	22	33	44	133
Palouse	2490	1.27	19	38	56	75	225
	2490	1.89	28	56	84	112	336
Santa	2490	1.27	18	35	52	70	211
	2490	1.89	27	52	79	105	315
Threebear	27000	1.27	86	172	258	344	1031
	27000	1.89	134	268	403	537	1611

Combining both sets of bulk density data (and knowing that these bulk densities encompass the range found in most soils):



Based on the previous graph, the final equation based on this approach would be:

$$Y = \left[0.0017 + 0.0141e^{(-0.1961C)}\right] * \left[\left(D_e * A_{DF}\right) * \left(Metal_{amorph} - P\right)\right]$$

Where:

Y = the lifetime of the soils beneath the drain field until the phosphorus concentration in these soils equals the specified phosphorus concentration at the vadose zone aquifer interface. The equation for drain field lifetime (Y) is composed of the slope of the adsorption process curve multiplied by the effective soil depth and amorphous aluminum (Al) and iron (Fe) concentration after resident phosphorus is removed: Y = (slope)*(Effective soil depth)*(Amorphous Al & Fe concentration-P)

Slope = $0.0017+0.0141e^{(-01961*C)}$

C = phosphorus concentration (ppm) being discharged to the drain field.

D_e = Effective soil depth = Depth to limiting layer multiplied by the soil's percent fine fraction.

A_{DF} = Drainfield Area (composed of trench bottom area and the combined areas of undisturbed native soils between trench; alternatively, the area designated for a drip dispersal system).

$Metal_{amorph}$ = the sum of amorphous aluminum (Al) and amorphous iron (Fe) determined from acidic ammonium oxalate extraction and Inductively Coupled Plasma (ICP) spectrometry (mg/kg).

P = The soil's existing phosphorus concentration determined by Ammonium Oxalate extraction and ICP spectrometry (mg/kg).

Appendix F

The transport of phosphorous through groundwater from a typical septic drainfield to a surface water body was performed using the following approach. A three-dimensional analytical model based on the Domenico equation for a continuous planar source (Domenico and Schwartz, 1998[1]) was used to simulate phosphorous transport in the shallow groundwater aquifer to the receiving surface water body. Upon reaching the surface water body, it is typically assumed that the groundwater would mix with 25 percent of the average flow over the last ten years. For conservative modeling, it was assumed that this mixing flow rate was 1 cfs. This modeling approach is described in more detail in the following sections.

1.1 Predictive Modeling for Phosphorous Transport in Groundwater

1.1.1 Model Set-Up

A three-dimensional analytical model based the Domenico equation for a continuous planar source (Domenico and Schwartz, 1998[2]) was used to simulate phosphorous transport in the shallow groundwater aquifer to the nearest surface water body. For the purpose of this evaluation, it was assumed that the transport would be non-reactive. In a homogeneous and isotropic saturated porous medium in which groundwater is steady and uniform, the advection-dispersion equation is described by Freeze and Cherry (1979)[3] as:

$$D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2} + D_z \frac{\partial^2 C}{\partial z^2} - v_x \frac{\partial C}{\partial x} - v_y \frac{\partial C}{\partial y} - v_z \frac{\partial C}{\partial z} = \frac{\partial C}{\partial t} \qquad \textbf{1}$$

Where *C* is the solute concentration in the groundwater, D_x, D_y and D_z are the coefficients of dispersion in the *x*, *y* and *z* directions, and v_x, v_y and v_z are pore velocities in the *x*, *y* and *z* directions. A horizontal plane is represented by *x* and *y* (*x* - the groundwater flow direction, and *y* the transverse direction), and *z* represents the depth below the water table. If we ignore the effects of diffusion, then the coefficients of dispersion can be approximated by $D_x=\alpha_x v_x$, $D_y=\alpha_y v_x$, and $D_z=\alpha_z v_x$. α_x, α_y, and α_z, are the longitudinal, transverse, and vertical dispersivities, respectively.

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[1] Domenico, P.A., and Schwartz, F.W., 1998, Physical and Chemical Hydrogeology, John Wiley and Sons, New York, NY, 824 pages.

[2] Domenico, P.A., and Schwartz, F.W., 1998, Physical and Chemical Hydrogeology, John Wiley and Sons, New York, NY, 824 pages.

[3] Freeze, R. Allan, and Cherry, John A., 1979, Groundwater, Prentice Hall, Inc., Englewood Cliffs, New Jersey, 604 pages.

Equation 2 (the Domenico Equation) is a solution to Equation 1 given the assumptions described in this section.

$$\frac{C(x,y,z,t)}{C_o} = \left(\frac{1}{8}\right) erfc\left[\frac{x - v_x t}{2(\alpha_x v_x t)^{1/2}}\right]\left\{erf\left[\frac{y + \frac{Y}{2}}{2(\alpha_y x)^{1/2}}\right] - erf\left[\frac{y - \frac{Y}{2}}{2(\alpha_y x)^{1/2}}\right]\right\}\left\{erf\left[\frac{z + Z}{2(\alpha_z x')^{1/2}}\right] - erf\left[\frac{z - Z}{2(\alpha_z x')^{1/2}}\right]\right\} \quad \textbf{2}$$

Where: C(x,y,z,t) is the phosphate concentration at point x,y,z from the source at time t, C_o is the initial concentration at the source; the mixed concentration of the source in the aquifer is estimated by the following equation presented in US EPA (1989)[4]. $C_{background}$ is subtracted out since modeling the transport with this term subtracted is conservative.:

$$C_o = \frac{C_{septic} Q_{septic} + C_{background} v_x ZY}{Q_{septic} + v_x ZY} - C_{background} \quad \textbf{3}$$

Where:

C_{septic} is the concentration of the septic system effluent once it migrates through the vadose zone to the water table: assumed C_{septic} =10 mg/l for initial sensitivity analyses and then varied in the last model run;

Q_{septic} is the discharge rate of effluent from the septic system: assumed Q_{septic} = 300 gpd;

$C_{background}$ is the background groundwater phosphorous concentration; assumed $C_{background}$=0.01 mg/L;

Y is the width of the source perpendicular to the flow direction; assumed Y=50 feet;

Z is the mixing zone depth; assumed to be 3 feet based on the dispersion relationship $Z = (2\alpha_z Y)^{1/2}$ (US EPA, 1990)[5];

v_x is the seepage velocity $v_x = -Ki/n$;

α_x is the longitudinal dispersivity (in the x direction), assumed to be $\alpha_x = 0.83(\log_{10}x)^{2.414}$ based on the IDEQ Risk Evaluation Manual (REM)[6] and discussions with Mr. Bruce Wicherski of IDEQ;

α_y is the transverse dispersivity (in the y direction), assumed to be $\alpha_y = \alpha_x/10$ based on the IDEQ REM and relationships presented in Domenico and discussions with Mr. Bruce Wicherski of IDEQ;

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[4] USEPA, 1989, Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium for Examples,EPA/540/2-89/057, Office of Emergency and Remedial Response, Washington D.C.

[5] USEPA, 1990, Background Document for EPA's Composite Model for Landfills (EPACML), Prepared by Woodward-Clyde Consultants for USEPA, Office of Solid Waste, Washington D.C.

[6] Idaho Department of Environmental Quality, Risk Evaluation Manual. 2004.

α_z is the vertical dispersivity (in the z direction), assumed to be $\alpha_z = \alpha_x/100$ based on the IDEQ REM and relationships presented in Domenico and discussions with Mr. Bruce Wicherski of IDEQ;

K is the hydraulic conductivity of the aquifer: hydraulic conductivities of 1, 10, and 100 ft/day were evaluated as a typical range of hydraulic conductivity for Idaho aquifers;

i is the hydraulic gradient: hydraulic gradients of 0.025, 0.005, and 0.001 ft/ft were evaluated as a typical range for Idaho aquifers;

n is the effective porosity of the aquifer, assumed to be 0.3 based upon typical Idaho aquifer material types;

x' is the x-value used in the vertical dispersion term of Equation 2. Vertical dispersion cannot go beyond the vertical thickness of the aquifer, so to limit the extent of vertical dispersion, x' is used in the denominator of the error function of the z-term. The equation for x' from Domenico and Schwartz (1998) is as follows:

$$\text{if } \frac{(H-Z)^2}{\alpha_z} \geq x,\ x' = x;\ \text{if } \frac{(H-Z)^2}{\alpha_z} < x,\ x' = \frac{(H-Z)^2}{\alpha_z} \qquad \textbf{4}$$

Where:

H is the aquifer thickness in feet, conservatively assumed to be 15 feet; aquifer thickness is anticipated to be much thicker in most Idaho aquifers and increasing aquifer thickness, increases vertical dispersion and thereby would decrease phosphorous concentrations in groundwater with distance from the drainfield.

The increase in groundwater phosphorous concentrations was modeled for the typical drainfield every twenty feet along the downgradient centerline of the effluent plume. As a simplifying assumption for determining the impacts to the receiving surface water body, it was assumed the groundwater phosphorous concentration was constant and equal to the plume centerline phosphorous concentration along the surface water body reach in the mixing zone.

The increase in phosphorous concentration in the surface water body, $C_{increase\ stream}$, due to impacts from a typical septic drainfield was calculated using the following formula:

$$C_{increasestream} = \frac{C_{x,y,z} Q_{gw+septic}}{Q_{gw+septic} + 0.25 Q_{stream}} \qquad \textbf{5}$$

Where:

$C_{x,y,z}$ is the increase in groundwater phosphorous concentration (mg/L) calculated at a distance x from the drainfield, y feet off the groundwater flow centerline, and at a depth of z feet below the piezometric surface; the distance x from the drainfield was varied in the calculations. As a simplifying assumption, the groundwater phosphorous increase was

calculated along the centerline of the groundwater flow (y=0 ft) and at the piezometric surface (z=0).

$Q_{gw+septic}$ is the anticipated groundwater seepage into the water body. As a simplifying assumption it is assumed the flow from the top three feet (Z=3 ft) of the aquifer will enter the water body. For this calculation, the groundwater recharge width was assumed to be equal to a stream reach length equal to the drainfield width, Y. Also, it was assumed that since the drainfield is ostensibly close to a surface water body, the increased head on the aquifer due to the flow from the drainfield will cause 100% of the volume of liquid from the drainfield to pass to the receiving stream (though phosphorus concentrations will be diluted with groundwater advective flow as described above). In reality, the seepage flow mechanisms from groundwater to surface water are much more complex than described here and may involve contributions over a greater stream reach area, but using the above approach and the highest calculated groundwater phosphorous concentration (along the centerline and at y=0 and z=0) should provide a reasonable big picture estimate to evaluate whether setback reductions may be feasible and warrant additional evaluation. A more detailed evaluation should be performed to fine tune and check these results.

$$Q_{gw+septic} = Q_{septic} + kiYZ \qquad \textbf{6}$$

Q_{stream} is the average stream flow rate.

1.1.2 Model Results

Several model runs were performed to evaluate the sensitivity of various aquifer parameters that vary throughout Idaho. For each model run, charts showing increase in groundwater phosphorous concentration with distance from the drainfield at 20 years are shown as well as charts showing anticipated increase in surface water phosphorus concentration if mixed with a stream with a 1 cubic foot per second flow rate. A statewide phosphorus surface water quality standard is not available to evaluate stream phosphorus concentration increases. A red line is shown on the charts at an increase of 0.002 mg/l, the practical quantitation limit on typical EPA test method to evaluate total phosphorus concentrations in water. This is presented solely for presentation purposes and is not intended to be interpreted as a surface water quality standard for phosphorus or final evaluation criteria for drainfield setback determinations.

The first model run was performed to evaluate the sensitivity of aquifer hydraulic conductivity, K, which was varied from 1 to 100 ft/day. Hydraulic gradient was assumed to be 0.005 ft/ft and other input parameters are discussed in section 1.1.1. The model results (Charts 1 and 2) show increasing aquifer hydraulic conductivity generally reduces phosphorus concentration increase with distance except for very low hydraulic conductivities where equilibrium concentrations were not observed in the model time frame (20 years). The surface water mixing chart shows

hydraulic conductivity in the evaluated range has little influence on surface water phosphorus concentration increase at a stream flow rate of 1 cfs due to dilution effects in the stream.

