Florida Onsite Sewage Nitrogen Reduction Strategies Study

Task B.13

Task B PNRS Life Cycle Cost Analysis Report

Progress Report

May 2015

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In association with:

AET

Otis Environmental Consultants, LLC

Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK B.13
PROGRESS REPORT

Task B PNRS Life Cycle Cost Analysis Report

Prepared for:

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Bureau of Environmental Health
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May 2015

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Task B PNRS Life Cycle Cost Analysis Report

The LCCA tool developed by the project team to provide life cycle costs for the PNRS systems was applied to the seven prototype full scale PNRS evaluated in FOSNRS Task B. This report summarizes the LCCA result for each PNRS installed and provides a comparison to the actual reported as-built installation costs.

1.0 Life Cycle Cost Analysis Tool (PNRS LCCA)

The PNRS LCCA (Life Cycle Cost Analysis Tool for Passive Nitrogen Removal Systems) is a computer spreadsheet tool developed by the FOSNRS Project Team to estimate life cycle costs for PNRS systems. The user specifies a desired nitrogen removal efficiency range, and PNRS LCCA provides selections for treatment processes that achieve the selected nitrogen removal range and estimates the costs to meet the selected nitrogen removal efficiency. PNRS LCCA incorporates all system costs over the entire project life, including construction, engineering fees, state and county permitting, system maintenance, media and pump replacement, water quality monitoring, and energy, as well as primary treatment solids removal. PNRS LCCA applies discounting to future costs at a specified net interest rate to derive the Present Worth (PW) of a PNRS system, also termed Net Present Value (NPV). PNRS LCCA estimates Present Worth (PW) for both the entire treatment system (conventional OSTDS components + PNRS) and for the conventional OSTDS components alone (primary tank and STU). Although the default system sizing and cost data in PNRS LCCA are based on the OSTDS code and costs in Florida, the tool allows user specific inputs which allow its use elsewhere, with some limitations.

Three levels of nitrogen removal efficiency are available to choose from. Conventional treatment (primary + soil treatment and dispersal) can reduce total nitrogen by 25 to 35%, and is assigned a total nitrogen removal of 30% (Low Level) in PNRS LCCA. Stage 1 systems alone will nitrify wastewater and if recirculation is provided can provide 50 to 70% total nitrogen removal via pre-denitrification (Medium Level). Also, several of the simple in-ground system designs can achieve similar reductions in total nitrogen. A 60% TN removal rate is thus assigned for Medium Level systems. Adding Stage 2 biofilter systems will denitrify wastewater further and can increase total nitrogen removal to a High Level (95%) provided that they are preceded by highly effective nitrification and include a soil treatment unit (STU) for effluent dispersal. Additional details on the PNRS

LCCA tool can be found in the LCCA Report and User Guidelines (Hazen and Sawyer, 2015).

PNRS LCCA provides detailed cost breakouts for each life cycle analysis in both tabular and graphical format. Estimates are provided for the mass of nitrogen removed by each system and the unit cost of nitrogen removed ($PW/lb. nitrogen).

2.0 Application of PNRS LCCA

PNRS LCCA was applied to the seven prototype PNRS studied in Task B, and listed in Table 2-1. These PNRS each included Stage 1 and Stage 2 biofiltration processes. All systems were designed for high level nitrogen removal (ca. 95% including STU), however not all systems met that level of treatment during the study. As discussed in the monitoring reports, BHS-6 and BHS-7 PNRS had operational hydraulic issues and/or construction material flaws. The BHS-6 in-tank vertically stacked Stage 1 and Stage 2a tank water level fluctuated throughout the study period due to hydraulic blockages in the effluent collection and Stage 2 influent pipe. During monitoring events at the intended water level, the system performed at a high level of treatment. Therefore, this type of PNRS system was classified as High Level of treatment. The BHS-7 in-ground vertically stacked system hydraulics did not appear to allow much of the Stage 1 effluent flow into the liner media. With consideration to uncertainty in performance, this type of PNRS system was classified as Medium Level of treatment, although it is thought that an improved liner module design could correct the problem.

Table 2-1: Seven PNRS Evaluated

System ID	County	First Stage			Second Stage	
		Media	Enclosure	Hydraulics	Media	Enclosure
BHS-1	Wakulla	Aerocell™	tank	recirculation	Nitrex™	tank
BHS-2	Hillsborough	ex clay	tank	recirculation	dual media ligno-sulfur	tank
BHS-3	Seminole	stacked sand/ligno	in-ground liner	single pass	sulfur	tank
BHS-4	Seminole	ex clay	tank	single pass	dual media ligno-sulfur	tank
BHS-5	Seminole	ex clay	tank	single pass & recirculation	dual media ligno-sulfur	tank
BHS-6	Wakulla	stacked ex clay/ligno	tank	single pass	sulfur	tank
BHS-7	Marion	stacked sand/ligno	in-ground liner	single pass	ligno	liner

The sources of input data to the LCCA analysis included:

- Cost data from Task B.6 installation reports for each prototype PNRS
- Cost estimates of onsite contractors familiar with onsite system installation procedures and costs
- Florida Department of Health and counties permitting fee structures
- Electrical rates from Florida utilities

- Service Provider costs for inspection and maintenance visits and water quality monitoring

To provide a uniform basis for comparison of results, several inputs to PNRS LCCA were kept the same for all systems. These included:

- Project life of 30 years
- Net interest rate of 2.0%
- Two inspection and maintenance visits per year
- One water quality monitoring event per year of equal cost
- Primary treatment system solids removal every five years
- Stage 2 media replacement every 15 years
- Pump replacement every ten years

A brief summary of PNRS LCCA application for each prototype PNRS evaluated is included here. The default costs imbedded within PNRS LCCA were used without adjustment for four systems, while user override cost adjustments were applied for BHS-1, BHS-4 and BHS-6 as noted below.

- **BHS-1** Stage 1 was a commercial proprietary Stage 1 system (Aerocell™) followed by a commercial proprietary Stage 2 system (Nitrex™). Although individual components were proprietary, the packaged system was considered prototype as it was the first such system installed under a "passive nitrogen reduction" definition. Installed cost of the Stage 1 system is taken directly from cost documentation supplied by the vendor. An engineer design cost of $700 was entered into PNRS LCCA, which when added to the imbedded engineer design cost of $1,000 for PNRS systems equaled the vendor cost of $1,700 for engineer design plus as-built engineering design. Electricity use was the average daily electricity use measured for the home system scaled up to 300 gpd from measured mean flowrate. Cost esti-

mates for Stage 2 were based on those for lignocellulosic Stage 2 biofilters embedded in the PNRS LCCA. User override costs were entered for conventional system pump and conventional system energy cost.

- **BHS-2** Stage 1 and 2 were prototype PNRS systems designed for the site. Costs included a new primary tank. All costs were PNRS LCCA imbedded costs.

- **BHS-3** Stage 1 and 2 were prototype PNRS systems designed for the site. Costs included a new primary tank and new drip dispersal system. All costs were PNRS LCCA imbedded costs.

- **BHS-4** Stage 1 and 2 were prototype PNRS systems designed for the site. Costs included a new STU. User override costs were specified for STU, PNRS tankage and media.

