The Cascade 40B Apartment Complex

Threats to Wayland’s Health, Safety and Environment

Agenda:

McGregor & Legere, PC

Massachusetts Environmental Lawyers For Over 40 Years

Legal representative for ProtectWayland: The Board needs and is entitled to receive a proper hydrogeo study and flood zone study

Mark Hays

Co-founder of ProtectWayland and data analysis expert: The Cascade hydrogeo study and model are based on defective data

Scott W. Horsley

Hydrology expert: Key issues with the Cascade hydrogeo study

Luke H. Legere, Esq.

Legal and regulatory review

1. **The Project threatens local interests** of protecting public health, safety and the natural environment, including flooding and the unique habitat value associated with Pine Brook.
2. **The Board reasonably requested** a hydrogeological study and delineation of the Property's FEMA 'high risk' flood zone, which are required by the Town of Wayland's Health Regulations and state and federal regulations, respectively.
3. **The basic information provided by hydrogeo and flood zone studies is necessary** to understand existing site conditions, evaluate the Project's design and compliance with state and local standards, and identify and mitigate the Project's impacts on public health, safety and the natural environment.
4. **The Board is entitled to this fundamental information** under the broad authority granted by G.L. c. 40B, §21. That statute confers upon the Board "the same power to issue permits or approvals as any local board or official who would otherwise act with respect to such application … ." See *Zoning Bd. of Appeals of Sunderland v. Sugarbush Meadow, LLC*, 464 Mass. 166, 182-183 (2013) (citing *Dennis Hous. Corp. v. Zoning Bd. of Appeals of Dennis*, 439 Mass. 71, 79 (2003)).

MCGREGOR & LEGERE, PC

MASSACHUSETTS ENVIRONMENTAL LAWYERS FOR OVER 40 YEARS

Luke H. Legere, Esq.

Legal and regulatory review

5. **The Applicant's hydrogeological report is rife** with inconsistencies and deficiencies.
6. **The Applicant's refusal to provide a flood zone study** makes it impossible to determine what portion of the Property, proposed structures and septic leach fields may be within the FEMA 'high risk' flood zone and associated wetland Resource Areas.
7. **These fundamental pieces of information** govern many key aspects of the Project, including design and siting of the building and septic system. This information is necessary for the Board to determine the Project's compliance with local, state and federal standards including wetlands, health, septic and the state Building Code.
8. **Without this basic site information, it is impossible for the Board to assess** the Project's impacts on public health and safety, the unique natural environment, and to condition the Project to protect those and other important local concerns.

As a result, the Board should deny the Project a Comprehensive Permit, or at least deny the Applicant's request for waivers from local floodplain and wetlands bylaws, Wayland Board of Health Regulations and stormwater regulations.

Mark Hays

Co-founder of ProtectWayland and data analysis expert

The Cascade hydrogeo study is based on defective data

1. Critical soil permeability tests violated ASTM test standards and results cannot be relied on.
2. The number of soil sample tests from affected areas is limited and impacted by a classic ‘outlier’ value that should have been excluded.
3. The study used inaccurate LiDAR elevation data instead of survey data; accurate elevations are essential to determine where the septic mound will ‘break out’ and contaminated water will reach the surface.
4. These data are the foundation of the hydrogeo study and all of the conclusions based on the study. If the data are flawed and unreliable, so are the study and conclusions.
5. The hydrogeo model itself is plagued by design issues.

References: This review is designed to be simple and clear, but is backed by scientific research. References are included at the end of this presentation for each key point.

Mark Hays

Co-founder of ProtectWayland and data analysis expert

Two different soil permeability tests – most using D2434, a standard that was withdrawn by ASTM in 2015 due to inaccurate results:

Well	Samples	Soil Analysis?	Permeability Analysis?		Test Sample (inches)		
		ASTM D422	Test Standard Used	Test Equipment Used	Diameter	Height	Volume
B-1	S-1 / S-2	Yes	ASTM D2434	Unknown	4.00	1.10	13.80
B-2	S-3	No	No				
B-2	S-4	No	No				
B-2	S-5	No	No				
B-3	S-6	No	ASTM D2434	Unknown	4.00	3.00	37.70
B-3	S-7	Yes	No				
B-3	S-8	No	No				
B-5	S-9	No	ASTM D2434	Unknown	4.00	1.00	12.60
B-5	S-10	No	ASTM D5084	Flexible Wall Permeameter	2.96	2.55	17.50
B-5	S-11	Yes	No				
B-4	S-12	No	ASTM D2434	Unknown	4.00	1.20	15.10
B-4	S-13	No	ASTM D5084	Flexible Wall Permeameter	2.81	2.10	13.00
B-6	S-14	No	No				
B-7	S-15	Yes	No				
B-8	S-16	No	ASTM D2434	Unknown	4.00	2.80	35.20
B-8	S-17	Yes	No				
B-9	S-18	No	No				
B-9	S-19	No	ASTM D2434	Unknown	4.00	1.50	18.80
B-3	S-20	Yes	ASTM D2434	Unknown	4.00	3.70	46.50
B-4	S-21	No	No				

Note: See the Florida Department of Transportation study of variability in D2434 results, References #6

Mark Hays

Co-founder of ProtectWayland and data analysis expert

Two different soil permeability tests – most using D2434, a standard that was withdrawn by ASTM in 2015 due to inaccurate results:

Geosphere's memo to the ZBA on 28 August offered this rationale:

"The laboratory indicated which sample volumes were too small to perform the Fixed Wall test. "

"Fixed Wall" means the D2434 test. GeoSphere needs to check their data. Samples selected for the D5084 flexible wall test (highlighted in green) had *larger* volumes (not smaller) than samples selected for D2434 fixed wall tests – so this explanation does not make sense. We still do not know why they used two different tests.

							Test Sample (inches)		
						ed	Diameter	Height	Volume
							4.00	1.10	13.80
							4.00	3.00	37.70
							4.00	1.00	12.60
						ameter	2.96	2.55	17.50
							4.00	1.20	15.10
						ameter	2.81	2.10	13.00
							4.00	2.80	35.20
B-9	S-18		No		No				
B-9	S-19		No		ASTM D2434	Unknown	4.00	1.50	18.80
B-3	S-20		Yes		ASTM D2434	Unknown	4.00	3.70	46.50
B-4	S-21		No		No				

See: Geosphere memo, References #2

Mark Hays

Co-founder of ProtectWayland and data analysis expert

Soil tests with widely varying volumes violate the ASTM D2434 standard and basic test procedures:

A basic rule with tests like these is “use the minimum and standard sample size” to ensure accurate, reliable, repeatable results.

ASTM D2434 *requires* a minimum and standard sample size. Note the wide variation in these sample heights and volumes; some are very low. This clearly violates the ASTM standard and these test results cannot be relied on.

These basic errors in testing were not explained in Geosphere’s memo of 28 August.

					Test Sample (inches)		
				…sed	Diameter	Height	Volume
					4.00	1.10	13.80
					4.00	3.00	37.70
					4.00	1.00	12.60
				…neameter	2.96	2.55	17.50
					4.00	1.20	15.10
				…neameter	2.81	2.10	13.00
					4.00	2.80	35.20
B-8	S-17	Yes	No				
B-9	S-18	No	No				
B-9	S-19	No	ASTM D2434	Unknown	4.00	1.50	18.80
B-3	S-20	Yes	ASTM D2434	Unknown	4.00	3.70	46.50
B-4	S-21	No	No				

Note: See the ASTM D2434 standard in the Appendix.

Mark Hays

Co-founder of ProtectWayland and data analysis expert

Sample size in ASTM D2434:

The permeameter must be filled with soil until the level is 2cm above the top manometer outlet, as shown in the photo to the right.

ASTM D2434, section 6.5:

> “Compact successive layers of soil to the desired relative density by appropriate procedures, as follows, to a height of about 2 cm (0.8 in.) above the upper manometer outlet.”

Clearly many of the samples used in these critical tests were far too small – most were less than 2” tall.

See: ASTM D2434 standard, References #3

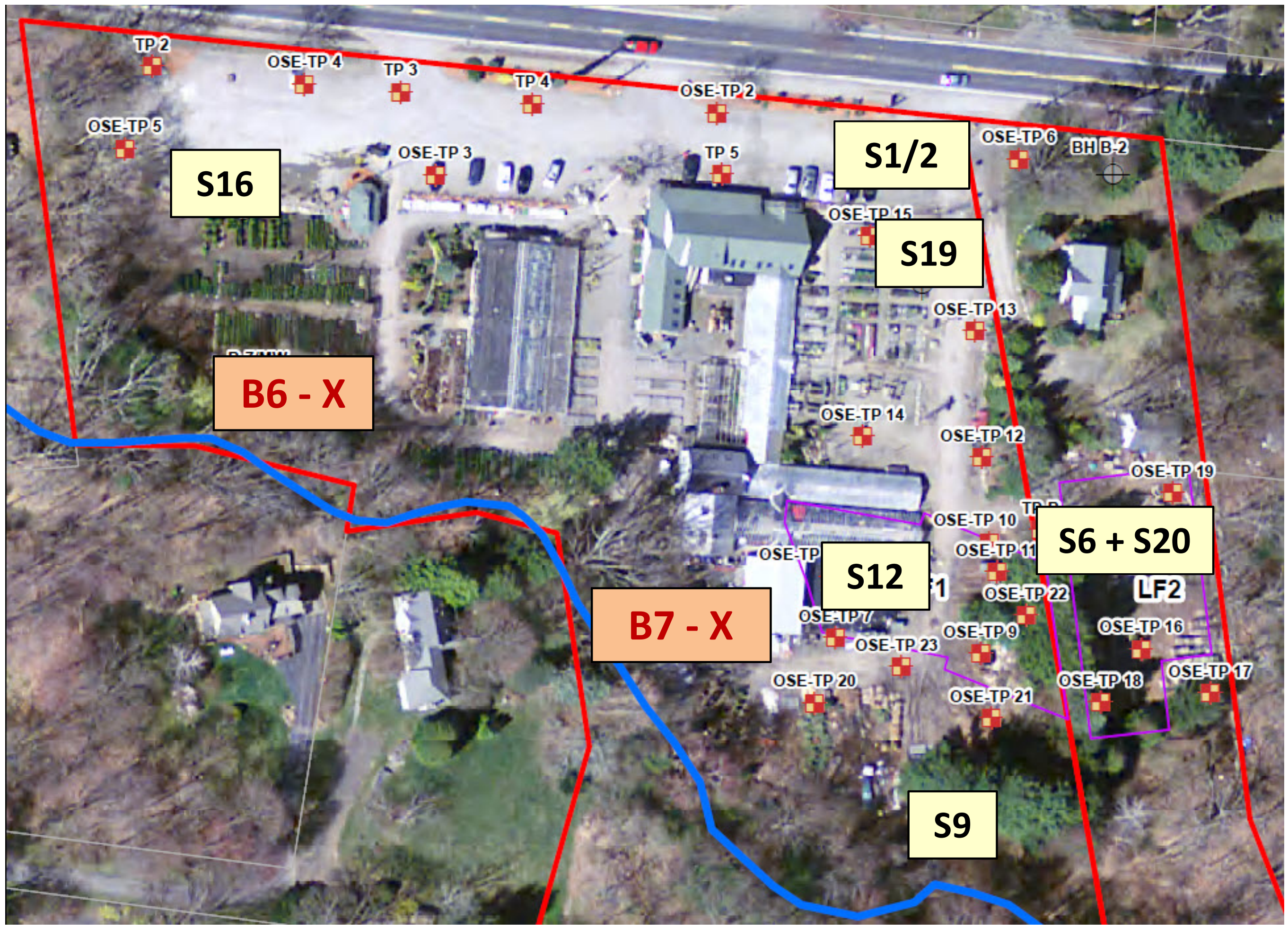
Mark Hays

Co-founder of ProtectWayland and data analysis expert

Not enough data:

Only seven soil permeability tests were performed for use in the model, out of 21 soil samples.

