SURPRISE
ARIZONA

Water Design Standards
and Technology Assessments
City of Surprise Project No. COS08-053

Wastewater Technology Assessment

Carollo Project No. 8267A.00

FINAL REPORT

APRIL 2011

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City of Surprise
Water Design Standards and Technology Assessment
Project No. COS08-053

WASTEWATER TECHNOLOGY ASSESSMENT REPORT

FINAL
April 2011

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City of Surprise
Water Design Standards and Technology Assessment
Project No. COS08-053

WASTEWATER TECHNOLOGY ASSESSMENT REPORT

TABLE OF CONTENTS

Page No.

EXECUTIVE SUMMARY ES-1

1.0 INTRODUCTION 1
- 1.1 Project Objectives 1
- 1.2 General References 2

2.0 PLANNING INTERFACE AND STUDY AREA DOCUMENTATION 3
- 2.1 Integrated Water Master Plan 3
  - 2.1.1 Current and Future Water Reclamation Facilities 3
  - 2.1.2 Wastewater Infrastructure Alternative Evaluation 9
  - 2.1.3 Reclaimed Water Facilities 10
- 2.2 Study Area Boundaries and Constraints 12
- 2.3 Project Methodology Overview 15

3.0 WATER QUALITY STANDARDS AND REGULATORY REQUIREMENTS 17
- 3.1 Wastewater and Reuse Regulations and Guidelines 17
  - 3.1.1 National Pollutant Discharge Elimination System (NPDES) Program 17
  - 3.1.2 Federal Guidelines for Reclaimed Water Reuse 19
  - 3.1.3 ADEQ BADCT Requirement 19
  - 3.1.4 ADEQ Reuse Applications 22
  - 3.1.5 Aquifer Protection Permits 22
  - 3.1.6 Disinfection and Disinfection Byproduct Requirements 23
- 3.2 Emerging Contaminants and Reuse 24
- 3.3 Emerging Organisms 25
- 3.4 Salinity and Reuse Potential 26
  - 3.4.1 Total Dissolved Solids 26
  - 3.4.2 Whole Effluent Toxicity 26
  - 3.4.3 Reclaimed Water Salinity and Sodium Adsorption Ratio 27
- 3.5 Biosolids Regulations 27
  - 3.5.1 Biosolids Rules 27

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EXPIRES 03-31-2014

3.5.2 Pathogen Reduction for Class B Biosolids 30
3.5.3 Landfill Disposal Regulations 35
3.5.4 Current Biosolids Trends..... 35
3.5.5 Odor, Noise, and Aesthetic Control Regulations 36
3.5.6 Odor Producing Compounds..... 37

4.0 WASTEWATER AND BIOSOLIDS TREATMENT STANDARDS 38
4.1 Existing City of Surprise Reclaimed Water Quality Standards 38
4.2 Basis for Establishing New Water Quality Standards..... 38
4.3 City of Surprise Water Quality Standards 38
4.4 City of Surprise Biosolids Treatment Standards..... 42

5.0 WASTEWATER QUALITY DATA AND DESIGN CONSIDERATIONS..... 43
5.1 Surprise Historical Wastewater Quality Data 43
5.2 Historical Wastewater Quality for Other Utilities..... 43
5.3 Reclaimed Water Disinfection Byproducts Data..... 45
5.4 Reclaimed Water Salinity Data 45
5.5 Impacts of Water Conservation and Industrial Wastes..... 46
5.6 Water Quality Constituents of Concern..... 47
5.6.1 Critical Constituents of Concern..... 48
5.6.2 Potential Constituents of Concern..... 49

6.0 TREATMENT PROCESS EVALUATION 49
6.1 Categories of Treatment Technologies..... 49
6.2 Treatment Technology Prescreening..... 51
6.3 Three-Tier Technology Assessment..... 51
6.4 Preliminary Treatment Technologies 56
6.4.1 Coarse Screening 57
6.4.2 Fine Screening..... 60
6.4.3 MBR Process Screening 62
6.4.4 TSS Removal..... 62
6.4.5 BOD Removal..... 62
6.4.6 Odor Control 62
6.4.7 Screening Handling..... 63
6.4.8 Summary of Preliminary Treatment Technologies..... 64
6.5 Grit Removal Technologies 67
6.5.1 Aerated Grit Removal..... 67
6.5.2 Free Vortex Grit Removal 69
6.5.3 Mechanical Vortex Grit Removal..... 70
6.5.4 Horizontal Flow Grit Removal..... 71
6.5.5 Grit Pumping, Washing, and Dewatering 72
6.5.6 Summary of Grit Removal Technologies..... 74
6.6 Primary Treatment Technologies..... 77
6.6.1 Primary Clarification..... 77
6.6.2 Summary of Primary Treatment Technologies 79
6.7 Biological Treatment Technologies..... 82
6.7.1 Sequencing Batch Reactor (SBR)..... 83
6.7.2 Trickling Filters..... 85
6.7.3 Activated Sludge..... 86
6.7.4 Moving Bed Biofilm Reactor and Integrated Fixed Film Activated Sludge..... 93

6.7.5 Membrane Bioreactor 95
6.7.6 Summary of Biological Treatment Technologies 100
6.8 Clarification Treatment Technologies 103
6.8.1 Circular Clarifier Basins 103
6.8.2 Rectangular Clarifier Basin 105
6.8.3 Conventional Circular and Rectangular Clarifier Comparison 105
6.8.4 Ballasted Flocculation 107
6.8.5 Dissolved Air Flotation 108
6.8.6 Summary of Clarification Technologies 109
6.9 Tertiary Filtration Treatment Technologies 112
6.9.1 Granular Media Filters 112
6.9.2 Cloth Media Filters 117
6.9.3 Membrane Filtration 122
6.9.4 Summary Tertiary Filtration Technologies 123
6.10 Disinfection Treatment Technologies 126
6.10.1 Chlorination 126
6.10.2 Gaseous Chlorine 127
6.10.3 Liquid Chlorine (Bulk) 128
6.10.4 Liquid Chlorine (Onsite) 129
6.10.5 Chloramines 130
6.10.6 Ultraviolet Disinfection 132
6.10.7 Ozone 136
6.10.8 Dechlorination 138
6.10.9 Summary of Disinfection Technologies 138
6.11 Odor Control Treatment Technologies 141
6.11.1 Chemical Addition 142
6.11.2 Wet Chemical Scrubber 144
6.11.3 Biofilters 146
6.11.4 Carbon Adsorption 149
6.11.5 Ion Addition 151

7.0 BIOSOLIDS TREATMENT TECHNOLOGY AND MANAGEMENT EVALUATION 158
7.1 Level of Biosolids Management 158
7.2 Biosolids Thickening Treatment Technologies 159
7.2.1 Gravity Thickeners 159
7.2.2 Dissolved Air Flotation Thickeners 160
7.2.3 Gravity Belt Thickeners 161
7.2.4 Rotary Drum Thickener 162
7.2.5 Centrifuge Thickener 163
7.2.6 Summary of Thickening Technologies 164
7.3 Biosolids Dewatering Treatment Technologies 167
7.3.1 Solar/Air Drying Beds 167
7.3.2 Centrifuge 169
7.3.3 Belt Filter Press 170
7.3.4 Summary of Dewatering Technologies 171
7.4 Biosolids Stabilization Treatment and Advanced Biosolids Management Technologies 174
7.4.1 Conventional Aerobic Digestion 174
7.4.2 Autothermal Thermophilic Aerobic Digestion (ATAD) 176
7.4.3 Second Generation ATAD 177
7.4.4 Conventional Anaerobic Digestion 178

7.4.5 Temperature-Phased Anaerobic Digestion 180
7.4.6 Multi-Phase (Acid / Gas) Anaerobic Digestion 181
7.4.7 Multi-Stage Thermophilic Anaerobic Digestion 184
7.4.8 Cannibal® Process 185
7.4.9 Air Drying 186
7.4.10 Composting 187
7.4.11 Thermal Drying 189
7.4.12 Solar Drying 191
7.4.13 Incineration 193
7.4.14 Summary of Biosolids Stabilization Technologies 195
7.5 Biosolids Disposal Alternatives 198

8.0 EVALUATIONS OF WASTEWATER TREATMENT TECHNOLOGIES USING SURPRISETREE™ WASTEWATER MODEL 198
8.1 Description of SurpriseTree™ Wastewater Model 200
8.1.1 Introduction, Instruction Sheets and Tool Bars 200
8.1.2 Step 1 – General 201
8.1.3 Step 2 – Wastewater Qualities 201
8.1.4 Step 3 – Land and Odor 204
8.1.5 Step 4 – Decision Making 206
8.1.6 Detailed Process Ranking Sheets 211
8.1.7 Train Generator 213
8.1.8 Costs 215
8.1.9 Additional Considerations 218
8.2 Most Favorable Wastewater Treatment Technologies 218
8.3 Implementation Packages 219

9.0 SUMMARY AND CONCLUSIONS 281

LIST OF APPENDICES

APPENDIX A WORKSHOP TA3 WASTEWATER TREATMENT TECHNOLOGY EVALUATION
APPENDIX B SURPRISETREE™ WASTEWATER MODEL USER'S GUIDE
APPENDIX C SURPRISETREE™ WASTEWATER MODEL REPORT

LIST OF TABLES

Table ES.1 City of Surprise Reclaimed Water Quality Constituents of Concern ES-6
Table ES.2 Treatment Technology Alternatives ES-8
Table WWT.1 Wastewater Projections 8
Table WWT.2 Recommended Wastewater Flow Design Criteria 9
Table WWT.3 Reclaimed Water Projections 10
Table WWT.4 ADEQ BADCT Effluent Requirements 20
Table WWT.5 ADEQ Reclaimed Water Quality Standards 21
Table WWT.6 Six Alternatives for Meeting EQ and Class A Pathogen Requirements 29
Table WWT.7 Processes to Further Reduce Pathogens (PFRPs) 30
Table WWT.8 Site Restrictions for Class B Biosolids Land Application 31

Table WWT.9 Three Alternatives for Meeting Class B Pathogen Requirements 32
Table WWT.10 Processes to Significantly Reduce Pathogens (PSRPs) 32
Table WWT.11 Options for Meeting Vector Attraction Reduction 33
Table WWT.12 Pollutant Limits for Biosolids 34
Table WWT.13 Biosolids Classifications and Disposal Options Summary 34
Table WWT.14 Summary of Reclaimed Water Quality Standards 39
Table WWT.15 Biosolids Treatment Standards 42
Table WWT.16 Influent Wastewater Quality Design Criteria 43
Table WWT.17 Summary of Similar WRF Maximum Month Design Wastewater Characteristics 44
Table WWT.18 Reclaimed Water Data from SPA 1 45
Table WWT.19 City of Surprise Reclaimed Water Quality Constituents of Concern 48
Table WWT.20 Categories of Treatment for Wastewater and the Identified Constituents of Concern 50
Table WWT.21 Prescreened Treatment Technology Alternatives 52
Table WWT.22 Treatment Process Performance Based Criteria 54
Table WWT.23 Treatment Process Implementation Based Criteria 55
Table WWT.24 Treatment Process Financial Based Criteria 56
Table WWT.25 Preliminary Treatment Unit Operations – Performance Based Criteria 65
Table WWT.26 Preliminary Treatment Unit Operations – Implementation Based Criteria 66
Table WWT.27 Grit Removal Unit Operations – Performance Based Criteria 75
Table WWT.28 Grit Removal Unit Operations – Implementation Based Criteria 76
Table WWT.29 Primary Treatment Unit Operations – Performance Based Criteria 80
Table WWT.30 Primary Treatment Unit Operations – Implementation Based Criteria 81
Table WWT.31 BOD and Nutrient Removal Unit Operations – Performance Based Criteria 101
Table WWT.32 BOD and Nutrient Removal Unit Operations – Implementation Based Criteria 102
Table WWT.33 Clarifier Basin Configuration Summary 106
Table WWT.34 Clarification Unit Operations – Performance Based Criteria 110
Table WWT.35 Clarification Unit Operations – Implementation Based Criteria 111
Table WWT.36 Filtration Unit Operations – Performance Based Criteria 124
Table WWT.37 Filtration Unit Operations – Implementation Based Criteria 125
Table WWT.38 Disinfection Unit Operations – Performance Based Criteria 139
Table WWT.39 Disinfection Unit Operations – Implementation Based Criteria 140
Table WWT.40 Odor Producing Water Reclamation Facility Treatment Processes 141
Table WWT.41 Odor Control Processes Removal Efficiencies 154
Table WWT.42 Odor Producing Process Areas Recommendations 155
Table WWT.43 Odor Control Unit Operations – Performance Based Criteria 156
Table WWT.44 Odor Control Unit Operations – Implementation Based Criteria 157
Table WWT.45 Biosolids Thickening Unit Operations – Performance Based Criteria 165
Table WWT.46 Biosolids Thickening Unit Operations – Implementation Based Criteria 166
Table WWT.47 Biosolids Dewatering Unit Operations – Performance Based Criteria 172
Table WWT.48 Biosolids Dewatering Unit Operations – Implementation Based Criteria 173

Table WWT.49 Typical Design Parameters for Conventional and Multi-Phase Digestion....183
Table WWT.50 Biosolids Stabilization Unit Operations – Performance Based Criteria....196
Table WWT.51 Biosolids Stabilization Unit Operations – Implementation Based Criteria....197
Table WWT.52 Treatment Process Implementation Based Weighting Criteria as Assigned by City of Surprise and Developer Representatives....209

LIST OF FIGURES

Figure ES.1 Wastewater Technology Assessment Logic Flow Diagram....ES-4
Figure WWT.1 Study Area....4
Figure WWT.2 Existing Wastewater Collection System Infrastructure....5
Figure WWT.3 Near Term (2009-2020) Wastewater Infrastructure Improvements....6
Figure WWT.4 Long Term (2020 - Buildout) Wastewater Infrastructure Improvements....7
Figure WWT.5 Existing Reclaimed Water and Recharge Infrastructure....11
Figure WWT.6 Near Term Reclaimed Water Transmission Main Improvements....13
Figure WWT.7 Long Term Reclaimed Water Transmission Main Improvements....14
Figure WWT.8 Wastewater Technology Assessment Logic Flow Diagram....16
Figure WWT.9 SurpriseTree™ Wastewater Model Step 1 – General....202
Figure WWT.10 SurpriseTree™ Wastewater Model Step 2 – Wastewater Qualities....203
Figure WWT.11 SurpriseTree™ Wastewater Model Step 3 – Land and Odor....205
Figure WWT.12 SurpriseTree™ Wastewater Model All Options Treatment Process Ranking Table....207
Figure WWT.13 SurpriseTree™ Wastewater Model Step 4 – Decision Making....212
Figure WWT.14 SurpriseTree™ Wastewater Model Screening and Grit Removal Detailed Process Ranking....214
Figure WWT.15 SurpriseTree™ Wastewater Model Train Generator....216
Figure WWT.16 SurpriseTree™ Wastewater Model Costs....217

LIST OF ABBREVIATIONS

µg/L	microgram per liter
AAC	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
AL	alert limit
AOP	advanced oxidation process
APP	Aquifer Protection Permit
AQL	aquifer quality limit
ASR	aquifer storage and recovery
ATAD	autothermal thermophilic aerobic digestion
AWQS	Aquifer Water Quality Standards
AZPDES	Arizona Pollution Discharge Elimination System
BADCT	best available demonstrated technology
BOD	basis of design
BOD	biological oxygen demand
CDHS	California Department of Health Services
CFR	Code of Federal Regulations
cfu/mL	colony forming units per milliliter
CH_4	methane
CO_2	carbon dioxide
COC	constituent of concern
COD	chemical oxygen demand
DAF	dissolved air flotation
DAFT	dissolved air flotation thickening
DBP	disinfection byproduct
DL	discharge limit
EDCs	endocrine disrupting compounds
EQ	exceptional quality
GAC	granular activated carbon
GBT	gravity belt thickener
gpd	gallons per day
gpm/ft^2	gallons per minute per square foot
H_2S	hydrogen sulfide
HAAs	haloacetic acid
HRT	hydraulic retention time
IFAS	integrated fixed film activated sludge
IWMP	integrated water master plan
LP/HO	low pressure / high output
LP/LO	low pressure / low output
MCESD	Maricopa County Environmental Services Department
MF/UF	microfiltration/ultrafiltration
mg/L	milligrams per liter
mgd	million gallons per day
MLE	Modified Ludzack Ettinger
mm	millimeter
MP/HO	medium pressure / high output
MBBR	moving bed bioreactor
MBR	membrane bioreactor
NDMA	N-nitrosodimethylamine
NH_3	ammonia

NPDES	National Pollution Discharge Elimination System
NWRI	National Water Research Institute
O&M	operation and maintenance
ORP	oxidation reduction potential
PFD	process flow diagram
PFRP	process to further reduce pathogens
PPCP	pharmaceuticals and personal care products
PSRP	process to significantly reduce pathogens
ppm	parts per million
RAS	return activated sludge
RDT	rotary drum thickener
RO	reverse osmosis
SAR	sodium adsorption ratio
SBR	sequencing batch reactor
SCADA	supervisory control and data acquisition
SDWA	Safe Drinking Water Act
SFF	submerged fixed film
SPA	special planning area
SRT	solids retention time
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TSS	total dissolved solids
TTHMs	total trihalomethanes
UF	ultrafiltration
UIC	underground injection control
USEPA	United Stated Environmental Protection Agency
USGS	United Stated Geological Survey
VOC	volatile organic compounds
VS	volatile solids
VSS	volatile suspended solids
WAS	waste activated sludge
WET	whole effluent toxicity
WRF	water reclamation facility
WWTP	wastewater treatment plant

INTRODUCTION

Like many communities in the Phoenix metropolitan area, the City of Surprise (City) experienced unprecedented growth over the last decade. While growth has slowed with the recent downturn in the economy, it is only a matter of time before growth returns and development expands into new areas of the City. In order to accommodate this future growth, the City wanted to take a proactive approach to developing a variety of new water and wastewater infrastructure including water production, storage and distribution facilities, and wastewater collection, treatment, and effluent disposal/recharge facilities.

The goals of this Wastewater Treatment Technology Assessment included the following. In combination with the Wastewater Design Standards and Guidelines (Carollo 2010):

- Provide the foundation for uniformity in approach to future City of Surprise wastewater treatment facilities and infrastructure.
- Provide a mechanism to obtain consensus from all sectors and levels of City management on City wastewater treatment and infrastructure policy.
- Provide technically feasible, cost effective, and reliable approaches to meet the regulatory requirements for wastewater treatment facilities and infrastructure.
- Establish a position that enhances the City's control over the planning and implementation process for its future wastewater treatment facilities and infrastructure.

The scope of work for the Wastewater Technology Assessment included a review of the City's current wastewater quality data, a review of associated regulatory requirements, an evaluation of appropriate treatment technologies for the City's wastewater, and development of tools and implementation packages to assist the City when developing its future wastewater treatment facilities and infrastructure. The project objectives were achieved through completing the following specific tasks:

- Reviewing the current, proposed, and future wastewater and reclaimed water quality regulations and requirements.
- Collecting and reviewing the City's current wastewater quality data for its existing water reclamation facilities.
- Establishing and achieving consensus with developer's representatives regarding the City's reclaimed water quality and biosolids treatment standards.
- Establishing and achieving consensus with the developer's representatives regarding criteria that will be used to identify and evaluate viable treatment technologies.

- Reviewing, screening, and evaluating selected treatment technologies based on their benefits and challenges, capital, and operational and maintenance (O&M) costs.
- Providing the City and the developer's representatives with multiple cost-effective and technically feasible treatment technology alternatives that can achieve the City's reclaimed water quality and biosolids standards.

The City of Surprise Integrated Water Master Plan (IWMP) - Water Infrastructure (2009, Final), and IWMP - Water Resources (2008, Final) define the City's current and future wastewater system boundaries. These documents provide a master planning interface and platform for the Wastewater Technology Assessment Report. Recommendations from the IWMP were incorporated directly and used to establish criteria for the Wastewater Technology Assessment. Data contained in the IWMP was validated to confirm that the parameters used in the Wastewater Technology Assessment were accurate and consistent with the established goals of the City. Based on information presented in the IWMP, the following project constraints have been adopted as part of the Wastewater Technology Assessment Report:

- The focus period for the Wastewater Technology Assessment is approximately the next five to ten years. It is anticipated that this document will be reviewed and updated every five to ten years (in conjunction with the IWMP) to address changing growth patterns, regulations, treatment technologies, capital and O&M costs, etc.
- The IWMP will be updated every five years to reflect changes in wastewater parameters (both quantity and quality) and wastewater reclamation facilities and infrastructure. Changes to the IWMP may affect the validity of the Wastewater Technology Assessment results. Therefore, as noted above, it is recommended that the Wastewater Technology Assessment Report be reviewed and updated following each IWMP update. This approach will allow the City to improve the accuracy of planning and budgeting associated with wastewater reclamation facilities and infrastructure.
- The assessment is completed under the assumption that there will be one water reclamation facility (WRF) per SPA, for a total of six WRFs. Each facility will be treated as an "End-of-Line" plant with a dedicated biosolids handling facility. The decision regarding whether to build a joint solids handling facility can be deferred to future updates of the IWMP and Technology Assessment Report.
- The IWMP identified WRFs of varying capacities are necessary to meet the City's future needs. The Wastewater Technology Assessment identifies the technologies that are appropriate for the various treatment capacities.
- The City is currently developing a list of preferred equipment manufacturers. This information will be included in the appendices of this report when available.

PROJECT METHODOLOGY OVERVIEW

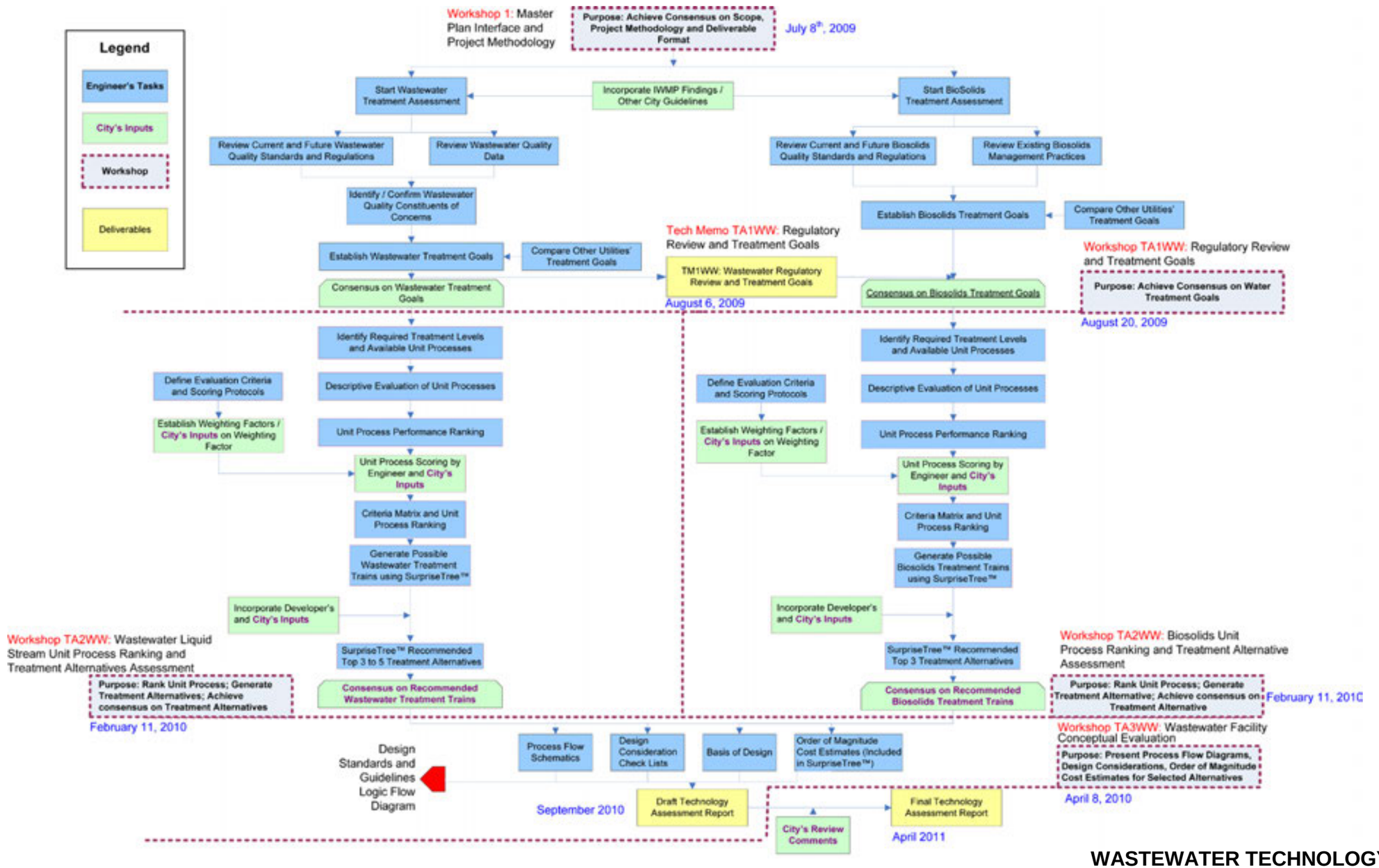
The methodology proposed to meet the City's current and near term wastewater treatment and infrastructure needs is systemic, as illustrated in the logic flow diagram outlined in Figure ES.1. The Wastewater Technology Assessment logic flow diagram was developed by the project team to include the proposed tasks and the strategy for completing the Wastewater Technology Assessment.

The logic flow diagram includes an overview of the primary tasks associated with the Wastewater Technology Assessment. In short, the Wastewater Technology Assessment began with a wastewater and biosolids regulatory review and establishment of the City's treatment standards (presented in Section 3.0 of the Wastewater Technology Assessment). These activities were performed in parallel with a review of available wastewater quality data associated with the City's wastewater (see Section 5.0 of the Wastewater Technology Assessment). Through comparing the water quality data and the treatment standards, water quality Constituents of Concern (CoCs) and levels of treatment required to address these CoCs were identified (see Section 4.0 of the Wastewater Technology Assessment).

Section 6.0 of the Wastewater Technology Assessment presents the prescreened treatment technology alternatives, which were evaluated for each level of treatment. This evaluation addressed questions for each technology including what it is, what it does, how it works, and what are the associated pros and cons. The technology alternatives were then compared in tabular format and ranked using evaluation matrixes. The evaluation matrixes utilized a set of evaluation criteria developed by the City staff and developer representatives. Nine individuals (City and developer) participated in assigning weighting factors for these criteria. The averaged weighting factors were used for the final ranking evaluation.

A conventional technology assessment approach, which results in a single fixed set of recommended technologies, cannot fit the exact needs of the all of the City's future WRFs. To provide the City with a useful tool in selecting the optimum treatment technology for future WRFs that can assess available treatment alternatives for a given set of water quality inputs and site-specific conditions (such as CoCs, facility size, etc.), the team developed an innovative approach. The core of this approach is an advanced macro-based Excel model called the SurpriseTree™ Wastewater Model. Refer to Section 8.0 of the Wastewater Technology Assessment for detailed descriptions regarding how the model works and how/when it should be used.

Using SurpriseTree™ Wastewater, the results of the technology alternative assessment represent a dynamic and customized solution, which automatically responds to the desired reclaimed water and biosolids quality and site-specific condition inputs for future facilities. Through incorporating the City's institutional and technical knowledge, the model was "calibrated" and improved to better represent potential future conditions.



WASTEWATER TECHNOLOGY ASSESSMENT LOGIC FLOW DIAGRAM

FIGURE ES.1

CITY OF SURPRISE
WASTEWATER TECHNOLOGY ASSESSMENT REPORT EXECUTIVE SUMMARY

The Wastewater Technology Assessment Report is designed to provide the City and the developer with useful planning level design information for the most common and effective treatment alternatives for implementation at the City's future water reclamation facilities. The treatment alternatives presented are viable options for the City's facilities, based on their technical feasibility and cost effectiveness. Process flow diagrams, basis of design, and design considerations were developed for each of the selected treatment alternatives and are included as part of this report.

RECLAIMED WATER AND BIOSOLIDS TREATMENT STANDARDS

To produce reclaimed water for beneficial reuse, the City of Surprise has set uniform reclaimed water quality standards for all City water reclamation facilities within the City limits. All future water reclamation facilities shall be designed to achieve these water quality requirements. The Wastewater Technology Assessment Report establishes standards and provides policy justifications and regulatory basis for each.

As part of the Wastewater Technology Assessment, the reclaimed water quality standards were established to meet the requirements of the governing reclaimed water application. The following reclaimed water quality standards were established for the City of Surprise based on regulatory requirements:

- Alert levels defined in the APP
- BADCT requirements
- Arizona Class A+ Reclaimed Water Quality Standards
- The City's wastewater treatment facilities shall be designed to meet, at a minimum, these standards.

Relative to biosolids treatment, the City is currently sending all biosolids to a landfill for disposal. In the short term, the City would like to produce biosolids with a minimum classification of Class B that can be either landfilled or land-applied. Although it is not anticipated that Class A biosolids will become mandatory in the near future, the City's long-term plan includes treating solids onsite through thickening, advanced digestion and dewatering processes to produce Class A biosolids that can be land-applied. These advanced biosolids stabilization technologies can provide further pathogen and volume reductions and cost savings, which may be desirable regardless of the biosolids classification.

WASTEWATER QUALITY REVIEW

Historical wastewater quality data from the City's South Plant (SPA 1 WRF) and historical wastewater quality data from other Utilities within the State of Arizona were reviewed as part of the Wastewater Technology Assessment. In general, the Surprise data is consistent with other valley cities. It is expected that the future WRFs within the City will receive

wastewater with similar water quality, with potential industrial impacts and water conservation impacts in some planning areas.

Based on a review of existing water quality data, a list of critical CoCs was identified including TSS, BOD, TKN, turbidity, and fecal coliform (See Section 5.0 in the Wastewater Technology Assessment Report). The City's water reclamation facilities shall be designed to sufficiently remove these contaminants to achieve the established reclaimed water treatment standards. Table ES.1 summarizes these CoCs and their associated treatment standards. The Wastewater Technology Assessment will focus on the treatment processes required to address these critical CoCs.

Table ES.1 City of Surprise Reclaimed Water Quality Constituents of Concern Wastewater Technology Assessment Report Executive Summary City of Surprise

Parameter	BADCT Effluent Limits	Class A+ Effluent Limits	APP SPA 1 WRF(1)	City of Surprise Reclaimed Water Quality Standards
Critical Constituents of Concerns				
BOD_5 (mg/L)	< 30	--	--	< 30
TSS (mg/L)	< 30	--	--	<30
Total Nitrogen (mg/L as N) (4)	< 10	< 10	8(2)	< 8
Turbidity (NTU)				
Daily (24--hour) average	--	2	2(3)	< 2
Single sample maximum	--	5	5(3)	< 5
Fecal Coliform (cfu/100 mL)				
Single sample maximum	23	23	23(3)	23
Seven sample median	2.2	--		2.2
Four out of last seven daily samples	--	Non-detect	Non-detect(3)	Non-detect
THM (mg/L)			0.08	0.08

Notes:
(1) State of Arizona Aquifer Protection Permit No. P-102478, July 2009. Sampling and reporting frequency is Daily, Weekly, Monthly or Quarterly, as outlined in the APP.
(2) Discharge Monitoring Alert Level.
(3) Reclaimed Water Monitoring Discharge Limit.
(4) Based on a five-sample rolling geometric mean.

Table ES.1 also includes other CoCs that may limit the reuse / recharge potential of the reclaimed water. These parameters include disinfection byproducts, such as TTHMs. Currently, there are no numerical standards for TTHMs or HAAs in the BADCT or Class A+ reuse rules. However, a standard for TTHMs is established in the City's current APP for the SPA 1 WRF. Treatment standards for these parameters were established for the City based on meeting the APP discharge limits. The Wastewater Technology Assessment Report evaluates technologies that can assist in achieving these standards.

Other contaminants such as salinity, sodium, and chloride may become a concern for the City's reclaimed water reuse potential in the future. These parameters are not anticipated to be an issue in the near term. However, as the City grows, the impacts of these parameters may become more severe. For example, sodium may limit the reuse potential for irrigation purposes. Consequently, it is recommended that the City develop and maintain a reclaimed water sampling program to routinely monitor these parameters.

The current list of critical, potential, and other CoCs should be revisited when updating the IWMP and the Wastewater Technology Assessment Report in the future.

TREATMENT PROCESS EVALUATION

For a given WRF, several categories, including preliminary treatment, grit removal, primary treatment, BOD and nitrification-denitrification treatment, clarification, filtration and disinfection, may be required to treat the identified critical, other and potential CoCs in the City's wastewater and achieve the established reclaimed water standards. Biosolids handling and odor control may also be required.

In order to determine the most applicable and beneficial wastewater treatment technologies for the City of Surprise, four principals were used to prescreen each of the treatment technology alternatives:

1. Technology alternatives must be capable of achieving the established treatment standards for the City.
2. Technology alternatives must be established, proven technologies that can be reliably implemented at full-scale without significant additional testing.
3. In general, technology alternatives were evaluated based on the contaminant removal mechanism. Individual manufacturers/equipment/commercial names were referenced, but generally not evaluated individually.
4. Technology alternatives that have specific local experience/application or which the City has indicated specific interest in were generally included in the evaluation.

Based on the detailed evaluation in Sections 6.4 through 6.11 in the Wastewater Technology Assessment Report and input from the City and developer representatives, the original alternatives were further narrowed to a list of recommended alternatives for potential implementation. These recommended treatment technology alternatives were further evaluated using the SurpriseTree™ Wastewater Model (See Section 8.0 in the Water Technology Assessment Report) by comparing the treatment processes using a three-tier evaluation consisting of performance based evaluation criteria, implementation based evaluation criteria, and financial evaluation criteria.

The performance based evaluation utilizes a set of criteria established to identify the effectiveness of a treatment process in removing target CoCs. The implementation based evaluation focuses on the ability to effectively implement each treatment technology. The City and the developer representatives participated in the development of these criteria. Compared to the performance-based criteria, the implementation based criteria are more comprehensive, covering technical, environmental, economic, and social aspects. The financial based evaluation focuses on the financial impacts of each treatment technology. Treatment technologies are compared to each other based on a "dollar per gallon of water treated" basis.

A list of the treatment technology alternatives evaluated as part of the Wastewater Technology Assessment Report, along with the recommended treatment technology alternatives further evaluated using the SurpriseTree™ Wastewater Model, are included in Table ES.2.

Table ES.2 Treatment Technology Alternatives
Wastewater Technology Assessment Report Executive Summary
City of Surprise

Treatment Categories	Prescreened Treatment Technology Alternatives	Evaluated in Wastewater Technology Assessment Report	Evaluated in the SurpriseTree™ Wastewater Model
Preliminary Treatment	Coarse screens	X	X
	Rotary Drum Screen	X	X
	Step Screen	X	X
	Fine screens	X	X
	Ultrafine screens	X	-
Grit Removal	Aerated grit chamber	X	X
	Free vortex grit chamber	X	X
	Mechanical vortex grit chamber	X	X
	Horizontal flow chamber	X	-
BOD Removal and N-DeN Process	Sequencing Batch Reactor (SBR)	X	X
	Trickling Filters	X	X
	Conventional Activated Sludge	X	X
	MLE Activated Sludge	X	X
	Extended Aeration Activated Sludge	X	X
	Integrated Fixed Film Activated Sludge (IFAS)	X	X
	Membrane Bioreactor (MBR)	X	X

Table ES.2	Treatment Technology Alternatives Wastewater Technology Assessment Report Executive Summary City of Surprise		
Treatment Categories	**Prescreened Treatment Technology Alternatives**	**Evaluated in Wastewater Technology Assessment Report**	**Evaluated in the SurpriseTree™ Wastewater Model**
Secondary Clarification	Conventional Clarifier	X	X
	Dissolved Air Flotation	X	X
	Ballasted Flocculation	X	X
Filtration	Conventional Down Flow Granular Media Filters	X	X
	Upflow Continuous Backwashing Filters	X	X
	Traveling Bridge Filters	X	X
	Cloth Media Filters	X	X
	Microfiltration / Ultrafiltration (MF/UF)	X	X
Disinfection	Gaseous Chlorine Disinfection	X	X
	Sodium Hypochlorite Onsite Generation Disinfection	X	X
	Sodium Hypochlorite Bulk Disinfection	X	X
	Chloramines Disinfection	X	--
	Ultraviolet Disinfection	X	X
	Ozonation Disinfection	X	X
Odor Control	Chemical (e.g., ferric chloride, ferrous chloride) addition	X	X
	Wet Chemical Scrubber	X	X
	BioFilter	X	X
	BioTower	X	X
	Carbon Absorption	X	X
	Odor Removal Through Ion Addition	X	X
Biosolids – Thickening	Dissolved Air Flotation Thickening	X	X
	Gravity Thickening	X	X
	Gravity Belt Thickening	X	X
	Rotary Drum Thickening	X	X
	Centrifuge Thickening	X	X

Table ES.2	Treatment Technology Alternatives Wastewater Technology Assessment Report Executive Summary City of Surprise		
Treatment Categories	**Prescreened Treatment Technology Alternatives**	**Evaluated in Wastewater Technology Assessment Report**	**Evaluated in the SurpriseTree™ Wastewater Model**
Biosolids - Stabilization	Aerobic Digestion	X	X
	Autothermal Thermophilic Aerobic Digestion (ATAD)	X	--
	Second Generation ATAD	X	X
	Conventional Anaerobic Digestion	X	X
	Temperature Phased Anaerobic Digestion	X	X
	Multi-Phase (acid / gas) Anaerobic Digestion	X	X
	Multistage Thermophilic	X	--
	Cannibal® Process	X	--
	Air Drying	X	X
	Heat Drying	X	X
	Composting	X	X
	Incineration	X	X
	Lagoon	--	X
Biosolids - Dewatering	Drying Beds	X	X
	Belt Filter Press	X	X
	Centrifuges	X	X

EVALUATION OF WASTEWATER TREATMENT TECHNOLOGIES USING THE SURPRISETREE™ WASTEWATER MODEL

The Wastewater Technology Assessment Report is designed to serve as a water quality and technology master planning document that governs future efforts such as site-specific planning, technology selection/feasibility studies, preliminary design, and detailed design. At this master planning level, the main objectives of the effort were identifying current and future key reclaimed water and biosolids quality concerns, establishing reclaimed water and biosolids quality treatment standards, identifying multiple technology options that could be used to collectively meet the City's reclaimed water and biosolids treatment standards, and providing high-level implementation guidelines associated with the applicable technologies.

As discussed throughout the Wastewater Technology Assessment Report, the optimum wastewater and biosolids treatment technology for a new WRF could depend on a variety of factors including the specific wastewater quality, the reclaimed water quality goals, and the site-specific inputs. There is likely no single technology that can fit the exact needs of the all of the City's future water reclamation facilities. In order to provide a useful tool for the City in selecting the optimum treatment technology for future water reclamation facilities, a more holistic and flexible approach was needed.

To provide the City with a useful tool that could assess available treatment alternatives for a given set of wastewater quality inputs and site-specific conditions, the team employed an innovative, advanced macro-based excel model named SurpriseTree™ Wastewater. Using SurpriseTree™ Wastewater, the results of the technology alternative assessment are not limited to a single fixed set of recommendations. Instead, the model provides a dynamic and customized solution, which automatically generates the most technically feasible and cost effective treatment options in response to the wastewater quality and site-specific condition inputs.

The SurpriseTree™ Wastewater Model computerizes the documentation of the evaluation methodology in a logical way. Criteria established by the City staff and developer representatives (referred to as implementation-based criteria) are utilized in the SurpriseTree™ Wastewater Model, supplemented by performance-based evaluation and capital, O&M and lifecycle cost analysis developed by engineers. Weighting factors for the implementation-based criteria were developed by averaging the City staff and developer representatives' inputs. All weighting factors, ranking scores, and unit costs are fully adjustable by the City, providing significant flexibility to adjust to changing future conditions. The model employs a user-friendly spreadsheet structure, powered by macro-based selector buttons to make the site-specific analysis prompt and easy.

In general, this planning document was created to assist in establishing a mechanism and an evaluation methodology for the City to perform site-specific evaluations when actual wastewater quality and other site information are more clearly defined for a given facility. It provides a baseline for technology selection and outlines the general required design criteria and considerations for a specific application in an effort to give the City confidence in their ultimate treatment technology selection. However, it leaves detailed design decisions, facility layouts, and other site-specific decisions to the design engineer to promote more informed and effective decision making.

RECOMMENDED TREATMENT TECHNOLOGIES

The Wastewater Technology Assessment Report is designed to provide the City and the developer with useful planning level design information for the most likely treatment alternatives to be implemented at the City's future WRFs. These treatment alternatives are viable options for the City's facilities, considering their technical feasibility and cost effectiveness. Categories of treatment are identified as individual components. The individual components can be combined to generate the most feasible liquid treatment train. For biosolids treatment, the categories of biosolids thickening, stabilization and dewatering can be used in combination or thickening and dewatering categories can be used as individual processes. For odor control, one odor control technology may be used for an entire treatment facility or a combination of multiple odor control technologies may be used throughout the facility.

The most favorable treatment technologies were reviewed with City personnel. These treatment technologies represent the best unit process components to achieve the City's treatment standards. Based on the review of applicable treatment technologies for the City's wastewater and the SurpriseTree™ Wastewater Model output results for treating the identified City of Surprise CoCs, the top recommended treatment technologies were identified, including:

- Preliminary Treatment: Step/stair screen, rotary screen, fine screens
- Grit Removal: Mechanical vortex, free vortex.
- Primary Treatment: Primary clarifiers.
- Biological Treatment: Extended aeration, MLE activated sludge, MBR.
- Clarification: Secondary clarifiers.
- Filtration: Cloth type disk filter, continuous upflow granular media filter, traveling bridge filter.
- Disinfection: UV, sodium hypochlorite bulk, sodium hypochlorite onsite.
- Biosolids Thickening: Rotary drum thickening, gravity belt thickening, centrifuge thickening.
- Biosolids Stabilization: Conventional anaerobic digestion, conventional aerobic digestion, multi-phase anaerobic digestion.
- Biosolids Dewatering: Centrifuge dewatering, belt filter press.
- Odor Control: Liquid chemical scrubber, BioTower, carbon, electrically charged ion addition.

Process flow diagrams, basis of design and design considerations were developed for each of these selected treatment alternatives as a part of an implementation package for use by the City and developers. Implementation packages can be found in Section 8.0 of the Wastewater Technology Assessment Report.

SUMMARY

As growth continues to occur within the City of Surprise, the Wastewater Technology Assessment Report, in combination with the Water and Wastewater Facility Guidelines (Carollo 2011), will provide the City with a foundation for uniformity in approach to their future water reclamation facilities and infrastructure, assist in obtaining consensus from the City and developers on wastewater treatment and infrastructure policy, provide technically feasible, cost effective, and reliable approaches to meet the regulatory requirements and City standards for wastewater treatment facilities and infrastructure, and enhance the City's control over the planning and implementation process for its future water reclamation facilities and infrastructure.

1.0 INTRODUCTION

1.1 Project Objectives

Like many communities in the Phoenix metropolitan area, the City of Surprise (City) experienced unprecedented growth over the last decade. While growth has slowed with the recent downturn in the economy, it is only a matter of time before growth returns and development expands into new areas of the City. In order to accommodate this future growth, the City needs to take a proactive approach to developing a variety of new water and wastewater infrastructure including water production, storage and distribution facilities, and wastewater collection, treatment, and effluent recharge facilities.

The goals of this Wastewater Treatment Technology Assessment included the following:

- Provide the foundation for uniformity in approach to future City of Surprise wastewater treatment facilities and infrastructure.
- Provide a mechanism to obtain consensus from all sectors and levels of City management on City wastewater treatment and infrastructure policy.
- Provide technically feasible, cost effective, and reliable approaches to meet the regulatory requirements for wastewater treatment facilities and infrastructure.
- Establish a position that enhances the City's control over the planning and implementation process for its future wastewater treatment facilities and infrastructure.

The scope of work for the Wastewater Technology Assessment included a review of the City's current wastewater quality data, a review of associated regulatory requirements, an evaluation of appropriate treatment technologies for the City's wastewater, and development of tools and implementation packages to assist the City when developing its future wastewater treatment facilities and infrastructure. The project objectives were achieved through completing the following specific tasks:

- Reviewing the current, proposed, and future wastewater and reclaimed water quality regulations and requirements.
- Collecting and reviewing the City's current wastewater quality data for its existing water reclamation facilities.
- Establishing and achieving consensus with developer's representatives regarding the City's reclaimed water quality and biosolids treatment standards.
- Establishing and achieving consensus with the developer's representatives regarding criteria that will be used to identify and evaluate viable treatment technologies.
- Reviewing, screening, and evaluating selected treatment technologies based on their benefits and challenges, capital, and operational and maintenance (O&M) costs.

- Providing the City and the developer's representatives with multiple cost-effective and technically feasible treatment technology alternatives that can achieve the City's reclaimed water quality and biosolids standards.

1.2 General References

The following documents were used as reference when developing the Wastewater Technology Assessment Report:

- City of Surprise documents:
  - Wet Process Wastewater Technology Assessment Report (2005, RT Engineers)
  - Integrated Water Master Plan - Water Infrastructure (July 2009, Final Report, Malcolm Pirnie, Inc.)
  - Integrated Water Mater Plan - Water Resources (November 2008, Final Report, Malcolm Pirnie, Inc.)
  - Engineering Development Standards (2009, City of Surprise)
  - Water and Wastewater Facility Guidelines (September 2010, Carollo Engineers)
- Wastewater and Reuse Regulations:
  - National Pollutant Discharge Elimination System (NPDES) Permit
  - Arizona Department of Environmental Quality (ADEQ) Best Available Demonstrated Control Technology (2005)
  - ADEQ Reclaimed Water Quality Standards (2001)
  - Standards for the Use or Disposal of Sewage Sludge (1993)
- Other Reference Projects:
  - City of Surprise SPA 2 Water Reclamation Facility Design Information Memorandums, Design Drawings and Specifications (Carollo Engineers 2009)
  - City of Surprise SPA 2 Conceptual Design Report (Final Draft, Carollo Engineers, 2007)
  - Special Planning Area 3 Water Reclamation Facility Conceptual Design Report (Brown and Caldwell 2007)
  - Ak-Chin Water Reclamation Facility Preliminary Design Report (Draft, Carollo Engineers, 2009)
  - City of Avondale Water Reclamation Facility Phase 1 Final Design Report (DSWA, PCL and Carollo Engineers, 2007)
  - Casa Grande Water Reclamation Facility Phase 3 Expansion Design, Design Information Memoranda, (Carollo Engineers, 2007).
  - Gilbert-Mesa-Queen Creek South Water Reclamation Facility Design, Technical Memoranda (Carollo Engineers, 2002).

- Other References:
  - USEPA “Cleaner Water Through Conservation” Chapter 1, How We Use Water In These United States
  - USEPA “Cleaner Water Through Conservation” Chapter 3, How to Conserve Water and Use It Effectively
  - Wastewater Engineering Treatment and Reuse, Metcalf and Eddy, Fourth Edition, 2003.

2.0 PLANNING INTERFACE AND STUDY AREA DOCUMENTATION

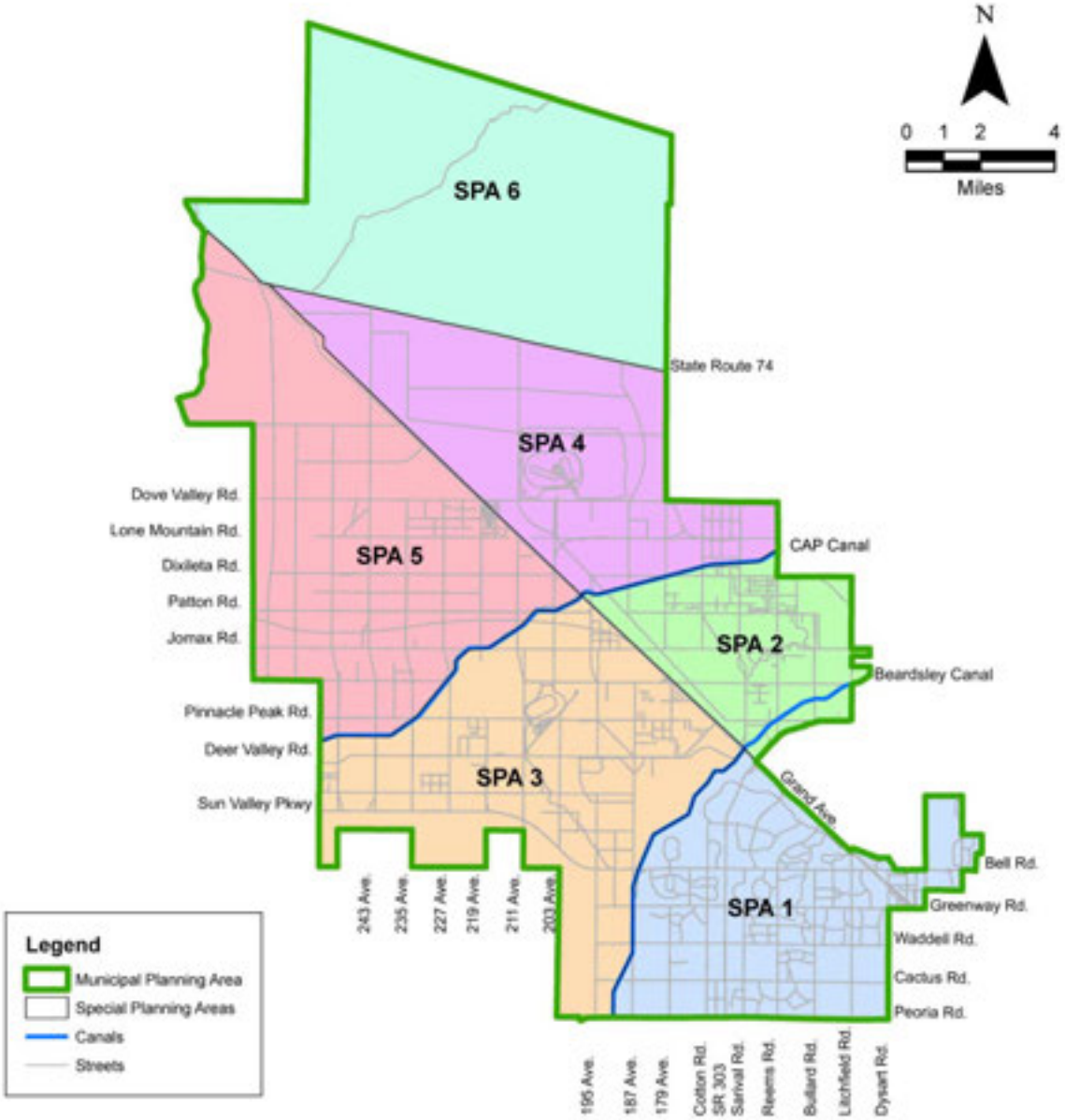
2.1 Integrated Water Master Plan

The City of Surprise Integrated Water Master Plan (IWMP) – Water Infrastructure (2009, Final), and IWMP - Water Resources (2008, Final) define the City’s current and future wastewater system boundaries. These documents provide a master planning interface and platform for the Wastewater Technology Assessment Report. This section summarizes the IWMP conclusions directly and indirectly associated with this project.

2.1.1 Current and Future Water Reclamation Facilities

The City of Surprise’s wastewater service area is divided into six special planning areas (SPAs) as illustrated in Figure WWT.1. Each service area generally uses gravity as the principle means of conveying the wastewater to a water reclamation facility. As illustrated in Figure WWT.2, the City currently has several water reclamation facilities (WRFs) - the regional SPA 1 WRF, regional SPA 2 WRF (not shown in the figure), and a developer phase WRF located in SPA 3 (not shown in the figure). A temporary facility, Desert Oasis WRF, located in SPA 2, has recently been decommissioned.

