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Literature Review: Impacts of Onsite Wastewater Treatment Systems on Water Quality

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1.0 INTRODUCTION

The Lake George Park Commission is a NYS agency charged with the long-term protection of Lake George, per Article 43 of the NYS Environmental Conservation Law. Lake George is one of the most well protected waterbodies in the Northeast, with robust stormwater management, stream corridor and invasive species protections in place. These initiatives have been successfully advanced and implemented with considerable cooperation from state agency, municipal and non-profit partners.

It is incumbent upon the Park Commission to identify point and nonpoint source pollution entering Lake George, from all sources, including wastewater treatment systems. Section 110 of Environmental Conservation Law Article 43 relates to the discharge of wastewater in the Lake George Park, specifically in relation to onsite wastewater treatment systems (OWTS). With Lake George experiencing its first ever Harmful Algae Bloom in November of 2020, it is incumbent on the Commission and partners to determine root causes of this event, and to implement measures to help prevent such events from occurring in the future.[1]

The Commission has formed an ad-hoc committee to study the issue of onsite wastewater treatment systems and water quality on Lake George in an effort to further protect the lake and public health. The committee has engaged the services a consultant to review existing literature regarding the impacts of OWTS on water quality.

2.0 LITERATURE REVIEW SUMMARY FINDINGS

With guidance from regional subject matter experts and the Commission, the review of existing literature was focused on eleven (11) studies of particular relevance to Lake George and as identified through review of readily available resources. The literature reviewed covers nearly a 40-year span from 1981 to 2020, and includes research from academia, the public sector, and private sector.

Findings from the literature suggest the efficacy of OWTS is highly variable depending on system maintenance, design, and local environmental factors such as soil type and proximity to groundwater or vadose zone depth. The risk of groundwater contamination from OWTS is largely dependent on system size, soil composition, and vadose zone depth or a system's proximity to shallow groundwater. The siting of systems and understanding septic plume migration patterns in the context of local groundwater systems is critical to mitigating the risk of groundwater contamination.

Properly functioning septic systems can contribute to elevated levels of nitrates in groundwater. High concentration of nitrates in septic plumes are a frequent concern with OWTS. Many regulations for OWTS are aimed at mitigating the risk of groundwater contamination from high concentrations of nitrates.
Specific to Lake George, the report entitled "The Total Phosphorous Budget Analysis, Lake George" suggests that OWTS's contribution to annual phosphorus load is minor when compared to surface runoff (Stearns & Wheler, 2001). However, the results of this study are based on a small sampling of just four (4) sites around Lake George. Literature reviewed indicates that historical assumptions about phosphorus loading and migration from OWTS may not be accurate.

[1] https://lgpc.ny.gov/septic-systems

Phosphorus from properly functioning septic systems may migrate to surface water. This condition was observed on a seasonal lake front community and coincide with increased algal blooms. Of note, septic systems can contribute 4 to 55% of total phosphorus to lakes (Lombardo, 2006). However, the main threat to phosphorus loading of surface waters from septic systems is from system failures where overloaded or saturated drainfields, or short circuiting via drainage ditches and pipes results in surface breakout of untreated wastewater (Robertson et al., 2019).

Work conducted by the U.S. Geological Survey found that phosphorus plumes may migrate slowly within groundwater systems and rise steeply upward to discharge into surface waters at localized discharge points (U.S. Geological Survey, 2016). Finally, research on phosphorus loading finds that while phosphorus loading from septic systems is generally a small component of the total phosphorus load to waterbodies such as lakes, impacts can be substantial since the phosphorus is in a soluble form and readily available to algae (Green, 2002). Because near-lake systems are often seasonal, this phosphorus is added to lakes at the height of the algal growing season.

Septic systems are not specifically design to treat or remove trace organics which contribute to degradation of groundwater quality. Trace organic compounds such as surfactant metabolites, metal-chelating agents, antimicrobials, antibiotics, and stimulants have been found in groundwater proximate to OWTS at concentrations that can be significantly higher than those reported in centralized treatment plant wastewaters (Conn et al., 2010).

In summation, properly sited and maintained OWTS are an effective method of wastewater treatment for many rural communities and locations where public sewer is not viable. However, systems that are not sited and constructed appropriately or functioning properly may result in negative impacts to water quality and present significant risk to public health. Regular maintenance and monitoring of OWTS can be highly effective for mitigating negative impacts of OWTS on water quality.