- Three tests are from the north side, far from the septic leach fields.
- Only one test near Pine Brook.
- No samples from B6 and B7 were tested – two of three boreholes close to Pine Brook and breakout areas from the septic system mound.



Mark Hays

Co-founder of ProtectWayland and data analysis expert

Outlier biased the entire model:
The limited number of soil permeability tests increased the risk that an 'outlier' (an unusually high or low value) could skew the average used in the hydrogeo model.

This is exactly what happened.
You can easily spot the outlier: S6 from borehole B3, 216% higher than the next-closest test result and 445% higher than the average of all other results.

'Permeability' is the key variable , the rate that water will flow through the soil. If the rate is lower, the septic mound will be higher, which increases the risk of breakouts.

Including S6 biased the entire model.

Test	Borehole	Permeability
S1/2	B1	51.02' per day
S6	B3	311.81' per day
S9	B5	31.18' per day
S12	B4	39.69' per day
S16	B8	147.40' per day
S19	B9	107.72' per day
S20	B3	39.69' per day

Average with S6 outlier: 104'

Value used in the model: 90'

Average without S6: 70'

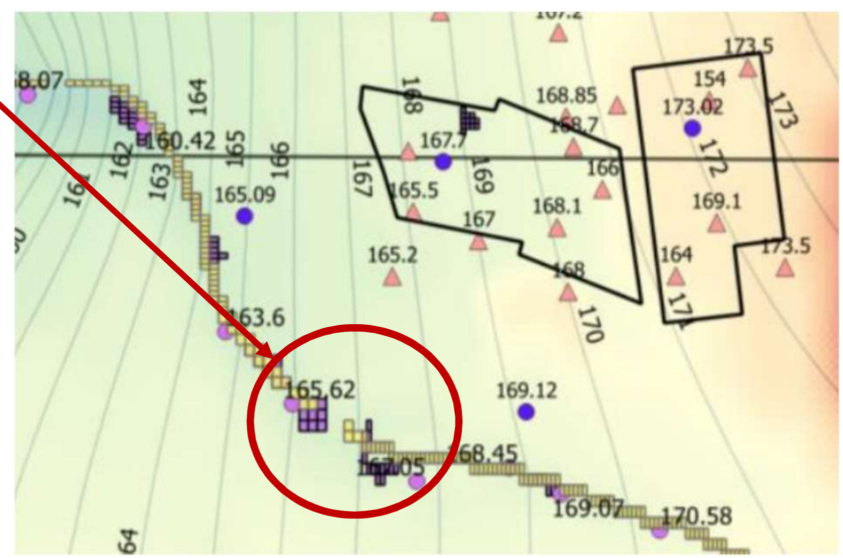
Mark Hays

Co-founder of ProtectWayland and data analysis expert

Errors / anomalies in the hydrogeo model

1. **MODFLOW 'Drain' function instead of 'River':** MODFLOW includes a "Drain" (DRN) package used to simulate the effects of features such as agricultural drain pipes. Geosphere's hydrologist picked this instead of the 'River' (RIV) package, which is used to model streams and rivers like Pine Brook. No explanation was provided in Geosphere's response on 28 August.

2. **Gap in the drain:** There is a gap in the drain as shown in the map to the right. This would affect groundwater and stream flow near two of the outbreak areas. No explanation was provided in Geosphere's response on 28 August.

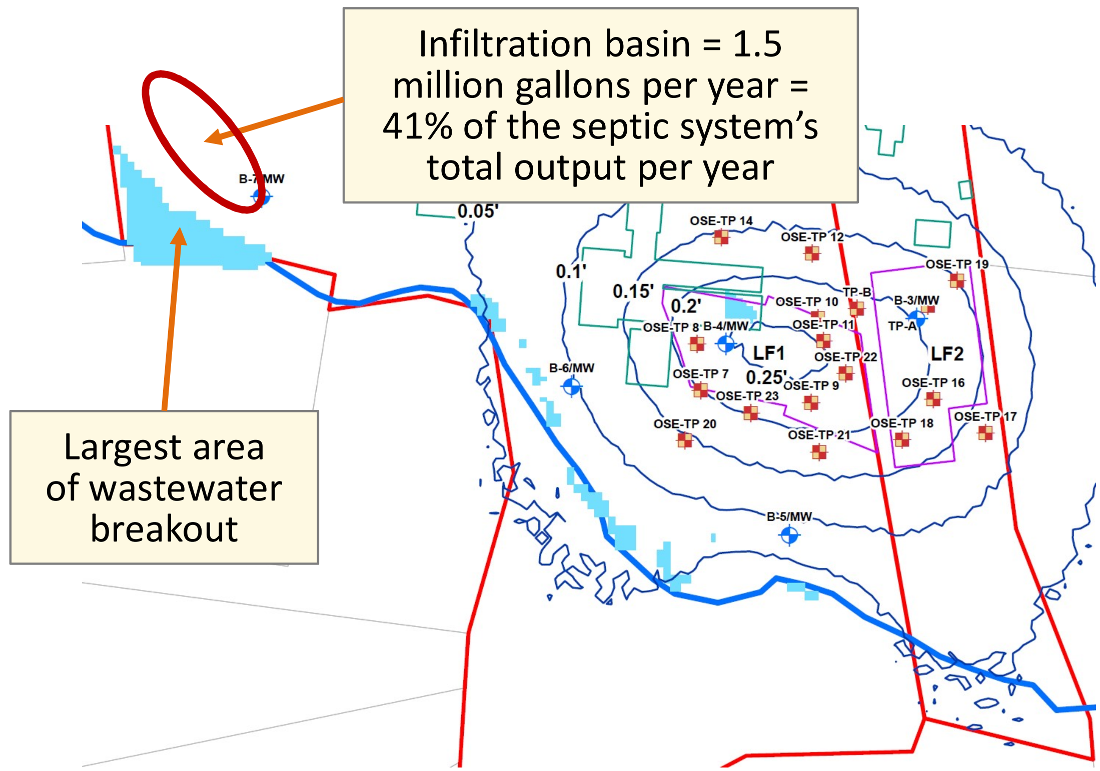


Mark Hays

Co-founder of ProtectWayland and data analysis expert

Errors / anomalies in the hydrogeo model

3. **No stormwater infiltration:** Even though 1.5 million gallons of stormwater from the large roof, exterior driveways and parking areas will be infiltrated annually through a basin next to the largest wastewater breakout area, this basin and large volume of water were not included in the hydrogeo model.



Mark Hays

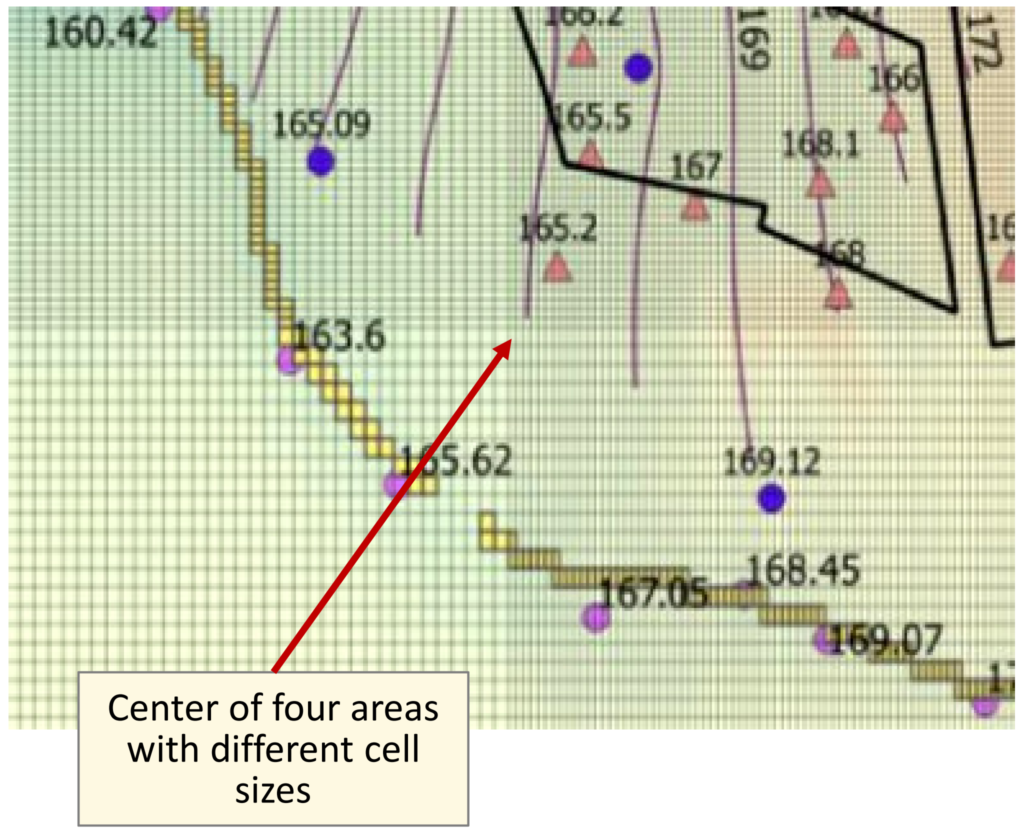
Co-founder of ProtectWayland and data analysis expert

Errors / anomalies in the hydrogeo model

4. **Different cell sizes:**
   On arbitrary boundaries, the model is divided into areas with different cell sizes. This changes the way ‘head’ (pressure) is calculated.