Chart 1

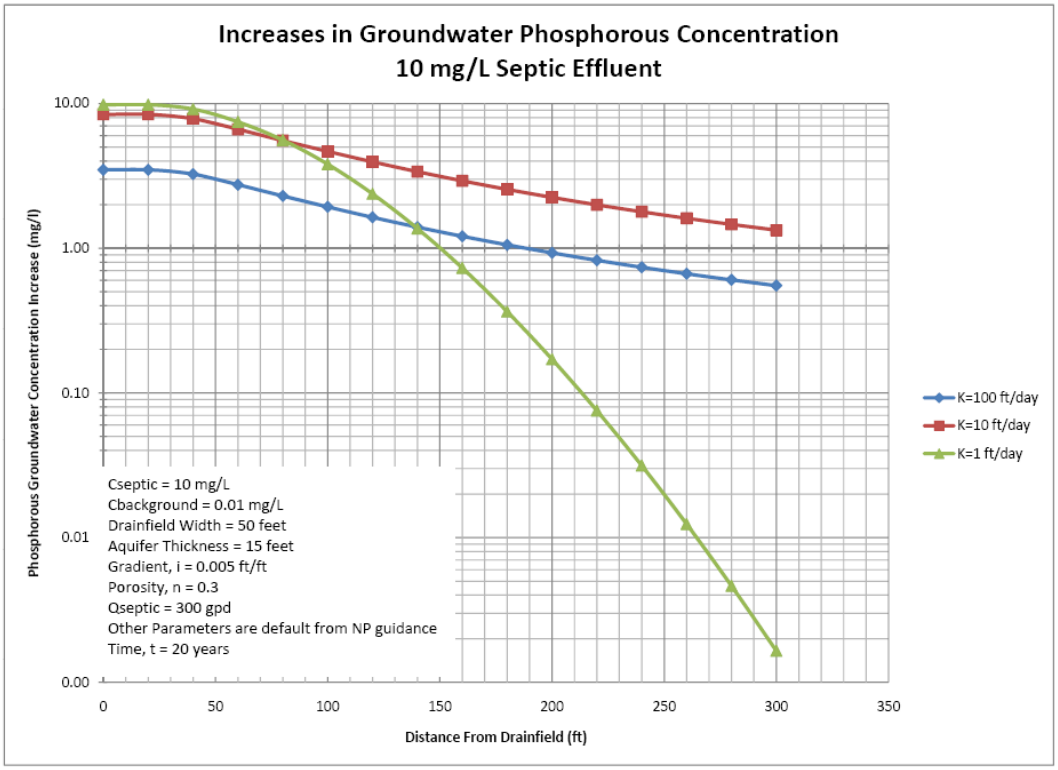
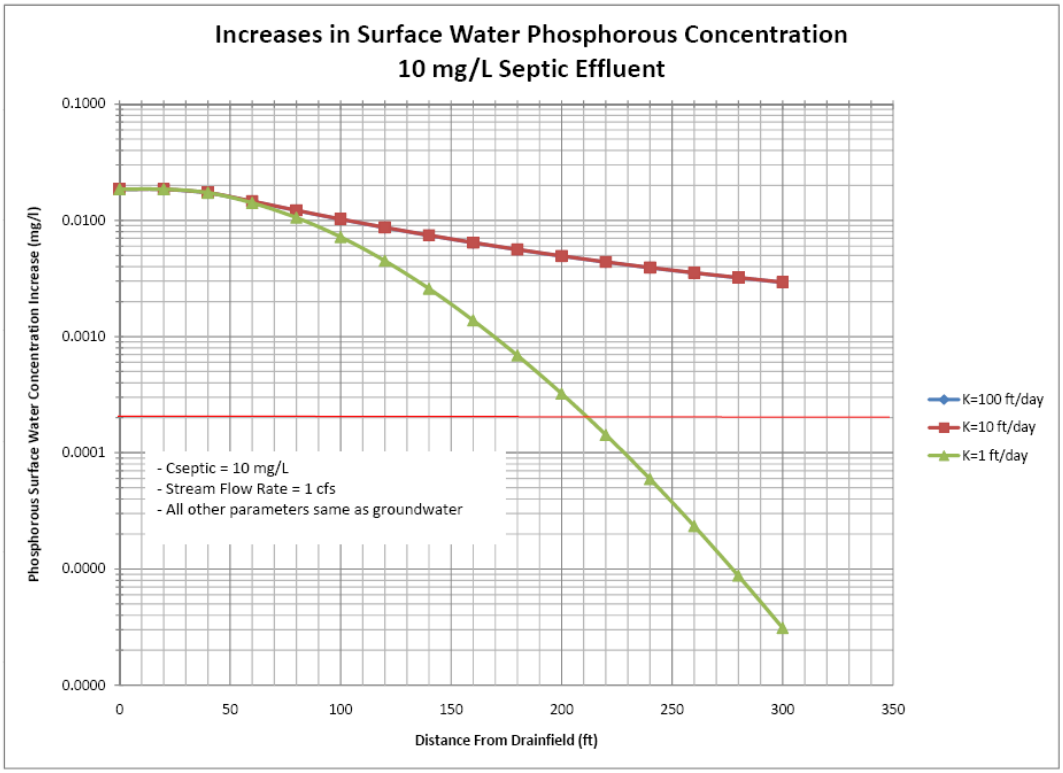


Chart 2



The second model run was performed to evaluate the sensitivity of aquifer hydraulic gradient, i, which was varied from 0.001 to 0.025 ft/ft. Hydraulic conductivity was assumed to be 10 ft/day and other input parameters are discussed in section 1.1.1. The model results (Charts 3 and 4) show increasing aquifer hydraulic gradient generally reduces phosphorus concentration increase with distance except for very low hydraulic gradients where equilibrium concentrations were not observed in the model time frame (20 years). The surface water mixing chart shows hydraulic gradient in the evaluated range has little influence on surface water phosphorus concentration increase at a stream flow rate of 1 cfs due to dilution effects in the stream.

Chart 3

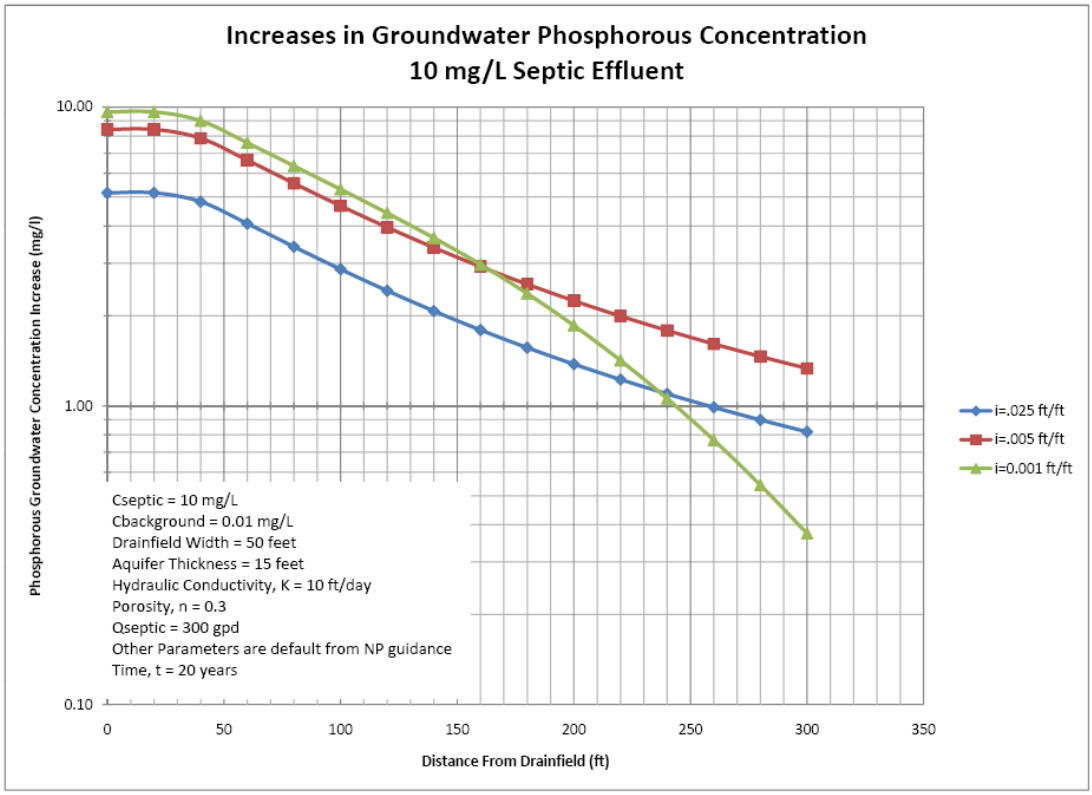
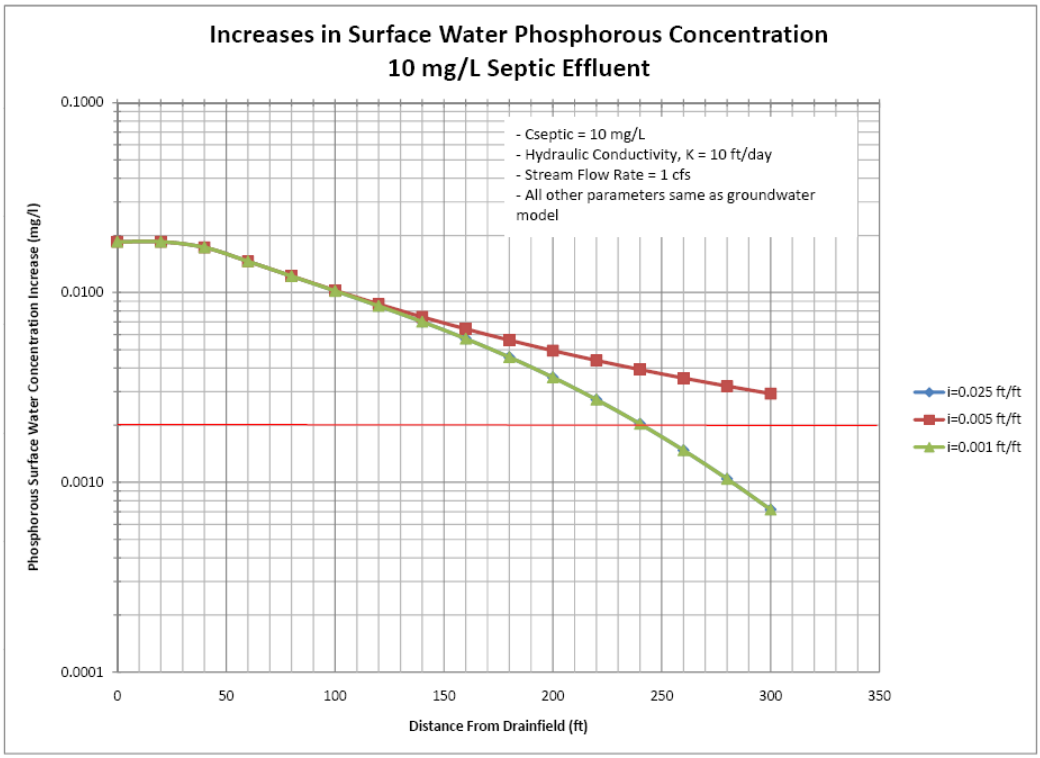


Chart 4



It appears the model (mixed concentration in surface water) had little sensitivity to aquifer hydraulic conductivity and gradient in the ranges evaluated, so changes in the concentration of septic effluent migrating to groundwater was evaluated in the third model run (Charts 5 and 6). Septic effluent concentrations ranging from 2 mg/L to 20 mg/L were evaluated while aquifer hydraulic conductivity was set equal to 10 ft/day and aquifer hydraulic gradient was set equal to 0.005 ft/ft. The model results show that the effluent phosphorus concentration reaching groundwater has significant effect on phosphorus increases in the receiving surface water body at a flow rate of 1 cfs. Note that many streams have much higher flow rates, however lakes and ponds could have significantly lower abilities to dilute phosphorus groundwater concentration increases.

Chart 5

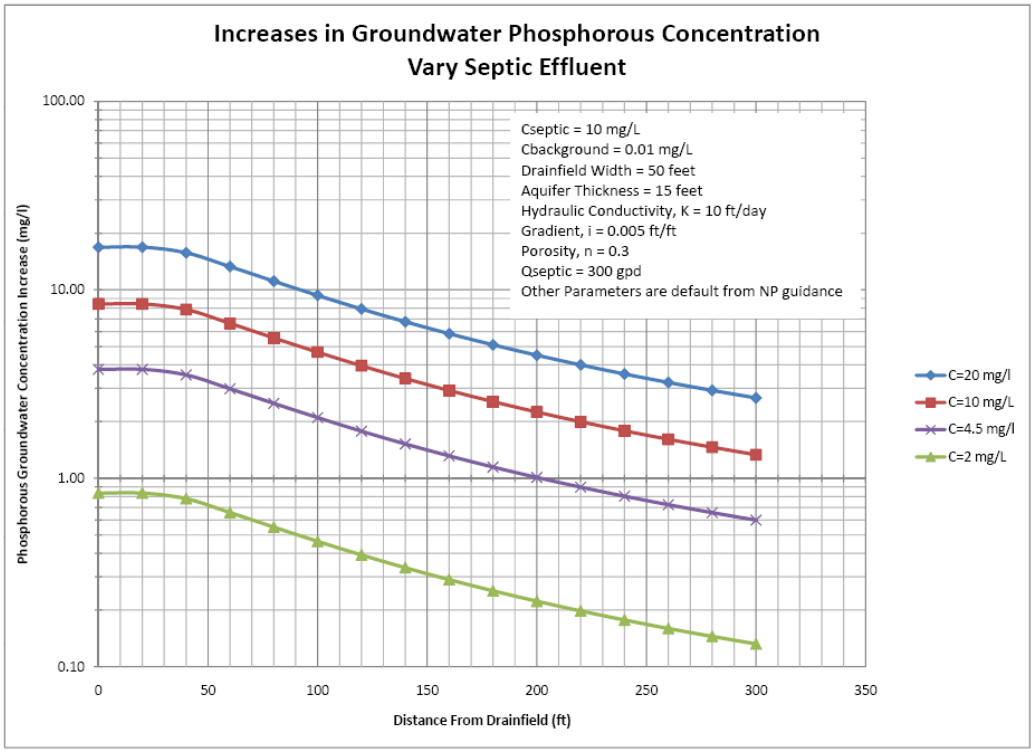
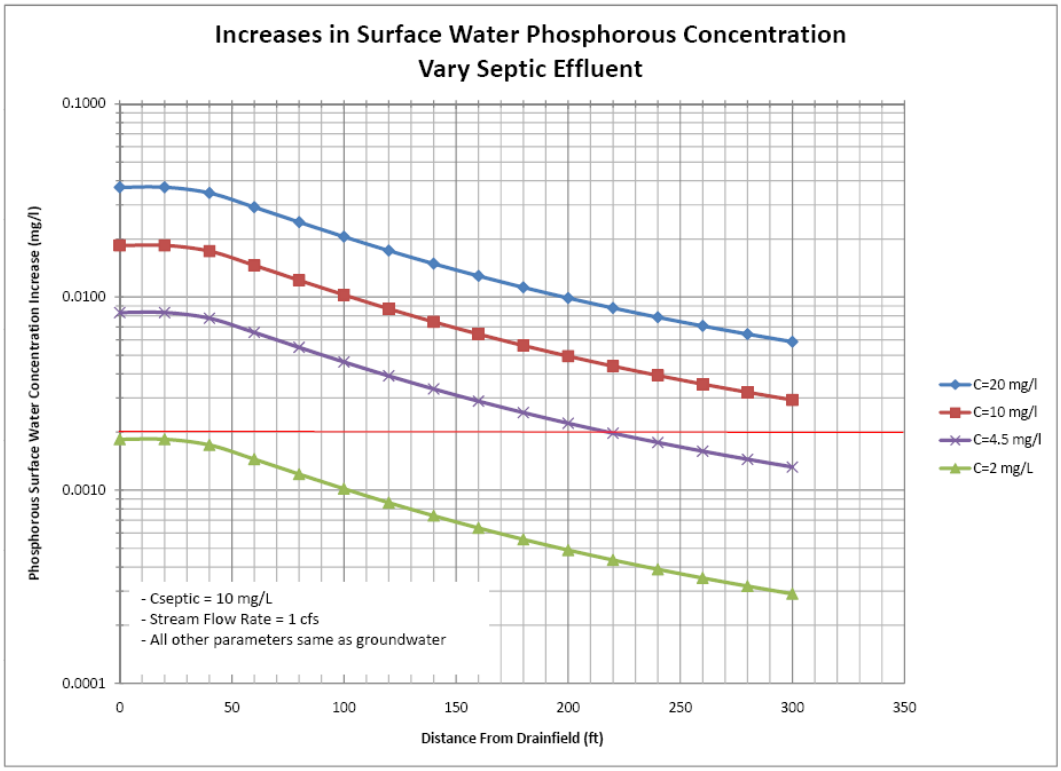


Chart 6


Increases in Surface Water Phosphorous Concentration
Vary Septic Effluent
Phosphorous Surface Water Concentration Increase (mg/l)
0.1000
0.0100
0.0010
0.0001
0
50
100
150
200
250
300
350
Distance From Drainfield (ft)
C=20 mg/l
C=10 mg/l
C=4.5 mg/l
C=2 mg/L
- Cseptic = 10 mg/L
- Stream Flow Rate = 1 cfs
- All other parameters same as groundwater

2.0 REFERENCES

Domenico, P.A., and Schwartz, F.W., 1998, Physical and Chemical Hydrogeology, John Wiley and Sons, New York, NY, 824 pages.

