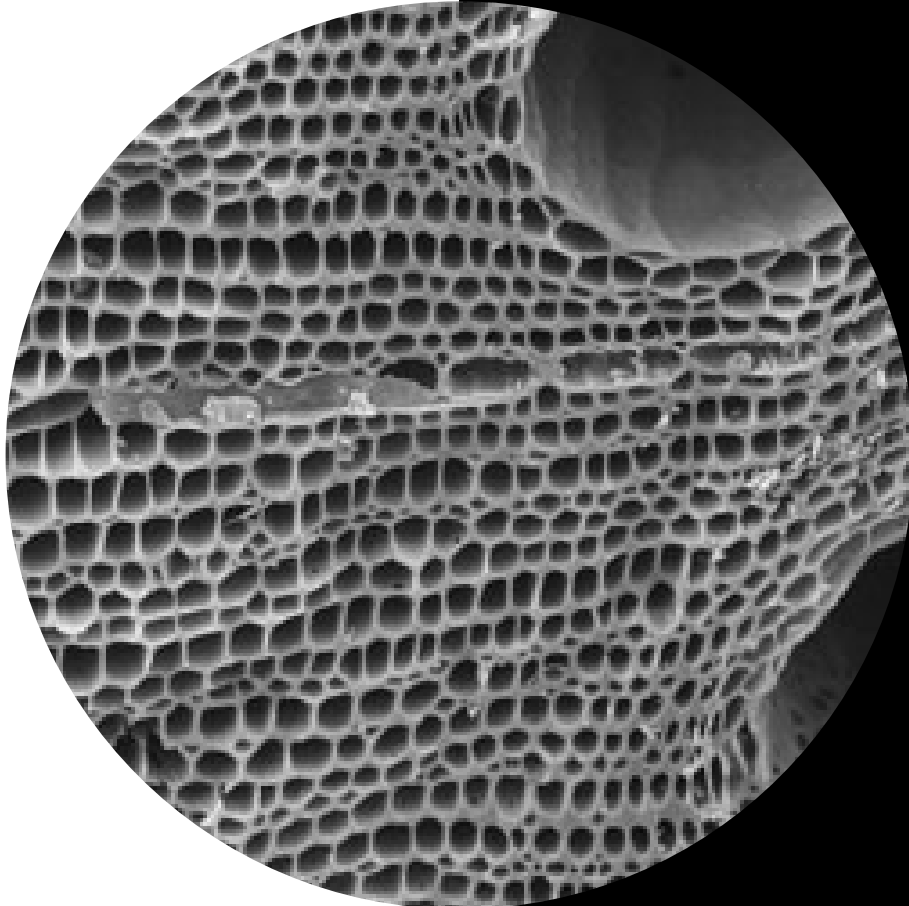


Preview Sample

Emerging Biochar Standards

**Opportunities for
micro-based solutions
to manage macro-
environments.**

A technical summary



Compliance vs. Innovation

The stormwater industry is driven by legal compliance only. New solutions are showing results far beyond what RFPs are requiring. Most government agencies follow established methods and are risk-averse, when it comes to innovation.

By contrast, the state of Washington raises regulatory standards, as well as innovates, based on the critically sensitive ecosystems affected by stormwater runoff. This is best exemplified by the adoption of biochar as a key component in reversing 100% mortality of spawning salmon in urban

waterways, whose lives were cut short by NPPD-q, a highly toxic derivative of tire dust, coming from roadways. Over a few years, the collaborative efforts of research and government resulted in 100% survival of the salmon.

How this example adapts to other states and up to the federal level remains to be seen. Minnesota DOT, however, is following up with new biochar infrastructure standards, based on feedstock and porosity.



Collaborative Community in the state of Washington

Tacoma's Center for Urban Waters is one of several institutions in the state that have raised the bar of compliance to define what's possible with innovation, using biochar as one focus area.

As described on their website:

Discovery

Environmental research explores fundamental and applied scientific questions, providing the foundation for rational and effective environmental stewardship. The center is designed to attract researchers and scientists from across the Pacific Northwest.

Analysis

State-of-the-science analytical laboratories support scientists who are monitoring levels of pollutants in water, soils, sediment, flora and fauna, and air throughout the Puget Sound region.