   There was no rationale and no explanation was offered in Geosphere’s memo on 28 August.

   Was the model ‘tuned’ to improve results?



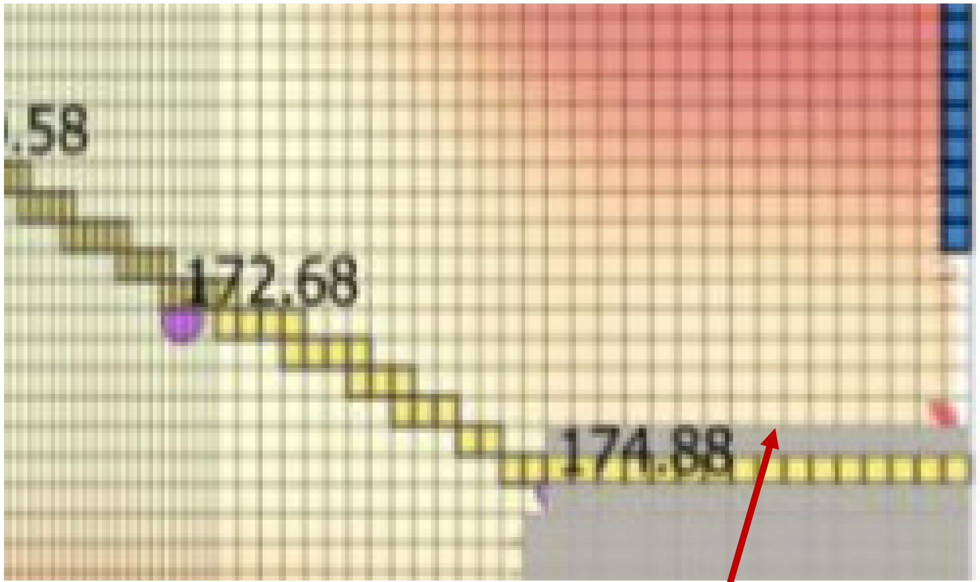
Mark Hays

Co-founder of ProtectWayland and data analysis expert

Errors / anomalies in the hydrogeo model

5. **No-flow boundary:** A boundary was added above the Pine Brook 'drain' on the eastern side. This blocks all flow of groundwater into the drain in the model, affecting flows from the nearby septic leach fields.

   There was no rationale and no explanation was offered in Geosphere's memo on 28 August.



No-flow boundary (gray area) above the drain representing Pine Brook

Mark Hays

Co-founder of ProtectWayland and data analysis expert

Errors /

5. No-

A b
abo
'dra
sid
flow
into
mo
fro
lea

The
and
offe
me

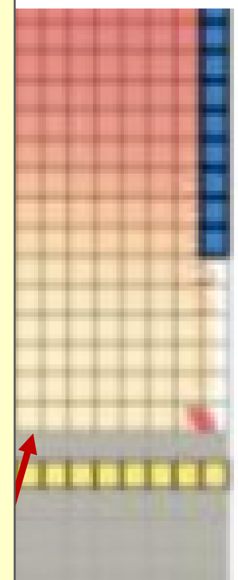
No answers were provided to almost all of the questions raised by ProtectWayland experts.

We reviewed the Applicant's hydrogeo study and delivered 22 questions to the ZBA on 26 July, giving the Applicant and Geosphere an entire month to reply. Very few answers were offered, however, in the Geosphere memo on 28 August.

As noted by Scott Horsley in his letter to the ZBA:

> "It is difficult for me (or anyone) to complete a meaningful review of this report until these questions are answered."

Please see "Cascade Hydrogeo Study: Questions and Clarification", for all of the questions asked by ProtectWayland.



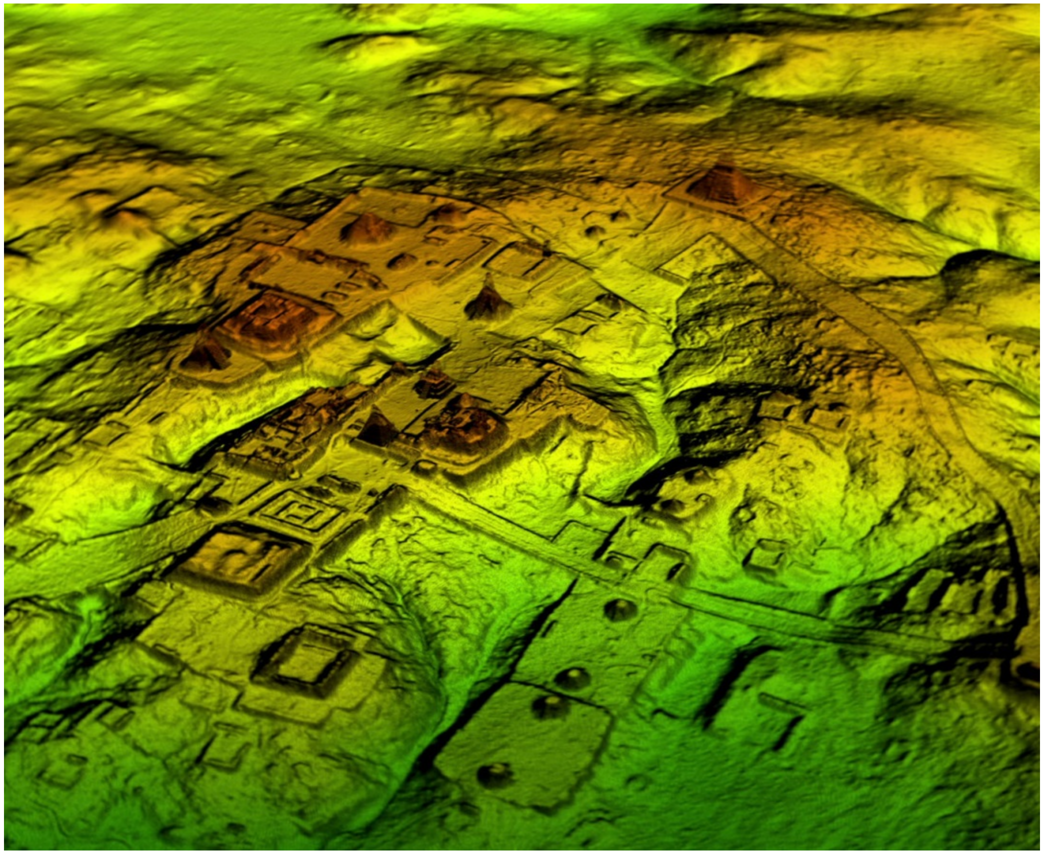
lary (gray
he drain
ine Brook

Mark Hays

Co-founder of ProtectWayland and data analysis expert

Inaccurate LiDAR elevation data

The Cascade hydrogeo study used 2010 LiDAR (Light Distance and Ranging) data from FEMA for the elevations in the model. LiDAR has been used to find Mayan ruins hidden in the jungle, as shown to the right. Why not use LiDAR to reduce costs for local surveys, hydrogeo studies, etc?



The answer: LiDAR accuracy varies based on the equipment, whether an airplane is used to gather data quickly over a large area, or a helicopter over a small area, etc. 2010 FEMA LiDAR data is not accurate enough for this study. Accurate survey data was available and should have been used instead.

Mark Hays

Co-founder of ProtectWayland and data analysis expert

FEMA's 2010 LiDAR accuracy specs

Contractor specs for FEMA's 2010 LiDAR project highlight the accuracy issues for this large scale survey where data was collected from airplanes:

Equivalent Contour Accuracy	FEMA Specification Level	$RMSE_z$	NSSDA $Accuracy_z$ 95% confidence level	SVA (target)	CVA (mandatory)
1 ft		0.30 ft or 9.25 cm	0.60 ft or18.2 cm	0.60 ft or18.2 cm	0.60 ft or18.2 cm
2 ft	Highest	0.61 ft or 18.5 cm	1.19 ft or 36.3 cm	1.19 ft or 36.3 cm	1.19 ft or 36.3 cm
4 ft	High	1.22 ft or 37.1 cm	2.38 ft or 72.6 cm	2.38 ft or 72.6 cm	2.38 ft or 72.6 cm
5 ft		1.52 ft or 46.3 cm	2.98 ft or 90.8 cm	2.98 ft or 90.8 cm	2.98 ft or 90.8 cm
8 ft	Medium	2.43 ft or 73.9 cm	4.77 ft or 1.45 m	4.77 ft or 1.45 m	4.77 ft or 1.45 m
10 ft		3.04 ft or 92.7 cm	5.96 ft or1.82 m	5.96 ft or1.82 m	5.96 ft or1.82 m
12 ft	Low	3.65 ft or 1.11m	7.15 ft or 2.18 m	7.15 ft or 2.18 m	7.15 ft or 2.18 m

Even at the "Highest" level, this elevation data is accurate only within 1.19 feet. The data file states: "Vertical Accuracy (cm): 17.8 - Tested fundamental vertical accuracy at 95th percentile in mixed land covers. Horizontal Accuracy (cm): 100 - Not tested." This means that the *position* of elevation points are estimated to be inaccurate +-39".

See: FEMA specifications, References #10 and FEMA 2010 data file

Mark Hays

Co-founder of ProtectWayland and data analysis expert

LiDAR accuracy degrades with tree cover

The laser beam in a LiDAR system has the most difficulty measuring surface elevation if it is covered by trees and shrubs. Research projects have shown:

- Laser pulses are reflected by trees and shrubs and fewer reach the ground, creating errors. The surface must be interpolated to fill in gaps in the data.
- Error rates vary in direct proportion to the density of foliage cover, increasing as coverage rises, as shown in the graph to the right.
- Trees and shrubs cover sections of the Cascade site, including both sides of Pine Brook. This increases errors, particularly near the Brook.

