Summary report on proposed natural wastewater management system design for the Yestermorrow campus

This summary report was prepared by the YM 2013 Constructed Wetland class, instructed by Barton Kirk PE, Pete Munoz PE, and Harold Leverenz PE. The student design team was Sean Powers, James Kinnie, Brittany Schroeder, and Alexander Van Steen. Kate Stephenson provided guiding principles for the wastewater design to the team in order of priority:

1. Plan for evolution, versatility and resilience
2. The nature of the land, its healthy functioning, its living systems, and physics inform the structuring of human habitat
3. Scaled modules of design to allow a kit-of-parts approach for ease of phasing, budgeting, flexibility, diversity, reuse at a residential scale
4. Design to limit operational expenses
5. Campus systems should be accessible and visible for educational demonstration purposes

Additional objectives for the design developed by the class are as follows:

- Provide an opportunity for education
- Minimize impacts on groundwater
- Minimize electro-mechanical systems, e.g., gravity operation and passive design as much as possible
- Low operation and maintenance requirements
- Mechanical systems and other systems that require vehicle access for maintenance to be located in a centralized area

A number of assumptions were necessary for the design process. The assumptions are generally related to the maximum number of people that would be present on campus during regular operations. The water usage and constituent loading used in the design is based on textbook and other reference data sources. One assumption is that portable toilets or other facilities will be made available during events that would result in a higher population on campus that the design values. The May 2013 YM master plan was used as the primary reference for population and flow estimates. A summary of the population and flow data is presented in Table 1. Because of the relatively small change in flowrate between planning Phases 1 and 2 / 3, the design presented in this report is expected to accommodate the flows for all phases of the campus expansion. Therefore, the proposed system would be constructed during the Phase 1 expansion and new buildings constructed at later construction phases would be connected to the system without substantial expansion. The proposed system was selected from four general design scenarios considered for the campus. A summary of alternative scenarios is listed in Appendix B.

Table 1
Summary of design population and projected flowrate[a]

Condition	Design population	Design flow rate, gal/d
Current flow	50	2045
Phase 1	70	3221
Phase 2	100	4316
Phase 3	100	4316

[a] See Appendix A for details of flow estimation

A sketch of the proposed treatment system is shown on Figures 1 and 2. The expected water quality at various locations in the treatment system is summarized in Table 2.