The SPA 1 WRF utilizes extended aeration (oxidation ditch), tertiary filtration, and onsite generation chlorine disinfection, and is capable of producing a State of Arizona Class A+ effluent and biosolids for beneficial reuse. The SPA 2 WRF consists of the Phase 1 developer’s phase facility and Phase 2 regional treatment facility. Phase 1 utilizes sequencing batch reactor (SBR) technology and Phase 2 utilizes membrane bioreactor (MBR) technology along with UV disinfection. Both SPA 2 facilities produce Arizona Class A+ effluent. The developer’s phase treatment facility in SPA 3 utilizes SBR technology. The design of a new WRF to service SPA 3 has been put on hold until future growth requires additional infrastructure. The proposed near-term wastewater infrastructure improvements are illustrated in Figure WWT.3 and the proposed long-term improvements are illustrated in Figure WWT.4. Additional WRFs associated with SPA 4 and SPA 5 will be necessary as the City continues to grow. No plans for a SPA 6 WRF have been identified to date.

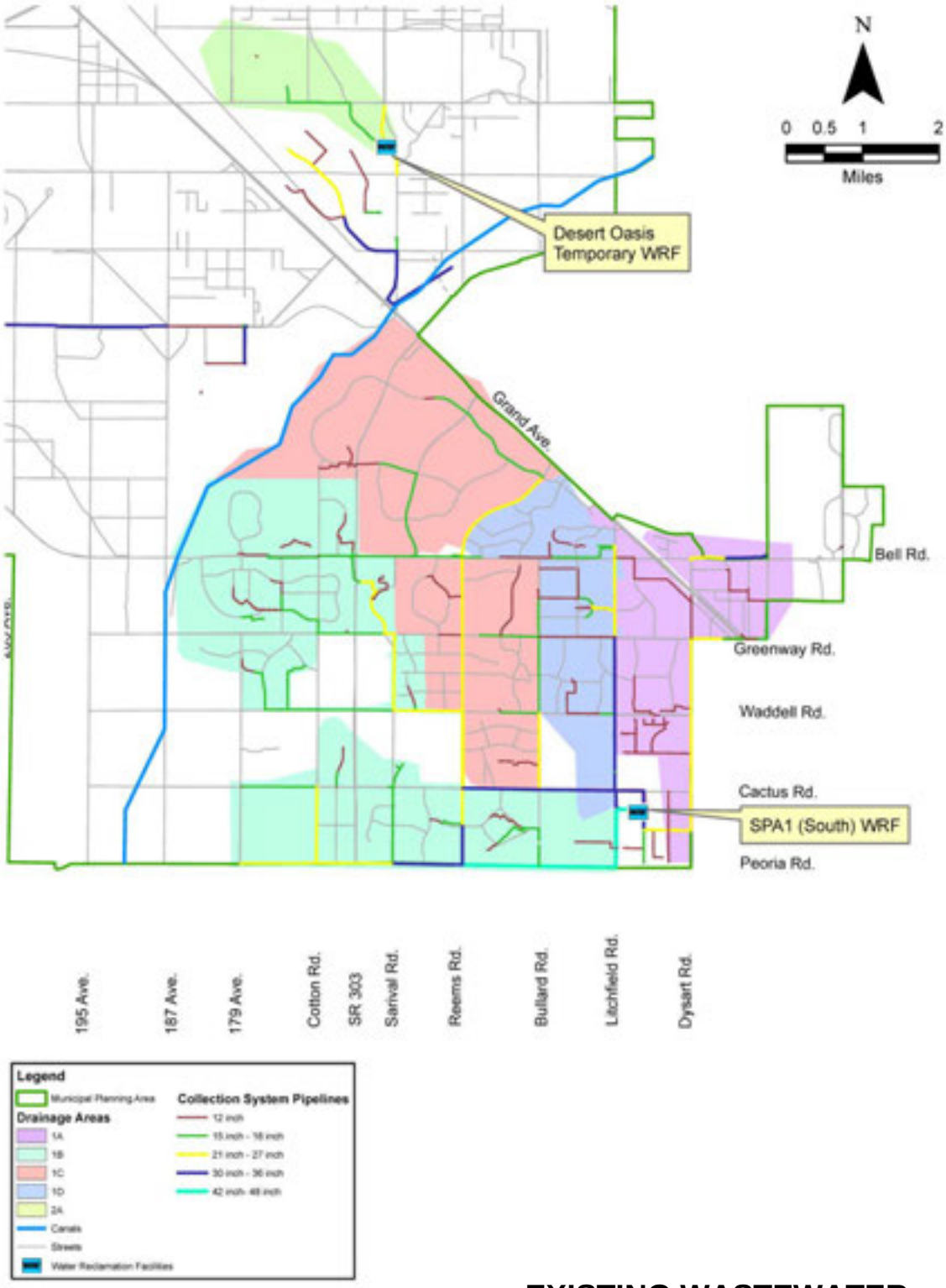


Note: Figure data adapted from Figure 1-1 in the IWMP-Water Infrastructure (Final 2009)

STUDY AREA

FIGURE WWT.1

CITY OF SURPRISE
WASTEWATER TECHNOLOGY ASSESSMENT REPORT



Note: Figure data adapted from Figure 3-4 in the IWMP-Water Infrastructure (Final 2009)

EXISTING WASTEWATER COLLECTION SYSTEM INFRASTRUCTURE

FIGURE WWT.2

CITY OF SURPRISE
WASTEWATER TECHNOLOGY ASSESSMENT REPORT

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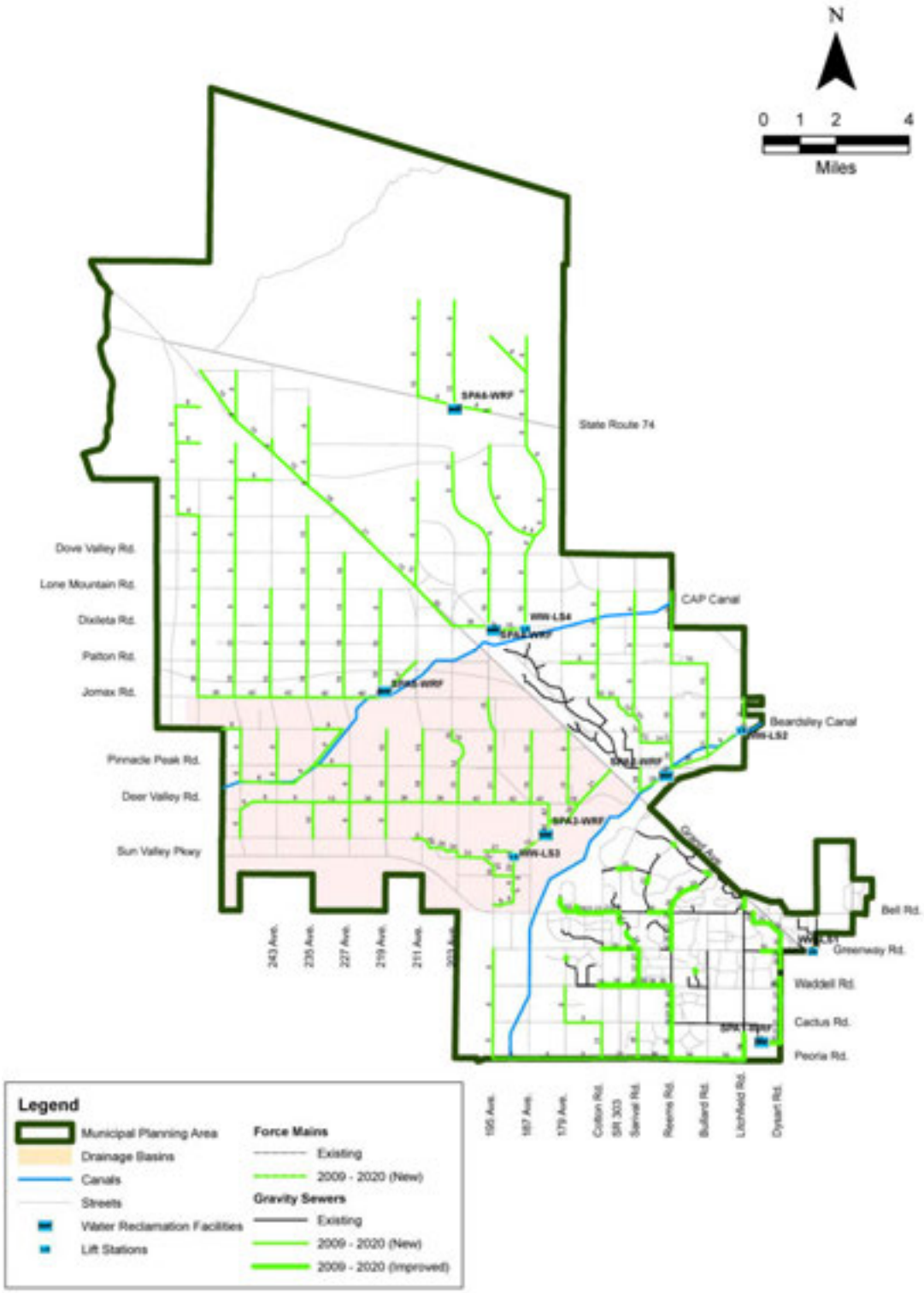
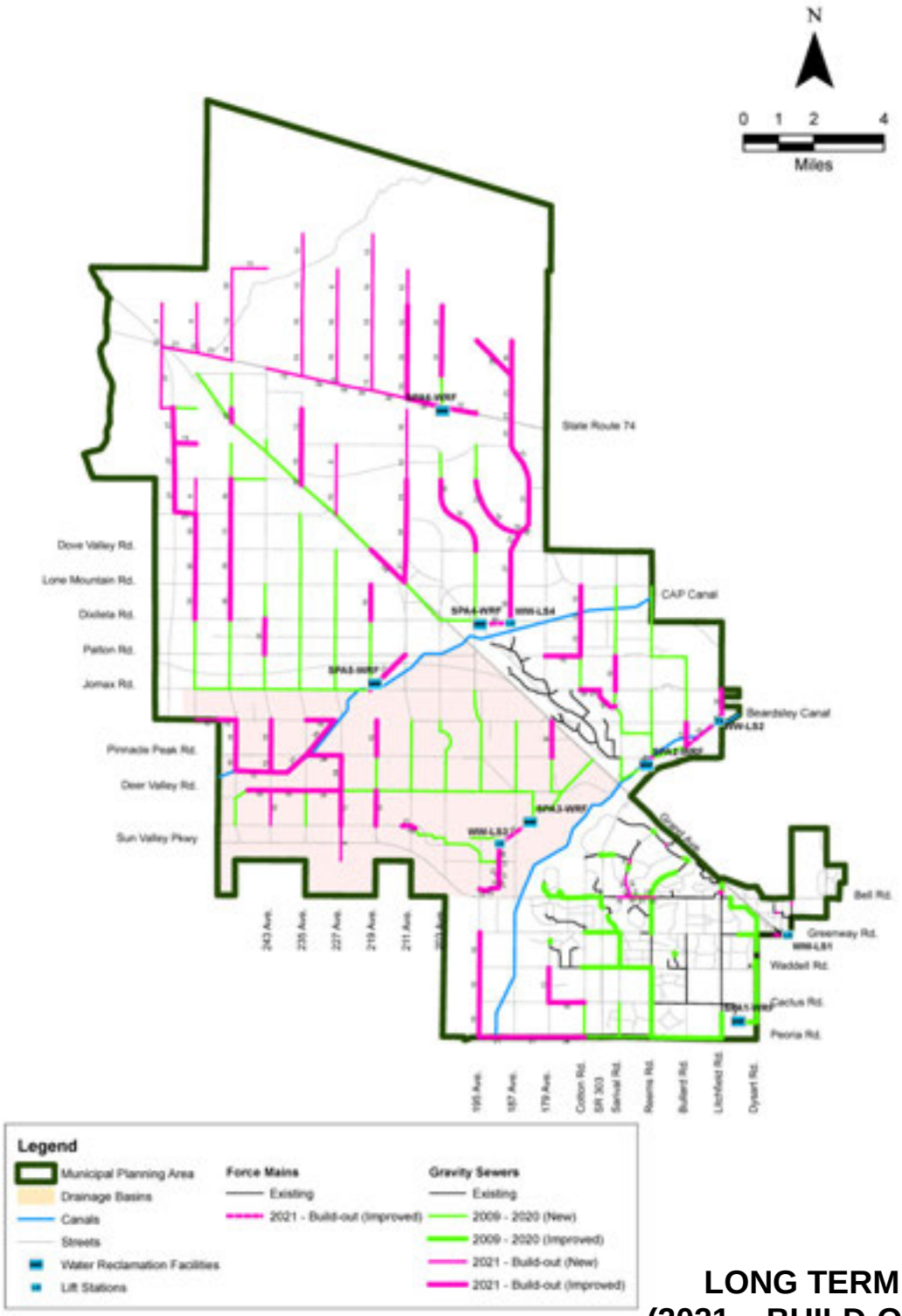


Note: Figure data adapted from Figure 7-6 in the IWMP-Water Infrastructure (Final 2009)

NEAR TERM (2009 – 2020) WASTEWATER INFRASTRUCTURE IMPROVEMENTS

FIGURE WWT.3

CITY OF SURPRISE
WASTEWATER TECHNOLOGY ASSESSMENT REPORT



Note: Figure data adapted from Figure 7-7 in the IWMP-Water Infrastructure (Final 2009)

LONG TERM (2021 – BUILD-OUT) WASTEWATER INFRASTRUCTURE IMPROVEMENTS

FIGURE WWT.4

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WASTEWATER TECHNOLOGY ASSESSMENT REPORT

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The IWMP proposed wastewater flow projections for all SPAs as outlined in Table WWT.1. The SPA 1 WRF currently has a treatment capacity of 16.3 mgd with an ultimate capacity of 24 - 28 mgd. The SPA 2 WRF developer's Phase 1 facility has a capacity of 1.2 mgd and the regional Phase 2 facility has an initial treatment capacity of 2.0 mgd with an ultimate capacity of 4.0 mgd. The developers' phase SPA 3 facility has a capacity of 1.8 mgd.

The ultimate capacity of a water reclamation facility will ultimately impact the Wastewater Technology Assessment evaluation and subsequent results. Specific treatment processes may be more economical or feasible at a smaller scale than at a larger scale - or vice versa. As shown in Table WWT.1, the planned treatment facility capacities range from 5.4 mgd to 22.8 mgd at buildout. This represents a reasonably wide range of capacities, which must be carefully considered when performing the Wastewater Technology Assessment.

Table WWT.1 Wastewater Projections[(1)]
Wastewater Technology Assessment Report
City of Surprise

	Wastewater Flow[(2)]	
SPA	**2020 (mgd)**	**Buildout (mgd)**
1	17.4	22.8
2	2.8	9.1
3	5.6	19.4
4	2.0	14.8
5	3.9	15.7
6	0.07	5.4
Totals	**31.8**	**87.2**

Notes:
(1) Data adapted from Table 7-1 in the IWMP-Water Infrastructure (FINAL 2009).
(2) Based on mid-population scenario described in the Water Resources component of the Integrated Master Plan.

2.1.1.1 Historical Peaking Factors

The wastewater flows presented in Table WWT.1 represent annual average day flows. When designing a wastewater treatment facility, peaking factors must be applied to accommodate the maximum day and peak hour flows. The IWMP established the historical peaking factor based on daily wastewater flow data for 2006 and 2007 from the SPA 1 WRF SCADA system. The historical wastewater flow data were used to calculate a maximum month to annual average peaking factor. In September 2006 and October 2007, the maximum month peaking factors were 1.17 and 1.22, respectively.

The design peaking factors may vary depending on types of land use (industrial versus residential), plant capacity ranges, etc. As an example, Table WWT.2 summarizes the design peaking factors used for the SPA 2 WRF design. These peaking factors were established based on the SPA 1 WRF data for January 2005 to July 2006. Peaking factors

for future WRFs should be determined during the preliminary design of the associated facilities.

Projected peaking factors will be taken into consideration as part of the Wastewater Technology Assessment evaluation. Certain treatment technologies accommodate changes in flow (i.e., peaks) better than other technologies. For example, an extended aeration process in an oxidation ditch configuration with large basin volume can adsorb peak flows better than a small MBR. For the purposes of this Wastewater Technology Assessment, all processes will be evaluated on the same basis, with peaking factors similar to the SPA 2 WRF. If peaking factors for a future facility vary widely from this baseline, additional analyses may be required.

Table WWT.2 Recommended Wastewater Flow Design Criteria Wastewater Technology Assessment Report City of Surprise

Parameter	SPA 2 WRF
ADMM HPF	1.32
Peak Day HPF	2.5

AAD = Annual Average Day
ADMM = Average Day Maximum Month
HPF = Hydraulic Peaking Factor

2.1.2 Wastewater Infrastructure Alternative Evaluation

Based on the close connection between wastewater, reclaimed water, and recharge, the IWMP included a wastewater infrastructure alternative evaluation. The location and number of WRFs affects reclaimed water distribution piping and pumping. Reclaimed water that is not reused must be recharged through some alternative means. Therefore, the alternative evaluation included wastewater collection and treatment infrastructure, reclaimed water infrastructure, and reclaimed water recharge infrastructure. Three wastewater infrastructure alternatives were evaluated, assuming three, four, or six WRFs servicing the six SPAs. The evaluation recommended the “six WRFs” alternative for future wastewater, reclaimed water, and recharge systems. The analysis indicated that there were no appreciable differences in the long-term costs of any of the alternatives evaluated. However, the proposed “six WRFs” alternative provided the following benefits:

- It could be more accommodating to future development by affording more flexibility in phasing the WRFs and infrastructure as development occurs within each WRF service area.
- It reduces the need for larger conveyance and distribution piping.
- It reduces pumping requirements for the reclaimed water.
- It is consistent with the recommendations in the previous master plan that the City has been following and implementing since 2004.
- Allows recharge to occur in the same geographic area as withdrawals are occurring to ensure some level of long-term sustainability of the aquifer.

The wastewater infrastructure evaluation did not consider the differences in treatment costs between a combined facility and several satellite facilities. These cost differences could be significant and could impact the Wastewater Technology Assessment results. For example, should biosolids be treated at a regional facility, or should they be treated individually at each of the six WRFs? A future centralized biosolids treatment facility was discussed during design of the SPA 2 and SPA 3 WRFs. The joint solids handling strategy could lower the City's water reclamation facility complexity, provide the ability to implement other more sustainable treatment technologies, and lower the overall operational costs. This concept should be evaluated in further detail as part of the next IWMP.

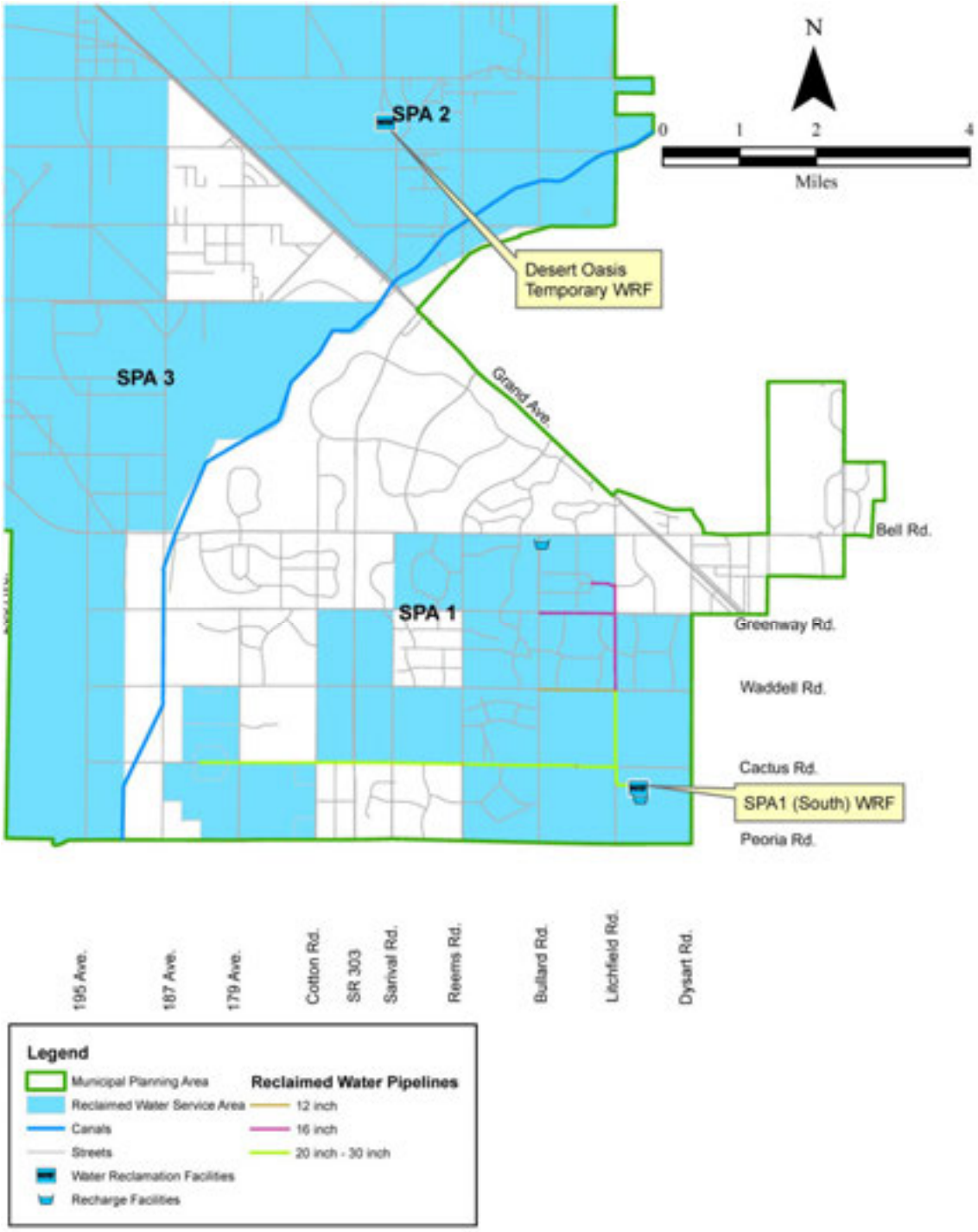
2.1.3 Reclaimed Water Facilities

The IWMP provided a master planning basis for the City's reclaimed water facilities. The existing reclaimed water infrastructure for the City is shown in Figure WWT.5. Currently, all City of Surprise WRFs produce Arizona Class A+ reclaimed water, which is suitable for direct reuse. The SPA 1 WRF distributes its reclaimed water to local farms, homeowner's associations, and commercial landscape areas, and is planning to distribute reclaimed water to the Surprise Center. Reclaimed water at the SPA 1 WRF is disinfected and then stored in two separate reservoirs, one open reservoir prior to direct reuse, and one covered reservoir prior to distribution to the onsite recharge system. Prior to distribution, reclaimed water at the SPA 2 WRF is disinfected and then stored in an open reservoir. The projected reclaimed water available and associated reclaimed water demands are outlined in Table WWT.3.

Table WWT.3 Reclaimed Water Projections(3)
Wastewater Technology Assessment Report
City of Surprise

	Reclaimed Water Available(2)		Reclaimed Water Demand	
SPA	**2020 (mgd)**	**Buildout (mgd)**	**2020 (mgd)**	**Buildout (mgd)**
1	15.6	20.5	2.2	2.2
2	2.5	8.2	0.4	1.6
3	5.1	17.4	0.5	2.4
4	1.8	13.3	0.2	2.5
5	3.5	14.1	0.5	3.5
6	0.006	4.9	0.02	3.1
Totals	**28.6**	**78.4**	**3.8**	**15.3**

Notes:
(1) Based on mid-population scenario described in the Water Resources component of the Integrated Master Plan.
(2) Reclaimed water not used for irrigation will be recharged.
(3) Data adapted from Table 7-1 in the IWMP-Water Infrastructure (FINAL 2009).



Note: Figure data adapted from Figure 3-5 in the IWMP-Water Infrastructure (Final 2009)

EXISTING RECLAIMED WATER AND RECHARGE INFRASTRUCTURE

FIGURE WWT.5

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WASTEWATER TECHNOLOGY ASSESSMENT REPORT

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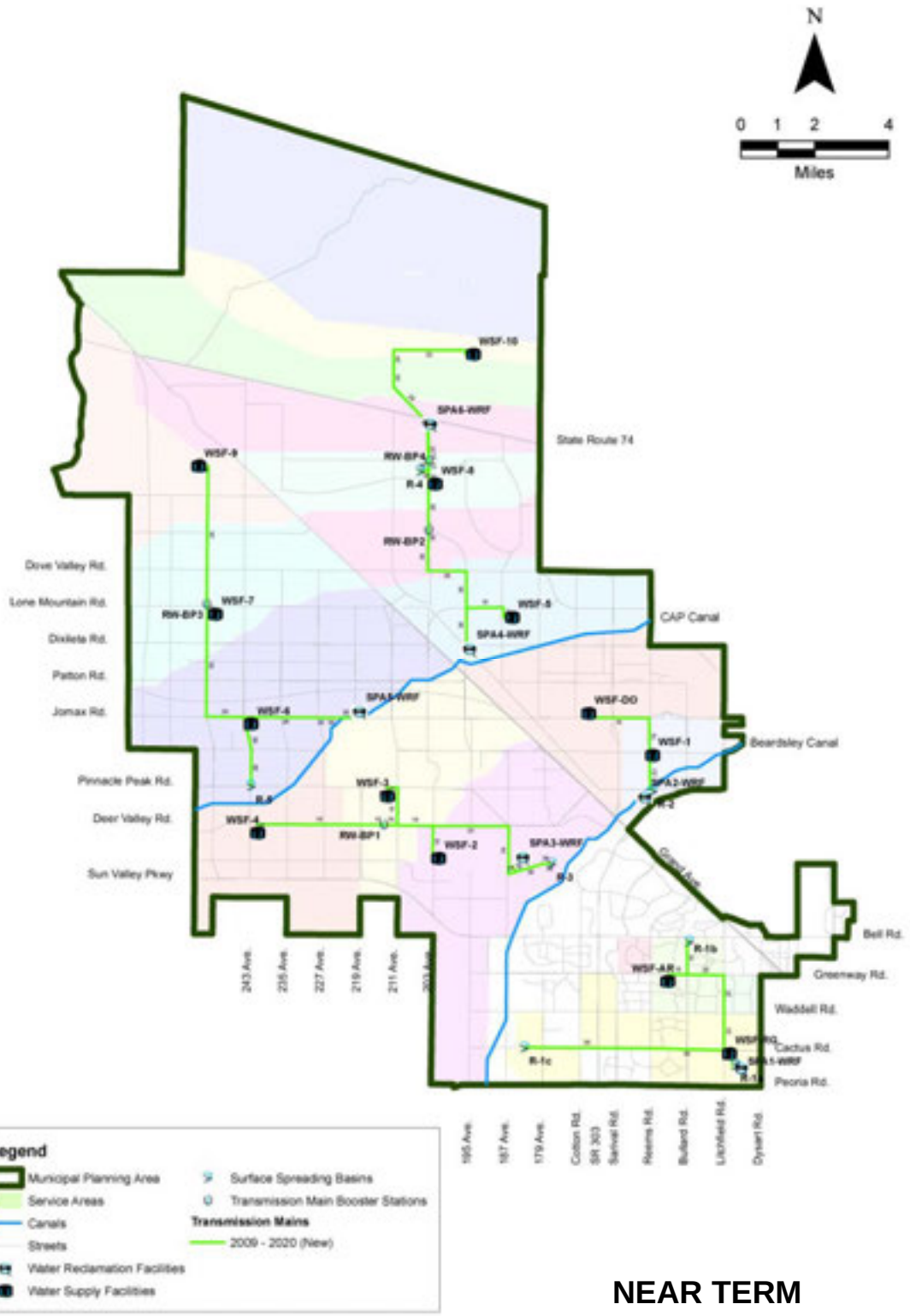
Any reclaimed water that is not utilized for direct reuse is recharged through infiltration basins and vadose zone injection wells. At the SPA 1 WRF, the City currently utilizes two infiltration basins and five vadose zone injection wells to recharge reclaimed water. The City has plans to add 10 additional injection wells to assist in recharge of the reclaimed water at the SPA 1 WRF in 2012. At the SPA 2 WRF, a combination of spreading basins and five injection wells are currently used as the primary method to recharge reclaimed water. In the future, a reclaimed water system will be constructed and serve as the primary use of reclaimed water, delivering a majority the reclaimed water for direct reuse.

For the future SPA 3 WRF, infiltration basins are proposed to recharge reclaimed water not delivered for direct reuse. The proposed near-term infiltration basin locations are illustrated in Figure WWT.6. The proposed long-term infiltration basin locations are illustrated in Figure WWT.7.

2.2 Study Area Boundaries and Constraints

The IWMP established the groundwork for the development of this Wastewater Technology Assessment document. Many of the recommendations from the IWMP are incorporated directly and used to establish criteria for the Wastewater Technology Assessment. Other data contained in the IWMP are validated to confirm that the parameters used in the Wastewater Technology Assessment are accurate and consistent with the established goals of the City. Based on information presented in the IWMP, the following project constraints have been established for the Wastewater Technology Assessment Report:

- The focus period for the Wastewater Technology Assessment is approximately the next five to ten years. It is anticipated that this document will be reviewed and updated every five to ten years (in conjunction with the IWMP) to address changing growth patterns, regulations, treatment technologies, capital and O&M costs, etc.
- The IWMP will be updated every five years to reflect changes in wastewater parameters (both quantity and quality) and wastewater reclamation facilities and infrastructure. Changes to the IWMP may affect the validity of the Wastewater Technology Assessment results. Therefore, as noted above, it is recommended that the Wastewater Technology Assessment Report be reviewed and updated following each IWMP update. This approach will allow the City to improve the accuracy of planning and budgeting associated with wastewater reclamation facilities and infrastructure.
- The assessment is completed under the assumption that there will be one WRF per SPA, for a total of six WRFs. Each facility will be treated as an “End-of-Line” plant with a dedicated biosolids handling facility. The decision regarding whether to build a joint solids handling facility can be deferred to future updates of the IWMP and Wastewater Technology Assessment Report.
- The IWMP identified WRFs of varying capacities are necessary to meet the City’s future needs. The Wastewater Technology Assessment identifies the technologies that are appropriate for the various treatment capacities.
- The City is currently developing a list of preferred equipment manufacturers. This information will be included in the appendices of this report when available.



Note: Figure data adapted from Figure 7-8 in the IWMP-Water Infrastructure (Final 2009)

NEAR TERM RECLAIMED WATER TRANSMISSION MAIN IMPROVEMENTS

FIGURE WWT.6

CITY OF SURPRISE
WASTEWATER TECHNOLOGY ASSESSMENT REPORT

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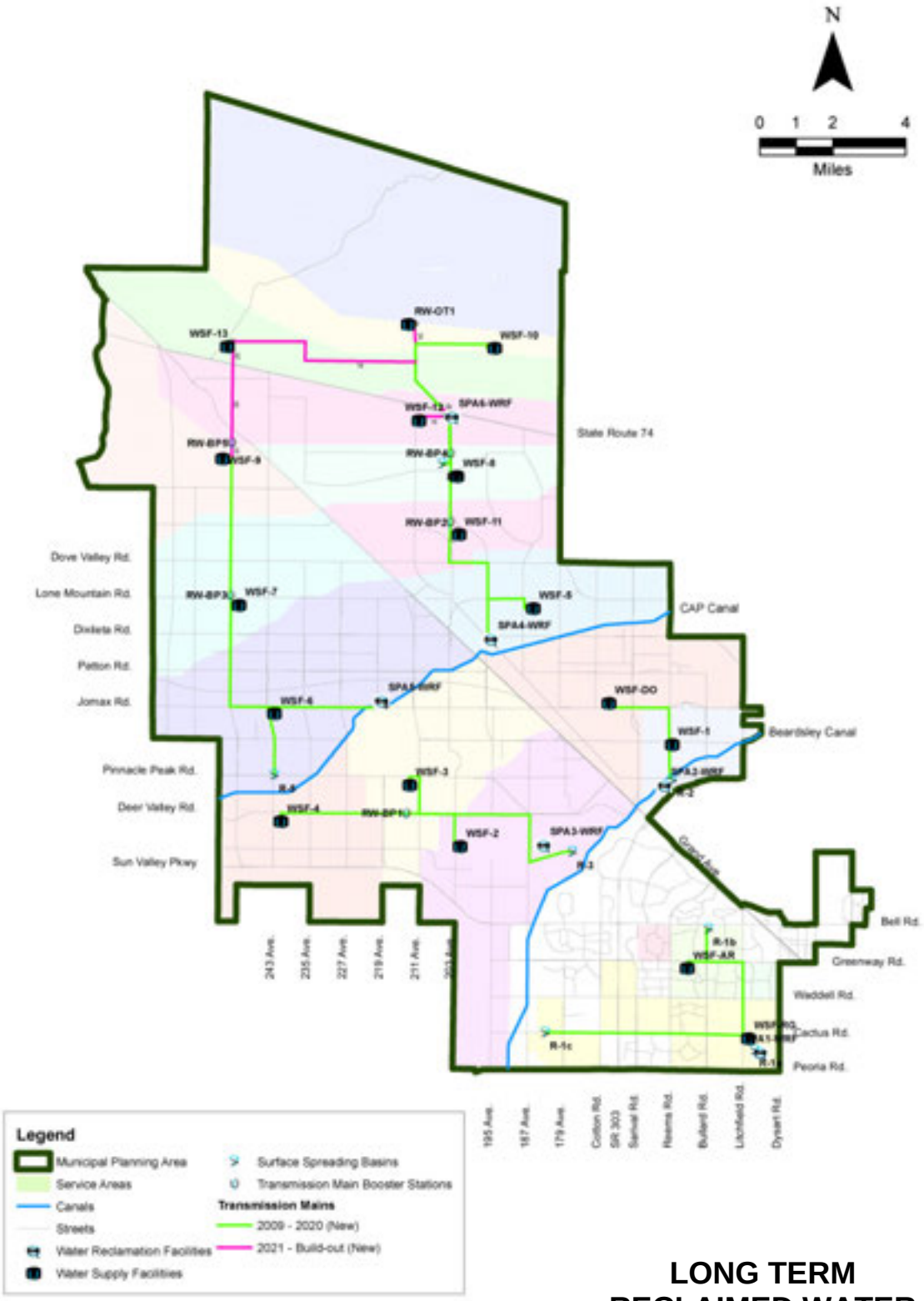

Note: Figure data adapted from Figure 7-9 in the IWMP-Water Infrastructure (Final 2009)

LONG TERM RECLAIMED WATER TRANSMISSION MAIN IMPROVEMENTS

FIGURE WWT.7

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WASTEWATER TECHNOLOGY ASSESSMENT REPORT

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2.3 Project Methodology Overview

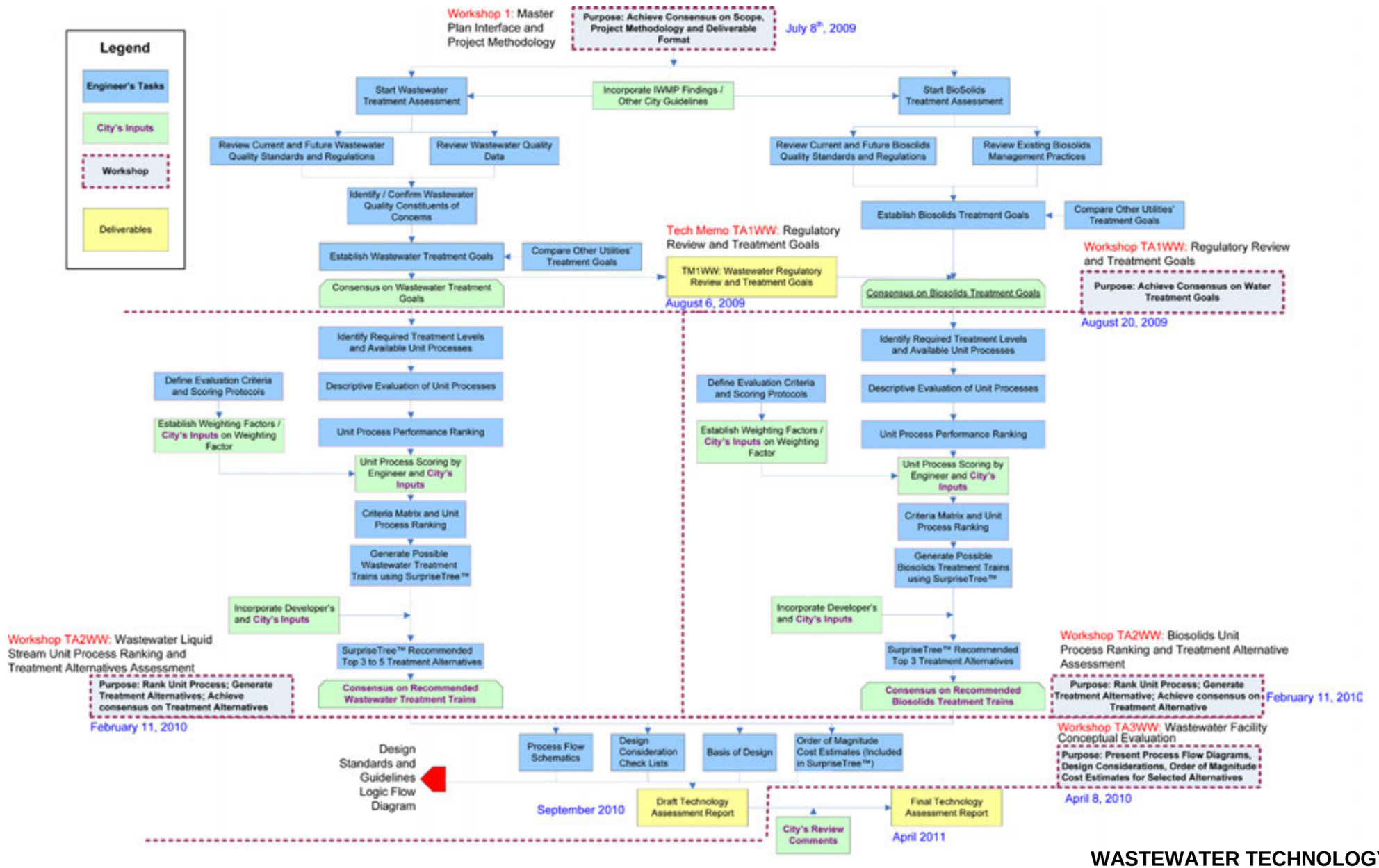
The subsequent sections of this report present a systemic technology assessment. The methodologies proposed to meet the City's current and near future wastewater needs are illustrated in the logic flow diagram outlined in Figure WWT.8. The wastewater technology assessment logic flow diagram was presented at Workshop 1 - Project Methodology and Master Plan Interface, held on July 8, 2009. As part of the workshop, the project team agreed on the proposed tasks and the strategy for completing the Wastewater Technology Assessment.

The logic flow diagram includes an overview of the primary tasks associated with the Wastewater Technology Assessment. It outlines the order of tasks, how the results from individual tasks relate directly and indirectly to other tasks, and how the individual task results incorporate into the final report. As illustrated in the logic flow diagram, input from the City is critical at several key points during the assessment. The wastewater technology assessment logic flow diagram includes two flow paths - one for wastewater treatment and one for biosolids treatment. Each flow path was performed independently with the results combined into the final report.

The logic flow diagram was revised to reflect changes in project deliverable format and progressing timeline. Such changes were necessary to help achieve consensus between the City and the developer representatives to assist in overcoming the project challenges associated with site-specific conditions.

In short, the Wastewater Technology Assessment begins with a wastewater effluent regulatory review (presented in Section 3.0), which was performed in parallel with a review of available water quality data (see Section 5.0). Water quality standards / treatment goals were established (presented in Section 4.0). Comparing the wastewater quality data and the treatment standards allowed the identification of water quality constituents of concern (CoC) and establishment of levels of treatment required to achieve the standards.

Section 6.0 presents the prescreened treatment technology alternatives, which were evaluated for each level of treatment. This evaluation addressed questions for each technology including what it is, what it does, how it works, and the associated pros and cons. The technology alternatives were then compared in tabular format and ranked using evaluation matrixes. The evaluation matrixes utilized a set of evaluation criteria developed by the City staff and developer representatives. Nine individuals (City and developer) participated in assigning weighting factors for these criteria. The averaged weighting factors were used for the final ranking evaluation.



WASTEWATER TECHNOLOGY ASSESSMENT LOGIC FLOW DIAGRAM

FIGURE WWT.8

CITY OF SURPRISE
WASTEWATER TECHNOLOGY ASSESSMENT REPORT

A conventional technology assessment approach, which results in a single fixed set of recommended technologies, may not provide the City with sufficient flexibility to accommodate site-specific conditions. To provide the City with a useful tool that can assess available treatment alternatives for a given set of site-specific conditions (such as facility size, land availability), the team developed an innovative approach. The core of this approach is an advanced macro-based Excel model called SurpriseTree™ Wastewater. A copy of this model is located on a CD attached with this report. Refer to Section 8.0 for detailed descriptions regarding how the model works and how/when it should be used.

Using SurpriseTree™ Wastewater, the results of the technology alternative assessment represent a dynamic and customized solution, which automatically responds to the site-specific condition inputs for future facilities. Through incorporating the institutional and technical knowledge of the City, developer, and engineer, the model was "calibrated" and improved to better represent potential future conditions.

The Wastewater Technology Assessment Report is designed to provide the City and the developer with useful planning-level design information for the most common treatment alternatives to be implemented at the City's future WRFs. These treatment alternatives are viable options for the City's facilities, considering their technical feasibility and cost effectiveness. Process flow diagrams, basis of design information, and design considerations were developed for each of the selected treatment alternatives. This information is presented in Section 8.0.

Similarly, a biosolids technology assessment was performed. A biosolids regulatory review was completed to establish the proposed biosolids treatment standards (see Section 3.0). Section 7.0 presents the prescreened biosolids treatment technology alternatives, which were evaluated for each level of treatment. Process flow diagrams, basis of design information, and design considerations were developed for each of the selected biosolids treatment alternatives. This information is presented in Section 8.0.

3.0 WATER QUALITY STANDARDS AND REGULATORY REQUIREMENTS

This chapter reviews and summarizes the current, pending, and future rules and regulations associated with wastewater treatment.

3.1 Wastewater and Reuse Regulations and Guidelines

3.1.1 National Pollutant Discharge Elimination System (NPDES) Program

The National Pollutant Discharge Elimination System (NPDES), established by USEPA, is a permitting program that establishes requirements for wastewater effluent discharge to water bodies. The NPDES is enforced through monitoring and reporting. NPDES permits are site-specific discharge standards that incorporate Federal Clean Water Act mandates and the State Surface Water Quality Standards. On December 5, 2002, Arizona became one of

45 states with authorization from EPA to operate the NPDES Permit Program (Section 402 of the Clean Water Act) on the state level.

Under the Arizona Pollutant Discharge Elimination System (AZPDES) Permit Program, all facilities that discharge pollutants from any point source into waters of the United States (navigable waters) are required to obtain or seek coverage under an AZPDES permit. Pollutants can enter waters of the United States from a variety of pathways, including agricultural, domestic, and industrial sources. For regulatory purposes, these sources are generally categorized as either point source or non-point sources. ADEQ developed rules for the AZPDES program in 2001 and revised them in 2002 and again in 2004. The most recent revision was published in the Arizona Administrative Code on Dec. 26, 2003.

A.A.C. R18-11 sets the numerical water quality standards for surface water within the state. When discharging to the surface waters, the discharge stream must meet these standards. The City of Surprise is planning to recharge and reuse all of its reclaimed water. However, if the City chooses to discharge to a surface water, such as the Agua Fria River, at any point in the future, these numerical water quality standards would need to be met.

Among the many parameters listed in A.A.C. R18-11, phosphorous is the most likely to significantly impact the wastewater treatment technology selection. A phosphorous limit of 125 - 160 µg/L was set for the Agua Fria River (A.A.C. R18-22-108.03D). Because a typical biological nutrient removal process can only lower the phosphorous to a level of 200 to 300 µg/L, achieving the regulatory limit of 125 to 160 µg/L would likely require advanced treatment such as Reverse Osmosis (RO).

Another parameter that could impact wastewater treatment technology selection includes chlorine. An effluent with a chlorine residual cannot be discharged to a surface water. Therefore, a dechlorination process is required prior to discharging chlorinated water.

Applicability of NDPES to City of Surprise:

The City is currently planning to reuse and recharge all of its reclaimed water. While the City does not have current plans to discharge effluent to a surface water body, if surface water discharge is considered as a backup effluent recharge method at any point in the future, an AZPDES permit would be required and the numerical standards associated with the surface water discharge would need to be met. The proposed wastewater treatment technologies should be able to meet these standards, including the phosphorous limitations, if necessary in the future.

3.1.2 Federal Guidelines for Reclaimed Water Reuse

Although there are no federal regulations for reclaimed water use, there are federal requirements that apply to the injection of reclaimed water into the aquifer via wells under the USEPA Underground Injection Control (UIC) Program. The vadose zone well and storm water drywells are considered Class V wells and have to be registered prior to use with the USEPA. This registration can be completed online at the USEPA UIC Program website. The USEPA UIC works in concert with the aquifer protection permit (APP) requirements but does have the ability to enforce separately from the APP as the Safe Drinking Water Act (SWDA) National Primary Drinking Water Regulations (NPDWRs) are used for UIC. Additionally, there is a tendency to use the SDWA NPDWRs when defining requirements for reclaimed water that is used for non-potable reuse. Current drinking water standards, however, were developed based on freshwater sources, and were not based on municipal wastewater as a source. Furthermore, none of the emerging constituents of concern, including endocrine disruptors, pharmaceuticals, personal care products, and hormones, are currently regulated by maximum contaminant levels in the SDWA.

3.1.3 ADEQ BADCT Requirement

The Arizona Department of Environmental Quality (ADEQ) sets forth the regulations pertaining to wastewater treatment effluent quality and effluent management in Arizona. The recent ADEQ rules require that a wastewater treatment plant with a capacity greater than 250,000 gpd must meet the conditions of Best Available Demonstrated Control Technology (BADCT). Treated effluent must (at a minimum) meet or exceed the current standards set forth in the Arizona Administrative Code (A.A.C.), specifically as defined in R18-9 and R18-11.

Tertiary filtration is a vital component in producing Class A+ effluent. Tertiary filtration assists in meeting the ADEQ regulations for Class A+ reclaimed water, which specify turbidity limits of 2 NTU or less based on a 24-hour average, with no exceedances of 5 NTU at any time. In addition to the ADEQ Class A+ turbidity limits, the current regulations for Class A+ reclaimed water require that chemical filter aid (coagulant or polymer) feed facilities be provided to supplement tertiary filtration systems. For most Class A+ systems, chemical feed and flocculation systems are provided for contingency purposes to satisfy ADEQ requirements, but are not typically used under normal operating conditions.

The BADCT treatment performance requirements and reclaimed water quality standards are presented in Table WWT.4 and Table WWT.5, respectively.

Table WWT.4 ADEQ BADCT Effluent Requirements Wastewater Technology Assessment Report City of Surprise		
	Effluent Limits (1)	
Parameters	**Average Daily Flow < 250,000 gpd**	**Average Daily Flow > 250,000 gpd**
pH	6.0 - 9.0	6.0 - 9.0
BOD (30-day average)	< 30 mg/L	< 30 mg/L
BOD (7-day average)	< 45 mg/L	< 45 mg/L
TSS (30-day average)	< 30 mg/L	< 30 mg/L
TSS (7-day average)	< 45 mg/L	< 45 mg/L
Removal Efficiency for BOD, CBOC, TSS	85%	85%
Total Nitrogen (as N) (2)	< 10 mg/L	< 10 mg/L
Fecal Coliform (3)		
Single sample maximum	800 cfu/100 mL	23 cfu/100 mL
Seven sample median	200 cfu/100 mL	2.2 cfu/100 mL
R18-11-406(B-G) constituents	Numeric water quality standards must be met	
A.R.S. 49-243(I) regulated chemicals	Removal to greatest extent possible without regard to cost	
Trihalomethanes	Minimize THM compounds generated as disinfection byproducts using chlorination, dechlorination	

Notes:
(1) Reference: A.A.C. R18-9-B204.
(2) Five-month rolling geometric mean.

Applicability of BADCT to City of Surprise:

The City must meet or exceed all ADEQ BADCT requirements at each of their water reclamation facilities. This Wastewater Technology Assessment considers only technologies that are capable of achieving these minimum effluent parameters.

Table WWT.5 ADEQ Reclaimed Water Quality Standards
Wastewater Technology Assessment Report
City of Surprise

Parameter	Effluent Limits		
	Class A+ (1)	**Class B+ (2)**	**Class C (3)**
Secondary treatment	X	X	Stabilization ponds with 20-day detention
Filtration	X	NR	NR
Denitrification	X	X	NR
Disinfection	X	X	With or without
Total Nitrogen (as N) (4)	< 10 mg/L	< 10 mg/L	N/A
Turbidity			
Daily (24-hour) average	2 NTU	N/A	N/A
Single sample maximum	5 NTU	N/A	N/A
Fecal Coliform			
Single sample maximum	23 cfu/100 mL	800 cfu/100 mL	4,000 cfu/100 mL
Four out of last seven daily samples	Non-detect	200 cfu/100 mL	1,000 cfu/100 mL
Meet BADCT Requirements	X	--	--

Notes:
X = Requirement
NR = Not Requirement
(1) Reference: A.A.C. R18-11-303
(2) Reference: A.A.C. R18-11-305
(3) Reference: A.A.C. R18-11-307
(4) Five sample geometric mean
(5) Class A, B, C etc. uses are listed in A.AC. R18-11 Table A

Applicability of ADEQ Reclaimed Water Quality Standards to City of Surprise:

The City currently produces reclaimed water for use in landscape irrigation and recharge. The IWMP - Water Resources Report emphasizes that reclaimed water will be a sustainable and necessary water source for the City in the future. Consequently, the Wastewater Technology Assessment assumes that Reclaimed Water Quality Standards will apply to any water reclamation facility that intends to produce reclaimed water for beneficial reuse purposes.

3.1.4 ADEQ Reuse Applications

The required quality of an effluent is dependent on its intended end use. If the effluent will be recharged using recharge basins, BADCT limitations along with aquifer water quality standards (AWQS) must be met. However, if the effluent will be reused for irrigation on turf areas, including golf courses, parks, and recreational areas, then the reuse rules apply.

The reuse regulations categorize reclaimed water into three main classes: A, B or C effluent. In addition, if nitrogen removal is provided, the water can be classified as A+ or B+. Class A+ water can be used for any type of direct non-potable water reuse as outlined in the A.A.C R18-11-303. Class B+, though unacceptable for use on schools, parks and recreational lakes, is adequate for golf courses and other turf irrigation, as outlined in the A.A.C. The primary difference between A+ and B+ reclaimed water is the level of disinfection required. Note that Class A, B, B+, and C reclaimed water does not meet BADCT for a facility having an average daily flow of > 250,000 gpd.

3.1.5 Aquifer Protection Permits

An Aquifer Protection Permit (APP) is required for any facility that discharges a pollutant either directly to an aquifer or to the land surface or the vadose zone (the area between an aquifer and the land surface) in such a manner that there is a reasonable probability that the pollutant will reach an aquifer. Wastewater treatment facilities and injection wells are considered to be discharging pollutants and require permits. Aquifer water quality standards are outlined in A.A.C. Title 18, Chapter 11, Article 4. Aquifer water quality standards apply to aquifers that are classified for drinking water-protected use. There are numerous requirements specified in the A.A.C. regarding aquifer protection. However, the following are the most critical:

1. The BADCT must be used by the facility.
2. The applicant must demonstrate that AWQS will not be violated at a point of compliance as a result of discharge from the facility. If the level of a pollutant in the aquifer already exceeds the AWQS at the time of permit issuance, the aquifer must not be further degraded.

APPs have monitoring requirements for both the facility discharge compliance point and also for the groundwater in the influenced aquifer point of compliance. Each compliance point is assigned a discharge limit along with an alert limit while groundwater monitoring locations are assigned an aquifer quality limit along with an alert level.

Applicability of APPs to City of Surprise:

The City currently has an APP for all WRFs in operation. All future City of Surprise WRF also will require an APP prior to operation. Effluent from SPA 1 WRF is discharged via vadose zone wells and recharge basins, located over groundwater in the West Salt River Valley Sub-basin of the Phoenix Active Management Area within the Middle Gila watershed. Based on APP requirements, the City's WRFs will likely be required to meet Class A+ reclaimed water quality and achieve the aquifer water quality standards. These requirements are considered as part of the Wastewater Technology Assessment evaluation.