Synthesis

Teams of researchers and engineers work to extract information from a wide variety of data, providing quantitative, unbiased assessments for policymakers.

Application

The latest scientific findings and assessments inform policy makers in their development of innovative plans for effective environmental restoration, stewardship and sustainable growth.

Education

Undergraduate and graduate students work side-by-side with Urban Waters scientists and analysts, developing necessary skills for successful careers in environmental science and management. In addition, staff from a variety of specialties work with the Foss Waterway Seaport to support their K-12 education programs to pass on environmental science to the next generation of students."

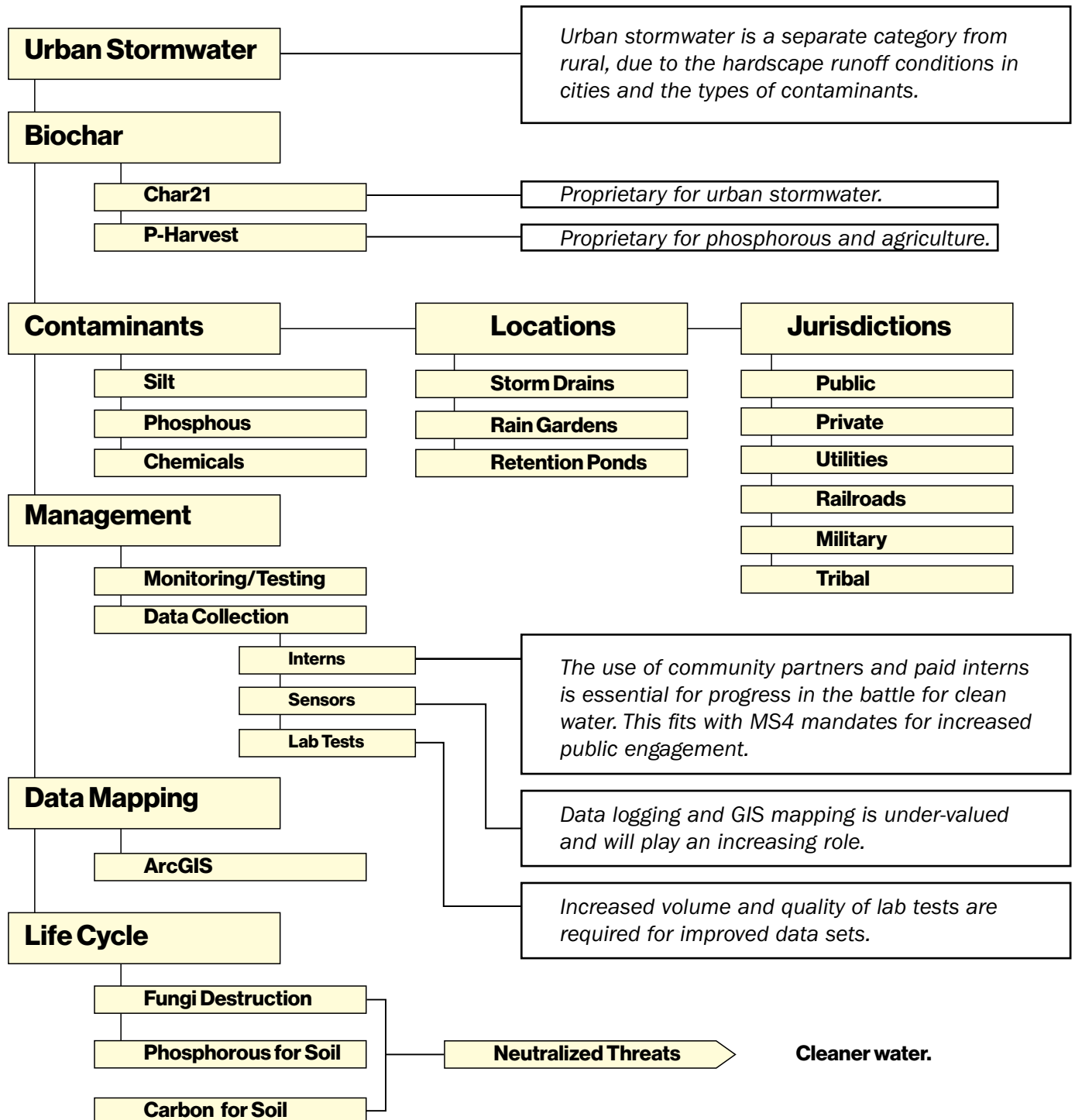
Overview

Green infrastructure

1.2

Biochar fits into the mix of stormwater solutions that have been in development for decades. Added to that are new technology solutions.