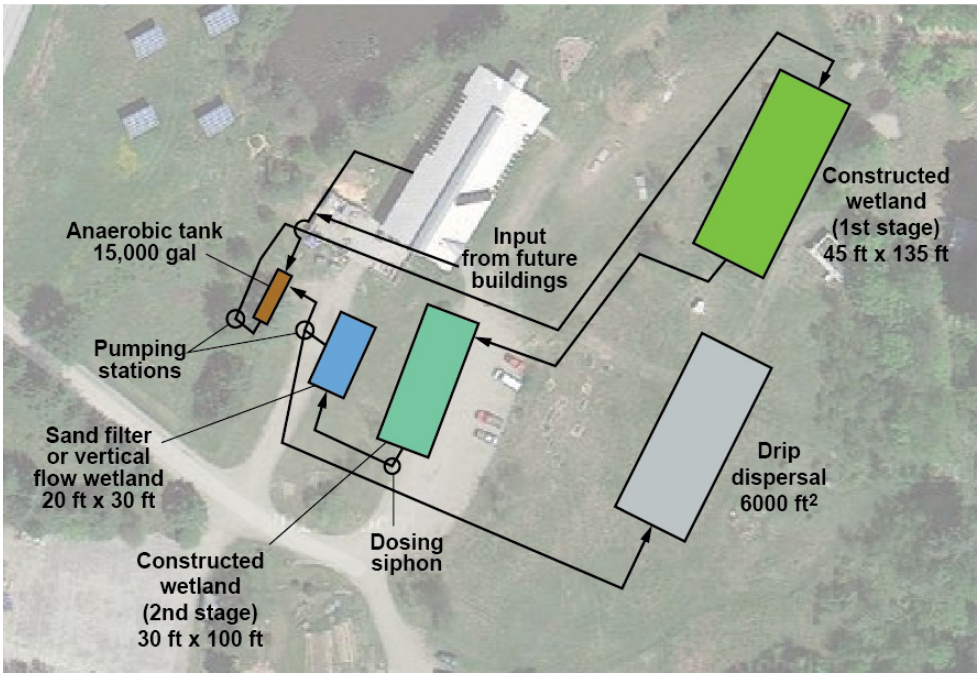

Figure 1
Conceptual plan view of proposed treatment system

Table 2
Summary of expected effluent concentrations at various locations in the proposed treatment system.

		Concentration, mg/L[a]				
Constituent	Mass Loading, g/capita day	Influent	Primary Effluent	CW Effluent	Vertical wetland / sand filter	Vadose water
BOD_5	85	450	174	10	< 1	~ 0
COD	198	1050	442	50	< 20	< 5
TSS	95	503	25	10	< 1	~ 0
TKN as N	13.3	70	35	~5	< 1	~ 0
Nitrate as N	2.05	N/A	N/A	~ 20	~ 10	< 10
Total P as P	3.28	17	17	13	12	~ 0
Trace chemicals[b]	Unknown	Present	Present	Partially reduced	Reduced	Negligible
Pathogens[b]	Unknown	10^5	10^4	10^3	10^2	Negligible

[a] Based on per capita flow rate of 50 gal/d
[b] Values are not known, example values are used for illustration purposes

