A METHODOLOGY FOR QUANTITATIVE CUMULATIVE EFFECTS ASSESSMENT

For Onsite Wastewater Systems in a Watershed
Supplying Drinking Water to a Large Municipality

Bryer Manwell, M.Sc., P.Eng., Hydrogeological Engineer
CaulWell Engineering And Geoscience Ltd.
Salmon Arm, British Columbia, Canada

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Methodology Focus | Parcel-Level Cumulative Effects Index (P-CEI)

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PRESENTER INTRODUCTION

Bryer Manwell M.Sc., P.Eng.

- 25+ years experience in solution focused environmental engineering and geoscience throughout Canada
- M.Sc. – Environmental Engineering – specializing in hydrogeology (U of C)
- Owner of CaulWell Engineering and Geoscience Ltd., based on Salmon Arm , BC, Canada
- Registered Professional Engineer in British Columbia, Canada

Consultant:

- Groundwater supply development
- Contaminant Hydrogeology
- Research and reporting on cumulative environmental impacts
- Support of the onsite wastewater industry and regulators
- Development and delivery of curriculum on passive inground treatment of onsite wastewater (https://equiptraining.ca/)
- Past President of WCOWMA British Columbia
- Associate with Canadian Onsite Technical Resource Association (https://onsitetechnicalresource.com/)

CONTEXT & CHALLENGE

Intensifying land-use pressures in a source watershed

Water Quality Trends

Rising nitrate, chlorophyll-a and periphyton in the creek and north bay of the receiving lake that supplies municipal drinking water.

Onsite Wastewater Load

Thousands of septic systems, including higher-density temporary foreign worker housing, discharging into a shallow, creek-connected aquifer.

Cumulative Effects Gap

Watershed-scale vulnerability maps identify risk zones but do not quantify parcel-level contributions or prioritize action.

WHY A PARCEL-LEVEL APPROACH?

Limitations of Watershed-Scale Maps

- Identify broad vulnerability zones but not individual contributors
- Difficult to prioritize enforcement or education resources
- Do not quantify mass loading from specific land uses or systems
- Limited utility for risk-based inspections of onsite systems
- Hard to link observed water-quality trends to specific parcels

Value of Parcel-Level Indexing

- Assigns a quantitative risk score to every parcel
- Enables Pareto prioritization (vital few parcels)
- Incorporates onsite wastewater discharge estimates
- Supports targeted audits and policy tools
- Creates a transparent, updatable decision-support layer

THE PARCEL-LEVEL CUMULATIVE EFFECTS INDEX (P-CEI)

A GIS-enabled first-order mass-flux approach

The P-CEI estimates daily nitrate export (kg/day) from each parcel as a quantitative proxy for cumulative land-use impact on the receiving creek and lake. Nitrate was selected because it accumulates along the creek length and is strongly linked to agricultural activity and onsite wastewater effluent.

Scale	Primary CoC	Pathways	Output
~2,860 parcels in valley bottom	Nitrate (mass flux proxy)	Shallow groundwater + surface runoff	Normalized 0–100 risk score per parcel

METHODOLOGY OVERVIEW — SIX STEPS

1

Delineate Parcels

Filter parcel fabric to study area; assign zoning & attributes

2

Indicators

Land use, septic status, agricultural practices, distance to receptor

3

Mass Flux

Estimate nitrate load (kg/day) via zoning rates or Darcy flux

4

Normalize

Scale mass flux to 0–100 P-CEI score

5

Map & Rank

Spatial cumulative assessment and risk categories

6

Validate

Cross-check with monitoring data; sensitivity analysis

CaulWell, 2026 : bryer@caulwell.ca

QUANTIFYING ONSITE WASTEWATER CONTRIBUTIONS

How septic systems enter the P-CEI calculation

1 Assign Discharge

Zoning-based daily flow (m^3/day). Many residential & commercial zones use 1.6–3.2 m^3/day; higher-density or campground-type uses approach the 22.7 m^3/day threshold.

2 Apply Concentration

Septic effluent assigned 0.035 kg/m^3 NO_3 based on long-term point-of-application monitoring data.