The chart below outlines a logical process to re-think green infrastructure with manageable biochar as a key filter element.



Definitions

Carbon forms

2.1

These three forms of charcoal vary by production method and end application. Biochar's value is continuing to grow, based on its unique potential for environment and economy.



	Biochar	Activated Carbon	Charcoal
Feedstock	Wood (preferred), biosolids, organic material	Wood	Hardwood
Production	Pyrolysis	Steam or chemical activation	
Temperature	< 700° C	800° C to 1000° C	
Cost	Low to Moderate	High	NA
Applications	Soil amendment, carbon sequestration, industrial innovations.	Industrial contaminant filter systems.	Cooking/ heating fuel

INNOVATIONS

1. We advance the storm and wastewater industry using patented **biochar structural composites**, with improved performance compared to activated carbon.

2. We add fungi and pyrolysis as two options to destroy the contaminants in filter units, increasing their functional life cycle.

3. Structural biochar composites open a new pathway for insulated building materials.

Summary

Activated carbon is the standard industry filtration medium. It has a higher surface area than biochar, due to high-temperature activation, but is expensive and energy-intensive.

Biochar advantages over AC: More abundant surface functional groups; Produced at lower temperatures, lower energy footprint; Reduced cost; Increased physical and chemical adsorption value. Structural composites for filtration and thermal insulation.

Charcoal's primary purpose is for cooking and it can contain original wood chemistry or with starch, limestone, sawdust, and borax, (to help form briquettes). It contains varying amounts of ash, volatile substances, and moisture.

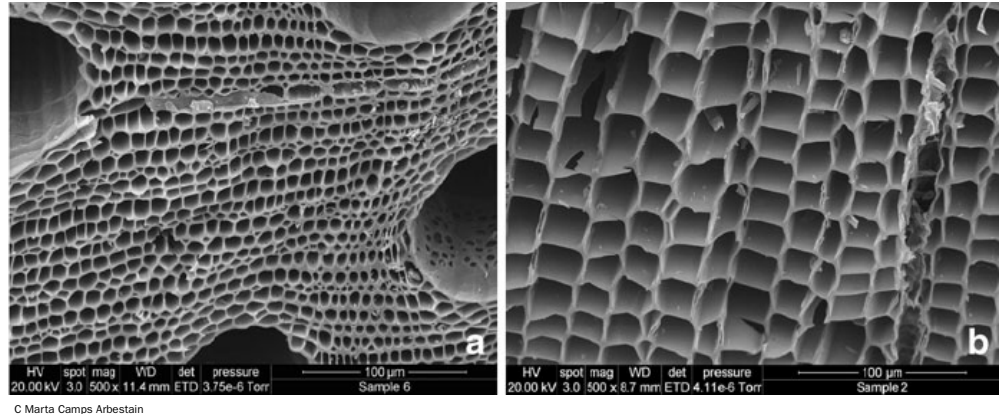
Porosity, ionic charge and additives.

Biochar is a higher-end version of charcoal, or carbon, with more options to engineer the end product for increased effectiveness as an adsorbent for molecules and nanoparticles.

It is most commonly known for its capacity to sequester enormous amounts of CO₂ from the atmosphere into the soil. This is driving the industry growth, with the support of carbon credits backed by major financial and corporate entities.

It is able to restore depleted or contaminated soils. For farming and ecosystems it serves as a micro-medium to store water and nutrients, providing as well a platform to restore native fungi. Companies are now developing and promoting a variety of biochar soil products with customized amendments for specific crops.

For roadways, DOTs are interested in its capacity to reduce storm water contaminants as well as strengthening the plant ecosystem adjacent to roadways, which increases the overall biofiltration factors. In addition, it can be added to asphalt, concrete or as an underlayment.



One gram of hardwood biochar can contain a microscopic surface area of 1000 square meters. One metric ton of biochar equals 1,000,000 grams, with a surface area of a billion square meters, ideal for PFAs remediation.