Idaho Department of Environmental Quality, Risk Evaluation Manual. 2004.

U.S. Environmental Protection Agency, 1980, Design Manual--Onsite Wastewater Treatment and Disposal Systems: EPA 625/1-80-012 Oct. 1980, Cincinnati, Ohio,
295 pages, 6 appendices.

USEPA, 1989, Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium for Examples,EPA/540/2-89/057, Office of Emergency and Remedial Response, Washington D.C.

USEPA, 1990, Background Document for EPA's Composite Model for Landfills (EPACML), Prepared by Woodward-Clyde Consultants for USEPA, Office of Solid Waste, Washington D.C.

Appendix G

Onsite Setback Distance Determination:

Modeling Phosphorus in the Environment as the Critical Constituent

Idaho Department of Environmental Quality
Technical Services Division

revised 2/27/2011

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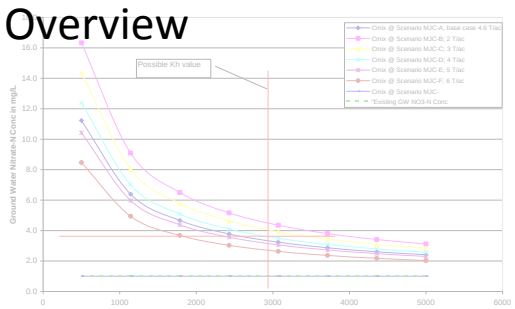
Overview



Introduction

The problem addressed through this modeling effort is to define a technical rationale for determining setback distances from a down gradient boundary of a drainfield other than those specified in Rule or the TGM. The physical system modeled is shown in Figure 1.

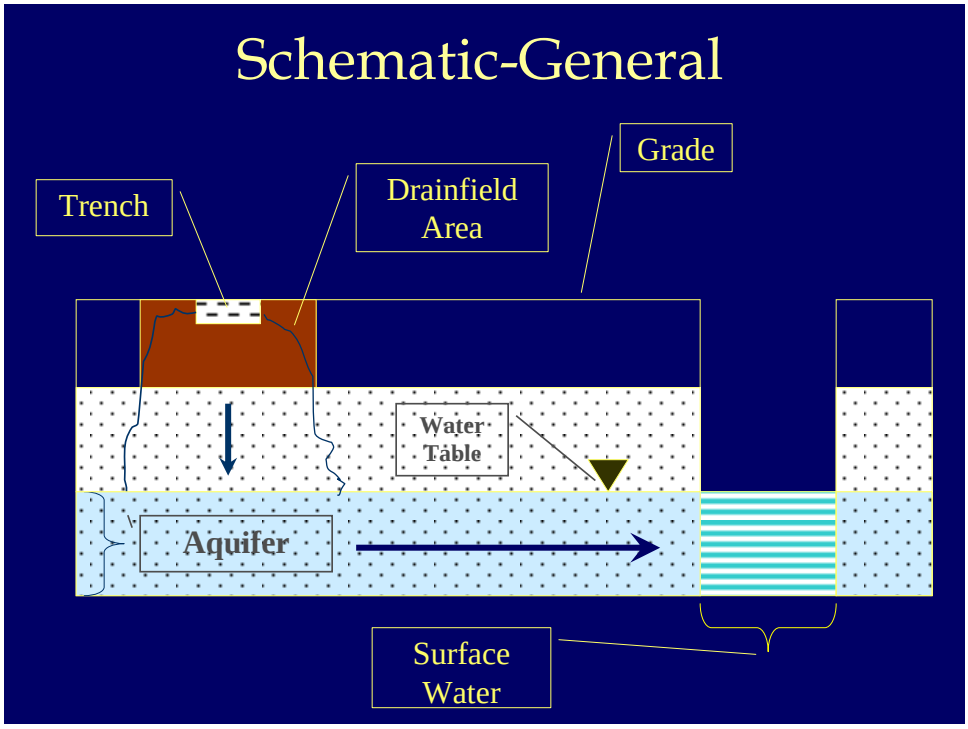


Figure 1.

There are two mechanisms being modeled here: phosphorus (P) sorption capacity in the drainfield soils, and P dilution during aquifer transport. The first mechanism has been characterized for the purposes of this effort by Dr. Jim Ippolito of the Agricultural Research Service. His results of P sorption as a function of amorphous Fe and Al content of the soil is discussed elsewhere in this report. These results have been generalized and mathematical relationships created, and have been incorporated into the model. The second mechanism – that of P attenuation in aquifer (contaminant) transport is presented in some detail by Mr. William Holder and is discussed elsewhere in this report. The general schematic of the systems being modeled is shown in Figure 2.

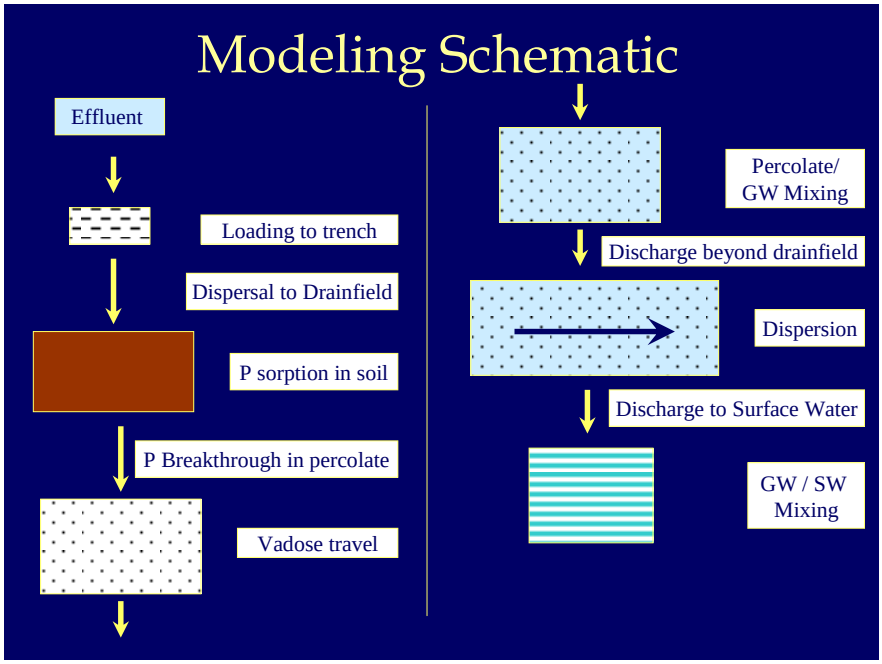


Figure 2

The regulatory role is to (1) determine the point of compliance, (2) set qualitative and quantitative criteria at the points of compliance, and (3) evaluate numerical model outputs to verify compliance with the site's constraints to determine acceptability of a proposed project. Points of compliance will be influenced by the anticipated life of the drainfield site. Site life could be defined as the time until breakthrough occurs at an allowed phosphorus concentration ([P]). It could also be the time until down gradient ground water [P] reaches a limit at a setback distance.

Setback distances would then be set where a specified [P] limit in ground water is met prior to entry into surface water. Setback distances should include provision for de minimus setback distances for systems with minimal predicted impact. Such a minimum distance would be protective and allow for uncertainties in modeling.

Model Description

The model incorporating these two removal/attenuation mechanisms discussed above is presented in the following sections of this document. The general structure of the tool uses a spreadsheet that provides a convenient format for the inputs, and conveniently places the model outputs in accessible sheets. The input sheet is divided into two parts: one part for drainfield and operational inputs, and the other for aquifer characteristics. These two input areas are shown in Figure 3 and Figure 4. Quantities used in these figures are for demonstration purposes only and do not reflect potential concentrations that may be used in actual modeling efforts. Actual concentrations must be determined on a site by site basis due to the variability of upstream watershed contributions and natural background.

Onsite Drainfield Setback Model			
2/19/2011 18:19			
Scenario		1732 Logan Soils (Ippolito)	
Parameter	Units	Value	Comments
Ground Water [P] Limit at Setback Distance	mg/L	0.55	here, a 0.5 mg/L increase above bkgrnd
Soil Class	none	C-2	model works for B-2 and C-2 so far
Number of Bedrooms	none	4	
WW flow to drainfield (Recommended)	gpd	300	Don't overwrite cell
WW flow to drainfield	gpd	300	keep at 300 gpd for now
Required Setback to Surface Water	ft	100	Don't overwrite cell
Proposed Setback to Surface Water	ft	50	
Acceptible Percolate Conc	mg/L	1	<---------- Set at 1 mg/L----------
Expected Site Life of Installation	yr	30	
Trench Area (Recommended)	ft2	1500	Don't overwrite cell
Trench Area Proposed	ft2	1500	
Adjacent Area (Recommended)	ft2	3000	Don't overwrite cell
Adjacent Area Proposed	ft2	3000	
Fe + Al: (oxalate extr.);1000 - 3000 range	mg/kg	1732	
P: Residual P in Soil	mg/kg	10	
Db: Soil Bulk Density (1.27 - 1.89)	g/cm3	1.58	
Soil Depth	ft	4	
Coarse Fragment Content	fraction	0.1	
Critical Acceptibility Outputs			
Modeled WW Application Rate to Trench	gpd/ft2	0.20	Does Meet gpd/ft2 Criterion
P Breakthrough Time (to Reach [P] Perc Limit)		19.73	Disallow Deminimus Setback
GW [P] disch to Surface Water - Scenario A	mg/L	1.079	Not Acceptible: [P] exceeds limit

Figure 3.

The drainfield design and operational inputs include (1) drainfield geometry, (2) soil class, (3) life expectancy, (4) distance to surface water, and several soil related characteristics such as (5) soil amorphous metal content, (6) bulk density, (7) soil depth, (8) coarse fragment content, (9) soil bulk density (D_b), etc. These inputs are all required to calculate effluent P breakthrough time, breakthrough concentration, and effluent loading rate to the trench areas.

The model estimates the [P] at breakthrough below the drainfield, which establishes the [P] that then mixes with ground water and travels down gradient to surface water. The next input section – that of aquifer parameters and ground water characteristics – serves to calculate to what degree P will be diluted in ground water, and the contaminant plume geometry. The concentration of P at a proposed down gradient distance is calculated. See Figure 4 for this input sheet.

Mixing Zone Depth Calculation Inputs	Units	Input	Data Sources and Comments
Drainfield Length Parallel to GW Flow	ft	67.08	assume a square site for now
Drainfield Width Perpendicular to GW Flow	ft	67.08	assume a square site for now
Percolate Volume	in/ac	39.0	Calculated from Drainfield Column
Percolate Concentration: Phosphorus (Scenario A	mg/L	6.80	From Drainfield Column - acceptible limit
Upgradient GW Concentration: Phosphorus	mg/L	0.05	assumption mjc; to run some scenarios;
Percolate Concentration: Phosphorus (Scenario B	mg/L	9	don't use
Upgradient GW Concentration: Phosphorus	mg/L	0.01	don't use
Aquifer Hydraulic Conductivity: High Range	ft/d	1000	Driscoll, sand
Aquifer Hydraulic Conductivity: Low Range	ft/d	100	Driscoll, sand
Aquifer Hydraulic Gradient	none	0.002	shallow gw USBR 12/77 Map 2.
Aquifer Material	Driscoll, 1987 - Sand		
Aquifer Porosity (Suggested literature values, in pct)	none	25 – 40%	Suggested value. Don't overwrite
Aquifer Effective Porosity (enter suggested or other value as	none	33%	~midrange of suggested values
Aquifer Thickness	ft	80	assumption mjc
Model Domain & Other Spatial Inputs			
Spatial Coordinates of Concern (Origin is plume centerline at DG discharge boundary			
X (longitudinal)	ft	50	X coord at setback distance from surface water.
Y (latitudinal/transverse)	ft	0	
Z (depth)	ft	0	
Depth of Vertical Profile to Calculate and Observe	ft	50	range where mixing taking place in this scenario
Time that the Source is Discharging	d	3747	Travel time from drainfield to surface water
AREAL Model Calculation Domain (dinensions of area modeled)			
Length (ft)	ft	500	assumed mjc
Width (ft)	ft	200	assumed mjc
Validation: Vertical Dispersion of Nitrate-N Within Actual Aquifer Depth			
Validation: Vertical Dispersion of TDS Within Actual Aquifer Depth			

Figure 4.

Model Outputs

This tool calculates an estimate of ground water constituent concentration at some distance down-gradient from the drainfield discharge boundary. Attenuation of the constituent concentration in the ground water can be significant at distance. This attenuation may be important for determining the possible degree of impact on down-gradient areas and the degree of protection necessary for down-gradient receptors such as surface water.

There are two main model outputs:
(1) A centerline concentration profile from the down gradient drainfield boundary, shown in Figure 5. The ground water [P] limit appears as a dashed red line in Figure 5. Several scenarios appear that reflect differing aquifer hydraulic conductivities (K_h). The minimum acceptable setback distance is identified as where the plotted line intersects the red 'limit line'.