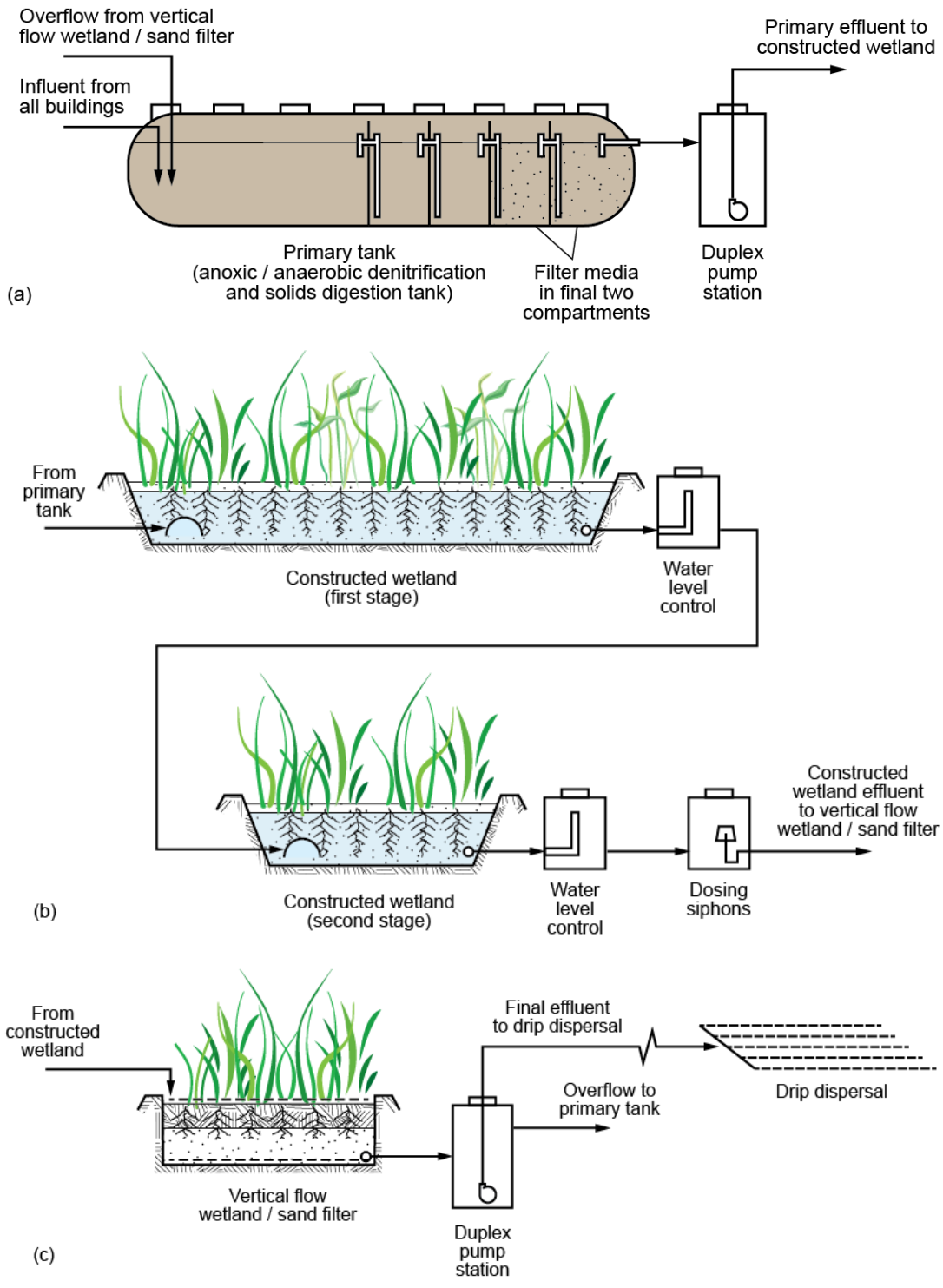

Figure 2

Process flow diagram for proposed treatment system: (a) primary treatment system, (b) secondary treatment constructed wetland, and (c) tertiary treatment and drip dispersal system.

Appendix A: Flow Estimation

Current conditions were initially assessed using three estimation methods, primarily as a class exercise. Wastewater flows were then evaluated for each phase (horizon) of the May 2013 master plan. For the purposes of considering distributed and phased infrastructure, the campus was divided into 3 zones based on elevation relative to the proposed dispersal field(s) (in the sloping undeveloped meadow in the center of the campus). The Lower Zone comprised all buildings and infrastructure at or below the current grade of the main building upper floor. The Middle Zone comprised all buildings between the main building and the proposed wastewater dispersal field(s). The Upper Zone comprised all buildings upslope of the proposed wastewater dispersal field(s). *Estimation Method 2* utilized textbook flowrates from Crites & Tchbonaglous 1998 and was applied to all 3 three horizons for each of the three zones.

Current Conditions

Estimation Method 1 *Standard VT Residential Rate*

People Type	#	GPD / Capita	Max Avg Daily Flow
Interns	6	70	420
Staff (day use only)	10	70	700
Instructors (in dorms)	2	70	140
Instructors (day use only)	3	70	210
Students (on campus, in dorm)	8	70	560
Students (on campus, camping)	9	70	630
Students (on campus, cabins)	12	70	840
Totals	**50**		**3500**

Estimation Method 2 *C&T Table 4-3 Institutional Flow Rates*

People Type	#	GPD / Capita	Max Avg Daily Flow	Notes
Interns	6	50	300	school boarding low estimate
Staff (day use only)	10	15	150	school day with cafeteria only
Instructors (in dorms)	2	50	100	school boarding low estimate
Instructors (day use only)	3	15	45	school day with cafeteria only
Students (on campus, in dorm)	8	50	400	school boarding low estimate
Students (on campus, camping)	9	50	450	school boarding low estimate
Students (on campus, cabins)	12	50	600	school boarding low estimate
Totals	**50**		**2045**	

Estimation Method 3a (Flow to Pump Station) *C&T Table 4-3 Institutional Flow Rates*