- **BHS-5** Stage 1 and 2 were prototype PNRS systems designed for the site. An existing primary tank and STU was present, so no conventional system costs were incurred. All costs were PNRS LCCA imbedded costs.

- **BHS-6** Stage 1 and 2 were prototype PNRS systems designed for the site. No conventional system costs incurred. User override costs were specified for PNRS tankage, media, pump and control panel, and contractor fee.

- **BHS-7** Stage 1 and 2 were prototype PNRS systems designed for the site. No conventional system costs were incurred. All costs were PNRS LCCA imbedded costs.

3.0 PNRS LCCA Results

Detailed life cycle cost output reports generated by PNRS LCCA for each of the evaluated prototype PNRS are presented in Tables 3-1 through 3-7. PNRS LCCA cost estimates for the total systems (including PNRS and conventional treatment components) are summarized in Table 3-8. Also shown are as-built construction costs estimated from the Task B full scale system installation reports. Adjustments were made to the full scale costs to reflect treatment system construction costs only, e.g. costs for permitting, experimental monitoring equipment, and other non-construction costs were removed. PNRS LCCA construction cost estimates for PNRS treatment components only are listed in Table 3-9.

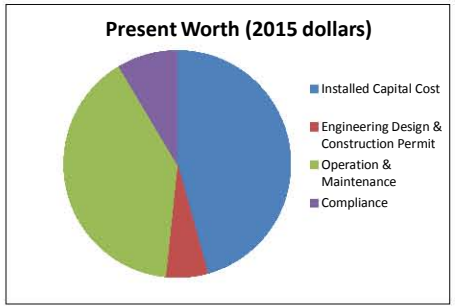
Table 3-1: PNRS LCCA Result Output for BHS-1 PNRS

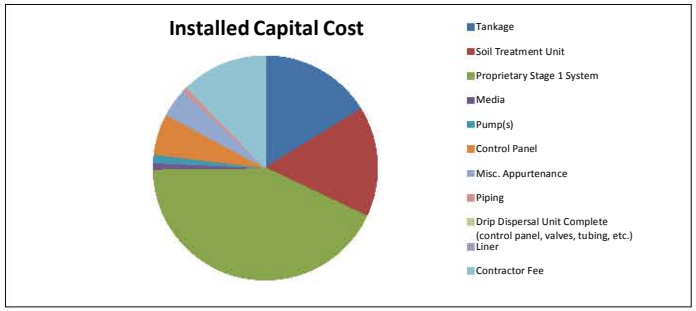
PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-1

Worksheet

1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System





Conventional System Summary

No. of Bedrooms	3
Building area, square feet	2200
Depth to seasonal high water table (inches)	32
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

No user override Conventional costs have been specified

PNRS System Summary

PNRS System	26
Stage 1: PNRS or proprietary	proprietary
PNRS Stage(s)	Stage 2 only
Stage 1 in-tank or in-ground	0
Stage 1 single pass or recirculation	0
Stage 1 media type	0
Ligno disposition	Tank
Stage 2 media type	Ligno only
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	3.1
Pump tank	600.00	26.79	1.3
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	3,225.00	144.00	7.2
Subtotal Conventional	5,225.00	233.30	11.7
Proprietary Stage 1 system	8,700.00	388.45	19.5
PNRS Installation			
Tankage	1,300.00	58.04	2.9
Media	182.54	8.15	0.4
PNRS Pump	250.00	11.16	0.6
Control Panel	1,200.00	53.58	2.7
Piping	144.80	6.47	0.3
Misc. Appurtenance	846.50	37.80	1.9
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	5.6
Subtotal	6,423.84	286.82	14.4
Total System Installation	20,348.84	908.57	45.7
Engineering Design & Construction Permit			
Construction permit	955.00	42.64	2.1
Engineering design fees	1,700.00	75.90	3.8
Operation and Maintenance			
Annual energy cost	8,063.12	360.02	18.1
Annual inspection & maintenance	7,838.76	350.00	17.6
Primary tank pump out	937.90	41.88	2.1
Stage 2 media replacement	135.63	6.06	0.3
Equipment replacement	746.66	33.34	1.7
Subtotal	17,722.07	791.29	39.8
Compliance			
Operating permit fee	1,119.82	50.00	2.5
Water quality monitoring	2,687.58	120.00	6.0
Subtotal	3,807.40	170.00	8.5
Total	44,533.30	1,988.41	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	3,300.00	147.34	16.2
Soil Treatment Unit	3,225.00	144.00	15.8
Proprietary Stage 1 System	8,700.00	388.45	42.8
Media	182.54	8.15	0.9
Pump(s)	250.00	11.16	1.2
Control Panel	1,200.00	53.58	5.9
Misc. Appurtenance	846.50	37.80	4.2
Piping	144.80	6.47	0.7
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	12.3
Total System	20,348.84	908.57	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	20,348.84	908.57	45.7
Engineering Design & Construction Permit	2,655.00	118.55	6.0
Operation & Maintenance	17,722.07	791.29	39.8
Compliance	3,807.40	170.00	8.5
Total	44,533.30	1,988.41	100.0
$/lb nitrogen removed	57.84	77.48	

Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET Applied Environmental Technology

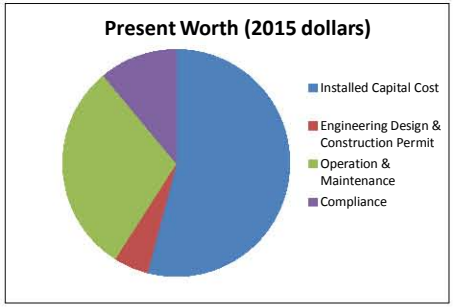
Table 3-2: PNRS LCCA Result Output for BHS-2 PNRS

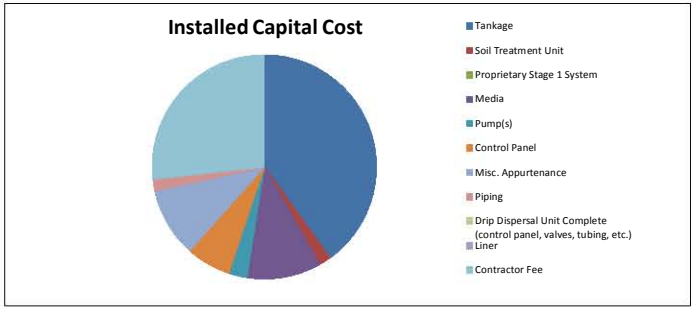
PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-2

Worksheet

1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System





Conventional System Summary

No. of Bedrooms	3
Building area, square feet	2542
Depth to seasonal high water table (inches)	12
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	360