3 Calculate Mass Flux

Discharge × Concentration = nitrate mass flux (kg/day) for that parcel component.

4 Add to Parcel Total

Septic flux is combined with any agricultural or secondary land-use flux on the same PID.

EXAMPLE DISCHARGE RATES BY ZONING CATEGORY

First-order estimates used for non-agricultural parcels (selected examples)

Zoning Category	Typical Discharge (m^3/day)	Notes
Residential Single Family	1.6	Standard household septic
Residential Two-Family / Multi	3.2	Higher occupancy
Manufactured Home Community	22.7	Approaches SSR/MWR threshold
Campground / Resort Commercial	22.7	High occupancy seasonal
General Commercial	2.0	Low-to-moderate flow
Agricultural Farm (A1)	300*	Darcy-based or high assigned rate
Agricultural Small Lot	60*	Scaled agricultural rate

** Agricultural rates use either assigned high values or site-specific Darcy flux calculations using local aquifer properties.*

CONCENTRATION ASSUMPTIONS & MASS FLUX

Assigned NO_3 Concentrations

Septic effluent

0.035 kg/m³

25+ years of monitoring

Agricultural lands

0.003 kg/m³

Local groundwater wells

Composting / RIB

0.015 kg/m³

Monitoring reports

Simple Mass-Flux Equation

$$\text{Mass Flux (kg/day)} = \text{Discharge (m}^3\text{/day)} \times \text{Concentration (kg/m}^3\text{)}$$

Multiple land-use components on the same parcel are summed to produce the total parcel nitrate flux before normalization.

NORMALIZATION & RISK CATEGORIES

Mass flux is scaled to a 0–100 P-CEI score for communication and prioritization

0-10	Low	Voluntary BMPs; annual septic maintenance
10-40	Moderate	Inspection; pump-out every 2 years
40-60	High	Mandatory upgrades / advanced treatment; scaled EIS
60-80	Very High	Riparian restoration + runoff controls
>80	Critical	Mandatory BMPs; sewer connection or buyout options

KEY RESULTS — PRIORITIZATION INSIGHT

~1.4%

of parcels account for the majority of estimated nutrient loading risk

Top 40

parcels (mostly intensive agricultural with ancillary uses) drive the bulk of the load

Septic + Ag

combination on the same parcels produces the highest cumulative scores

Pareto Application

By focusing compliance audits, education, and policy resources on the highest-ranked parcels, local governments can achieve the greatest water-quality improvement per unit of effort. The index makes the “vital few” visible and defensible.

REGULATORY CONTEXT — THE 22.7 m³/DAY DIVIDE

A structural gap that enables cumulative loading without environmental assessment

British Columbia
Sewerage System Regulation (SSR)

- Applies to systems ≤ 22.7 m³/day
- Filing-based; accepted by health authority
- No mandatory environmental impact study
- No routine provincial monitoring upload requirement
- Multiple filings on one parcel can avoid MWR trigger

British Columbia
Municipal Wastewater Regulation (MWR)

- Applies above 22.7 m³/day (or discharge to water)
- Requires authorization under the EMA
- Environmental assessment and ongoing monitoring expected
- Data should be uploaded to provincial systems
- Higher administrative and technical burden

TEMPORARY FOREIGN WORKER HOUSING & CUMULATIVE LOAD

A growing source of concentrated onsite wastewater in agricultural zones

High occupancy density

TFW housing on agricultural parcels can generate significant daily wastewater volumes while remaining under the SSR filing threshold when split across systems.

Same parcel, multiple stressors

Agricultural nutrient applications + processing waste + onsite systems create stacked nitrate loads that the P-CEI captures as elevated mass flux.

Limited environmental assessment

Because individual systems stay ≤ 22.7 m^3/day, site-specific hydrogeology and cumulative effects are rarely evaluated before installation.

Index utility

The P-CEI makes these combined contributions visible so that inspections, education, and policy can target the highest combined-risk parcels.