People Type	#	GPD / Capita	Max Avg Daily Flow	Notes
Interns	6	8	48	cafeteria employee
Staff (day use only)	8	3	24	cafeteria customer
Instructors (in dorms)	4	50	200	school boarding low estimate
Instructors (day use only)	0		0	school day with cafeteria only
Students (on campus, in dorm)	0		0	school boarding low estimate
Students (on campus, not in dorm, on meal plan)	7	8	56	cafeteria employee
Students (on campus, not in dorm, not on meal plan)	3	1	3	intern kitchen meals
Totals	**28**		**331**	

Estimation Method 3b (Flow after Pump Station) *C&T Table 4-3 Institutional Flow Rates*

People Type	#	GPD / Capita	Max Avg Daily Flow	Notes
Interns	6	8	48	cafeteria employee
Staff (day use only)	8	3	24	cafeteria customer
Instructors (in dorms)	4	50	200	school boarding low estimate
Instructors (day use only)	0		0	school day with cafeteria only
Students (on campus, in dorm)	0		0	school boarding low estimate
Students (on campus, not in dorm, on meal plan)	7	8	56	cafeteria employee
Students (on campus, not in dorm, not on meal plan)	3	0	0	intern kitchen meals
Totals	**28**		**328**	

Phase 1 Horizon

Lower Zone 25 - Main Building

Estimation Method 2

C&T Table 4-3 Institutional Flow Rates

People Type	Use	#	GPD / Capita	Max Avg Daily Flow	Notes
Interns	kitchen, dining, studio, not showering	8	15	120	school day with cafeteria only
Staff (day use only)	office, kitchen, dining	13	15	195	school day with cafeteria only
Instructors (in dorms)	laundry, dining, studio, showers	3	50	150	school boarding low estimate
Instructors (day use only)	dining, studio	2	15	30	school day with cafeteria only
Semester Students (dorm	laundry, dining, (separate studio zone mid), (separate showers zone upper)	16	15	240	school day with cafeteria only
Students (on campus, in dorm)	laundry, dining, studio, showers	8	50	400	school boarding low estimate
Students (on campus, camping)	laundry, dining, studio, (showers in upper zone)	9	15	135	school day with cafeteria only
Students (on campus, cabins)	laundry, dining, studio, (showers in upper zone)	12	15	180	school day with cafeteria only
Totals		**71**		**1450**	

Phase 1 Horizon

1 - Semester Program Shop

Middle Zone — 3, 4, 8 - Semester Program Studios & Offices

Estimation Method 2 — *C&T Table 4-3, 4-2 Institutional Flow Rates*

People Type	Use	#	GPD / Capita	Max Avg Daily Flow	Notes
Interns	occasional office use	8	0	0	
Staff (day use only)	office (just facility staff)	13	7	91	office/employee school day without cafeteria
Instructors (in dorms)	bathroom	3	5	15	school day without cafeteria
Instructors (day use only)	bathroom	2	5	10	school day without cafeteria
Semester Students (dorm	bathroom	16	5	80	
Students (on campus, in dorm)		8	0	0	
Students (on campus, camping)		9	0	0	
Students (on campus, cabins)		12	0	0	
Totals		**71**		**196**	

Phase 1 Horizon

Upper Zone

Buildings 15 (bathhouse), 5A (intern housing), 6A (semester program dorm)

Estimation Method 2

C&T Table 4-3 Institutional Flow Rates

People Type	Use	#	GPD / Capita	Max Avg Daily Flow	Notes
Interns	showering, toilets, kitchens	8	35	280	laundry?
Staff (day use only)		13	0	0	
Instructors (in dorms)		3	0	0	
Instructors (day use only)		2	0	0	
Semester Students (dorm	showering, toilets, kitchens	16	35	560	laundry?
Students (on campus, in dorm)		8	0	0	
Students (on campus, camping)	bath house	9	35	315	
Students (on campus, cabins)	bath house	12	35	420	
Totals		**71**		**1575**	