No user override Conventional costs have been specified

PNRS System Summary

PNRS System	9
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in-tank or in-ground	Tank
Stage 1 single pass or recirculation	Recirculation
Stage 1 media type	Expanded Clay
Ligno disposition	Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	4.0
Pump out analysis life (PL), years	28.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.24262
P/A PL	21.281
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	4.1
Pump tank	600.00	26.79	1.7
Conventional system pump	250.00	11.16	0.7
Soil treatment unit	326.00	14.56	0.9
Subtotal Conventional	2,576.00	115.02	7.5
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	5,489.90	245.12	15.9
Media	2,000.07	89.30	5.8
PNRS Pump	250.00	11.16	0.7
Control Panel	1,200.00	53.58	3.5
Piping	318.56	14.22	0.9
Misc. Appurtenance	1,862.30	83.15	5.4
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	14.5
Subtotal	16,120.83	719.79	46.7
Total System Installation	18,696.83	834.81	54.1
Engineering Design & Construction Permit			
Construction permit	710.00	31.70	2.1
Engineering design fees	1,000.00	44.65	2.9
Operation and Maintenance			
Annual energy cost	1,004.95	44.87	2.9
Annual inspection & maintenance	6,718.94	300.00	19.4
Primary tank pump out	1,290.84	57.64	3.7
Stage 2 media replacement	569.13	25.41	1.6
Equipment replacement	746.66	33.34	2.2
Subtotal	10,330.51	461.26	29.9
Compliance			
Operating permit fee	1,119.82	50.00	3.2
Water quality monitoring	2,687.57	120.00	7.8
Subtotal	3,807.40	170.00	11.0
Total	34,544.74	1,542.42	100.0

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	7,489.90	334.42	40.1
Soil Treatment Unit	326.00	14.56	1.7
Proprietary Stage 1 System	0.00	0.00	0.0
Media	2,000.07	89.30	10.7
Pump(s)	500.00	22.32	2.7
Control Panel	1,200.00	53.58	6.4
Misc. Appurtenance	1,862.30	83.15	10.0
Piping	318.56	14.22	1.7
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	26.7
Total System	18,696.83	834.81	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	18,696.83	834.81	54.1
Engineering Design & Construction Permit	1,710.00	76.35	5.0
Operation & Maintenance	10,330.51	461.26	29.9
Compliance	3,807.40	170.00	11.0
Total	34,544.74	1,542.42	100.0
$/lb nitrogen removed	44.87	60.10	

Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists **and** AET

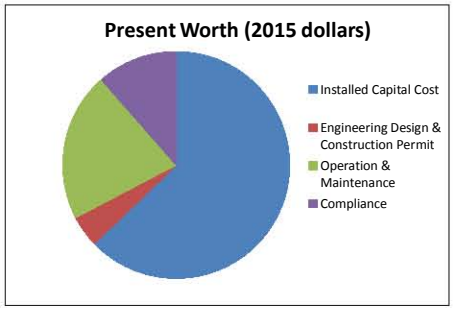
Table 3-3: PNRS LCCA Result Output for BHS-3 PNRS

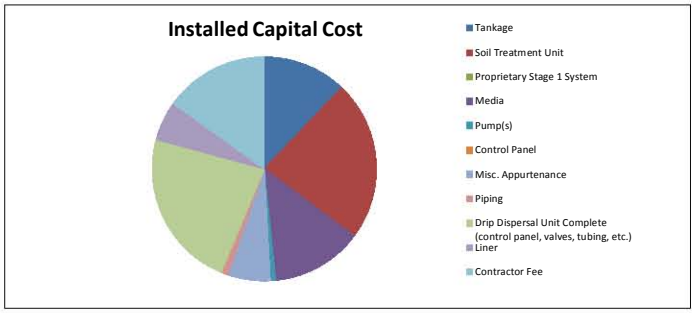
PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-3

Worksheet

1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System





Conventional System Summary

No. of Bedrooms	5
Building area, square feet	4940
Depth to seasonal high water table (inches)	12
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	580

No user override Conventional costs have been specified

PNRS System Summary

PNRS System	18
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in-tank or in-ground	In-ground
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Native Sand
Ligno disposition	Underlying Stage 1 in-ground liner
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	45.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	42.77

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	2,108.97	94.17	4.0
Pump tank	700.00	31.25	1.3
Conventional system pump	250.00	11.16	0.5
Soil treatment unit	7,675.00	342.69	14.5
Subtotal Conventional	10,733.97	479.27	20.3
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	1,200.00	53.58	2.3
Media	4,357.03	194.54	8.3
PNRS Pump	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Piping	347.52	15.52	0.7
Misc. Appurtenance	2,031.60	90.71	3.9
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	7,600.00	339.34	14.4
Liner	1,884.53	84.14	3.6
Contractor Fee	5,000.00	223.25	9.5
Subtotal	22,420.68	1,001.08	42.5
Total System Installation	33,154.65	1,480.35	62.8
Engineering Design & Construction Permit			
Construction permit	870.00	38.85	1.6
Engineering design fees	1,500.00	66.97	2.8
Operation and Maintenance			
Annual energy cost	391.43	17.48	0.7
Annual inspection & maintenance	7,838.76	350.00	14.9
Primary tank pump out	937.90	41.88	1.8
Stage 2 media replacement	1,276.99	57.02	2.4
Equipment replacement	746.66	33.34	1.4
Subtotal	11,191.73	499.71	21.2
Compliance			
Operating permit fee	3,359.49	150.00	6.4
Water quality monitoring	2,687.57	120.00	5.1
Subtotal	6,047.04	270.00	11.5
Total	52,763.43	2,355.88	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	4,008.97	179.00	12.1
Soil Treatment Unit	7,675.00	342.69	23.1
Proprietary Stage 1 System	0.00	0.00	0.0
Media	4,357.03	194.54	13.1
Pump(s)	250.00	11.16	0.8
Control Panel	0.00	0.00	0.0
Misc. Appurtenance	2,031.60	90.71	6.1
Piping	347.52	15.52	1.0
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	7,600.00	339.34	22.9
Liner	1,884.53	84.14	5.7
Contractor Fee	5,000.00	223.25	15.1
Total System	33,154.65	1,480.35	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	33,154.65	1,480.35	62.8
Engineering Design & Construction Permit	2,370.00	105.82	4.5
Operation & Maintenance	11,191.73	499.71	21.2
Compliance	6,047.04	270.00	11.5
Total	52,763.43	2,355.88	100.0
$/lb nitrogen removed	41.12	55.08	

Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET Applied Environmental Technology

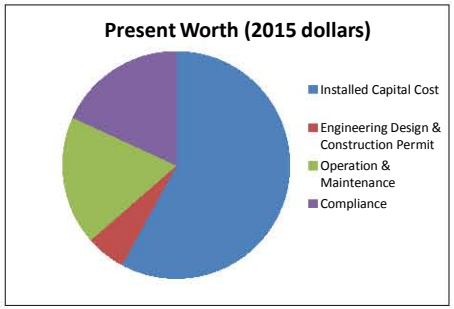
Table 3-4: PNRS LCCA Result Output for BHS-4 PNRS