Key Mechanisms of Chemical Adsorption by Biochar

Physical Adsorption (Pore Filling): Biochar possesses a massive, porous surface area, which traps smaller molecules inside its micropores, mesopores, and macropores.

Surface Sorption & Hydrophobic Interaction: Organic pollutants (phenols, pharmaceuticals) stick to the carbon surface. The hydrophobic nature of biochar attracts hydrophobic contaminants, removing them from water.

Electrostatic Interaction: The surface of biochar can be modified by pH. **Anionic (Negatively charged) pollutants:** Attracted at low pH, where high H⁺ concentration

gives the biochar a positive charge. **Cationic (Positively charged) pollutants** (e.g., Heavy Metals): Attracted at higher pH, where biochar's functional groups (carboxylic, hydroxyl) become negatively charged, causing metals like lead to stick.

π-π Stacking/Electron Donor-Acceptor: Aromatic compounds can interact with the graphene-like structures in biochar, strengthening the bond between the chemical and the biochar.

Hydrogen Bonding: Functional groups on the biochar surface, such as hydroxyl and carboxyl groups, can form hydrogen bonds with pesticide molecules.

Absorb vs Adsorb

ABsorption is where a liquid is soaked up into something like a sponge, cloth or filter paper. The liquid is completely absorbed into the absorbent material.

ADsorption refers to individual molecules, atoms or ions gathering on surfaces. The surface of a material is made up of atoms and bonds that are exposed to the air. For example, the surface of a piece of glass will be covered in silicon and oxygen atoms. Molecules or ions can interact with this surface via intermolecular interactions. This allows them to 'stick', or adsorb, to the surface. If a material has a very high surface area, then lots of molecules can stick to the surface.

Many line items in a DOT expense category can be enhanced with the value of biochar.