3.0 STUDIES REVIEWED:

3.1 An Evaluation of Five Lake George Septic Disposal Systems. 1981

Min Chen, of the New York State Department of Health – Division of Laboratories and Research evaluated wastewater treatment of five septic disposal systems located on the western shore of Lake George. The study included groundwater sampling between the septic systems and the lake, using ground water samples “above” the system as control. Groundwater sampling did not occur at two of the five sites. The sampling was conducted to determine the fate of fecal coliforms, phosphate, nitrogen and other nutrients discharges from three septic systems. Three of the five systems were constructed on the top of rocky hills while the remaining two were constructed on the beach. Four of the systems included seepage pits and one was a tile field.

Groundwater sampling occurred at varying distances away from the systems and at varying depths of groundwater. The study showed that in general, coliform bacteria and phosphate were found in high concentrations near the discharge points of two of the systems, (while no fecal coliform and little phosphate was found near the third system) but levels were reduced as distance was gained from the system. The Author concludes that he believes in part of the basin, proper treatment of wastewater prior to entry into the lake is prevented by the lack of adequate soil cover. Further, that in areas with adequate soil cover, fecal coliforms and phosphate are removed if local conditions are favorable, but nitrogen and chlorides reach the lake, and the effluent may be low in dissolved oxygen.

3.2 Effects of Septic Systems on Ground Water Quality – Baxter Minnesota. 1999.

The Minnesota Pollution Control Agency, Ground Water and Toxics Monitoring Unit conducted a study to determine the effects of septic systems on ground water quality in residential areas where ground water has a direct connection with neighboring lakes. The study consisted of testing and monitoring at 52 wells for nitrate at varying depths. Additionally, ground water plumes originating beneath individual septic systems were examined to better understand typical septic plume composition and migration.

Findings from well testing and monitoring showed that median nitrate concentrations were significantly higher in areas with OWTS than in areas with municipal sewers. All cases where nitrate exceeded drinking water standards were in areas with OWTS. Additionally, total and dissolved carbon was greater in these areas. The monitoring of septic plumes revealed that the average plume length is 82ft and ranged from approximately 33ft to 328ft. Nitrate concentrations exceeded drinking water criteria were present throughout most of the plumes and nitrate concentrations decreased slowly along the plume lengths. While aquifer characteristics are unique and location dependent, the study found that OWTS in the study area should result in approximately 7% of the shallow portion of the aquifer having nitrate concentrations above the drinking standard.

3.3 Total Phosphorous Budget Analysis, Lake George Watershed, New York. 2001.

A private environmental engineering firm, Stearns & Wheeler, LLC, conducted a study to update the total phosphorus budget into Lake George by quantifying total phosphorus concentrations and load associated with specific sources including runoff from forested and developed areas; precipitation; and groundwater flow, including migration of total phosphorus from wastewater treatment and septic systems. The study consisted of a literature review of existing water quality and nutrient loading of Lake George paired with groundwater monitoring of septic systems at four sites around the lakeshore (it is noted that the six sites were originally intended for groundwater monitoring, but two did not produce enough data to ultimately be included).

Findings of the study showed that groundwater contributions, specifically in relation to septic systems, are relatively inconsequential when compared to surface runoff contributions. Developed areas account for 5% of the land area in the watershed yet produce 43% of all the phosphorus that enters the lake as surface runoff. In all, developed areas account for almost 37% of all the phosphorus that flows into the lake while the contribution of septic systems is estimated to be approximately 1% of the annual phosphorus load.

3.4 Evaluating Phosphorus Migration from Septic Systems Near Otsego Lake. 2002.

Researchers at the State University of New York (SUNY) College at Oneonta conducted studies to understand the unique characteristics of phosphorus migration from near-lake septic systems and their impacts to Otsego Lake. A literature review of phosphorus migration and soil suitability for septic systems was paired with field studies to examine phosphorus plume migration and test existing treatment technologies near Otsego Lake.