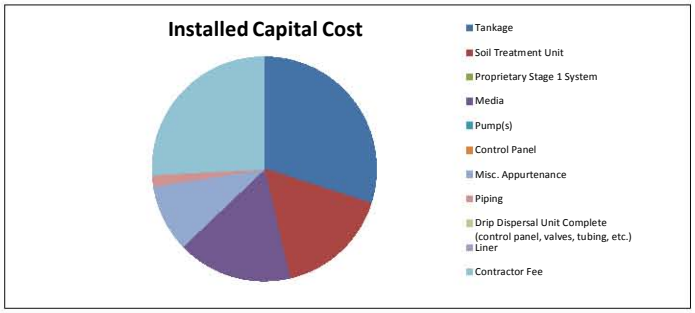
PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-4

Worksheet

1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System





Conventional System Summary

No. of Bedrooms	4
Building area, square feet	2517
Depth to seasonal high water table (inches)	60
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	400

User override Conventional costs have been specified

PNRS System Summary

PNRS System	3
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in-tank or in-ground	Tank
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Expanded Clay
Ligno disposition	Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

User override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	36.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	34.22

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	0.00	0.00	0.0
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	3,170.75	141.57	9.5
Subtotal Conventional	3,170.75	141.57	9.5
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	5,800.15	258.98	17.4
Media	3,198.73	142.82	9.6
PNRS Pump	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Piping	318.56	14.22	1.0
Misc. Appurtenance	1,862.30	83.15	5.6
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	15.0
Subtotal	16,179.74	722.42	48.5
Total System Installation	19,350.49	864.00	58.0
Engineering Design & Construction Permit			
Construction permit	870.00	38.85	2.6
Engineering design fees	1,000.00	44.65	3.0
Operation and Maintenance			
Annual energy cost	0.00	0.00	0.0
Annual inspection & maintenance	4,479.29	200.00	13.4
Primary tank pump out	937.90	41.88	2.8
Stage 2 media replacement	688.99	30.76	2.1
Equipment replacement	0.00	0.00	0.0
Subtotal	6,106.18	272.64	18.3
Compliance			
Operating permit fee	[illegible]	[illegible]	0.1
Water quality monitoring	2,687.57	120.00	8.1
Subtotal	6,047.04	270.00	18.1
Total	33,373.71	1,490.13	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	5,800.15	258.98	30.0
Soil Treatment Unit	3,170.75	141.57	16.4
Proprietary Stage 1 System	0.00	0.00	0.0
Media	3,198.73	142.82	16.5
Pump(s)	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Misc. Appurtenance	1,862.30	83.15	9.6
Piping	318.56	14.22	1.6
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	25.8
Total System	19,350.49	864.00	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	19,350.49	864.00	58.0
Engineering Design & Construction Permit	1,870.00	83.50	5.6
Operation & Maintenance	6,106.18	272.64	18.3
Compliance	6,047.04	270.00	18.1
Total	33,373.71	1,490.13	100.0
$/lb nitrogen removed	32.51	43.55	

Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET Applied Environmental Technology

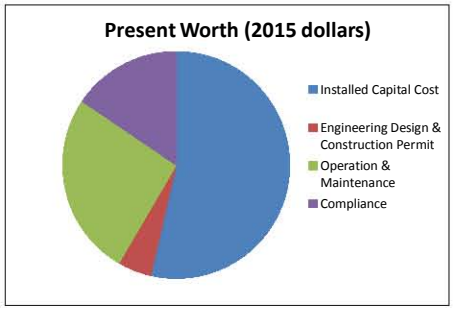
Table 3-5: PNRS LCCA Result Output for BHS-5 PNRS

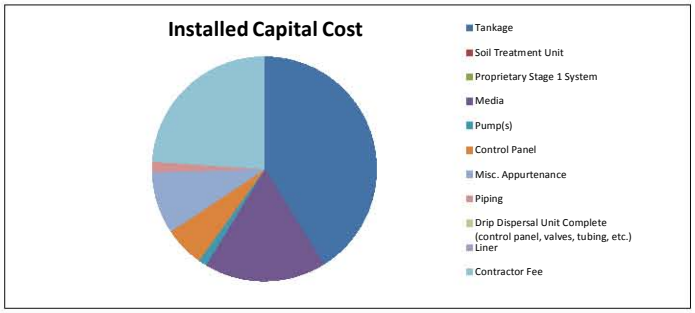
PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-5

Worksheet

1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System





Conventional System Summary

No. of Bedrooms	5
Building area, square feet	3315
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	460

No user override Conventional costs have been specified

PNRS System Summary

PNRS System	9
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in-tank or in-ground	Tank
Stage 1 single pass or recirculation	Recirculation
Stage 1 media type	Expanded Clay
Ligno disposition	Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	45.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	42.77

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	0.00	0.00	0.0
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	0.00	0.00	0.0
Subtotal Conventional	0.00	0.00	0.0
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	8,618.58	384.82	22.1
Media	3,670.69	163.90	9.4
PNRS Pump	250.00	11.16	0.6
Control Panel	1,200.00	53.58	3.1
Piping	318.56	14.22	0.8
Misc. Appurtenance	1,862.30	83.15	4.8
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	12.8
Subtotal	20,920.13	934.08	53.6
Total System Installation	20,920.13	934.08	53.6
Engineering Design & Construction Permit			
Construction permit	870.00	38.85	2.2
Engineering design fees	1,000.00	44.65	2.6
Operation and Maintenance			
Annual energy cost	1,241.77	55.44	3.2
Annual inspection & maintenance	6,718.94	300.00	17.2
Primary tank pump out	937.90	41.88	2.4
Stage 2 media replacement	893.48	39.89	2.3
Equipment replacement	373.33	16.67	1.0
Subtotal	10,165.42	453.89	26.1
Compliance			
Operating permit fee	[illegible]	[illegible]	8.6
Water quality monitoring	2,687.57	120.00	6.9
Subtotal	6,047.04	270.00	15.5
Total	39,002.60	1,741.46	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	8,618.58	384.82	41.2
Soil Treatment Unit	0.00	0.00	0.0
Proprietary Stage 1 System	0.00	0.00	0.0
Media	3,670.69	163.90	17.5
Pump(s)	250.00	11.16	1.2
Control Panel	1,200.00	53.58	5.7
Misc. Appurtenance	1,862.30	83.15	8.9
Piping	318.56	14.22	1.5
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	23.9
Total System	20,920.13	934.08	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	20,920.13	934.08	53.6
Engineering Design & Construction Permit	1,870.00	83.50	4.8
Operation & Maintenance	10,165.42	453.89	26.1
Compliance	6,047.04	270.00	15.5
Total	39,002.60	1,741.46	100.0
$/lb nitrogen removed	30.40	40.72	

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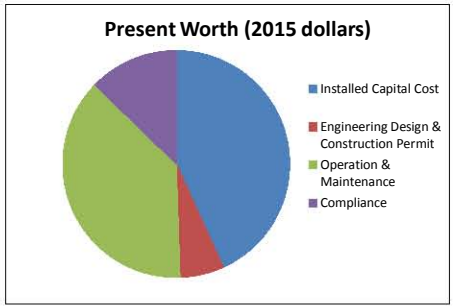
Table 3-6: PNRS LCCA Result Output for BHS-6 PNRS