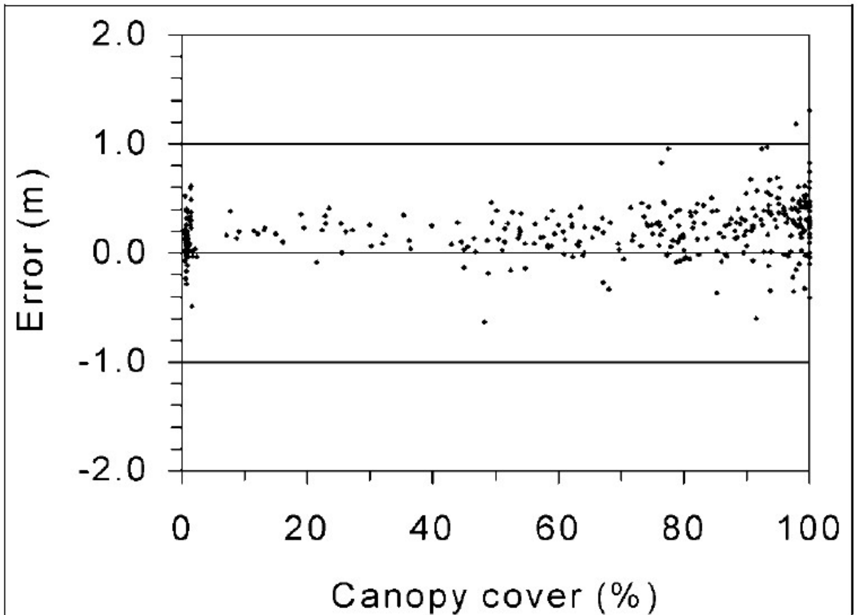


Figure 11. Scatter of elevation error across the range of canopy cover at the checkpoints.

See: References #15 - 22

Mark Hays

Co-founder of ProtectWayland and data analysis expert

LiDAR errors are biased

LiDAR elevation errors are not evenly distributed plus / minus. LiDAR positively biases elevation data, as shown in the graph below and on the previous page.

Almost all of the errors *increase* the elevation, a key factor for the Cascade hydrogeo study.

The Cascade hydrogeo model shows that the wastewater mound is very close to the surface of the ground with 'breakout' in a number of areas including along Pine Brook.

The actual surface elevation is >1 foot lower than the LiDAR data used in the model, which would lead to breakouts in more and larger areas.

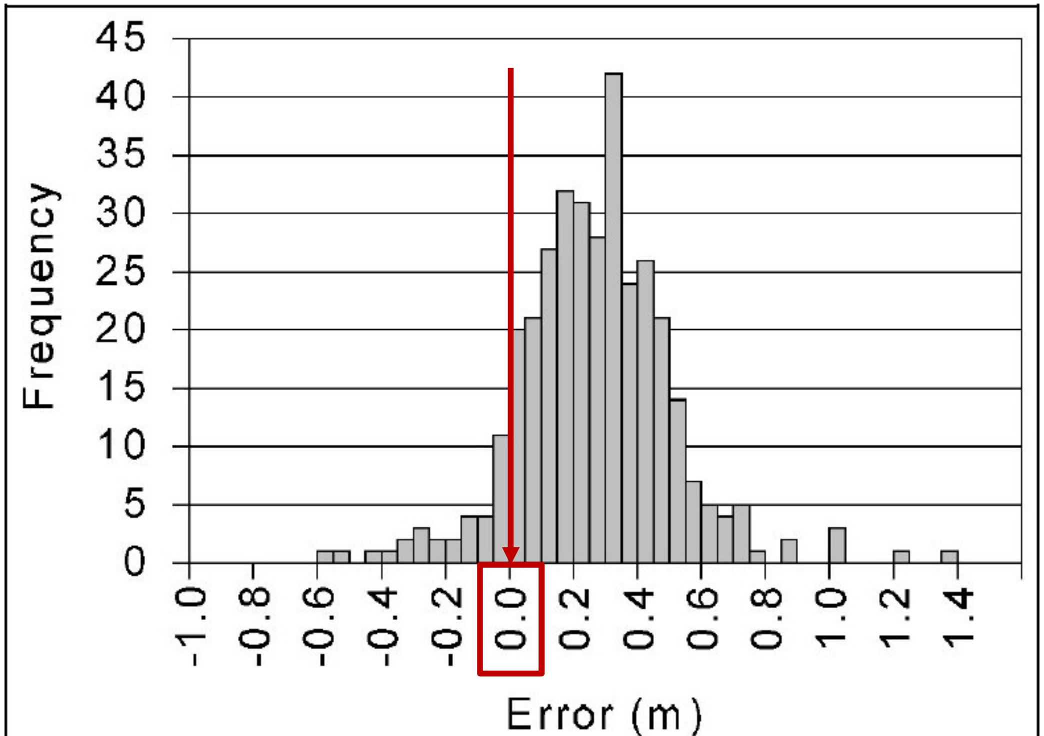


Figure 6. Distribution of lidar DTM error compared with 347 surveyed checkpoints.

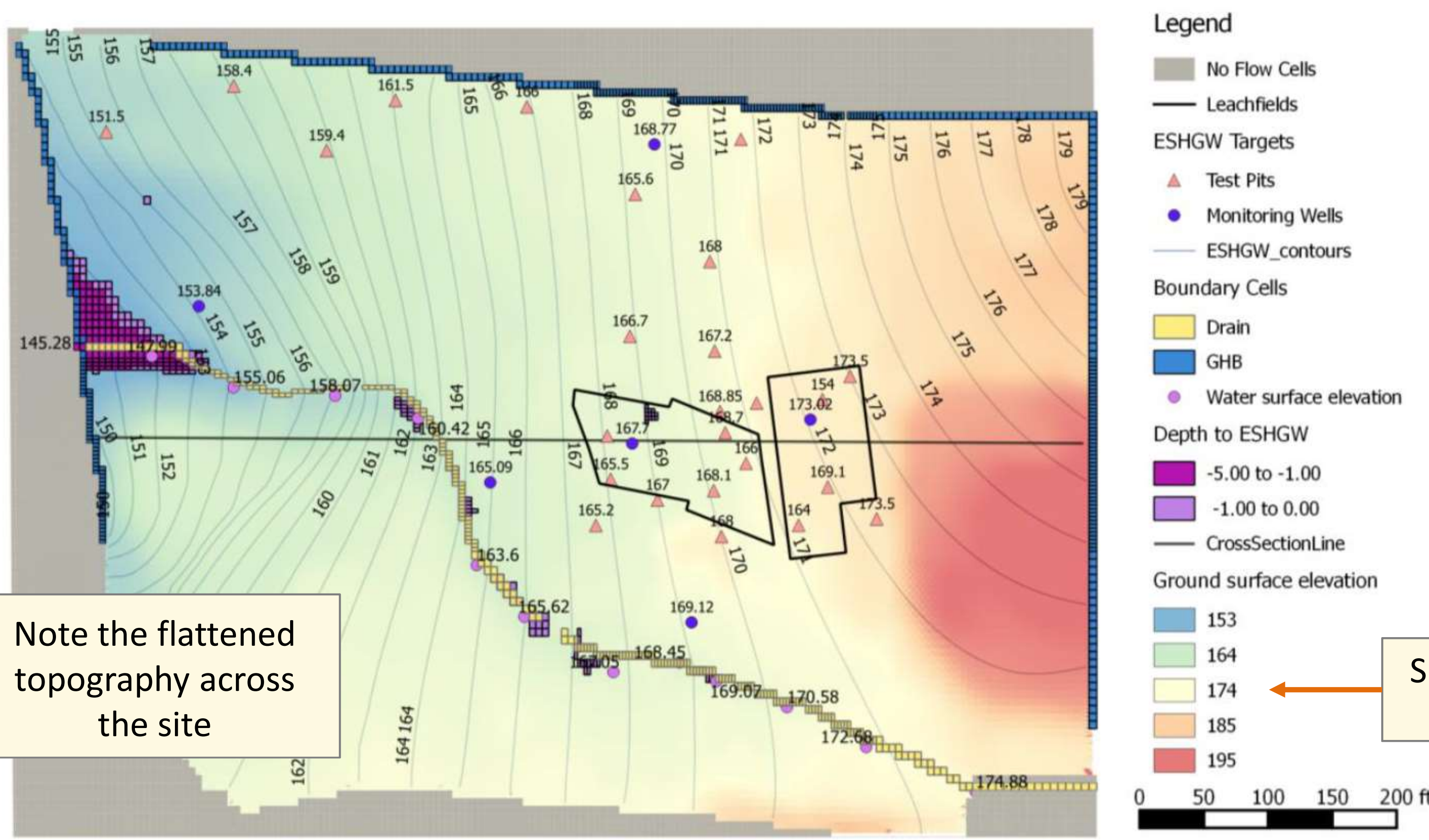
See: References #15 - 22, *emphasis added*

Mark Hays

Co-founder of ProtectWayland and data analysis expert

You can see these LiDAR errors in the study

Model maps plainly show the impact of LiDAR errors. Elevations are averaged and flattened across the site. Steep banks next to Pine Brook were not detected:



Note the flattened topography across the site

Surface elevations are color coded

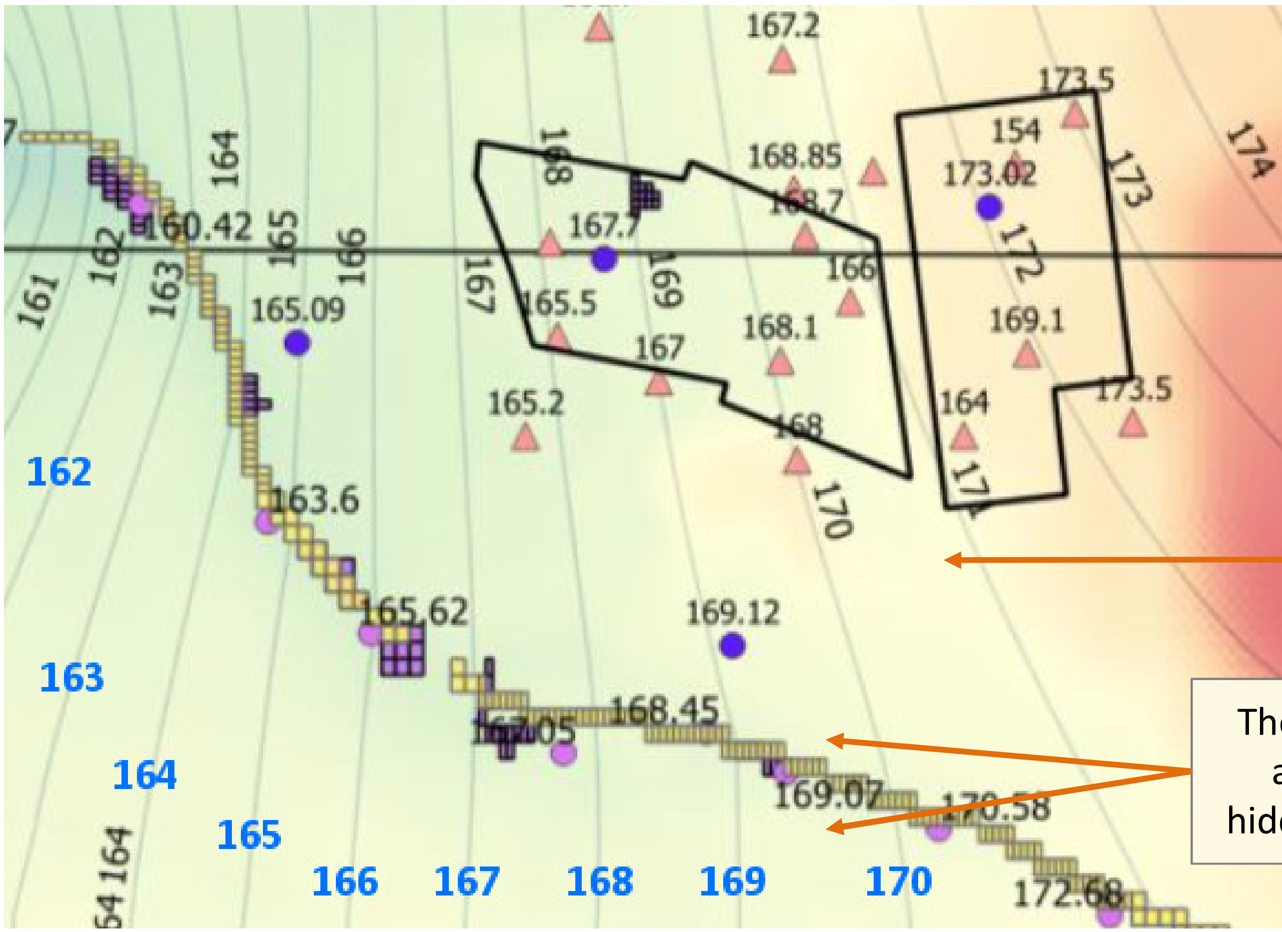
See: Cascade Hydrogeo Report, Appendix D, page 5