3.1.6 Disinfection and Disinfection Byproduct Requirements

3.1.6.1 ADEQ Requirements Associated with Disinfection

According to A.A.C. Title 18 Chapter 9 (R18-9-B204), a fecal coliform limit, using the membrane filter technique, of 2.2 (cfu) per 100 mL (seven-sample median) and less than 23 cfu per 100 mL (single sample maximum), or equivalent numbers using the multiple tube fermentation method, is required to prove a facility is meeting the disinfection requirements of ADEQ BADCT for treatment facilities greater than 250,000 gpd. Unit treatment processes, such as chlorination-dechlorination, ultraviolet disinfection, and ozone, may be used to achieve this standard.

3.1.6.2 ADEQ Requirements Associated with Disinfection Byproducts

As part of the BADCT requirements, the A.A.C. requires all new sewage treatment facilities to minimize total trihalomethanes (TTHMs) generated as disinfection byproducts to the greatest extent practical, regardless of cost. The requirement can be met using chlorination, dechlorination, ultraviolet, or ozone as the disinfection technology, or through implementation of a technology demonstrated to have equivalent or better performance for removing or preventing TTHMs.

There is no current numerical standard for TTHMs in Arizona for reuse, although both BADCT and Class A+ Reuse Rules require minimization of TTHMs.

For recharge, ADEQ regulates TTHMs through APPs and sets a discharge limit. The A.A.C. R18-11-406 establishes AWQS for any water discharged to a drinking water aquifer. The A.A.C. AWQS for TTHMs is 0.1 mg/L at the discharge water compliance point.

3.1.6.3 Potential Future Requirements on Disinfection and TTHMs

Concerns regarding water quality and potential health hazards led to California issuing guidelines for groundwater recharge. These regulations recommended spreading over injection, disinfection prior to recharge, and minimization of DBPs (Crook et al, 1990). With rising public concerns regarding health hazards associated with TTHM formation and non-disinfected recharge water, it is anticipated that ADEQ will enact requirements on recharge stream disinfection to go along with the established TTHM compliance in the near future.

Applicability of Disinfection and Disinfection Byproduct Requirements to City of Surprise:

Recent TTHM sampling within the City's system indicated that the reclaimed water exceeded the existing and proposed aquifer water quality standards. These TTHM issues are believed to be a result of the disinfection method and disinfection byproduct precursors (e.g., TOC, bromide, pH, temperature). Unless disinfection byproduct precursors are removed or reduced, the addition of chlorine will cause the formation of TTHMs, which when recharged, will likely exceed the aquifer water quality standards.

This Wastewater Technology Assessment Report analyzes the best technologies to achieve ADEQ disinfection and disinfection byproduct requirements, with the goal of minimizing TTHM formation.

3.2 Emerging Contaminants and Reuse

Emerging contaminants are a class of compounds that include endocrine disruptors, pharmaceuticals, and personal care products. These compounds may pose long-term health effects even if ingested in small quantities (in the microgram and nanogram/liter range). With the advent of new analytical techniques capable of measuring extremely low concentrations, numerous trace organic compounds have been detected in treated wastewater. Some of the compounds (e.g., N nitrosodimethylamine [NDMA]) that have been identified in treated effluent are known to cause acute and chronic health effects depending on the concentration. However, the long-term health and environmental effects of most emerging contaminants are not yet well understood.

The United States Geological Survey (U.S.G.S.) completed a nationwide survey in 2000 that tested for the occurrence of pharmaceuticals, hormones, and other organic wastewater contaminants (OWCs) in streams across the U.S. A total of 139 streams in 30 states were tested for 95 OWCs using five new research methods developed by the U.S.G.S. All the sampling locations selected were located near urban areas. Four sampling locations were selected in Arizona including the Santa Cruz River near Rio Rico, 91st Ave. Wastewater Treatment Plant (WWTP) outfall, Santa Cruz River at Cortaro Road, and Gila River above diversions at Gillespie Dam.

At least one OWC was detected in 80 percent of the streams sampled, with 82 of the 95 analyzed OWCs detected in at least one sample. Steroids, nonprescription drugs, and an insect repellent were the three chemical groups most commonly detected in the streams. Detergent metabolites, steroids, and plasticizers were generally found at the highest concentrations.

Applicability of Emerging Contaminants and Reuse to City of Surprise:

Endocrine disruptors, pharmaceuticals, and personal care products are contaminates that could be regulated in the future. Although it is too early in the regulatory process to determine which contaminants may be regulated and to what level, the City should be aware of these contaminants and understand the impacts of possible future regulations. The removal of such contaminants should also be taken into consideration when master planning and implementing advanced treatment processes at the City's treatment facilities.

3.3 Emerging Organisms

Bryozoans are tiny colonial animals that typically build stony skeletons of calcium carbonate, superficially similar to coral (although some species lack any calcification in the colony and instead have a mucilaginous structure). Members of the phylum bryozoa are known as "moss animals," "moss animalcules," or "sea mats." They generally prefer warm, tropical waters, but are known to occur worldwide. There are approximately 8,000 living species, with several times that number of fossil forms known.

Several species of freshwater bryozoans are notorious for clogging pipes that carry unfiltered water from rivers and lakes. The branching, tubular animal colonies attach firmly to any solid substrate, often appearing as clumps of brownish moss. In the last century, major cities in Europe and the United States have experienced disruption of public water service due to blockages by bryozoans (Kraepelin, 1886).

Bryozoan biofouling has been reported at multiple water and wastewater treatment facilities in the United States, including many local facilities. The City of Tempe Kyrene Water Reclamation Facility has been plagued with a microscopic bryozoa organism. Bryozoa typically grows in clear water with minimal sunlight. The existing covered final clarifiers, filters, and effluent channels provided a perfect environment for bryozoa to form sheets of sticky growth on the walls. Periodically, the sheets would slough off the walls and quickly plug the effluent filters. There is no clear reason why the facility was infected. Operators determined there was not an easy fix beyond methodically cleaning the filters and preparing for the next outbreak. The plugging filters resulted in fecal coliform issues and high O&M costs associated with the required cleaning.

At other local facilities, bryozoa caused problems from fouling secondary clarifiers to plugging recharge wells. Moreover, bryozoa occurrence can compromise disinfection and ruin UV lamps.

Bryozoa is resistant to chemicals such as chlorine. Process control measures including lowering the DO may help to reduce its growth. Based on the Kyrene WRF experience, membrane filtration may be less vulnerable to bryozoa plugging than conventional filtration.

Applicability of Emerging Organisms to City of Surprise:

Bryozoan biofouling has been reported at water and wastewater treatment facilities in close proximity to the City of Surprise. The City should be aware of the threat of possible infection of bryozoa type organisms in their treatment facilities and recognize the early warning signs (i.e., moss like growth). In recent experience, the City has been successful at controlling bryozoa through the use of ammonia.

3.4 Salinity and Reuse Potential

3.4.1 Total Dissolved Solids

TDS is the total quantity of salts dissolved in water and is comprised of anions, such as bicarbonate, carbonate, chloride, sulfate, and silica, and cations, such as sodium, calcium, and magnesium. TDS originates in natural geologic formations and is concentrated in processes such as irrigation return and field run-off, water reclamation, and membrane technologies.

Salt build-up in the Phoenix metropolitan area is a growing concern. TDS concentrations in the City of Surprise's groundwater sources range from 200 to 400 mg/L. Salt levels become more concentrated as water is used and reclaimed. Because the potential for reclaimed water reuse opportunities diminishes (especially for irrigation uses) as salt concentrations rise, the cities in the Phoenix metropolitan area need to understand the importance of controlling salt build-up in the future. Due to the importance of establishing and maintaining reclaimed water as a viable future water supply, the City must be aware of the affects of increasing TDS. TDS removal and concentrate disposal alternatives may need to be examined in the future. As more efficient and practical methods of TDS removal and concentrate disposal evolve, the City should consider establishment of numerical TDS standards and implementation of control measures, as appropriate.

3.4.2 Whole Effluent Toxicity

Whole effluent toxicity (WET) describes the toxic effect to aquatic organisms from all pollutants found in a wastewater treatment facility's effluent. WET tests measure wastewater's effects on specific test organisms' ability to survive, grow, and reproduce. WET must be minimized to prohibit the discharge of toxic pollutants in toxic amounts. A chloride level of less than 250 mg/L is recommended to lower the toxicity potential of the effluent.

The WET methods are specified in 40 CFR 136.3, Table IA. Any effluent parameter that meets the WET criteria will have requirements within the NPDES permit to control the toxic parameters.

3.4.3 Reclaimed Water Salinity and Sodium Adsorption Ratio

Sodium adsorption ratio (SAR) is a measure of the suitability of water for use in agricultural irrigation, as determined by the concentrations of solids dissolved in the water. It is also a measure of the sodicity of soil, as determined from analysis of water extracted from the soil.

The formula for calculating sodium adsorption ratio is:

$$SAR = [Na+] / \{([Ca2+] + [Mg2+]) / 2\}1/2$$

where sodium, calcium, and magnesium are in mequivalents/liter or mmole/liter.

Although SAR is only one factor in determining the suitability of water for irrigation, in general, the higher the sodium adsorption ratio, the less suitable the water is for irrigation. Irrigation using water with a high sodium adsorption ratio may require soil amendments to prevent long-term damage to the soil.

Applicability of Salinity and Reuse Potential to City of Surprise:

The City should be aware of the effects of reclaimed water recharge on TDS in the groundwater supply and resulting soil conditions. The City of Scottsdale has adopted a reuse water TDS goal of 1,000 mg/L and sodium goal of 150 mg/L. As the result of a study at a City of Phoenix WRF, a chloride goal of 250 mg/L was proposed for toxicity reduction. While treatment may not be required to address salinity, sodium, and chloride issues in the near term, these reuse water goals should be considered by the City of Surprise when evaluating future available treatment technologies.

3.5 Biosolids Regulations

3.5.1 Biosolids Rules

The USEPA has established rules related to biosolids in the Code of Federal Regulations Title 40, Section 503 (40 CFR 503) in 1993. This rule governs the land application of biosolids. Regulation for the disposal, use, and transportation of biosolids within the State of Arizona are established in A.A.C Title 18, Chapter 9, Article 10. The Biosolid Rules is discussed in detail in the following sections.

3.5.1.1 Classification of Biosolids

Two terms are commonly used to describe the solids generated by a typical wastewater treatment process - “sludge” and “biosolids.” The term “sludge” is generally used to describe wastewater solids prior to stabilization and in conjunction with a specific process descriptor, such as in “primary sludge,” “waste activated sludge,” or “secondary sludge.” Biosolids are defined as organic solid residuals resulting from the treatment of domestic sewage at a wastewater treatment facility. The term “biosolids” is promoted by The Water Environment Federation to indicate that wastewater solids are organic products, which have beneficial end-use properties. Sludge generated by a wastewater treatment facility is

defined as biosolids once beneficial use criteria (as determined by compliance with the USEPA 40 CFR 503) have been achieved through stabilization processes. Stabilization processes are described as those that help reduce pathogens, reduce vector attraction, and eliminate offensive odors and the potential for decomposition.

Biosolids are typically disposed in landfills or are beneficially reused through land application. The broad category of land application includes all forms of applying bulk biosolids to land for beneficial use at agronomic rates (i.e., the nutrient uptake of the associated crop that the biosolids fertilize). As nitrogen is typically the limiting nutrient, the biosolids application must match the crop's nitrogen uptake rate. Biosolids disposal and land application is federally regulated by the USEPA 40 CFR 503.

The 40 CFR 503 regulations classify biosolids as Exceptional Quality (EQ), Class A, or Class B according to the level of treatment provided to reduce pathogens and vector attraction. Pathogens are defined as disease-causing organisms such as bacteria, viruses, and parasites. The reduction of pathogens in biosolids is necessary to prevent the spread of disease. Pathogens can be carried and transferred via vectors such as flies, mosquitoes, fleas, rodents, and birds. To further prevent the spread of disease-laden pathogens, biosolids must also be treated to reduce their attractiveness to vectors.

The 40 CFR Part 503 regulations also regulate the allowable biosolids inorganic content (i.e., heavy metals). Lower inorganic content further reduces the restrictions placed on beneficial use practices. EQ is the highest quality defined by the 503 regulations. EQ biosolids have very low heavy metal content and have been treated to Class A pathogen and vector attraction reduction levels.

Class B biosolids may only be applied where there is no possibility of contact with the general public (i.e., certain types of agriculture, landfill, etc.). Additional restrictions associated with Class B biosolids prevent crop harvesting, animal grazing, and public access for a defined period of time until environmental conditions have further reduced pathogens. EQ and Class A biosolids, however, have less stringent requirements associated with application and may be land applied where contact with the general public is possible (i.e., nurseries, gardens, golf courses, etc.). The 503 regulations allow unrestricted distribution and reuse of EQ biosolids up to agronomic limits. Ultimately, the higher the level of treatment to reduce pathogens and vector attraction, the less restrictions there are for beneficial reuse.

The 40 CFR 503 regulations classify biosolids as Class A, Class B or EQ according to the level of treatment provided to reduce pathogens and vector attraction, and metals concentrations. EQ and Class A biosolids must undergo treatment to reduce pathogen levels to below detectable limits, whereas Class B biosolids must simply undergo pathogen reduction. To meet the requirements of EQ, the biosolids must also meet more stringent metals concentrations than Class A biosolids. As the treatment requirements associated with Class B are less stringent than EQ and Class A, the options for disposal of Class B biosolids are more limited. This section will outline the various options and alternatives for pathogen and vector reduction associated with EQ, Class A, and Class B biosolids.

3.5.1.2 Pathogen Reduction for Exceptional Quality and Class A Biosolids

EQ and Class A biosolids must undergo stringent treatment for pathogen reduction to decrease the pathogen level to below detectable limits. Due to the stringent treatment requirements, EQ and Class A biosolids provide more disposal and application opportunities than their Class B counterparts. Biosolids that meet the standards for EQ and Class A pathogen reduction can be land applied at sites where contact with the general public is possible, such as parks, golf courses, and gardens. In order to meet EQ and Class A criteria, biosolids must undergo one of the alternatives for pathogen reduction listed in Table WWT.6

Table WWT.6 Six Alternatives for Meeting EQ and Class A Pathogen Requirements
Wastewater Technology Assessment Report
City of Surprise

Alternatives[(1)]	Requirements
Alternative 1: Thermally Treated Biosolids	Biosolids must be subjected to one of four time-temperature regimes.
Alternative 2: Biosolids Treated in High pH-High Temperature Process	Biosolids must meet specific pH, temperature, and air-drying requirements.
Alternative 3: Biosolids Treated in Other Processes	Demonstrate that the process can reduce enteric viruses and viable helminth ova. Maintain operating conditions used in the demonstration after pathogen reduction demonstration is completed.
Alternative 4: Biosolids Treated in Unknown Processes	Biosolids must be tested for pathogens - *Salmonella* sp. or fecal coliform bacteria, enteric viruses, and viable helminth ova - at the time the biosolids are used or disposed, or prepared for use or disposal.
Alternative 5: Biosolids Treated in a Process to Further Reduce Pathogens (PFRP)	Biosolids must be treated in one of the PFRPs (see Table WWT.7).
Alternative 6: Biosolids Treated in a Process Equivalent to a PFRP	Biosolids must be treated in a process equivalent to one of the PFRPs, as determined by the permitting authority.

Note:
(1) Alternatives are defined in greater detail in 40 CFR 503.

To meet the requirements of pathogen reduction via Alternative 5, the biosolids must undergo one of the treatment technologies known as the Processes to Further Reduce Pathogens (PFRP) listed in Table WWT.7.

Table WWT.7 Processes to Further Reduce Pathogens (PFRPs) Wastewater Technology Assessment Report City of Surprise	
Process[(1)]	**Definition**
Composting	Using either the within-vessel or the static aerated pile composting method, the temperature of the biosolids is maintained at 55 degrees Celsius (° C) or higher for 3 days. Using the windrow composting method, the temperature of the biosolids is maintained at 55° C or higher for 15 days or longer. During the period when the compost is maintained at 55° C or higher, the windrow is turned a minimum of 5 times.
Heat Drying	Biosolids are dried by direct or indirect contact with hot gases to reduce the moisture content of the biosolids to 10% or lower. Either the temperature of the biosolids particles exceeds 80° C or the wet bulb temperature of the gas in contact with the biosolids as the biosolids leave the dryer exceeds 80° C.
Heat Treatment	Liquid biosolids are heated to a temperature of 180° C or higher for 30 minutes.
Thermophilic Aerobic Digestion	Liquid biosolids are agitated with air or oxygen to maintain aerobic conditions, and the mean cell residence time of the biosolids is 10 days at 55° to 60° C.
Beta Ray Irradiation	Biosolids are irradiated with beta rays from an accelerator at dosages of at least 1.0 megarad at room temperature.
Gamma Ray Irradiation	Biosolids are irradiated with gamma rays from certain isotopes, such as Cobalt 60 and Cesium 137, at room temperature.
Pasteurization	The temperature of the biosolids is maintained at 70° C or higher for 30 minutes or longer.
Note: (1) Treatment processes are defined in detail in 40 CFR 503.	

3.5.2 Pathogen Reduction for Class B Biosolids

Unlike EQ and Class A biosolids, in which pathogen levels are required to be below detectable limits, Class B requirements simply mandate a reduction in the amount of pathogens. Consequently, Class B biosolids may still contain some level of pathogens. Due to these less stringent treatment requirements, Class B biosolids are more restricted in terms of acceptable land application sites. Class B biosolids may only be applied at sites where there is no possibility of contact with the general public. In addition, Class B requirements for land application of biosolids also include site restrictions that prevent crop harvesting, animal grazing, and public access for a defined period of time after application until environmental conditions have further reduced pathogens. These site restrictions are summarized in Table WWT.8.

Table WWT.8 Site Restrictions for Class B Biosolids Land Application Wastewater Technology Assessment Report City of Surprise	
Type/Use of Crop	**Restriction[(1)]**
Food Crops with Harvested Parts That Come in Contact with the Biosolids/Soil Mixture	Shall not be harvested for **14 months** after application of biosolids.
Food Crops with Harvested Parts Below the Land Surface	Shall not be harvested for **20 months** after application of biosolids when the biosolids remain on the land surface for **4 months or longer** prior to incorporation into the soil. Shall not be harvested for **38 months** after application of biosolids when the biosolids remain on the land surface for **less than 4 months** prior to incorporation into the soil.
Food Crops with Harvested Parts That Do Not Come in Contact with the Biosolids/Soil Mixture, Feed Crops, and Fiber Crops	Shall not be harvested for **30 days** after application of biosolids.
Animal Grazing	Animals shall not be grazed on the land for **30 days** after application of biosolids.
Turf Growing	Shall not be harvested for **1 year** after application of the biosolids when the harvested turf is placed on either land with a high potential for public exposure or a lawn, unless otherwise specified by the permitting authority.
Public Access	Public access to land with a **high potential** for public exposure shall be restricted for **1 year** after application of biosolids. Public access to land with a **low potential** for public exposure shall be restricted for **30 days** after application of biosolids.
Note: (1) These restrictions are defined in greater detail in 40 CFR 503.	

Class B pathogen reduction requirements may be met through one of the three alternatives outlined in Table WWT.9.

Table WWT.9 Three Alternatives for Meeting Class B Pathogen Requirements Wastewater Technology Assessment Report City of Surprise	
Alternatives[(1)]	**Requirements**
Alternative 1: The Monitoring of Indicator Organisms	Test for fecal coliform density as an indicator for all pathogens. The geometric mean of seven samples shall be less than 2 million MPNs per gram per total solids or less than 2 million colony forming units (cfu) per gram of total solids at the time of use or disposal.
Alternative 2: Biosolids Treated in a Process to Significantly Reduce Pathogens (PSRP)	Biosolids must be treated by one of the PSRPs (see Table WWT.10).
Alternative 3: Biosolids Treated in a Process Equivalent to a PSRP	Biosolids must be treated in a process equivalent to one of the PSRPs, as determined by the permitting authority.
Note: (1) These alternatives are defined in greater detail in 40 CFR 503.	

To meet the requirements for Class B pathogen requirements through Alternative 2, the biosolids must be treated using one of the treatment technologies known as the Processes to Significantly Reduce Pathogens (PSRP) as outlined in Table WWT.10.

Table WWT.10 Processes to Significantly Reduce Pathogens (PSRPs) Wastewater Technology Assessment Report City of Surprise	
Process[(1)]	**Definition**
Aerobic Digestion	Biosolids are agitated with air or oxygen to maintain aerobic conditions for a specific mean cell residence time at a specific temperature. Values for the mean cell residence time and temperature shall be between 40 days at 20° C and 60 days at 15° C.
Air Drying	Biosolids are dried on sand beds or on paved or unpaved basins. The biosolids dry for a minimum of 3 months. During 2 of the 3 months, the ambient average daily temperature is above 0° C.
Anaerobic Digestion	Biosolids are treated in the absence of air for a specific mean cell residence time at a specific temperature. Values for the mean cell residence time and temperature shall be between 15 days at 35-55° C and 60 days at 20° C.
Composting	Using either the within-vessel, static aerated pile or windrow composting methods, the temperature of the biosolids is raised to 40° C or higher and maintained for a 5-day period. The temperature in the compost pile must exceed 55° C.
Lime Stabilization	Sufficient lime is added to the biosolids to raise the pH of the biosolids to 12 for 2 hours of contact.
Note: (1) The treatment processes are defined in detail in 40 CFR 503.	

3.5.2.1 Vector Attraction Reduction

In addition to reducing pathogen levels, EQ, Class A, and Class B requirements mandate that biosolids must undergo treatment to reduce the risk that pathogens can be transmitted via vectors such as flies, mosquitoes, fleas, rodents, and birds. The options outlined in Table WWT.11 achieve vector attraction reduction through either reducing the attractiveness of biosolids to vectors or preventing vectors from coming into contact with the biosolids. In order to qualify as EQ biosolids, one of the first eight vector attraction reduction options in Table WWT.11 must be implemented, while any of the twelve options may be utilized to achieve Class A or Class B biosolids. Note that some of these options may be achieved concurrently using the mechanisms outlined for pathogen reduction.

Table WWT.11 Options for Meeting Vector Attraction Reduction
Wastewater Technology Assessment Report
City of Surprise

Options	Requirements[(1)]
Option 1	Meet 38% reduction in volatile solids content.
Option 2	Demonstrate vector attraction reduction with additional anaerobic digestion in a bench-scale unit.
Option 3	Demonstrate vector attraction reduction with additional aerobic digestion in a bench-scale unit.
Option 4	Meet a specific oxygen uptake rate (SOUR) for aerobically digested biosolids.
Option 5	Use aerobic processes at greater than 40° C for 14 days or longer.
Option 6	Alkali addition under specified conditions.
Option 7	Dry biosolids with no unstabilized solids to at least 75% solids.
Option 8	Dry biosolids with unstabilized solids to at least 90% solids.
Option 9	Inject biosolids beneath the soil surface.
Option 10	Incorporate biosolids into the soil within 6 hours of application to or placement on the land.
Option 11	Cover biosolids placed on a surface disposal site with soil or other material at the end of each operating day (for surface disposal only).
Option 12	Alkaline treatment of domestic septage to pH 12 or above for 30 minutes without adding more alkaline material.

Note:
(1) The treatment processes are defined in detail in 40 CFR 503.

3.5.2.2 Pollutant Concentration Limits

In addition to meeting pathogen and vector attraction reduction requirements, biosolids must also meet heavy metal pollutant concentration limits. All biosolids (EQ, Class A, and Class B) must meet the Ceiling Concentration Limits. The Ceiling Concentration Limits are the maximum concentration limits allowed for 10 heavy metals that can occur in biosolids, including arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc. The values for the Ceiling Concentration Limits are presented in Table WWT.12. In addition, for biosolids to qualify as EQ, they must meet the Pollutant

Concentration Limits presented in Table WWT.12. The Pollutant Concentration Limits are more stringent heavy metal pollutant concentration levels than the Ceiling Concentration Limits. Both the Pollutant and Ceiling Concentration Limits are based on dry weight.

Table WWT.12 Pollutant Limits for Biosolids
Wastewater Technology Assessment Report
City of Surprise

Pollutant	Ceiling Concentration Limits (mg/kg) (1)	Pollutant Concentration Limits (mg/kg) (1)
Arsenic	75	41
Cadmium	85	39
Chromium	3,000	1,200
Copper	4,300	1,500
Lead	840	300
Mercury	57	17
Molybdenum	75	--
Nickel	420	420
Selenium	100	36
Zinc	7,500	2,800

Note:
(1) The pollutant limits are defined in detail in 40 CFR 503.

Table WWT.13 presents a brief summary of the EQ, Class A, and Class B biosolids requirements and associated land application restrictions.

Table WWT.13 Biosolids Classifications and Disposal Options Summary
Wastewater Technology Assessment Report
City of Surprise

	Exceptional Quality	Class A	Class B
Requirement	Fecal coliform density < 1,000 MPN/g total dry solids **or** *Salmonella* density < 3 MPN/4 g total dry solids. Reduce pathogen levels to below detectable limits. Achieve vector attraction reduction via limited options. Must meet monthly average metal concentration limits.	Fecal coliform density < 1,000 MPN/g total dry solids **or** *Salmonella* density < 3 MPN/4 g total dry solids. Reduce pathogen levels to below detectable limits. Achieve vector attraction reduction. Must meet ceiling metal concentration limits and metal loading rates.	Achieve pathogen and vector attraction reduction.
Can be applied to…	Anywhere.	Nurseries, gardens, golf courses, parks, and areas where contact with general public is possible.	Agriculture, landfill, & areas with no potential contact with general public.

3.5.3 Landfill Disposal Regulations

This section briefly reviews the regulatory basis for biosolids disposal in a landfill.

Biosolids from the City's WRFs could potentially be thickened, dewatered, and/or stabilized to recover additional water, separate solids from the water, and ultimately reduce the biosolids volume. If beneficial reuse of the solids is not available or economical, or if the biosolids do not meet the requirements for land application, the biosolids are typically disposed in a municipal landfill.

To be disposed in a solid waste landfill, the biosolids must pass a paint filter test, be non-hazardous and contain less than 50 parts per million of polychlorinated biphenyls. Resource Conservation Recovery Act (RCRA) and the state's solid waste regulations will govern the final disposal for a sanitary landfill. Under current RCRA guidelines, the wastewater plant biosolids must be classified as non-hazardous by passing the Toxicity Characteristics Leaching Procedure (TCLP) test. The TCLP test sets maximum concentration limits on contaminants that are considered toxic. Included in the list is arsenic < 5.0 mg/L and lead < 5.0 mg/L. The presence of any of the listed contaminants at or above the regulatory level deems the substance hazardous and prohibits disposal in a solid waste landfill. Conventional WRF dewatered biosolids typically pass the TCLP test.

Federal waste regulations would also prevent sanitary landfills from receiving any wastes that contain free-flowing liquids as determined by Paint Filter Solids Tests. Wastewater treatment plant residuals generally must have a solids concentration of 18-25 percent to pass this test.

3.5.4 Current Biosolids Trends

The ADEQ is responsible for enforcing the 503 regulations in Arizona. Beyond this jurisdiction, there are no formal restrictions for the land application of biosolids in the State of Arizona. However, a number of counties in California have implemented full or partial bans of Class B biosolids land application. Others have restricted the application of biosolids entirely - regardless of their classification.

As a result of the various bans and restrictions on biosolids application in Southern California and increasing public concern, many Southern California municipalities have resorted to transporting Class B biosolids to agricultural lands in Arizona, where less stringent restrictions exist. Due to the influx of Class B biosolids from California, along with changing land uses throughout the state, the availability of land for application of Class B biosolids in Arizona is continually decreasing. In addition, some Arizona counties are considering restrictions on Class B biosolids land application, similar to those already implemented in California.

Based on the continually changing status of regulations associated with biosolids disposal, any decisions regarding long-term biosolids management practices must carefully consider the dynamics of local biosolids regulations. These changing regulations, and the resulting

availability of application sites, can ultimately have significant impacts on the potential applicability of various biosolids management options.

Applicability of Biosolids Regulations to City of Surprise:

The SPA 1 WRF is currently dewatering WAS and landfilling the solids. This plant, with several modifications/improvements, could produce Class B biosolids. The City is sending biosolids to the landfill for disposal and in the past, when producing Class B biosolids, has land applied a small portion of the biosolids. In the near term, the City should consider achieving Class B biosolids at all WRFs. This will allow the City an opportunity to diversify their biosolids disposal options through land application.

Although it is not anticipated that producing Class A biosolids will become mandatory in the near future, the City's long-term plan includes treating solids onsite through thickening, advanced digestion, and dewatering processes to produce Class A biosolids that can be land-applied. The City should keep potential future regulations in mind when selecting biosolids disposal options and desired biosolids classification for their future water reclamation facilities.

3.5.5 Odor, Noise, and Aesthetic Control Regulations

The Arizona Department of Environmental Quality (ADEQ) has developed specific criteria relative to setback requirements for the design of new water reclamation facilities. These setback requirements are stipulated in the Arizona Administrative Code, Title 18, Chapter 9, Subpart B201.I (A.A.C. R18-9-B201.I), as part of ADEQ's Unified Water Quality Permit process and corresponding Best Available Demonstrated Control Technologies (BADCT) requirements. For facilities larger than 1 mgd, the current setback distances from the nearest property line are as follows:

- 1,000 feet if no odor, noise or aesthetic controls are provided; and
- 350 feet if full noise, odor, and aesthetic controls are provided.

According to ADEQ, "...full noise, odor, and aesthetic control means that all treatment components are fully enclosed, odor scrubbers are installed on all vents, and fencing aesthetically matched to that in the area surrounding the facility." The owner or operator may decrease setbacks if setback waivers are obtained from affected property owners in which the property owner acknowledges awareness of the established setbacks, basic design of the wastewater treatment facility, and the potential for noise and odor.

Noise control is important at the WRFs to help ensure the health and safety of operations staff, and to ensure the facilities are considered "good neighbors" to the surrounding community.

The Maricopa County Department of Environmental Services (MCDES) also has a 30 parts per billion (ppb) fence line limit for acceptable hydrogen sulfide (H_2S) concentrations.

3.5.6 Odor Producing Compounds

Odor-producing compounds found in domestic wastewater are typically small, relatively volatile molecules with molecular weights between 15 and 150. Generally speaking, the lower the molecular weight of a compound, the higher the volatility and potential for emission to the atmosphere. Substances of high molecular weight tend to be less volatile and soluble, but have lower odor thresholds.

Odors generated from domestic wastewater solids are relatively low in concentration, but high in volume (i.e., highly diluted). Most of these compounds result from the anaerobic decomposition of organic matter containing sulfur and nitrogen. Inorganic gases produced from this anaerobic decomposition include hydrogen sulfide (H_2S), ammonia (NH_3), carbon dioxide (CO_2), and methane (CH_4). Other odor-producing substances include organic vapors such as mercaptans, indoles, skatoles, and nitrogen-bearing organics.

The primary offensive odors associated with domestic wastewater are H_2S, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide. These odors are often characterized by the following:

- Hydrogen sulfide - “rotten eggs”
- Methyl mercaptan - “decayed cabbage”
- Dimethyl sulfides - “decayed vegetables”

In liquid stream treatment, odors can be significant at the headworks and primary sedimentation processes, but tend to lessen with each downstream unit process within the treatment facility. Solids processes tend to produce odors at least one order of magnitude greater than the liquid stream.

Although hydrogen sulfide (H_2S) is not the only odorant of concern in wastewater systems, it is usually one of the primary odorants and often the most significant - particularly at plant inlet facilities. H_2S is a colorless gas that is extremely toxic at high concentrations. It is also a precursor to the formation of sulfuric acid, which corrodes metals and concrete. Material selection for new construction will be particularly important to prevent damage within the enclosed areas. Typically, concrete is protected by high-build corrosion-resistant coatings. Equipment, pipe, supports, fasteners, and other appurtenances that must be located within enclosed spaces are typically either stainless steel or a suitable plastic.H_2S typically generates some of the most problematic odor issues (from the public’s perspective), because it can be sensed at very low concentrations by humans. The practical limit of detectability, or odor threshold level, is normally in the range of 1 to 10 parts per billion by volume (ppbv) in air. Therefore, it is imperative that all odor sources be contained and treated to very low outlet concentrations to prevent detection. Conditions leading to H_2S formation generally favor the production of other odorous organic compounds. Thus, solving H_2S problems can often alleviate odors from other compounds as well.

Applicability of Odor, Noise and Aesthetics to City of Surprise:

Odor, noise, and aesthetic control will need to be assessed on a case-by-case basis for the City of Surprise, depending on the available setbacks. The City should plan to have some level of odor, noise, and aesthetic control at each WRF, appropriate for the site-specific conditions.

4.0 WASTEWATER AND BIOSOLIDS TREATMENT STANDARDS

To produce a reclaimed water for beneficial reuse, the City of Surprise has set uniform reclaimed water quality standards for all City water reclamation facilities within the City limits. All future water reclamation facilities shall be designed to achieve these water quality requirements. This section establishes these standards and provides policy justifications and a regulatory basis for each.

4.1 Existing City of Surprise Reclaimed Water Quality Standards

The City's existing effluent quality is governed by the associated WRF Aquifer Protection Permit (APP). Based on the APP requirements, all of the City's existing WRFs produce Arizona Class A+ quality effluent.

4.2 Basis for Establishing New Water Quality Standards

The APP permit defines the alert levels (AL) at 80 percent of the discharge limits for discharge monitoring or 80 percent of the aquifer quality limit (AQL) for groundwater monitoring. It also defines a flow alert level as 95 percent of the flow limit (capacity in average month flow permitted). Exceeding the ALs triggers a series of actions and consequences, as defined in the APP permit. The discharge limits (DLs) and ALs are the regulatory basis for establishing reclaimed water treatment standards.

4.3 City of Surprise Water Quality Standards

Based on the above discussion, the following reclaimed water quality standards were established for the City of Surprise. The City's wastewater treatment facilities shall be designed to meet at a minimum:

- Alert levels, discharge limits, and performance standards defined in the APP
- BADCT requirements
- Arizona Class A+ Reclaimed Water Quality Standards

Table WWT.14 includes a summary of the City of Surprise Reclaimed Water Quality Standards.

Table WWT.14 Summary of Reclaimed Water Quality Standards
Wastewater Technology Assessment Report
City of Surprise

Parameter	BADCT Effluent Limits	Class A+ Effluent Limits	Aquifer Protection Permit SPA-1 WRF[1]					City of Surprise Reclaimed Water Quality Standards
			Discharge Monitoring[2]		Reclaimed Water Monitoring[2]	Groundwater Monitoring[2]		
			Alert Level	Discharge Limit	Discharge Limit	Alert Level	Aquifer Quality Limit	
Effluent Quality Class Requirement	--	--	--	--	--	--	--	Class A+
pH (std)	6.0 -- 9.0	--	--	--	--	--	--	6.0 -- 9.0
DO (mg/L)	--	--	--	--	--	--	--	2.0[3]
BOD_5 (mg/L)	< 30		--	--	--	--	--	< 30
TSS (mg/L)	< 30	--	--	--	--	--	--	< 10[4]
Total Nitrogen (mg/L as N)[5]	< 10	< 10	8	10	10	8	10	< 8
Nitrate (mg/L as N)	--	--	--	--	--	8	10	< 8
Turbidity (NTU)								
Daily (24-hour) average	--	2	--	--	2	--	--	2
Single sample maximum	--	5	--	--	5	--	--	5
Total Coliform (cfu/100 mL)	--	--	--	--	--	Non-detect	Non-detect	--
Fecal Coliform (cfu/100 mL)								
Single sample maximum	23	23	Not established	23	23	Non-detect	Non-detect	23
Seven sample median	2.2	--	--	--	--	--	--	--
Four out of last seven daily samples	--	Non--detect	Not established	Non--detect	Non--detect	Non--detect	Non--detect	Non--detect
TDS (mg/L)	--	--	--	--	--	--	--	1000[6]
Chloride (mg/L)	--	--	--	--	--	--	--	250[6]
Sodium (mg/L)	--	--	--	--	--	--	--	150[6]
Antimony (mg/L)	--	--	0.0048	0.006	--	0.0048	0.006	0.0048
Arsenic (mg/L)	--	--	0.04	0.05	--	0.04	0.05	0.04

Table WWT.14 Summary of Reclaimed Water Quality Standards
Wastewater Technology Assessment Report
City of Surprise

Parameter	BADCT Effluent Limits	Class A+ Effluent Limits	Aquifer Protection Permit SPA-1 WRF[1]					City of Surprise Reclaimed Water Quality Standards
			Discharge Monitoring[2]		Reclaimed Water Monitoring[2]	Groundwater Monitoring[2]		
			Alert Level	Discharge Limit	Discharge Limit	Alert Level	Aquifer Quality Limit	
Barium (mg/L)	--	--	1.60	2.00	--	1.60	2.00	1.60
Beryllium (mg/L)	--	--	0.0032	0.004	--	0.0032	0.004	0.0032
Cadmium (mg/L)	--	--	0.004	0.005	--	0.004	0.005	0.004
Chromium (mg/L)	--	--	0.08	0.1	--	0.08	0.1	0.08
Cyanide (mg/L)	--	--	0.16	0.2	--	0.16	0.2	0.16
Fluoride (mg/L)	--	--	3.2	4.0	--	3.2	4.0	3.2
Lead (mg/L)	--	--	0.04	0.05	--	0.04	0.05	0.04
Mercury (mg/L)	--	--	0.0016	0.002	--	0.0016	0.002	0.0016
Nickel (mg/L)	--	--	0.08	0.1	--	0.08	0.1	0.08
Selenium (mg/L)	--	--	0.04	0.05	--	0.04	0.05	0.04
Thallium (mg/L)	--	--	0.0016	0.002	--	0.0016	0.002	0.0016
Benzene (mg/L)	--	--	0.004	0.005	--	0.004	0.005	0.004
Carbon tetrachloride (mg/L)	--	--	0.004	0.005	--	0.004	0.005	0.004
o-Dichlorobenzene (mg/L)	--	--	0.48	0.6	--	0.48	0.6	0.48
para-Dichlorobenzene (mg/L)	--	--	0.06	0.075	--	0.06	0.075	0.06
1,2-Dischloroethane (mg/L)	--	--	0.004	0.005	--	0.004	0.005	0.004
1,1-Dichloroethylene (mg/L)	--	--	0.0056	0.007	--	0.0056	0.007	0.0056
cis-1,2-Dichloroethylene (mg/L)	--	--	0.05	0.07	--	0.05	0.07	0.05
trans-1,2-Dichloroethylene (mg/L)	--	--	0.08	0.1	--	0.08	0.1	0.08
Dichloromethane (mg/L)	--	--	0.004	0.005	--	0.004	0.005	0.004
1,2-Dichloroproane (mg/L)	--	--	0.004	0.005	--	0.004	0.005	0.004
Ethylbenzene (mg/L)	--	--	0.56	0.7	--	0.56	0.7	0.56

Table WWT.14 Summary of Reclaimed Water Quality Standards
Wastewater Technology Assessment Report
City of Surprise

Parameter	BADCT Effluent Limits	Class A+ Effluent Limits	Aquifer Protection Permit SPA-1 WRF[1]					City of Surprise Reclaimed Water Quality Standards
			Discharge Monitoring[2]		Reclaimed Water Monitoring[2]	Groundwater Monitoring[2]		
			Alert Level	Discharge Limit	Discharge Limit	Alert Level	Aquifer Quality Limit	
Monochlorobenzene (mg/L)	--	--	0.08	0.1	--	0.08	0.1	0.08
Styrene (mg/L)	--	--	0.08	0.1	--	0.08	0.1	0.08
Tetrachloroethylene (mg/L)	--	--	0.004	0.005	--	0.004	0.005	0.004
Toluene (mg/L)	--	--	0.8	1.0	--	0.8	1.0	0.8
Trihalomethanes (total) (mg/L)	--	--	0.08	0.1	--	0.08	0.1	0.08
1,1,1-Trichloroethane (mg/L)	--	--	0.16	0.2	--	0.16	0.2	0.16
1,2,4-Trichlorobenzene (mg/L)	--	--	0.056	0.07	--	0.056	0.07	0.056
1,1,2-Trichloroethane (mg/L)	--	--	0.004	0.005	--	0.004	0.005	0.004
Trichloroethylene (mg/L)	--	--	0.004	0.005	--	0.004	0.005	0.004
Vinyl Chloride (mg/L)	--	--	0.0016	0.002	--	0.0016	0.002	0.0016
Xylenes (Total) (mg/L)	--	--	8.0	10.0	--	8.0	10.0	8.0

Notes:
(1) State of Arizona Aquifer Protection Permit No. P-102478, July 2009
(2) Sampling and Reporting Frequency is Daily, Weekly, Monthly, or Quarterly, as outlined in the APP.
(3) For secondary treatment process control.
(4) Based on a Turbidity < 2 NTU
(5) Based on a 5 sample rolling geometric mean.
(6) Based on City of Phoenix and City of Scottsdale Reclaimed Water Quality Goals. High salinity and sodium will impact the reuse potential as irrigation water. High chloride causes effluent toxicity and could limit the discharge capability.

Based on the reclaimed water quality data provided by the City, TDS, sodium, and chloride are not expected to be an issue for the City in the near term. Adopting these water quality standards requires no treatment in the near term, but provides a longer-term vision regarding review and selection of treatment technologies.

4.4 City of Surprise Biosolids Treatment Standards

Currently, the City is sending all biosolids for landfill disposal. In the short term, the City would like to produce biosolids with a minimum classification of Class B that can be either landfilled or land-applied. Although it is not anticipated that Class A biosolids will become mandatory in the near future, the City's long-term plan includes treating solids onsite through thickening, advanced digestion, and dewatering processes to produce Class A biosolids that can be land-applied. Potential beneficial uses of biosolids to produce commercial composting products or generate energy through anaerobic digestion, cogeneration, fuel cells, or other green technologies are also being considered by the City.

Table WWT.15 presents the near-term and long-term biosolids treatment standards established by the City. These advanced biosolids stabilization technologies can provide further pathogen and volume reductions and cost savings, which may be desirable regardless of the biosolids classification.

Table WWT.15 Biosolids Treatment Standards
Wastewater Technology Assessment Report
City of Surprise

Biosolids Treatment Parameters	USEPA 40 CFR 503	Near-Term Standard Class B Biosolids	Long-Term Standard Class A Biosolids
Arsenic	75	75	75
Cadmium	85	85	85
Chromium	3,000	3,000	3,000
Copper	4,300	4,300	4,300
Lead	840	840	840
Mercury	57	57	57
Molybdenum	75	75	75
Nickel	420	420	420
Selenium	100	100	100
Zinc	7,500	7,500	7,500
Volatile Solids Reduction (%)	Minimum 38%	45%	50%
Fecal Coliform or Salmonella	Depending on Classification of Biosolids	Fecal coliform density < 1,000 MPN/g total dry solids or *Salmonella* density < 3 MPN/4 g total dry solids`	Achieve pathogen and vector attraction reduction

5.0 WASTEWATER QUALITY DATA AND DESIGN CONSIDERATIONS

5.1 Surprise Historical Wastewater Quality Data

Table WWT.16 summarizes the wastewater quality data collected at the City's SPA 1 WRF. These data were evaluated during design of the SPA 1 Plant IV and V and SPA 2 WRF MBR facilities. It is expected that the future WRFs will receive wastewater with similar water quality, with potential industrial impacts and water conservation impacts in some planning areas.

Table WWT.16 Influent Wastewater Quality Design Criteria Wastewater Technology Assessment Report City of Surprise

	Annual Average Day (mg/L)	Maximum Month (mg/L)
Design BOD, mg/L	231	273
Design TSS, mg/L	257	300
Design TKN, mg/L	46.3	54.7

Wastewater strength may vary from one SPA to another. For example, heavy commercial or industrial dischargers planned for a specific area (i.e., SPA 3) could heavily impact the wastewater characteristics, and in turn, the size and design criteria of the treatment facility required (e.g., aeration basin volume and process air for biological treatment). This Wastewater Technology Assessment is focused on providing optimum treatment solutions for the most likely wastewater qualities in the City of Surprise. However, the evaluation does attempt to account for site-specific issues that may impact wastewater quality (such as industrial impacts, water conservation, etc.) through generation of specific design notes and considerations.

5.2 Historical Wastewater Quality for Other Utilities

Table WWT.17 compares the City's proposed wastewater quality design values with the design wastewater concentrations of several other communities in the State of Arizona with similar size WRFs. In general, the Surprise data is consistent with other valley cities.

Table WWT.17 Summary of Similar WRF Maximum Month Design Wastewater Characteristics
Wastewater Technology Assessment Report
City of Surprise

	Phoenix Cave Creek WRF	Mesa-Gilbert Greenfield WRF	Casa Grande WRF	Avondale WRF	Buckeye Sundance WRF	Sahuarita WRF	Surprise SPA 2 (Non-Water Conservation)	Surprise SPA 2 (Water Conservation)(3)
Year of Design	1999	2003	2005	2006	2005	2006	2006	2006
Maximum Month BOD	300	300	266	376	344(1)	368(2)	273	320
Maximum Month TSS	300	375	290	434	--	390(2)	300	351
Maximum Month TKN	48	60	43	67	--	62(2)	54.7	62

Notes:

(1) Average BOD. Comments received from the Maricopa County Environmental Services Department (MCESD) on a recent project.

(2) Annual average concentrations.

(3) Water conservation adds up to 20% to the wastewater strength according to the evaluation performed in during SPA 2 WRF design. Considering the impact of water conservation on the wastewater strength allows the City reasonable operational flexibility in the short term and readiness for the potential increases in wastewater strength in the long term.

5.3 Reclaimed Water Disinfection Byproducts Data

As noted previously in Section 3.1.3, BADCT requires all new sewage treatment facilities to minimize total trihalomethanes (TTHMs) generated as disinfection byproducts to the greatest extent practical, regardless of cost. While there is no current numerical standard for TTHMs in Arizona for reuse, both BADCT and Class A+ Reuse Rules require minimization of TTHMs. For recharge, the A.A.C. R18-11-406 established an AWQS for TTHMs of 0.1 mg/L at the discharge water compliance point for any water discharged to a drinking water aquifer. With rising public concerns regarding health hazards associated with TTHM formation and non-disinfected recharge water, it is anticipated that ADEQ will enact requirements on recharge stream disinfection to go along with the established TTHM compliance in the near future.

The treatment technology evaluation addressed the need to minimize the formation of TTHMs and HAAs to the greatest extent possible to maintain recharge/reuse flexibility for the City.

5.4 Reclaimed Water Salinity Data

Table WWT.18 summarizes the SPA 1 reclaimed water TDS and hardness data. The average TDS is less than 600 mg/L and the maximum is less than 780 mg/L. It is not expected that similar salinity levels would impact the City's reclaimed water reuse potential in the near future.

Table WWT.18 Reclaimed Water Data from SPA 1
Wastewater Technology Assessment Report
City of Surprise

Sample Date	Ca Hardness (mg/L)	Mg Hardness (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	pH	Temp °C
1/7/2008	55	33	88	568	7.9	5.6
2/1/2008	60	33	93	606	7.8	4.3
2/15/2008	57	29	86	560	7.6	15.2
2/28/2008	55	33	88	577	7.8	22.8
3/14/2008	62	33	95	574	7.8	11.8
3/26/2008	60	33	93	606	7.4	30.9
4/11/2008	57	29	86	403	7.6	18.4
4/25/2008	62	33	95	776	7.7	14
5/9/2008	60	33	93	654	7.6	21.6
5/22/2008	58	32	90	624	7.6	24.3
Average	**58.6**	**32.1**	**90.7**	**594.8**	**7.68**	**16.9**

For any reclaimed water that is recharged through infiltration basins or ASR wells, the City must consider the potential impacts that reclaimed water can have on groundwater sources in the future.

5.5 Impacts of Water Conservation and Industrial Wastes

The USEPA Energy Policy Act of 2005 provides guidance on the use of water-conserving plumbing fixtures to reduce water use in residential, commercial, and institutional buildings. Minimum water efficiency requirements defined in the energy policy act must be met. Use of water conservation plumbing and fixtures for individual residential water users is encouraged. It is anticipated that mandatory minimum water efficiency will become more stringent in the future.

The USEPA guideline entitled “Cleaner Water through Conservation” (USEPA 841-B-95-002, April 1995) explored a number of water use efficiency practices. Many researchers have evaluated these practices, and there is a growing body of literature that presents the results of many studies related to water use efficiency.

Installation of water-efficient fixtures and equipment can result in significant, long-term financial and environmental savings. These practices include low-flush toilets, no-water-using urinals, composting toilets, toilet displacement devices, low-flow showerheads, faucet aerators, and pressure reduction devices.

Industrial/commercial users can apply a number of conservation and water use efficiency practices. Users in the other water use categories can also apply some of these practices. These practices include water reuse and recycling, cooling water recirculation, and the use of automatic leak detection.

It is expected that water conservation practices will reduce the wastewater flow and increase the wastewater strength. Recent experience suggests that many rapidly growing communities have encountered increases in wastewater strength resulting from the use of low-flow plumbing fixtures (i.e., low-flush toilets, low-flow showerheads, faucet aerators, etc.) or other behavioral changes (i.e., increased use of garbage disposals, etc.) Based on the typical breakdown of residential indoor water uses provided in the USEPA “Cleaner Water Through Conservation” document (Chapter 1 How We Use Water In These United States, and Chapter 3 How to Conserve Water and Use It Effectively), it was estimated during the SPA 2 WRF design that such reductions in flow can increase wastewater strength 15 to 40 percent.

The resulting increases in wastewater strength (and parallel decreases in flow) can pose significant challenges associated with operation of facilities outside of original design criteria and can result in facility capacity limitations. Consequently, this factor must be considered during wastewater treatment design. The City should continue to monitor wastewater characteristics relative to historical data and original WRF design criteria to ensure efficient operation of existing WRFs and adequate design of future facilities. This factor must be considered during wastewater treatment design.

Industrial waste discharge may change the wastewater characteristics dramatically. Depending on the type of industry, the impacts on individual water quality parameters may vary. Typically, such discharges may increase the COD dramatically and result in a high

COD:BOD ratio. This reduces the biological degradable fraction of the wastes and poses challenge to the biological process. Industrial discharge may also impact the BOD:TKN ratio and increase the complexity of biological wastewater treatment. As a result, pretreatment may be required or an external carbon or nitrogen source may be needed. Some types of industries may discharge material that may be toxic and interfere with the biological process. Even simple food processing factories may discharge high concentrations of salt and affect the wastewater salinity. The flows, contaminant levels, and blending from industrial wastes must be considered.

In 2006, the USEPA developed WaterSense, a program that seeks to protect the future of our nation's water supply by promoting water efficiency. WaterSense helps consumers identify water-efficient products and programs that meet established water efficiency and performance criteria. WaterSense has approved ultra-low flow fixtures, which further decrease wastewater flows and increase wastewater strength.

The SurpriseTree™ Wastewater Model recognizes water conservation and industrial waste impacts on wastewater treatment. The model provides design considerations and recommendations related to industrial and water conservation impacts when users specify the wastewater quality or dictate the level of impacts.

Applicability of Water Conservation and Industrial Wastes to City of Surprise:

Recent experience suggests that many rapidly growing communities have encountered increases in wastewater strength resulting from the use of low-flow plumbing fixtures (i.e., low-flush toilets, low-flow showerheads, faucet aerators, etc.) or other behavioral changes (i.e., increased use of garbage disposals, etc.) To some extent, the influent data collected from the SPA 1 WRF reflects this trend (i.e., the observed increase of influent BOD, TSS, and TKN concentrations since winter 2005 are most likely a result of the implementation of low-flow fixtures in the SPA 1 residential development areas.)

It is important to consider the impact of water conservation on the City's WRF design. For example, the City anticipates that the SPA 2 service area will be comprised primarily of residential and commercial development. Currently, the City does not have low-flow plumbing requirements. However, it is the City's intention to implement water conservation practices on all new residential development in the future. It is expected that these requirements will reduce wastewater flow while increasing the concentrations of the wastewater constituents by 17 to 34 percent.

5.6 Water Quality Constituents of Concern

The following summarizes the critical and potential water quality constituents of concern (CoC) for the City of Surprise reclaimed water supply system:

- **Critical CoC**: TSS, BOD, TKN, turbidity, fecal coliform, TTHMs and HAAs.
- **Potential Future CoC**: TDS, chloride, and sodium.