The research showed that phosphorus derived from septic systems can migrate through soils at rates that make contamination of nearby surface waters likely, even when conventional systems are located on suitable sites and soils. While phosphorus loading into lakes from septic systems is generally a small component of the total phosphorus load, impacts can be substantial because the phosphorus is in a soluble form and readily available to algae. Additionally, because most near-lake septic systems are seasonal, phosphorus is added to lakes at the height of the algal growing season. Regulations requiring regular maintenance and inspections of septic systems in addition to site specific design and treatment requirements can lead to water quality improvement.

3.5 Ground-Water Quality Impacts from On-site Septic Systems. 2004

Research from the National Onsite Wastewater Recycling Association examined ground-water contaminants from septic systems using indicators other than nitrates to understand septic impacts to anoxic aquifers. The study examined chloride and stable isotopes to geochemically fingerprint the impacts of septic systems versus other sources of groundwater contamination.

Findings showed that nitrate is not a universal indicator of ground-water contamination by sewage. Septic systems have caused regional nitrate contamination in many areas, but only in oxic aquifers. In anoxic conditions, the ammonia in sewage may not undergo nitrification, and ground-water nitrate contamination typically does not occur. Anoxic aquifers are also vulnerable to chemical contamination from sewage. Microbial biodegradation of the organic matter added by septic effluent can change the chemistry of the aquifer, and cause increased amounts of manganese and iron to dissolve into the ground water from soil and rock. Chloride is a good indicator parameter for sewage contamination because it is present in all sewage.

3.6 Phosphorus Geochemistry in Septic Tanks, Soil Absorption Systems, and Groundwater. 2006.

A private environmental engineering firm, Lombardo Associates, Inc., conducted a study with funding from the U.S. Environmental Protection Agency (EPA) in collaboration with Washington University to document the current understanding of phosphorus chemistry and removal in septic tanks and soil absorption systems. The research included an extensive literature review on phosphorus geochemistry principles, phosphorus removal in various wastewater systems, groundwater, riparian zones, and receiving waterbodies. The study examines various forms of phosphate removal noting soil characteristics, chemical characteristics of sewage and site conditions greatly influence the effectiveness of removal and that ”septic systems located on thin soils, as often occur in association with lakeside dwellings, are probably most at risk of phosphate contamination.” The study noted that “studies performed as part of total maximum daily load (TMDL) development and lake water quality suggest that septic systems can contribute 4 to 55% of total phosphorus to lakes.”

3.7 Fate of Trace Organic Compounds during Vadose Zone Soil Treatment in an Onsite Wastewater System. 2010.

Researchers from the Colorado School of Mines Environmental Science and Engineering Division conducted a study to examine the effectiveness of onsite wastewater treatment systems in removing endocrine disrupting compounds and other trace organic compounds that have been historically overlooked in groundwater contamination. The consisted of examination of wastewater from an eight-unit apartment complex using an array of engineered and soil-based treatment units fitted with varied sampling and monitoring devices.

Results of the study were that trace organic compounds such as surfactant metabolites, metal-chelating agents, antimicrobials, antibiotics, and stimulants occur in onsite wastewater treatment systems frequently and at concentrations that can be orders of magnitude higher than typical concentrations reported in centralized treatment plant wastewaters. Assuming shallow groundwater and no removal during groundwater transport, trace organic compound concentrations at the point of exposure can exceed the U.S. Environmental Protection Agency's toxicity-based water quality criteria. In areas with a deeper vadose zone or removal during groundwater transport, trace organic compound concentrations at the point of exposure would not be expected to exceed the water quality criteria.

3.8 Tracing Microorganisms and Surrogate Organisms in the Septic Effluent of Conventional and Alternate Septic Treatment Systems. 2012.

The New York State Department of Health Center for Environmental Health, Bureau of Water Supply Protection conducted a study to determine the effectiveness of NYS approved septic system designs regarding nutrient, hydraulic, and organic loadings. The study consisted of examination of 24 systems of various NYS approved system types (75-A conventional, 75-A raised bed, aerobic treatment units, sand filters, peat filters).

The results of the study were that most systems, except for the conventional system with raised bed, removed vegetative microorganisms reasonably well. Regarding *E. Coli*, when nutrient data and hydraulic and organic loadings were taken into consideration the daily capacity of most systems could be exceeded without long term negative impacts. The systems appear to have, by design, substantial excess capacity.

