Sustainable Engineering & Design: Water Treatment

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College of Engineering

ABSTRACT

As the world's population continues to grow and the demand for clean drinking water increases daily, the challenges of providing adequate amounts of potable water for human consumption, while maintaining a sustainable practice, are looming issues. Although the science and techniques of water treatment have drastically evolved since the construction of the first treatment plant by Robert Thorn in the early 1800s, the challenges of making plants and processes more sustainable are the crucial tasks ahead for future civil engineers.

PROJECT GOALS

Overall:

- Design a traditional treatment facility with a focus on efficiency and plant sustainability
- Achieve minimal chemical and electrical use
- Meet all sizing requirements and treatment standards

Project Specific:

- Plan for a projected demand in correspondence with a plant design life of 25 years
- Draw untreated water from Beaver Lake and cater to the private and industrial demand of the Northwest Arkansas region
- Focus on preliminary design and optimization of the treatment train; from the rapid mix stage to the disinfection stage

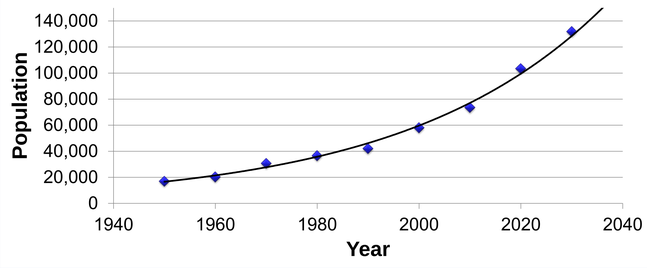
SITE LOCATION & MAP

Intake Structure	
Coordinates	36° 25" 7' N, 93° 15" 6' W
Elevation	1162 ft.
Treatment Plant	
Coordinates	36° 25" 8' N, 93° 48" 9' W
Elevation	1368 ft.

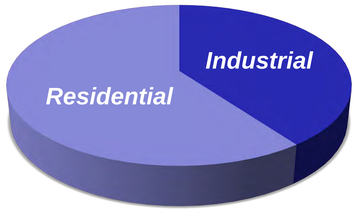
PROJECTED DEMAND

Estimating the future demand is crucial for obtaining a design flow rate. This estimation is based on historical population data and information obtained from communications with industrial companies in regards to planned growth and factory expansion.

Exponential Growth Model



Water Usage



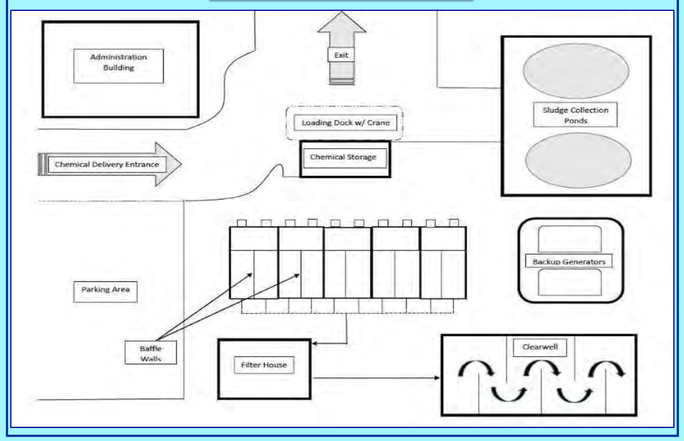
Year	Population
1950	17,071
1960	20,274
1970	30,729
1980	36,608
1990	42,099
2000	58,047
2010	73,580
2020	103,404
2030	131,844
2040	**168,106**

DESIGN FLOW RATE

Distributed Daily Consumption per Population Unit		
Industrial Usage	48	gpd
Residential Usage	72	gpd
Total Usage	120	gpd
Projected Demand	20.17	mgd
Design Flow Rate	**0.88**	**m³/s**

This calculated design flow rate will be used in the sizing, design and power requirement calculations of each individual process.

SITE LAYOUT

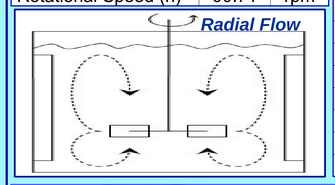


OPTIMIZING EFFICIENCY

Calculations were made to determine design parameters for each treatment stage. These parameters portray the ideal design for the plant to operate at optimum efficiency for the design flow rate while maintaining plant sustainability.

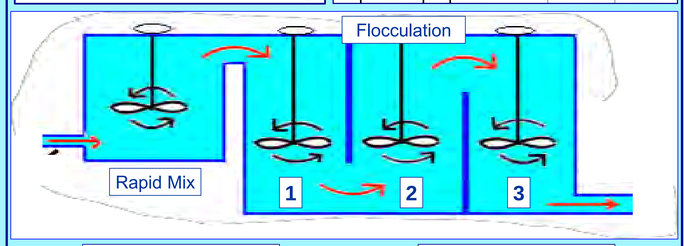
Rapid Mix

Rapid Mix Time (t)	5	s
Rapid Mix (G)	600	s^{-1}
Water Temperature	4.4	°C
Dynamic Viscosity (μ)	0.00155	Pa · s
Total Volume	4.42	m^3
Design Volume	4.5	m^3
Number of Basins	5	-
Basin Volume (V)	0.88	m^3
Tank Diameter (T)	1.92	m
Water Depth (H)	3.83	m
Impeller Type	radial	-
Impeller Diameter	0.5	m
Depth Below Impeller	1.28	m
Power Number (N_P)	5.7	-
Power Required (P)	492	W
Motor Power Required	616	W
Rotational Speed (n)	1.51	rps
Rotational Speed (n)	90.71	rpm