5.6.1 Critical Constituents of Concern

Based on a review of existing water quality data, a list of critical CoC were identified including TSS, BOD, TKN, turbidity, fecal coliform, TTHMs, and HAAs. The City's water reclamation facilities shall be designed to sufficiently remove these contaminants to achieve the established reclaimed water treatment standard. Table WWT.19 summarizes these CoC and their treatment standards. The Wastewater Technology Assessment Report will focus on the treatment processes required to address these critical CoC.

Table WWT.19 also includes critical CoCs that may limit the reuse / recharge potential of the reclaimed water. These parameters include disinfection byproducts, such as TTHMs. Currently, there are no numerical standards for TTHMs or HAAs in the BADCT or Class A+ reuse rules. However, a standard for TTHMs is established in the City's current APP for the SPA 1 WRF. Treatment standards for these parameters were established for the City based on meeting the APP discharge limits. The Wastewater Technology Assessment Report will evaluate technologies that can assist in achieving these standards.

Table WWT.19 City of Surprise Reclaimed Water Quality Constituents of Concern
Wastewater Technology Assessment Report
City of Surprise

Parameter	BADCT Effluent Limits	Class A+ Effluent Limits	APP SPA 1 WRF(1)	City of Surprise Reclaimed Water Quality Standards
Critical Constituents of Concerns				
BOD_5 (mg/L)	< 30	--	--	< 30
TSS (mg/L)	< 30	--	--	<30
Total Nitrogen (mg/L as N) (4)	< 10	< 10	8(2)	< 8
Turbidity (NTU)				
Daily (24--hour) average	--	2	2(3)	< 2
Single sample maximum	--	5	5(3)	< 5
Fecal Coliform (cfu/100 mL)				
Single sample maximum	23	23	23(3)	23
Seven sample median	2.2	--	--	2.2
Four out of last seven daily samples	--	Non-detect	Non-detect(3)	Non-detect
THM (mg/L)	--	--	0.08	0.08

Notes:
(1) State of Arizona Aquifer Protection Permit No. P-102478, July 2009. Sampling and reporting frequency is Daily, Weekly, Monthly or Quarterly, as outlined in the APP.
(2) Discharge Monitoring Alert Level.
(3) Reclaimed Water Monitoring Discharge Limit.
(4) Based on a five-sample rolling geometric mean.

5.6.2 Potential Constituents of Concern

Other contaminants such as salinity, sodium, and chloride may become a concern for the City's reclaimed water reuse potential in the future. These parameters are not anticipated to be an issue in the near term. However, as the City grows, the impacts of these parameters may become more severe. For example, sodium may limit the reuse potential for irrigation purposes. Consequently, it is recommended that the City develop and maintain a reclaimed water sampling program to routinely monitor these parameters. The list of potential CoC should be revisited when updating the IWMP and the Wastewater Technology Assessment Report in the future.

6.0 TREATMENT PROCESS EVALUATION

This section evaluates potential wastewater treatment processes for treating the CoC in the City's wastewater sources to achieve the established reclaimed water quality standards.

6.1 Categories of Treatment Technologies

The wastewater CoC and associated treatment standards were identified and established in Section 5.6. These CoC include:

- **Critical CoC**: TSS, BOD, TKN, turbidity, fecal coliform, TTHMs and HAAs.
- **Potential Future CoC**: TDS, chloride, and sodium.

Table WWT.20 summarizes the treatment categories that are anticipated for the City's WRFs. More than one treatment step is required to remove or control all the above CoC. For a given WRF, several categories, including preliminary treatment, grit removal, primary treatment, BOD and nitrification-denitrification treatment, clarification, filtration, and disinfection, may be required to treat the identified critical and potential CoC in the City's wastewater and achieve the established reclaimed water standards.

As illustrated in Table WWT.20, different treatment categories target different CoC. For example, preliminary treatment can help improve the removal of TSS, BOD, and turbidity and assist in nitrification-denitrification processes. Filtration is effective in reducing pathogens and turbidity. Disinfectants protect water from microbial contamination (total coliform, virus, etc.) and protect against contamination in the reclaimed water distribution system. Strictly speaking, while DBPs are not the target CoC (rather byproducts) for the disinfection treatment category, their control is closely related with this treatment category.

Ultimately, the treatment technologies selected and the facility design must be based on achieving the applicable water quality regulations outlined in Section 3.0, reclaimed water quality goals established in Section 4.0, and end use of the reclaimed water as outlined in Section 3.0.

Table WWT.20 Categories of Treatment for Wastewater and the Identified Constituents of Concern
Wastewater Technology Assessment Report
City of Surprise

Treatment Categories	Target CoC or Related Issues											
	TSS	BOD	Nitrogen-Denitrification	Turbidity	Pathogens	DBPs	Volatile Solids Reduction	Biosolids Pathogen Reduction	Biosolids Volume Reduction	H_2S Odor	Ammonia Odor	Reduced Sulfides Odor
Preliminary	X	X	X	X								
Grit Removal	X	X	X	X								
Primary	X	X	X									
BOD and N-DeN	X	X	X	X								
Clarification	X	X	X	X								
Filtration				X	X							
Disinfection					X	X(1)						
Odor Control										X	X	X
Biosolids Thickening									X			
Biosolids Dewatering									X			
Biosolids Stabilization							X	X	X			
Advanced Biosolids Stabilization							X	X	X			

Note:
(1) Strictly speaking, DBPs are not the target CoC (rather byproducts) for the disinfection treatment category. DBP control is closely related with this treatment category.

Generally speaking, mitigation strategies to reduce the formation of DBPs include reducing TOC concentrations in the reclaimed water prior to chlorine addition, delaying chlorine addition, and reducing the applied chlorine dose (while still maintaining required levels for disinfection). Strategies for reducing DBP concentrations in the reuse water distribution system include minimizing water age in the storage reservoirs and optimizing chlorine residuals in the system (while still maintaining required residual concentrations). The proposed treatment categories (such as primary treatment, secondary clarification, tertiary filtration, etc.) produce biosolids that must be handled/disposed. Biosolids treatment technologies are discussed in Section 7.0.

6.2 Treatment Technology Prescreening

In order to determine the most applicable and beneficial wastewater treatment technologies for the City of Surprise, four principals were used to prescreen each of the treatment technology alternatives:

1. Technology alternatives must be capable of achieving the established treatment standards for the City.
2. Technology alternatives must be established, proven technologies that can be reliably implemented at full-scale without significant additional testing.
3. In general, technology alternatives were evaluated based on the contaminant removal mechanism. Individual manufacturers/equipment/commercial names were referenced, but generally not evaluated individually.
4. Technology alternatives that have specific local experience/application or which the City has indicated specific interest in were generally included in the evaluation.

Table WWT.21 summarizes the prescreened treatment technology alternatives for each treatment category discussed above. Input from the City and the developer representatives are incorporated into the table. Each of the noted technology alternatives was considered a potentially viable option for the City's wastewater treatment and was recommended for further evaluation.

6.3 Three-Tier Technology Assessment

Sections 6.4 through 6.11 provide a detailed description for each of the prescreened liquid stream treatment technology alternatives, and Section 7.0 provides a detailed description for each of the prescreened biosolids treatment technology alternatives listed in Table WWT.21. The sections include a general description of each technology, why it is applicable for the City's WRFs, how it works, and what critical implementation considerations may impact its applicability. Additional details associated with each technology can be found in the presentation material developed for Workshop TA3 Wastewater Treatment Technology Evaluation (see Appendix A).

Table WWT.21 Prescreened Treatment Technology Alternatives Wastewater Technology Assessment Report City of Surprise		
Treatment Categories	**Prescreened Treatment Technology Alternatives**	**Functions**
Preliminary Treatment	• Coarse screens • Fine screens	Preliminary treatment protects the downstream treatment processes and equipment by removing large debris, assists in maximizing the associated treatment efficiency, and minimizes downstream operational and maintenance issues.
Grit Removal	• Aerated grit chamber • Free vortex grit chamber • Mechanical vortex grit chamber • Horizontal flow chamber	Grit removal physically removes heavy, abrasive, inorganic solids from the flow stream. The removal of such grit is important to protect the downstream process equipment from excessive wear, reduce the formation of deposits in pipeline and process basins, and reduce solids handling.
Primary Treatment	• Primary clarification	Primary treatment reduces the load on the downstream biological treatment system by removing TSS and BOD.
BOD Removal and N-DeN Process	• Extended aeration • Sequencing batch reactor (SBR) • Trickling filters • Activated sludge • Integrated fixed film activated sludge (IFAS) • Membrane bioreactor (MBR)	The function of the biological treatment process is to remove BOD, COD, TSS, suspended and non-settleable colloidal solids, nitrogen, and phosphorous from the wastewater to below acceptable effluent limits.
Secondary Clarification	• Circular clarifier • Rectangular clarifier • Dissolved air flotation • Ballasted flocculation	The main purpose of secondary clarification is to separate the treated water from the activated sludge from the biological process.
Filtration	• Granular media filters • Cloth media filters • Microfiltration / ultrafiltration (MF/UF)	The purpose of tertiary filtration is to remove suspended solids and to provide a high-quality filtrate. Tertiary filtration is a vital component in producing required Class A+ effluent.
Disinfection	• Gaseous chlorine disinfection • Sodium hypochlorite onsite generation disinfection • Sodium hypochlorite bulk disinfection • Chloramines disinfection • Ultraviolet disinfection • Ozonation(1)	Disinfection processes protect public safety by killing and inactivating pathogens (i.e., bacteria, viruses, *Cryptosporidium*, *Giardia)* in reclaimed water. Selection of disinfection technologies must also consider impacts on DBP formation.

Table WWT.21 Prescreened Treatment Technology Alternatives Wastewater Technology Assessment Report City of Surprise		
Treatment Categories	**Prescreened Treatment Technology Alternatives**	**Functions**
Odor Control	• Chemical (e.g., ferric chloride, ferrous chloride) addition • Wet chemical scrubber • Biofiltration • Carbon absorption • Odor removal through ion addition	Odor control reduces odors emitted from wastewater treatment facilities. The main treatment categories contributing odors include headworks, secondary treatment, and solids handling.
Biosolids – Thickening	• Dissolved air flotation • Gravity thickener • Gravity belt thickener • Rotary drum thickener • Centrifuge thickening	Thickening processes reduce the volume of biosolids prior to dewatering, and/or stabilization and final disposal.
Biosolids - Dewatering	• Drying beds • Belt filter press • Centrifuges	Dewatering processes reduce the volume of biosolids prior to final disposal.
Biosolids - Stabilization	• Aerobic digestion • Second generation ATAD • Conventional anaerobic digestion • Temperature phased anaerobic digestion • Multi-phase (acid / gas) anaerobic digestion • Multistage thermophilic • Cannibal® process • Air drying • Heat drying • Composting	Biosolids stabilization processes provide pathogen reduction, vector attraction reduction, and solids reduction of biosolids prior to final disposal.
Note: (1) Besides disinfection, ozone and other oxidants may also be used to enhance efficiencies of other treatment categories, such as the performance of the biological process and membrane flux. Refer to Section 6.10.7 for more details.		

Based on the detailed evaluation in Sections 6.4 through 6.11 and input from the City and developer representatives, the original alternatives were further narrowed to a list of recommended alternatives for potential implementation. These recommended treatment technology alternatives were further evaluated using the SurpriseTree™ Wastewater Model (see Section 8.0) by comparing the treatment processes using a three-tier evaluation consisting of:

- Performance based criteria evaluation, utilizing a set of criteria established to identify the effectiveness of a treatment process in removing target CoC.
- Implementation based criteria evaluation, focusing on the ability to effectively implement each treatment technology.
- Financial evaluation, focusing on the financial impacts of each treatment technology.

The performance based criteria evaluation utilizes a set of criteria established to identify the effectiveness of a treatment process in removing target CoC. As defined in Table WWT.22, these criteria include TSS removal, BOD removal, nitrification-denitrification processes, turbidity removal, pathogen removal, and DBP control.

Table WWT.22 Treatment Process Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Performance Criteria	Definition / Description
TSS Removal	Does this option remove or help to improve the removal efficiency of TSS?
BOD Removal	Does this option remove or help to improve the removal efficiency of BOD?
Nitrification – Denitrification Processes	Does this option assist or help to assist in the nitrification and denitrification processes?
Turbidity Removal	Does this option remove or help to improve the removal efficiency of particles? Is it subject to fouling by particles?
Pathogen Removal	Does this option provide log-removal credits for pathogens? Does this process help to improve the pathogen kill by other processes?
DBP Control	Does this option reduce the formation of chlorinated DBPs? Does this option produce other non-chlorinated DBPs (e.g., bromated) and emerging (non-regulated) DBPs?
Volatile Solids Reduction	Does this option provide volatile solids reduction in the biosolids?
BS Pathogens	Does this option provide biosolids pathogen reduction?
BS Volume Reduction	Does this option provide biosolids volume reduction?
H_2S Odor	Does this option remove or help to improve H_2S odor?
Ammonia Odor	Does this option remove or help to improve ammonia odor?
Reduced Sulfides Odor	Does this option remove or help to improve reduced sulfides odor?

A table summarizing the performance of each treatment alternative relative to each of these criteria is included at the end of each section.

The implementation based criteria evaluation focuses on the ability to effectively implement each treatment technology. The City and the developer's representatives participated in the development of these criteria. Compared to the performance-based criteria, these criteria are more comprehensive, covering technical, environmental, economical, and social aspects. As defined in Table WWT.23, this set of criteria includes O&M Costs, Capital Costs, Process Robustness, Maturity of Technology, City of Surprise Familiarity, Maintenance Intensity, Operation Flexibility, System Complexity, Process Footprint, Regulatory Requirements, Risks and Safety, Residuals Impacts/Handling, Versatility, Expandability, Odor, Energy Savings, and Air Quality Impacts. Class A biosolids criteria applies to biosolids treatment only.

Table WWT.23 Treatment Process Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Water Process Screening Criteria	Definition / Description
O&M Costs	What are the annual operation and maintenance cost for the alternative?
Capital Costs	What are the equipment costs, initial installation costs, and construction costs for the alternative?
Process Robustness	Does the alternative provide sufficient treatment stability with expected wastewater quality variations? Is it more reliable than the other alternatives?
Maturity of Technology	Is the alternative mature in design and operation?
City of Surprise Familiarity	Does the City of Surprise have operational experience with this alternative? Is the City's operation staff familiar with the process?
Maintenance Intensity	What are the maintenance requirements for the alternative?
Operation Flexibility	Does the alternative allow flexible operation to meet process control goals?
System Complexity	How complex is the equipment and required operation of the alternative?
Process Footprint	How much land area is required for the alternative?
Regulatory Requirements	How much regulatory coordination effort is associated with implementation and operation of the alternative?
Risks and Safety	Does the alternative have concerns associated with process safety such as hazardous material handling and process risk management?
Biosolids	What volume/type of biosolids are produced by the alternative? How can the biosolids generated by this alternative be treated compared to other alternatives? Does the alternative produce low ammonia content in digested sludge, (i.e., low ammonia concentration in centrate after dewatering)? Can the additional load of centrate ammonia be accommodated by the plant liquid stream treatment process, when returned to the headworks?
Versatility	Is the alternative versatile in removing multiple contaminants, including emerging concerns?

Table WWT.23 Treatment Process Implementation Based Criteria Wastewater Technology Assessment Report City of Surprise	
Water Process Screening Criteria	**Definition / Description**
Expandability/Ultimate Capacity	Does the alternative provide a configuration that allows easy future expansion using a module design concept (to accommodate the ultimate treatment capacity on the site)?
Odor Control	Does the alternative require an odor control facility? What is the efficiency of the odor control system associated with the alternative?
Energy Savings	Does the alternative have any energy saving features or produce reusable energy byproduct?
Air Quality Impacts	What volume/type of air pollutants/emissions does the alternative generate?
Class A Biosolids	Will the alternative be capable of producing Class A biosolids?

A table summarizing the implementation of each treatment alternative relative to each of these criteria is included at the end of each section.

The financial based criteria evaluation focuses on the financial impacts of each treatment technology. Treatment technologies are compared to each other based on a dollar per gallon of wastewater treated basis. As defined in Table WWT.24, this set of criteria includes Capital Costs, O&M Costs, and Life Cycle Costs.

Table WWT.24 Treatment Process Financial Based Criteria Wastewater Technology Assessment Report City of Surprise	
Financial Criteria	**Definition / Description**
Capital Cost	What are the equipment costs, initial installation costs, and construction costs for the alternative?
Operation and Maintenance Cost	What are the annual operation and maintenance cost for the alternative?
Life Cycle Cost	What are the capital costs plus O&M costs over a 20-year period for the alternative?

6.4 Preliminary Treatment Technologies

Raw wastewater from the collection system must be screened prior to entering the biological treatment process to remove items such as rags, fibers, and other large debris. Influent screening protects the downstream treatment processes and equipment, assists in maximizing the associated treatment efficiency, and minimizes downstream operational and maintenance issues.

A wide variety of coarse and fine screens are available for preliminary treatment depending on the degree of removal desired. Coarse screens generally have openings from 6 inches to 1/2 inch (150 mm to 6 mm), while fine screens have openings 1/2 inch to 1/25 inch (6 mm to 1 mm). Coarse screens will allow more rags and solids to pass through, while fine screens generally remove a greater degree of smaller debris. A screen with a 1/2-inch opening removes coarse particles of greater than 1/2 inch in size from the influent flow.

The screenings materials for coarse and fine screens include parallel bars, rods or wires, grating, wire mesh or perforated plates. The shapes of the openings are commonly rectangular or circular. Coarse screens are usually parallel bars and fine screens are usually perforated plates, steel mesh, or wedge wire materials.

Redundancy in screening is recommended. To achieve redundancy in screening, an additional standby screen can be provided or a bypass channel with a manually cleaned screen can be provided.

6.4.1 Coarse Screening

	• Coarse screening provides protection for downstream treatment processes from large debris. • Coarse screens typically have an opening size between 1/2 inch to 6 inches.

Coarse screens generally have openings greater than 1/2 inch. Some method of coarse screening should be used at every WRF to protect the treatment processes from large debris. The coarse screening alternatives discussed in this section include trash racks, manually cleaned screens, and mechanically cleaned bar screens. Additional details associated with each technology can be found in Appendix A.

6.4.1.1 Trash Racks

Trash racks are designed to prevent logs, timbers, and other large debris from entering pumping equipment or treatment processes. Trash racks typically have an opening size of 1/2 inch to 6 inches.

6.4.1.2 Manually Cleaned Bar Screens

Manually cleaned bar screens typically have an opening size of 1 inch to 2 inches. The bar configuration is typically set at a 30- to 45-degree angle from vertical to facilitate cleaning of the screen. The primary uses of manually cleaned bar screens are in older or smaller treatment facilities, or in bypass channels. Manually cleaned bar screens can require significant operator attention, and thus typically have a high associated O&M cost.

6.4.1.3 Mechanically Cleaned Bar Screens

Mechanically cleaned bar screens typically have an opening size of 1/2 inch or larger. This type of screen is self-cleaned and is ideal for deep influent channels that would be extremely difficult to clean manually. Mechanically cleaned bar screens are able to withstand high screenings loads due to the relatively high screenings removal rates. This type of screen is capable of treating high wastewater flow rates with a low head loss across the screen.

Two considerations for mechanically cleaned screens include the type of drive and rake orientation:

- **Drives:** There are several types of mechanical bar screens available in today's market (i.e., chain-operated, reciprocating rake, etc.). The pin rack/cogwheel-operated design is recommended. With this type of drive, the drive assembly is not submerged, the unit is supported at the top and bottom, and routine maintenance is limited to lubrication at the operating floor level.
- **Rake Orientation:** There are two principal rake orientations available: front-cleaned and back-cleaned. With a back-cleaned unit, the bars are protected from damage by the debris. However, the unit is typically less rugged - generally more susceptible to solids carryover to the downstream side (as the wipers wear out) - and the top of the unit is unsupported to allow pass-though of the rake tines. With a front-cleaned unit, the screen is generally more efficient in retaining captured solids.

Many different configurations of mechanically cleaned bar screens are available. The mechanically cleaned bar screens discussed in this section include catenary and chain driven rake, reciprocating rake, continuous belt, and spiral screen.

6.4.1.3.1 <u>Catenary and Chain Driven Rake</u>

Catenary type screens have a front clean, front return, chain drive cleaning mechanism. The only submerged moving part of the screen is the chain. This type of screen requires small amounts of headroom and requires a relatively large footprint. Catenary screens have an open configuration, which may make odors more difficult to contain/treat.

6.4.1.3.2 <u>Chain Driven Rake</u>

Chain driven rake type screens have multiple chain drive cleaning configurations: front clean, front return; front clean, back return; and back clean, back return. This type of screen is good for heavy-duty screening applications but has submerged moving parts that may

require dewatering of the channel for maintenance purposes. Chain driven rake screens are also susceptible to screenings carryover or rake jam. This type of screen requires a relatively large footprint.

6.4.1.3.3 Reciprocating Rake (Climber)

The mechanical climber-type bar screen is a reliable screening device used in many wastewater treatment plants. The climber-type bar screen rakes solids from the screen at regular intervals. The reciprocating rake screen imitates the movement of manually raking the screen. While the rake device can handle large objects, grit accumulation may impede rake movement. Reciprocating rakes require more headroom than other screens. A benefit to this type of screen is that there are no submerged moving parts, thereby minimizing maintenance requirements.

6.4.1.3.4 Continuous Belt

Continuous belt type screens require flow to pass through the screens twice. Screen cleaning is critical to the performance of the screen. Perforated plates are used for the screen material. The continuous belt screen is a fairly compact design with a low installation height. This screen type can be completely encased for odor control withdrawal.

6.4.1.3.5 Spiral Screen

Spiral screens provide an economical screening method with integral compaction solids handling component. The spiral screen configuration is typically 35 to 45 degrees from vertical. Spiral screens can be channel mounted or tank mounted. Spiral screens can be fully enclosed for odor control.

6.4.1.4 TSS Removal

Coarse screens are capable of removing some TSS. The smaller the opening size, the more TSS removal will occur. TSS removal is not a primary function of coarse screens; but it helps to improve the performance of downstream TSS removal process.

6.4.1.5 BOD Removal

Coarse screens cannot remove much BOD. As the opening size reduces, some BOD removal may occur. However, BOD removal is not a primary function of coarse screens. In fact, screen handling equipment such as screen washers are designed to reduce the BOD content in the screening wastes and release the BOD back to the wastewater stream.

6.4.1.6 Odor Control

Coarse screens will generate odors. Some types of screens can be fully enclosed to promote easy draw off of foul air for odor control directly from the source. Odor control may be required, depending on site setbacks available. Refer to Section 6.11 for a description of odor control technologies and their applicability to screening.

Anticipated Performance of Coarse Screening for the City of Surprise

Coarse screens provide protection of downstream treatment processes from large debris and are capable of removing some TSS and BOD. Coarse screening is **recommended** for every WRF. Mechanically cleaned coarse screens are **recommended** for the City's consideration and are included for further evaluation using the SurpriseTree™ Wastewater Model. Trash racks and manually cleaned bar screens are **not recommended** for the City's regional WRFs due to the large amount of maintenance required to maintain these screens.

6.4.2 Fine Screening

- Fine screening assists in maximizing the associated treatment efficiency in downstream processes.
- Fine screens typically have an opening size less than 1/2 inch.
- Fine screens are required prior to MBR treatment processes.

Fine screens are capable of achieving a greater removal of solids compared to coarse screens. Fine screens can be used in place of or following coarse screens where a greater removal of solids is required. Fine screens generally have openings less than 1/2 inch. The perforations of fine screens are configured in a V or wedge wire, perforated plate, or woven mesh. Fine screens may eliminate the need for primary clarification. Fine screen alternatives discussed in this section include inclined (static), rotary drum screens, step/stair screens, band/belt fine screens, and ultra fine screens. Additional details associated with each technology can be found in Appendix A.

6.4.2.1 Inclined (Static) Screen

Inclined static screens are most applicable for small capacity plants with low screenings loadings. This type of screen can be very economical as there are no mechanical components. Inclined screens are typically in a wedge wire configuration with openings from 0.01 inch to 0.2 inch. Cleaning is performed manually using high-pressure hot water, steam, or a degreaser. The inclined static screen is designed for pumped flow applications.

6.4.2.2 Rotary Drum Screen

Rotary drum screens are rotating screens consisting of wedge wire or perforated plates with opening sizes ranging from 0.5 to 6 mm. The drum screens consist of a rotating perforating drum with a transport screw, which transports the separated solids out of the drum. The internal drum typically rotates on wheels and operates by a cog gear motor. Drum screens can be internally or externally fed. For internally fed screens, the flow enters the end of the drum and screenings are collected inside the drum and conveyed to a discharge point. The

screened wastewater flows out of the drum. For externally fed screens, the flow enters the top of screen and screenings are collected on the outside of the drum and conveyed to a discharge point. The screened wastewater flows into the drum. Internally fed screens have a higher hydraulic capacity compared to externally fed screens.

Rotary drum screens are an economical fine screen alternative. These screens are designed for pumped flow applications where the water must be pumped over an influent weir and into the drum of the screen. Blinding can occur on the screen surface. Blinding can generate additional head loss through the screen but can also provide additional filtering through smaller openings than the actual screen size. Rotary screens can be applied in channel or in vessel applications. A rotary screen can provide the required protection for membrane pretreatment. Rotary drum screens can be fully enclosed and the flow channels to and from the screens can be covered to control odors.

6.4.2.3 Step/Stair Screen

Step screens, also known as stair screens, can be sized down to 3-mm openings. The screened material on the screen face enhances the screening process by capturing particles smaller than the actual screen opening size. The step screen removes the screenings by stepping them up to a discharge point. These types of screens are best applied for deep channels and are typically installed at an angle of 40-57 degrees from vertical.

Step screens are capable of screening high flows at a low head loss across the screen. These screens are also capable of handling a high screenings load. This type of screening technology has a proven record of reliable operation and long operation life. A flush bottom base plate design of the screen prevents solids accumulation at the base of the screen.

6.4.2.4 Belt/Band Screen

Band screens, also known as belt screens, have openings as fine as 2 mm. Band screens have a center feed design point, which eliminates solids carry over. Band screens are relatively compact, requiring a reasonably small footprint. A band screen can provide required protection for membrane pretreatment, although most MBR manufacturers prefer rotary drum screens due to their ability to minimize bypass of solids.

6.4.2.5 Ultra Fine Screens

Ultra fine screens typically have an opening size of 0.06 to 0.25 inch (0.2 to 1.5 mm). The small opening size of this type of screen allows for new applications of screens. Ultra fine screens are placed after coarse or fine screens, but cannot be used as the sole screening mechanism due to the likelihood of the screen clogging or blinding. Ultra fine screens are capable of reducing suspended solids to level near those achieved by primary clarification, thus requiring one less treatment process. Ultra fine screens are ideal for membrane bioreactor pretreatment as it provides reliable separation of hairs and fibrous material.

Ultra fine screens are capable of reducing COD, BOD, and organics. Ultra fine screens may be beneficial in reducing COD, BOD, and organics when discharging into a receiving watercourse at a river or ocean outfall. Coagulants can be added in front of ultra fine screens to further improve the screens efficiency, including up to 95 percent filterable solids, 65 percent COD and BOD, and 60 percent phosphorous.

6.4.3 MBR Process Screening

As debris in the flow stream could damage membrane fibers, fine screening is required by membrane manufacturers to remove the debris and protect the downstream membranes. Based on requirements from MBR manufacturers, fine screening systems should have a maximum opening size of 1 to 2 mm. In addition, the screens should be equipped with a perforated plate style screen to better screen stringy or fibrous material that could collect in the MBR basins. These fibers could ultimately tangle around the membrane fibers, affecting the operation of the system and the life span of the membranes. A coarse screen should be provided prior to the fine screening to prevent the large debris from blinding the fine screen.

6.4.4 TSS Removal

Fine screens are capable of removing TSS and help to improve the performance of downstream TSS removal process. The smaller the opening size, the more TSS removal will occur. For example, 3-mm screens typically remove 25 to 45 percent TSS.

6.4.5 BOD Removal

Fine screens are capable of removing some BOD. The smaller the opening size, the more BOD removal will occur. For example, 2-mm screens typically remove 25 to 50 percent BOD.

6.4.6 Odor Control

Fine screens will generate odors. Some types of screens can be fully enclosed to promote easy draw off of foul air for odor control directly from the source. Odor control may be required, depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to screening.

Anticipated Performance of Fine Screening for the City of Surprise

Fine screens provide protection of downstream treatment processes from small debris and are capable of removing some TSS and BOD. Fine screens including step screens and rotary drum screens are **recommended** for the City's consideration and are included for further evaluation using the SurpriseTree™ Wastewater Model. 2-mm fine screening is required if MBR is selected as the BOD and nutrient removal process. Inclined static screens, band screens, and ultra fine screens were **not recommended** for the City of Surprise. Inclined static screens require manual cleaning; band screens are not as efficient and reliable as other available alternatives; and ultra fine screens are not necessary for the treatment processes discussed in this report.

6.4.7 Screening Handling

- Screening handling systems can substantially decrease the volume and weight of screenings material removed in the screening process.
- Screenings handling areas and stored screenings prior to disposal can generate significant odors.

The screening material removed by fine or coarse screens must be handled and disposed. Conveyance is often required to move the screening material from the screen discharge to the handling location. To reduce manpower requirements associated with manually hauling influent screenings to a gondola or dumpster, an automatic conveyance mechanism can be used. Options for this type of system include belt conveyors, augers, and shafted or shaftless screw conveyors. Typical components of this type of system include a hopper to collect screenings off the screen and a drive mechanism.

The use of coarse and fine screens will result in organic matter being captured with the screenings. A washer can also be provided to reduce organics from the screenings, and a built-in press can be provided to reduce the water content in the screenings prior to discharge to a dumpster. The washing allows the organics to be recovered from the screenings and returned to the flow stream. Typical screenings contain 85 to 95 percent wastewater. With the use of a press, the water content can often be reduced to approximately 50 to 55 percent. This results in a weight reduction of approximately 65 to 85 percent, and a volume reduction of approximately 70 to 75 percent. Decreasing the volume and weight of screenings materials will drastically decrease the hauling costs associated with disposing of this material. Screenings wash water will be discharged to the drain for return to the influent flow stream for treatment. Dewatered screenings must be transported from the treatment site and disposed in a landfill.

Screenings handling areas and stored screenings prior to disposal will generate odors. Some types of systems can be fully enclosed to promote easy draw off of foul air for odor control directly from the source. Odor control may be required, depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to screening.

Anticipated Performance of Screening Handling for the City of Surprise

Screening handling components including conveyance mechanisms and screenings washers and compacters decrease the O&M costs associated with handling screenings materials. Screenings handling components are **recommended** for the City's consideration. Screening handling components are included in the SurpriseTree™ Wastewater Model as a universal add-on to all type of screening facilities.

6.4.8 Summary of Preliminary Treatment Technologies

Table WWT.25 summarizes the anticipated performance of the proposed preliminary treatment technologies as well as their applicability to the City of Surprise typical wastewater. Table WWT.26 summarizes the evaluation results for preliminary treatment technologies using the implementation based criteria. Coarse screens, fine screens (2 mm), step screens (3 mm) and rotary screens (3 mm) are recommended for further evaluation in the SurpriseTree™ Wastewater Model. 2-mm fine screening is required if MBR is selected as the biological treatment process. Both coarse and fine screens are recommended for large treatment facilities.

Table WWT.25 Preliminary Treatment Unit Operations – Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operation	Performance Based Criteria					
	TSS Removal	**BOD Removal**	**Nitrification-Denitrification**	**Turbidity Removal**	**Pathogen Removal**	**DBP Control**
Coarse Screens[1]	Good. Some removal.	Poor. Not primary function.	N/A	N/A	N/A	N/A
Fine Screens (2 mm)	Excellent. Often required by MBR manufacturers as the preferred pretreatment, capable of achieving 25-45% removal.	Good. Capable of achieving removal comparable to primary treatment, 25-50% removal.	Poor. Not primary function.	Poor. Not primary function.	N/A	N/A
Rotary Screen (3 mm)	Very good. Capable of achieving 25-45% removal.	Good. Capable of achieving some removal.	Poor. Not primary function.	Poor. Not primary function.	N/A	N/A
Step/Stair Screen (3 mm)	Very good. Capable of achieving 25-45% removal.	Good. Capable of achieving some removal.	Poor. Not primary function.	Poor. Not primary function.	N/A	N/A

Note:

(1) While the proposed coarse screens each have differences in screening mechanisms or configuration, they are essentially identical with regard to the Performance Based Criteria noted. Consequently, all coarse screens were included as a single category as part of this evaluation.

Table WWT.26 Preliminary Treatment Unit Operations – Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operations	Implementation Based Criteria																	
	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Foot-print	Regulatory	Safety	Residuals	Versatility	Expand-ability	Odor	Energy Savings	Class A Biosolids	Air Quality
Coarse Screens	Very good.	Very good.	Good.	Very good.	Good.	Good. Infrequent equipment jams.	Good.	Very good. Relatively simply operation.	Good.	Good.	Good.	Good. Less volume of residuals removed.	Good.	Good.	Good. Odor concerns with screenings removed.	Good. Uses less energy.	N/A	Good.
Fine Screens (2 mm)	Fair. More expensive.	Fair. Removes more particles.	Very good.	Good.	Good.	Good.	Good.	Good.	Good.	Very good. More easily accepted compared to coarse.	Good.	Good. More volume of screenings removed.	Very good., especially for MBR pretreat-ment.	Good.	Very good. Enclosed, odor concerns with removed screenings.	Good.	N/A	Good.
Rotary Screen (3 mm)	Good.	Good.	Very good.	Good.	Good.	Good.	Very good.	Very good.	Good.	Very good.	Good.	Good.	Very good.	Good.	Very good. All enclosed, odor concerns with screenings removed.	Good.	N/A	Good.
Step / Stair Screen (3 mm)	Good.	Good.	Very good.	Very good.	Very good.	Very good.	Very good.	Very good.	Good.	Very good.	Good.	Good.	Very good.	Good.	Good. Odor concerns with screenings removed.	Good.	N/A	Good.

6.5 Grit Removal Technologies

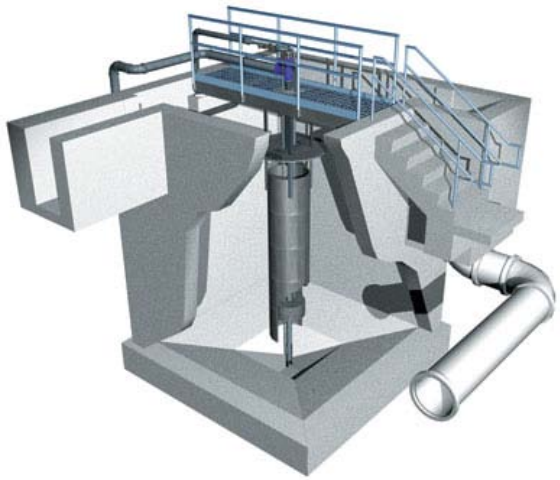
A grit removal process physically removes heavy, abrasive, inorganic solids from the flow stream. The removal of such grit, including sand, gravel, and other large particles, is important to protect the downstream process equipment from excessive wear, reduce the formation of deposits in pipelines and process basins, and reduce solids handling.

Grit is typically removed from the screened influent wastewater in a grit chamber, and is deposited in a grit storage hopper. The grit is then removed from the hopper by grit pumps and transferred to the grit washing/dewatering units where the grit is cleaned of organic material, and the overall volume of grit is reduced. The grit is deposited in a roll-off bin or similar container for ultimate landfill disposal.

A properly designed and operated grit removal system should effectively remove grit of the size range that would be harmful to downstream processes, through either abrasion and wear of mechanical equipment, plugging of pipes, or settlement in relatively quiescent zones of processes. Typically, grit removal is approximately 95 percent greater than 50 mesh size, 85 percent of the 50 to 70 mesh size, and 65 percent of the 70 to 100 mesh size. Fine screening of the influent wastewater flow stream is typically conducted at the plant headworks upstream of the grit removal system to remove as much plastic and stringy material as possible. All open-tank grit removal facilities will also require covers for containment and odor control. If anaerobic digestion is selected as the solids stabilization process, grit removal is necessary to remove the inert grit material from the process. If a centrifuge is used for solids dewatering or thickening, grit removal is necessary to prevent grit accumulation in the centrifuge process.

Grit removal alternatives discussed in this section include aerated grit chambers, mechanical vortex systems, free vortex systems, and horizontal flow systems. Additional details associated with each technology can be found in Appendix A.

6.5.1 Aerated Grit Removal

	• Aerated grit removal involves using air to keep organics in suspension while settling out grit. • A simple mechanical design is utilized for aerated grit removal, which includes no moving parts below the water surface.

Aerated grit chambers use a specific velocity of roll or agitation to keep organics in suspension while settling out the grit. If the velocity is properly adjusted, roll can produce a very low percentage of organic material in the grit. A simple mechanical design is utilized for this type of grit removal, which includes no moving parts below the water surface. The aerated grit removal process typically consists of a rectangular tank with coarse bubble diffusers along one wall, and a bottom floor sloped to a collection trough under the diffusers. Aerated grit removal is typically more expensive than vortex grit removal because of the structure and supplemental equipment.

Detention time and basin dimensions are the critical design parameters for aerated grit removal. A minimum detention time of 3 minutes at peak flow is required. This can be increased to as high as 10 minutes if a high degree of fine grit removal is desired along with a significant amount of pre-aeration and odor stripping. Recent data has shown that ideal aerated grit basin design incorporates a width-to-depth ratio of 0.8 or 0.9 to 1, instead of the traditional 2 to 1.

6.5.1.1 TSS Removal

The aerated grit removal process is capable of removing some TSS. However, during the grit handling process, the removed grit is washed and TSS are returned back into the wastewater liquid stream. Aerated grit chambers are capable of removing 100 percent of grit particles 0.21 mm in diameter or larger.

6.5.1.2 BOD Removal

The aerated grit removal process is capable of removing some BOD. However, during the grit handling process, the removed grit is washed and organics are returned back into the wastewater liquid stream.

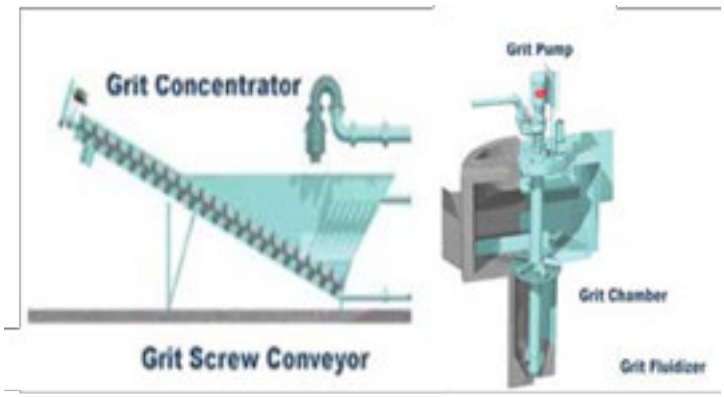
6.5.1.3 Odor Control

The grit removal processes may generate odors. All open-tank grit removal facilities will require covers for containment and odor control, depending on site setbacks. Aerated grit removal has more potential for off gassing to occur compared to other grit removal technologies; so, an odor control system with a larger capacity may be necessary for aerated grit. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to grit removal.

Anticipated Performance of Aerated Grit Removal for the City of Surprise

Aerated grit removal is an effective way to remove grit from the wastewater flow stream and produce clean grit due to the grit washing effect. Aerated grit removal can be further considered by the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model. Due to the requirement of structure and supplemental equipment, it is generally more expensive than mechanical vortex grit removal systems.

6.5.2 Free Vortex Grit Removal



- Free vortex grit removal uses centrifugal forces caused by tank configuration to remove grit.
- Free vortex systems are a hydraulic, non-mechanical design with no moving parts.

The vortex grit removal process is a simpler, less mechanically intensive method of grit removal than aerated grit removal, and requires a smaller footprint. A vortex grit removal system consists of a circular, conical-shaped chamber in which the flow enters tangentially, creating a vortex flow pattern. The process works on the principle of gravity and centrifugal action in the chamber. Upon entering the chamber, the grit is moved to the outside of the chamber due to the centrifugal forces created by the spiraling flow, and settles by gravity into the bottom grit hopper. Effluent exits at the top of the chamber. The grit settles into the hopper and is then removed by a grit pump to a grit washer/classifier. The main benefits of vortex grit removal are that it is lower in cost than an aerated system and typically does not require odor control. However, the short detention time of vortex grit removal process can decrease the efficiency of fine grit removal and can limit its ability to handle flow fluctuations in comparison to that of an aerated process. Vortex systems are generally classified as mechanically induced vortex or free vortex.

A free vortex system takes advantage of the centrifugal and gravitational forces created by the orientation of the inlet piping into the circular basin without the use of a mechanical turbine. These systems have minimal head loss and high efficiency flow distribution through the chamber. The layout of vortex grit removal provides a large surface area for settling within a compact footprint. Unlike horizontal flow through, vortex grit removal achieves increasing performance as flows and grits loadings increase. The primary advantages of the free vortex system are that it is an all hydraulic, non-mechanical design with no moving parts - creating a simple, low maintenance operation. The primary disadvantage of a free vortex system is that operational flexibility for adequately handling variable flow rates is minimized, as compared to mechanically induced vortex systems. Additionally, there is very limited competition in the market for free vortex grit systems. Free vortex grit systems are best suited for treatment capacities up to 6 mgd.

6.5.2.1 TSS Removal

Free vortex type grit removal processes are capable of removing some TSS. However, during the grit handling process, the removed grit is washed and TSS is returned back into the wastewater liquid stream. Vortex type grit removal processes are capable of removing 95 percent of 0.33 mm size, 85 percent of 0.24 mm size, and 65 percent of 0.15 mm size grit.

6.5.2.2 BOD Removal

Free vortex type grit removal processes are capable of removing some BOD. However, during the grit handling process, the removed grit is washed and organics are returned back into the wastewater liquid stream.

6.5.2.3 Odor Control

The grit removal processes may generate odors. All open-tank grit removal facilities will require covers for containment and odor control, depending on site setbacks. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to grit removal.

Anticipated Performance of Free Vortex Grit Removal for the City of Surprise

Free vortex grit removal is an effective way to remove grit from the wastewater flow stream. The free vortex grit removal process is **recommended** for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

6.5.3 Mechanical Vortex Grit Removal

- Mechanical vortex grit removal requires a mechanically induced force to remove grit.
- Velocity is controlled within the mechanical vortex grit chamber by a rotating turbine, which increases removal efficiency and flexibility.

A mechanically induced vortex system uses a rotating turbine to control the velocity inside the circular chamber. The turbine impeller is located at the center of the chamber, above the grit collection hopper. The lifting action created by the impeller suspends the lighter organic material that exits the basin through the effluent channel. Unlike the free vortex grit basins with only one or a few manufacturers, many manufacturers offer grit chambers with either a flat bottom or a sloped, conical bottom. Mechanical vortex grit systems provide significant operational flexibility for adequately handling variable flow rates and are best suited for treatment capacities greater than 6 mgd.

6.5.3.1 TSS Removal

Similar to free vortex grit removal, mechanical vortex type grit removal processes are capable of removing some TSS. However, during the grit handling process, the removed grit is washed and TSS is returned back into the wastewater liquid stream. Vortex type grit

removal processes are capable of removing 95 percent of 0.33 mm size, 85 percent of 0.24 mm size and 65 percent of 0.15 mm size grit.

6.5.3.2 BOD Removal

Similar to free vortex grit removal, mechanical vortex type grit removal processes are capable of removing some BOD. However, during the grit handling process, the removed grit is washed and organics are returned back into the wastewater liquid stream.

6.5.3.3 Odor Control

The grit removal processes may generate odors. All open-tank grit removal facilities will require covers for containment and odor control, depending on site setbacks. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to grit removal.

Anticipated Performance of Mechanical Vortex Grit Removal for the City of Surprise

Mechanical vortex grit removal is an effective way to remove grit from the wastewater flow stream. The mechanical vortex grit removal process is **recommended** for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

6.5.4 Horizontal Flow Grit Removal

- Horizontal flow grit removal achieves optimal removal when maintaining constant velocity through the chamber.
- Turbulence within a horizontal flow grit chamber will significantly impact the system performance.

In a horizontal flow grit system, grit removal is based on achieving a constant velocity in the grit chamber. The wastewater flow passes in a horizontal direction, and the straight-line flow velocity is controlled by the dimensions of the unit, an influent distribution gate, and a weir at the effluent end. While horizontal flow grit chambers are simple to operate, they are not widely used. The main disadvantages include the significant impact of turbulence on the system performance, the requirement of maintaining a constant velocity of approximately 1 foot per second, and the fact that it is an older technology with limited suppliers in the market.

6.5.4.1 TSS Removal

The horizontal flow grit removal process is capable of removing TSS. However, during the grit handling process, the removed grit is washed and TSS is returned back into the wastewater liquid stream. Aerated grit chambers are capable of removing 95 percent of grit particles 0.15 mm in diameter.

6.5.4.2 BOD Removal

The horizontal flow grit removal process is capable of removing some BOD. However, during the grit handling process, the removed grit is washed and organics are returned back into the wastewater liquid stream.

6.5.4.3 Odor Control

The grit removal processes may generate odors. All open-tank grit removal facilities will require covers for containment and odor control, depending on site setbacks. Horizontal flow type grit removal is more difficult to odor control compared to other grit removal processes due to the large open surface area of the chambers. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to grit removal.

Anticipated Performance of Horizontal Flow Grit Removal for the City of Surprise

Horizontal flow grit removal is an effective way to remove grit from the wastewater flow stream. However, the other grit removal processes discussed in this section provide a more effective alternative for removing grit. Consequently, horizontal flow grit removal is **not recommended** for the City of Surprise and was not included for further evaluation using the SurpriseTree™ Wastewater Model.

6.5.5 Grit Pumping, Washing, and Dewatering

- Grit pumping, washing, and dewatering can substantially decrease the volume and weight of grit material removed in the grit removal process.
- Following pumping, washing, and dewatering, removed grit materials are disposed in a landfill.

Grit is typically removed from the screened influent wastewater in a grit chamber, and is deposited in a grit storage hopper. The grit is then removed from the hopper by grit pumps and transferred to the grit washing/dewatering units where the grit is cleaned of organic material, and the overall volume of grit is reduced. Cleaned grit is deposited in a roll-off bin or other storage container for landfill disposal.

Grit is typically removed using an airlift pump, a turbo suction lift pump, or a torque flow (recessed impeller) pump. The objective of grit pumping is to move the grit to a grit washer while preventing the grit from clogging the pipes. For these types of pumps, careful consideration must be given to the material of construction, overpressure protection, and types of lubrication and seal systems.

After removing the grit from the hopper, it is typically washed and dewatered to reduce the grit volume and associated transportation costs, and to ease transport and handling during disposal. In addition, washing the grit to remove putrescible organic material makes grit handling and disposal more manageable, while minimizing potential odor problems. This practice will allow the organics to separate and be returned to the flow stream. Concentrating and washing the grit are frequently conducted together in series, often with compatible hydrocyclone-type separators and grit-classifying equipment provided by a single manufacturer and operated intermittently.

- **Grit Separators:** A hydrocyclone separator concentrates the grit centrifugally. Sizing of hydrocyclone separators is based on the cycled grit slurry feed flow rate and solids concentrations. Hydrocyclones typically work best at feed concentrations of less than 1 percent solids. The centrifugal action in a hydrocyclone separator can increase the solids content to an average of 5 to 15 percent. Approximately 90 to 95 percent of the grit slurry feed flow will be discharged through the vortex finder at the top of the hydrocyclone back into the waste stream. Grit pumps are typically sized to meet the high head requirements of the cyclone separators, static head, and pipe and friction losses.
- **Grit Classifiers:** Grit classifiers, either inclined screw or reciprocating rake type, wash the grit to separate putrescible organics from the grit. Classifiers are based on the settling velocity of the particles to be settled, feed flow capacity, and grit raking capacity. Classifiers are typically inclined 15 to 30 degrees from horizontal. In addition to slope, proper flight tip speeds and pitch assists in particle removal. The screw or rake is sized to convey anticipated peak grit mass loading.

6.5.5.1 Odor Control

The grit removal processes may generate odors. All open-tank grit removal facilities will require covers for containment and odor control, depending on site setbacks. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to grit removal.

Anticipated Performance of Grit Handling for the City of Surprise

Grit pumping, washing, and dewatering components decrease the O&M requirements associated with grit handling. Grit handling components are **recommended** for the City's consideration. Grit handling components are included in the SurpriseTree™ Wastewater Model as a common add-on to all types of grit removal.

6.5.6 Summary of Grit Removal Technologies

Table WWT.27 summarizes the anticipated performance of the grit removal technologies as well as their applicability to the City of Surprise typical wastewater. Table WWT.28 summarizes the evaluation results for grit removal technologies using the implementation based criteria. Free vortex, mechanical vortex and aerated grit chambers are recommended for further evaluation in the SurpriseTree™ Wastewater Model. Horizontal flow grit removal is not recommended for further consideration.

Table WWT.27 Grit Removal Unit Operations – Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operation	Performance Based Criteria					
	TSS Removal	**BOD Removal**	**Nitrification-Denitrification**	**Turbidity Removal**	**Pathogen Removal**	**DBP Control**
Free Vortex	Good. Better performance during peak flow events.	Fair. BOD washed in grit washer and returned to treatment process.	Poor. Not primary function.	Poor. Not primary function.	N/A	N/A
Mechanical Vortex	Good. TSS washed in grit washer and returned to treatment process.	Fair. BOD washed in grit washer and returned to treatment process.	Poor. Not primary function.	Poor. Not primary function.	N/A	N/A
Aerated Grit Removal	Good. TSS washed by air and returned to treatment process.	Fair. BOD is washed by air and returned to treatment process.	Poor. Not primary function.	Poor. Not primary function.	N/A	N/A

Table WWT.28 Grit Removal Unit Operations – Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operations	Implementation Based Criteria																	
	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Footprint	Regulatory	Safety	Residuals	Versatility	Expand-ability	Odor	Energy Savings	Class A Biosolids	Air Quality
Free Vortex	Good.	Fair. Relatively expensive.	Very good. Accommodates variable flow conditions and smaller size particles.	Good.	Good.	Good. No moving parts.	Good. Less flexible with variable flow rates.	Good.	Good.	Good.	Good.	Good.	Very good for accom-modating peak flows and smaller sized particles.	Good.	Good. Require odor control.	Good. No moving parts necessary to induce vortex.	N/A	Good.
Mechanical Vortex	Good.	Good.	Good.	Good.	Good. City is familiar with this technology.	Fair.	Good.	Good.	Good. Relatively small footprint.	Good.	Good.	Good.	Good.	Good.	Good. Require odor control.	Good.	N/A	Good.
Aerated Grit Removal	Fair. High costs to aerate.	Good.	Good.	Good.	Good.	Good. No submerged moving parts.	Good.	Very good. Simple operation.	Good. Relatively small footprint.	Good.	Good.	Good.	Good.	Good.	Good. Requires odor control.	Fair. Aeration required.	N/A	Good.

6.6 Primary Treatment Technologies

The role of primary treatment is to remove readily settleable solids and floating materials from the flow stream. Primary treatment is accomplished by primary clarification methods. This section discusses primary clarification. Additional details associated with primary clarification can be found in Appendix A.

6.6.1 Primary Clarification

- Primary treatment provides substantial BOD and TSS removal, thus reducing the load on the downstream biological treatment processes.
- The primary sludge produced in the primary clarifiers provides readily available biomass for digestion.

The main objective of primary clarification is to reduce the load on the downstream biological treatment system. Primary clarifiers typically remove 50 to 70 percent of total suspended solids (TSS), 25 to 40 percent of biochemical oxygen demand (BOD), and 10 to 20 percent total Kjeldahl nitrogen (TKN). By decreasing the biological load on the downstream biological treatment process, the aeration costs for the biological treatment process are also reduced. Primary clarification can also enhance biological phosphorous removal. Primary clarification is recommended for influent wastewater containing TSS greater than 500 mg/L. However, if the BOD to TKN ratio is less than 3, primary clarification is not recommended. A BOD to TKN ratio greater than 3 is necessary for the biological treatment process. For space limited treatment facility sites, primary clarification is not recommended as this process adds additional treatment basins to the required treatment processes. Primary clarification can also provide flow equalization to the biological treatment process. Primary clarification is most commonly used at larger treatment facilities.