3.9 Phosphorus Doesn't Migrate in Ground Water? Better Think Again! 2016.

The U.S. Geological Survey Toxic Substances Hydrology Program examined the long-term migration of phosphorus in subsurface plumes of treated sewage. The report represents summary findings from multiple studies conducted at a research site in Cape Cod, Massachusetts.
The study refutes previous assumptions that phosphorus migration in groundwater is minimal and not of ecological concern. Years of monitoring data on phosphorus concentrations in plumes of treated sewage on Cape Cod have shown that phosphorus does migrate in groundwater. Additionally, past assumptions that phosphorus plumes would discharge into a water body over a broad area were refuted. Monitoring data from the studies show that plumes typically rise steeply upward and discharge in a narrow area within 100ft of shore. This finding suggests that treating concentrated discharge areas is expected to be a cost-effective approach than treating larger plumes upgradient of a waterbody.

3.10 Review of Phosphorus Attenuation in Groundwater Plumes from 24 Septic Systems. 2019.

Researchers from the University of Waterloo and Canadian Department of Environment and Climate Change conducted a longitudinal study to better understand the extent to which properly functioning septic systems represent a threat of phosphorus loading to nearby watercourses. The study consisted of monitoring and evaluation of phosphorus concentrations in groundwater plumes from 24 on-site wastewater treatment systems encompassing a variety of domestic wastewater types and geological terrain over a 30-year period.

The study's findings showed that capacity for phosphorus removal in properly functioning septic systems is robust. At 17 of 24 sites, phosphorus retention meets or exceeds removal that would normally be achieved during conventional sewage treatment. Additionally, the study found that excavation or replacement of septic drainage bed materials should be conducted with caution, especially near sensitive surface water bodies. These drainage beds have high phosphorus accumulation and redistribution of these sediments on nearby surfaces during maintenance or replacement of tilebed materials can lead to high phosphorus loading. The study concludes that the main threat of phosphorus loading to surface waters from septic systems is likely to be from failing system.

3.11 Concurrent improvement and deterioration of epilimnetic water quality in an oligotrophic lake over 37 years. 2020.

Researchers from an array of institutions (including the Darrin Freshwater Institute on Lake George), Universities, and IBM Research conducted a 37-year (1980-2016) study to understand how concurrent environmental stressors such as climate change, eutrophication, and salinization affect long-term lake water quality. The study included sampling of 18 water quality parameters at 7 sites in the epilimnetic zone of Lake George over the period. The study concluded that deterioration of water quality in the Lake over the period was small compared to many lakes and some water quality parameters evaluated saw improvements. Small increases in Chlorophyll *a* and orthophosphate were observed, but the degree of increase indicates that watershed-scale conservation efforts to protect the water quality of the Lake are robust given the degree of development and tourism in the watershed. Despite the concentration of Chlorophyll *a* having increased by 32% the absolute increase was small. While Chlorophyll *a* concentration increased and there was a small increase in orthophosphate over the period, Total Phosphorus did not increase. Temperature of the epilimnetic zone increased by 1.8-degrees C over the period, due to global warming, and the study indicated that this may trigger algal blooms and other negative outcomes. Salinization of the Lake from road de-icing has increased substantially over the 37-year period. The study suggests that further study salt impacts to groundwater and the lakes tributaries, adjacent wetlands is needed. While salt contamination of Lake George is considered on the low end of North American Lakes, the study suggests proactive measures to limit road salt in the Lake's ecosystem.

4.0 CLOSING

The review of the cited literature suggests a clear link between improperly sited/designed or improperly functioning OWTSs and water quality impacts. For example, poorly functioning/sited/designed OWTSs can lead to excess phosphorus release. Phosphorus is a critical nutrient for life and is considered a limiting nutrient in aquatic ecosystems. “Too much phosphorus can cause increased growth of algae and large aquatic plants, which can result in decreased levels of dissolved oxygen– a process called eutrophication. High levels of phosphorus can also lead to algae blooms that produce algal toxins which can be harmful to human and animal health.” [2]

While properly designed, installed and maintained septic systems may be an effective means to manage residential wastewater in an ideal environment; many factors can contribute to systems which do not fully or adequately treat septic effluent. Site conditions (separation to groundwater, depth to bedrock, slopes, separation distance to surface water, stormwater runoff loading of systems), the routine maintenance (pump out), useful life of systems, and physical system failures.