Mark Hays

Co-founder of ProtectWayland and data analysis expert

Close-up highlights LiDAR errors:

Here is a close-up view along Pine Brook, where the model shows breakout areas:



Surface elevations are color coded. Note how smooth the surface is.

The banks along Pine Brook are completely missing, hidden from LiDAR by foliage

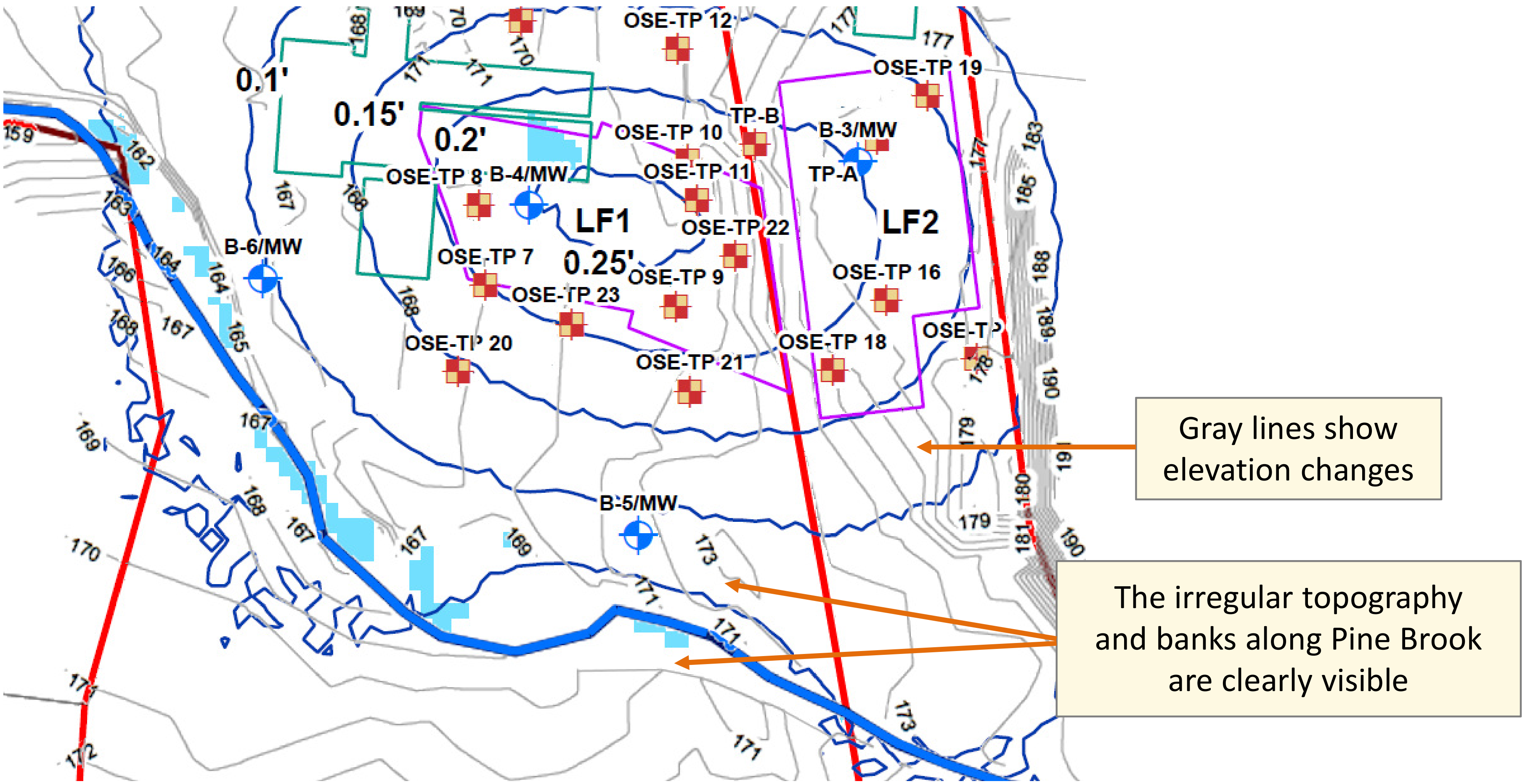
See: Cascade Hydrogeo Report, Appendix D, page 5

Mark Hays

Co-founder of ProtectWayland and data analysis expert

Close-up with the actual topography:

This is the same area along Pine Brook with surveyed elevations that should have been used in the model:

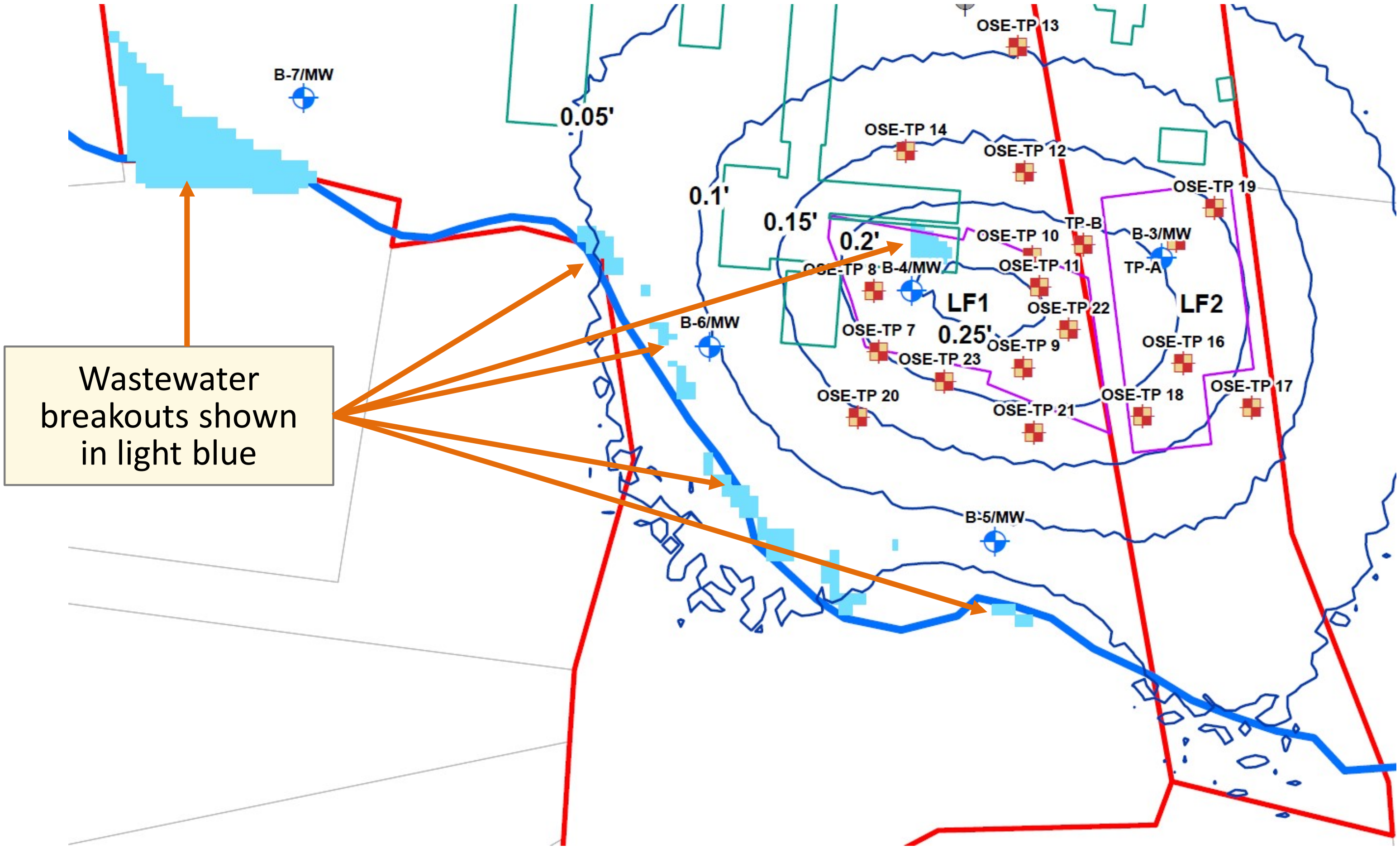


Mark Hays

Co-founder of ProtectWayland and data analysis expert

Breakouts based on LiDAR

The model map shows breakouts in a number of areas based on LiDAR, where wastewater would reach the surface:

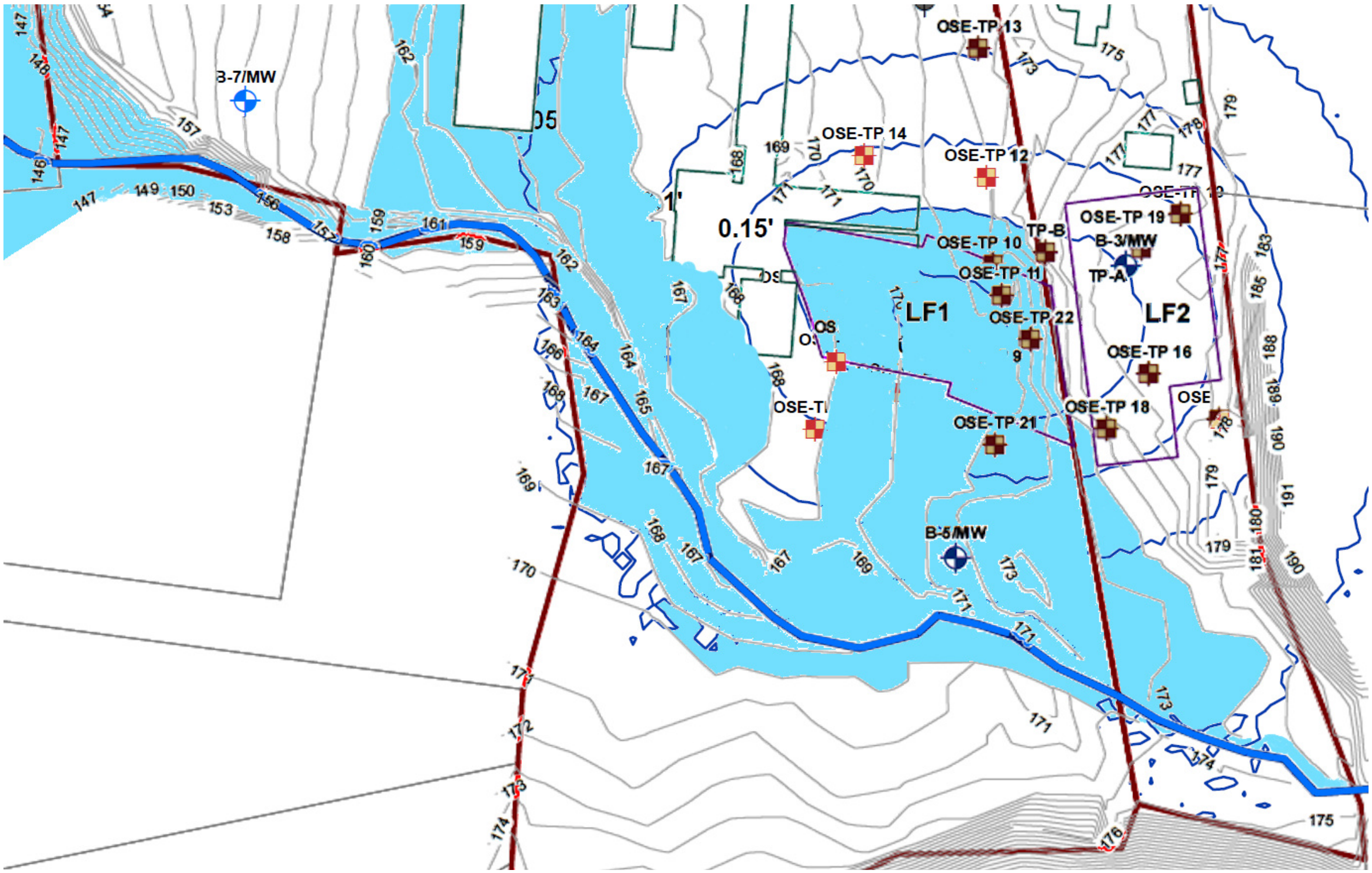


See: Cascade Hydrogeo Report, Figure #6

Mark Hays

Co-founder of ProtectWayland and data analysis expert

Using accurate elevations and subtracting an average LiDAR error of one foot, breakout areas expand significantly:



Scott W. Horsley

Hydrology & Water Resources Consultant

Background:

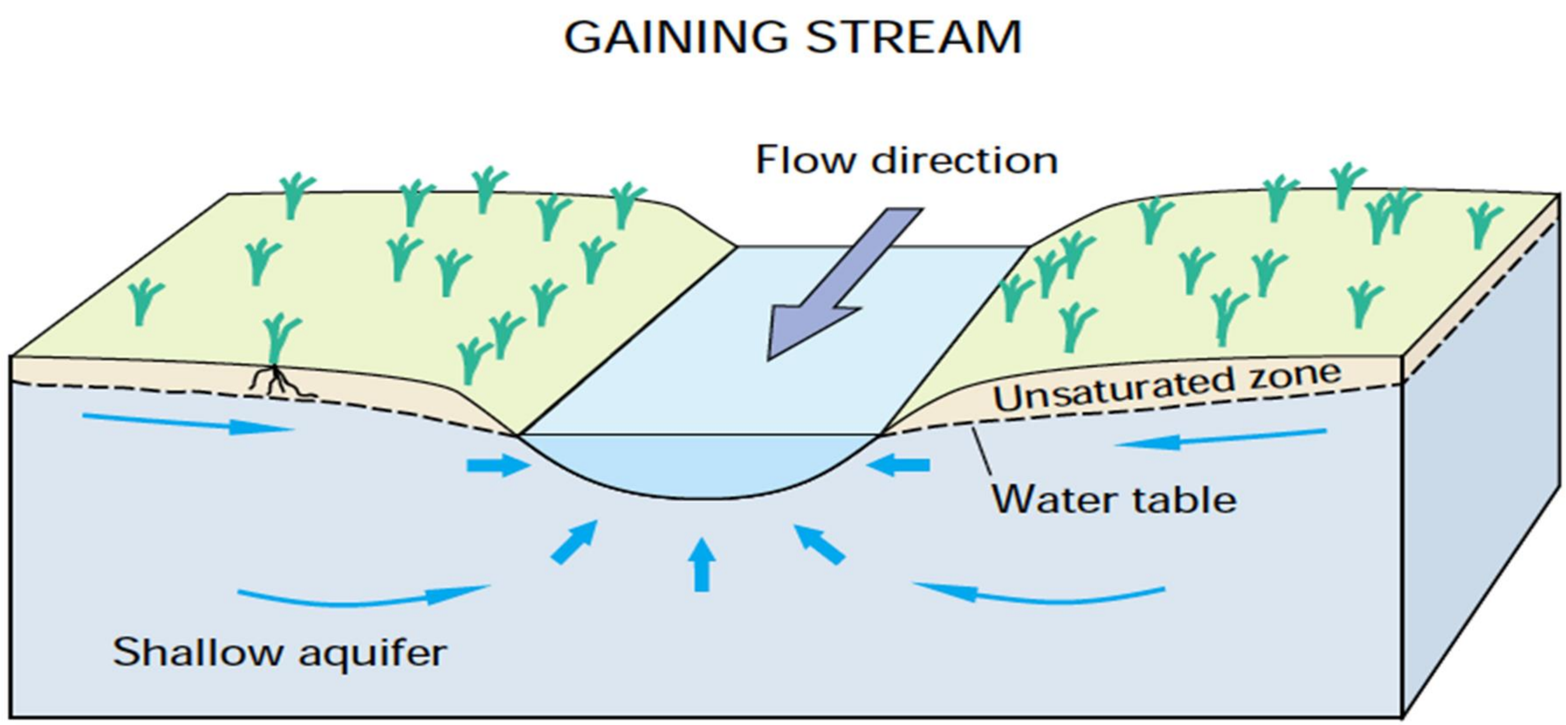
- Thirty years of experience as a consulting hydrologist, including with the U.S. Environmental Protection Agency and MADEP.
- Developed Watershed Protection Guidance documents and provided related training in 43 states nationwide.
- Served on the MADEP Stormwater Advisory Committee, Sustainable Water Initiative, Climate Change Adaptation Advisory Committee and Title 5 Wastewater Advisory Committee.
- Assisted in the preparation of the Massachusetts Smart Growth and Smart Energy Toolkit.
- Serve as adjunct faculty at Tufts University and Harvard Extension School for graduate courses in Water Resources Management, Low Impact Development, and Green Infrastructure.

Scott W. Horsley

Hydrology & Water Resources Consultant

Key issues with the Cascade hydrogeo study:

1. **The Cascade site is a riparian area** with a shallow water table. Rate of flow, temperature and water quality are critical to sustaining the valuable Pine Brook habitat and ensuring public safety.



Scott W. Horsley

Hydrology & Water Resources Consultant

2. Town of Wayland Regulations

a) **Board of Health Regulations** for On-Site Subsurface Sewage Disposal Systems, Section II (Design Requirements), Subsection D (Distances): 100 feet for a facility with a design flow greater than 1000 gallons per day – the minimum that may be increased for "multiple" dwellings or "higher volume sewage discharges".

b) **Subsection L (Hydrogeological Evaluation):** Wastewater flows of >9,000 gallons per day are required to have a hydrogeological evaluation with review by the Board of Health to determine that "…the ground and surface water is not compromised."

c) **Subsection C4 (Leaching Facilities):** Systems designed to receive more than 1000 gallons per day must be at least four feet above the maximum ground water elevation including mounding.

Scott W. Horsley

Hydrology & Water Resources Consultant

3. Basic problems in the hydrogeo study

a) **Inaccurate soil testing data:** D2434 tests did not follow the ASTM standard. D2434 was withdrawn in 2015 due to problems with accuracy. These data are the foundation of the hydrogeo model.

b) **Inaccurate LiDAR elevation data** which increases the apparent altitude of land– particularly areas covered by foliage, e.g. around Pine Brook. More accurate survey data was available. Accurate elevations are essential in the hydrogeo model to determine areas of potential breakout.

c) **Anomalies and apparent errors in the model** which have not been explained, e.g. the gap in the Pine Brook 'drain', variations in cell size, the choice not to use the more accurate MODFLOW 'RIV' package, etc.

d) **No sensitivity analyses were conducted** to measure the relative impact of soil permeability, water levels, flow rates etc. This is standard step in hydrogeo studies.

e) **No answers to most of the 22 questions** we delivered on 26 July. As noted in my letter to the ZBA, it is difficult for me (or anyone) to complete a meaningful review of this report until these questions are answered.

Scott W. Horsley

Hydrology & Water Resources Consultant

4. Bedrock under the site

a) **"No bedrock was found"** at any of the test well locations sunk by Crawford Drilling Services, according to the Cascade hydrogeo report. Most locations encountered "refusal" at unusually shallow depths, however, between 12' and 14.5' – which is still unexplained by GeoSphere and the Applicant. (Only larger GeoProbe units can sample bedrock with a special attachment; see: https://geoprobe.com/videos/7822dt-confirmatory-rock-sampling)

b) **2003 drilling for an irrigation well ran into bedrock at ~20'** in an area between the Crawford boreholes. This probably indicates why the GeoProbe unit encountered refusal at shallow depths.

c) **Underlying bedrock is important for hydrogeo models** because bedrock can affect the height of the septic mound and cracks in the rock create channels for accelerated movement of water. Additional test wells should be drilled (not 'direct pushed') to determine the extent and elevations of this apparent layer of bedrock across the site.