(2) A vertical concentration profile at the selected setback distance for several K_h values. Those scenarios that do not cross to the right of the 'limit line' are acceptable. See Figure 6.

Figure 5 and Figure 6 are based upon the following example inputs:

- Logan Soil: Class C-2
  - D_b = 1.58
  - 4 ft deep; 10% coarse fraction (CF)
  - Amorphous Fe/Al concentration = 1732 mg/L
- 1500 ft^2 trench; 3000 ft^2 adjacent area
- 4 bedrooms; 300 gpd flow
- Aquifer properties:
  - K_h = 100 – 1000 ft/d
  - Other: gradient, background [P], effective porosity (n_e), depth, etc.

This example and example outputs show that an 80 ft setback distance would be acceptable for the scenario of K_h=1000 ft/d. It also shows that an 100 ft setback distance would be acceptable for the scenario of K_h=775 ft/d. For a K_h of 550 ft/d, a 150 ft setback distance would be acceptable.

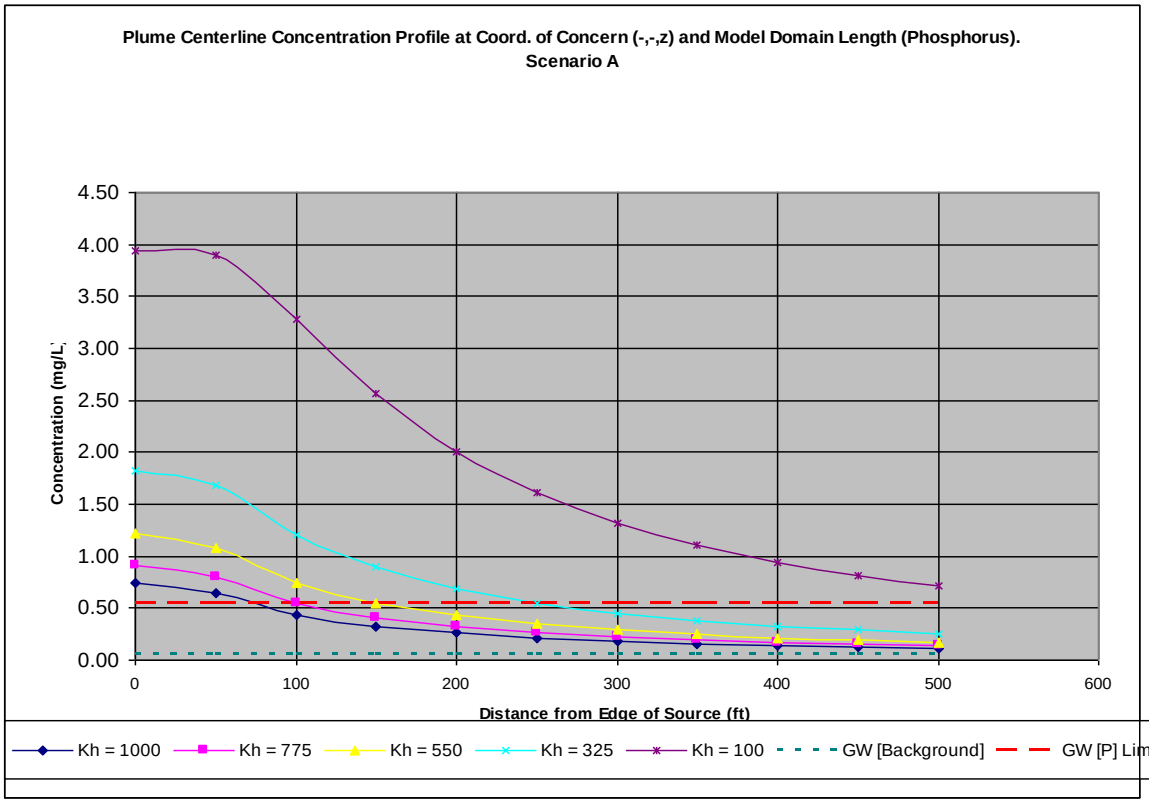


Figure 5.

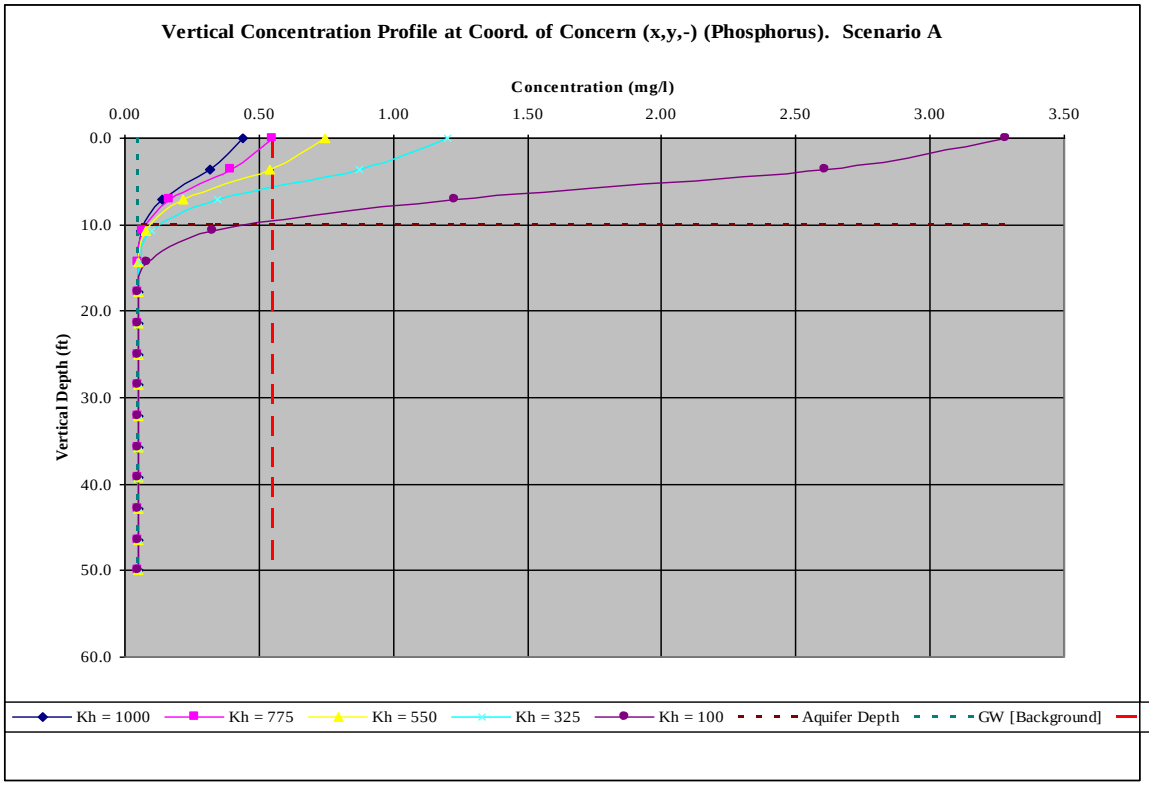
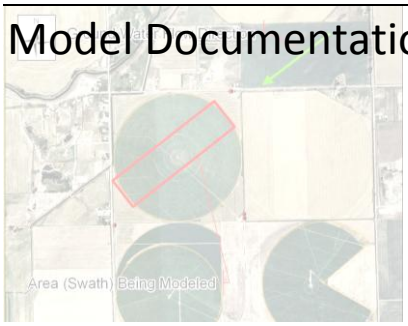

Vertical Concentration Profile at Coord. of Concern (x,y,-) (Phosphorus). Scenario A
Concentration (mg/l)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Vertical Depth (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Kh = 1000
Kh = 775
Kh = 550
Kh = 325
Kh = 100
Aquifer Depth
GW [Background]

Figure 6.

Model Documentation



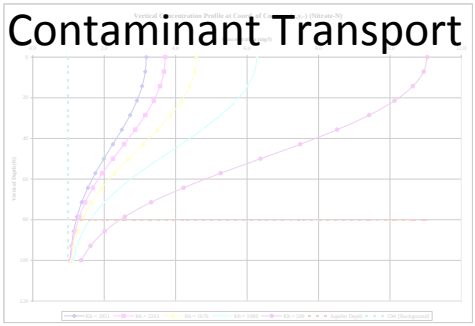
Various Assumptions and Documentation for the Model – In Development

Following are several points to explain how this model has been developed. These points constitute informal notes needing further editing and organization, but are provided here to clarify the state this task is in at this point in the subcommittee's efforts.

1. Predictions made with the summary equation of ARS did not correlate well with model results from Minteq. The outlier (Three Bear) was skewing the correlation at lower values of Fe/Al. Soil bulk density also appeared to play a large role.
2. Correlations were redone using all ARS scenarios except the outlier scenario (Three Bear). This necessitated re-plotting data, deriving new relationships (fitted curves) which are better representative of the data in the 'common range' (1000 - 3000 mg/L Fe/Al).
3. Provision was made to input estimated soil bulk density (D_b) and then perform a linear interpolation between high and low values used by ARS. This made for better correlation
4. Omitting the outlier meant that correlations needed to be done for the different effluent input concentrations. Due to time constraints, only the 9 mg/L results were 're-correlated'
5. There are three criteria that are proposed to be met:
   a. Some assigned ground water (GW) [P] limit at the setback distance to surface water.
   b. WW loading rate of the trench area in gpd/ft^2, based on soil class.
   c. Some assigned expected site life of the installation, which would include:
      i. Time for P breakthrough (at an allowed concentration) plus
      ii. Ground water travel time from the installation to the setback boundary.
6. A contaminant transport (CT) 'module' derived from the Nutrient-Pathogen (NP) spreadsheet tool is used to determine GW [P] at a given point down gradient of the drainfield. This value decreases with distance, and where the calculated [P] meets the GW limit assigned in the regulatory process, determines the setback distance from surface water.

7. Aquifer parameters are entered into this CT module below Drainfield inputs. Inputs from both CT and Drainfield Input cells are routed to CT calc sheets to render [P] at a down gradient point.
8. The 'Scenario B' in the 'Transp Inputs' sheet should be ignored - not used.
9. For now, the model is designed for 300 GPD flow, B-2 and C-2 soils, and 9 mg/L [P] influent.
10. Suggested values of wastewater (WW) flow (GPD), trench area, and adjacent area appear in grey cells, and the proposed values can be entered below the suggested values. Drainfield dimension recommendations are a function of the soil class entered.
11. A toggle switch is included to choose between 'Individual' and 'Community' systems. Flags are included mandating the use of recommended WW flow values for 'Individual' systems, and design-specific inputs for 'Community' systems.
12. A 'breakthrough time reduction factor' relates the breakthrough time for percolate P at concentrations ranging from 1 - 9 mg/L: breakthrough factor ranges from 1 - 0.77 as percolate [P] ranges from 9 - 1 mg/L. These factors were calculated by plotting modeled breakthrough times v. breakthrough concentrations and getting the slope of the function. The factor is applied to the initially calculated breakthrough time (based on 9 mg/L percolate [P].
13. The 'drainfield size breakthrough factor' allows the user to adjust the size of the trenches and adjacent areas to increase/decrease breakthrough time - in particular to meet site life requirements.
14. There is an 'All Plots' sheet that has several plots of interest, including GW plume centerline and vertical profile plots'; breakthrough time v soil Fe/Al content, breakthrough time v. percolate [P], GW [P] at setback boundary v percolate discharge [P].
15. The 'Plot Data' sheet has CT GW [P] outputs for centerline and vertical profile plots.
16. There is a 'Utility' sheet that has various lookup tables and other materials important to the model's function.

Contaminant Transport Module



Description

This spreadsheet module is an adaptation of the *DEQ Onsite Wastewater Evaluation* tool, which in turn is an adaptation of the *Pennsylvania Department of Environmental Protection (2002) Quick Domenico* implementation of the Domenico (1987) analytical solution for multi-dimensional transport of a decaying contaminant species. Adaptations include:

1. Inclusion of a procedure to estimate the mixing zone depth in ground water of contaminants beneath the wastewater land treatment source area. This procedure is taken from Equation 38 on Page 44 of the Technical Background Document for the USEPA Soil Screening Guidance (1996). This mixing zone depth, along with the estimated width of the source perpendicular to ground water gradient, provides the dimensions of the rectangular patch source used in the Domenico solution.
2. Inclusion of a mass-balance mixing calculation to estimate the source zone chemical concentration in ground water resulting from the mixing of site percolate and up-gradient ground water. The chemical concentration of the up-gradient ground water is assumed to be zero. This provides a relative increase over the site specific background value for the constituent of concern.
3. Inclusion of the Xu and Eckstein (1995) empirical equations for estimation of longitudinal dispersivity, as corrected by Al-Suwaiyan (1996).
4. Inclusion of charts plotting the vertical concentration profile at a specified distance down-gradient from the source and the centerline concentration profile. The charts show the absolute concentration change with background chemical concentrations added in, and show five scenarios for K_h between the upper and lower ranges specified by the user.

Instructions for Use

Inputs

The following sections give general instructions for inputting parameters, and descriptions of inputs for aquifer parameter, ground water quality, and ground water impact analysis inputs.

General

1. Cells having red font are for data input.
2. **Data Sources/Comments:** The column titled 'Data Sources/Comments' is a space where the user should document sources and rationale for input parameters chosen.
3. **Project and Scenario Description:** The Project/Facility and the permit number and other info can be entered here. Also, describe the scenario that is being run, especially how a particular scenario differs from other scenarios. This label will carry over to other sheets.
4. **Run Date:** The time/date 'stamp' is automatically calculated for the particular model run.
5. **Prepared By:** enter users name here.
6. **Contaminant:** enter contaminant being modeled here.