Depending on the other treatment processes, primary clarification may not be necessary. With sufficient preliminary treatment, primary clarification may not be required. Fine screening provides similar BOD and TSS removal as primary clarification. If an extended aeration treatment process is selected, or if the wastewater BOD:TKN ratio is low, primary clarifiers are not necessary. Primary clarification can also be used with other biological treatment processes when there is a high influent TSS or a need to reduce the loading on the downstream processes. If fine screening is utilized, primary clarification is not required. However, primary clarification may be a good combination with conventional activated sludge, trickling filters, oxidation ditches (not operated in extended aeration mode) and IFAS, especially when the wastewater contains high TSS and high BOD:TKN ratio or anaerobic digestion process is desired. At existing treatment facilities, the addition of

primary clarifiers may in some cases be able to increase plant treatment capacity, without having to expand the biological treatment process.

Primary clarification typically requires primary sludge pumping and scum removal. Sludge is typically removed from the bottom of the primary clarifier and is pumped from the clarifier to the solids handling location. Scum collection and scum removal from the surface of the primary clarifier is required. Scum removal is typically accomplished through a rake arm that skims the surface. The primary sludge produced in the primary clarifiers provides readily available biomass for digestion. Anaerobic digestion is the most applicable digestion process for primary sludge, which has a high methane gas yield and can produce clean energy while reducing the aeration requirement for the biological process. Also, primary sludge improves dewaterability of digested sludge. Therefore, if anaerobic digestion is selected, primary clarification is recommended unless land availability or other constraints do not allow primary clarifiers.

6.6.1.1 BOD Removal

Typical primary clarification processes remove 25 to 40 percent of influent BOD.

6.6.1.2 TSS Removal

Typical primary clarification processes remove 50 to 75 percent of influent TSS removal.

6.6.1.3 Nutrient Removal

Typical primary clarification processes remove 10 to 20 percent of influent TKN. However, nitrogen in the form of ammonia will be recycled back into the main liquid process from solids handling processes centrate. 30 to 50 percent total phosphorous can be removed across primary clarifier. However, it is not expected that phosphorous removal is an issue for the City of Surprise.

6.6.1.4 Odor Control

The grit removal processes may generate odors. All clarifiers will require covers for containment and odor control, depending on site setbacks. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to primary clarification.

Anticipated Performance of Primary Clarification for the City of Surprise

Primary treatment provides substantial BOD and TSS removal, thus reducing the load on the downstream biological treatment process. Primary clarification processes are a **recommended** alternative for the City of Surprise's further consideration and were included for further evaluation using the SurpriseTree™ Wastewater Model. The necessity of primary clarifiers depends on the other treatment processes selected for the treatment facility and the site-specific conditions such as land availability. Primary clarification is **recommended** for influent wastewater with TSS greater than 500 mg/L. The primary sludge produced in the primary clarifiers provides readily available biomass for anaerobic digestion.

6.6.2 Summary of Primary Treatment Technologies

Table WWT.29 summarizes the anticipated performance of the primary treatment technologies as well as their applicability when evaluated with the City of Surprise typical wastewater. Table WWT.30 summarizes the evaluation results for primary treatment technologies using the implementation based criteria. Primary clarification is recommended for further evaluation in the SurpriseTree™ Wastewater Model.

Table WWT.29 Primary Treatment Unit Operations – Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operation	Performance Based Criteria					
	TSS Removal	**BOD Removal**	**Nitrification-Denitrification**	**Turbidity Removal**	**Pathogen Removal**	**DBP Control**
Primary Clarifier	Very good. Removal (50 to 75%).	Good. Removal (25 to 40%). Reduces loading on downstream processes.	Fair. Some removal. Reduces loading on downstream processes.	Fair. Some removal. Reduces loading on downstream processes.	N/A	N/A

Table WWT.30 Primary Treatment Unit Operations – Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operations	Implementation Based Criteria																	
	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Footprint	Regulatory	Safety	Residuals	Versatility	Expand-ability	Odor	Energy Savings	Class A Biosolids	Air Quality
Primary Clarifier	Fair.	Fair. Adds costs associated with an additional treatment process but reduces costs of downstream processes.	Good.	Very good.	Good.	Good.	Excellent.	Good.	Fair. Large footprint required.	Very good.	Good.	Fair. Primary sludge produced.	Good.	Good.	Fair. Odor control required.	Good.	N/A	Good.

6.7 Biological Treatment Technologies

The function of the biological treatment process is to remove BOD, COD, TSS, suspended and non-settleable colloidal solids, nitrogen, and phosphorous from the wastewater to below acceptable effluent limits.

Biological treatment processes utilize attached growth and suspended growth processes to maintain biological activity. Suspended growth processes use biomass suspended in the wastewater to perform the required biological transformations. Suspended growth systems include sequencing batch reactors, activated sludge processes, and membrane bioreactors. Attached growth processes use biomass attached to media to perform the required biological transformations. In these applications, the attached growth forms a film on the media referred to as biofilm. Attached growth systems include trickling filters, rotating biological contactors, and packed bed reactors. Integrated fixed film activated sludge incorporates both suspended and attached biological growth processes.

Biological processes typically operate in a continuous flow mode of operation but can also be operated in a batch process mode. The biological process includes mixed liquor suspended solids (MLSS) composed of wastewater, microorganisms, and inert biodegradable and nonbiodegradable suspended and colloidal mater. A recycle stream is typically used in the biological treatment process to maintain the microorganism population within the treatment process. The solids retention time and hydraulic retention time of the biological process are critical to achieving adequate biological treatment.

Nitrogen is removed in the biological treatment process through the two-step process of nitrification and denitrification. Many biological treatment processes are designed to include both processes.

The biological treatment alternatives discussed in this section include sequencing batch reactors, trickling filters, activated sludge including conventional, MLE and extended aeration, integrated fixed film activated sludge, and membrane bioreactor processes. Additional details associated with each technology can be found in Appendix A.

6.7.1 Sequencing Batch Reactor (SBR)

- SBR technology achieves all steps of biological treatment within one reactor basin.
- The SBR process requires a small process footprint with a minimal amount of process equipment.

A sequencing batch reactor (SBR) provides biological treatment through a batch process utilizing suspended biological growth processes. The process is accomplished in five main stages within one process basin: fill, react, settle, decant, and idle. The fill cycle represents the period when the influent wastewater is pumped into the SBR vessel and distributed into an existing sludge blanket contained in the vessel. The fill can occur under mixed or unmixed conditions, and/or aerated or unaerated conditions, depending on the treatment objectives. The react cycle includes mixing and aeration of the wastewater in the SBR vessel. The settle cycle allows the mixed liquor solids to settle, creating a supernatant layer on the top of the vessel. The decant cycle allows the supernatant to be drawn off the top of the vessel and transferred to a separate filtration process. The idle cycle promotes sludge wasting to maintain the desired MLSS concentration in the SBR reactor. Once a batch is complete, the process starts again.

Sequencing batch reactors produce a relatively high quality effluent at widely varying flows and loadings. The process does not require a sludge recycle system or a separate clarification process. Filtration is required following the SBR process to achieve Class A+ reclaimed water. The batch process may require equalization prior to filtration and disinfection processes. The SBR process can be accomplished in a relatively small footprint as it combines multiple processes in one basin. The flexible design of SBRs can accommodate varying flow rates and wastewater quality. To accommodate continuous flow, multiple SBR tanks can be provided such that one tank receives flow while the other completes its treatment cycle.

SBRs remove organic material and suspended solids similar to other conventional activated-sludge systems and can also be used to biologically remove nutrients such as nitrogen and phosphorus. The SBR process provides significant system flexibility for operations staff to adjust time intervals for each cycle to produce the desired process modifications and easily adapt to effluent limitations.

SBR technology is a proven biological treatment process with a wide variety of applications throughout the world. SBRs have a relatively low capital and O&M cost. Separate clarification basins and return activated sludge pumping and piping are not required as solids separation and clarification occurs in the same basin. In general, the SBR process is considered most cost effective for treatment facilities with capacities 3 mgd or smaller.

6.7.1.1 BOD Removal

SBR technology achieves sufficient BOD removal to achieve the City's effluent limits.

6.7.1.2 TSS Removal

SBR technology achieves TSS removal during the settling cycle.

6.7.1.3 Nutrient Removal

When operated in anoxic and aerobic cycles, SBR technology can accomplish good nitrification and denitrification. Well-operated SBR system can achieve total nitrogen less than 8 to 10 mg/L. However, batch operation limits the process efficiency compared to continuous processes with dedicated anoxic zones, because various types of bacteria (e.g., carbonaceous bacteria and nitrifiers) live in the same SBR tank instead of each living under their own optimized living conditions.

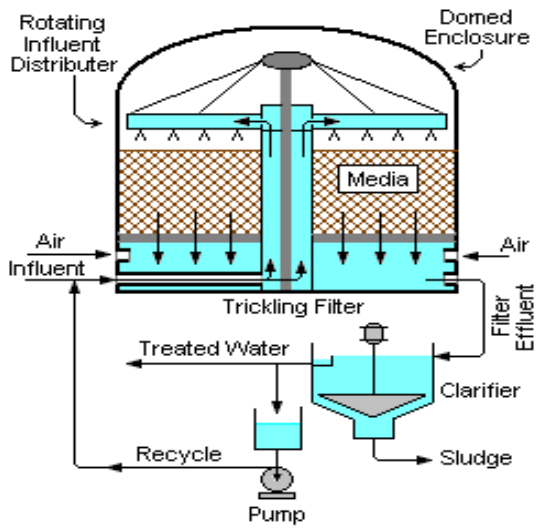
6.7.1.4 Odor Control

The SBR process can generate odors. If the system is equipped with an equalization basin prior to the SBR process, the equalization basin will typically generate the most odor concerns. Odor control may be required, depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to SBRs.

Anticipated Performance of SBR for the City of Surprise

SBR processes are a proven, cost effective biological treatment process capable of removing BOD, and nitrogen from wastewater. SBRs are most commonly used for small treatment facilities, less than 3 mgd in capacity. SBR technology is a **recommended** alternative for the City of Surprise's further consideration and was included for further evaluation using the SurpriseTree™ Wastewater Model.

6.7.2 Trickling Filters



- Trickling filters provide biological treatment through an attached growth process.
- The hydraulic and organic loading rates of trickling filters will determine the level of treatment that occurs.
- Trickling filters are typically used in combination with primary and secondary clarification.

Trickling filters consist of a fixed bed of rocks, gravel, or plastic media to promote attached biological growth. A biofilm grows and builds up on the media until it eventually sloughs off. Within the filter, wastewater is evenly distributed over the media by distribution arms that provide a uniform application rate. The wastewater flows downward, through the bed of media via gravity. Aerobic conditions are maintained in the filter by splashing, diffusion, forced or natural air. Treatment occurs as the wastewater flows over the attached biofilm. Trickling filters may be circular or rectangular in shape and are equipped with an underdrain system to collect the effluent.

The trickling filtration process can occur with filters in a single-stage configuration or in a two-stage configuration. A clarification process typically follows trickling filters to remove TSS. An intermediate clarification process can be used between two stages of filters to achieve a higher level of biological removal. A stream of trickling filter effluent is typically recycled to the trickling filter influent to dilute the strength of the incoming wastewater and to maintain a flow rate to keep the biofilm moist. Primary clarification is generally implemented upstream of trickling filters to reduce the BOD and TSS loading on the filters. A relatively large footprint is required for the trickling filter process based on the requirement for three separate processes - primary clarification, trickling filters, and secondary clarification.

Trickling filters are classified as low rate, intermediate rate, or high rate depending on the hydraulic and organic loading rate of the filter. Low rate trickling filters have the lowest hydraulic and organic loading rate and achieve the highest level of biological treatment. High rate trickling filters have the highest hydraulic and organic loading rate and achieve a lower level of biological treatment. Low rate filters can produce a consistent effluent quality with an influent of varying strength as the biofilm has more time to remove contaminants. High rate filters produce an effluent quality with more variability as the biofilm may not have sufficient time to accommodate influent of varying strength. A two-stage filter configuration

is more common for high rate filters as it provides two stages to achieve removal below effluent limits.

6.7.2.1 BOD Removal

Trickling filters are capable of achieving 50 to 90 percent BOD removal and achieve the City's wastewater treatment goal for organics.

6.7.2.2 TSS Removal

Well-operated trickling filters are capable of achieving a very high TSS removal in the subsequent clarification process.

6.7.2.3 Nutrient Removal

Well-operated trickling filters are capable of achieving good nitrification (often ≥ 95%) when operated at low organic loading rates.

6.7.2.4 Odor Control

Odors emissions are a common problem with trickling filters. Odor control may be required, depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to trickling filters.

Anticipated Performance of Trickling Filters for the City of Surprise

Trickling filtration processes are capable of achieving the required biological treatment for the City of Surprise. Trickling filters achieve optimum performance at low hydraulic and organic loading rates, but require a large footprint. The high rate filters also require a large footprint for the multiple stage filter configuration, and primary and secondary clarification. Odor and vector attraction are common problems for this technology. Trickling filter technology is **not recommended** as an alternative for the City of Surprise's further consideration but was included in the SurpriseTree™ Wastewater Model.

6.7.3 Activated Sludge

- Activated sludge is a common biological treatment process with a long history of successful application.
- The activated sludge process typically requires primary clarification, aeration basins, secondary clarification, and tertiary filtration to achieve Class A+ reclaimed water.

The activated sludge process involves the production of an activated mass of microorganisms capable of stabilizing a waste aerobically. Activated sludge is a proven technology that produces relatively high quality effluent. The activated sludge treatment process utilizes a suspended growth process to achieve biological treatment. The process has three main components: an aerated reactor for the microorganisms to achieve treatment while in suspension; liquid/solids separation (commonly achieved in a clarification tank); and a return activated sludge recycle system to return solids from the separation process back to the reactor. Many variations of the activated sludge process are available including conventional, Modified Ludzack-Ettinger (MLE), step feed, contact stabilization, high purity oxygen, and extended aeration. This section specifically discusses conventional, MLE, and extended aeration type activated sludge processes.

6.7.3.1 Conventional Activated Sludge Process

- Anoxic and aerobic zones of the activated sludge process provide nitrification, denitrification, BOD removal, and TSS removal.
- Solids are returned to the front of the activated sludge process to maintain the desired level of microorganisms in the treatment process.

Influent to a conventional activated sludge process typically flows from a primary clarification process through anoxic and aerobic zones, and to a clarification process. Following the activated sludge process, the MLSS is transferred to a separate clarifier to achieve gravity separation of the MLSS from the treated wastewater. The separated MLSS (return activated sludge – RAS) is recycled to the front of the aeration basin process to maintain the desired concentration of microorganisms in the treatment process. Some of the MLSS is generally wasted from the process (waste activated sludge – WAS). Filtration is required following the clarification process to achieve Class A+ reclaimed water. Process equalization may be required upstream of the activated sludge process to minimize the impacts of peak flows to the process. The aerobic zones of the reactor are equipped with diffusers to provide air for the biological treatment process. The diffuser density is typically the highest in the first aerobic zone and decreases in subsequent zones to achieve a tapered aeration effect. The anoxic zones are equipped with submersible mixers to keep the mixed liquor in suspension and well mixed at all times.

A conventional activated sludge process has a two-stage nitrification-denitrification configuration that can provide operational flexibility in achieving nutrient removal. The activated sludge process includes anoxic (un-aerated) zones to achieve denitrification, and aerobic (aerated) zones to achieve nitrification, BOD, and TSS removal. The basins can be internally compartmentalized using baffles, which provide a physical separation between

the different treatment zones within the basins. Baffles are designed to promote serpentine flow and minimize potential short-circuiting and back-mixing between adjacent zones.

6.7.3.1.1 Anoxic Zone Mixing

In the activated sludge process, raw wastewater is introduced into an anoxic zone where it is mixed with internally recycled mixed liquor. No aeration occurs in the anoxic zone. The mixer's primary function is to circulate liquids at a flow rate and velocity that disburses, mixes, blends, and dissolves particles to the extent required by the process. Submersible propeller mixers are commonly used to provide anoxic zone mixing. Wastewater mixing usually occurs in areas of turbulent flow where inertia is the prevailing force. Wastewater flow with a greater velocity and more turbulence often experiences more efficient mixing.

6.7.3.1.2 Aeration System

The aeration system includes the aeration blowers that provide the required process air, and the aeration diffusers that distribute the air and transfer the oxygen in the air to the mixed liquor. The oxygen transfer efficiency of the aeration diffusers has a significant impact not only on the required blower capacity (capital costs), but also on the power consumption of the aeration blowers (operational costs). More efficient oxygen transfer translates to reduced required blower capacities and reduced operational costs due to reduced power consumption. Fine bubble diffusers can achieve a high oxygen transfer efficiency. Membrane disc type fine bubble diffusers are used in many WRFs and are recommended for the City of Surprise.

6.7.3.1.3 BOD Removal

The conventional activated sludge process can typically produce a stabilized secondary effluent having a BOD concentration of 3 to 5 mg/L.

6.7.3.1.4 TSS Removal

The conventional activated sludge process can typically produce a stabilized secondary effluent having a TSS concentration of 3 to 5 mg/L.

6.7.3.1.5 Nutrient Removal

The conventional activated sludge processes are proven and reliable means to achieve total nitrogen and phosphorous removal. Advanced configurations of the conventional activated sludge process allow flexible control of the nitrification, denitrification, and biological phosphorous removal. Typically, such systems can produce a stabilized secondary effluent containing 6 to 10 mg/L of total nitrogen. However, conventional activated sludge system design may be limited in nitrification and denitrification with certain wastewater characteristics and organic loadings.

6.7.3.1.6 Odor Control

The activated sludge processes has the potential to generate some odors. Odor control may be required, depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to activated sludge.

Anticipated Performance of Conventional Activated Sludge for the City of Surprise

The conventional activated sludge process is a proven, cost effective process, capable of achieving required biological treatment. The conventional activated sludge process is a **recommended** alternative for the City of Surprise's further consideration and was included for further evaluation using the SurpriseTree™ Wastewater Model. In the model, the conventional activate sludge process and the MLE process are considered as one option, assuming process improvements that are proven beneficial, such as the internal mixed liquid return, are all incorporated in the design.

6.7.3.2 MLE Activated Sludge Process

- MLE type activated sludge processes provide an additional recycle stream to enhance nutrient removal.
- The MLE process provides operational flexibility to adjust operations to changing influent organic loadings.

The flow configuration for the Modified Ludzack-Ettinger (MLE) type activated sludge process is similar to a conventional configuration. However, the MLE process includes an additional solids recycle stream, provided as an internal recycle from the aerobic zone to the influent. The internal recycle enhances nutrient removal.

The MLE activated sludge process combines an anoxic zone with an aerobic zone in a common basin structure. Baffle walls are frequently provided for zone separation, to minimize short-circuiting or back-mixing. Flow first enters the anoxic zone, where it is mixed with internally recycled mixed liquor. Aeration is not provided in the anoxic zone. The combination of raw wastewater, RAS, and nitrified mixed liquor under anoxic conditions (nitrate, but no free oxygen) promotes denitrification, where microorganisms in the mixed liquor use nitrate as their oxygen source to metabolize the organic material in the raw wastewater - thereby destroying nitrate and releasing nitrogen gas to the atmosphere. In

the aerobic zone, influent ammonia is converted to nitrate by nitrifying microorganisms. Carbon oxidation of the waste stream also occurs under aerobic conditions. An SRT of 7 to 20 days is typical for the MLE process.

The availability of adequate, readily biodegradable carbon is crucial to the denitrification process. A typical BOD:TKN ratio of 4:1 and COD:TKN ratio of 16:1 are suitable for single-stage carbon oxidation and nitrification, where there is a sufficient fraction of nitrifying organisms present in the mixed liquor without requiring a separate anoxic selector basin or other separate-stage nitrification requirements. When the BOD:TKN ratio is less than 3 ~ 4, external carbon source may be required, resulted in expensive operation. When the BOD:TKN ratio is higher than 10, the biological process can still perform well, but a low-cost pretreatment (aerated pond) may be considered to reduce the main aeration requirement.

Options for operational flexibility in an MLE process include compartmentalization to facilitate variations in the anoxic zone volume, and alternative routings of feed and recirculation streams to allow for modification of the treatment configuration. Advantages of increased process flexibility include:

- The extent of nitrogen removal achievable is strongly dependent on the influent wastewater characteristics. To accommodate changes in influent characteristics or recycle streams, it is valuable to have the flexibility to operate in different configurations.
- Promoting plug flow by compartmentalizing the treatment tankage enhances plant performance, both through increased nitrification rates and through improved settleability.
- Continuing research on new biological treatment concepts makes it advisable to provide a degree of flexibility that would easily allow reconfiguration of the process flow scheme to implement process improvements.
- Future regulatory changes may make it necessary to intensify process performance, or change the process configuration to maintain mandated treatment compliance.

6.7.3.2.1 BOD Removal

The MLE activated sludge process can typically produce a stabilized secondary effluent having a BOD concentration of 3 to 5 mg/L.

6.7.3.2.2 TSS Removal

The MLE activated sludge process can typically produce a stabilized secondary effluent having a TSS concentration of 3 to 5 mg/L.

6.7.3.2.3 Nutrient Removal

MLE process anoxic zones can accomplish biological nitrification and denitrification. The MLE activated sludge process can typically produce a stabilized secondary effluent containing 6 to 8 mg/L of total nitrogen.

6.7.3.2.4 Odor Control

The MLE activated sludge process has the potential to generate some odors. Odor control may be required, depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to activated sludge.

Anticipated Performance of MLE Activated Sludge for the City of Surprise

The MLE activated sludge process is a proven, flexible, and robust process capable of achieving required biological treatment. The additional internal RAS provides operational flexibility to address varying influent organic loadings. MLE activated sludge technology is a **recommended** alternative for the City of Surprise's further consideration and was included for further evaluation using the SurpriseTree™ Wastewater Model. In the model, the conventional activate sludge process and the MLE process are considered as one option, assuming process improvements that are proven beneficial, such as the internal mixed liquid return, are all incorporated in the design.

6.7.3.3 Extended Aeration

- Extended aeration is a proven technology capable of achieving BOD and nutrient removal through anoxic and aerobic treatment zones.
- Extended aeration can be an economical treatment process for small treatment plants, but requires a very large footprint.

Extended aeration is a proven biological treatment technology that produces relatively high quality effluent. Nitrification and denitrification can occur in a single tank. The anoxic zones provide denitrification and aerobic zones provide nitrification and oxidation. When the basins are configured with anoxic and aerobic zones, an extended aeration process with a solids retention time (SRT) of 15 to 20 days can be achieved. This SRT is capable of producing a well stabilized sludge. Extended aeration is most cost effective for treatment facilities up to 10 to 15 mgd in capacity.

Extended aeration can be operated as an oxidation ditch; however, not all oxidation ditches are designed and operated in an extended aeration mode. Oxidation ditches often use a ring or oval shaped channel equipped with mechanical aeration and mixing - typically accomplished by surface mechanical aerators. The tank configuration, aeration and mixing devices promote plug flow for a system with a relatively long hydraulic detention time. With oxidation ditches, the SRT is typically increased to 20 to 30 days.

Extended aeration using oxidation ditches require little maintenance, due to the small amount of mechanical equipment required, and often produce less odors compared to other biological treatment processes. This process can be an economical treatment alternative for small treatment plants. The oxidation ditch process is a proven technology with multiple manufacturers for supply of equipment. The process is capable of achieving biological nutrient removal and is flexible and reliable under highly variable wastewater conditions. Secondary clarification and filtration processes are required following the oxidation ditch to achieve Class A+ reclaimed water.

The aerators must be capable of maintaining the MLSS in suspension. The flow rate in the basin is also important in keeping the solids in suspension. A flow rate of 0.3 m/s to 0.5 m/s should be maintained. The oxidation ditch process typically occurs in 2 to 4 process basins.

Extended aeration using oxidation ditches require a very large footprint. However, capital costs can be low, especially without the need for a primary clarification basin. The process also provides low operating costs due to reduced solids handling requirements and power requirements compared to other biological treatment technologies. The basin aerators can be designed to allow for deep basins with a smaller footprint. Minimal mechanical equipment is required for the process - resulting in low energy consumption.

6.7.3.3.1 BOD Removal

Extended aeration aerobic zones will consume a majority of the degradable BOD in the wastewater. It can produce a stabilized secondary effluent with a BOD concentration of 3 to 5 mg/L.

6.7.3.3.2 TSS Removal

Secondary clarification is necessary following extended aeration to achieve TSS removal. It can produce a stabilized secondary effluent with a TSS concentration of 3 to 5 mg/L.

6.7.3.3.3 Nutrient Removal

Extended aeration anoxic zones can accomplish good biological nitrification and denitrification. The total nitrogen can be removed down to less than 8 to 10 mg/L.

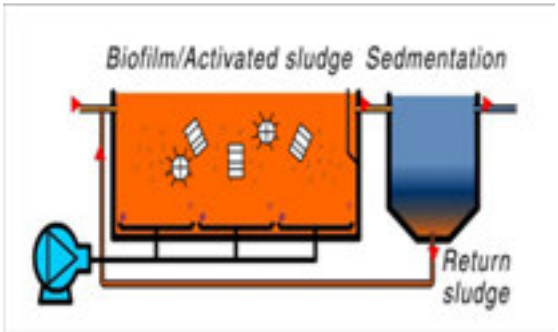
6.7.3.3.4 Odor Control

Extended aeration processes have the potential to generate some odors. Oxidation ditches often produce less odors compared to other biological treatment processes. However, because of the large footprint required for extended aeration, it is difficult to achieve full odor control for the process. Odor control may be required, depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to extended aeration processes.

Anticipated Performance of Extended Aeration for the City of Surprise

Extended aeration is capable of achieving required biological treatment by removing BOD, and nitrogen from wastewater. Extended aeration technology is a **recommended** alternative for the City of Surprise's further consideration and was included for further evaluation using the SurpriseTree™ Wastewater Model.

6.7.4 Moving Bed Biofilm Reactor and Integrated Fixed Film Activated Sludge



- MBBR and IFAS attached growth treatment processes provide sufficient biological treatment.
- MBBR and IFAS processes can achieve a higher level of biological treatment as compared to conventional activated sludge processes in the same footprint.

There are two versions of the modern attached growth process: moving bed bioreactor (MBBR) or submerged fixed film (SFF) and integrated fixed film activated sludge (IFAS). Modern attached growth processes differ from the more traditional attached growth processes in that in the modern process, the media is submerged below the water surface. Consequently, for suspended growth processes, aeration must be introduced, but increased contact times are possible. Modern attached growth processes are relatively new technologies to the wastewater treatment industry.

Both the MBBR and IFAS processes occur in a similar configuration as the conventional activated sludge process consisting of an activated sludge basin along with a sedimentation/clarification process. However, the modern attached growth systems contain submerged media to promote biofilm growth. For the modern attached growth processes, primary effluent enters the reactor containing the media and the attached biomass. The effluent from the reactor basin passes through a clarifier before proceeding to tertiary treatment. Settled sludge is wasted from the process. The IFAS process schematic is similar to the MBBR process schematic. The primary difference is the presence of a RAS line that allows the cultivation of suspended biomass in addition to the attached biomass. For MBBR, the TSS concentration in the bioreactor effluent is low, similar to trickling filter processes. However, for IFAS, the TSS concentration in the bioreactor effluent is high, similar to suspended growth processes. Aeration is used to provide oxygen and mixing in the process. Slow speed mixers are used for mixing in the post denitrification application. Screens must be used to maintain the media in each reactor. Multiple reactors can be used to select/control the bacteria for each application. The media used in this process provide a large surface area for bacteria to grow within a small unit volume.

The IFAS system has some important advantages, especially the ability to partially control biomass inventory (or SRT). In addition, the suspended biomass does not have to be attached to media - resulting in a reduction in the total surface area of the required media.

Two different kinds of media that can be used with the IFAS system are free floating and fixed. The free-floating media consist of small plastic elements that have positive buoyancy. Fixed media is typically attached to a frame that can be lowered to the floor of the basin. Fixed media can consist of either rigid media (like structured packing used in trickling filters) or pliable media (typically attached to a frame that allows for limited media movement).

Free-floating media require fine screens upstream of the basin to prevent plugging of the screens in the basin itself. Coarse bubble aeration is required to achieve enough turbulence to ensure a good distribution of the media throughout the basin depth. The coarse air also helps to prevent plugging of the basin's screens. The free-floating media allows greater treatment capacity for a given basin volume, due to its greater surface area.

IFAS is a potentially good solution for several applications: existing activated sludge treatment plants that require expansion but have limited site availability; facilities with marginal final clarifier performance and significant risk for washout; and facilities with adequate leniency in the existing plant hydraulic profile. The IFAS process is not economical compared to the MLE activated sludge process for a new WRF design with adequate available land area. However, the IFAS process does require a smaller footprint compared to other processes and can be desirable if the basins need to be covered to minimize visual or odor issues. In general, the IFAS process is more economical than biological aerated filters and MBR processes.

6.7.4.1 BOD Removal

MBBR and IFAS can provide sufficient BOD removal, similar to the conventional activated sludge system.

6.7.4.2 TSS Removal

MBBR and IFAS can provide sufficient TSS removal, similar to the conventional activated sludge system. MBBR process effluent has a lower effluent TSS compared to IFAS effluent, due to the differences in activated sludge recycle.

6.7.4.3 Nutrient Removal

MBBR and IFAS can both be designed to sufficiently reduce nutrients and achieve total nitrogen less than 6 to 10 mg/L.

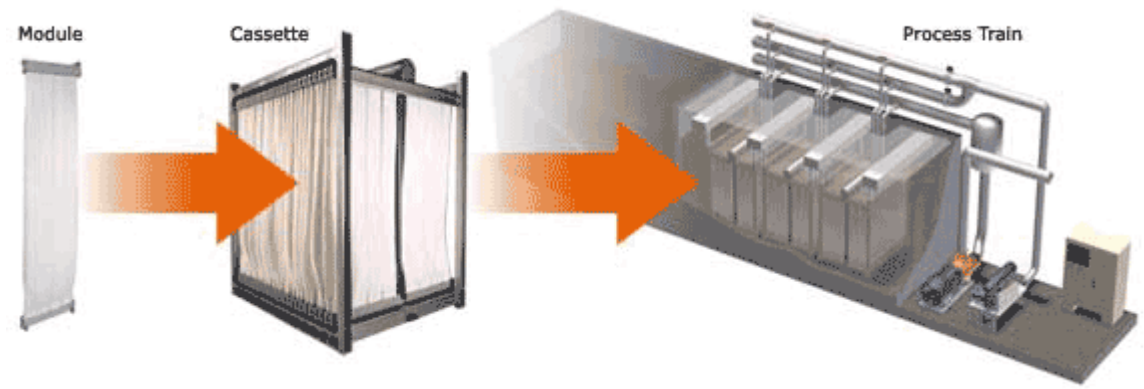
6.7.4.4 Odor Control

The MBBR and IFAS processes have the potential to generate some odors. Odor control may be required, depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to MBBR and IFAS processes.

Anticipated Performance of MBBR and IFAS for the City of Surprise

Modern attached growth processes such as MBBR and IFAS are capable of achieving the City's wastewater treatment standards for biological process. The process configuration is similar to the activated sludge process and can achieve biological treatment in a very compact footprint. It is a good low-cost alternative to MBR treatment, especially suitable for facilities with existing conventional activated sludge system that can be retrofitted. However, with the declining price of MBR treatment, there are only limited numbers of installations in the U.S. MBBR and IFAS technologies are **recommended** alternatives for the City of Surprise's further consideration and were included for further evaluation using the SurpriseTree™ Wastewater Model.

6.7.5 Membrane Bioreactor



- The MBR process utilizes suspended growth biological treatment in an activated sludge process followed by membrane filtration to achieve solids-liquid separation.
- The MBR process acts as an ultimate barrier to particulate matter and produces high quality effluent with low BOD, TSS, and turbidity.
- No secondary clarification is required for the MBR process. However, for existing facility with secondary clarifiers, MBR as a retrofit option to use membranes as tertiary filtration with secondary clarification. Refer to Section 6.9.3 for additional information regarding filtration using membranes.

The membrane bioreactor (MBR) process utilizes suspended growth biological treatment in an activated sludge process followed by membrane filtration to achieve solids-liquid separation. The MBR treatment train is similar to conventional treatment processes except that membranes replace the secondary clarifiers and tertiary filters. Because the process incorporates a membrane barrier, it produces a low turbidity effluent that is not impacted by quality changes in the feed water. The effluent TSS concentration is low enough that tertiary filtration is not required. In addition, the process produces a very consistent treated effluent turbidity, promoting optimal operation of downstream treatment processes. Finally, because the MBR system operates at a longer SRT, some endogenous destruction of the biomass occurs within the process. Therefore, total sludge production from the facility is

generally reduced by about 10 to 15 percent, compared with comparable conventional activated sludge systems.

The higher SRT also provides benefits related to future regulatory requirements including better performance in WET testing, and improved destruction of recalcitrant compounds including EDCs. The consistently low TSS concentration in the MBR effluent also promotes more efficient disinfection and enables utilization of more potential disinfection process options. MBR effluent is most compatible with advanced oxidation processes (such as ozone) to destroy remaining organic compounds. All of these factors make the MBR process the easiest to combine with advanced tertiary treatment options to meet future effluent limits.

In the MBR process, the MLSS can be increased beyond that which is possible in conventional activated sludge systems. Typically, MBR systems operate at MLSS concentrations in the range of 8,000 to 10,000 mg/L, compared with approximately 2,500 to 3,000 mg/L in a conventional activated sludge system. The higher MLSS provides the benefit of greater treatment capacity per unit volume of aeration basin. In order to minimize the solids buildup near the membrane surface, which would reduce the flow of water through the membranes, membrane agitation air is introduced to scour the membrane surface. This air is typically provided in addition to the biological process air requirements. The waste activated sludge (WAS) from an MBR process is typically approximately 1 percent solids.

The MBR process has many advantages over other biological treatment alternatives. The MBR process produces an overall high quality effluent regardless of sludge settling characteristics. The complete retention of slow growing nitrifying bacteria results in removal of both organic matter and nitrogen. The process provides complete retention of suspended matter as the membrane acts as an ultimate barrier. The MBR process provides high operational reliability and does not require primary or secondary clarification, or tertiary filtration to achieve Class A+ effluent - thus requiring a smaller overall treatment footprint.

Membrane filtration is a proven technology for the removal of wastewater contaminants and can provide reliable treatment over a wide range of influent qualities. Process equalization is typically required prior to the MBR process to help eliminate the stress of peak flows on the membranes. The MBR process is most economical for treatment facilities greater than 1 mgd, although continuing developments in MBR technology are making MBR economical for facilities of any size

6.7.5.1 MBR Pretreatment

All MBR systems require screening of the influent to protect the membranes. In systems that incorporate hollow-fiber membranes (most systems), it is important that abrasive solids, hair and other stringy materials be removed prior to membrane filtration. To accomplish this, MBR systems require fine screening of the feed water in the range of 1 to 2 mm. Abrasive solids can wear through the membrane fibers and cause failures, while hair and other stringy materials wrap around the fibers and cause clumping of the mixed liquor and

are very difficult to remove. Ideally, fine screens should be installed upstream of the aeration basins, but they can also be installed in the sludge recycle line between the aeration basins and the membrane tanks (not recommended).

6.7.5.2 Types of Membranes and MBR Configurations

There are many membrane manufacturers in the wastewater treatment industry. Each manufacture has a unique membrane design. Membrane filtration can occur in an inside-out or outside-in arrangement. In the inside-out configuration, membrane feed water flows through the inside of the membrane and the permeate (filtered water) flows through the membrane pores to the outside of the membrane. In the outside-in configuration, membrane feed water flows from the outside of the membrane and the permeate flows through the membrane pores to the inside of the membrane.

The membrane configuration is typically hollow fiber or flat plate. Hollow fiber membrane systems are most common in the industry and achieve filtration through numerous strands of membrane fibers grouped together. The hollow fibers have fixed pore sizes to prevent suspended solids from passing through. The basic component of hollow fiber membranes is a bundle of membrane fibers called a membrane module. Modules are grouped together into membrane cassettes, and multiple cassettes are configured into a membrane train. Each membrane train is typically equipped with a dedicated permeate pump. Permeate pumps create a vacuum in the membrane fibers, which drives flow from the outside of the membrane fiber to the inside of the fiber, filtering the flow through the membrane. Two major configurations of the hollow fiber membranes are seen in the market, one with both ends bundled together, and the other with only the bottom end bundled. The use of a single header design fixing the fibers at the bottom of the module and allowing them to float freely at the top is an advanced feature, which eliminates a problem often found with other hollow fiber membrane modules utilizing a dual header design, the accumulation of fibers, hair and other stringy debris at the top of the module.

Membranes can also be procured in a flat sheet membrane configuration. Flat plate membrane systems are far less common in the industry, but are growing in popularity. They achieve filtration through multiple sheets of membranes grouped together. The flat sheet membrane configuration achieves filtration through gravity and is less susceptible to issues with hair and other stringy materials. However, it is still subject to abrasion. Flat sheet membrane systems can be used with 3-mm screens. This type of membrane does not require backpulsing equipment and generally requires less cleaning compared to fibrous type membrane systems.

The membranes can be configured in two ways: submerged/integral MBRs or external MBRs. For the submerged/integral MBR process, both the membrane filtration and activated sludge process occur in a single basin. The membranes are immersed in open tanks of aerated mixed liquor.

The external MBR process utilizes a dedicated, separate membrane tank from the activated sludge process. The mixed liquor is circulated from the aeration basin to the membrane

tank and back to the aeration basin. In this configuration, the membrane tank can be divided into cells that can be taken off-line and cleaned in place, simplifying operations. A disadvantage of this approach is that a separate tank is required.

The design of MBR systems is generally based on the flux rate through the membranes. Flux describes the rate of water filtered through the membrane in gallons per day per square foot of membrane area (gfd). A maximum design flux is established so that the membranes are not subjected to excessive vacuum pressure from the permeate pumps and to help control membrane fouling.

In addition to permeate pumps, ancillary equipment associated with the MBR process includes blowers, and chemical cleaning systems. The MBR process blowers distribute air into the MBR basins to assist with the treatment process and to provide air scouring of the membrane fibers. A backpulse tank is also provided to serve as the water source for membrane backpulsing and cleaning operations. Chemical feed systems are provided to clean the membranes and assist in restoring membrane performance after fouling.

6.7.5.3 Membrane Fouling

Membrane fouling is a build up of organic and inorganic material on the membrane material that negatively affects the membrane performance. Membrane fouling can occur by cake development on the surface of the membrane, pore blockage of the membrane pores, and pore constriction by filling spacing inside the pore. Membrane fouling is inevitable and causes deterioration in filtration performance and an increase in pressure loss.

Membrane fouling can be controlled by multiple means. Pretreatment of the influent including screening, microsieving, and combined grit, oil, sand, and hair removal. Also, sustaining the process at a low permeate flux will assist in minimizing the amount of fouling. Introducing turbulent conditions and fluid motion near the membrane surface through aeration will also help minimize fouling. Even with air agitation, membranes lose their water permeability (flux rate) with time and require cleaning. Physical cleaning techniques including membrane relaxation and membrane backwashing. Chemical membrane cleaning can also restore some of the membrane permeability by removing fouling from the membrane surface. Depending on operating conditions, a chemical clean is required periodically to restore membrane performance. Chemical cleaning typically involves submerging the membranes in a solution of either sodium hypochlorite (to remove biological fouling) or citric acid (to remove lime scale).

The UV transmittance of the MBR process effluent is generally higher than 75 percent. Because of the high quality water produced by membranes, a lower UV dose is needed to accomplish complete disinfection. Even though the MBR process normally provides good log removal of pathogens and UV disinfection may not be necessary, it is a common practice to include both MBR treatment and UV disinfection in a treatment flow stream to provide multiple pathogen barriers. Compared to open channel UV disinfection, a closed vessel UV disinfection system could take advantage of the permeate pumps associated

with the MBR system (to pump the water through the UV vessels) and could provide a more compact system orientation.

6.7.5.4 BOD Removal

With proper biological design, the MBR process produces high quality effluent with low BOD (< 2- 5 mg/L), similar to the conventional activated sludge system.

6.7.5.5 TSS Removal

The MBR process produces a consistent, very low effluent TSS concentration (< 0.5 mg/L). No tertiary filtration is required to achieve Class A+ reclaimed water.

6.7.5.6 Nutrient Removal

The MBR system can be designed to achieve good nutrient removal (< 5 to 8 mg/L). Nitrification and denitrification processes are accomplished in the aerobic and anoxic biological processes prior to the membrane tank. The high DO in the mixed liquid returned from the membrane tank to the anoxic zone may impact the denitrification capabilities. But properly designed process configuration can overcome this issue.

6.7.5.7 Turbidity Removal

The MBR process produces a consistently low turbidity (< 0.1 - 0.2 NTU) effluent that is not impacted by quality changes in the feed water.

6.7.5.8 Pathogen Removal

The MBR process provides some level of effluent disinfection through the rejection of both bacteria and viruses. Typically, the MBR process can achieve 5- to 7-log removal of total coliform bacteria, > 5.5- to > 6.0-log removal of fecal coliform bacteria, and 0.5- to 4-log removal of indigenous MS-2 coliphages (virus).

6.7.5.9 Odor Control

The MBR process has the potential to produce some odors. However, MBR basins and the preceding activated sludge process are typically covered to protect the integrity of the membranes from foreign objects. The covers, in conjunction with adequate odor control, can prevent odors from escaping to surrounding areas. Odor control may be required, depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to MBR process.

Anticipated Performance of MBR for the City of Surprise

The MBR process produces consistent, high quality effluent. Clarification and tertiary filtration are not necessary with MBR technology. Consequently, the process is capable of achieving biological treatment in a relatively small footprint. MBR technology is a **recommended** alternative for the City of Surprise's further consideration and was included for further evaluation using the SurpriseTree™ Wastewater Model.

6.7.6 Summary of Biological Treatment Technologies

Table WWT.31 summarizes the anticipated performance of the biological treatment technologies as well as their applicability with the City of Surprise typical wastewater. Table WWT.32 summarizes the evaluation results for biological treatment technologies using the implementation based criteria. Extended aeration, sequencing batch reactors, trickling filters, conventional aeration basins, integrated fixed film activated sludge and membrane bioreactor processes were recommended for further evaluation in the SurpriseTree™ Wastewater Model.

Table WWT.31 BOD and Nutrient Removal Unit Operations – Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operation	Performance Based Criteria					
	TSS Removal	**BOD Removal**	**Nitrification Denitrification**	**Turbidity Removal**	**Pathogen Removal**	**DBP Control**
Extended Aeration	Very good. Requires large basin volume.	Very good.	Very good.	Good with secondary clarification and tertiary filtration.	Poor. Little to no removal.	Good. Some DBP precursors removed in clarification process.
Sequencing Batch Reactor	Good. Capable of achieving high removal.	Very good.	Good with appropriate time controlled. Less robust.	Good with tertiary filtration.	Poor. Little to no removal.	Good. Some DBP precursors removed in clarification process.
Trickling Filters	Good. Capable of achieving high removal.	Good, depending on loading rates.	Good, depending on loading rates.	Good with secondary clarification and tertiary filtration.	Poor. Little to no removal.	Good. Some DBP precursors removed in clarification process.
Activated Sludge	Good. Capable of achieving high removal.	Very good.	Excellent. Proven, reliable process.	Good with secondary clarification and tertiary filtration.	Poor. Little to no removal.	Good. Some DBP precursors removed in clarification process.
Moving Bed Biofilm Reactor / Integrated Fixed Film Activated Sludge	Good. Capable of achieving high removal.	Very good.	Very good.	Good with secondary clarification and tertiary filtration.	Poor. Little to no removal.	Good. Some DBP precursors removed in clarification process.
Membrane Bioreactor	Excellent. Consistent, high water quality produced.	Excellent. Consistent, high water quality produced.	Very good water quality. Some dissolved oxygen carry over from MBR basins possible.	Excellent water quality.	Excellent. Consistent, high water quality. Membranes can remove *E. coli*, fecal coliform and virus.	Good. Some DBP precursors removed in clarification process.

Table WWT.32 BOD and Nutrient Removal Unit Operations – Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operations	Implementation Based Criteria																	
	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Footprint	Regulatory	Safety	Residuals	Versatility	Expand-ability	Odor	Energy Savings	Class A Biosolids	Air Quality
Extended Aeration	Very good. Minimal mechanical equipment.	Good. Highest costs associated with concrete for basin.	Good.	Very good. Proven technology.	Very good.	Very good. Minimal mechanical equipment to maintain.	Good.	Very good.	Fair. Large footprint required.	Very good.	Good.	Very good. Less solids produced.	Very good.	Poor.	Good.	Very good.	N/A	Good.
Sequencing Batch Reactor	Very good.	Good. Single treatment basin.	Good.	Very good. Proven technology.	Good.	Good.	Fair.	Good.	Good. Compact - only one treatment basin.	Very good.	Good.	Good.	Good.	Good.	Good.	Good.	N/A	Good.
Trickling Filters	Good.	Good.	Good.	Very good. Proven technology.	Good.	Good.	Fair.	Very good. Simple operation.	Good.	Good.	Good.	Good.	Good.	Good.	Fair. Typically need odor control.	Good.	N/A	Good.
Activated Sludge	Good.	Good.	Very good. Able to handle variable influent quality.	Very good. Proven technology.	Good.	Good.	Very good.	Good.	Good.	Very good.	Good.	Good.	Very good.	Good.	Good.	Good.	N/A	Good.
Moving Bed Biofilm Reactor / Integrated Fixed Film Activated Sludge	Good.	Good.	Good.	Good.	Fair.	Good.	Good.	Good.	Good.	Fair.	Good.	Good.	Good.	Good.	Good.	Good.	N/A	Good.
Membrane Bioreactor	Fair.	Good, when considering that secondary sedimentation and filtration are not required.	Very good. Able to handle variable influent quality.	Good. Proven technology.	Good.	Fair.	Excellent.	Fair. Complex system design.	Excellent. Compact.	Good.	Good.	Very good. Some reduction in biosolids can be achieved.	Very good.	Excellent.	Good.	Good.	N/A	Good.

6.8 Clarification Treatment Technologies

The primary purpose of the secondary clarification process is to separate the treated water from the activated sludge following the biological process. Solids separation is the final step in the production of a well-clarified stable effluent, and as such, represents a critical link in the operation of an activated sludge treatment process. Clarification can occur in conventional clarification processes and high rate clarification processes. Conventional clarifier basins can be configured as circular or square - although circular basins are more common. High rate clarification processes include ballasted flocculation and dissolved air flotation. High rate clarification processes use modifications or alternatives to the flocculation and sedimentation processes utilized by traditional clarifiers. Consequently, high rate clarification processes may be operated at hydraulic and/or solids loading rates greater than those of typical clarifiers.

Secondary clarification is necessary following aeration basins, extended aeration, IFAS, and trickling filters utilized for BOD and nutrient removal. Secondary clarification is not required if MBR technology is utilized for BOD and nutrient removal.

The clarified effluent from the secondary clarification process undergoes tertiary filtration before exiting the treatment process. A portion of the thickened activated sludge from the bottom of the clarifier is typically recycled back to the treatment process to control the solids retention time of the system. The rest of the separated solids are sent to a solids handling facility for final disposal.

The clarification alternatives discussed in this section include conventional circular clarification basins, conventional rectangular clarification basins, dissolved air flotation (DAF), and ballasted flocculation. Additional details associated with each technology can be found in Appendix A.

6.8.1 Circular Clarifier Basins

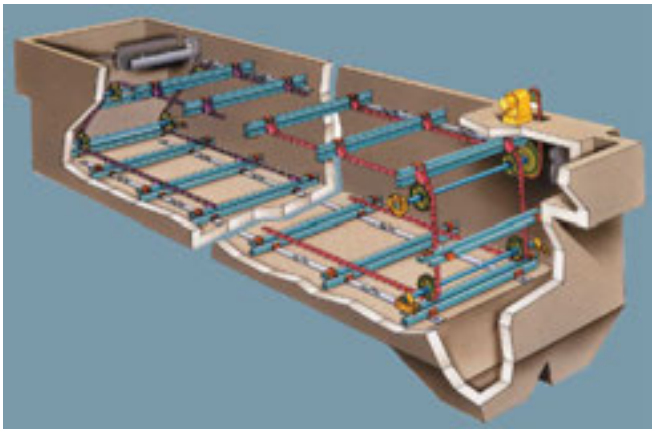
	• Circular clarifier basins often require a larger footprint compared to rectangular basins because they cannot utilize common wall construction. • Circular clarifiers typically use a spiral scraper or hydraulic suction for sludge collection.

The sludge removal mechanism is a critical component of the secondary clarifier design. Rapid sludge removal mechanisms are typically preferred over the conventional segmented-scraper mechanisms. Two primary options for effective rapid sludge removal from secondary clarifiers are available: sloped bottom construction with spiral-type rake mechanisms and flat bottom construction with hydraulic suction mechanisms.

- **Spiral Scrapers:** One option commonly employed for activated sludge clarification is the use of sloped floor clarifiers equipped with spiral scrapers that transport the thickened sludge to a central hopper. The rate of sludge removal is rapid, but typically slower than hydraulic suction. One disadvantage of this type of system is the potential for increasing sludge blankets once the limiting solids flux is exceeded. Short-circuiting can occur between the inlet and sludge return pocket. Additionally, there is less sludge storage volume available in a conical bottom than a flat bottom at the same center depth. Mechanism costs for spiral scrapers are typically on the order of 10 percent higher than hydraulic suction.
- **Hydraulic Suction:** Another option commonly employed for removal of settled solids is the use of flat floor units equipped with either a manifold header-type sludge collector or a series of uptake pipes (also known as organ pipe or multiple tube collectors). The manifold type has a single or double arm extending the full radius of the basin. The arm is tubular in shape, and has a number of orifice openings sized and located to obtain uniform withdrawal of sludge. Sizing and spacing is pre-determined by the manufacturer. Flow pulled into the tube is transported to the center of the tank where it is discharged into an annular ring that, in turn, is connected to a withdrawal pipe. With this type of mechanism, solids are removed across the entire tank floor, as opposed to just at a central hopper. Lower sludge blankets can be expected compared to scraper-equipped units. Higher sludge blankets most often translate to higher effluent solids concentrations. A flat-bottom design is typically constructed at the same depth as the center area of a sloped-bottom design. Thus, the side water depth (SWD) of a flat-bottom design is typically 3 to 5 feet deeper than a sloped-bottom SWD design. The rate of sludge removal is rapid, typically faster than spiral scrapers. One disadvantage of the hydraulic suction system is the potential for plugging. At the annular ring, a seal is provided to prevent leakage of tank contents into the RAS system. Keeping this seal tight has been a problem on some installations. Direct pumping of RAS can sometimes create enough suction to pull water through the seals, or even cause the seals to fail if enough of the ports become plugged. Mechanism costs for hydraulic suction are typically lower than spiral scrapers. However, the increase in excavation and concrete costs may offset this savings.

The primary advantages associated with circular clarifiers are simple sludge collection systems, relatively low maintenance requirements, and good performance under high solids loading conditions. The primary disadvantages associated with circular clarifiers include a higher likelihood for short circuiting (due to a shorter flow path for solids), a larger required footprint (because common wall construction is not available), and the potential for uneven distribution of sludge loads on the collecting devices.

6.8.2 Rectangular Clarifier Basin



- Rectangular clarifier basins use common wall construction, resulting in a footprint that is typically smaller than comparable circular basins.
- Rectangular clarifiers typically use a chain and flight sludge collection system.

Rectangular clarifier basins benefit from the ability to use common wall construction. Consequently, the footprint and associated concrete costs required for rectangular clarifiers is typically less than for comparable circular clarifier basins. The sludge collection mechanism in rectangular clarifiers typically consists of a chain and flight system that slowly drags scrapers along the floor and pushes the sludge to a collection trench. Rectangular clarifiers are less effective in addressing high solids loading rates. They also have higher maintenance requirements associated with the chain and flight collector system. Rectangular clarifiers provide a longer flow path for the water to leave the clarifier, thus reducing the opportunity for short circuiting of solids.