Septic System Failures-Inspections

USEPA estimates 10-20% on OWTS do not adequately treat wastewater, half of all septic systems are in excess of 30 years old. Observed failure rates can vary. Thurston County in Washington observed failure

[2] Indicators: Phosphorus | US EPA

rates of 14-29% during shoreline surveys. This study completed inspection of 1,219 systems with an average failure rate of 18%. Failure is defined by state and county law as "when the system, or a component of the system threatens public health by inadequately treating sewage, or by creating a potential for direct or indirect contact between sewage and the public." (Thurston County Public Health and Social Services Thurston County Washington April 11, 2017). Similarly, Public Sector Consultants reported 10-25% septic system failure rate in the Saginaw Bay Region (An Assessment of Failing Septic Systems in the Saginaw Bay Region September 17, 2018 prepared by the Public Sector Consultants.)

Regular inspection of septic systems can identify many of the causes or evidence of improper system operation or failure. Such inspections can be an effective means to eliminate a serious threat to water quality and public health from onsite wastewater treatment systems.

BIBLIOGRAPHY

Chen, Min (1981) *An Evaluation of Five Lake George Septic Disposal Systems,* New York State Department of Health

Conn, K. E., Siegrist, R. L., Barber, L. B., & Meyers, M. T. (2010). Fate of Trace Organic Compounds During Vadose Zone Soil Treatment in an Onsite Wastewater System. *Environmental Toxicology and Chemistry*, 285-293. Retrieved from https://setac.onlinelibrary.wiley.com/doi/10.1002/etc.40

Dziewulski, D. M., & Boutros, S. (2012). *Tracing Microorganisms and Surrogate Organisms in the Septic Effluent of Conventional and Alternate Septic Treatment Systems.* Troy, NY: New York State Department of Health.

Green, J. E. (2002). *Evaluating Phosphorus Migration from Septic Systems Near Otsego Lake.* Oneonta, NY: SUNY Oneonta. Retrieved from https://www.oneonta.edu/academics/biofld/PUBS/ANNUAL/2001%20content/(088)%20phosphorus%20paper.pdf

Ground Water Monitoring and Assessment Program. (1999). *Effects of Septic Systems on Ground Water Quality - Baxter, Minnesota.* St. Paul, Minnesota: Minnesota Pollution Control Agency. Retrieved from https://www.pca.state.mn.us/sites/default/files/septic.pdf

Lombardo, P. (2006). *Phosphorus Geochemistry in Septic Tanks, Soil Absorption Systems, and Groundwater.* Newton, MA: Lombardo Associates, Inc. Retrieved from http://lombardoassociates.com/pdfs/060410-P-Geochemistry-FINAL-LAI-Version.pdf

McQuillan, D. (2004). *Ground-Water Quality Impacts from On-Site Septic Systems.* Albequerque, NM: National Onsite Wastewater Recycling Association. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=EDB9BCF087E63DA6446F68EA23ECFA0A?doi=10.1.1.525.4030&rep=rep1&type=pdf

Robertson , W. D., Van Stempvoort, D. R., & Schiff, S. L. (2019). Review of Phosphorus Attenuation in Groundwater Plumes from 24 Septic Systems. *Science of the Total Environment*, 640-652. doi:https://doi.org/10.1016/j.scitotenv.2019.07.198

Stearns & Wheler, LLC. (2001). *Total Phosphorus Budget Analysis Lake George Watershed New York.* Cazenovia, NY: Stearns & Wheler.

U.S. Geological Survey. (2016, June 22). *Environmental Health Toxic Substances.* Retrieved from Phosphorus Doesn't Migrate in Ground Water? Better Think Again!: https://toxics.usgs.gov/highlights/phosphorous_migration.html

Hintz, William D., et al. (2020) *Concurrent improvement and deterioration of epilimnetic water quality in an oligotrophic lake over 37 years.* Darrin Fresh Water Institute, Department of Biological Sciences, Rensselaer Polytechnic Institute, Troy, New York; Lake Erie Center, Department of Environmental Sciences, University of Toledo, Oregon, Ohio; Department of Biology, Montclair State University, Montclair, New Jersey; School of Natural Sciences and Mathematics, Stockton University, Galloway, New Jersey; IBM Research, Yorktown Heights, New York