Mixing Zone Depth Calculation Inputs

1. **Land Treatment Swath Length Parallel to GW Flow:** The length of the swath defined in the Constituent / Hydraulic Balance Module. Enter it here.
2. **Land Treatment Swath Width Perpendicular to GW Flow:** The width of the swath defined in the Constituent / Hydraulic Balance Module. Enter it here.
3. **Percolate Volume (Q_p):** as calculated in the Constituent / Hydraulic Balance Module. Enter it here.
4. **Percolate Constituent Concentration (C_p) – Phosphorus-P:** as calculated for the Swath in the Constituent / Hydraulic Balance Module. Enter it here.
5. **Up-gradient Ground Water Constituent Concentration (C_{gw}) – Phosphorus-P:** enter a value for NO_3-N here. Up-gradient (background) concentration is shown on plots for reference.
4. **Percolate Constituent Concentration (C_p) – TDS (or Other):** as calculated for the Swath in the Constituent / Hydraulic Balance Module. Enter it here.
5. **Up-gradient Ground Water Constituent Concentration (C_{gw}) – TDS (or Other):** enter a value for TDS, or other constituent (if needed) & identify the constituent. Up-gradient (background) concentration is shown on plots for reference.
6. **Aquifer Hydraulic Conductivity (K_h) (upper and lower range):** enter these values in ft/d. Usually, there is much uncertainty in estimating this parameter. See Guidance for Reclamation and Reuse of Municipal and Industrial Wastewater, Sections 2.5.3 through 2.5.8 and Guidance Section 2.1.4.2.2 for further information on K_h values. Also see the same guidance document's Section 7.7.5.2.2 for a detailed discussion of how aquifer parameters are used in mixing zone calculations. Five different K_h scenarios, including those of the upper and lower range, as well as three intermediate values, are generated and plotted. Pplots are described in Section 0.

7. **Aquifer gradient (i) (unitless):** gradient is derived from potentiometric maps or other sources.
8. **Aquifer Material:** from the drop down menu, select the aquifer material. A suggested porosity will appear below.
9. **Effective porosity of aquifer matrix (n_e):** See Guidance for Reclamation and Reuse of Municipal and Industrial Wastewater, Sections 2.1.4.2.2 and 2.5.9 for further information on n_e values. Note it is a convenient but not accurate assumption that porosity is the same as effective porosity.
10. **Aquifer Thickness (b):** This is the thickness of the aquifer, *not* the mixing zone depth (which is calculated from various aquifer parameters and site geometry). Geological studies and/or well logs should be consulted for aquifer thickness information. Aquifer thickness is plotted on vertical profile plots for reference. Note that at the bottom left of the 'Inputs' area there are two cells that alert the user if significant dispersion of the constituent of concern is occurring below the specified depth of the aquifer (which would represent an unrealistic scenario). In this model depth of vertical dispersion cannot be limited so it must be 'manually' checked. If **aquifer thickness** is greater than the **depth of vertical profile to be observed** (Section 0(3)), then aquifer thickness will set the scale of the vertical plots. If **aquifer thickness** is less than the **depth of vertical profile to be observed**, then depth of vertical profile to be observed will set the scale of the vertical plots.

Ground Water Transport Calculation Inputs

On the 'Inputs' worksheet, there are input parameters related to ground water contaminant transport modeling. These include:

1. **Soil and Chemical Properties:** Recommended values for the parameters discussed in this section should be chosen, given the assumptions that the species being modeled are conservative species that do not react with the environment (non-decaying, movement not retarded, don't precipitate, etc.)

   Soil properties include bulk density (see Reuse Guidance Section 4.4.15.1) and the fraction of organic carbon. Chemical properties include the K_{oc} (organic carbon partition coefficient) and lambda (λ) (the biodegradation constant). These parameters influence the soil sorption and biodegradation of chemicals.

   Where non-reactive transport is being modeled, as is often *assumed* with NO_3-N, TDS, chloride and other 'conservative' constituents common at land treatment sites, K_{oc} and λ are zero and need not be changed. Fraction of organic carbon and soil bulk density are not necessary to input when K_{oc} and λ are zero.

   If the species modeled are reactive – i.e. they decay, are sorbed, precipitated etc. – then time inputs intermediate to steady-state time frames may be of additional importance (e.g. how long until a constituent attenuates to an acceptable level at a down-gradient point of compliance).
2. **Spatial Coordinates (x,y,z) of Concern:** a point in space is specified (x,y,z). See Figure which shows the coordinate system of a contaminant plume. The coordinate system consists of the following:

The y axis: is perpendicular to ground water flow along the down-gradient boundary of the wastewater land treatment site (i.e. the y value specified refers to the distance from the center of the source area in a horizontal direction perpendicular to the direction of ground water flow). Zero is located at the midpoint (center) of the site at the down-gradient boundary.
The x axis: is parallel to the direction of ground water flow through the center of the site, passing through the origin and is positive down-gradient along the plume centerline (i.e. the x value specified refers to the distance down-gradient from the source discharge boundary).
The z axis: is depth below the water table surface. The water table surface is a z=0. Positive numbers represent depth below the water table.
A constituent concentration at the selected (x,y,z) coordinate of concern is calculated in 'Domenico Outputs' sheet. This may be a point of compliance or a location where ground water criteria should be met.

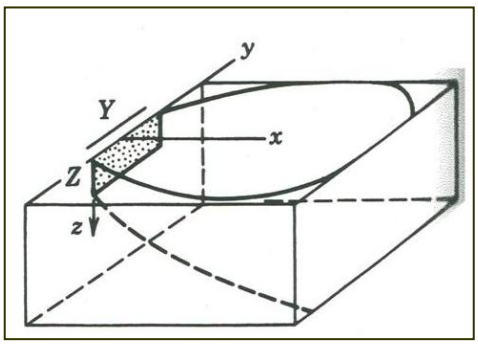


Figure 7. Coordinate System for a Contaminant Plume.

3. **Depth of Vertical Profile to Observe:** This entry determines over what thickness of the aquifer, starting at the water table, the chemical concentrations will be calculated by the model. If **depth of vertical profile to be observed** is greater than **aquifer thickness** (Section 0(10)), depth of vertical profile to be observed will set the scale of the vertical plots. If **depth of vertical profile to be observed** is less than **aquifer thickness**, then aquifer thickness will set the scale of the vertical plots. Initially, set the **depth of vertical profile to observe** slightly greater than the **aquifer depth**.
4. **Location and Time Information:** The location and time information inputs are used to calculate the predicted chemical concentration at a specific location away from the source at a specific time after source release begins. The time is specified in days from the start of chemical release. If steady-state conditions are to be simulated the value for time should be set at an appropriately large value. Steady state conditions are reached when concentration profiles no longer change with increasing time. Other values of time should be input if certain time frames need to be considered.
5. **Areal Model Calculation Domain:** The planar (length and width) dimensions of the area modeled are input, in relation to the center of the source, for which chemical concentrations are predicted. This provides a general areal description of the

distribution of chemical concentration increases throughout the plume as a result of the source. The length input determines the x scale dimension on the plume centerline profile plots.

Outputs

This section describes both the graphical outputs and calculated outputs of this module.

Graphical Outputs

1. **Centerline Profile sheets -** provides graphical representation of the horizontal (x) distribution of constituent of concern's chemical concentration, including background ground water concentrations, for five K_h scenarios. See Figure 8 for an example of the Centerline Profile output. It shows concentration distributions for the centerline of the plume (y = 0) down-gradient from the source to a distance determined by the length value input for the model domain. This concentration profile will be calculated at the z value chosen in the coordinate of concern; if Z = 0, this indicates the top of the water table, else at a depth specified below the water table. See Coordinate of Concern inputs in Section 4.2.1.3.2.
2. **Vertical Profile sheets -** provides graphical representations of the vertical distribution of constituent of concern's chemical concentration, including background ground water concentrations, for five K_h scenarios. See Figure for an example of the Vertical Profile output. The vertical plot shows the concentration distribution from the water table to a specified depth at an (x,y) coordinate down-gradient of the source, specified in the Coordinate of Concern inputs in Reuse Guidance Section 4.2.1.3.2.

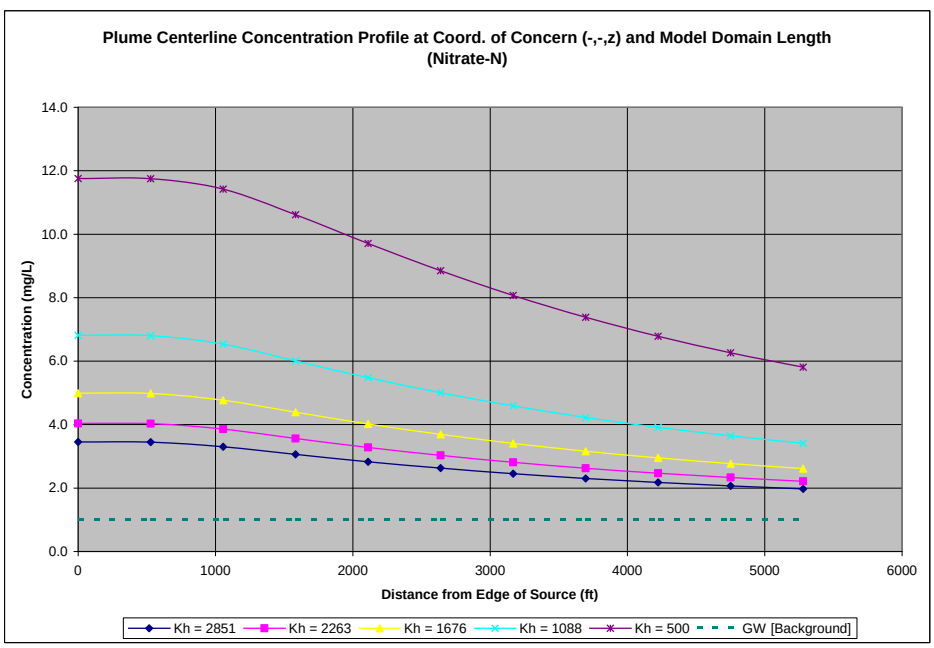


Figure 8. Plume Centerline Concentrations.

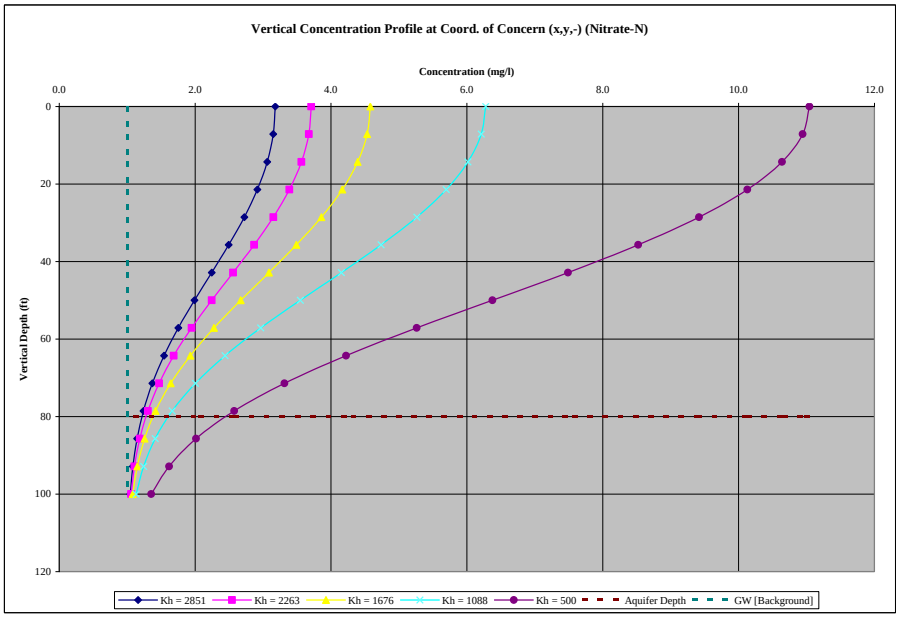


Figure 9. Vertical Concentration Profiles at a Point on the Plume

Calculation Outputs

There are calculation outputs that are a) below the Input area on the 'Inputs' sheet, b) contained in several other sheets, and c) in a Plot Data sheet that compiles plotting data from all the calculation sheets.

Calculation Outputs Below the Input Area of the 'Inputs' Sheet

Below the Input area at the top of the 'Inputs' sheet there are several calculation areas that are delimited by black borders. They include the following:

1. 'Domenico Outputs' - shows:

- Numerical results of calculations (done mostly in 'Domenico Calcs' sheet) which are utilized to create plots in Centerline Profile and Vertical Profile sheets.
- x, y, and z dispersivities and constituent concentration at the coordinate of concern chosen in the 'Inputs' sheet.
- Retardation coefficient (1 for conservative species) and ground water velocity
- Reiteration of previously input or calculated values for further use elsewhere.

2. 'MZA Outputs' - calculates:

- Mixing zone depth, with a default feature if aquifer depth is less than calculated mixing zone depth.
- Source zone chemical concentration (i.e. the concentration of the percolate / ground water mix discharging from the down-gradient boundary of the site).
- Selected input fields, such as aquifer properties, source zone (swath) width, and up-gradient ground water concentration are also passed to the 'MZA Outputs' worksheet.

3. 'Domenico Calcs' - contains intermediary Domenico (dispersion) calculations, the final calculation outputs being found in the 'Domenico Outputs' sheet.

4. 'Misc' - contains soil texture, bulk density, aquifer materials, and aquifer porosity lookup tables for use in drop-down menus in 'Inputs' sheet.

References

Allen, R.G. and C. Robison. April 2007. Evapotranspiration and Consumptive Irrigation Water requirements for Idaho. University of Idaho. 246 pages plus appendicies.

Al-Suwaiyan, Mohammad S. July-August 1996. Discussion on "Use of Weighted Least-Squares Method in Evaluation of the Relationship between Dispersivity and Field Scale" by Xu and Eckstein, Discussion Ground Water, V. 34, No.4, November-December 1995.

Domenico, P.A.1987. An Analytical Model for Multidimensional Transport of a Decaying Contaminant Species. Journal of Hydrology. Volume 91. Pages 49-58.

Environmental Protection Agency. October 1981. Process Design Manual – Land Treatment of Municipal Wastewater. EPA 625/1-81-013. Center for Environmental Research Information, Cincinnati OH.

Idaho Department of Environmental Quality. September 2007. Guidance for Reclamation and Reuse of Municipal and Industrial Wastewater. (Guidance)
See the website:
http://www.deq.idaho.gov/water/permits_forms/permitting/guidance.cfm

Pennsylvania Department of Environmental Protection. 2002. Quick Domenico.xls. Available at the Pennsylvania DEP website at:
http://www.depweb.state.pa.us/landrecwaste/cwp/view.asp?a=1241&q=455451
at the link entitled Fate and Transport Analysis Tools in the section entitled Technical Guidance.