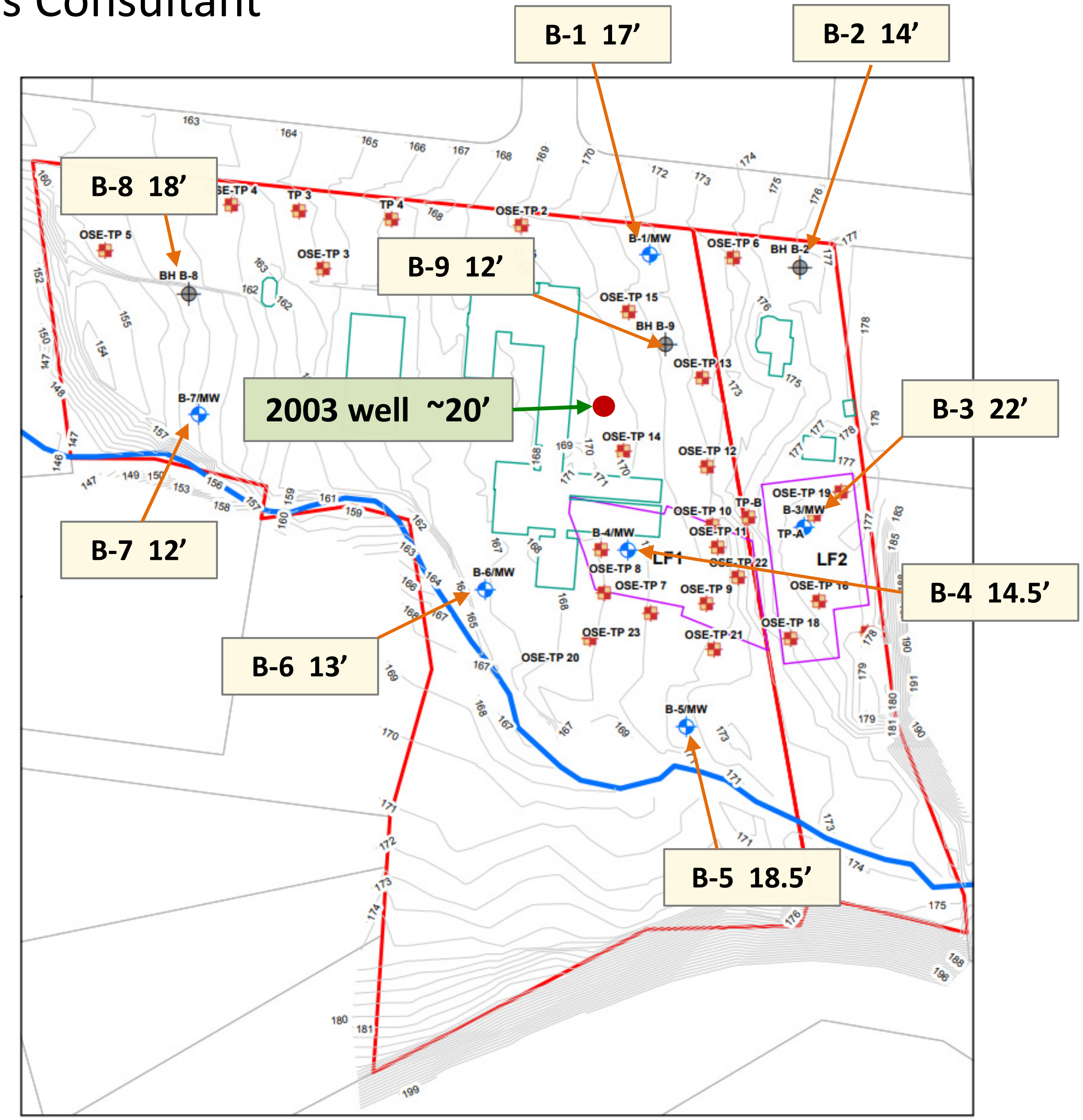
Scott W. Horsley

Hydrology & Water Resources Consultant

GeoSphere boreholes and refusal depths:

B-1 17’
B-2 14’
B-3 22’
B-4 14.5’
B-5 18.5’
B-6 13’
B-7 12’
B-8 18’
B-9 12’

2003 irrigation well hit bedrock at ~20’, in an area in the middle of the 2017 boreholes. (See: 2003 well drilling report

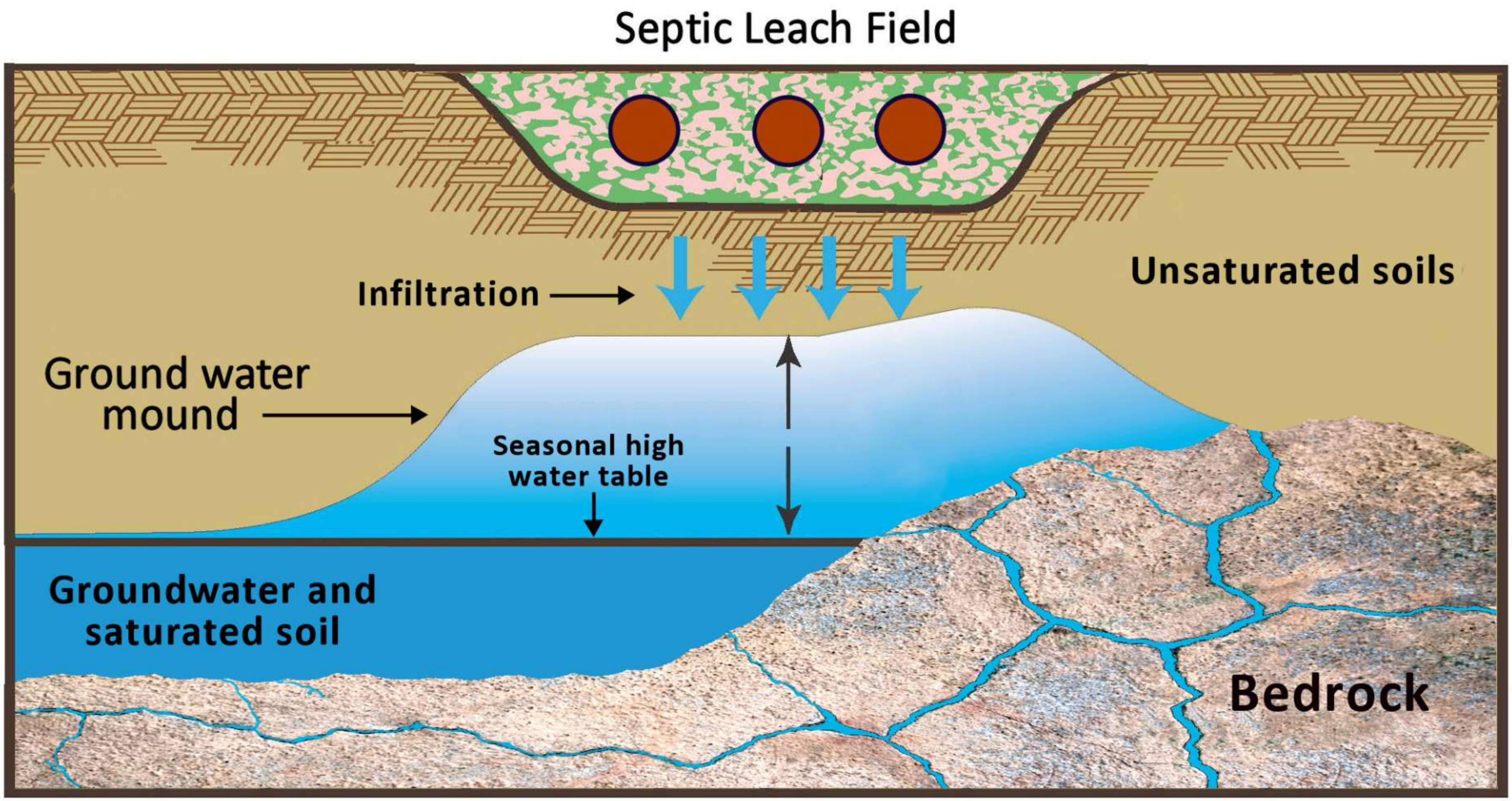


Scott W. Horsley

Hydrology & Water Resources Consultant

Bedrock is significant

Bedrock can raise the height of the septic system mound, and cracks in the rock can transport contaminated water beyond the estimated boundaries of the mound. The apparent bedrock also has an irregular surface – not the smooth surface used in the model:



Scott W. Horsley

Hydrology & Water Resources Consultant

5. Long-term Hydrology Alterations

Existing recharge rate = 16.5 inches / year (B soils) = 1.3 million gallons / year

New recharge rate post-development:

A. **Stormwater infiltration system** would recharge 34 inches / year from 1.6 acres of impervious surfaces = 1.5 million gallons / year (This was not included in the Cascade hydrogeo model.)

B. **Remaining B Soils:** 4.9 acres at 16.5 inches / year = 2.1 million gallons / year (Increase due to more pervious area post-development.)