A hybrid clarifier option, which has been implemented at several local treatment plants, includes installation of a circular collector in a rectangular basin. This combines the footprint advantages of common wall construction and the lower maintenance requirements of a circular sludge collection mechanism. The primary challenge associated with this option is associated with difficulty in cleaning the basin corners, which is typically addressed by sloping/installing fillets in the basin corners. However, grouting the corners has historically presented construction challenges that often result in poor quality.

6.8.3 Conventional Circular and Rectangular Clarifier Comparison

Table WWT.33 summarizes the advantages and disadvantages of common circular and rectangular clarifier basin and sludge collector configurations.

Table WWT.33 Clarifier Basin Configuration Summary Wastewater Technology Assessment Report City of Surprise		
	Advantages	**Disadvantages**
Circular Clarifier Basin with Circular Collector	• Less maintenance intensive sludge collection system.	• Requires larger footprint. • Higher concrete cost.
Rectangular Clarifier Basin with Rectangular Collector	• Requires smaller footprint (common wall construction). • Lower concrete costs.	• Maintenance intensive sludge collection system.
Rectangular Clarifier Basin with Circular Collector	• Requires smaller footprint (common wall construction). • Lower concrete cost. • Less maintenance intensive sludge collection system.	• Sludge build-up in basin corners outside the reach of the circular collector.

6.8.3.1 BOD Removal

Conventional secondary clarifiers provide BOD removal in the settleable solids and produce stable effluent, low in BOD.

6.8.3.2 TSS Removal

Conventional secondary clarifiers provide TSS removal in the settleable solids and produce stable effluent, low in TSS.

6.8.3.3 Nutrient Removal

Secondary clarification itself does not remove nutrients. However, in a non-MBR type of biological process, clarifier performance is critical in achieving the target treated water quality and maintain a healthy biological growth. On the contrary, an undersized or poorly-designed clarifier could upset the process, creating biomass with reduced activity.

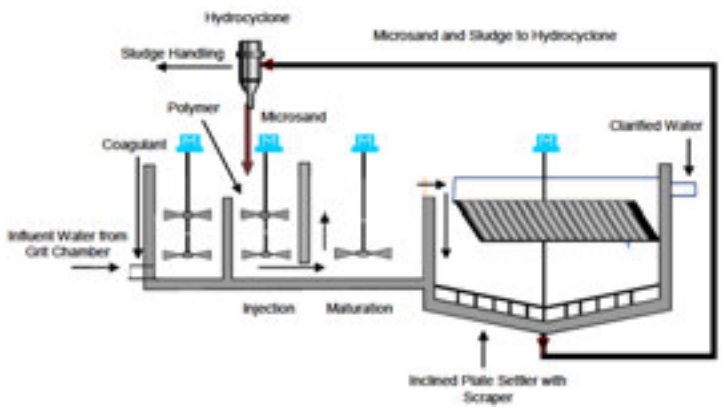
6.8.3.4 Odor Control

The secondary clarification process has the potential to produce some odors. Odor control may be required (although unlikely), depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to clarification process.

Anticipated Performance of Secondary Clarifiers for the City of Surprise

Conventional secondary clarifiers provide solid separation following the biological treatment process. Either circular or rectangular basins can be implemented depending on site and other considerations, but circular clarifiers are more common. Conventional secondary clarification is a **recommended** alternative for the City of Surprise's further consideration and was included for further evaluation using the SurpriseTree™ Wastewater Model.

6.8.4 Ballasted Flocculation



- Ballasted flocculation achieves high rate clarification within a compact footprint.
- The ballasted flocculation process utilizes a ballasting agent to promote formation of flocs and enhance settling within the basin.

Ballasted flocculation systems utilize a microsand or other ballasting agent to bond with suspended solids in the clarification process and increase the settling velocity of the resulting flocs. Typical proprietary ballasted flocculation systems are equipped with coagulation and flocculation upstream of a settling basin equipped with gravity plate settlers. The ballasting agent is recovered from the settled sludge using a hydrocyclone or similar mechanism, and recovered and reused in the process.

The greatest advantage of ballasted flocculation systems is the high loading rates that can be achieved. The relatively high hydraulic loading rate of the process results in a small overall process footprint. It helps to resolve the poor settling of sludge in some cases. The primary disadvantage of the ballasted flocculation clarification process is the difficulty in treating solids produced and the impact of polymer and sand on the sludge recycle. The solids stream from the ballasted flocculation process is typically approximately 0.1 percent solids.

6.8.4.1 BOD Removal

Ballasted flocculation clarifiers can provide adequate BOD removal. The BOD removal ultimately depends on the loading rate of the system.

6.8.4.2 TSS Removal

Ballasted flocculation clarifiers can provide adequate TSS removal and produce better water quality than conventional secondary clarifiers. This technology may not be necessary for the secondary clarification application, considering its additional costs compared to conventional clarifiers.

6.8.4.3 Nutrient Removal

Similar to secondary clarifier, ballasted flocculation itself does not remove nutrients. Together with the biological process, a well-designed ballasted flocculation can help maintain a healthful biological growth and steady nutrient removal.

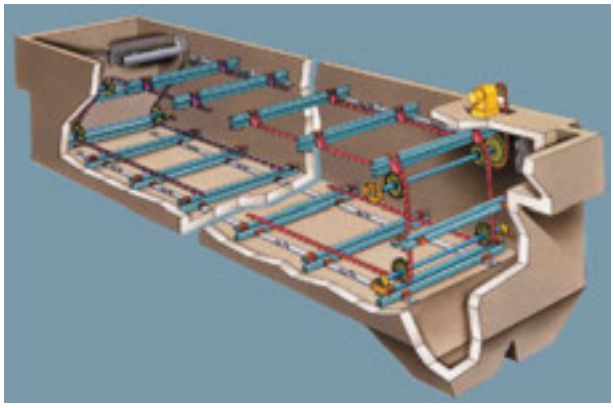
6.8.4.4 Odor Control

The ballasted flocculation process has the potential to produce some odors. Odor control may be required (although unlikely), depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to the clarification process.

Anticipated Performance of Ballasted Flocculation for the City of Surprise

Ballasted flocculation clarification processes provide solid separation following the biological treatment process. The high loading rate capabilities of the technology allow the clarification process to occur in a relatively small footprint. Given its higher costs than secondary clarification, ballasted flocculation may not be necessary for the City of Surprise's future WRFs unless justified by other reasons. However, it is **recommended** for the City of Surprise's further consideration and was included for further evaluation using the SurpriseTree™ Wastewater Model.

6.8.5 Dissolved Air Flotation



- Dissolved air flotation achieves high rate clarification within a compact footprint.
- The dissolved air flotation process utilizes microbubbles to float suspended particles to the surface for removal by an integral skimming mechanism.

Dissolved air flotation (DAF) systems are generally proprietary systems that utilize air microbubbles to float coagulated particles to the surface of a basin. Floating solids are removed hydraulically or mechanically. A typical dissolved air flotation system is enhanced with chemical additives. Compressed air is introduced into a recycle stream under pressure, causing the water to become air saturated. This saturated solution is then piped into the air flotation chamber, where the solution is exposed to a sudden pressure drop. The pressure drop causes air microbubbles to be released into the flotation chamber. Floating floc is removed from water surface of the air flotation chamber using a skimming mechanism.

The primary advantages of DAF are that the system requires a relatively small footprint. In addition, the DAF process allows very small particles to be removed completely, potentially providing better performance than a comparable conventional clarification process (which may not provide sufficient SRT to completely remove the small particles). DAF processes are most efficient when used for clarification following suspended growth biological treatment processes. The performance of the DAF system primarily depends on the ratio of volume of air to the mass of solids required to achieve a degree of clarification. Because

biosolids are typically light compared to water treatment residuals, a DAF system, where light solids float to the surface, may work more efficiently than a ballasted flocculation, where heavy solids settle to the bottom, especially for plants with primary clarifiers.

6.8.5.1 BOD Removal

DAF clarifiers can provide adequate BOD removal in the separated floating solids. The BOD removal ultimately depends on the loading rate of the system.

6.8.5.2 TSS Removal

DAF clarifiers can provide adequate TSS removal in the separated floating solids and better settled water quality than conventional secondary clarifiers. This technology may not be necessary for the secondary clarification application, considering its additional costs compared to conventional clarifiers.

6.8.5.3 Nutrient Removal

Similar to secondary clarifiers, DAF itself does not remove nutrients. Together with the biological process, a well-designed ballasted flocculation can help maintain a healthful biological growth and steady nutrient removal.

6.8.5.4 Odor Control

The DAF clarification process has the potential to produce some odors. Odor control may be required (although unlikely), depending on site setbacks available. Refer to Section 6.11 for descriptions of odor control technologies and their applicability to the clarification process.

Anticipated Performance of Dissolved Air Flotation for the City of Surprise

Dissolved air flotation clarification processes provide solid separation following the biological treatment process. The high rate loading capabilities of the process allow the clarification to occur in a relatively small footprint. Due to its higher costs, dissolved air flotation may not be necessary for the City of Surprise unless justified by other reasons. However, it is **recommended** for the City of Surprise's further consideration and was included for further evaluation using the SurpriseTree™ Wastewater Model.

6.8.6 Summary of Clarification Technologies

Table WWT.34 summarizes the anticipated performance of the clarification technologies as well as their applicability to the City of Surprise typical wastewater. Table WWT.35 summarizes the evaluation results for clarification technologies using the implementation based criteria. Conventional secondary clarifiers, DAF, and ballasted flocculation are recommended for further evaluation in the SurpriseTree™ Wastewater Model.

Table WWT.34 Clarification Unit Operations – Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operation	Performance Based Criteria					
	TSS Removal	**BOD Removal**	**Nitrification-Denitrification**	**Turbidity Removal**	**Pathogen Removal**	**DBP Control**
Conventional Secondary Clarifiers (Circular and Rectangular)	Good.	Good.	Good.	Good.	Poor. Not primary function.	Poor. Not primary function.
Dissolved Air Flotation	**Very good. Chemical enhanced settling. Sludge is already aerated.**	Very good.	Very good.	Very good. Capture occurs by attachment to microbubbles.	Poor. Not primary function.	Poor. Not primary function.
Ballasted Flocculation	Very good. Chemical enhanced settling.	Good.	Good.	Very good. Capture occurs in flocs formed by chemical enhancement. May not be as efficient as DAF for activated sludge application due to the use of polymer and microsand.	Poor. Not primary function.	Poor. Not primary function.

Note:
(1) Bold and shaded cells highlight dependencies on water quality or facility size.

Table WWT.35 Clarification Unit Operations – Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operations	Implementation Based Criteria																	
	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Footprint	Regulatory	Safety	Residuals	Versatility	Expand-ability	Odor	Energy Savings	Class A Biosolids	Air Quality
Conventional Secondary Clarifiers (Circular and Rectangular)	Very good.	Very good.	Good.	Very good.	Good.	Good.	Good.	Very good.	Good. Requires larger footprint.	Very good.	Good.	Good.	Good.	Good.	Good.	Very good.	N/A	Good.
Dissolved Air Flotation	Good.	Good.	Very good. Able to capture smaller sized particles.	Good.	Fair.	Good.	Good.	Good.	Very good. Compact footprint due to high loading rate.	Good.	Good.	Good.	Good.	Good.	Good.	Fair.	N/A	Good.
Ballasted Flocculation	Good.	Good.	Very good.	Good. Proprietary technology.	Fair.	Good.	Good.	Good.	Very good. Compact footprint due to high loading rate.	Good.	Good.	Fair. Residuals may be problematic for thickening.	Good.	Good.	Good.	Fair.	N/A	Good.

6.9 Tertiary Filtration Treatment Technologies

The purpose of tertiary filtration is to remove suspended solids that carry over from the biological treatment process and/or secondary clarifiers, and to condition the water, providing a high-quality filtrate to optimize the efficiency of the disinfection process. Tertiary filtration is a vital component in producing Class A+ effluent. ADEQ regulations for Class A+ reclaimed water, as discussed in Section 3.1.3, specify turbidity requirements of 2 NTU or less based on a 24-hour average, with no exceedances of 5 NTU at any time.

In addition to the ADEQ Class A+ turbidity limits, the current regulations for Class A+ reclaimed water require that chemical filter aid (coagulant or polymer) feed facilities be provided to supplement tertiary filtration systems. Although chemical feed and flocculation systems are required by permit, they are often not used under normal filter operating conditions if not necessary to meet effluent quality requirements.

The filtration alternatives discussed in this section include granular media filters, cloth media filters, and membrane filtration. Additional details associated with each technology can be found in Appendix A.

6.9.1 Granular Media Filters

Multiple configurations of granular media filters are available. The types of granular media filters discussed in this section include conventional downflow filters, deep bed downflow filters, continuous upflow filters, and traveling bridge filters.

6.9.1.1 Conventional Downflow Media Filters and Deep Bed Downflow Filters

	• Conventional downflow media filters typically consist of sand and/or anthracite media beds. Filtration rates for conventional downflow media filters are typically 2-5 gpm/ft^2, requiring a relatively large filtration footprint. • The deeper media bed of deep bed is able to store more solids and run for an extended period between backwash cycles compared to conventional media filters.

Although more commonly applied to potable water treatment, conventional downflow granular media filters can be used to provide tertiary wastewater treatment. Filters are designed with mono-, dual-, or multi-media configurations supported by an underdrain system. Mono-media filters typically consist of sand (~30 inches deep); dual-media filters are typically sand with a layer of anthracite above the sand (~36 inches deep); multi-media filters generally consist of sand, under a layer of anthracite, under a layer of garnet or

ilmenite (~36 inches deep). Mono-media filters experience rapid head loss buildup as particles are generally retained within the top few inches of sand, while dual- and multi-media filters allow particles to penetrate deeper into the media bed, and thus experience slower head loss formation and have longer filter run times.

The filtration/backwash cycle is sequential. Therefore, multiple filters are typically provided to account for one filter being out of service during backwash. Filtration rates are typically 2 to 5 gpm/sf.

To accommodate the backwash requirements, large pumps and a backwash water supply tank are required. In addition, spent backwash water clarification and equalization tanks are needed. The footprint requirements for conventional downflow granular media filters are generally larger than other filtration technologies.

Deep bed downflow filters are similar to conventional downflow media filters, except that the depth and size of media is greater than a conventional filter in order to store more solids and extend the filter run time between backwash cycles. Media depths generally range from 6 to 9 feet.

Backwashing deep bed downflow filters requires higher backwash volumes than conventional filters and generally incorporates an air scour component to achieve effective cleaning.

The following list of advantages and disadvantages applies to both conventional downflow and deep bed downflow filters. The advantages of this type of filtration include:

- Simple process;
- Low head loss through process; and
- Well-established criteria for effective filtration.

The disadvantages of this type of filtration include:

- High backwash volumes are required;
- The filter must be taken off-line during a backwash cycle;
- The process requires pumps, clarification/equalization basins to support the sequential backwash cycles;
- An underdrain system is required;
- Periodic media replacement is required - adding to O&M requirements/costs; and
- A larger footprint is required compared to other filtration technologies.

Anticipated Performance of Conventional Media Filters for the City of Surprise

Conventional downflow media filters and deep bed downflow granular media filters are capable of achieving adequate wastewater filtration. These filters are a **recommended** alternative for wastewater filtration for the City of Surprise's further consideration and are included for further evaluation using the SurpriseTree™ Wastewater Model.

6.9.1.2 Upflow Continuous Backwashing Filters

	• Continuous backwashing filters achieve filter backwash without removing the filter from operation. • Filtration rates for continuous backwashing filters are typically 2-12 gpm/ft^2, requiring a smaller filtration footprint than conventional filtration processes.

Continuous backwash filters are a type of deep bed granular media filter. The technology is gaining popularity for large filter installations due to its smaller footprint and low operational requirements. As the name implies, these filters backwash while in operation, and involve the movement of the media in the cleaning process.

Wastewater is injected into the filter at the bottom of the filter tank and flows upward through the downward traveling filter media. Solids are removed from the water by the media and the clean water is conveyed over a filter effluent trough. At the same time, the filter media is continuously circulated within the filter cell by an airlift pump at the middle of the filter module. The solids laden (dirty) media is air-lifted from near the base of the filter to the top of the filter. During the turbulent airlift process, the media is cleaned by agitation. A mechanism is then provided to separate the solids from the media, before the media is returned to the filter bed. The cleaned sand is redistributed on top of the sand bed allowing for a continuous uninterrupted flow of filtered effluent and backwash water. The quantity of wasted backwash water can be changed by adjusting the reject weir.

These filters are designed in modules and may be fitted into a rectangular housing constructed of cast-in-place concrete. The primary auxiliary equipment required for the continuous backwash filter includes an airlift pump and an air compressor that supplies air to the airlift pump. The overall depth of continuous backwash filters is typically 10 to 25 feet, depending on the size of the module. The units can be installed below or above grade. Typically, the design filtration rates are in the range of 2 to 12 gpm/ft^2, depending on the application. There are a growing number of manufacturers of continuous backwash filters.

Some advantages of continuous backwash filters include:

- Smaller footprint than conventional downflow and traveling bridge filters;
- Lower potential for algae growth than traveling bridge filters;
- Continuous backwash eliminates need for standby filter cells;
- No underdrains or backwash pumps are required; and
- No internal moving parts, limiting operator maintenance.

Some disadvantages of continuous backwash filters include:

- No chemical cleaning system is provided - difficult to clean if filter media is fouled;
- Separate air compressor system;
- Large number of filter modules required;
- Deeper units compared to traveling bridge filters;
- Poor media size distribution within filter;
- High power consumption for air compressor; and
- Higher backwash reject flows compared to traveling bridge and disc filters.

Anticipated Performance of Upflow Continuous Backwashing Filters for the City of Surprise

Upflow continuous backwashing filters achieve wastewater filtration in a relatively compact footprint, and allow the filtration process to maintain continuous operation during backwashing operations. Upflow continuous backwashing filters are a **recommended** alternative for wastewater filtration for the City of Surprise and are included for further evaluation using the SurpriseTree™ Wastewater Model.

6.9.1.3 Traveling Bridge Filters

- Traveling bridge filters are a common WRF filtration process capable of maintaining continuous filtration during backwash.
- Filtration rates for traveling bridge filters are typically 2 gpm/ft^2 based on average day flows - requiring a comparable filtration footprint to conventional filtration processes.

Traveling bridge filters are low head (typically one foot of head loss), shallow media depth (16 to 24 inches), gravity-type filters. Filter media can be mono (sand) or dual (sand and anthracite), although mono-media sand filters are generally recommended for wastewater applications.

These types of filters are divided into individual cells. The traveling bridge traverses the length of the bed, backwashing one cell at a time, such that the entire filter does not have to be taken off-line. Backwashing occurs under the hood, below the traveling carriage. The backwash pump draws filtered water from the effluent chamber to use as backwash water. A backwash “shoe” seals onto each effluent port during backwash, forcing water up through the media in the cell. The backwash can be automatic based on pre-set time interval or water level in the filter, or operator (manually) initiated. No separate backwash sump is

necessary, as the backwash pump utilizes the filtered effluent in the channel as the backwash water source.

Typically, if multiple filters are installed with common-wall construction, some mechanism for accessing and removing pumps and mechanical equipment (e.g., monorail) from the central basins will be required.

Typical design filtration rates are 2 gpm/ft^2 and 4 to 5 gpm/ft^2, based on average and peak day flows, respectively. One manufacturer also identifies a limiting solids loading rate of 1.2 lbs TSS/ft^2/day as applicable design criteria. There are several manufacturers of traveling bridge filters.

Some advantages of the traveling bridge filter include:

- Easy to operate;
- Continuous filtering during backwash;
- Head loss is minimal - typically 6 to 10 inches;
- Low maintenance; and
- Numerous installations in Arizona and locally in the Valley.

Based on operational experience from local plants, some disadvantages of using traveling bridge filters include:

- Requires more area than continuous backwash and disc filters;
- Problems with plugging of the underdrains and limited access to underdrains;
- Potential backwash water short-circuiting from certain nozzle underdrain designs;
- Poor media size distribution within the filter;
- Periodic media replacement required; and
- Potential for high algae growth if exposed to sunlight, which necessitates continuous chlorine dosing or installation in a building. It is difficult to completely cover traveling bridge filters, as there are numerous moving parts above the filter walls.

Anticipated Performance of Traveling Bridge Filters for the City of Surprise

Traveling bridge filters are a proven filtration process used at many WRFs. The technology allows the filtration process to continue during backwashing operations. Traveling bridge filters are a **recommended** alternative for wastewater filtration for the City of Surprise and are included for further evaluation using the SurpriseTree™ Wastewater Model.

6.9.1.4 BOD Removal

The majority of the BOD will be removed prior to the filtration process. The filters are not designed to function as a BOD removal process. However, granular media filters will further reduce BOD remaining in the secondary effluent to less than 2 ~ 5 mg/L typically.

6.9.1.5 TSS Removal

The majority of the TSS will be removed prior to the filtration process especially in the primary and secondary clarification processes. However, granular media filters will further remove TSS remaining in the secondary effluent. Filtration effluent, often referred as tertiary effluent, TSS is typically 5-10 mg/L.

6.9.1.6 Turbidity Removal

Filtration is a critical requirement for achieving Class A and Class A+ reclaimed water quality. The filters will be designed to meet the turbidity standards set forth in Section 4.3. Granular media filters are capable of achieving turbidity removals below the ADEQ reclaimed water requirements. However, turbidity breakthrough can occur at times and cause spikes in the effluent turbidity above the ADEQ reclaimed water requirements. A filter aid feed system can assist in minimizing breakthrough and is required for Class A+ facilities.

6.9.1.7 Pathogen Removal

Granular media filtration removes microbes through a combination of physical - hydrodynamic properties and surface and solution chemistry. Under optimal conditions, the combination of coagulation, flocculation, sedimentation, and granular media filtration can result in 4-log or better removal of protozoan pathogens. However, without proper chemical pretreatment, this type of rapid rate filtration works as a simple strainer and is not an effective barrier to microbial pathogens. The efficiency of filtration technologies vary significantly for the removal of particles smaller than 20 µm in size. Particles between 5 to 20 µm still provide significant shading and shielding effects for pathogens during the disinfection process. Therefore, poor disinfection efficiencies can still be expected if the filter effluent contains a considerable amount of suspended particles between 5 to 20 µm, even if the filtered effluent turbidity is less than 2 NTU.

6.9.2 <u>Cloth Media Filters</u>

Multiple configurations of cloth media filters are available. The types of cloth media filters discussed in this section include disc filters, drum filters, and traveling bridge cloth media filtration.

6.9.2.1 Disc Filters

	• Disc filters achieve wastewater filtration by using a cloth media to achieve solids separation. • Wastewater filtration can be achieved in a compact footprint due to relatively high hydraulic loading rates.

Disc filtration is a relatively new technology for wastewater use in the United States. This process, in use since the late 1990s, uses cloth media to filter out particles in wastewater. Removable filter cloth segments are mounted on a center manifold to form double-sided discs.

There are two major configurations of disc filtration systems.

- **Outside-in flow**: Wastewater (secondary effluent) enters the filter tank and passes through the cloth media by gravity. The filtrate enters the internal portion of the discs and is directed to discharge from the center manifold. Solids are retained outside of the disc surface and accumulate on the media. The filter discs are fully submerged during filtration. During backwash, solids are removed by suction “shoes” as the disc rotates, and pumped out of the filter basin to the headworks. Discs can be individually cleaned without interrupting the filtration process.
- **Inside-out flow**: Secondary effluent flows by gravity into the filter segments through the center feed drum. Filtration occurs as water flows from the inside to the outside of the disc through the filter cloth. Solids are retained within the filter discs. The filter discs are 60 percent submerged during filtration. Using counter-current backwash, solids are removed by a spray wash system and drained to a collection trough. The backwash water is typically 1 to 3 percent of the influent flow and maximum head loss is approximately 12 inches.

In both configurations, filter discs remain static during filtration. As the solids mat is formed on the media, the hydraulic resistance increases, and the hydraulic head loss rises. When a pre-determined head loss setpoint is reached, a level sensor automatically activates a backwash procedure. Filter discs rotate slowly during backwash to make certain each disc segment is cleaned. Backwash water is discharged through the tank drain piping or the center collection trough.

Typical design loading rates for cloth disc filters are 3 gpm/ft^2 and 6 gpm/ft^2 for average and peak day flows, respectively. One configuration also identifies a limiting solids loading rate of 3.25 lbs TSS/ft^2/day as applicable design criteria.

The major advantages of disc filtration include:

- Compact design and small footprint;
- Relatively high hydraulic loading rate: 3 (average) to 6 (peak) gpm/ft^2;
- Operation flexibility;
- Easy modular expansion;
- Low operating head loss (typically 8 to 14 inches);
- Relatively low maintenance;
- City of Surprise operations staff is familiar with technology;
- Continuous filtration is available;
- Requires no underdrain;
- Produces better filtrate quality, even during peak flow and turbidity events;
- Better particle size distribution - good for pretreatment for UV;
- Lower backwash rates compared to granular media filters; and
- No media replacement is required.

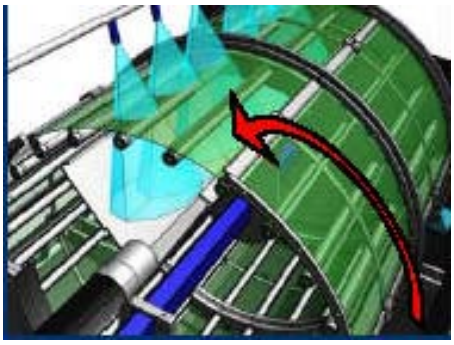
The major disadvantages of disc filtration include:

- There are fewer installations in the U.S. compared to other types of filters due to the relatively recent development of the technology;
- Actual life span of the cloth media is unpredictable based on current experiences;
- The cloth media is more susceptible to fouling, wear and tear compared to granular media;
- Manufacturer serviceability is unknown; and
- Requires multiple pieces of mechanical equipment.

6.9.2.1.1 Type of Fabrics

Filter discs are available in three types of material: nylon, acrylic, or polyester. Based on the cost, durability, and chlorine resistance considerations, polyester media is most common. Typical pore sizes are in the range of 10 to 30 microns for the complex pile fabric and 10 microns to 1 mm for the monofilament polyester. Pile fabric has been more effective during backwashing compared to needle felt cloth media.

6.9.2.2 Drum Filters

	• Drum filters achieve wastewater filtration using a microscreen type fabric. • Drum filters use gravity to separate the solids within the rotating drum.

Drum filters utilize a microscreen concept for solids separation. Water passes into the center of the drum, which is covered by a polyester or stainless steel fabric of a pore size based on the application. Water passes through the fabric by gravity and solids are retained on the inside of the drum. A series of nozzles outside the drum sprays through the fabric as the drum rotates and solids are collected by a backwash trough and conveyed out of the filter. Drum filters are a relatively new filtration technology in wastewater filtration applications.

6.9.2.3 Traveling Bridge Cloth Media Filtration

	• Traveling bridge cloth media filtration can achieve 3 times the filtration rate of a conventional granular media traveling bridge filter in the same footprint. • Traveling bridge cloth media filters produce high effluent with less susceptibility to turbidity break through.

One type of cloth media filtration combines a cloth media with a traveling bridge backwash configuration. This type of filtration can achieve 2.5 to 3 times the flow capacity of a granular media traveling bridge filter with an equivalent footprint. This configuration can be ideal for existing WRFs needing to expand their hydraulic capacity. The cloth media can be retrofitted into existing filtration basins.

The major advantages of traveling bridge cloth media filtration include:

- Gravity flow operation;
- Capable of installation in new or existing concrete tanks;
- Produces reuse quality effluent;
- Higher solids loading per square foot of media compared to granular media traveling bridge filters;

- Reduced backwash water volume requirements; and
- Higher hydraulic loadings and reduced footprint compared to granular media traveling bridge filters.

The major disadvantages of traveling bridge cloth media filtration include:

- Unique pile cloth media manufactured by a single supplier.

6.9.2.4 BOD Removal

The majority of the BOD will be removed prior to the filtration process. Filters are not designed to function as a BOD removal process. However, cloth media filters will further reduce BOD remaining in the secondary effluent to less than 2 ~ 5 mg/L typically.

6.9.2.5 TSS Removal

The majority of the TSS will be removed prior to the filtration process especially in the primary and secondary clarification processes. However, cloth media filters will further remove TSS remaining in the secondary effluent. Filtration effluent, often referred as tertiary effluent, TSS is typically 5-10 mg/L.

6.9.2.6 Turbidity Removal

Filtration is a critical requirement for achieving Class A and Class A+ reclaimed water quality. The filters shall meet the turbidity standards set forth in Section 4.3.

Cloth filters are capable of achieving turbidity removals below the ADEQ reclaimed water requirements. However, turbidity breakthrough can occur at times and cause spikes in the effluent turbidity above the ADEQ reclaimed water requirements. A filter aid feed system can assist in minimizing breakthrough and is required for Class A+ facilities.

6.9.2.7 Pathogen Removal

Typical cloth filters have pore sizes in the range of 10 to 30 microns for the complex pile fabric and 10 microns to 1 mm for the monofilament polyester. Particles between 5 to 20 µm still provide significant shading and shielding effects for pathogens during the disinfection process. Therefore, poor disinfection efficiencies can still be expected if the filter effluent contains a considerable amount of suspended particles between 5 to 20 µm, even if the filtered effluent turbidity is less than 2 NTU.

Anticipated Performance of Cloth Filters for the City of Surprise

Disc filters, drum filters, and traveling bridge cloth media filtration are viable filtration technologies. However, of the cloth filters discussed in this section, disc type are a **recommended** alternative for wastewater filtration for the City of Surprise and are included for further evaluation using the SurpriseTree™ Wastewater Model. Disc filters are recommended for new treatment facilities, as a reliable technology capable of achieving filtration in a compact footprint.

6.9.3 Membrane Filtration

- Membranes provide filtration through size exclusion of particles larger than the membrane pore size.
- Membranes produce a reliable, high quality filtrate with turbidity less than 0.1 NTU.
- Refer to Section 6.7.5 for additional information regarding MBR technology.

Microfiltration (MF) and ultrafiltration (UF) processes utilize membranes with pore sizes ranging from 0.1 to 10 micrometers (µm) in a low-pressure application (up to approximately 30 psi). Solids removal is achieved through size exclusion in which particles larger than the membrane pore size are retained on the membrane surface and filtered water passes through the membrane (filtrate). Membranes are typically air scoured on a frequent cycle to physically remove solids accumulated on the membrane surface. Periodic chemical cleaning is required to remove scaling and prevent long-term fouling. Reject water produced by the cleaning cycles generally ranges from 10 to 15 percent of flow.

MF/UF processes are capable of reliably producing a high quality effluent, with turbidity less than 0.1 NTU, and 0.5-log removal of viruses.

Membranes are available in an outside-in or an inside-out configuration, and can be installed in pressure vessels or directly submerged in a tank. Membrane filtration is achieved in a compact footprint, due to the associated high loading rates. Refer to Section 6.7.5 for additional information on the MBR process using membrane technology.

Anticipated Performance of Membrane Filtration for the City of Surprise

Membrane filtration is a proven, reliable filtration process for wastewater treatment and can provide a consistent, high quality effluent. When membranes are used in wastewater applications, they are typically installed in a MBR configuration with an aeration basin followed by the membrane basins. Membrane filtration is a **recommended** alternative for retrofitting existing facility with secondary clarifiers for wastewater filtration for the City of Surprise and is included for further evaluation using the SurpriseTree™ Wastewater Model.

6.9.3.1 BOD Removal

The majority of the BOD will be removed prior to the filtration process. The filters are not designed to function as a BOD removal process. Membrane filtration will further reduce BOD remaining in the secondary effluent and help to produce a good effluent quality with BOD typically less than 2 mg/L.

6.9.3.2 TSS Removal

Membrane filtration process produces a consistent, very low effluent TSS concentration (< 0.5 mg/L).

6.9.3.3 Nutrient Removal

Properly designed biological system can achieve good nutrient removal (< 5 to 8 mg/L). Nitrification and denitrification processes are accomplished in the aerobic and anoxic biological processes prior to the membrane filtration.

6.9.3.4 Turbidity Removal

Membrane filtration process produces a consistently low turbidity (< 0.1 - 0.2 NTU) effluent that is not impacted by quality changes in the feed water.

6.9.3.5 Pathogen Removal

The membrane filtration process provides some level of effluent disinfection through the rejection of both bacteria and viruses. Typically, membranes can achieve 5- to 7-log removal of total coliform bacteria, > 5.5- to > 6.0-log removal of fecal coliform bacteria, and 0.5- to 4-log removal of indigenous MS-2 coliphages (virus).

6.9.4 Summary Tertiary Filtration Technologies

Table WWT.36 summarizes the anticipated performance of the evaluated filtration technologies as well as their applicability to the City of Surprise typical wastewater. Table WWT.37 summarizes the evaluation results for filtration technologies using the implementation based criteria. Disc filters, traveling bridge filters, continuous upflow granular media filters, conventional granular media filters, and membrane filtration were recommended for further evaluation in the SurpriseTree™ Wastewater Model.

Table WWT.36 Filtration Unit Operations – Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operation	Performance Based Criteria					
	TSS Removal	**BOD Removal**	**Nitrification-Denitrification**	**Turbidity Removal**	**Pathogen Removal**	**DBP Control**
Conventional Granular Media Filters	Good.	Very good with properly designed biological system.	N/A	Very good.	Very good.	Good.
Traveling Bridge Filters	Good.	Good with properly designed biological system.	N/A	Good.	Very good.	Good.
Disc Filters	Very good.	Good with properly designed biological system.	N/A	Very good.	Very good.	Good.
Membrane Filtration	Excellent regardless of feed quality.	Good with properly designed biological system.	N/A	Excellent regardless of feed quality.	Excellent.	Good.
Continuous Upflow Granular Media Filters	Good.	Fair with properly designed biological system.	N/A	Good.	Very good.	Good.

Notes:
(1) The effectiveness of the filtration unit operations will depend on the biological treatment and/or clarification process they are paired with.

Table WWT.37 Filtration Unit Operations – Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operations	Implementation Based Criteria																	
	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Footprint	Regulatory	Safety	Residuals	Versatility	Expand-ability	Odor	Energy Savings	Class A Biosolids	Air Quality
Conventional Granular Media Filters	Good.	Good.	Very good.	Very good.	Good.	Good.	Very good.	Good.	Good.	Very good.	Good.	Good.	Good.	Good.	Good. No odors requiring control produced in filtration process.	Good.	N/A	Good.
Traveling Bridge Filters	Good.	Very good.	Very good.	Good.	Good.	Good.	Very good.	Very good.	Good.	Good.	Good.	Good.	Fair.	Very good.	Good. No odors requiring control produced in filtration process.	Good.	N/A	Good.
Disc Filters	Good.	Very good.	Good.	Very good.	Good.	Good.	Good.	Very good.	Very good.	Very good.	Good.	Good.	Good.	Good.	Good. No odors requiring control produced in filtration process.	Very good.	N/A	Good.
Membrane Filtration	Fair.	Fair.	Excellent.	Good.	Good.	Good.	Very good.	Good.	Very good.	Good.	Good.	Very good.	Very good.	Good.	Good. No odors requiring control produced in filtration process.	Good.	N/A	Good.
Continuous Upflow Granular Media Filters	Very good.	Good.	Good.	Very good.	Good.	Good.	Very good.	Very good.	Good.	Good.	Good.	Good.	Good.	Good.	Good, No odors requiring control produced in filtration process.	Good.	N/A	Good.

Note:
(1) The effectiveness of the filtration unit operations will depend on the biological treatment and/or clarification process they are paired with.

6.10 Disinfection Treatment Technologies

Disinfection is the inactivation, or killing, of pathogens in water. This process is a necessary barrier to prevent the transmission of waterborne diseases by microorganisms. Chemical disinfection is the accepted practice within the wastewater industry in the U.S. All wastewater treatment systems must provide disinfection. For wastewater treatment systems where the influent water contains high levels of organic matter, another important consideration driving disinfection process selection is the control of disinfection byproduct (DBP) formation. The influent wastewater is anticipated to contain organic matter. The end use of the effluent may dictate the type of disinfection, depending on the necessity of DBP formation mitigation.

In general, the disinfection requirement for wastewater is to achieve pathogen inactivation and fecal coliform reduction, and to maintain disinfection residual for reclaimed water distribution systems using chlorine or other disinfectants that can provide measureable residuals. Maintaining a residual chlorine concentration is necessary to prevent bacterial growth in the reclaimed water distribution system. For some effluent discharge applications (i.e., discharge to washes or habitat), a residual cannot be present. Dechlorination may be necessary for such applications.

The disinfection alternatives discussed in this section include gaseous chlorine, bulk sodium hypochlorite, onsite generated sodium hypochlorite, chloramines, UV disinfection, and ozone. Additional details associated with each technology can be found in Appendix A.

6.10.1 Chlorination

Chlorination of wastewater to provide disinfection has been an industry standard for many years. Chlorination can be accomplished using gaseous chlorine, liquid chlorine (bulk or onsite generated), or chloramines. In general, chlorine is an effective disinfectant. It is very effective for virus inactivation, but is not as effective for *Cryptosporidium* inactivation when compared to UV and ozone. Free chlorine is also not necessarily as effective as chloramines to control biofilm growth in reclaimed water distribution system piping. A chlorine contact basin may be necessary to achieve the required concentration x time (CT) requirement of disinfection. Dechlorination may be necessary for end use applications associated with surface water discharge, to comply with the NPDES requirements.

6.10.2 Gaseous Chlorine

- Chlorine gas has a long history of successful use as a disinfectant in wastewater treatment.
- Chlorine gas is an economical means of providing disinfection.
- Safe storage and handling of chlorine gas is an important concern to prevent accidental releases to neighboring communities.

Gaseous chlorine has a long history of successful operation for disinfection in wastewater treatment plants. It is readily available in conventional 150-pound cylinders, 1-ton containers, or 17-ton tank trucks and provides an economical option for disinfection. However, there are many safety concerns associated with the use of chlorine gas. The accidental release of chlorine gas during transportation or operation at the treatment facility can cause clouds of the poisonous gas to travel significant distances, potentially endangering surrounding communities. A risk management plan is required by the Clean Air Act for locations having more than 2,500 pounds of chlorine gas on site. The use of chlorine gas can be an operation and maintenance intensive process. In fact, extensive training and additional respiratory protection is required for operation and maintenance staff working around chlorine gas.

6.10.2.1 Pathogen Removal

Chlorine disinfection achieves pathogen removal/inactivation.

6.10.2.2 DBP Control

Free chlorine reacts with natural organic matter (NOM) in water to form TTHMs, HAAs, and other DBPs. When using chlorine for wastewater disinfection that contains high organic material, the likelihood of generating DBPs is greatly increased. In addition, chlorate is formed when sodium hypochlorite decays. Minimizing the use of chlorine for wastewater treatment will help minimize DBPs.

Anticipated Performance of Chlorine Gas at City of Surprise

Chlorination using chlorine gas is **not recommended** for the City of Surprise due to its safety concerns. However, due to the economics of utilizing gaseous chlorine for disinfection, the technology was included for further evaluation using the SurpriseTree™ Wastewater Model to provide the City with multiple disinfection options and design considerations for site-specific applications.

6.10.3 Liquid Chlorine (Bulk)

- Bulk sodium hypochlorite has a long history of successful disinfection in wastewater treatment.
- Bulk 12.5 percent sodium hypochlorite is considered a hazardous material.
- Significant degradation of the solution can occur over time due to exposure to high temperatures and UV.

Bulk sodium hypochlorite is also known as bleach. The 12.5 percent sodium hypochlorite solution is widely used and has a long history of successful disinfection in the wastewater treatment industry. Bulk sodium hypochlorite is considered a hazardous material, but is much safer to transport, store, and handle than gaseous chlorine. The storage and feed systems are inexpensive to construct; but the chemical costs associated with bulk deliveries are expensive compared to gaseous chlorine and the O&M costs for using onsite generated sodium hypochlorite. The bulk chemical feed process is relatively easy to operate and maintain.

Bulk sodium hypochlorite solutions degrade rapidly under elevated temperature and exposure to UV, thus reducing the concentration of the effective chlorine content. In addition, the potential for air binding, plugging, and mechanical malfunction can be operational challenges associated with the use of this chemical.

6.10.3.1 Pathogen Removal

Chlorine disinfection achieves pathogen removal/inactivation.

6.10.3.2 DBP Control

Free chlorine reacts with NOM in water to form TTHMs, HAAs, and other DBPs. When using chlorine for wastewater disinfection that contains high organic material, the likelihood of generating DBPs is greatly increased. In addition, chlorate is formed when sodium hypochlorite decays. Minimizing the use of chlorine for wastewater treatment will help minimize DBPs.

Anticipated Performance of Bulk Chlorine at City of Surprise

Chlorination using bulk sodium hypochlorite is **recommended** for wastewater disinfection for the City of Surprise water reclamation facilities. The technology is included for further evaluation using the SurpriseTree™ Wastewater Model. A life cycle cost evaluation and payback analysis is recommended to compare this alternative with onsite sodium hypochlorite generation based on market conditions at the time of implementation.

6.10.4 Liquid Chlorine (Onsite)

- Onsite generation is an effective method of disinfection in wastewater treatment.
- Onsite generation of chlorine occurs through a reaction of salt, water, and electricity.
- < 1 percent sodium hypochlorite solution is produced by the generation system. The resultant solution is considered a non-hazardous material.

Liquid chlorine can be generated on site in the form of sodium hypochlorite solution by combining salt, water, and electricity. The generated solution is typically less than 1 percent concentration, which is considered a non-hazardous material. Since the chemical is generated onsite and at a lower concentration, there is less concern for chemical degradation compared to bulk chlorine. Consequently, consistent solution strength is provided for disinfection. In addition, producing chlorine on site provides operational staff with flexibility in chemical production and operations.

Onsite generation systems will generate a greater addition of TDS and sodium to the water compared to bulk solution. An increase in TDS of 10 to 14 mg/L and an increase in sodium of 5 to 6 mg/L can be expected in the disinfected water from the use of onsite generated sodium hypochlorite versus bulk sodium hypochlorite due to differing methods of chemical creation.

Onsite generation systems produce a hydrogen gas byproduct that must be carefully vented and monitored to avoid potential safety issues.

Two types of systems are most commonly available for onsite generation. The first and most common systems generate a very dilute (0.8 percent) sodium hypochlorite solution directly from salt water. The second type of system generates pure chlorine gas directly and sodium hydroxide as a byproduct. In the second method, the chlorine can be fed in two distinct ways. The generated chlorine can be fed either directly via a conventional chlorine feed system or generated chlorine can be remixed with the generated sodium hydroxide to generate a concentrated (12.5 percent) sodium hypochlorite solution, which is stored on

site and fed with conventional metering equipment. The first system has seen widespread use in the U.S. while the second system is much more complex and has seen limited use.

Disinfection can also be achieved through the use of a mixed oxidant onsite generation system. A mixed oxidant onsite generation system is similar to a sodium hypochlorite onsite generation system. However, mixed oxidants are used to accomplish disinfection in lieu of sodium hypochlorite.

On-site sodium hypochlorite generation generally requires a higher initial capital investment than comparable bulk or gaseous chlorine systems. However, the O&M costs are generally considerably lower than comparable bulk systems. From a life cycle standpoint, onsite generation could offer cost savings, especially for high chemical use or large facilities.

6.10.4.1 Pathogen Removal

Chlorine disinfection using onsite generation achieves pathogen removal/inactivation.

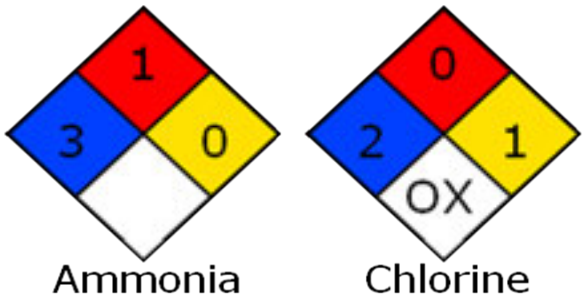
6.10.4.2 DBP Control

Free chlorine reacts with NOM in water to form TTHMs, HAAs, and other DBPs. When using chlorine for wastewater disinfection that contains high organic material, the likelihood of generating DBPs is greatly increased. In addition, chlorate is formed when sodium hypochlorite decays. Minimizing the use of chlorine for wastewater treatment will help minimize DBPs.

Anticipated Performance of On-site Generation Chlorine at City of Surprise

Chlorination using onsite sodium hypochlorite generation is **recommended** for wastewater disinfection for the City of Surprise water reclamation facilities. The technology was included for further evaluation using the SurpriseTree™ Wastewater Model. A life cycle cost evaluation and payback analysis is recommended to compare this alternative with bulk sodium hypochlorite based on market conditions at the time of implementation.

6.10.5 Chloramines



$$NH_3 + HOCl = NH_2Cl + H_2O$$
$$NH_3 + 2HOCl = NHCl_2 + 2H_2O$$
$$NH_3 + 3HOCl = NCl_3 + 3H_2O$$

- Disinfection using chloramines is a viable method of providing secondary disinfection to maintain required residual.
- The use of chloramines reduces the formation of DBPs compared to free chlorine.

The use of chloramines in wastewater treatment has become more widespread due to their ability to provide a degree of disinfection without substantial THM formation. Chloramines have a tendency to form lower levels of TTHMs and HAAs compared to chlorine disinfection. Chloramination is accomplished by combining free chlorine with ammonia, or an ammonium salt, to form chloramine. Chloramines provide additional benefits including maintenance of a more stable residual in distribution systems. If improperly managed, the application of chloramines can support bacterial growth in the reclaimed water distribution system, due to biological nitrification of the free ammonia. Chloramination requires two chemical feed systems for two hazardous chemicals. Consequently, the system generally requires a higher initial capital cost and additional O&M considerations.

Chloramine is not as strong a disinfectant as chlorine and is not recommended as a primary disinfectant by the USEPA. Chloramine, does however, form a persistent disinfectant residual. Chloramine is slower to react with substances on the walls of transmission mains and thus is more effective at penetrating tubercles and biofilms and killing resident bacteria. Chloramine is toxic to fish and amphibians at levels required for disinfection. In addition, chloramines can be problematic for kidney dialysis machines.

6.10.5.1 Pathogen Removal

Chloramine disinfection achieves pathogen removal/inactivation.

6.10.5.2 DBP Control

Chloramine is known to reduce the production of chlorinated DBPs compared to free chlorine, as the free chlorine first reacts with ammonia to form the chloramines molecule. However, chloramination in the presence of bromide can produce DBPs including bromamines and bromochloramine.

N-nitrosodimethylamine (NDMA), a known carcinogen, is a chloramine related DBP. During disinfection, NDMA appears to be formed by several different reactions, depending on the water matrix and chemicals used. USEPA has established a recommended level of NDMA in surface waters.

Chloramination, cationic polymers, and detention times appear to be factors that may increase the levels of NDMA. Chloramination provides nitrogen species that may trigger the formation of NDMA. Some cationic polymers may be releasing precursors of NDMA into the water.

In some instances, NDMA is formed slowly; so, long detention times in the distribution system may increase levels. Nitrification by nitrifying bacteria may occur in systems that practice chloramination. Similarly, other bacteria species may cause the formation of NDMA. By controlling these factors, water systems should be able to reduce the formation potential of NDMA.

Anticipated Performance of Chloramines at City of Surprise

Chloramines are **not recommended** for use by the City or Surprise. In general, other available disinfectants serve as more viable wastewater disinfectant alternatives and the City can address potential DBP issues through alternative means. Chloramine is not included for further evaluation using the SurpriseTree™ Wastewater Model.

6.10.6 Ultraviolet Disinfection

- UV disinfection provides an effective primary disinfectant for wastewater treatment.
- UV disinfection reduces secondary chlorine disinfection requirements, thereby reducing the DBP formation potential.

Ultraviolet (UV) emits light rays that inactivate pathogens in water. The UV energy is generated electrically with special germicidal lamps. The UV disinfection process can be accomplished in either a closed vessel or open channel reactor. UV light can be produced by low-pressure, medium-pressure, or high-intensity lamps. The use of UV light as a disinfectant does not create any disinfection byproduct (DBP) formation and no in-stream chemicals are required to achieve primary disinfection. The UV process has a relatively high electrical power consumption that can contribute to high O&M costs and UV disinfection can only be used to achieve primary disinfection. Therefore, an additional disinfection process is necessary to provide secondary disinfection for reuse applications.

As a primary disinfectant, UV provides a safe disinfection process within a compact footprint. Closed vessel reactors require a smaller footprint than open channel reactors. UV disinfection can be easily upgraded with the addition of more lamps, and also provides flexibility to treating future emerging contaminants, such as EDCs and PPCPs. The use of UV disinfection for effluent used in reclaimed water applications prevents the need for a dechlorination process prior to discharge. The use of UV disinfection assists in minimizing total trihalomethanes (TTHM) formation in the effluent through minimizing the use of chlorine. When chlorine is added to water, some of the chlorine reacts first with organic materials and metals in the water and is not available for disinfection. The applied chlorine dose includes the demand plus the total chlorine remaining in the water. Total chlorine has to meet the CT requirements for pathogen removal if chlorine is the primary disinfectant. However, if UV is the primary disinfectant, chlorine is not required for CT, and the applied chlorine dose equals the demand plus the minimum residuals required, ultimately reducing the chlorine addition required.

UV radiation for the disinfection of wastewater has been in development over the last 20 years, and is generally accepted throughout the United States as an effective disinfection process. Some of the significant factors that have attributed to the growing popularity of UV radiation are:

- Increasing awareness of the impact of chlorine and chlorinated compounds on the environment;
- Improvements in UV systems technology and equipment, resulting in a reduction in the cost of UV disinfection;
- More stringent regulations regarding the amount of residual chlorine and TTHMs in wastewater effluent;
- Increased costs associated with chlorination systems due to the need to provide dechlorination of the effluent prior to discharge;
- Regulations on the storage and handling of chlorine, especially in its gaseous form; and
- Public concerns with operation and safety in the use of chlorine and dechlorination agents.

UV radiation has proved to be a viable disinfection method regardless of the effluent requirements for reuse. UV disinfection is capable of routinely producing an effluent meeting the pathogen removal standard, which is currently required under ADEQ's BADCT requirements for an APP, as discussed in Section 3.1.3. ADEQ's Class A+ reclaimed water standards require no detectable fecal coliform organisms in 4 of the last 7 daily reclaimed water samples taken.

UV disinfection is a physical process that uses no toxic chemicals and produces no known toxic residuals or byproducts. The disinfection mechanism of UV light involves damage or destruction of an organism's genetic material due to the transference of electromagnetic energy (i.e., wavelength of 254 nanometers) from an ultraviolet lamp to the genetic material. The lethal effects of this energy result primarily from the organism's inability to reproduce. The effectiveness of the radiation is a direct function of the quantity of energy (i.e., dose) absorbed by the organism. Dose is defined as the product of the rate at which the energy is delivered (i.e., intensity) and the time to which the organism is exposed to this intensity (i.e., duration). Intensity is largely limited by the percent transmission of the UV light to the organism. An effluent with a high turbidity is thus more resistant to UV disinfection than an effluent with a low turbidity. As such, the utilization of tertiary filtration upstream of UV disinfection is an important design consideration.

Pilot plant studies have shown UV disinfection to be as effective as chlorine disinfection for eliminating coliform bacteria, and more effective than chlorine for eliminating viruses. Although a chlorine residual may be required for effluent reuse, the use of UV disinfection precludes the need for a chlorine contact basin. In addition, ADEQ's BADCT requirements call for minimization of TTHM compounds generated as disinfection byproducts, as discussed in Section 3.1.3. UV disinfection does not generate such byproducts.

6.10.6.1 UV Disinfection Configurations

Three main types of UV systems/lamps can be utilized for UV disinfection: low pressure/low output (LP/LO), medium pressure/high output (MP/HO), and low pressure/high output (LP/HO). Low-pressure UV systems require a large number of low-wattage lamps. LP/LO systems have been successfully operated at wastewater treatment facilities in the U.S. for many years. These systems are considered “conventional UV” systems and have been proven to be reliable and efficient. Historically, the low-pressure lamp has not been used in large wastewater treatment plants, due to the relatively large number of lamps required and the maintenance associated with cleaning the lamps.