United States Environmental Protection Agency.1996. Soil Screening Guidance: Technical Background Document. Office of Solid Waste and Emergency Response. 9355.4-17A. EPA/540/R-95/128. May 1996.

Xu, Moujin and Y. Eckstein. 1995. Use of weighted least-squares method in evaluation and relationship between dispersivity and field scale. Ground Water. v. 33, no. 6, pp. 905-908.

Appendix H

Lombardo Associates, Inc.

Representative Phosphorus Removal Project Descriptions

PhosRID™

- PhosRID™ Phosphorus Removal Technology Description
- Residential Installations- Nantucket, MA
- Office Building- Central Hudson Gas & Electric, Ulster, NY

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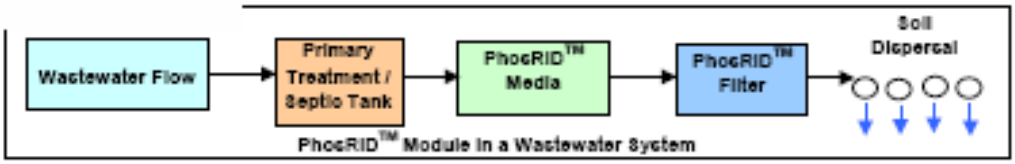
E-mail: pi.o@LombardoAssociates.com

PhosRID™ Passive Phosphorus Wastewater Removal System



The PhosRID™ system removes phosphorus from water through reductive iron dissolution and mineralization of phosphorus.

Septic System Test Center, MA Project

Project Description

Lombardo Associates, Inc. (LAI) and the University of Waterloo installed a demonstration PhosRID™ phosphorus removal system at the Massachusetts Septic System Test Center. Data collection and analysis was performed by the Barnstable County Health Department.

Project Application Data

- Location: Otis Air Force Base, MA
- Site Application: Massachusetts Septic System Test Center (MASSTC)
- Installation Date: August 2002

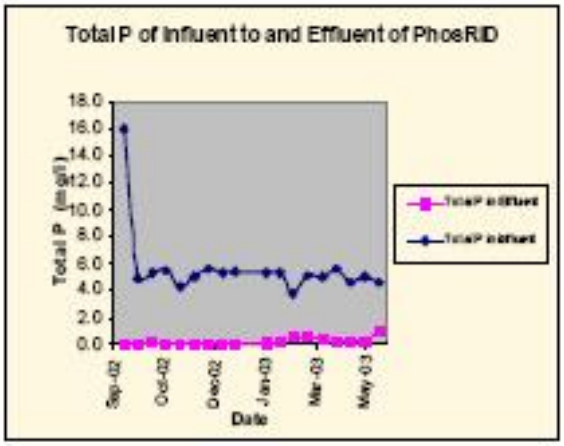
Design Profile

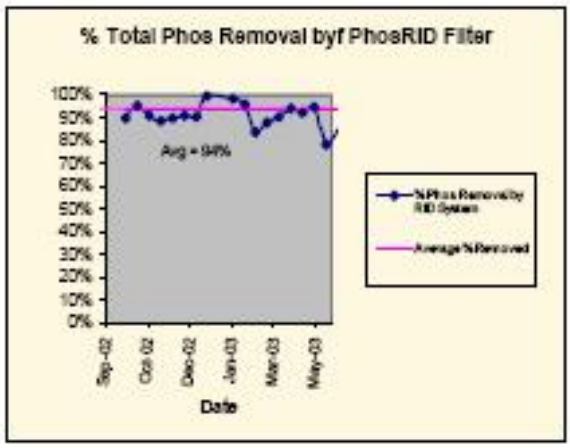
- Design Wastewater Flow: 330 gpd
- Wastewater Treatment Process: Septic Tank – PhosRID™ - Media Filter - Leaching Trench

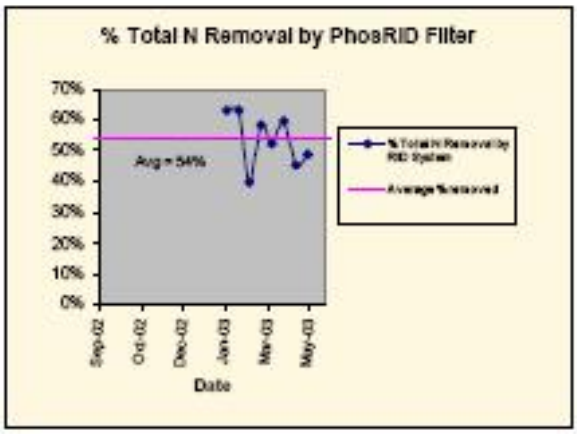
PhosRid™ Treatment Performance

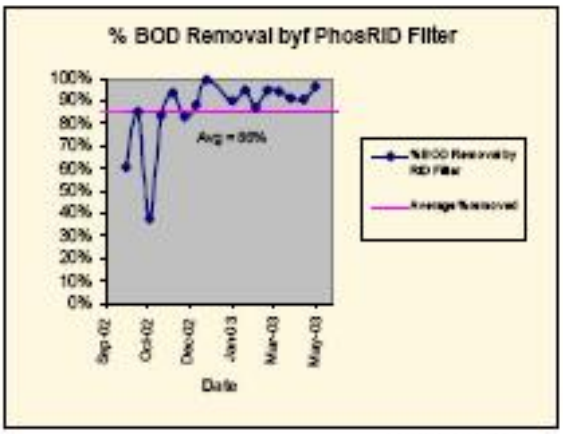
The PhosRID™ installed at the Massachusetts Septic System Test Center has reduced phosphorus in the effluent by an average of 94% over the one year that it has been in operation. In addition, the PhosRID™ has reduced the Total Nitrogen by 54% and BOD in the effluent by 86%.

Result	Influent to RID					RID Filter			
	PO4 -3 (mg-P/L)	BOD_5 (mg/L)	Total P (mg/L)	TSS (mg/L)	TN (mg/L)	Total P (mg/L)	% P Removal	% BOD Removal	% N Removal
Average (mean)	4.2	150.0	5.7	23.2	33.3	0.4	94%	86%	54%
Standard Deviation	0.6	67.9	2.6	7.3	3.9	0.3	7%	15%	9%
MIN	3.1	46.0	3.8	4.4	26.2	0.0	79%	37%	40%
MAX	5.5	277.0	16.0	40.7	37.2	1.0	100%	99%	63%









Reference:
Mr. George Heufelder
Barnstable County Department of Health
Post Office Box 427
Barnstable, MA 02630
(508) 375-6616

Nantucket, MA Projects

Lombardo Associates, Inc. (LAI) designed PhosRID™ system components to be integrated with the property's septic tank and soil absorption system. The design flows is 440 gpd for Sites 1 and 2 and 330 gpd for Site 3.

The PhosRID™ technology has proven extremely effective at removing phosphorus from septic tank effluent. In addition, PhosRID™ also provides nitrogen reduction, BOD reduction and reduction in the total suspended solids.

The Nantucket, MA sites performance summary is presented below:

	Site #1					Site #2					Site #3				
	56 Meadow View Drive					11 Columbus Ave					76 Millbrook				
Date	Average Monthly Flow (gpd)	Septic Tank Effluent TP (mg/l)	PhosRID™ System Effluent (mg/l)			Average Monthly Flow (gpd)	Septic Tank Effluent TP (mg/l)	PhosRID™ System Effluent (mg/l)			Average Monthly Flow[1] (gpd)	Septic Tank Effluent TP (mg/l)	PhosRID™ System Effluent (mg/l)		
			TP	BOD	TSS			TP	BOD	TSS			TP	BOD	TSS
7/5/2007		1.83	0.12			130.9	1.30	<0.02							
8/9/2007		9.5	0.1			144.9	4.10	0.08							
9/11/2007		9.5	0.11	<4		35.2	5.00	0.04	<4						
12/17/2007		8	0.07	<4	<2	17.7	6.30	<0.02	<4	<2					
3/26/2008						1.6	9.50	0.03	<4	<2	180.6				
5/14/2008						57.9						2.4	0.11	<4	6.0
6/25/2008						96.6	4.10	<0.02	12.0	5.0	103.3	2.8	<0.02	<4	<4
7/31/2008						307.1					105.0	2.7	<0.02	<4	<2
9/30/2008						50.3	8.00	0.03	44.0	17.0					
10/30/2008						5.1					68.2	4.2	<0.02	<4	<2
1/28/2009						0.7	8.70	<0.02	<12	4.0	99.0	5.3	<0.02	<4	<2
4/30/2009											50.3	6.5	0.07		
7/22/2009						11.2	4.95	0.03	16.0	<2					
9/10/2009							5.70	0.18	<4	10.0					
9/24/2009											89.3	3.9	0.01	<4	14
12/23/2009												4.2	<0.01	<4	17
Average		*7.21*	*0.10*	*<4*	*<2*	*81.1*	*5.77*	*0.05*	*10.8*	*5.6*	*111.2*	*4.00*	*0.03*	*<4*	*<3*
Percent P Removal			98.6%					99.1%					99.3%		

Lombardo Associates, Inc. (LAI) has been Engineer of Record for over $200 million of wastewater management projects, including numerous wastewater treatment facilities utilizing a wide variety of on-site and decentralized systems. LAI provides a wide range of services, including engineering feasibility studies, traditional engineering services of planning, design and construction engineering, and the turnkey services of designing, building, owning/financing, and operating wastewater and water facilities. Among our areas of nationally recognized expertise are the planning and implementation of on-site and decentralized wastewater systems and innovative nitrogen and phosphorus removal technologies.

LAI is a recipient of the prestigious American Consulting Engineer's Council Engineering Excellence Award for its innovative wastewater project. Pio Lombardo was an *Engineering News Record* Construction Man of the Year candidate.

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PROJECT DESCRIPTION – CENTRAL HUDSON GAS & ELECTRIC

PhosRID™ Passive Phosphorus Wastewater Removal System

Project: Office Building Wastewater Management Treatment System

Client: Central Hudson Gas & Electric

Wastewater Engineer: Pio Lombardo, P.E.
Lombardo Associates, Inc.
Boston, MA & Malibu, CA
617-964-2924
Pio@LombardoAssociates.com
www.LombardoAssociates.com

Lombardo Associates, Inc. (LAI) designed & implemented an innovative decentralized wastewater management project for the **Central Hudson Gas & Electric Wastewater Treatment System.**

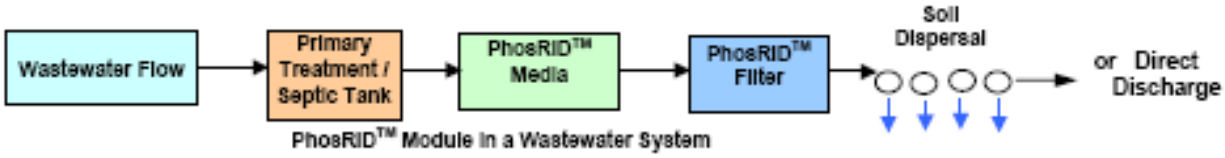
The system has been operational since **September 2008.**

LAI designed & implemented an innovative **PhosRID™** Passive Phosphorus Wastewater Removal System with the following parameters:

Design Criteria: **2,500 gpd**
Application: **Residential type wastewater, limited showers, no laundry**
Influent: **Septic tank effluent**
Influent P: **19.9 mg/l**
Effluent P: **1.6 mg/l**

Date	Average Flow for Period (gpd)	Septic Tank Effluent TP (mg/l)	Effluent TP (mg/l)
6/22/2009	1,201	21.8	2.4
7/28/2009	893	18.0	1.44
8/26/2009	1,180	12.6	0.9
Average	*1,201.09*	*17.5*	*1.6*
Percent P Removal			91.0%

- The PhosRID™ technology has proven extremely effective at removing phosphorus from septic tank effluent. In addition, PhosRID™ also provides BOD and total suspended solids reduction



PhosRID™ Module in a Wastewater System

- PhosRID™ system is a passive system for phosphorus removal, requiring little O&M. It is estimated that PhosRID™ Media will need to be replenished in 7 – 10 years, which can be accomplished with an injection of materials into the proposed chamber.

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Appendix I

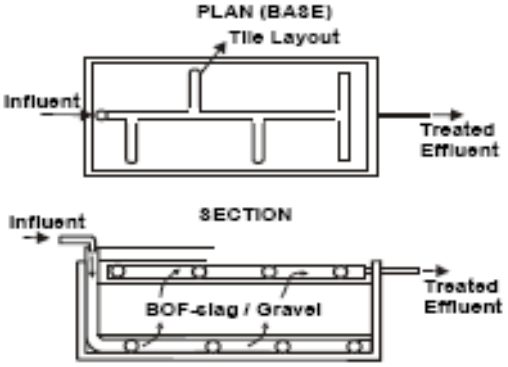
Application of PHOSPHEX™ Treatment System at Otis Demonstration Site

Today's municipal and home/lake association managers face increasingly complex wastewater or water management challenges due to inadequate onsite systems, deteriorating water quality, and water supply shortages.

In populated areas lacking municipal services, treatment and disposal of wastewater is commonly achieved using onsite systems. The purpose of these systems is to provide levels of primary treatment anaerobically in a septic tank, such as lowering the biological oxygen demand and suspended solids as well as removal or filtration of pathogenic microbes and viruses, upon final disposal through an aerobically unsaturated soil absorption bed. To date, however, onsite systems have not been specifically designed to remove nutrients such as phosphorus. Phosphorus is a major component of wastewater and elevated concentrations have been observed in groundwaters near onsite wastewater disposal systems. Since phosphorus is the limiting nutrient in most inland waterbodies, excess levels will negatively impact the aquatic ecosystems, and therefore, phosphorus contamination of adjacent groundwater flow systems is a major concern.

The PHOSPHEX™ system is an inexpensive and low maintenance approach to phosphorus treatment by allowing pretreated effluent to percolate through a permeable reactive mixture turning the phosphorus from aqueous phase to solid phase. The benefit of this system is that it significantly reduces the phosphorus content of the wastewater prior to discharge and that the mass of phosphorus is accumulated in a finite and accessible volume of material that is suitable for future collection and disposal if necessary.