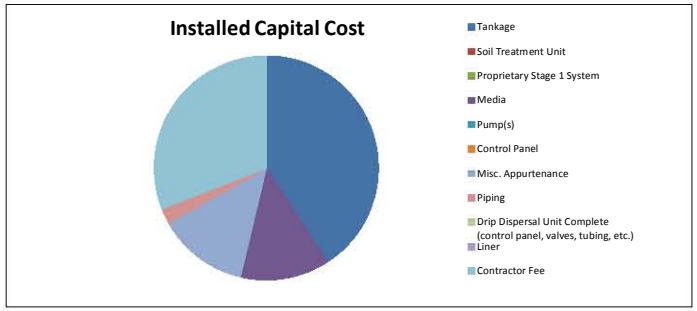
PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-6

Worksheet

1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System





Conventional System Summary

No. of Bedrooms	3
Building area, square feet	1200
Depth to seasonal high water table (inches)	32
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

No user override Conventional costs have been specified

PNRS System Summary

PNRS System	13
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in-tank or in-ground	Tank
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Expanded Clay
Ligno disposition	Underlying Stage 1 in Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

User override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	0.00	0.00	0.0
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	0.00	0.00	0.0
Subtotal Conventional	0.00	0.00	0.0
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	5,276.68	235.60	17.6
Media	1,666.85	74.42	5.6
PNRS Pump	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Piping	289.60	12.93	1.0
Misc. Appurtenance	1,693.00	75.59	5.7
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	4,000.00	178.60	13.4
Subtotal	12,926.13	577.15	43.2
Total System Installation	12,926.13	577.15	43.2
Engineering Design & Construction Permit			
Construction permit	875.00	39.07	2.9
Engineering design fees	1,000.00	44.65	3.3
Operation and Maintenance			
Annual energy cost	202.46	9.04	0.7
Annual inspection & maintenance	6,718.94	300.00	22.5
Primary tank pump out	937.90	41.88	3.1
Stage 2 media replacement	3,084.91	137.74	10.3
Equipment replacement	373.33	16.67	1.2
Subtotal	11,317.54	505.33	37.8
Compliance			
Operating permit fee	1,119.82	50.00	3.7
Water quality monitoring	2,687.58	120.00	9.0
Subtotal	3,807.40	170.00	12.7
Total	29,926.07	1,336.20	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	5,276.68	235.60	40.8
Soil Treatment Unit	0.00	0.00	0.0
Proprietary Stage 1 System	0.00	0.00	0.0
Media	1,666.85	74.42	12.9
Pump(s)	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Misc. Appurtenance	1,693.00	75.59	13.1
Piping	289.60	12.93	2.2
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	4,000.00	178.60	30.9
Total System	12,926.13	577.15	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	12,926.13	577.15	43.2
Engineering Design & Construction Permit	1,875.00	83.72	6.3
Operation & Maintenance	11,317.54	505.33	37.8
Compliance	3,807.40	170.00	12.7
Total	29,926.07	1,336.20	100.0
S/lb nitrogen removed	38.87	52.07	

Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET Applied Environmental Technology

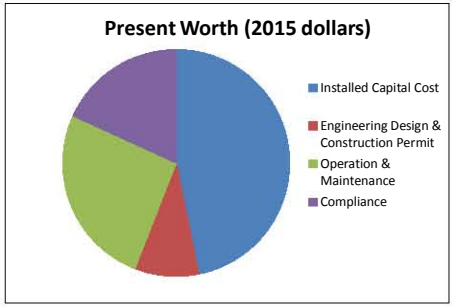
Table 3-7: PNRS LCCA Result Output for BHS-7 PNRS

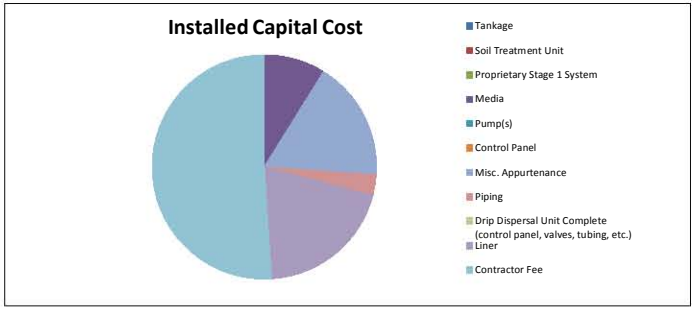
PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-7

Worksheet

1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System





Conventional System Summary

No. of Bedrooms	2
Building area, square feet	1112
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	200

No user override Conventional costs have been specified

PNRS System Summary

PNRS System	17
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in-tank or in-ground	In-ground
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Native Sand
Ligno disposition	Underlying Stage 1 in-ground liner
Stage 2 media type	Ligno only
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	Medium

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	18.0
Removal efficiency, %	60.0
Mass removal/year, lbs.	10.81

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	0.00	0.00	0.0
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	0.00	0.00	0.0
Subtotal Conventional	0.00	0.00	0.0
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	0.00	0.00	0.0
Media	867.50	38.73	4.1
PNRS Pump	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Piping	289.60	12.93	1.4
Misc. Appurtenance	1,693.00	75.59	8.1
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	1,950.00	87.07	9.3
Contractor Fee	5,000.00	223.25	23.9
Subtotal	9,800.10	437.57	46.8
Total System Installation	9,800.10	437.57	46.8
Engineering Design & Construction Permit			
Construction permit	915.00	40.85	4.4
Engineering design fees	1,000.00	44.65	4.8
Operation and Maintenance			
Annual energy cost	0.00	0.00	0.0
Annual inspection & maintenance	4,479.29	200.00	21.4
Primary tank pump out	937.90	41.88	4.5
Stage 2 media replacement	0.00	0.00	0.0
Equipment replacement	0.00	0.00	0.0
Subtotal	5,417.19	241.88	25.9
Compliance			
Operating permit fee	1,119.82	50.00	5.3
Water quality monitoring	2,687.57	120.00	12.8
Subtotal	3,807.40	170.00	18.2
Total	20,939.69	934.96	100.0

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	0.00	0.00	0.0
Soil Treatment Unit	0.00	0.00	0.0
Proprietary Stage 1 System	0.00	0.00	0.0
Media	867.50	38.73	8.9
Pump(s)	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Misc. Appurtenance	1,693.00	75.59	17.3
Piping	289.60	12.93	3.0
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	1,950.00	87.07	19.9
Contractor Fee	5,000.00	223.25	51.0
Total System	9,800.10	437.57	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	9,800.10	437.57	46.8
Engineering Design & Construction Permit	1,915.00	85.50	9.1
Operation & Maintenance	5,417.19	241.88	25.9
Compliance	3,807.40	170.00	18.2
Total	20,939.69	934.96	100.0
$/lb nitrogen removed	64.60	86.53	

Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists **and** AET

Table 3-8: Summary of Construction Costs for Full Scale PNRS, LCCA Tool vs. As-built Cost