MP/HO UV systems use high-wattage lamps and therefore require fewer lamps than LP/LO systems to achieve similar disinfection. MP/HO systems operate at much higher temperatures than LP/HO systems. This presents two primary concerns - safety for the plant operators, and the increased fouling potential as the temperature increases. The primary advantage to these systems is the dramatic reduction in number of lamps required.

LP/HO UV systems require an intermediate number of lamps (i.e., between their low and medium pressure counterparts) and also have an intermediate UV output. Scaling potential is much lower compared to the MP/HO lamps, due to the lower lamp operating temperature. The LP/HO UV system is rapidly becoming the UV system of choice in wastewater applications. These systems combine the advantages of the previous two lamp systems. There is a correlation between the required power input (per lamp) and the number of lamps required for a certain level of disinfection power. Depending on the specific manufacturer, LP/HO systems may require up to 8 times the number of lamps as a comparable MP/HO system. However, the power input for the LP/HO system is often 25 to 50 times less wattage per lamp than the MP/HO system. Generally speaking, as the power requirements increase per lamp, the lamp efficiency decreases.

UV systems can be provided in open channel or closed vessel configurations. Open channel UV systems flow by gravity through an open channel, which is often covered to discourage algal growth. Closed vessel UV systems are pressurized vessels in which the water must be pumped through the unit. For UV disinfection following an MBR process, a closed vessel UV system could take advantage of the permeate pumps associated with the MBR system (to pump the water through the UV vessels) and could provide a more compact system orientation. Closed vessel UV systems are typically more expensive compared to open channel UV systems.

Some UV manufacturers offer a self-cleaning system requiring either a chemical and/or mechanical wiper system. This type of cleaning system provides a mechanism to reduce lamp fouling and reduce the operational costs of manually cleaning the lamps.

6.10.6.2 NWRI UV Design Guidelines

The National Water Research Institute (NWRI) UV Disinfection Guidelines were developed in an effort to standardize UV system design among manufacturers and consultants for water reuse applications. The California Department of Health Services is applying the

NWRI guidelines of UV disinfection design to meet Title 22 regulations. Many other states are currently considering adopting NWRI guidelines to regulate UV disinfection processes.

The NWRI UV disinfection guidelines require that UV reactors be validated to prove their disinfection capabilities. This is achieved by evaluating UV dose delivered based on multiple factors. For water reuse applications, the standards require differing amounts of UV dose to be delivered to the process water depending on the preceding filtration process. The UV dosage is calculated by multiplying lamp intensity by duration. The UV transmittance is also recommended by NWRI Guidelines and is similarly based on the preceding treatment processes.

6.10.6.3 Pathogen Removal

UV for primary disinfection along with sodium hypochlorite for secondary disinfection achieves pathogen removal/inactivation.

6.10.6.4 DBP Control

The use of UV disinfection assists in minimizing DBP formation in the effluent water through minimizing the use of chlorine. However, chlorine addition is still required for systems utilizing reuse applications to establish a distribution system residual.

Anticipated Performance of UV Disinfection Chloramines for the City of Surprise

UV is an effective primary disinfectant that can reduce chlorination requirement - thus minimizing DBP formation potential. However, the O&M costs associated with UV disinfection can be high and a secondary disinfectant is required for systems using effluent for water reuse applications. UV primary disinfection followed by chlorination for residual disinfection is a **recommended** alternative for wastewater disinfection for the City of Surprise and included for further evaluation using the SurpriseTree™ Wastewater Model. If the effluent is reused and a residual is required, UV disinfection must be accompanied with other chlorination technologies (such as sodium hypochlorite bulk or onsite generation). A life cycle cost evaluation and payback analysis is recommended to compare the chlorination alternatives based on market conditions and treatment objectives at the time of implementation.

6.10.7 Ozone

	• Ozone is a strong oxidant that can achieve primary disinfection. • Ozone must be generated at the treatment facility. • The DBP bromate can be formed when ozone reacts with bromide. • Besides disinfection, ozonation can have other uses in enhancing biological treatment performance and improving filtration process efficiency.

While considered a favorable alternative to chlorine disinfection in the water treatment industry, ozone is rarely used to disinfect wastewaters. Recently, newer technologies such as pressurized ozone systems improved efficiencies and cost effectiveness for wastewater ozonation and some utilities have started to implement ozone for wastewater applications.

Besides disinfection, ozone is effective in addressing taste and odor, trace organic compounds, and helps to remove EDCs and PPCPs. Ozone is also a very strong oxidizing agent of metals such as iron and manganese, organics, and taste and odor causing compounds. The City of Scottsdale is currently designing ozone for its Advanced Water Treatment Plant as a pretreatment for tertiary RO. Completed studies concluded that ozone could enhance the membrane flux, reduce membrane fouling, and address NDMA or other emerging compound concerns.

Ozone is a strong oxidant and disinfectant and does not form chlorinated DBPs. However, like UV disinfection, ozonation still requires a secondary disinfectant to maintain a residual within the distribution system. Ozone does react with bromide and forms another regulated DBP - bromate (MCL = 10 µg/L). The formation of bromate varies depending on the ozone dose, bromide levels, and other water quality parameters such as pH and temperature. Considering a regional average bromide level of between 80 and 100 µg/L, typical water ozone dosage could lead to a violation of the bromate MCL. Wastewater contains more organic compounds and often has a high ozone demand. It is anticipated that the bromate MCL will be exceeded when ozone dosage is higher than 1 mg/L (assuming a 5-minute contact time, 80 µg/L bromide, pH 7.5, and temperature of 24 degrees Celsius).

In addition to potential concerns associated with bromate formation, ozonation increases the biodegradability of NOM in the treated water. On one hand, when ozone is coupled with biological treatment, it can enhance the performance of the biological process and improve effluent water quality. However, if not controlled properly, this may result in bacterial regrowth in ozonated wastewater effluent or cause biological fouling on downstream filters or membranes. In drinking water applications, ozone can be coupled with hydrogen peroxide as an advanced oxidation process. For wastewater applications, the presence of natural organic matter may generate sufficient hydroxyl radicals with ozone, eliminating the

need for peroxide, thereby lowering the chemical costs. However, generally speaking, high capital and O&M costs are associated with the use of ozone as well as safety concerns associated with the storage and use of liquid oxygen. Unless there are other drivers (e.g., removal of emerging compounds or treatment process requiring improvements) justifying the use of ozone, it is not recommended to implement ozone as a disinfection agent for the City's water reclamation facilities.

6.10.7.1 Advanced Oxidation Processes

Advanced oxidation processes (AOP) are a relatively new technology, which destroy hydrocarbon contaminants by converting them to carbon dioxide and water. The current emerging AOPs include high intensity UV oxidation via photolysis and coupling UV with hydrogen peroxide, ozone, or a catalyst such as TiO_2. Most systems consist of several reaction chambers with UV lamps and oxidant injectors. These systems can provide remediation for oxidizing emerging contaminants such as EDCs and PPCPs. Limited data is available for full-scale treatment plant installations.

AOP systems are generally complicated, energy intensive, and operation and maintenance intensive. The capital costs and the associated operation and maintenance requirements do not merit the recommendation of the AOP at this time. However, if future regulations require treatment or removal of EDCs, PPCPs, etc., AOPs may need to be further considered.

6.10.7.2 Reduction of Disinfectant Demand

In some cases, ozone can be used to oxidize DBP precursors, thereby reducing subsequent DBP formation during chlorination. However, for other waters, ozone reacts with organics and makes them more prone to DBP formation during subsequent chlorination.

6.10.7.3 Pathogen Removal

Ozone for primary disinfection followed by sodium hypochlorite for secondary disinfection can achieve pathogen removal/inactivation.

6.10.7.4 DBP Control

Ozonation of waters containing organic material can produce hydrogen peroxide, bromate, bromoform, aldehydes, glyoxal, methyl glyoxal, and biodegradable matter. In waters with low bromide concentrations (< 50 µg/L), ozone does not react to form halogenated DBPs. When bromide concentrations are substantial, ozone reacts to form brominated organic and inorganic DBPs such as bromoform and bromate, respectively. Bromate is an inorganic byproduct of ozonation of waters containing bromide. Ozonation of the City's wastewater has the potential to form concentrations of bromate.

Methods of reducing bromate formation during ozonation include: 1) using lower ozone dosages; 2) lowering the pH; and 3) ammonia addition. Regulated organic brominated DBPs, such as bromoform, cyanogen bromide, and dibromoacetic acid, can also be formed during ozonation.

Anticipated Performance of Ozone at the City of Surprise

Ozone is a very strong oxidizing agent of metals. Ozone can still be used as an oxidant at a dosage low enough to avoid bromate formations above the MCL. However, the capital costs of ozone generation and the associated risk likely do not merit the recommendation of ozone. Considering its effectiveness in addressing emerging contaminants such as certain trace organic compounds, ozone for primary disinfection followed by chlorination for secondary disinfection is included as a group in the SurpriseTree™ Wastewater Model, but is not ranked favorably given the City's current needs and interests. A life cycle cost evaluation and payback analysis is recommended to compare the chlorination alternatives based on market conditions and treatment objectives at the time of implementation.

6.10.8 Dechlorination

A residual is required for direct and indirect effluent reuse applications. However for effluent discharge applications, there is no residual requirement. In fact, a dechlorination process is usually needed to prevent chlorinated water from being discharged to a surface water source. Dechlorination processes add another chemical system to the overall treatment process.

6.10.9 Summary of Disinfection Technologies

Table WWT.38 summarizes the anticipated performance of the disinfection technologies as well as their applicability to the City of Surprise typical wastewater. Table WWT.39 summarizes the evaluation results for disinfection technologies using the implementation based criteria. Chlorine gas, bulk sodium hypochlorite, onsite generated sodium hypochlorite, UV with sodium hypochlorite, and ozone with sodium hypochlorite are recommended for further evaluation in the SurpriseTree™ Wastewater Model.

Table WWT.38 Disinfection Unit Operations – Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operation	Performance Based Criteria					
	TSS Removal	**BOD Removal**	**Nitrification-Denitrification**	**Turbidity Removal**	**Pathogen Removal**	**DBP Control**
Gaseous Chlorine	N/A	N/A	N/A	N/A	Very good.	Poor. Chlorination can generate DBPs. Chlorate is formed when sodium hypochlorite decays.
Bulk Sodium Hypochlorite	N/A	N/A	N/A	N/A	Very good.	Poor. Chlorination can generate DBPs. Chlorate is formed when sodium hypochlorite decays.
Onsite Generation Sodium Hypochlorite	N/A	N/A	N/A	N/A	Very good.	Poor. Chlorination can generate DBPs. Chlorate is formed when sodium hypochlorite decays.
UV + Sodium Hypochlorite	N/A	N/A	N/A	N/A	Excellent.	Very good. Less formation of chlorinated DBPs due to lower chlorine dose.
Ozone + Sodium Hypochlorite	N/A	N/A	N/A	N/A	Very good.	Fair.

Table WWT.39 Disinfection Unit Operations – Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operations	Implementation Based Criteria																	
	O&M Costs	**Capital Costs**	**Process Robustness**	**Maturity of Technology**	**City of Surprise Familiarity**	**Maintenance Intensity**	**Operation Flexibility**	**System Complexity**	**Foot-print**	**Regulatory**	**Safety**	**Residuals**	**Versatility**	**Expand-ability**	**Odor**	**Energy Savings**	**Class A Biosolids**	**Air Quality**
Gaseous Chlorine	Excellent. Least expensive alternative.	Very good. Least expensive alternative.	Very good. Relies on chemical deliveries.	Excellent. Long history.	Fair. City is familiar with technology but has concerns about chlorine gas.	Good. Relatively simple but many safety concerns.	Good.	Good. Simple but requires additional safety equipment.	Good.	Poor due to safety concerns.	Poor. Hazardous material.	N/A	Good.	Good.	Good.	Good.	N/A	Poor. Potential for chlorine gas leak.
Bulk Sodium Hypo-chlorite	Fair. Expensive for large facilities.	Very good. Low capital.	Very good. Relies on chemical deliveries.	Very good. Simple and mature.	Very good. City is familiar with technology.	Very good. Relatively easy to handle. Similar to other chemicals.	Very good.	Very good. Simplest system.	Good.	Good. 12.5% sodium hypochlorite is a hazardous material.	Good. Hazardous solution.	N/A	Good.	Very good. Easy to expend.	Good.	Good.	N/A	Good. Potential for off gassing.
Onsite Generation Sodium Hypo-chlorite	Good. Less expensive compared to bulk for large facilities.	Fair. High capital.	Good. Relies on complex generation system, salt deliveries and onsite storage capacity.	Good. Relatively mature.	Very good. City is familiar with technology.	Good. Complex system requires electrode replacement.	Very good.	Fair. Complex system.	Very good.	Very good. 0.8% sodium hypochlorite is not a hazardous material.	Good. Hydrogen gas is released during generation.	N/A	Good.	Good. Expands with modular generators.	Good.	Fair. Electricity required for generation.	N/A	Good. Potential for chlorine or hydrogen gas leaks.
UV + Sodium Hypo-chlorite	Poor. Requires two separate disinfection processes.	Fair. Requires two separate disinfection processes.	Good. Dual disinfection barriers. Relies on chemical deliveries for sodium hypo.	Very good.	Good.	Good.	Very good. Dual disinfection barrier.	Good. Complex system but requires smaller processes due to dual disinfection barrier. Requires two separate chemical systems.	Good.	Very good. Reduces DBP formation. Provides inactivation of organisms.	Good.	N/A	Very good Provides disinfection, DBP reduction, AOP ready.	Good.	Good.	Good.	N/A	Very good.
Ozone + Sodium Hypo-chlorite	Poor. Requires two separate disinfection processes.	Fair. Requires two separate disinfection processes.	Good. Dual disinfection barriers. Relies on chemical deliveries for LOX and sodium hypo.	Fair. Wastewater application is fairly new but gaining experience.	Poor. The City is not familiar with ozone.	Fair.	Very good. Dual disinfection barrier.	Fair. Complex system. Requires two separate chemical systems.	Good.	Very good. Reduces DBP formation but has concerns with bromate formation.	Fair. LOX has some safety concerns.	N/A	Very good. Provides disinfection, DBP reduction, AOP ready, EDC removal, organics removal.	Good.	Good.	Good.	N/A	Very good.

6.11 Odor Control Treatment Technologies

In recent years, the demand for odor control at wastewater treatment facilities has increased significantly. The general public is continuing to exert pressure on public officials to reduce odors emitted from facilities. For WRFs that are not able to acquire the required setbacks from adjacent properties, odor and noise control is required. The three types of odors of concern from a WRF are H_2S, ammonia, and reduced sulfides. Odor control technologies are available to address each of these types of odors.

There are three primary areas in a WRF where odor control will likely be required:

- Plant headworks and preliminary treatment (including screening, grit removal, primary clarifiers, and flow splitting structures),
- Secondary treatment (including aeration basins, secondary clarifiers, and splitter structures), and
- Solids handling and treatment (including blending, thickening, dewatering, loading, and storage).

All potential odor-producing facilities are recommended to be enclosed, either with covers or within buildings.

Table WWT.40 summarizes typical odor producing processes, and the types of compounds causing the odor.

Table WWT.40 Odor Producing Water Reclamation Facility Treatment Processes
Wastewater Technology Assessment Report
City of Surprise

Odor Producing Area	Type of Odorous Compounds
Headworks	Hydrogen sulfide (1 - 50 ppm) Reduced sulfur organic odors
Extended Aeration / Aeration Basins	Hydrogen sulfide (< 0.1 ppm) Reduced sulfur organic odors
Secondary Clarifiers	Hydrogen sulfide (None) Weak organic musty odors
Sludge process and Storage	Hydrogen sulfide (1 - 100 ppm) Strong reduced sulfur organic odors; ammonia odor from digested sludge dewatering

The development of an odor control strategy requires careful planning. The first step in the process should include identifying the sources of odors and compounds in odorous air streams. Following identification, the cause of the odors should be determined, and if appropriate, the control strategy and treatment technology should be developed accordingly. Odor control effectiveness, capital costs, operating costs, O&M impacts, energy impacts, and site-specific considerations are all factors to consider when selecting odor control technologies.

Odors generated at WRFs have historically been controlled using either liquid stream or air stream treatment technologies. Liquid stream treatments add chemicals to the wastewater stream to minimize odors before they can be emitted. Air stream treatments use an enclosure surrounding the odorous area to capture the affected air, and then ventilate the collected gases to an odor control unit for treatment. The following odor control alternatives are evaluated in the following sections: chemical addition, wet chemical scrubber, biofilter, biotower, carbon adsorption, and ion addition. Additional details associated with each technology can be found in Appendix A.

6.11.1 Chemical Addition

- Chemical addition odor control involves adding metal salts to the wastewater flow stream to control sulfide odorous compounds in wastewater.
- Chemical addition odor control is moderately effective at reducing odors, and typically serves as a backup odor control process to another more effective alternative.

Under anaerobic conditions, sulfides are biologically formed from sulfates in wastewater. Chemicals used for liquid stream treatment either oxidize the reduced sulfur, form a sulfur precipitate, or alter the pH to change the ratio of the sulfur species. Oxidation reduction potential (ORP) of the wastewater is often measured to estimate sulfide production potential. A positive ORP reading indicates aerobic conditions, while a negative ORP reading indicates anaerobic conditions. A highly negative ORP indicates conditions favorable to the addition of oxidants or precipitants to the liquid stream.

Metal salts are often used to form a metal sulfide precipitate with dissolved sulfide in the waste stream, thus decreasing the amount of relatively insoluble hydrogen sulfide (H_2S). Iron (Fe) salts are typically used because iron has a less restrictive allowable sludge concentration. Ferrous chloride ($FeCl_2$), ferric chloride ($FeCl_3$), and ferrous sulfate ($FeSO_4$)

are often used because they are generally cost-effective. Ferrous and ferric ions react with dissolved sulfides according to the following reactions:

$$Fe^{2+} + 2Fe^{3+} + 4HS^{-} \rightarrow Fe_3S_4(s) + 4H^{+}$$
$$Fe^{2+} + HS^{-} \rightarrow FeS + H^{+}$$

Potential concerns regarding the treatment of waste streams with iron salt addition include the following:

- Organic matter in the wastewater may preferentially bind with the ferrous or ferric ions.
- Free hydrochloric acid (HCl) in ferrous or ferric chloride solutions can drop the pH if overdosed.
- Addition of ferrous chloride increases the sludge volume from the primary clarifiers. However, this typically results in better solids removal and increased BOD removal in the primary clarifiers.
- Some ferrous solutions are waste pickle liquor solutions that may have undesirable metals. Allowable sludge metals concentrations may restrict the use of these solutions.
- The presence of iron can decrease the effectiveness of various treatment processes (i.e., UV disinfection).

In general, liquid stream additives are moderately effective in reducing odors. However, the effectiveness of liquid stream treatment is very site specific. It is impossible to cost-effectively treat all of the odorous compounds in the liquid stream in a manner that eliminates air phase emissions use in chemical additional alone. However, chemical addition has proven to be an effective backup when air phase treatment systems are out of service, or to supplement control in some processes (such as digesters).

Several disadvantages of chemical addition include:

- It is not as effective as air stream treatment alternatives in reducing odorous compounds.
- The technology results in high chemical costs (with many of the chemicals classified as hazardous).
- Chemical addition can potentially impact downstream solids handling, solids disposal, and disinfection alternatives.

6.11.1.1 H_2S Odor Control

Chemical addition type odor control can reduce some H_2S odors but it is not a cost effective method for treatment of all odorous compounds. Effectiveness of the odor control is site specific.

6.11.1.2 Ammonia Odor Control

Chemical addition type odor control can reduce some ammonia odors but it may not be a cost effective method for treatment of all odorous compounds. Effectiveness of the odor control is very site specific.

6.11.1.3 Reduced Sulfides Odor Control

Chemical addition type odor control can reduce some reduced sulfides odors but it is not very efficient in removing this type of odor.

Anticipated Performance of Chemical Addition Odor Control at the City of Surprise

As part of the odor control systems, all potential odor-producing facilities are recommended to be enclosed, either with covers or within buildings. Chemical addition is a viable alternative for odor control but is not as affective as air stream odor control processes. Chemical addition odor control can serve as a backup system to other more affective odor control technologies and is a **recommended** alternative for wastewater odor control for the City of Surprise. The technology was included for further evaluation using the SurpriseTree™ Wastewater Model.

6.11.2 Wet Chemical Scrubber

- Wet chemical scrubber type odor control treats the vapor phase of odors produced at WRFs.
- Wet chemical scrubbers utilize chemicals such as caustic and sodium hypochlorite to oxidize H_2S, ammonia and reduced sulfide odors.

Vapor phase treatments rely on transferring odorants to the liquid or solid phase via absorption, condensation, and/or adsorption. The most popular absorption technology is wet chemical scrubbing using either packed towers or mist chambers. Packed towers are the predominant odor control technology employed in the U.S.

Packed-tower wet scrubbers have been used extensively for odor control at wastewater treatment plants. They are capable of handling high airflow rates and high odor concentrations, removing as much as 99.9 percent of the H_2S content. Packed-tower scrubbers are typically single- or multi-stage systems that use both absorption and oxidation to remove air contaminants, or single-stage systems using only an absorbent.

There are two general configurations used in packed tower design: vertical countercurrent and horizontal cross-flow. The countercurrent tower is the more common of the two types. In this design, air enters from the bottom of the tower and moves upward through a packing material (exiting through the top) while in contact with an absorbing solution, which flows downward (cascading through the packing media into a collection sump). The packing provides large interfacial contact between the air and the absorbing solution, thereby enhancing the transfer of odorants from the air to the liquid stream. The solution is collected in the vessel sump and pumped back to the top of the tower to repeat the process. Chemicals and water are continually added to replace those lost to evaporation and entrainment. A blowdown stream removes the absorbed constituents, minimizing the buildup of contaminants.

The number of scrubber stages required and the type of scrubbants used (i.e., caustic, hypochlorite, acid) depends on the concentration and type of contaminants in the odorous air stream to be treated. Caustic-only scrubbers provide moderate H_2S removal and treat a number of acid gases. However, caustic scrubbers do not destroy sulfides - they are simply transferred from the air stream to the liquid phase. Oxidants (such as hypochlorite, or bleach) provide treatment of the widest range of compounds, and when combined with caustic, can oxidize (i.e., destroy) the sulfide compounds. Caustic-only scrubbers are also less efficient than the caustic/bleach scrubber, and are typically only used to reduce chemical costs and associated O&M. Acid scrubbers provide excellent ammonia removal, but may strip off H_2S odors. However, in most typical wastewater applications, acid scrubbers are not necessary.

The primary advantages associated with packed-tower wet chemical scrubbers include:

- They are capable of treating high inlet odor concentrations; and
- They respond well to variable inlet concentrations.

The primary disadvantages associated with packed-tower wet chemical scrubbers include:

- They have high chemical requirements;
- They have high electrical consumption, and high noise potential;
- Multi-stage systems often have pressure drops of 8 to 12 inches of water column, depending on the number of stages; and
- There are high corrosion potential and safety concerns with the handling of the hazardous chemicals utilized as part of the process.

6.11.2.1 H_2S Odor Control

Wet chemical scrubber type odor control is effective at treating H_2S odors, removing as much as 99.9 percent of the H_2S content. Combined caustic and sodium hypochlorite type scrubbers are most efficient for H_2S removal.

6.11.2.2 Ammonia Odor Control

Wet chemical scrubber type odor control is effective for treating ammonia odors. Acid type scrubbers provide excellent ammonia removal.

6.11.2.3 Reduced Sulfides Odor Control

Wet chemical scrubber type odor control can reduce some reduced sulfides odors. Combined caustic and sodium hypochlorite type scrubbers are most efficient at oxidizing certain sulfide compounds such as carbonyl sulfide, dimethyl sulfides, etc., but are not very efficient in removing methyl mercaptan, isopropyl mercaptan, or n-propyl mercaptan.

Anticipated Performance of Wet Chemical Scrubber Odor Control at the City of Surprise

As part of the odor control systems, all potential odor-producing facilities are recommended to be enclosed, either with covers or within buildings. Wet chemical type odor control is a viable alternative for odor control at a WRF. Packaged tower systems are commonly used at WRFs and can provide robust treatment for a wide range of potential odor causing compounds. Wet chemical type odor control is a **recommended** alternative for wastewater odor control for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

6.11.3 Biofilters

Biofilters are vapor phase odor control systems that utilize a natural media with indigenous microorganisms to treat odorous compounds. Because biofilters rely on microorganisms instead of chemicals to treat odorous compounds, operational costs are usually lower than chemical systems.

Biofilters remove odors from a foul air stream by adsorption and absorption of odor causing compounds onto a natural media bed where microorganisms oxidize the compounds. The indigenous bacteria and other microorganisms of the media acclimate to the compounds present and are sufficient to provide the “scrubbing” action required. Few chemical additions and no bacterial inoculation is required.

Generally, there are two configurations of biofiltration odor control systems: package type (biotower) and in-ground type. A major limitation of in-ground type biofilters is the large land area required for installation.

Biofilters provide significant reduction of overall odor emissions including VOC emissions. The technology is relatively simple, with minimum moving parts and low energy requirements. However, the need to keep the biofilters moist results in significant water usage and the need to treat or dispose of leachate and condensate. Biofilters may not be appropriate for very strong or highly variable odors.

Poor biofilter performance is usually attributed to lack of moisture in the filter media. It is important that biofilters be kept moist so that the microbial community remains healthy and

effective. The goal is to operate the biofilters as close to 100 percent humidity as possible. It is also important to keep sufficient void space and avoid air channeling, which results in short circuiting the media. Large amounts of dust and particulate matter in the foul air will build up in the biofilter media and shorten the replacement time.

The advantages of biofilters include:

- Relatively low operating costs compared to chemical odor control systems;
- Can remove ammonia, hydrogen sulfide, and VOCs; and
- Have low head requirements.

The disadvantages of biofilters include:

- Large footprint requirements (specifically for in-ground biofilters); and
- Biofilters must be maintained at specific operating conditions to support the growth of microorganisms.

Biotowers and in-ground biofilters are discussed in detail in the following sections.

6.11.3.1 Biotower Biofilter

	• Biotowers achieve biological odor control within a compact footprint. • Biofilters must be maintained at optimum conditions (e.g., proper moisture) to support the growth of microorganisms. • Biofilters are a green technology with essentially no chemical usage.

A biotower consists of a rectangular or circular vessel, air distribution system, medium, and a means of maintaining minimum moisture content in the medium. Biofilters can be operated either under a vacuum, where the odorous air is pulled through the vessel, or under positive pressure. Normally, odorous air is pulled from the source area via air duct into a fan (i.e., positive pressure method). The fan sends the odorous air to the biofilter for treatment and the clean air is exhausted. Inside the treatment vessel, dry air passes through a humidification system to add moisture to the odorous air to optimize the biological degradation. This can be a challenge in Arizona climate.

6.11.3.2 In-Ground Biofilter

	• In-ground biofilters require a large footprint to achieve biological odor control. • Biofilters must be maintained at optimum conditions (e.g., proper moisture) to support the growth of microorganisms. • Biofilters are a green technology with essentially no chemical usage. • In-ground biofilter require a large footprint.

In-ground biofilters generally consist of an air distribution piping system installed within a basin. The air piping is embedded in a porous media, typically a few feet of lava rock or wood chips, selected to support the growth of microorganisms to treat the odorous compounds. The moisture content of the media must be maintained with a sprinkler system. An underdrain collects excess water. In-ground biofilter facilities typically require a larger footprint than comparable towers.

6.11.3.3 H_2S Odor Control

Biofilter type odor control is effective at reducing H_2S odors. Effectiveness of the odor control is dependent on the effectiveness of the associated microorganisms. Optimum conditions must be maintained to support the growth and health of the organisms.

6.11.3.4 Ammonia Odor Control

Biofilter type odor control can reduce some ammonia odors. Effectiveness of the odor control is dependent on the effectiveness of the associated microorganisms. Optimum conditions must be maintained to support the growth and health of the organisms.

6.11.3.5 Reduced Sulfides Odor Control

Biofilter type odor control is effective at reducing H_2S odors. Effectiveness of the odor control is dependent on the effectiveness of the associated microorganisms. Optimum conditions must be maintained to support the growth and health of the organisms.

Anticipated Performance of Biofilter Odor Control at the City of Surprise

The City has not had positive experience with a biofilter type odor control system at SPA 1 WRF. However, we do not recommend eliminating an alternative based on negative experience with a product from a single manufacturer and/or a single installation. Biofiltration is a potentially viable alternative for odor control. Biotowers odor control is a **recommended** alternative for wastewater odor control for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model. The in-ground system requires significant land and is harder to operate in Arizona climate. Therefore, it is not recommended.

6.11.4 Carbon Adsorption

- Carbon adsorption is an excellent alternative for secondary odor polishing.
- Carbon adsorption requires regeneration and replacement of the carbon media.

Although several different types of media can be used to adsorb odorous compounds, the most widely applied is granular activated carbon (GAC). The carbon is thermally treated to create tiny pores, which substantially increases the surface area and creates active sites for bonding locations. Odorous compounds bond to the adsorptive surfaces. GAC effectiveness decreases as adsorptive sites are taken up by the contaminants. This eventually requires regeneration or replacement of the media. Carbon adsorption is most commonly used for secondary odor polishing.

Carbon adsorption systems are typically easy to operate and reliable. The effectiveness of carbon is directly related to the number and size of the active sites available for adsorption. When the influent odorous air streams contain high concentrations, the carbon sites will be consumed rapidly. Since wastewater air streams often contain a mixture of odorous compounds, it is difficult to predict carbon breakthrough without some type of pilot testing. Isotherms are available to estimate carbon breakthrough for single components, but not for multi-component mixtures. Electrical consumption can also be high, primarily due to the pressure drop through the carbon bed, which increases markedly with higher face velocities through the beds.

The advantages of carbon adsorption include:

- Reliable and easy to operate; and
- Good for secondary odor polishing - especially with sensitive neighboring facilities.

The disadvantages of carbon adsorption include:

- Carbon sites consumed rapidly at high odor concentrations;
- Requires regeneration and replacement of carbon; and
- Difficult to predict carbon breakthrough for multiple odor components.

There are two general types of carbon adsorption systems: caustic-regenerated impregnated carbon and water-regenerated catalytic carbon.

6.11.4.1 Caustic-Regenerated Impregnated Carbon

Traditionally, air streams containing high levels of H_2S have been treated with alkali-impregnated carbon. Impregnated carbon employs chemical additives to increase contaminant capacity. The most common additive is an alkaline or caustic reagent, primarily sodium hydroxide (NaOH) or potassium hydroxide (KOH). The reagent reacts with H_2S, the product of which remains fixed on the carbon. As the chemical impregnate is consumed, sulfur will clog the pores in the activated carbon, reducing the effectiveness as the adsorption sites become saturated. The carbon then has to be replaced or regenerated. Soaking the vessel with caustic solutions will regenerate the carbon's capacity to remove H_2S. This method of regeneration restores the adsorptive capacity of the carbon to approximately 80 percent of its former capacity.

As the adsorption capacity decreases, the time between regenerations also decreases. Generally, after three of four regenerations, replacement of the carbon is required. For replacement-type carbon systems, the adsorber unit is taken off line to remove the exhausted carbon, which results in facility downtime.

Another concern associated with chemical regeneration is that it creates heat, posing a potential fire danger. Caustic-impregnated carbon can reduce the kindling temperature from around 500 degrees Celsius to about 250-300 degrees Celsius. On-site regeneration of impregnated activated carbon also has other drawbacks. Disposal of the spent caustic solution can become a handling problem. However, since the caustic solution is a high pH stream, it could potentially help keep sulfides in solution if bled back into the waste stream appropriately.

6.11.4.2 Water-Regenerated Catalytic Carbon

One carbon manufacturer has developed a proprietary vapor-phase virgin activated carbon, which is specifically intended for wastewater facilities. The carbon is a bituminous coal-based product that catalytically oxidizes H_2S and converts it to water-soluble sulfur compounds. Unlike impregnated carbon, this catalytic carbon does not require a caustic reagent for an acid-base neutralization and regeneration. As a result, it can be restored for H_2S uptake through simple water washing. This method of regeneration restores the

adsorptive capacity of the carbon to approximately 85 percent of its original capacity - with an approximate 5 percent decrease each subsequent regeneration - down to approximately 60 percent of the original capacity. Again, as the adsorption capacity decreases, the time between regeneration also decreases. After approximately six regenerations, replacement of the carbon is generally recommended.

Sulfuric acid is formed in the vessel upon water regeneration. The acid stream may have a pH as low as 2. The low pH drainage is of concern because: (1) it may shift the equilibrium of the sulfides in the wastewater to 100 percent hydrogen sulfide, which will exacerbate odor problems downstream; (2) it is corrosive; and (3) it presents a hazard to workers. However, in most cases, the quantity of low pH regeneration water is minimal compared to the influent flow. Potable water should be used for regeneration because non-potable water may contain solids that can clog carbon pores. The water-regenerated catalytic carbon does have a much higher kindling temperature than impregnated carbons, so spontaneous combustion is much less of a concern.

6.11.4.3 H_2S Odor Control

Carbon adsorption type odor control is effective at reducing H_2S odors. The carbon media will need to be replaced more frequently with high odor concentrations.

6.11.4.4 Ammonia Odor Control

Carbon adsorption type odor control can reduce some ammonia odors. The carbon media will need to be replaced more frequently with high odor concentrations.

6.11.4.5 Reduced Sulfides Odor Control

Carbon adsorption type odor control is effective at reducing reduced sulfide odors. The carbon media will need to be replaced more frequently with high odor concentrations.

Anticipated Performance of Carbon Adsorption Odor Control at the City of Surprise

As part of the odor control systems, all potential odor-producing facilities are recommended to be enclosed, either with covers or within buildings. Carbon adsorption is a viable alternative for odor control. However, carbon will need to be replaced more frequently with high odor concentrations. Carbon adsorption is recommended for secondary odor polishing, following another odor control process. Carbon adsorption is a **recommended** alternative for wastewater odor control for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

6.11.5 Ion Addition

Odor control via ion addition involves generating electrically charged ions that react with and neutralize odor-producing compounds. Ion addition occurs at the source of the odor, and uses the odorous space as the reactor to oxidize the odors and stop corrosion. The added ions oxidize odorous compounds to produce inert compounds or precipitates. Ion

addition type odor control has a lower capital cost and is generally less maintenance intensive compared to other alternatives. Two specific manufacturers of ion addition type odor control systems are discussed in the following sections - Vapex/Oxy-Phogg and Aerisa.

6.11.5.1 Vapex/Oxy-Phogg

- Vapex/Oxy-Phogg odor control systems do not extract odors from the treatment process but instead treat the contaminated air in the odorous space.
- Vapex/Oxy-Phogg systems create a hydroxyl ion fog that is injected into the odorous space, oxidizing the odors.

The Vapex/Oxy-Phogg Hydroxyl Ion Fog odor control system is a newly patented technique for odor (particularly H_2S and VOCs) removal and pH corrosion control in wastewater facility structures. The system is suitable for wet wells, pump stations, lift stations, sludge holding tanks, scrubber pretreatment, and sludge holding tanks.

The Vapex/Oxy-Phogg system is different from conventional scrubbing technologies in that it does not extract odors from the application and then attempt to treat them. Instead, it uses the odorous space as the reactor to oxidize the odors and stop corrosion. The system utilizes air, water, and power to generate a hydroxyl ion fog that is injected into the odorous space. No chemicals are purchased, handled, or stored. The hydroxyl ion fog is produced via a proprietary atomizing nozzle, flooding the contaminated air space with very fine water particles (a mist), which collects the contaminants and washes them and the reactants back to the solution stream. Thus, contaminants never enter the vented air stream.

The primary advantages associated with the Vapex/Oxy-Phogg system include no chemical costs, low maintenance, low O&M, easy installation, and a small footprint. While the system has been extremely effective in numerous applications throughout the western United States, it is still a relatively new technology with a short operational history.

6.11.5.2 Aerisa

- The Aerisa odor control system distributes ionized air throughout a treatment process, attacks odor-causing chemicals at their source, and knocks them out of the air.
- Aerisa provides odor control for enclosed treatment processes in a relatively small footprint.

The Aerisa system distributes ionized air throughout a treatment process, attacks odor-causing chemicals at their source, and knocks them out of the air. The application of Aerisa solutions in wastewater treatment facilities has been particularly effective at reducing H_2S. The manufacturer claims that the Aerisa Systems cleans the air completely in any size facility with 99 percent effectiveness. This system provides an alternative to traditional odor control and eliminates the need for filter add-ons and chemically based wet scrubbers or carbon absorption systems. Unlike traditional filtration systems that utilize chemicals or various filters to treat air at a separate location, Aerisa attacks air problems at their source. Ionization tubes are used to push positive and negative ions into the odorous area at regular intervals based on the desired number of air changes. The system utilizes automated controls to adjust the flow based on changing odor conditions. The reactions between oxygen ions and chemicals in the system will generally produce inert gases and/or precipitates with minimal impact.

Aerisa solutions produce oxygen-based ions (reactants) that easily react and breakdown a broad set of chemical compounds (including VOCs and possibly bacterial, fungal, and viral compounds). Aerisa is applied at the source of contamination, which maximizes effectiveness. The system is sized based on the overall requirements and toxin and chemical levels in the air.

The reported advantages of the Aerisa system include:

- Effective removal of H_2S;
- No chemicals, carbon, or hazardous waste disposal;
- Easily retrofitted to existing facilities; and
- Able to treat from small to large size enclosed spaces from lift stations to entire treatment facilities.

The disadvantages of the Aerisa system include:

- The process is relatively new technology, with very few installations and little operational experience to prove the operation reliability or application-based effectiveness of the process.

6.11.5.3 H_2S Odor Control

Ion addition type odor control is effective at reducing H_2S odors.

6.11.5.4 Ammonia Odor Control

Ion addition type odor control can reduce some ammonia odors.

6.11.5.5 Reduced Sulfides Odor Control

Ion addition type odor control is effective at reducing H_2S odors.

Anticipated Performance of Ion Exchange Odor Control at the City of Surprise

As part of the odor control systems, all potential odor-producing facilities are recommended to be enclosed, either with covers or within buildings. Ion addition is a viable alternative for odor control, specifically for enclosed areas such as pump stations and covered process basins. As a new technology, limited installations are available to prove the operation reliability of the process. However, ion addition is a **recommended** alternative for wastewater odor control for the City of Surprise in enclosed applications and is included for further evaluation using the SurpriseTree™ Wastewater Model.

6.11.5.6 Summary of Odor Control Technologies

Table WWT.41 summarizes odor control performance for the most common odor-producing compounds.

Table WWT.41 Odor Control Processes Removal Efficiencies
Wastewater Technology Assessment Report
City of Surprise

Parameter	Chemical Tower Removal Efficiency %	Packed Carbon Tower Removal Efficiency %	Bio-Tower Removal Efficiency %	Bio Filter Removal Efficiency %	Ion Addition Removal Efficiency %
Hydrogen Sulfide	99	99	99	99	99
Carbonyl Sulfide	99	99	99	99	90+
Methyl Mercaptan	< 50	99	99	99	
Ethyl Mercaptan	ND	ND	ND	ND	
Dimethyl Sulfide	99	99	99	99	
Carbon Disulfide	99	98	98	98	
Isopropyl Mercaptan	< 50	ND	ND	ND	
N-Propyl Mercaptan	< 50	ND	ND	ND	
Dimethyl Disulfide	99	ND	ND	ND	
Methane	< 10	< 50	< 50	< 50	
TGNMO	< 10	95	95	95	
Ammonia	99	50	50	50	90

Note:
ND = none detected

Table WWT.42 summarizes the odor control recommendations for each odor-producing process area.

Table WWT.42 Odor Producing Process Areas Recommendations Wastewater Technology Assessment Report City of Surprise		
Odor Producing Area	**Type of Odorous Compounds**	**Typical Odor Control Technology**
Headworks	Hydrogen sulfide (1 - 50 ppm) Reduced sulfur organic odors	Covered wet well; Enclosed screens; Covered grit removal Ion addition, Two stage wet chemical scrubber or biotowers
Biological Treatment Process (i.e., Extended Aeration / Aeration Basins)	Hydrogen sulfide (< 0.1 ppm) Reduced sulfur organic odors	Covered basins Wet scrubbers or biotowers
Secondary Clarifiers	Hydrogen sulfide (None) Weak organic musty odors	Covered clarifiers Ion addition, Two stage wet chemical scrubber or biotowers
Biosolids Thickening, Dewatering, Stabilization and Storage	Hydrogen sulfide (1 - 100 ppm) Strong reduced sulfur organic odors; Ammonia odor from digested sludge dewatering	Enclosed in building Two stage wet scrubber or biotowers
Note: For sensitive residential areas, consider using carbon adsorption as a polishing treatment system.		

Table WWT.43 summarizes the anticipated performance of the odor control technologies as well as their applicability to the City of Surprise typical wastewater. Table WWT.44 summarizes the evaluation results for odor control technologies using the implementation based criteria. Chemical addition, biofilters, biotowers, carbon adsorption, wet chemical scrubbers, and ion addition were recommended for further evaluation in the SurpriseTree™ Wastewater Model.

Table WWT.43 Odor Control Unit Operations – Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operation	Performance Based Criteria		
	H_2S Odor	Ammonia Odor	Reduced Sulfides Odor
Chemical Addition	Good.	Good.	Poor.
Wet Chemical Scrubber	Very good.	Very good.	Good.
Biofilters	Very good.	Good.	Very good.
Biotowers	Very good.	Good.	Very good.
Carbon Adsorption	Very good.	Good.	Very good.
Ion Addition	Very good.	Very good.	Very good.

Table WWT.44 Odor Control Unit Operations – Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operations	Implementation Based Criteria																	
	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Foot-print	Regulatory	Safety	Residuals	Versatility	Expand-ability	Odor	Energy Savings	Class A Biosolids	Air Quality
Chemical Addition	Good.	Very good.	Fair.	Very good.	Good.	Good.	Good.	Very good.	Good.	Good.	Fair.	Fair.	Fair.	Fair.	Good.	Very good.	N/A	Fair.
Wet Chemical Scrubber	Fair.	Good.	Good.	Very good.	Good.	Fair.	Good.	Good.	Good.	Good.	Fair.	Good.	Good.	Good.	Very good.	Good.	N/A	Good.
Biofilters	Good.	Good.	Good.	Good.	Fair.	Fair.	Good.	Good.	Poor	Good.	Good.	Good.	Good.	Good.	Very good.	Good.	N/A	Good.
Biotowers	Good.	Good.	Good.	Good.	Fair.	Fair.	Good.	Good.	Fair.	Good.	Good.	Good.	Good.	Good.	Very good.	Good.	N/A	Good.
Carbon Adsorption	Fair.	Good.	Good.	Good.	Good.	Good.	Good.	Very Good.	Good.	Good.	Good.	Good.	Good.	Good.	Very good.	Good.	N/A	Good.
Ion Addition	Excellent.	Good.	Very good.	Good.	Poor.	Good.	Very good.	Good.	Very good.	Fair.	Good.	Very good.	Very good.	Very good.	Very good.	Good.	N/A	Good.

7.0 BIOSOLIDS TREATMENT TECHNOLOGY AND MANAGEMENT EVALUATION

This section identifies biosolids management strategies and describes biosolids thickening, biosolids dewatering, and biosolids stabilization treatment technologies.

7.1 Level of Biosolids Management

Two primary issues drive most biosolids management decisions: the desired biosolids quality and the available disposal options. As discussed in Section 3.5, regulations classify biosolids as Class A, Class B, or Exceptional Quality (EQ) according to the level of treatment provided to reduce pathogens and vector attraction, and metals concentrations. Land disposal options, also discussed in Section 3.5, include land application, landfill, or commercial products. Disposal options are dependent on the classification of biosolids produced.

Land application can be a cost effective disposal option if land is available. Land application used for local agriculture requires minimal City involvement and could potentially eliminate the need for dewatering prior to disposal. However, applying solids to local agriculture provides no beneficial reuse to the City and also provides limited control over the costs and liability of application. Land application can also be used for City owed property, which would provide the City with a direct benefit from the reuse, promote cost savings and improved City public areas, and could potentially eliminate the need for dewatering prior to disposal. However, applying solids to City owned property adds additional capital and O&M costs and places the liability for ultimate disposal on the City.

Landfill application can provide potential flexibility in disposal. Direct disposal requires minimal City involvement but provides no beneficial reuse to the City and can have a high associated O&M cost. Alternatively, solids for daily cover applied at landfills have the potential to reduce O&M costs with reduction in gate fees at the landfill. However, alternative daily cover provides no beneficial reuse to the City, can still have reasonably high associated O&M cost associated, and requires dewatering prior to application.

Generation of a commercial product can be a viable alternative for biosolids disposal. Biosolids used for commercial products provide beneficial reuse options of the solids, have a potential for cost savings associated with disposal costs, and have the ability to be combined with other disposal options with portions of the solids going to different disposal locations. However, biosolids used as a commercial product require a Class A or EQ product and sludge drying equipment, and can have high capital and O&M costs.

The City shall review the most applicable and cost effective biosolids disposal alternative for each WRF. The disposal alternative selected impacts the type of biosolids treatment, thickening, stabilization, and/or dewatering.

7.2 Biosolids Thickening Treatment Technologies

Solids thickening is commonly used in wastewater treatment facilities to concentrate combined or separate solid streams. Thickening is beneficial for the purpose of reducing the volume of solid streams requiring treatment and increasing the efficiency of subsequent solids treatment processes. Thickening processes differ significantly in terms of extent of achievable solids thickening, chemical use, energy consumption, and required operator attention. Biosolids thickening is typically used prior to a biosolids stabilization process. If biosolids stabilization is not being employed, thickening may not be necessary and a dewatering process may be more appropriate.

Effective thickening processes evaluated as part this section include gravity thickening, dissolved air flotation thickening, gravity belt thickening, rotary drum thickening, and centrifuge thickening. Additional details associated with each technology can be found in Appendix A.

7.2.1 Gravity Thickeners

	• Gravity thickening is a relatively simple operation with minimal mechanical equipment. • Gravity thickening is most effective with primary and lime sludge.

A gravity thickener is similar in operation to a settling tank. Solid particles settle to the bottom of the tank under the force of gravity and clarified water flows over weirs at the top of the basin. Solids are concentrated as additional solids settle and compact. Gravity thickeners are equipped with rake arms that slowly sweep the sloped floor of the basin, pushing solids into the center hopper. Solids are removed at intervals for further processing.

Due to its reliance on gravity for effective operation, gravity thickening is best suited to sludges with rapidly settling solids, such as primary and lime sludges. Gravity thickening of biological solids, in particular from waste activated sludge (WAS), typically results in lower solids capture rates and solids concentrations. Solids underflow concentrations from 5 to 10 percent can be expected for primary sludges, while underflow concentrations of around 2 to 3 percent solids are typical for WAS.

Advantages of gravity thickening include:

- Simple, reliable operation;
- Low operating cost;
- Low operator attention required;

- Conditioning chemicals typically not required;
- Provides some sludge equalization for downstream processes; and
- Ideal for primary sludge.

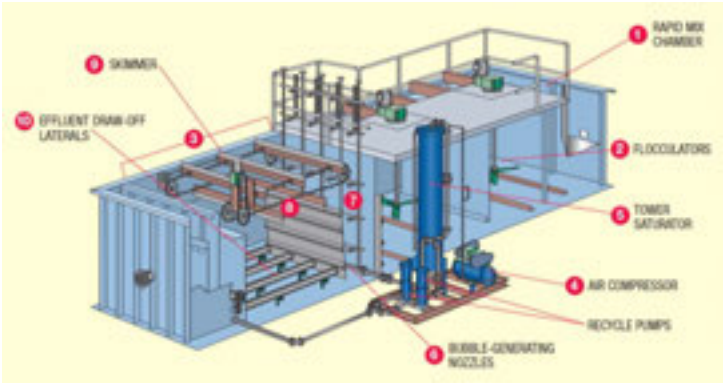
Disadvantages of gravity thickening include:

- Odor potential (would require a cover and odor control); and
- Limited effectiveness and large land area requirements for biological sludges (i.e., WAS).

Anticipated Performance of Gravity Thickeners at the City of Surprise

Gravity thickening is a cost effective method of increasing the solids content of primary solids prior to solids stabilization. Gravity thickening is a **recommended** alternative for biosolids thickening for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

7.2.2 Dissolved Air Flotation Thickeners



- Dissolved air flotation achieves biosolids thickening through the use of air bubbles to float the solids.
- Dissolved air flotation thickening is most effective with WAS and aerobically digested solids.

Dissolved air flotation thickening (DAFT) is the process by which solids and liquids are separated by the introduction of fine air bubbles to a solids stream. The bubbles attach to the solid particles increasing their buoyancy and causing them to rise to the surface. The floating particles are then removed by a skimmer system and conveyed for further solids processing. Clarified water flows over a weir and is conveyed back into the liquid stream treatment process. DAFT systems use polymer addition to assist with solids thickening. Added polymer could be present in the water removed during thickening and returned to the treatment process. Polymer may have a negative impact on the primary treatment processes, such as membrane filtration. Consequently, polymer usage should be carefully monitored to prevent excess feed and carryover in the liquids stream. DAFT is commonly used for WAS and aerobically digested solids, but is not typically economical for primary sludge. Floating solids concentrations are typically in the 2 to 5 percent range.

Advantages of DAFT include:

- Effective for WAS thickening;
- Effective for fats, oils, and grease removal; and

- Simple equipment components.

Disadvantages of DAFT include:

- Higher power consumption from blowers;
- Requires polymer use for high solids capture;
- Odor potential;
- Requires moderate operator attention; and
- Limited effluent solids concentration.

Anticipated Performance of DAFT at the City of Surprise

Dissolved air flotation thickening is an efficient method of increasing the solids content of WAS prior to solids stabilization. Dissolved air flotation thickening is a **recommended** alternative for biosolids thickening for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

7.2.3 Gravity Belt Thickeners

- Gravity belt thickeners achieve biosolids thickening through the use of coagulation, flocculation and gravity to remove water from the solids.
- Gravity belt thickening is achieved in a compact footprint.

A gravity belt thickener (GBT) is a mechanical filtration device designed to remove free water from sludge via a gravity process. The equipment consists of a fabric mesh belt that rotates on a frame. Sludge is conveyed onto the leading end of the belt and water drains through the mesh while the belt rotates toward a collection hopper at the other end. Stationary baffles or plows above the belt turn and rotate the sludge to encourage the release of free water. Initial solids concentrations for GBTs should be at least 0.4 to 0.5 percent - preferably around 1.0 percent concentration for better performance. Thickened solids will be in the range of 4 to 8 percent for an optimized system, which can achieve greater than 95 percent solids capture.

GBTs require coagulation (typically with a cationic polymer) and flocculation for successful thickening. Without polymer addition (3 to 10 lb/ton), solids loss through the mesh belt will be excessive and performance will be poor. The GBT is used widely for thickening because of its compact footprint, low power consumption, and moderate capital costs compared to other thickening processes.

Odor control requirements, however, can be more extensive for the GBT compared to more enclosed thickening processes (e.g., centrifuges). A GBT is open to the atmosphere in the

room in which it is installed. Therefore, to contain odor and create an acceptable working environment for the operators, the entire thickener space must be aggressively scrubbed. Hoods are frequently used over the thickeners to improve the extraction of air from the space directly over the sludge. However, much of the odorous air escapes into the room. Thus, a very large volume of air must be handled and treated.

Advantages of GBTs include:

- Compact footprint;
- High solids capture with minimum polymer addition;
- Able to achieve a high solids concentration;
- Low power consumption; and
- Moderate capital costs.

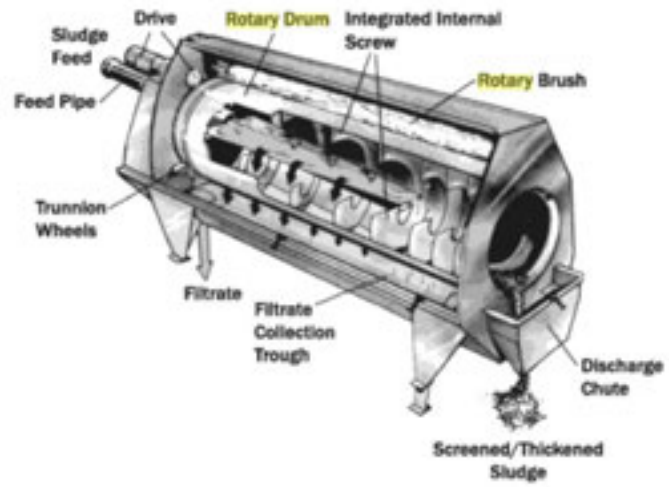
Disadvantages of GBTs are:

- Requires polymer addition; and
- Must be placed in enclosed building with full odor control.