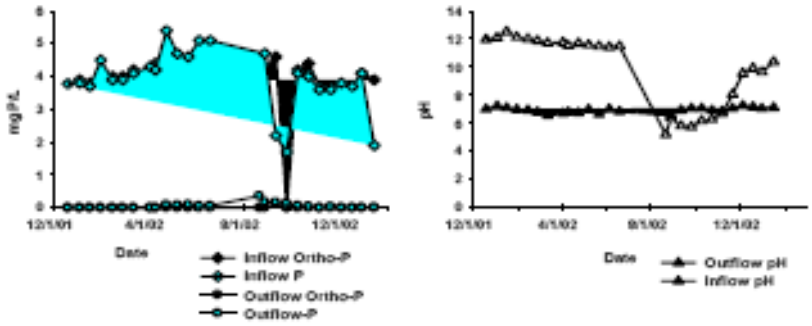
The PHOSPHEX™ chamber was installed at the Massachusetts Alternative Septic System Test Center in October 2001. Aerobically treated communal wastewater with low biological oxygen demand



(BOD) is introduced to the Phosphex™ chamber, which is contained in a concrete tank. Flow of water is upward through the Phosphex™ media. The effluent from the Phosphex™ chamber has contained less than 0.1 mg/L ortho-phosphate-P and less than 0.1mg/L total P throughout its operation. A second chamber containing peat was added to reduce the pH in August 2002. Buffering of the pH to less than 8 is currently being achieved by operating the peat chamber under saturated-unsaturated cycles. Removal of total phosphorus and ortho-phosphate P to concentrations of approximately 0.05mg/L or less has routinely been achieved.

	Inflow			Outflow		
Date	Total Ortho- PO_4	Total P	pH	Total Ortho- PO_4	Total P	pH
19-Dec-01	NA	3.78	7.01	<0.1	<0.1	11.97
3-Jan-02	3.9	3.8	7.23	BRL	BRL	12.09
16-Jan-02	3.8	3.7	7.10	BRL	BRL	12.52
30-Jan-02	4.1	4.5	6.99	BRL	BRL	12.12
14-Feb-02	4	3.9	6.94	<0.1	BRL	12.00
27-Feb-02	4	3.9	6.80	BRL	BRL	11.88
13-Mar-02	4.2	4.1	6.58	BRL	BRL	11.72
3-Apr-02	4.1	4.3	6.72	BRL	BRL	11.75
10-Apr-02	4.4	4.2	6.80	BRL	0.1	11.53
24-Apr-02	4.9	5.4	6.75	BRL	0.1	11.70
8-May-02	4.5	4.7	6.99	BRL	0.082	11.57
22-May-02	4.4	4.6	6.67	BRL	0.098	11.48
5-Jun-02	4.8	5.1	7.01	BRL	0.059	11.43
19-Jun-02	4.3	5.1	6.84	BRL	0.065	11.49
21-Aug-02				BRL	0.36	<0.5
28-Aug-02	4.3	4.7	6.57	BRL	0.18	<0.5
11-Sep-02	4.6	2.2	6.95	0.1	0.17	<0.5
25-Sep-02	0.05	1.7	7.07	BRL	0.14	<0.5
9-Oct-02	4.2	4.1	7.07	BRL	0.069	6.19
23-Oct-02	4.4	4	6.91	BRL	0.043	6.30
6-Nov-02	3.7	3.6	6.86	BRL	0.1	6.73
20-Nov-02	3.7	3.6	7.07	BRL	0.036	8.06
4-Dec-02	3.5	3.8	7.26	BRL	BRL	9.56
18-Dec-02	3.7	3.7	7.17	BRL	BRL	9.92
30-Dec-02	4.1	4.1	7.05	BRL	0.008	9.65
15-Jan-03	3.9	1.9	7.12	<0.1	<0.1	10.38

Routine monitoring results BRL= Below Reading Level



Treatment efficiencies of > 97%+ were achieved. The longevity of the media depends on the influent concentrations and is expected to be over

Application of PHOSPHEX™ Treatment System at the Waterloo STP

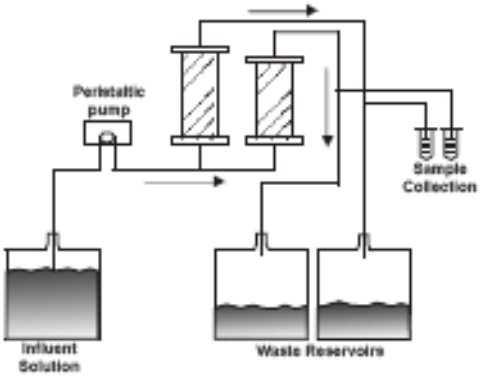
Today's municipal and home/lake association managers face increasingly complex wastewater or water management challenges due to inadequate onsite systems, deteriorating water quality, and water supply shortages.

In populated areas lacking municipal services, treatment and disposal of wastewater is commonly achieved using onsite systems. The purpose of these systems is to provide levels of primary treatment, such as lowering the biological oxygen demand and suspended solids as well as removal or filtration of pathogenic microbes and viruses, upon final disposal through the soil. To date, however, onsite systems have not been specifically designed to remove nutrients such as phosphorous. Phosphorous is a major component of wastewater and elevated concentrations have been observed in groundwaters near onsite wastewater disposal systems. Since phosphorous is the limiting nutrient in most inland waterbodies, excess levels will negatively impact the aquatic ecosystems, and therefore, phosphorous contamination of adjacent groundwater flow systems is a major concern.

The PHOSPHEX™ system is an inexpensive and low maintenance approach to phosphorous treatment by allowing pretreated effluent to percolate through a permeable reactive mixture. The benefit of this system is that it significantly reduces the phosphorous content of the wastewater prior to discharge and that the mass of phosphorous is accumulated in a finite and accessible volume of material that is suitable for future collection and disposal if necessary.

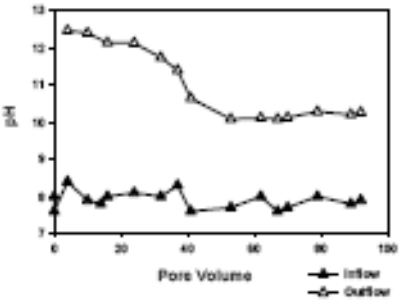
In 1996, phosphorus removal from wastewater was evaluated at a municipal wastewater treatment plant (Waterloo, Ontario) using columns containing Phosphex™ treatment media. Primary aerobic treatment of a portion of the primary clarifier effluent from the treatment plant was achieved using a Waterloo Biofilter™ system. The phosphorus was removed using the Phosphex ™ columns for a period of four months. Ortho-phosphate P concentrations decreased from between 2 and 3 mg/L in the influent to less than 0.1 mg/L in the Phosphex™ effluent, and total phosphorus decreased from more than 3 mg/L P to less than 0.3 mg/L in the Phosphex™ columns. The pH of the column effluent ranged from 10.1 to 12.5, and showed a trend of decreasing pH with time.

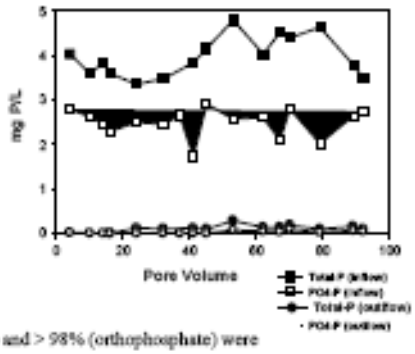
A Municipal Wastewater Treatment Plant



		Inflow			Outflow		
Date	Total Treatment (Pore Volume of Flow)	Total Ortho-PO_4	Total P	pH	Total Ortho-PO_4	Total P	pH
27-Jul-95	0	NA	3.78	8.0	NA	NA	
05-Jul-95	0	NA	3.50	7.6	NA	NA	
19-Jul-95	4	2.80	4.04	8.4	0.02	0.40	12.48
26-Jul-95	10	2.63	3.60	7.9	0.01	0.08	12.41
02-Aug-95	14	2.47	3.84	7.8	<.01	0.16	
09-Aug-95	16	2.30	3.60	8.0	<.01	0.34	12.15
16-Aug-95	24	2.51	3.36	8.1	<.01	0.12	12.14
23-Aug-95	32	2.46	3.48	8.0	<.01	0.11	11.75
30-Aug-95	37	2.66	NA	8.3	<.01	NA	11.41
06-Sep-95	41	1.74	3.84	7.6	<.01	0.12	10.65
13-Sep-95	46	2.91	4.16		<.01	0.10	
20-Sep-95	53	2.58	4.80	7.7	0.08	0.29	10.09
27-Sep-95	62	2.61	4.04	8.0	0.05	0.14	10.12
04-Oct-95	67	2.11	4.52	7.6	0.04	0.14	10.09
11-Oct-95	70	2.81	4.40	7.7	0.1	0.19	10.13
25-Oct-95	79	2.03	4.64	8.0	0.03	0.10	10.29
01-Nov-95	89	2.65	3.80	7.8	0.07	0.16	10.21
07-Nov-95	92	2.76	3.49	7.9	0.05	0.10	10.27

Routine monitoring results during 128-day wastewater treatment experiment.





Treatment efficiencies of > 95% (total phosphorous) and > 98% (orthophosphate) were achieved over a 128 day monitoring period. Absence of dissolved iron in the effluent indicates that the reactive mixture is stable under pre-treated wastewater conditions.

Application of PHOSPHEX™ Treatment System using Column BOF slag Experiments

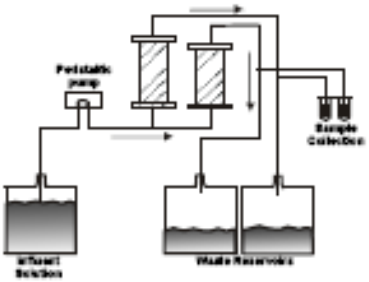
Today's municipal and home/lake association managers face increasingly complex wastewater or water management challenges due to inadequate onsite systems, deteriorating water quality, and water supply shortages.

In populated areas lacking municipal services, treatment and disposal of wastewater is commonly achieved using onsite systems. The purpose of these systems is to provide levels of primary treatment anaerobically in a septic tank, such as lowering the biological oxygen demand and suspended solids as well as removal or filtration of pathogenic microbes and viruses, upon final disposal through an aerobically unsaturated soil absorption bed. To date, however, onsite systems have not been specifically designed to remove nutrients such as phosphorus. Phosphorus is a major component of wastewater and elevated concentrations have been observed in groundwaters near onsite wastewater disposal systems. Since phosphorus is the limiting nutrient in most inland waterbodies, excess levels will negatively impact the aquatic ecosystems, and therefore, phosphorus contamination of adjacent groundwater flow systems is a major concern.

The PHOSPHEX™ system is an inexpensive and low maintenance approach to phosphorus treatment by allowing pretreated effluent to percolate through a permeable reactive mixture turning the phosphorus from aqueous phase to solid phase. The benefit of this system is that it significantly reduces the phosphorus content of the wastewater prior to discharge and that the mass of phosphorus is accumulated in a finite and accessible volume of material that is suitable for future collection and disposal if necessary.

Column experiments were initiated in 1992 to assess the phosphate attenuation capacities of selected reactive mixtures under conditions of saturated dynamic flow and continuous phosphate loading.

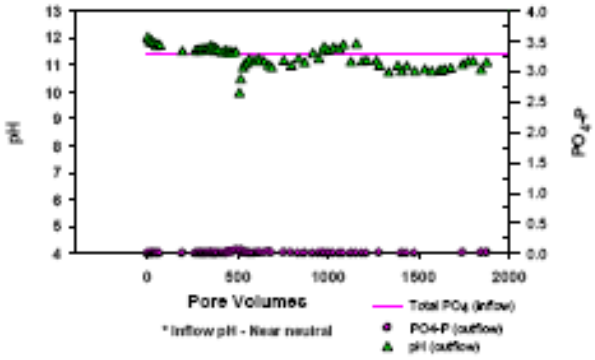
Columns were designed to ensure uniform flow over the cross-sectional area of the column. Solutions were administered continually through teflon tubing connected to a multi-channel variable speed peristaltic pump. The reactive materials in the columns were selected to promote phosphorus attenuation by adsorption onto oxide surfaces and by creating conditions suitable for the precipitation of calcium phosphate. Effluent samples have been collected at different times and the total volume of solution passing through the column has been monitored gravimetrically. Solid phase analysis has confirmed the formation of stable and sparingly soluble calcium phosphate within the reactive mixture.



Total Treatment (Pore Volume of Flow)	Outflow: Total PO_4-P (mg/L)	Outflow: pH
12.21	0.00	11.85
49.70	0.00	11.69
266.75	0.00	11.50
312.52	0.00	11.54
327.89	0.00	11.58
350.40	0.01	11.67
385.92	0.00	11.50
393.77	0.00	11.53
413.23	0.00	11.45
440.27	0.00	11.46
456.90	0.02	11.45
472.88	0.02	11.44
510.03	0.02	9.93
530.41	0.01	10.87
548.14	0.01	11.02
588.19	0.00	11.11
622.94	0.01	11.15
689.54	0.02	10.96
796.68	0.01	10.94
889.55	0.00	11.06
948.90	0.00	11.20
978.52	0.00	11.64
1030.80	0.00	11.62
1054.54	0.00	11.72
1157.00	0.00	11.76
1213.87	0.00	11.13
1282.99	0.01	10.95
1384.49	0.00	10.94
1435.44	0.00	10.92
1618.94	-0.03	10.78
1642.43	-0.06	10.81
1677.31	-0.01	10.85
1743.14	0.01	10.98

Inflow solutions contain approximately 3.3 mg/L PO_4-P and have near neutral pH.

Treatment efficiencies of > 90% were achieved over a 5 year monitoring period. Similar treatment efficiencies have been achieved through ten years of continuous column operations.



Appendix J

GreenTechGlobal

PhosRock Reactive Filter Media

The most common impairment of surface waters in the U.S. is eutrophication caused by excessive inputs of phosphorus and nitrogen. Impaired waters are those that are not suitable for designated uses such as drinking, irrigation, industry, recreation, or fishing. Eutrophication accounts for about half of the impaired lake area and 60% of the impaired river reaches in the U.S and is attributed to Nonpoint and Point Source Pollution.