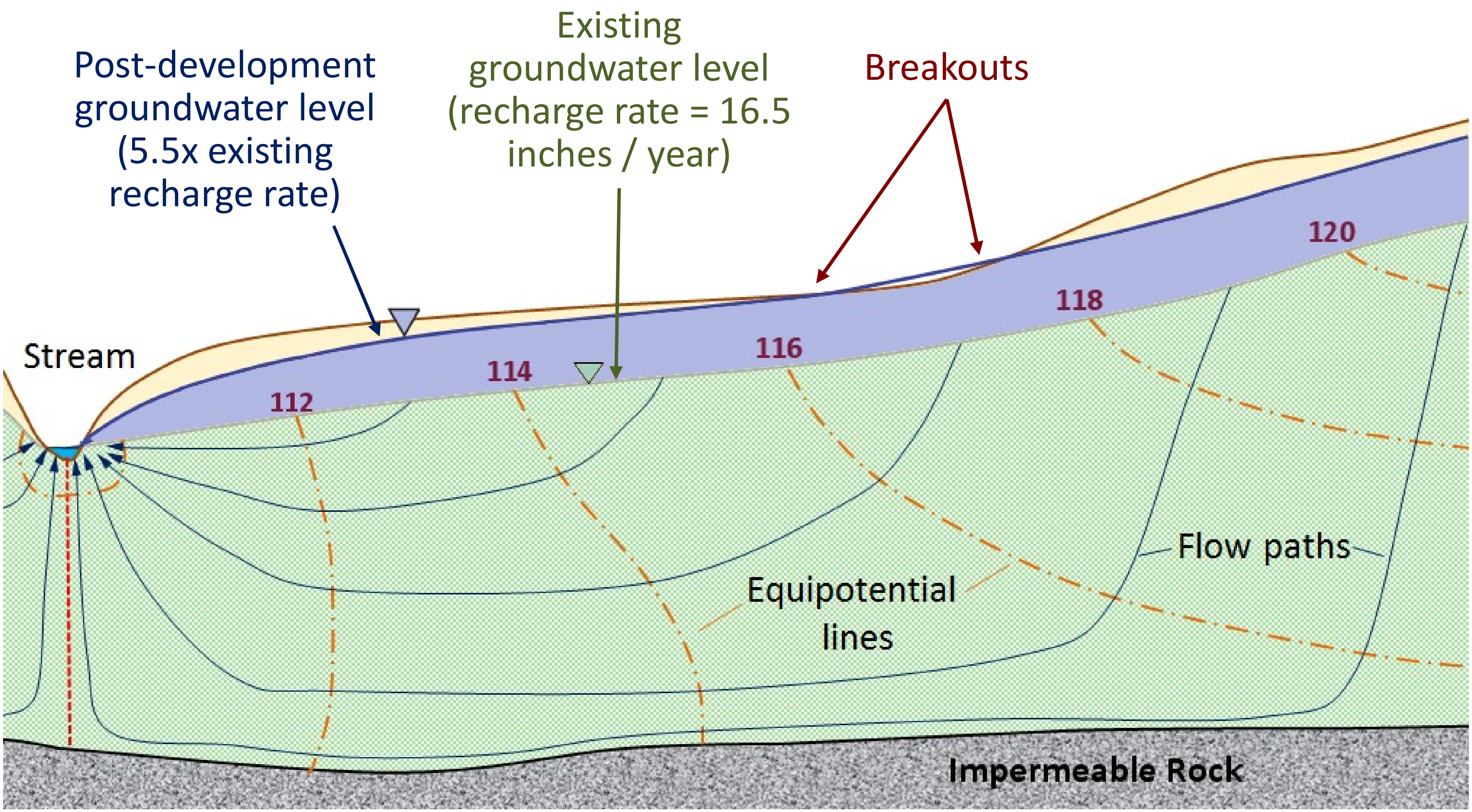
C. **Septic system wastewater infiltration** = 3.6 million gallons / year

Post-development = 7.2 million gallons / year recharged, a 5.5 x increase of 5.9 million gallons / year.

The water table will rise beyond levels shown in the hydrogeo model, compromising the septic leach field and downgradient break-outs.

Scott W. Horsley

Hydrology & Water Resources Consultant



6. Public health threats

Wastewater includes significant loads of pathogens including bacteria and viruses. Pine Brook is used for primary contact recreation by YMCA camp children.

Scott W. Horsley

Hydrology & Water Resources Consultant

Viruses have been shown to travel in groundwater for 200 feet or more. Cascade's septic leach field is only 90 feet from Pine Brook and their study shows multiple areas of breakout along the Brook:

a) **Microbial contamination is important because human infection and disease result** from small quantities of pathogens, particularly enteric viruses associated with diarrhea and gastroenteritis, respiratory infections, conjunctivitis, hepatitis, and diseases with high mortality rates including aseptic meningitis, encephalitis and paralysis in immunocompromised individuals. Some enteric viruses have been linked to chronic diseases such as myocarditis and diabetes.

b) **The Cascade Project site warrants a careful analysis of pathogen transport** to ensure that pathogens are not discharged to the brook. Children at YMCA Camp Chickami who play in the brook and adjacent ponds would be put at risk if a major source of pathogens is introduced into Pine Brook.

See: References #23 - 30

Scott W. Horsley

Hydrology & Water Resources Consultant

7. Threats to Pine Brook and Eastern Brook Trout

Pine Brook is the #1 stream for native Eastern Brook Trout in the entire Boston Metrowest area according to MA Fisheries & Wildlife.

Scott W. Horsley

Hydrology & Water Resources Consultant

Phosphorus contamination and eutrophication will harm or kill Eastern Brook Trout and other animals and insects in Pine Brook:

- Existing concentration in Pine Brook = **21 ppb**
  (EBT Environmental Consultants, Inc. on September 19, 2017)
- Maximum allowable concentration = **26 ppb**
  (Assabet River Total Maximum Daily Load for Total Phosphorus SuAsCo Watershed, Massachusetts MADEP, DWM TMDL Report MA82B-01-2004-01 Control Number CN 201.)
- Added phosphorus load from the Cascade project's large septic system = **5,000 ppb**
- Estimated resulting concentrations in Pine Brook:
  - 100% P transport = **157 ppb**
  - 10% P transport = **34 ppb**

See: References #7 - 14

References:

Applicant documents:

1. Geosphere, Hydrogeologic Report: Groundwater Mounding Analysis for Proposed Subsurface Disposal System, 26 June, 2018
2. Geosphere, Memo: CASCADE – WAYLAND, Hydrogeologic Report (GEOSPHERE, June 26, 2018), 28 August, 2018

ASTM soil testing standards:

3. ASTM D2434-68, Standard Test Method for Permeability of Granular Soils (Constant Head)
4. ASTM D422, Standard Test Method for Particle-Size Analysis of Soils
5. ASTM D5084, Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
6. University of Florida, Final Report - Examining the Variability of Granular Soil Permeability Testing Methodology across FDOT Districts, for the Florida Department of Transportation, 2003

Eastern Brook Trout:

7. Ashley D. Ficke, Douglas P. Peterson, and Bill Janowsky, Brook Trout (Salvelinus fontinalis), Technical Conservation Assessment for USDA Forest Service, 2009

References:

Eastern Brook Trout -- continued:

8. Brandon Faneuf, Ecosystem Solutions Inc., Threats to Eastern Brook Trout - Development Impacts to Avoid, 2017
9. Bruce Ingram, Disappearing Native - Individual landowners can make a big difference in restoring habitat to bring back the brookie, Outdoor America, 2014 Issue 1, page 39
10. Eastern Brook Trout Joint Venture, Conservation Strategy/Habitat Work Group, Conserving the Eastern Brook Trout: Action Strategies, 2011
11. Massachusetts Division of Fisheries & Wildlife, Massachusetts Eastern Brook Trout Conservation Strategies, 2007
12. S. Flint, OARS, Protecting Trout-Bearing Streams of the Sudbury River Watershed, Final Report, September 2014
13. Trout Unlimited, Eastern Brook Trout Conservation Portfolio, Range-wide Habitat Integrity and Future Security Assessment, and Focal Area Risk and Opportunity Analysis, Version 1.0, March 2017
14. Trout Unlimited for the Eastern Brook Trout Joint Venture (National Fish Habitat Partnership) Eastern Brook Trout: Status and Threats, https://easternbrooktrout.org

References:

LiDAR accuracy:

15. Aguilar, F.J., and Mills, J.P. 2008. Accuracy assessment of LiDAR derived digital elevation models. Photogramm. Rec. 23(122): 148–169.

16. Bates, C.W., and Coops, N.C. 2009. Evaluating error associated with LiDAR-derived DEM interpolation. Comput. Geosci. 35(2): 289–300.

17. Bowen, Z.H., and Waltermire, R.G. 2002. Evaluation of lightdetection and ranging (LiDAR) for measuring river corridor topography. J. Am. Water Resour. Assoc. 38(1): 33–41.

18. FEMA, Procedure Memorandum No. 61—Standards for Lidar and Other High Quality Digital Topography, 27 September, 2010

19. Stephen E. Reutebuch, Robert J. McGaughey, Hans-Erik Andersen, and Ward W. Carson , Hans-Erik Andersen, and Ward W. Carson, Accuracy of a high-resolution lidar terrain model under a conifer forest canopy, Can. J. Remote Sensing, Vol. 29, No. 5, pp. 527–535, 2003

20. Michael E. Hodgson and Patrick Bresnahan, Accuracy of Airborne Lidar-Derived Elevation: Empirical Assessment and Error Budget, Photogrammetric Engineering & Remote Sensing Vol. 70, No. 3, March 2004, pp. 331–339

References:

LiDAR accuracy - continued:

21. Jason Su and Edward Bork, Influence of Vegetation, Slope, and Lidar Sampling Angle on DEM Accuracy, Photogrammetric Engineering & Remote Sensing Vol. 72, No. 11, November 2006, pp. 1265–1274
22. Wade T. Tinkham, Alistair M.S. Smith, Chad Hoffman, Andrew T. Hudak, Michael J. Falkowski, Mark E. Swanson, and Paul E. Gessler, Investigating the influence of LiDAR ground surface errors on the utility of derived forest inventories, Can. J. For. Res. 42: 413–422 (2012)

Septic systems and wastewater contamination:

23. A.P. Blaschke, J. Derxa, M. Zessner, R. Kirnbauer, G. Kavka, H. Strelec, A.H. Farnleitner, L. Pangh, Setback distances between small biological wastewater treatment systems and drinking water wells against virus contamination in alluvial aquifers, Science of the Total Environment, 2016
24. AR Williams, A. Overbo, Unsafe return of human excreta to the environment: A literature review. 2015. The Water Institute at UNC, Chapel Hill, NC, USA
25. Laurel Schaider, Ph.D., Kathryn Rodgers, M.P.H., Ruthann Rudel, M.S., Contaminants of Emerging Concern and Septic Systems: A Synthesis of Scientific Literature and Application to Groundwater Quality on Cape Cod, Silent Spring Institute, 2013

References:

Septic systems and wastewater contamination -- continued:

26. Laurel A. Schaider, Kathryn M. Rodgers, Ruthann A. Rudel, Review of Organic Wastewater Compound Concentrations and Removal in Onsite Wastewater Treatment Systems, Environmental Science & Technology, 2017, 51, 7304−7317
27. Marc P. Verhougstraete, Sherry L. Martin, Anthony D. Kendall, David W. Hyndmanb, Joan B. Rosea, Linking fecal bacteria in rivers to landscape, geochemical, and hydrologic factors and sources at the basin scale, PNAS, August 18, 2015, vol. 112, no. 33, 10419–10424
28. Paul JA Withers, Philip Jordan, Linda May, Helen P Jarvie, Nancy Deal, Do septic tank systems pose a hidden threat to water quality?, Front Ecol Environ, 2014
29. Samia Richards, Eric Paterson, Paul J.A. Withers, Marc Stutter, Septic tank discharges as multi-pollutant hotspots in catchments, Elsevier, 2015
30. Samia Richards, Paul J.A. Withers, Eric Paterson, Colin W. McRoberts, Marc Stutter, Temporal variability in domestic point source discharges and their associated impact on receiving waters, Elsevier, 2016