Flocculation

Number of Basins	5	-
Flow per Basin	10.61	m^3/min
Total Basin Volume	318.33	m^3
Compartments per Basin	3	-
Volume per Compartment	159	m^3
Flocculation Time (t)	30	min
Floc. Compartment 1 (G)	70	s^{-1}
Floc. Compartment 2 (G)	50	s^{-1}
Floc. Compartment 3 (G)	30	s^{-1}
Surface Area	39.79	m^2
Length	3.98	m
Width	10.00	m
Water Depth (H)	4.00	m
Impeller Type	axial	-
Impeller Diameter	1.40	m
Tank Diameter (T)	7.12	m
Water Below Impeller (B)	1.33	m
Power Required (P_1)	1207	W
Power Required (P_2)	616	W
Power Required (P_3)	222	W
Motor Power Required (1)	1508	W
Motor Power Required (2)	769	W
Motor Power Required (3)	277	W
Rotational Speed (n)	0.53	rps
Rotational Speed (n)	32.02	rpm
Impeller Tip Speed	3.35	m/s



Sedimentation

Designation	*horizontal-flow*	
Basin Shape	*rectangular*	
Sludge Collector	*chain-and-flight*	
Design Flow Rate	76399	m^3/d
Overflow Rate	32.5	m/d
Number of Tanks	5	w/ b-wall
Tank Surface Area	470	m^2 /tank
Width/Length	10/47	m
Tank Depth	5.6	m
Water Depth	4	m
Side Water Depth	5	m
Velocity	0.00442	m/s
Reynolds Number	6351	-
Froude Number	8.97E-07	-
Launder Length	16	m
# Launders per Tank	3	-
Weir Loading Rate	162.5	m^3/d·m
Collector Speed	0.6	m/min

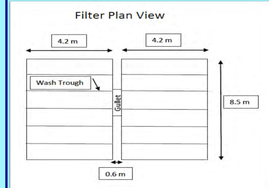
Disinfection

Q =	76399.19	m^3/d
$T_{DISTANT}$ at Min. =	30	hours
pH =	7.7	-
Temp. =	4.4	°C
Ct =	200	-
t_{10} =	100	min
t_{10}/t_0 =	0.7	-

Beaver Lake Water Analysis	
Constituent	Concentration
TOC	1.7 mg/L
Bromide	Not detected
Turbidity	0.3-4.5 NTU
Giardia Cysts	<1/100 L
Virus	<1/100 L
Crypto. Oocysts	<0.1/L

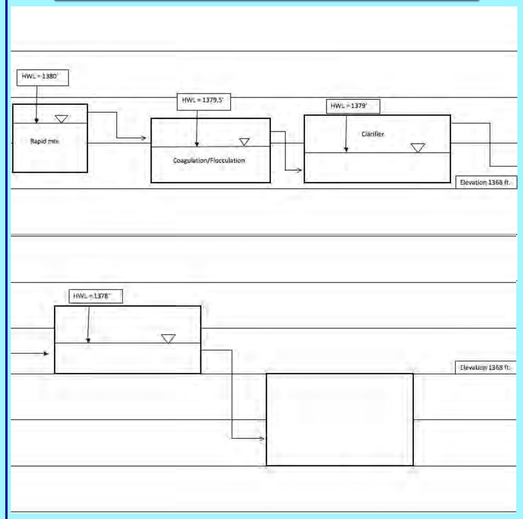
SUSTAINABLE FILTRATION

N =	5.39	=	10	filters
N per train		=	2	filters/train
A =	35.37	=	36	m^2/filter
A_a =	39.30	=	40	m^2/filter
Est. Width		=	8.4	m
L =	4.68	=	5	m



Backwash Calculations		
Backwash Velocity	36	m/h
Max Flow in Trough	321	m/h
Height Above Media	27.6	cm
Width of Trough	38	cm
Depth of Trough	51.6	cm
Media Expansion	0.12	m
Media to Water	0.79	m
Number of Cells	2	-
Backwash Time	0.25	hr
Calculated Backwash Volume	378	m^3

HYDRAULIC PROFILE



PLANT SUSTAINABILITY

✓Comparably lower power requirements
✓Effective use of gravity (elevations) to push water through the treatment chain
✓Optimized plant design and tank sizing
✓Less harmful chemical use
✓LEED certified structures
✓Environmentally friendly filtration
✓Sand filter media

THE BIG PICTURE

Designing any water treatment facility has its challenges, however taking the extra steps and making additional calculations to ensure an optimum design and sustainable resource use is worthwhile. A sustainably designed plant is a prime example of built-systems sustainability and benefits all of society.