FROM INDEX TO ACTION

Risk-Based Audits

Prioritize compliance inspections of waste authorizations and SSR filings on the highest P-CEI parcels.

Targeted Education

Deliver nutrient stewardship and septic maintenance outreach to owners/operators of high-scoring parcels.

Policy Integration

Incorporate P-CEI layers into OCPs, zoning, and development permit areas for source-water protection.

Development Review

Require parcel-scale risk assessment (or equivalent) for new intensive uses or TFW housing in high-risk zones.

Monitoring Alignment

Locate continuous water-quality stations to capture cumulative signals from high-P-CEI clusters.

Adaptive Management

Update the index periodically with new land-use, filing, and monitoring data.

POLICY TOOLS ENABLED BY THE INDEX

Environmental Development Permit Area

150 m (or site-specific) buffer from high-water mark of the creek and lake shoreline. Require QEP review and risk assessment for subdivision, construction, or intensive agricultural activities on high-P-CEI parcels.

Septic Maintenance Bylaws

Mandatory maintenance inspection/pump-out schedules scaled to risk category; tie building permits and occupancy to demonstrated system performance.

Nutrient Management Linkages

Require parcel-specific Nutrient Management Plans (NMPs) for high-P-CEI agricultural parcels, aligned with AEM Code thresholds for vulnerable aquifers.

POLICY TOOLS ENABLED BY THE INDEX (con't)

Cross-Agency Data Sharing

MOU among local government, health authority, and provincial regulators to share risk layers and trigger coordinated inspections.

Shifting Professional Due Diligence within the Onsite Industry

(https://onsitetechnicalresource.com/technical-information/)

One Water approach, emphasizing importance of understanding risk to environmental and human health from cumulative impacts.

LIMITATIONS & UNCERTAINTY

Proxy-based estimates

Mass flux uses assigned rates and concentrations rather than continuous per-parcel monitoring. Uncertainty estimated at ±20–30%.

Single primary CoC

Nitrate was chosen for its observed accumulation and data availability. Phosphorus, pathogens, and other indicators can be added in later iterations.

Data access constraints

Fragmented provincial databases and FOI requirements limited the completeness of authorization and monitoring inventories.

Temporal snapshot

Baseline reflects conditions at the time of assessment; annual updates with new land-use and water-quality data are recommended.

Validation needs

Cross-checking high-P-CEI hotspots against in-stream and near-creek groundwater sampling strengthens confidence and supports adaptive refinement.

TRANSFERABILITY

The method is designed to be adapted, not copied

Core logic travels

Parcel inventory → land-use discharge estimates → concentration assumptions → mass flux → normalization → prioritization can be applied in any jurisdiction with cadastral data and a known primary CoC.

Local calibration required

Discharge rates, concentrations, aquifer properties, and risk-category thresholds should be adjusted to local monitoring data, regulations, and receptor sensitivity.

Platform flexibility

Implemented in QGIS + Excel; the same workflow can be built in other GIS platforms or simple databases.

Value for onsite wastewater programs

Particularly useful where high densities of systems, TFW or multi-unit housing, or the regulatory threshold create cumulative-loading concerns that traditional complaint-driven approaches miss.

KEY TAKEAWAYS

1. A simple, GIS-enabled mass-flux index can turn broad vulnerability mapping into parcel-specific, actionable risk scores.
2. Onsite wastewater systems are quantifiable contributors; their cumulative effect becomes visible when combined with other land uses on the same parcels.
3. The 22.7 m^3/day jurisdictional threshold creates a structural gap that the index helps illuminate for regulators and local governments.
4. Pareto prioritization focuses limited inspection, education, and policy resources where they produce the greatest water-quality return.
5. The method is transferable with local calibration and supports development permit areas, maintenance bylaws, and risk-based compliance programs.

QUESTIONS & DISCUSSION

Thank You

Bryer Manwell, P.Eng., M.Sc., Hydrogeological Engineer
CaulWell Engineering And Geoscience Ltd.
Salmon Arm, British Columbia, Canada
1 (250) 878 2030 bryer@caulwell.ca

Methodology available for discussion and adaptation