System ID	System Description	PNRS LCCA Estimated Total System Costs		Total System As-built Construction Cost for Task B Systems		
		Total PW, $	Total Construction Cost, $	Task B Total Cost, $	Adjustment for permitting, monitoring, and other costs, $	Task B Total Construction Cost, $
BHS-1	Proprietary: Stage 1 Aerocell™ Stage 2 Nitrex™	44,533.30	20,348.84	23,600.00	4,994.00	18,606.00
BHS-2	In-tank Stage 1 with R, dual-media Stage 2	34,544.74	18,696.83	19,142.18	1,085.84	18,056.34
BHS-3	In-ground stacked Stage 1 over Stage 2a ligno with supplemental Stage 2b sulfur	52,763.43	33,154.65	40,129.79	8,014.05	32,115.74
BHS-4	In-tank SP Stage 1, dual-media Stage 2	33,373.71	19,350.49	22,030.34	5,933.17	16,097.17
BHS-5	In-tank Stage 1 with R, dual-media Stage 2	39,002.60	20,920.13	22,361.55	4,066.24	18,295.31
BHS-6	In-tank stacked Stage 1 over Stage 2a ligno with supplemental Stage 2b sulfur	29,926.07	12,926.13	13,727.12	3,327.88	10,399.24
BHS-7	In-ground stacked SP Stage 1 over Stage 2 ligno	20,939.69	9,800.10	13,836.66	3,320.81	10,515.86

Table 3-9: Summary of Estimated Construction Costs by Treatment component

System ID	System Description	Total System Costs		Conv. Component Construction Cost, $	PNRS Component Construction Cost, $
		Total PW, $	Total Construction Cost, $		
BHS-1	Proprietary: Stage 1 Aerocell™ Stage 2 Nitrex™	44,533	20,349	5,225	15,124
BHS-2	In-tank Stage 1 with R, dual-media Stage 2	34,545	18,697	2,576	16,121
BHS-3	In-ground stacked Stage 1 over Stage 2a ligno with supple-mental Stage 2b sulfur	52,763	33,155	10,734	22,421
BHS-4	In-tank SP Stage 1, dual-media Stage 2	33,373	19,350	3,171	16,180
BHS-5	In-tank Stage 1 with R, dual-media Stage 2	39,003	20,920	0	20,920
BHS-6	In-tank stacked Stage 1 over Stage 2a ligno with supplemental Stage 2b sulfur	29,926	12,926	0	12,926
BHS-7	In-ground stacked SP Stage 1 over Stage 2 ligno	20,940	9,800	0	9,800

Table 3-8 shows the reasonable comparison of PNRS LCCA estimated construction costs to actual as-built construction costs for the various PNRS evaluated. PNRS LCCA is to be used as a planning tool and contains many default values, while the actual construction costs are specific to details at each site, therefore some difference in costs are expected. Overall, PNRS LCCA should provide good planning level estimates of the various PNRS construction costs and life cycle costs of such a system.

The seven prototype systems required varying levels of new conventional OSTDS components, depending on site conditions. Some of the sites required a new primary tank and soil treatment unit, while others had conventional treatment components that could be reused within the new PNRS. Table 3-9 provides a comparison of the PNRS LCCA total estimated construction costs for the seven systems, the portion of that cost which was for required conventional treatment components, and the estimated construction cost of the PNRS components alone. This provides a more representative comparison of the cost of the PNRS installations, and narrows the range of PNRS costs relative to total system costs. Further analyses and comparisons of these cost results are discussed in the following sections.

4.0 Comparison of Life Cycle Costs of PNRS

The life cycle costs and unit nitrogen removal costs estimated by PNRS LCCA varied based on the size and complexity of the seven systems. Table 4-1 provides a statistical summary of these key life cycle cost metrics.

Table 4-1: Key Life Cycle Cost Statistics for Prototype PNRS

Metric	PNRS LCCA Statistics for the Seven PNRS Evaluated			
	Mean	Standard Deviation	Minimum	Maximum
Total PW, $	36,441	10,281	20,940	52,763
Total Construction Cost, $	19,314	7,381	9,800	33,155
lb. N removed per year	29.7	11.3	10.8	42.8
$ PW/ lb. N removed	44.32	12.70	30.40	64.60

4.1 PNRS System Total Present Worth and Construction Costs

The mean Total Present Worth (PW) of life cycle costs and total construction costs estimated by PNRS LCCA for the seven prototype systems were $36,441 and $19,314, respectively. Total Present Worth of life cycle costs reflected system complexity and ranged from $20,940 to $52,763 (Figure 4-1). Total Present Worth was highest for the dual drip irrigation system at BHS-3 and lower for relatively simpler systems such as BHS-7.

Construction costs estimated by PNRS LCCA ranged from $9,800 to $33,155 (Figure 4-1). The construction cost estimate was also highest for the dual drip irrigation system (BHS-3) and lower for relatively simpler systems such as BHS-7.

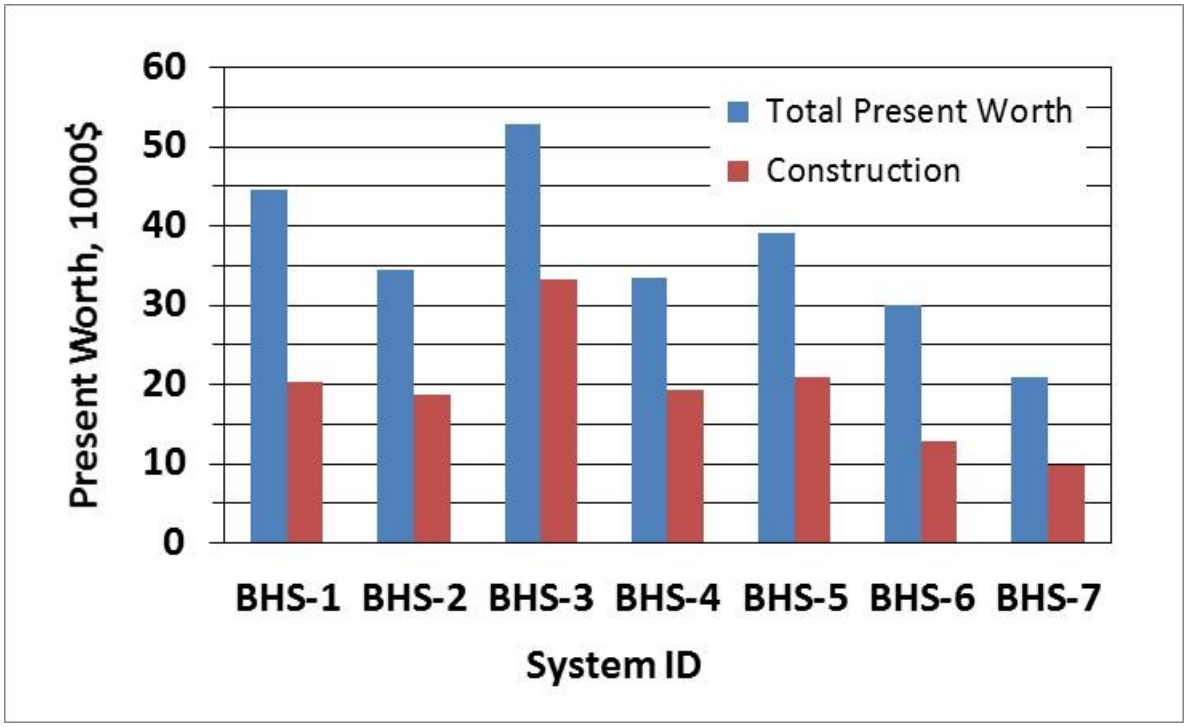


Figure 4-1: Total Present Worth of Life Cycle Costs and Estimated Construction Cost of PNRS Systems from PNRS LCCA

4.2 Task B System Construction Costs and PNRS LCCA Estimates

Task B as-built construction costs and PNRS LCCA construction cost estimates are shown in Figure 4-2. PNRS LCCA estimates provided somewhat higher costs than those derived from the Task B installation reports for six of the systems, with an average relative error for all systems of 10.2% versus the Task B cost. Task B as-built construction costs are plotted in Figure 4-3 versus the PNRS LCCA construction cost estimate. PNRS LCCA provides construction cost estimates that are quite acceptable for planning level analysis.