Item Group	Item Number	Item Description	Units	Quantity	Dollars (000S)	Average Price	Contract Occur.
2013	2013601/00120	GROUND WATER TREATMENT SYSTEM	LS	1.00	\$5,900.00	\$5,900,000.00	1
2013	2013609/00010	HAUL AND DISPOSAL OF HAZARDOUS WASTE	TON	24.00	\$6.00	\$250.00	1
2013	2013901/00025	ENVIRONMENTAL COMPLIANCE	LS	1.00	\$150.00	\$150,000.00	1
2016	2016601/00200	TOPSOIL MANAGEMENT	LS	1.00	\$54.00	\$54,000.00	1
2031	2031502/00110	FIELD LABORATORY	EACH	27.00	\$1,127.89	\$41,773.83	27
2031	2031502/00210	COMBINATION FIELD LABORATORY-OFFICE	EACH	31.00	\$743.15	\$23,972.65	31
2106	2106507/00070	GRANULAR EMBANKMENT (CV)	C Y	488,827.00	\$8,002.10	\$16.37	6
2106	2106507/00080	SELECT GRANULAR EMBANKMENT (CV)	C Y	1,723,479.00	\$32,642.69	\$18.94	58
2106	2106507/00090	SELECT GRANULAR EMBANKMENT MOD 5% (CV)	C Y	40,049.00	\$350.43	\$8.75	1
2106	2106507/00100	SELECT GRANULAR EMBANKMENT MOD 7% (CV)	C Y	76,020.00	\$2,592.28	\$34.10	10
2106	2106507/00110	SELECT GRANULAR EMBANKMENT MOD 10% (CV)	C Y	23,258.00	\$570.98	\$24.55	3
2106	2106507/00120	SELECT GRANULAR EMBANKMENT SUPER SAND (CV)	C Y	101,024.00	\$2,469.03	\$24.44	5
2106	2106507/00130	COMMON EMBANKMENT (CV)	C Y	2,942,139.00	\$8,179.15	\$2.78	91
2106	2106609/00220	HAUL AND DISPOSE OF CONTAMINATED MATERIAL	TON	101,937.70	\$5,772.73	\$56.63	28
2106	2106609/00230	HAUL AND DISPOSE OF CONTAMINATED SOIL	TON	9,722.00	\$324.91	\$33.42	2
2411	2411507/04060	GRANULAR BACKFILL MOD (CV)	C Y	3,224.00	\$90.53	\$28.08	2
2511	2511504/00011	GEOTEXTILE FILTER TYPE 1	S Y	361.00	\$1.62	\$4.50	1
2511	2511504/00013	GEOTEXTILE FILTER TYPE 3	S Y	6,222.80	\$34.41	\$5.53	21
2511	2511504/00014	GEOTEXTILE FILTER TYPE 4	S Y	46,974.30	\$170.52	\$3.63	42
2511	2511504/00015	GEOTEXTILE FILTER TYPE 5	S Y	55.40	\$0.29	\$5.20	1
2511	2511504/00017	GEOTEXTILE FILTER TYPE 7	S Y	15,858.50	\$55.66	\$3.51	15
2573	2573501/00020	STORM DRAIN INLET PROTECTION	LS	5.00	\$27.78	\$5,555.00	5
2573	2573501/00025	STABILIZED CONSTRUCTION EXIT	LS	69.00	\$979.73	\$14,199.03	69
2573	2573501/00030	EROSION CONTROL SUPERVISOR	LS	27.00	\$230.75	\$8,546.16	27
2573	2573502/00103	WATER TREATMENT TYPE SEDIMENT TANK	EACH	5.00	\$102.50	\$20,500.00	4
2573	2573502/00110	STORM DRAIN INLET PROTECTION	EACH	4,664.00	\$935.09	\$200.49	80
2573	2573502/00140	CULVERT END CONTROLS	EACH	1,122.00	\$207.90	\$185.29	61
2573	2573503/00020	SILT FENCE, TYPE HI	L F	63,445.00	\$224.60	\$3.54	28
2573	2573503/00022	SILT FENCE, TYPE SD	L F	950.00	\$40.05	\$42.16	3
2573	2573503/00023	SILT FENCE, TYPE MS	L F	289,303.00	\$619.11	\$2.14	52
2451	2451507/00080	GRANULAR BACKFILL (CV)	C Y	771.00	\$19.66	\$25.50	1
2451	2451507/00090	GRANULAR BACKFILL (MOD) CV	C Y	26,916.00	\$810.71	\$30.12	4
2451	2451507/00120	AGGREGATE BACKFILL (CV)	C Y	41.00	\$2.05	\$50.00	1
2451	2451507/00150	GRANULAR BEDDING (CV)	C Y	45.00	\$2.57	\$57.00	1
2451	2451507/00170	COARSE FILTER AGGREGATE (LV)	C Y	76.00	\$5.31	\$69.81	2
2451	2451507/00190	COARSE FILTER AGGREGATE (CV)	C Y	10,658.00	\$760.34	\$71.34	11
2451	2451507/00220	FINE FILTER AGGREGATE (CV)	C Y	4,677.00	\$188.53	\$40.31	5
2451	2451507/00240	FINE AGGREGATE BEDDING (LV)	C Y	3.00	\$0.14	\$48.00	1
2451	2451507/00250	FINE AGGREGATE BEDDING (CV)	C Y	33,199.00	\$1,489.31	\$44.86	55
2451	2451507/00270	COARSE AGGREGATE BEDDING (CV)	C Y	6,378.00	\$527.01	\$82.63	10

Coarse filter aggregate can be easily improved by adding biochar, produced onsite from available black ash feedstock in Minnesota.

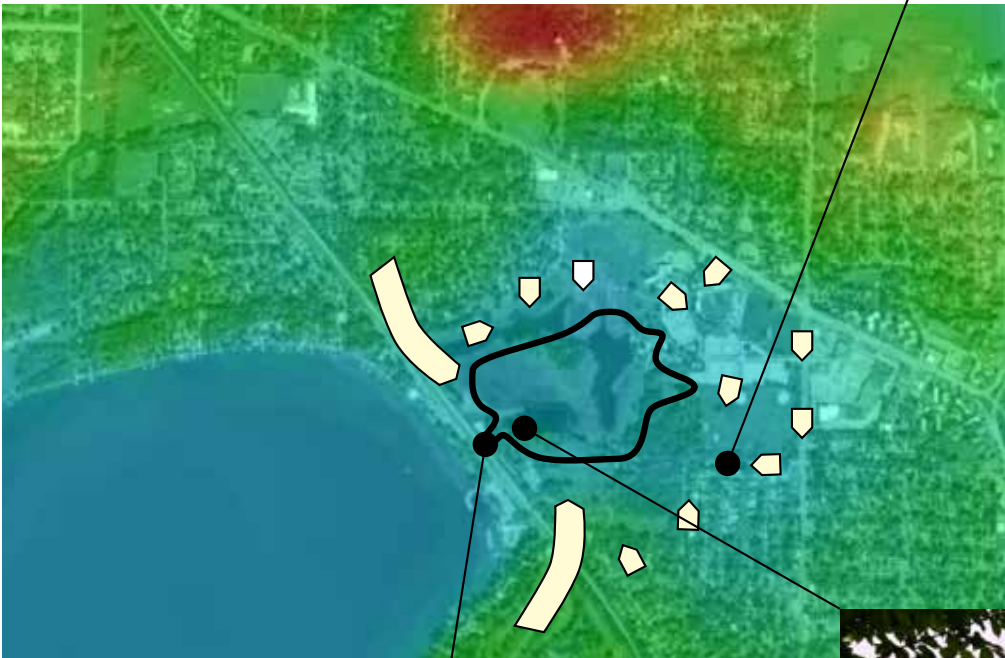
Urban watersheds often concentrate outflow in critical wetlands.