Phase 1 Horizon	
Lower & Middle Total	1646
All Zones Grand Total	3221

Phase 2 Horizon

Lower Zone 25 - Main Building

Estimation Method 2

C&T Table 4-3 Institutional Flow Rates

People Type	Use	#	GPD / Capita	Max Avg Daily Flow	Notes
Interns	kitchen, dining, studio, not showering	8	15	120	school day with cafeteria only
Staff (day use only)	office, kitchen, dining	13	15	195	school day with cafeteria only
Instructors (in dorms)	laundry, dining, studio, showers	8	15	120	school day with cafeteria only
Instructors (day use only)	dining, studio	2	15	30	school day with cafeteria only
Semester Students (dorm	laundry, dining, (separate studio zone mid), (separate showers zone upper)	16	15	240	school day with cafeteria only
Students (on campus, in dorm)	laundry, dining, studio (showers in upper zone)	24	15	360	school boarding low estimate
Students (on campus, camping)	laundry, dining, studio, (showers in upper zone)	9	15	135	school day with cafeteria only
Students (on campus, cabins)	laundry, dining, studio, (showers in upper zone)	12	15	180	school day with cafeteria only
Totals		**92**		**1380**	

Phase 2 Horizon

Middle Zone

1 - Semester Program Shop
3, 4, 8 - Semester Program Studios & Offices
7 - Woodworking Shop & Drafting Studio
9 - Carpentry Shop

Estimation Method 2

C&T Table 4-3, 4-2 Institutional Flow Rates

People Type	Use	#	GPD / Capita	Max Avg Daily Flow	Notes
Interns	occasional office use	8	0	0	
Staff (day use only)	office (just facility staff)	3	7	21	office/employee
Instructors (in dorms)	bathroom	4	5	20	school day without cafeteria
Instructors (day use only)	bathroom	2	5	10	school day without cafeteria
Semester Students (dorm	bathroom	16	5	80	school day without cafeteria
Students (on campus, in dorm)	bathroom	8	5	40	school day without cafeteria
Students (on campus, camping)	bathroom	7	5	35	school day without cafeteria
Students (on campus, cabins)	bathroom	7	5	35	school day without cafeteria
Totals		**55**		**241**	

Phase 2 Horizon

Upper Zone

Buildings 15 (bathhouse), 5A (intern housing), 6A (semester program dorm)

Estimation Method 2

C&T Table 4-3 Institutional Flow Rates

People Type	Use	#	GPD / Capita	Max Avg Daily Flow	Notes
Interns	showering, toilets, kitchens	8	35	280	
Staff (day use only)		0	0	0	
Instructors (in dorms)		8	35	280	
Instructors (day use only)		0	0	0	
Semester Students (dorm	showering, toilets, kitchens	16	35	560	
Students (on campus, in dorm)	showering, toilets, kitchens	24	35	840	
Students (on campus, camping)	bath house	9	35	315	
Students (on campus, cabins)	bath house	12	35	420	
Totals		**77**		**2695**	

Phase 2 Horizon	
Lower & Middle Total	1621
All Zones Grand Total	4316

Phase 3 Horizon

Lower Zone

25 - Main Building

Estimation Method 2

C&T Table 4-3 Institutional Flow Rates

People Type	Use	#	GPD / Capita	Max Avg Daily Flow	
Interns	kitchen, dining, studio, not showering	8	15	120	school day with cafeteria only
Staff (day use only)	office, kitchen, dining	13	15	195	school day with cafeteria only
Instructors (in dorms)	laundry, dining, studio, showers	8	15	120	school boarding low estimate
Instructors (day use only)	dining, studio	2	15	30	school day with cafeteria only
Semester Students (dorm	laundry, dining, (separate studio zone mid), (separate showers zone upper)	16	15	240	school day with cafeteria only
Students (on campus, in dorm)	laundry, dining, studio, showers	24	15	360	school boarding low estimate
Students (on campus, camping)	laundry, dining, studio, (showers in upper zone)	9	15	135	school day with cafeteria only
Students (on campus, cabins)	laundry, dining, studio, (showers in upper zone)	12	15	180	school day with cafeteria only
Totals		**92**		**1380**	