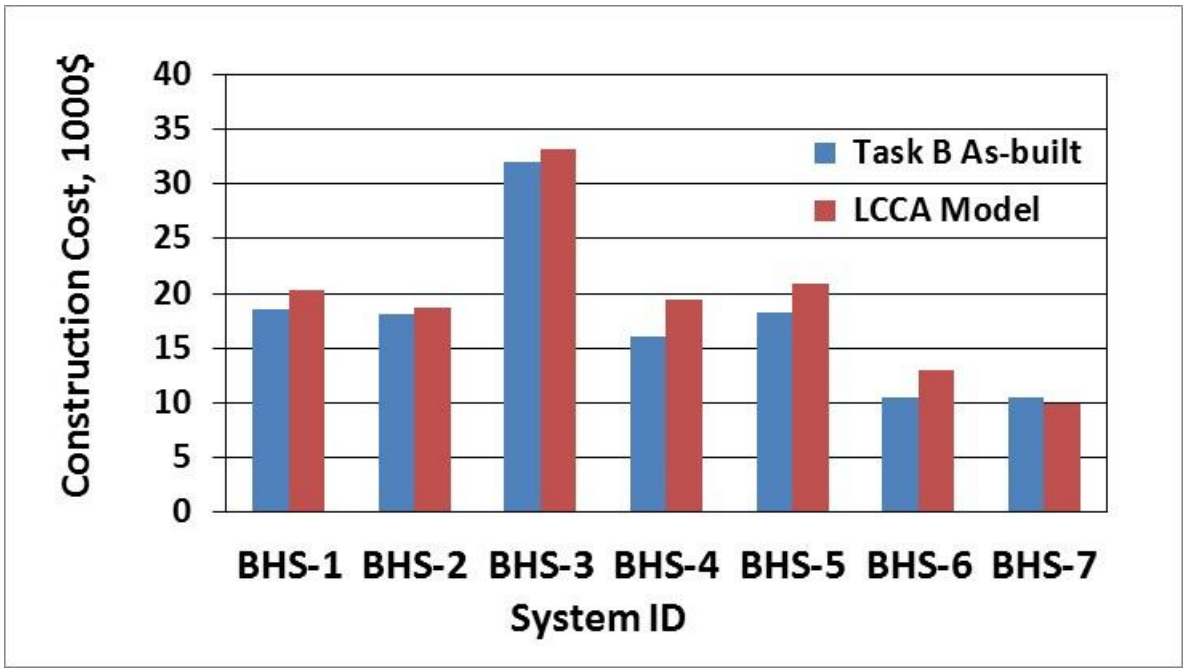


Figure 4-2: Comparison of PNRS As-built Construction Costs and PNRS LCCA Construction Cost Estimates

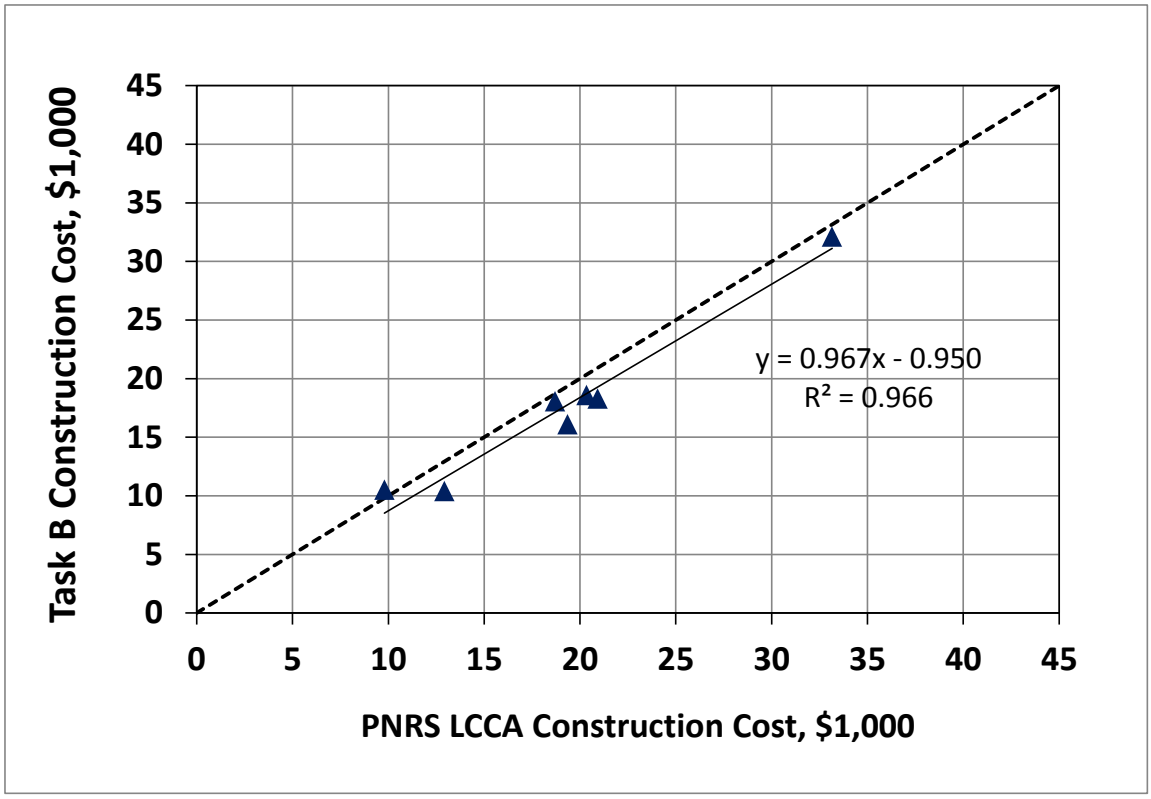


Figure 4-3: Trend Line for As-built Construction Costs and PNRS LCCA Estimates

4.3 PNRS LCCA Cosntruction Cost Estimate as Percentage of Present Worth

Estimated construction costs of the seven PNRS systems averaged 52% of the Total Present Worth of Life Cycle Costs and ranged from 43 to 63% (Figure 4-4). The balance of the Total Present Worth, which ranged from 36 to 57% of the total life cycle cost, includes the non-construction costs such as: site design, inspection and maintenance visits, permits, monitoring, media and pump replacement, energy, and primary treatment solids removal. For all home systems evaluated, non-construction costs are a significant component of total life cycle costs.