Assuming that 20% of drains in a system are responsible for 80% of contamination, locating hot spots is the basis for a filtration strategy.

Identifying single point outflows also helps to pinpoint the type and location of filters.



Street Drain



Wetland

Outfall



Algae bloom conditions are typical, and spread to the nearby lake, impacting recreation.



3.4

Solutions

Data monitoring

Filtration is not complete without water data measuring, monitoring and reporting.



Based on advanced lab-on-chip technology, the ClearWater Sensors miniaturized microfluidic phosphate sensor performs lab-grade measurements wherever you need them.

- Onboard calibration standards
- Long-term accuracy
- Sensitive wet-chemical method

Multi-Parameter



Based on advanced lab-on-chip technology, the ClearWater Sensors miniaturized microfluidic phosphate sensor performs lab-grade measurements wherever you need them.

- Onboard calibration standards
- Long-term accuracy
- Sensitive wet-chemical method
- Submersible to 6000m
- Measurements up to every 6 minutes
- User-swappable reagent canister

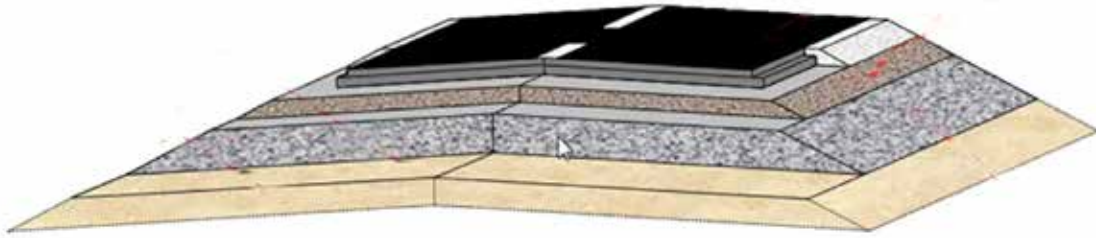


- Real Time Data: View data through customized dashboards and Google maps features.
- Alerts: Unlimited text message and email alerts. System and Sensor alarms.
- Exports: Via Excel or CSV file. Create automatic scheduled exports.
- Integration: Connect your data with third party software platform.
- Public URL: Option to share dashboards and station information via Public URL.
- User Credentials: Add users at no cost with guided access to the software.



Wireless Monitoring

- Dissolved Oxygen
- Turbidity
- Temp
- pH
- Salinity
- Conductivity
- Water Level
- PAR (Subsurface Light)
- 10,000' radius
- Extended with repeaters
- Up to 50 sensors



Carbon-negative and permeable roadbeds with biochar are feasible.

Uncertainties include: Effective life cycle of biochar under a variety of conditions. Sourcing and management of biochar production, to minimize cost. The role of fungi and microbes to manage contaminants in situ.

DESIGN CRITERIA

Carbon sequestration, with carbon credit values.

No compromise on life cycle or durability.

Temperature stability proven for application and life span.

Control over biochar specs and capacity to modify as needed.

Heavy metal sequestration.

Increased percolation.

Reduced worker risk from solvents.

Cold mix, to reduce energy usage.

Source: MN DOT



Asphalt additive.



Biochar slurry, with customized amendments, depending on conditions.