PhosRock, incorporates advanced onsite treatment and is a feasible and economical option to help meet water quality goals by reducing phosphorus. Incorporated into media filters, PhosRock, is used to achieve an environmentally friendly recycling of phosphorus from sewage effluent. Phosphorus in sewage effluent is caught in pre-packaged media filters . The reactive component is calcium silicate to which phosphorus is bound. The phosphorus that has been retained by PhosRock can be recycled to agriculture as a fertilizer

Ideally suited for use in small community decentralized wastewater treatment systems, PhosRock can be incorporated for tertiary treatment to further drop the phosphorus levels in wastewater effluent. Incorporated into the wastewater system process flow, the reactive filter bed unit can be designed for new wastewater plants or retrofitted into existing plants.

Additionally, traditional septic tanks are problematic in the reduction of phosphorus overloading. As a means of primary treatment, a septic tank allows organic solids to settle and digest by microorganisms in the wastewater These solids will remain in the tank while the effluent will drain into the soil absorption field. The soil absorption field depends on soil and site conditions to meet the targets on nutrient removal from wastewater. The effluent entering the field contains pathogens bacteria and nutrients nitrogen and phosphorus, which are harmful to ground and surface waters when in excessive amounts. By adding the PhosRock Reactive Media Filter in the process flow prior to the drainfield, the levels of phosphorus can be dropped as much as 90 % to 95% .

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Tel: 479-527-9880 Fax 479.527.9830 www.greentechglobal.us

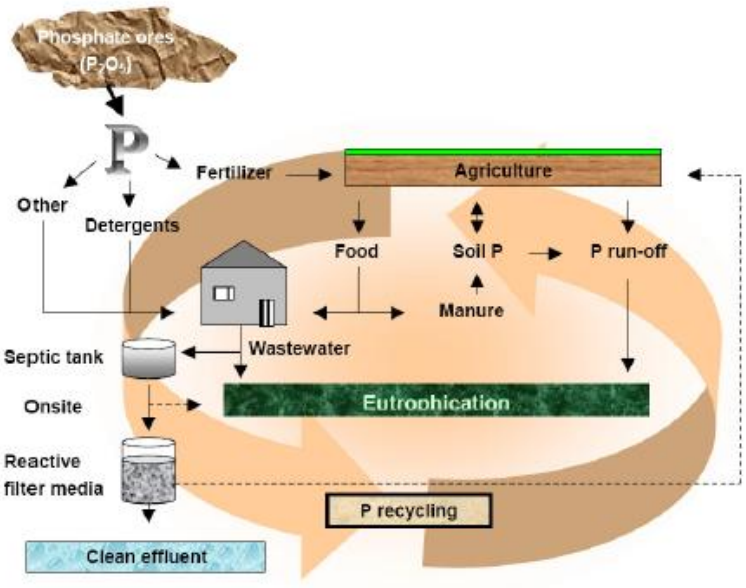

Figure 1. Sustainable P cycle

.Phosphorus Removal and Recovery

The principle of phosphorus removal is based in the transfer of soluble phosphorus to the solid phase, with a subsequent separation process. There are several alternatives for removing P from wastewater. This filter technology is a treatment system where wastewater is allowed to percolate, normally by gravity, through a reactive porous medium that removes the contaminant from the water. PhosRock removes between 90% and 100% of phosphorus during 1-2 years. Unlike chemical treatments, the PhosRock can be reused in agriculture as a controlled fertilizer. An example of waste being used as a resource in the right place.

PhosRock Reactive Bed Filter Media advantages:

- Purification is achieved by treatment in materials of natural origin or by products from industry
- Used solid filter materials or sludge from filtration and sedimentation are replaced regularly and returned to agriculture as P fertilizers and soil amendments
- Minor or no use of electricity, since pumps and other energy-consuming devices are not needed at all or only to a minor extent in the system
- A robust system in terms of function, control and management

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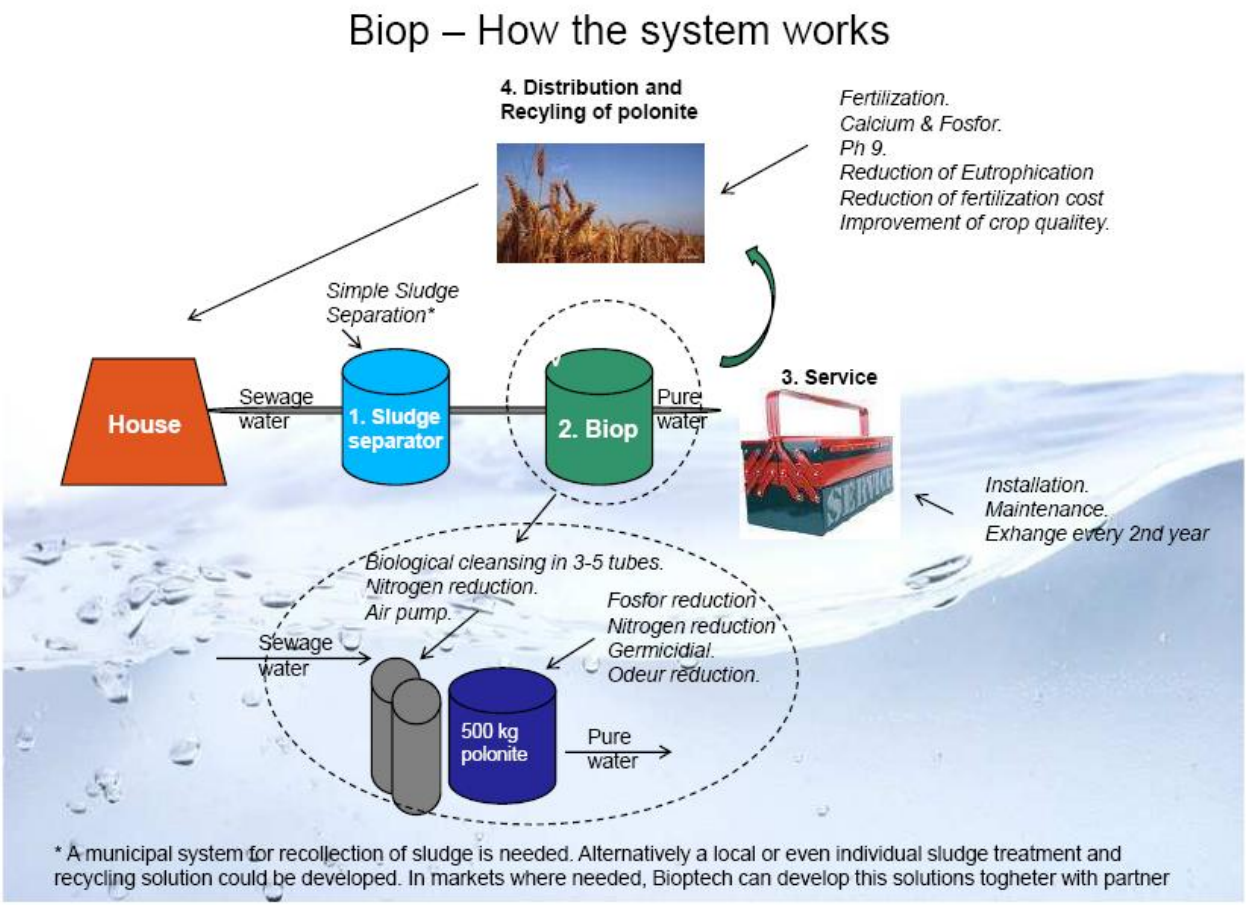
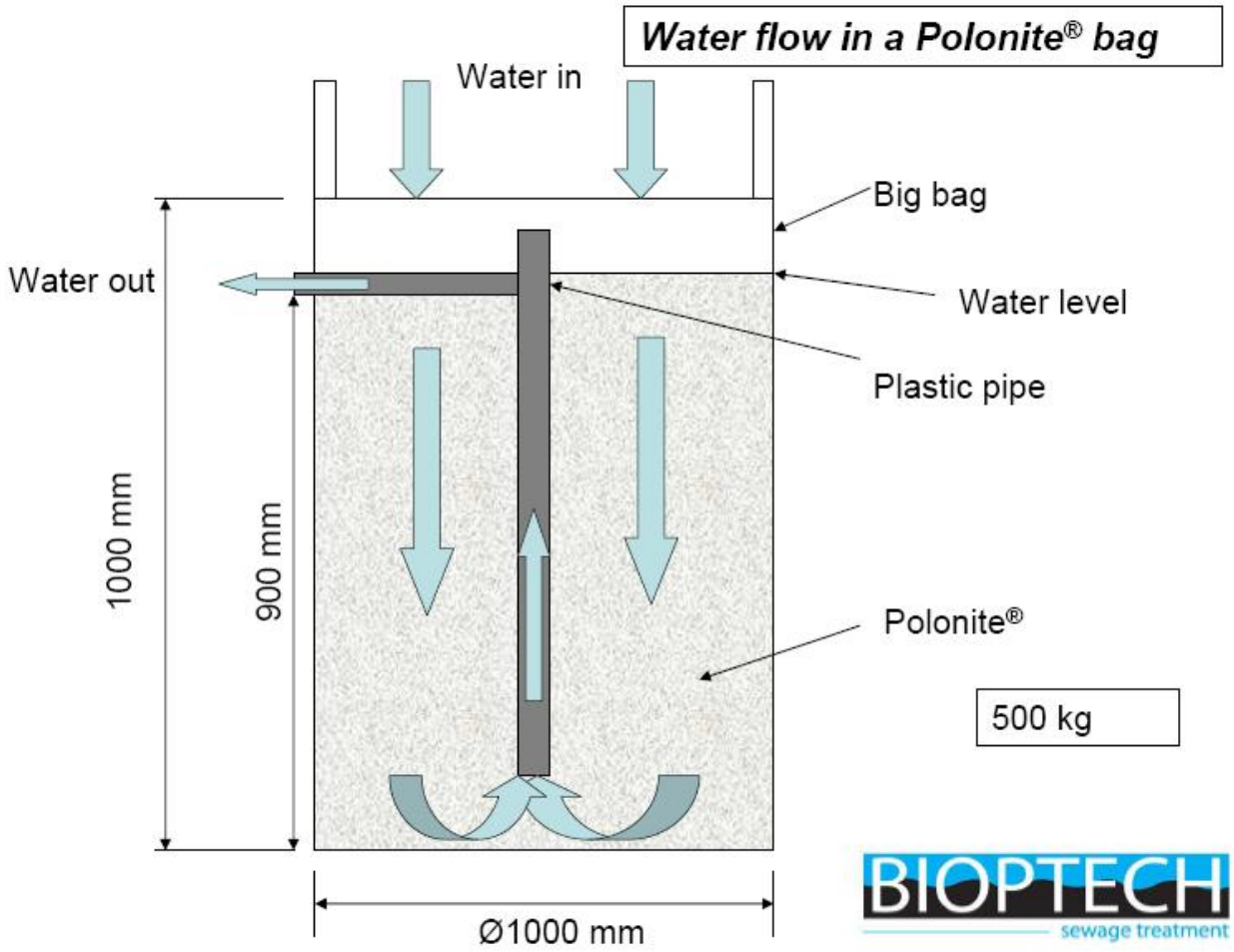

Biop – How the system works
4. Distribution and Recyling of polonite
Fertilization.
Calcium & Fosfor.
Ph 9.
Reduction of Eutrophication
Reduction of fertilization cost
Improvement of crop qualitey.
Simple Sludge Separation*
House
Sewage water
1. Sludge separator
2. Biop
Pure water
3. Service
Installation.
Maintenance.
Exhange every 2nd year
Biological cleansing in 3-5 tubes.
Nitrogen reduction.
Air pump.
Fosfor reduction
Nitrogen reduction
Germicidial.
Odeur reduction.
Sewage water
500 kg polonite
Pure water
* A municipal system for recollection of sludge is needed. Alternatively a local or even individual sludge treatment and recycling solution could be developed. In markets where needed, Bioptech can develop this solutions togheter with partner


Water flow in a Polonite® bag
Water in
Big bag
Water out
Water level
Plastic pipe
1000 mm
900 mm
Polonite®
500 kg
Ø1000 mm
BIOPTECH
sewage treatment

Polonite®

Polonite® is a calcium silicate based material which Bioptech produce in order to achieve an environmentally friendly recycling of phosphorus from sewage water. Polonite® can also remove metals form water. Phosphorus in sewage water is caught by the Polonite and converted so that it can then be absorbed by vegetation. Not only can Polonite® catch and release treated phosphorus, it even contributes to soil health composition with other supplemental substances which are needed by plants.

Phosphorus is an important nutrient in both animal and plant physiology. It is probably the element that is easiest to become limiting to living organisms. It is also considered an important pollutant in coastal and inland waters. The element is therefore a good example of waste as a resource in the wrong place, and it can therefore be concluded that the phosphorus management typical for a large part of the world is far from optimal.

Phosphorus is used as fertilizers by many farmers around the world. The price of this nutriant has become very high the last years due to low availability of natural phoshorus.

Polonite® that is used for sewage water treatment contains phosphorus that is used by crops, the calcium content in Polonite will also give right pH.

Many studies has been carried out at The Royal Technical Institute (KTH) in Stockholm. Visit *www.bioptech.eu* to dowload some of the results from their research concerning Polonite as sewage treatment and recycling of phosphorus.

In may places eutrophication has become a problem and phosphorus is here one of the most important contributors. Polonite® can remove this nutrient from wastewater in an effective and easy way and then release it to crops – Phosphorus recycling. Todays chemical treatments of wastewater is efficient but does not contribute to this recycling.

Polonite® removes between 90% and 100% of phosphorus during 1-2 years or even longer depending of dimensioning.

BIOPTECH
sewage treatment

Bioptech AB, Box 30, 19334 Sigtuna, Sweden • +46 (0)8 592 510 20 • info@bioptech.se • www.bioptech.se

Polonite® is a calcium silicate based filtermaterial to which phosphorus is bound.

Polonite® characteristics

- Polonite® is highly capable of catching phosphorus and retaining that nutrient by up to 12% (PO4-P) of its own weight
- The high pH value contributes to the elimination of bacteria or reduction of bacteria occurrence. Initial pH >12
- The phosphorus that has been retained by Polonite® can be recycled to agriculture as a fertilizer.
- The material is resistant and retains in its original form even after prolonged usage.
- All elements of Polonite® are natural materials, i.e. silicon.
- Long life for separation of phosphorus in sewage treatment
- Due to it's high pH Polonite® is an effective material to remove metals from different kind of waters.
- Let the water flow through the material. No pumps or electricity is needed.