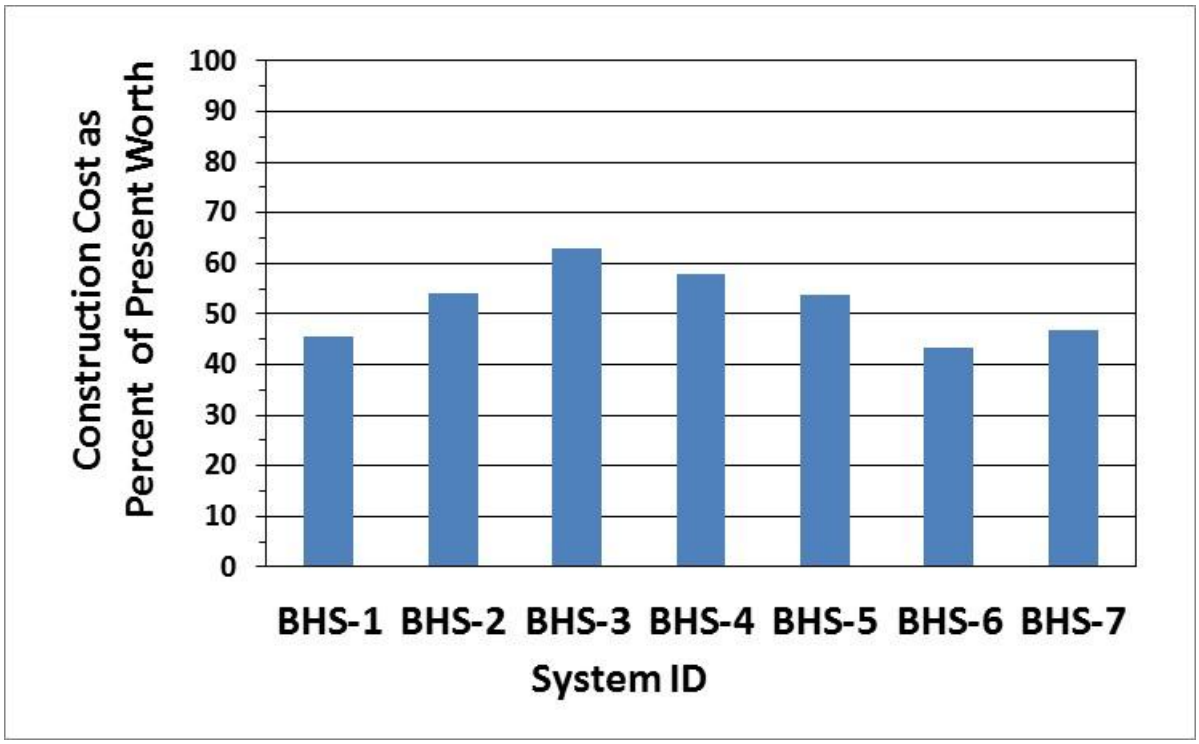


Figure 4-4: PNRS Construction Cost as Percentage of Present Worth

4.4 PNRS LCCA Cosntruction Cost Estimate as Percentage of Present Worth

The mean Total Present Worth per pound of nitrogen removed for all the prototype PNRS systems was estimated by PNRS LCCA as $44.32. Cost per nitrogen mass removed ranged from $31 to 65 (Figure 4-5). Present Worth per pound of nitrogen removed is affected by all system costs, the nitrogen generation rate of the home occupants, and the nitrogen reduction efficiency of the PNRS system.

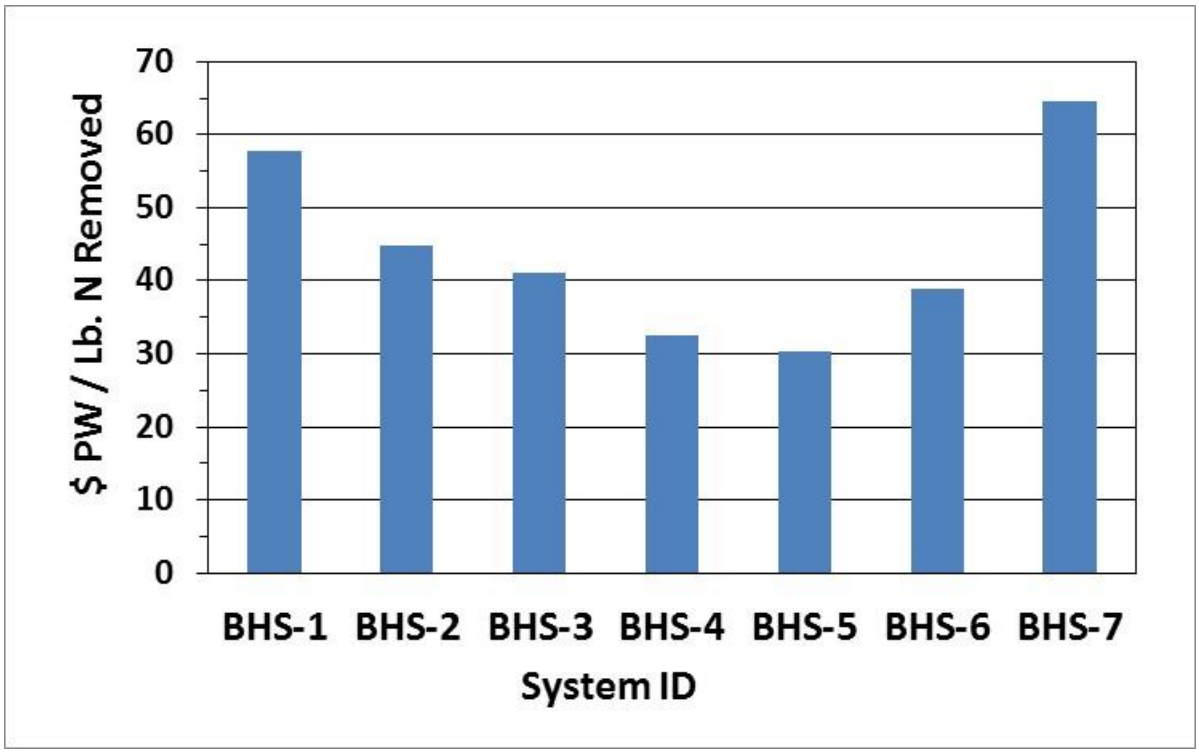


Figure 4-5: PNRS Present Worth per Mass of Nitrogen Removal

5.0 Summary

PNRS LCCA provides a useful planning level tool for Passive Nitrogen Removal Systems for nitrogen removal from onsite wastewater treatment systems. For the seven PNRS prototype systems, which varied significantly in design and operation, PNRS LCCA cost estimates were in reasonable agreement with actual Task B construction costs. For all seven prototype systems, PNRS LCCA results highlight that recurring costs are a significant component of the total life cycle costs of passive nitrogen removal systems for onsite wastewater treatment. Recurring costs must be included in any economic and planning analysis of Passive Nitrogen Removal Systems and alternative technologies as well.