Phase 3 Horizon

1 - Semester Program Shop
3, 4, 8 - Semester Program Studios & Offices
7 - Woodworking Shop & Drafting Studio
Middle Zone
9 - Carpentry Shop

Estimation Method 2

C&T Table 4-3, 4-2 Institutional Flow Rates

People Type	Use	#	GPD / Capita	Max Avg Daily Flow	Notes
Interns	occasional office use	8	0	0	
Staff (day use only)	office (just facility staff)	3	7	21	office/employee school day without
Instructors (in dorms)	bathroom	4	5	20	cafeteria school day without
Instructors (day use only)	bathroom	2	5	10	cafeteria school day without
Semester Students (dorm	bathroom	16	5	80	cafeteria school day without
Students (on campus, in dorm)	bathroom	8	5	40	cafeteria school day without
Students (on campus, camping)	bathroom	7	5	35	cafeteria school day without
Students (on campus, cabins)	bathroom	7	5	35	cafeteria
Totals		**55**		**241**	

Phase 3 Horizon

Upper Zone

Buildings 15 (bathhouse), 5A (intern housing), 6A (semester program dorm)

Estimation Method 2

C&T Table 4-3 Institutional Flow Rates

People Type	Use	#	GPD / Capita	Max Avg Daily Flow	Notes
Interns	showering, toilets, kitchens	8	35	280	
Staff (day use only)		0	0	0	
Instructors (in dorms)		8	35	280	
Instructors (day use only)		0	0	0	
Semester Students (dorm	showering, toilets, kitchens	16	35	560	
Students (on campus, in dorm)	showering, toilets, kitchens	24	35	840	
Students (on campus, camping)	bath house	9	35	315	
Students (on campus, cabins)	bath house	12	35	420	
Totals		**77**		**2695**	

Phase 3 Horizon	
Lower & Middle Total	1621
All Zones Grand Total	4316

Appendix B: Design Scenarios

Several scenarios were considered to accommodate the design principles and objectives established by Yestermorrow and the class. Each scenario consisted of a collection, treatment, and dispersal component. In most cases drip-irrigation was assumed to be the preferred dispersal method due to its ability to evenly distribute water over the upper layers of soil where treatment of trace organic materials and pathogens can be optimized. Scenarios for collection included centralized, clustered, and individual (per building) septic tanks. For each collection scenario, gravity flow septic tanks as well as using grinder pumps to transfer liquid and solids were considered. Treatment scenarios included combinations of centralized, clustered, and individual treatment wetlands; composting toilets with separate greywater dispersal areas for individual buildings;

1. Clustered septic tanks, clustered treatment wetlands
2. Distributed septic tanks, clustered treatment wetlands
3. Centralized septic tank, centralized treatment wetland
4. Distributed composting toilets and greywater dispersal

The final design chosen most closely resembles scenario 3 where a centralized septic tank is located between the main building, future admin building, and easily accessible from the future parking lot. This location of the septic tank would allow all facilities to gravity flow to it and wastewater with fewer solids may be pumped to a series of treatment wetlands and sand filters. By also centralizing treatment within a series of wetlands and sand filter, more effective treatment can be achieved.

For Yestermorrow's expansion distributed or clustered septic tanks and wetlands do not offer many advantages beyond potentially reducing the length of gravity sewer pipe and decreasing a small amount of pumping energy required. It would increase the number of tanks and components to be accessed and maintained separately and the same number of pumps if not more would be required. It is also unlikely that the clustered designs could achieve exceptional treatment quality without significantly increasing capital costs and operational requirements.

Lastly, the final design chosen does not preclude the integration of scenario 4: composting toilets, with or without urine diversion, and greywater dispersal areas particularly for the future "mid-Level" studio / shop buildings. The Middle Zone buildings represent the lightest greywater use and offer the best opportunity for demonstrating these alternative concepts. The choice to pursue composting toilets and greywater for these buildings would not significantly affect the final design as proposed.