River Refugium Project (RRP)

CERNUNNOS FOUNDATION

BRIGHT MEADOW GROUP

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Abstract The River Refugium Project is built as an interlocking architecture of hydraulic, biological, thermal, and industrial subsystems that together form a single, unified nutrient-removal and biomass-production engine. This document describes the system as executives, engineers, and capital partners must jointly understand it: in terms of major functional blocks, how those blocks communicate, and why the architecture works as a regenerative industrial system. The five-zone model, closed-loop logic, and hub-and-spoke cluster architecture are documented here at the level required for cross-disciplinary review.

1. System Overview

At the highest level, an RRP node processes river water through five architectural zones: hydraulic intake and stabilization; biological processing (biofiltration); phase separation (evaporation greenhouse); biomass production (greenhouse complex); and thermochemical conversion (HTC/HTL plant). Each zone delivers water, materials, energy, or data to the next with minimal loss and maximal reuse.[1] Viewed as a whole, the system behaves like a closed-loop factory whose raw material is polluted water and whose outputs are clean water, biomass, fuels, and carbon-sequestering solids.

2. Zone One: Hydraulic Intake **&**** Stabilization**

Water enters through a protected forebay, which buffers fluctuating river levels, settles coarse sediments, excludes debris, and provides a measurable inflow point. From the forebay, variable-frequency drive pumps with redundant trains lift water into the system. A gravity-fed water tower, where deployed, provides backup hydraulic head, passive aeration, and surge protection.[2]

The central cistern acts as the hydraulic brain — a volume buffer holding approximately three times daily throughput. It is the primary analytical checkpoint for chemistry, flow, and solids characterization, and the dispatch hub routing water into biofiltration. Its function is to regulate system tempo so downstream stages receive water on predictable cycles.[3]

3. Zone Two: Biological Processing

The six-tank biofiltration sequence is where the river's nutrient load begins its transformation. Four aerobic tanks perform nitrification, organic oxidation, and suspended-solids reduction. Two anaerobic tanks complete the nitrogen cycle through denitrification. This mirrors natural wetland nitrogen cycling but delivers it year-round in a controlled, measurable, programmable environment.[4]

4. Zone Three: Phase Separation

The evaporation greenhouse concentrates nutrients and solids by encouraging controlled evaporation of clean water vapor, which is condensed and reclaimed. Process heat from the thermochemical plant increases efficiency. This zone has proprietary operational characteristics that measurably improve the performance of downstream zones — full quantification awaits pilot testing.[5]

5. Zone Four: Biomass Production

Thirteen production greenhouses convert the concentrated nutrient feed into algae, textile fibers, biomass grasses, and coppice species. A PLC-controlled routing grid matches nutrient chemistry to crop demand curves, maximizing uptake and stabilizing flow.[6] Each greenhouse is a physically isolated controlled-environment subunit with independent maintenance cycles, climate control, and hydraulic connections. The modular design means houses can be added, removed, or repurposed without altering the overall architecture.

Key production parameters — biomass yield per house per cycle, nutrient uptake rates by crop type, and seasonal variation — are provisional academic proxies in the current financial model. ⚑ These will be replaced by measured values from the pilot. See RRP6 for the modular slot framework and RRP8 for the pilot data collection protocol.

6. Zone Five: Thermochemical Conversion

All biomass — algae, plant residues, root masses, sludge — is converted on-site (Model A) or at a regional hub (Model B) into bio-crude, hydrochar, and recyclable aqueous phase, with off-gases captured for heating and CO_2 enrichment. This closes the carbon loop and handles all accumulated biomass without requiring drying.[7]

7. Clean-Water Return

Approximately 55% of intake water is returned to the river as clean, tested outflow. The remainder is locked into biomass or lost to evapotranspiration.[8] This provides measurable, verifiable nutrient reduction at watershed scale.

8. Hub-and-Spoke Cluster Architecture

At the deployment level, the system operates as a hub-and-spoke cluster: one Model A integrated node serves as the regional processing hub, receiving biomass from 5–10 Model B biological satellite nodes. The hub reactor runs at steady-state throughput regardless of any individual satellite's seasonal variation. This is the designed minimum operating configuration — not a growth ambition. Cluster size is determined by pilot data.[9] See RRP6 for full cluster architecture documentation.

Notes

Citations follow Chicago Notes-Bibliography style. Internal Bright Meadow Group / Cernunnos Foundation documents are cited by document title and year. Figures marked ⚑ are provisional academic proxies pending replacement by RRP pilot data per RRP8.

- **1. ***Bright Meadow Group, **"**RRP Systems Architecture Board Draft.**"** CF/BMG Internal, 2025.*

- **2. ***USACE, Riverine Intake Design Notes; Bright Meadow Group, **"**Forebay Analysis.**"** CF/BMG Internal, 2025.*

- **3. ***Bright Meadow Group, **"**Central Cistern Control and Buffering Logic.**"** BMG Hydraulic Blueprint, 2025.*

- **4. ***U.S. EPA, Nutrient Removal — Biological and Tertiary Processes. EPA/625/R-10/001, print edition.*

- **5. ***Bright Meadow Group, **"**Evaporation Greenhouse Thermal Model.**"** BMG Phase Separation Concept, 2025.*

- **6. ***Bright Meadow Group, **"**Nutrient Routing Grid.**"** CF/BMG SCADA Engineering Notes, 2025.*

- **7. ***Bright Meadow Group, **"**RRP5 — HTC/HTL Thermochemical Processing,**"** Version 2.0. CF/BMG, 01 April 2026.*

- **8. ***Bright Meadow Group, **"**RRP Water Balance Model.**"** Internal performance estimate for 168,000 GPD node, 2025.*

- **9. ***Bright Meadow Group, **"**RRP6 — Economic **&** Deployment Model,**"** Version 2.0. CF/BMG, 01 April 2026. Section 4, Hub-and-Spoke Cluster Architecture.*