Anticipated Performance of GBT at the City of Surprise

Gravity belt thickening achieves biosolids thickening using coagulation/flocculation and gravity separation process to optimize the solids content of the thickened sludge. Gravity belt thickening is a **recommended** alternative for biosolids thickening for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

7.2.4 Rotary Drum Thickener



- Rotary drum thickeners achieve biosolids thickening of separating solids by gravity through a moving porous media.
- Rotary drum thickening is most effective with WAS for small to medium sized plants.

Similar to the GBT, a rotary drum thickener (RDT) separates free water from sludge by gravity through a moving porous media. The RDT consists of an outer drum and an inner screw. The outer drum is constructed of a porous media such as wedge-wire, stainless

steel fabric, polyester fabric, or a combination of the two. Free water flows through the media and is captured for further processing, while thickened sludge is conveyed out of the drum into a discharge chute. RDTs are typically used in small to medium sized plants for WAS thickening. They are especially well suited for either raw or digested municipal solids that contain a significant fraction of primary sludge.

Similar to GBTs, RDTs require polymer to condition the sludge prior to thickening. Feed solids should be above 0.5 percent and thickened solids are typically in the 4 to 9 percent range with greater than 90 percent solids capture achievable.

Advantages of RDTs include:

- Minimal space requirements;
- Low power consumption;
- High solids capture;
- Moderate capital costs;
- Flexible operation with varying sludge characteristics; and
- Simple to enclose for odors.

Disadvantages of RDTs include:

- Requires polymer addition; and
- Success is dependent upon solids characteristics and chemical conditioning.

Anticipated Performance of RDT at the City of Surprise

Rotary drum thickening is an efficient method of increasing the solids content of primary sludge prior to solids stabilization. Rotary drum thickening is a **recommended** alternative for biosolids thickening for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

7.2.5 Centrifuge Thickener

- Centrifuge thickeners achieve biosolids thickening through the use of centrifugal forces to separate solids.
- Centrifuge thickening is most effective with chemical conditioning of primary sludge and WAS.

A centrifuge is a common process used for thickening and dewatering sludge. The separation of the solids-liquids slurry occurs as a result of the centrifugal forces and the

difference in density between the solids and liquids. Because centrifugal force is applied, a high capacity can be achieved, and footprint requirements are minimized.

Centrifuges require relatively simple odor control as they are somewhat contained. Normally, foul air is exhausted from the sludge and centrate chutes only. A relatively small amount of air is involved, and it can be cost-effectively collected and conveyed to treatment. Grit removal is necessary as part of the primary treatment process to remove any grit prior to the centrifuge to protect the centrifuge from abrasive material and to prevent grit accumulation in the centrifuge process.

Chemical conditioning must be performed to achieve optimum results in centrifuge thickening. Power requirements are higher than other mechanical thickening processes and maintenance requires skilled staff. For these reasons, centrifuges have a higher O&M cost than most thickening processes.

Advantages of centrifuge thickening include:

- Minimal space requirement;
- Effective for thickening primary sludge and WAS;
- High thickened sludge concentration available (critical for some advanced digestion process);
- Ability to control process performance; and
- Ability to minimize odors.

Disadvantages of centrifuge thickening include:

- High capital and O&M;
- Sophisticated maintenance requirements; and
- Best suited for continuous operation.

Anticipated Performance of Centrifuge Thickening at the City of Surprise

Centrifuge thickening is an effective method of increasing the solids content of primary solids and WAS within a compact footprint. Centrifuge thickening is a **recommended** alternative for biosolids thickening for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

7.2.6 Summary of Thickening Technologies

Table WWT.45 summarizes the anticipated performance of the biosolids thickening technologies as well as their applicability to the City of Surprise typical wastewater. Table WWT.46 summarizes the evaluation results for biosolids thickening technologies using the implementation based criteria. Gravity thickening, dissolved air floatation thickening, gravity belt thickening, rotary drum thickening, and centrifuge thickening were recommended for further evaluation in the SurpriseTree™ Wastewater Model.

Table WWT.45 Biosolids Thickening Unit Operations – Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operation	Performance Based Criteria		
	Volatile Solids Reduction	Biosolids Pathogen Reduction	Biosolids Volume Reduction
Dissolved Air Flotation	N/A	N/A	Good.
Gravity Thickener	N/A	N/A	Fair.
Gravity Belt Thickener	N/A	N/A	Good.
Rotary Drum Thickener	N/A	N/A	Good.
Centrifuge Thickener	N/A	N/A	Very good.

Table WWT.46 Biosolids Thickening Unit Operations – Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operations	Implementation Based Criteria																	
	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Foot-print	Regulatory	Safety	Residuals	Versatility	Expand-ability	Odor	Energy Savings	Class A Biosolids	Air Quality
Dissolved Air Flotation	Fair.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Poor.	Good.	Good.	Good.	Good.	Fair.	Good.	Good.	N/A	Fair.
Gravity Thickener	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Very good.	Poor.	Good.	Good.	Good.	Good.	Fair.	Good.	Very good.	N/A	Fair.
Gravity Belt Thickener	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	N/A	Fair.
Rotary Drum Thickener	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Very good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Very good.	N/A	Good.
Centrifuge Thickener	Fair.	Fair.	Very good.	Good.	Very good.	Fair.	Very good.	Good.	Good.	Good.	Good.	Very good.	Very good.	Good.	Very good.	Fair.	N/A	Good.

7.3 Biosolids Dewatering Treatment Technologies

Solids dewatering is commonly used in wastewater treatment facilities to concentrate combined or separate solid streams. Dewatering is beneficial for the purpose of reducing the volume of solid streams requiring treatment. Dewatering processes differ significantly in terms of extent of achievable solids thickening, chemical use, energy consumption, and required operator attention. Biosolids thickening is typically implemented prior to a biosolids stabilization process. If biosolids stabilization is not being used, a dewatering process is more appropriate. Dewatering processes evaluated in this section include solar drying beds, centrifuges, and belt filter presses. Additional details associated with each technology can be found in Appendix A.

7.3.1 Solar/Air Drying Beds

	• Solar drying beds achieve biosolids dewatering through the use of evaporation to decrease the water content of the biosolids. • Solar drying beds dewatering requires a very large process footprint, but minimal mechanical components.

Solar drying beds have been used to dewater biosolids for over 100 years. While the technology can be applied in any climate, drying beds are used extensively in arid climates where high temperatures and minimal rainfall promote optimum operation. Drying beds in the southwest are typically paved beds that rely on evaporation to dewater solids. The pavement also facilitates sludge removal from the beds, typically accomplished using a front-end loader or similar equipment.

Conventional drying bed performance can be enhanced (and thus footprint requirements can be decreased) by utilizing decant weirs, wedge-wire dewatering screens, or by enclosing the bed in a greenhouse structure with fans. However, enclosing the bed can make sludge removal more challenging.

Drying beds are simple to operate, inexpensive to construct, and have a very low operation and maintenance cost. They are also more forgiving relative to changing solids characteristics than mechanical dewatering equipment. However, drying beds require a large footprint and represent a challenge associated with odor control, since the beds are not easily enclosed.

The advantages of solar drying beds for biosolids dewatering include:

- Lowest capital cost where land is readily available;
- Small amount of operator attention and skill required;

- Very low energy consumption; and
- Process is less sensitive to sludge variability.

The disadvantages of solar drying beds for biosolids dewatering include:

- Potential odor and vector attraction problems;
- Requires large land area;
- Design requires consideration of climatic effects; and
- Sludge removal is labor intensive.

7.3.1.1 Solar Sludge Dryer

A solar sludge dryer can accept digested or undigested liquid, thickened, or dewatered sludge. The system can generate dried biosolids with up to 90 percent solids content. The biosolids are dried using drying beds enclosed in a greenhouse-like structure. The greenhouse structure is designed to optimize biosolids drying by minimizing the impacts of climate changes through a computer-based system of fans, vents, etc. The biosolids discharged to the drying beds are tilled by a computerized “mole” or similar windrow device that aerates the material by moving in a random pattern around the drying bed.

Although the solar dryer can accept wet sludge, increasing the feed solids concentration ultimately reduces the feed volume, increases operational efficiency, and reduces capital costs (as a smaller facility footprint is required).

The advantages of solar sludge dryers for biosolids dewatering include:

- System can produce a Class A biosolids, providing beneficial reuse opportunities;
- A solids content of up to 50 to 90 percent can be achieved, thereby reducing hauling costs;
- The process has low energy and operating costs;
- Enclosed greenhouse configuration controls odors; and
- Enclosed greenhouse configuration allows continuous drying even during inclement weather.

The disadvantages of solar sludge dryers for biosolids dewatering include:

- The process is land intensive compared to mechanical dewatering; and
- The sludge turning device (“mole”) can be maintenance intensive.

Anticipated Performance of Solar Drying Beds at the City of Surprise

Solar sludge dryers are a cost effective method of dewatering solids with variable characteristics. Solar, greenhouse-style drying beds are a **recommended** alternative for biosolids dewatering for the City of Surprise if the required land is available and were included for further evaluation using the SurpriseTree™ Wastewater Model.

7.3.2 Centrifuge

- Centrifuges achieve biosolids dewatering through the use of centrifugal forces to separate solids.
- Centrifuge dewatering has a compact footprint with intense mechanical components.

Centrifuges are a common process used for thickening and dewatering sludge. The separation of the solids-liquids slurry occurs as a result of the centrifugal forces and the difference in density between the solids and liquids. Because centrifugal force is applied, a high capacity can be achieved, and footprint requirements are minimized. Refer to Section 7.2.5 for additional information on the centrifuge process.

The advantages of centrifuge dewatering include:

- Less odor potential and housekeeping required;
- Fast start-up and shut-down;
- Able to produce dry sludge cake;
- Ability to control process performance;
- Low capital cost to capacity ratio; and
- Small footprint required.

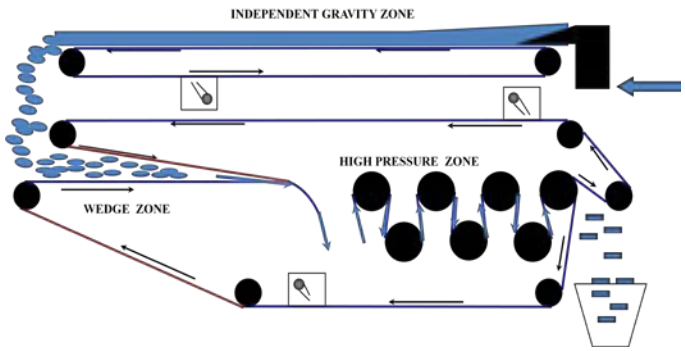
The disadvantages of centrifuge dewatering include:

- High capital and O&M;
- Requires upstream grit removal to reduce wear;
- Best suited for continuous operation applications;
- Skilled maintenance personnel required; and
- Moderate-high suspended solids in centrate.

Anticipated Performance of Centrifuge Dewatering at the City of Surprise

Centrifuge dewatering is a cost effective method of increasing the solids content of biosolids within a compact footprint. Centrifuge dewatering is a **recommended** alternative for biosolids dewatering for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

7.3.3 Belt Filter Press



- Belt filter presses achieve biosolids dewatering through the use of gravity and compression to separate solids.
- Belt filter presses have a simple operation capable of producing 15 to 30 percent dewatered solids.

The belt filter press utilizes a system of double belts to dewater solids through gravity and compression. Chemical conditioning through polymer addition is required to obtain optimum results. Similar to a GBT, a belt filter press employs a gravity zone with a fabric-mesh belt to eliminate free water from the sludge. The solids are then compressed between two belts around a series of drums to further reduce entrained liquid.

The advantages of belt filter press dewatering include:

- Low energy requirements;
- Relatively low capital and operating costs;
- Relatively simple and easy to maintain process;
- High-pressure presses are capable of producing dry cake in the range of 15 to 30 percent;
- Minimal effort required for system shutdown; and
- Continuous feed operation.

The disadvantages of belt filter press dewatering include:

- High odor potential;
- A sludge grinder may be required in the feed stream;
- Chemical addition is required to optimize the solids content;
- Sensitive to incoming sludge feed characteristics; and
- Requires operator's attention due to semi automatic operation.

Anticipated Performance of Belt Filter Press Dewatering at the City of Surprise

The belt filter press is a simple operation of dewatering biosolids using polymer addition to optimize the process. Belt filter press is a **recommended** alternative for biosolids dewatering for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

7.3.4 Summary of Dewatering Technologies

Table WWT.47 summarizes the anticipated performance of the biosolids dewatering technologies as well as their applicability to the City of Surprise typical wastewater. Table WWT.48 summarizes the evaluation results for biosolids dewatering technologies using the implementation based criteria. Centrifuges, belt filter presses and solar drying beds are recommended for further evaluation in the SurpriseTree™ Wastewater Model.

Table WWT.47 Biosolids Dewatering Unit Operations – Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operation	Performance Based Criteria		
	Volatile Solids Reduction	Biosolids Pathogen Reduction	Biosolids Volume Reduction
Drying Beds	N/A	N/A	Good.
Belt Filter Press	N/A	N/A	Good.
Centrifuge	N/A	N/A	Very good.

Table WWT.48 Biosolids Dewatering Unit Operations – Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operations	Implementation Based Criteria																	
	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Footprint	Regulatory	Safety	Residuals	Versatility	Expand-ability	Odor	Energy Savings	Class A Biosolids	Air Quality
Drying Beds	Very good.	Good.	Good.	Good.	Good.	Very good.	Very good.	Very good.	Fair. Large land area required.	Good.	Very good.	Good.	Fair.	Fair.	Fair.	Very good.	N/A	Fair.
Belt Filter Press	Good.	Good.	Very good.	Good.	Good.	Good.	Good.	Good.	Good. Compact footprint.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	N/A	Good.
Centrifuge	Fair.	Fair.	Very good.	Good.	Very good.	Fair.	Good.	Fair.	Very good. Compact footprint.	Good.	Fair.	Very good.	Very good.	Very good.	Very good.	Fair.	N/A	Good.

7.4 Biosolids Stabilization Treatment and Advanced Biosolids Management Technologies

The following sections identify and evaluate viable sludge stabilization technology and advanced biosolids management alternatives that produce Class B or higher biosolids quality. Each of the alternatives are summarized and evaluated based on various criteria, including their effectiveness in achieving the desired quality biosolids.

The intent of this evaluation is to provide a general analysis of the viable sludge stabilization technologies, including the following:

- Conventional Aerobic Digestion
- Autothermal Thermophilic Aerobic Digestion (ATAD)
- Second Generation ATAD
- Conventional Anaerobic Digestion
- Temperature-Phase Anaerobic Digestion
- Multi-Phase Anaerobic Digestion
- Multistage Thermophilic
- Cannibal® Process
- Air Drying
- Composting
- Thermal Drying
- Incineration

Additional details associated with each technology can be found in Appendix A.

7.4.1 Conventional Aerobic Digestion

	• Aerobic digestion can produce Class B biosolids, providing beneficial reuse opportunities. • Aerobic digestion is a relatively land intensive process due to a minimum 40-day SRT.

Aerobic digestion is a suspended-growth biological treatment process that oxidizes organisms and other organic matter, resulting in pathogen and solids reduction in the biosolids. The oxidation of organisms and other organic matter produces CO_2, water and ammonia. Oxidation is achieved by the continuous addition of air into the biosolids in order to maintain aerobic conditions. The oxidation process is limited by oxygen transfer

efficiency. The process will accept low and moderate feed solids concentrations and can achieve 30 to 50 percent volatile solids reduction. The aerobic digestion process consists of a digestion tank, blowers to provide air to the system, diffusers to distribute the air within the tank, and a mixing system to provide uniform solids concentrations throughout the tank.

To achieve Class B biosolids quality, aerobic digestion must provide at least 40 days of solids retention time (SRT, the average period of time the sludge remains in the digester), at 20 degrees Celsius (68 degrees Fahrenheit) or 60 days at 15 degrees Celsius (59 degrees Fahrenheit). The process meets the criteria for a process to significantly reduce pathogens by the time-temperature relationship, between 40 days at 20 degrees Celsius and 60 days at 15 degrees Celsius. 1 to 2 percent thickened sludge is preferable for sludge entering the conventional aerobic digestion process. Aerobic digestion can achieve solids stabilization in a relatively small footprint. Primary clarifiers are not necessary because primary sludge is not necessary to optimize this process, thus requiring fewer treatment basins/processes. Thickening is typically required prior to aerobic digestion.

The advantages of conventional aerobic digestion include:

- Can produce Class B biosolids, providing beneficial reuse opportunities;
- Relatively low capital cost to achieve biosolids stabilization; and
- Relatively simple to operate.

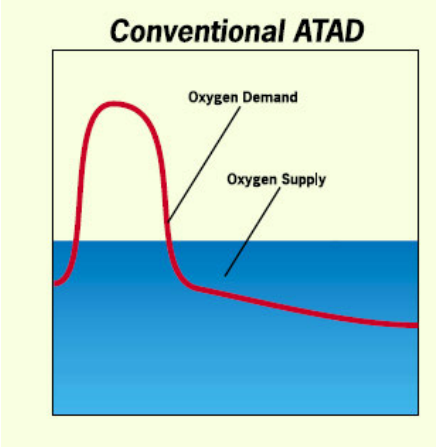
The disadvantages of conventional aerobic digestion include:

- Due to the aeration requirements, the process is relatively energy intensive;
- Potential to generate odors and foam;
- No energy recovery so process is not compatible with cogeneration;
- Relatively land intensive process due to the long SRT required to achieve Class B biosolids quality; and
- Process is generally coupled with a secondary treatment process without primary clarification, increasing the required aeration basin volume and the overall energy consumption in the secondary treatment process.

Anticipated Performance of Conventional Aerobic Digestion at the City of Surprise

Conventional aerobic digestion is a viable sludge stabilization treatment alternative due to its ability to produce Class B biosolids, its relatively simple operation, and its potential compatibility with the liquids treatment process. However, aerobic digestion requires a long HRT and large process footprint. This stabilization process consumes a lot of energy for aeration instead of recovering energy. Conventional aerobic digestion is a **recommended** alternative for biosolids stabilization for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

7.4.2 Autothermal Thermophilic Aerobic Digestion (ATAD)



- ATAD utilizes temperature to increase the biological activity in the digestion process, which reduces the detention time from 20 to 30 days to 10 to 15 days.
- ATAD can produce Class A biosolids, providing beneficial reuse opportunities.

Thermophilic aerobic digestion is a type of aerobic digestion capable of producing Class A biosolids. ATAD operates at a range of 50 degrees Celsius to 60 degrees Celsius (55 degrees Celsius optimally), higher than conventional aerobic digestion, and utilizes aerobic microorganisms. However, this technology rarely accomplishes destruction of the organic component beyond 40 percent of the feed. ATAD utilizes temperature to increase the biological activity, which reduces the detention time from 20 to 30 days to 10 to 15 days. The increase in temperature also reduces the number of pathogenic organisms to levels capable of meeting Class A requirements.

The advantages of ATAD include:

- Produces a Class A biosolids product;
- Self-heated aerobic digestion process; and
- Short detention time requires smaller digester volumes.

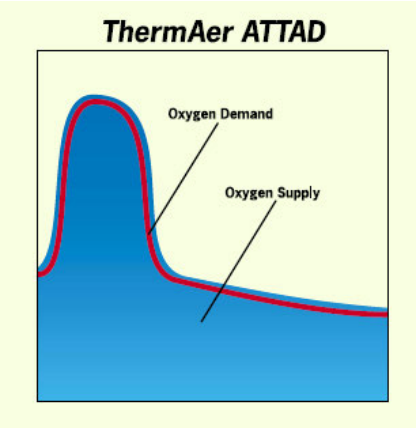
The disadvantages of ATAD include:

- Although this technology was developed with the concept that the temperature would be self-regulating, the evaporation of water due to air saturation cools the digester, requiring supplemental heating;
- Significant foaming issues are typical due to the high oxygen demand associated with increased biological rates and high air rates for mixing;
- Aerobic digestion is very energy intensive;
- Requires skilled operators to monitor and control optimum temperature range;
- Odor potential due to degradation of the organic compounds at high temperatures;
- Air from the digesters typically requires scrubbing; and
- Not compatible with cogeneration technologies.

Anticipated Performance of ATAD at the City of Surprise

Despite some temperature control, foaming, and odor issues, ATAD is a viable sludge stabilization treatment alternative capable of achieving Class A biosolids. With a shorter detention time, the biosolids can be stabilized within a smaller digester volume compared to aerobic digestion. However, the fuming control, odor control, and the cooling requirements are challenges for this technology. ATAD is **not a recommended** alternative for biosolids stabilization for the City of Surprise and was not included for further evaluation using the SurpriseTree™ Wastewater Model.

7.4.3 Second Generation ATAD



- Second generation ATAD adjusts the oxygen supply with varying oxygen demand, optimizing the biosolids stabilization process.
- Second generation ATAD can produce Class A biosolids, providing beneficial reuse opportunities.

For conventional ATAD, the oxygen supply remains constant, despite the oxygen demand. Second generation ATAD is similar to the ATAD process. However, the oxygen demand for second generation ATAD is automatically controlled based on the ORP. The oxygen supply is adjusted to meet the oxygen demand using online ORP instruments.

The advantages of second generation ATAD include:

- Relatively simple operation;
- High / moderate volatile suspended solids (VSS) reduction (~40 to 50 percent);
- No additional heating is required; and
- Capable of producing Class A biosolids.

The disadvantages of second generation ATAD include:

- Foaming control remains a challenge;
- Off-gas and odor control issues have not been proven reliable;
- Performance relies highly on DO and ORP control;
- Temperature control through off-gas is not effective; and
- Not compatible with cogeneration technologies.

Anticipated Performance of Second Generation ATAD at the City of Surprise

Second generation ATAD is a viable sludge stabilization treatment alternative due to its ability to produce Class A biosolids, its relatively simple operation, and its potential compatibility with the liquids treatment process. However, it optimizes the aeration process based on automatic oxygen uptake rate control, and attempted to overcome the cooling and fuming issues associated with the first generation ATAD. The City has unfavorable experience with this technology. Second generation ATAD is **not a recommended** alternative for biosolids stabilization for the City of Surprise and was not included for further evaluation using the SurpriseTree™ Wastewater Model.

7.4.4 Conventional Anaerobic Digestion

- Conventional anaerobic digestion is a well-established process that can reliably produce Class B biosolids when properly operated.
- Conventional anaerobic digestion can achieve approximately 50 percent volatile solids reduction with a 15-day SRT.

Anaerobic digestion is a widely used sludge stabilization process. This process is capable of meeting Class B biosolids criteria when operated in the mesophilic temperature range (35 to 55 degrees Celsius) with a SRT of at least 15 days. For anaerobic digestion, biosolids are treated in the absence of air for a specific amount of time at a specific temperature depending on the type of anaerobic digestion. Lack of oxygen promotes a fermentative state and degradation of organics through fermentation. Anaerobic digestion can typically achieve approximately 50 percent destruction of volatile solids (VS). Anaerobic digestion can be operated at both mesophilic (35 to 55 degrees Celsius) and themophilic (52 degrees Celsius) temperatures.

The anaerobic digestion process can be divided into three stages. During hydrolysis, the proteins, cellulose, lipids, and other complex organics are made soluble. During the acid phase, acetogens convert the biodegradable organics into low molecular weight volatile fatty acids (VFAs). In the final stage, methanogens convert the VFAs into methane and carbon dioxide. In conventional anaerobic digestion, all of these phases occur within a single reactor. This can lead to operational challenges as both groups of bacteria (the acetogens and methanogens) have considerably different optimal conditions for growth. However, conventional anaerobic digestion is a well-established process that can reliably produce Class B biosolids when properly operated. Anaerobic conditions require the appropriate pH, volatile acids, temperature, toxics, and alkalinity to achieve optimum performance.

A single stage, high rate anaerobic digester system includes the feed sludge, heat exchanger, and primary digester. Within the digester, both acid forming bacteria and methane forming bacteria are present. The byproducts of the process include the digested sludge and digester gas.

The digesters can be cylindrical or egg shaped with fixed or floating covers. A mixing system is used to mix generated gas through the digester to achieve uniform solids concentration throughout. A heating system composed of a boiler and heat exchangers maintains the required temperature within the digester. A gas handling system including piping and flares is used to handle the methane generated in the process. Sludge transfer piping is necessary to transport solids into and out of the digester.

A thickened sludge of 5 to 6 percent is preferable for sludge entering conventional anaerobic digestion. Consequently, thickening and dewatering of sludge is typically required prior to conventional anaerobic digestion. Sludge from primary clarification processes is ideal for anaerobic digestion. If primary clarification is used, anaerobic digestion is a recommended biosolids stabilization alternative. If anaerobic digestion is selected as the solids stabilization process, grit removal is necessary to remove the inert grit material from the treatment process.

The advantages of conventional anaerobic digestion include:

- Increased volatile solids reduction when compared to conventional aerobic digestion;
- Compatible with cogeneration in larger facilities;
- Operational costs low if methane is used, resulting in low net energy requirements,
- Process accepts thicker solids;
- Lower tank volume required compared to aerobic digestion;
- Able to treat high strength waste;
- Oxygen transfer is not a limiting factor;
- Process generates methane, a renewable energy source; and
- Higher volatile solids reduction.

The disadvantages of conventional anaerobic digestion include:

- Potential for odor and foam formation;
- Requires skilled operators;
- Relatively high capital cost;
- Complex system operation;
- System is slow to recover from upset;
- Supernatant is strong in COD, BOD, SS, and NH_4, impacting liquid treatment process; and
- Struvite deposit potential.

Anticipated Performance of Conventional Anaerobic Digestion at the City of Surprise

Conventional anaerobic digestion is a viable sludge stabilization treatment alternative due to its ability to produce Class B biosolids, and its compatibility with the liquids treatment process. Anaerobic digestion has reduced HRT requirement compared to other stabilization technologies and offers energy recovery through the production of methane gas. It requires relatively large capital investment in associated infrastructure (heating, mixing, gas collection, flares, boilers and/or cogeneration system, primary clarifiers, etc.). Conventional anaerobic digestion is a **recommended** alternative for biosolids stabilization for the City of Surprise and was included for further evaluation using the SurpriseTree™ Wastewater Model.

7.4.5 Temperature-Phased Anaerobic Digestion

- Temperature-phased anaerobic digestion achieves Class A biosolids by adjusting the temperature to accommodate both thermophilic and mesophilic bacteria.
- Temperature-phased anaerobic digestion can reduce odors typically associated with anaerobic digestion.

Another advanced digestion technology that may achieve Class A biosolids criteria is temperature-phased anaerobic digestion. This technology uses temperature to improve the disinfection potential and physical separation of the digestion phases. There are various configurations, including mesophilic-thermophilic, thermophilic-mesophilic, and three-phase systems. Various configurations of these processes are now being tested at large wastewater treatment plants.

The most promising configuration is a mesophilic-thermophilic-mesophilic three-phase system. One of the main advantages of this type of system is that the odorous sludge produced in a thermophilic stage can be mitigated through the use of a subsequent mesophilic stage. In effect, this type of process combines the best aspects of thermophilic digestion (disinfection) and two-phase mesophilic digestion (VSS reduction, dewaterability, gas production, and non-odorous sludge).

The advantages of temperature-phased anaerobic digestion include:

- Produces Class A biosolids (PFRP equivalent with 1 day batch tanks at ~68 degrees Celsius);
- Can reduce odors typically associated with anaerobic digestion;
- High reaction rates;

- Additional VS reductions; and
- Improved dewaterability.

The disadvantages of temperature-phased anaerobic digestion include:

- More complicated heat exchanger system design and operation;
- The only patented advanced digestion process that requires a royalty fee; and
- Lowering the temperature from thermophilic temperatures to mesophilic temperatures is difficult because microorganisms become acclimated to initial temperatures. This can make the process difficult to control and maintain desired sludge quality.

Anticipated Performance of Temperature Phased Anaerobic Digestion at the City of Surprise

Temperature-phased anaerobic digestion is considered a potential alternative sludge stabilization process due to its ability to produce Class A biosolids. However, it is important to note the operational difficulties associated with lowering process temperatures from the thermophilic to mesophilic range, while maintaining an efficient microorganism population capable of achieving the desired sludge stabilization. Given that better advanced anaerobic digestion alternatives (multi-phase acid/gas anaerobic digestion) are available, temperature-phased anaerobic digestion is **not a recommended** alternative for biosolids stabilization for the City of Surprise and was not included for further evaluation using the SurpriseTree™ Wastewater Model.

7.4.6 Multi-Phase (Acid / Gas) Anaerobic Digestion

- Multi-phase anaerobic digestion process separates the acid and methane phases of conventional anaerobic digestion into two different phases occurring in different reactors.
- Multi-phase anaerobic digestion can achieve Class A biosolids along with a volatile solids reduction of 55-75 percent.

The multi-phase anaerobic digestion process separates the acid and methane phases of conventional anaerobic digestion into two different phases occurring in different reactors. This separation promotes optimal growth conditions for the acetogenic and methanogenic bacteria, while also optimizing the process through manipulation of the loading rates and hydraulic detention time (by using separate digestion vessels). To accomplish the phase separation, all of the waste solids are fed into a single small reactor where the volatile suspended solids (VSS) are converted into VFAs. The solids are then directed into a second reactor where the methanogenic organisms convert the VFAs into methane and carbon dioxide. This second reactor is much larger than the acid-phase reactor to provide adequate detention for the microbial reactions.

This technology has no significant additional heating requirements as compared to conventional anaerobic digestion. This system is also very flexible, allowing the acid phase to be taken in and out of service as needed without disrupting the methane phase or sacrificing biosolids quality. Overall, this technology can produce pathogen limits comparable to Class A criteria when operated under mesophilic (35 degrees Celsius) - thermophilic (52 degrees Celsius) conditions (also referred to as “meso-thermo”). To be considered a Class A technology, additional monitoring is required to confirm coliform reductions will meet the PFRP requirements. Note that a third mesophilic phase can also provide additional reduction of odors, if required.

Within the acid-phase digester the following occurs:

- Degradation of celluloid materials (lignins) commonly undegradable in conventional anaerobic digestion.
- Destruction of foam causing microorganisms.
- Enhanced destruction of pathogenic organisms.
- Destruction of floc “Structure”, increasing dewaterability.

Within the methane-phase digester the following occurs:

- Released carbonate alkalinity (7,000 to 9,000 mg/L as $CaCO_3$) provides outstanding stability to changes.
- pH is controlled by carbonate alkalinity not VFAs.
- Over 90 percent of the gas is produced in this phase.
- Methane concentration is around 70 percent.
- Acid gases H_2S and CO_2 are suppressed due to pH conditions.

One major advantage of multi-phase digestion is the ability of the acid-phase digester to accept high VSS loadings. Conventional anaerobic digesters must limit the VSS loading to the digester, therefore limiting the percent solids in the feed. Acid-phase digesters can be fed more concentrated solids to accomplish acid conditions. Approximately 6 to 10 percent TSS feed is desired to the acid-phase digester. The acid-phase digester is also capable of accepting scum, oil, and grease.

Another major advantage of multi-phase digestion is the improved gas production and quality. The separation of phases and pH generates a much cleaner gas from the methane phase as compare to the gas produced from the conventional digester. The improved gas production represents better utilization of available VSS.

One major disadvantage of multi-phase digestion is that with high VSS reduction, more ammonia is released into the centrate. If the centrate is returned to preliminary treatment directly, additional load is added to the biological nitrification process. Additional oxygen and carbon source may be necessary to achieve nitrification in this process. This may result in the need to increase the size of the biological treatment process or provide a separate sidestream centrate treatment with nitrification.

Table WWT.49 summarizes the typical design parameters for multi-phase versus conventional anaerobic digestion.

Table WWT.49 Typical Design Parameters for Conventional and Multi-Phase Digestion Wastewater Technology Assessment Report City of Surprise			
	Conventional Anaerobic Digestion	**Multi-Phase Anaerobic Digestion (Meso-Thermo)**	
Hydraulic Retention Time	15-22 days	1-3 days	10-19 days
Temperature	95°F (35°C)	95°F (35° C)	125°F (52° C)
pH	7.0 - 8.0	5.0 - 5.5	7.5 - 8.5
Volatile Solids Reduction	50%	65%	
Solids Loading	0.12-0.13 lb VSS/day/cf	3 lb VSS/day/cf	N.A.

The advantages of multi-phase anaerobic digestion include:

- Class A biosolids is achievable;
- High volatile solids reduction (55-75 percent);
- Increased dewaterability;
- Ability to recover energy (use methane gas) and lower life cycle cost;
- Improved digester gas production and quality;
- Reduced foam;
- Resistant to oil and grease;
- Reduced digester volume;
- Increased, cleaner-burning gas production; and
- Compatibility with cogeneration technologies.

The disadvantages of multi-phase anaerobic digestion include:

- Requires skilled operators;
- Strong sidestream (supernatant) with high ammonia concentrations, potentially impacting the liquid treatment process;
- Safety issues with flammable gases;
- Requires additional monitoring to confirm Class A; and
- Relatively high capital cost.

Anticipated Performance of Multi-Phase Anaerobic Digestion at the City of Surprise

Multi-phase anaerobic digestion is a viable sludge stabilization treatment alternative due to its flexibility, and its ability to produce EQ or Class A biosolids. It requires much shorter HRT compared to aerobic and conventional anaerobic digestion, which offsets the investment on digester tankage. Multi-phase anaerobic digestion is a proven technology used at many facilities locally and nationwide. It achieves higher volatile solids reduction, improves the dewaterability of the sludge, and produces a larger volume of clean digester gas. Even though the capital costs for this technology are high compare to aerobic digestion, it is a **recommended** alternative for biosolids stabilization for the City of Surprise and is included for further evaluation using the SurpriseTree™ Wastewater Model.

7.4.7 Multi-Stage Thermophilic Anaerobic Digestion

Multi-stage thermophilic anaerobic digestion operates in a batch mode with multiple stages and is capable of achieving Class A biosolids. All reactors are operated at 55 degrees Celsius as methane reactors, within a pH of 7.2 to 7.8. The first stage of the process has an SRT of greater than 5 to 8 days. A variable HRT is used in the remaining stages. The use of multiple reactors reduces the opportunity for short circuiting. Multi-stage thermophilic anaerobic digestion can achieve VS reduction up to 65 percent.

The advantages of multi-stage thermophilic anaerobic digestion include:

- Improved VS reduction of up to 65 percent;
- Ease in achieving Class A;
- Heat recovery not required;
- “One” biological system; and
- Improved dewaterability of stabilized solids.

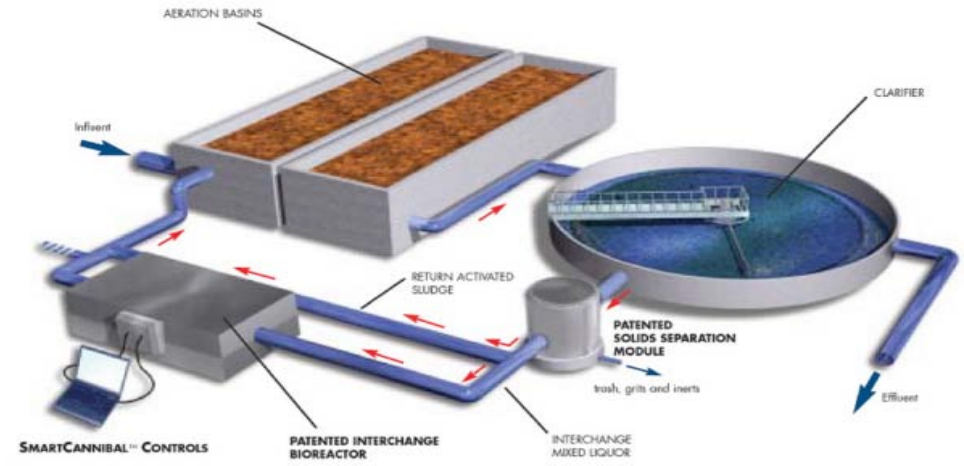
The disadvantages of multi-stage thermophilic anaerobic digestion include:

- Some product odor and VFA content;
- Reduced HRT not yet proven; and
- Added heat required over mesophilic digestion.

Anticipated Performance of Multi-Stage Thermophilic Anaerobic Digestion at the City of Surprise

Multi-stage thermophilic digestion is considered a potential alternative sludge stabilization process due to its ability to produce Class A biosolids. However, due to its limited full scale experience and the operational issues associated with the batch concept, multi-stage thermophilic digestion is **not a recommended** alternative for biosolids stabilization for the City of Surprise and is not included for further evaluation using the SurpriseTree™ Wastewater Model.

7.4.8 Cannibal® Process



- The Cannibal® process results in an overall decrease in solids production.
- The Cannibal® process is a proprietary technology with limited installations.

The Cannibal® Solids Reduction system is a proprietary biological process designed to minimize biosolids production. First, WAS is pumped from the secondary clarifier through a solids separation module (screening) to remove inert solids. The screened activated sludge that is typically wasted in a conventional plant then flows to an interchange bioreactor. Eliminating inerts from the WAS promotes more effective operation of the interchange bioreactor. In the anoxic environment of the interchange bioreactor, low-growth facultative bacteria destroy aerobic bacteria by breaking down their cells. The remaining facultative bacteria are then returned to the aeration basins where they are in turn, broken down by the aerobic bacteria. This process results in an overall decrease in solids production.

The advantages of the Cannibal® process include:

- The process can reduce overall biosolids production very significantly;
- The solids concentration is 40 to 50 percent;
- Process results in a reduced overall process footprint; and
- The process has relatively low power, O&M, and chemical costs.

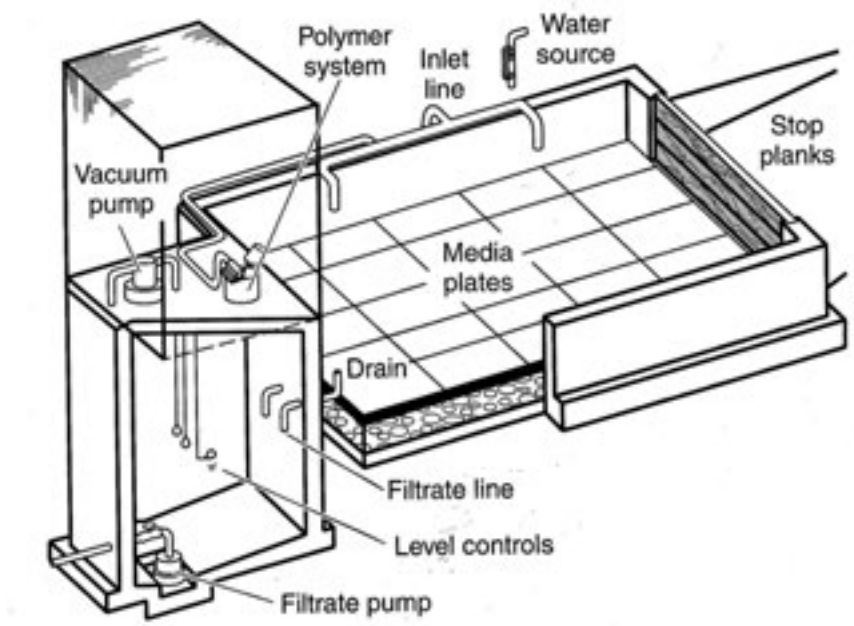
The disadvantages of the Cannibal® process include:

- Cannibal® is a proprietary technology that requires a licensing fee;
- The process has limited installations/success in the US; and
- Produces inert material, which does not provide beneficial reuse.

Anticipated Performance of Cannibal® at the City of Surprise

Cannibal® process is a proprietary technology that results in an overall decrease in solids production. However, due to the limited installations and success in the US, the Cannibal® process is **not a recommended** alternative for biosolids stabilization for the City of Surprise and was not included for further evaluation using the SurpriseTree™ Wastewater Model.

7.4.9 Air Drying



- Air drying involves drying biosolids for a minimum of 3 months to produce Class B biosolids.
- Air drying is an O&M and land intensive solids stabilization process.

According to the EPA 40 CFR 503 regulations, air drying involves drying biosolids on sand beds or in paved or unpaved basins for a minimum of 3 months to produce Class B biosolids. During 2 of the 3 months, the ambient average daily temperature must exceed 0 degrees Centigrade (32 degrees Fahrenheit).

The O&M costs associated with air drying are relatively low as there are no significant energy requirements. Polymer is typically added to sludge to assist with conventional air drying and labor cost is limited to removal of the dried biosolids from the beds. Drying beds require a large footprint and at least 1,000 foot setbacks from the closest property owner to meet regulations.

The advantages of air drying include:

- Reduces the volume of biosolids to be hauled for reuse or disposal;
- Uses solar and wind energy to dry biosolids. The low energy input and associated O&M costs make it a more sustainable process than other more mechanically intensive alternatives; and
- Relatively low capital cost.

The disadvantages of air drying include:

- Requires more time and land area than comparable mechanical dewatering processes; and
- Has a high odor production potential and requires dust control and buffer zones.

Anticipated Performance of Air Drying at the City of Surprise

Air drying is considered a potential alternative sludge stabilization process due to its ability to produce Class B biosolids. However, this process has the potential to produce significant odors and requires a very large footprint to achieve the 3 months of drying required to produce Class B biosolids. Air drying together with other advanced biosolids management options are included in the SurpriseTree™ Wastewater Model as a general category for the City's further consideration. The implementation of these advanced digestion processes require the City's commitment and policy making on the environmental and social aspects beyond economical and technical considerations.

7.4.10 Composting

- Biosolids composting is a stabilization process where the organic constituents of the biosolids are aerobically decomposed.
- Composting operations can meet both Class A and Class B pathogen reduction requirements depending on time and temperatures met during the process.

Biosolids composting is a stabilization process in which the organic constituents of the biosolids are aerobically decomposed. High temperatures achieved during the microbial decomposition reduce pathogenic organisms in the biosolids. The resultant humus-like material can be used as a soil amendment. The biosolids are typically dewatered prior to the composting process.

A bulking agent such as wood or paper waste is usually added to increase the carbon-to-nitrogen ratio. The bulking agent succeeds in producing higher quality biosolids as a soil amendment, raising the initial solids content of the mixture, and providing bulk porosity, which is important for efficient aeration.

During the composting process, the volatile solids content of the digested biosolids is reduced. The bulking agent can become partially decomposed and the solids content of the mixture can increase. When composting is complete, the compost material is typically screened to retrieve a portion of the bulking agent. The product is typically cured for several days before it is bagged and labeled or distributed in bulk form. Composting operations can meet both Class A and Class B pathogen reduction requirements depending on time and temperatures met during the process.

Because compost products have generally been associated with food and yard waste or agricultural waste, the public is more familiar with compost products and is more likely to accept biosolids compost. In addition, because the composting process requires carbon sources, these nutrients could be supplied through the use of municipal organic waste. Composting can also incorporate water treatment residuals, which could serve as a bulking agent.

There are three basic types of composting processes discussed in the following sections: windrow composting, aerated static piles, and in-vessel composting.

7.4.10.1 Windrow Composting

In windrow composting, the biosolids and bulking agent mixture is formed into long, open-air piles. The biosolids are turned frequently to ensure an adequate supply of oxygen throughout the compost pile and to guarantee high, uniform temperatures throughout the pile for optimal pathogen reduction. Windrow composting requires a significant amount of land and, due to the odor potential, is generally limited to rural areas with low population densities.

7.4.10.2 Aerated Piles Composting

Aerated static piles rely on forced air to supply air for both decomposition and moisture removal. Air is supplied by blowers connected to perforated pipes running under the piles. The blowers draw or blow air into the piles, assuring even distribution of air throughout the composting biosolids mixture. A layer of previously composted biosolids placed over the surface of the pile helps to insulate the pile and assure that sufficient temperatures are achieved throughout the pile.

Aerated static pile composting is usually conducted within an enclosed building in order to collect and scrub the gases emitted from the process. A static pile composting facility would require a large land area.

7.4.10.3 In-Vessel Composting

In this process, the feed biosolids, bulking agent, and recycled biosolids are fed into an enclosed vessel or reactor. Environmental conditions such as temperature and oxygen supply can be monitored and controlled inside the reactor. The biosolids mixture is maintained in an aerobic condition by forced air or continuous mixing. The air provides oxygen to the microorganisms and maintains decomposition rates of compost. The stabilization period in the system is approximately 14 to 21 days followed by an additional curing period of approximately 30 days. Curing is induced by stockpiling the composted material in a warehouse type building. Both the composting and curing locations would be fully enclosed, and air and odor emissions would be treated prior to releasing to the atmosphere. In-vessel systems are becoming more popular due to easier odor and gas emission collection and treatment, process control, and better public acceptance.

Currently, there are two basic types of in-vessel reactors: a tunnel reactor and a plug-flow, agitated bay system. Tunnel reactors may be constructed either vertically or horizontally. The plug-flow agitated bay system is offered by several manufacturers. The agitated bay system consists of modular units of parallel walls (or bays). For both systems, biosolids and bulking agents are initially mixed before entering the systems.

The advantages of in-vessel composting only include:

- General public acceptance;
- Requires a smaller footprint than other composting technologies but the composting process as a whole can be land intensive;
- Allows for simple gas collection and scrubbing; and
- Produces a Class A biosolids that could be a marketable product suitable for land application.

The disadvantages of in-vessel composting only include:

- Fire potential is high;
- Requires 18 to 30 percent dewatered solids;
- Requires additional odor control equipment, a bulking agent, carbon source, and a curing step, which requires additional process time and space; and
- Requires large footprint associated with 30 days of composted material storage (i.e., warehouse).

Anticipated Performance of Composting at the City of Surprise

Composing is considered a potential alternative sludge stabilization process due to its ability to produce Class A biosolids. However, this process has the potential to produce significant odors and requires a very large footprint to achieve the 30 days of composing material storage. Composting together with other advanced biosolids management options are included in the SurpriseTree™ Wastewater Model as a general category for the City's further consideration. The implementation of these advanced digestion processes require the City's commitment and policy making on the environmental and social aspects beyond economical and technical considerations.

7.4.11 Thermal Drying

- Thermal drying involves reduction of the moisture content of biosolids by induced evaporation.
- The thermal drying process must reduce the moisture content of the biosolids to 10 percent or lower in order to meet the Class A PFRP requirement.

The thermal (heat) drying process must reduce the moisture content of the biosolids to 10 percent or lower in order to meet the Class A PFRP requirement. In addition, the temperature of the biosolids must be greater than 80 degrees Celsius or the wet bulb temperature of the gas in contact with the biosolids as it leaves the dryer must exceed 80 degrees Celsius.

Heat drying involves reduction of the moisture content of biosolids by induced evaporation. Sludge is dried by direct or indirect contact with hot glass. The feed sludge to the heat dryer must be mechanically dewatered to optimize the efficiency of the drying step. Heat drying utilizes mechanical agitation and auxiliary heat to increase the evaporation rate and has the capability and flexibility to produce pathogen free biosolids with any desired percent solids, typically 10 percent or lower. Heat drying alternatives include flash drying, spray drying, and rotary heat drying. The USEPA reports that the most common type of dryer currently used in handling biosolids is the rotary dryer.

Heat drying can be achieved via direct or indirect methods. Direct heating exposes biosolids to full contact with hot gases. Indirect drying uses hot gas to heat up surface(s), which then come in contact with the sludge to evaporate moisture from the biosolids. The disadvantage to direct dryers is that new hot gas needs to be generated to evaporate moisture from the biosolids. Furthermore, the gas must be treated prior to release into the atmosphere. Alternatively, indirect dryers can recycle the gas used to heat the surfaces, which saves on power costs. In the past, heat drying alternatives tended to have high energy costs and were not widely used. Newer technology has made heat drying less energy intensive and more feasible.

Thermal drying technologies are also affected by air emissions permitting requirements, including 40 CFR, Part 60. The air pollutants of concern from a typical rotary drum-type thermal drying system are basically the byproducts of natural gas and/or digester gas combustion along with off-gases from the drying process. The main pollutants of concern are particulate matter less than 10 microns in diameter (PM10), volatile organic compounds (VOCs), sulfur oxides (SOx), nitrogen oxides (NOx), carbon monoxide (CO), hazardous air pollutants (HAPs), and trace amounts of metals. A natural gas or digester gas-fired regenerative thermal oxidizer (RTO) is typically used to control emissions of VOCs and CO. Up to 99 percent of VOCs and up to 85 percent of CO emissions can be controlled by the RTO. Any ammonia released from the sludge will also be oxidized to nitrogen dioxide (NO_2) in the RTO. Additionally, particulate control devices, such as Venturi scrubbers, are also typically employed to reduce particulate emissions.

In addition to the dryer itself, a rotary drum-type dryer system will also be comprised of product-handling equipment, including conveyors, bucket elevators, screens, grinders, product-cooling equipment, and product storage bins or silos. These units are typically completely enclosed and ventilated to scrubbers or fabric filters to control particulate emissions.

The advantages of thermal drying include:

- Produces a Class A biosolids product;
- Can be land applied or marketed commercially;
- Substantial volume reduction; and
- Can be started quickly (not a biological process).

The disadvantages of thermal drying include:

- Energy and labor intensive;
- Air permitting requirements;
- Odors, emissions; and
- Land application limitations due to moisture content.

Anticipated Performance of Thermal Drying at the City of Surprise

Thermal drying is considered a potential alternative sludge stabilization process due to its ability to produce Class A biosolids. However, the energy and labor intensity must be carefully considered before implementation. Thermal drying together with other advanced biosolids management options are included in the SurpriseTree™ Wastewater Model as a general category for the City's further consideration. The implementation of these advanced digestion processes require the City's commitment and policy making on the environmental and social aspects beyond economical and technical considerations.

7.4.12 Solar Drying

- Solar drying is accomplished in drying beds enclosed by greenhouse-like structures.
- Solar radiation evaporates water from sludge in the solar drying process.
- Windrow turner (SOLIAMIX™), aerates biosolids and digests.

Solar drying consists of drying beds enclosed within a greenhouse-like structure. The sludge is tilled with a device that systematically aerates the biosolids. The device promotes biosolids digestion and heat production, which further aids in the drying of biosolids. The feed sludge must be dewatered to approximately 20 percent solids.

The advantages of the solar drying system include:

- Produces Class A biosolids for beneficial reuse - sustainable management practice;
- Up to 45 to 90 percent solids content can be achieved;
- Low energy and operating costs - promotes sustainable technology;
- Existing sludge drying beds can be retrofitted to accommodate the process;
- Controls odors;
- Not affected by inclement weather; and
- Windrow turner provides effective aeration.

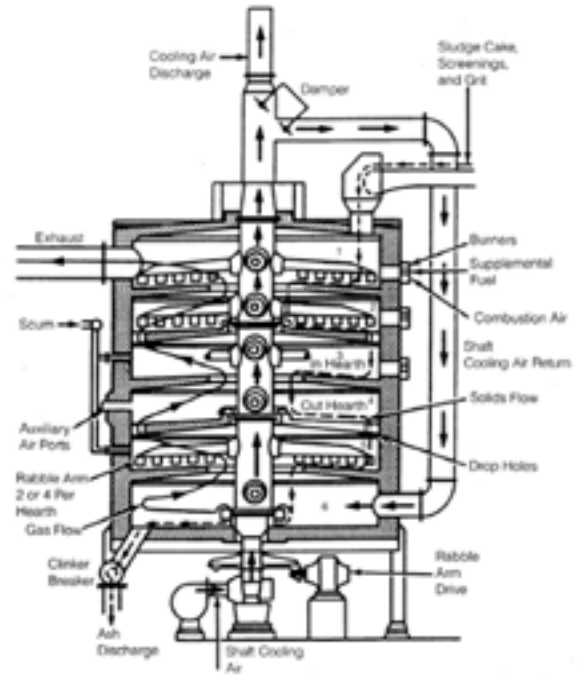
The disadvantages of the solar drying system include:

- Land intensive; and
- Requires dewatered biosolids.

Anticipated Performance of Solar Drying at the City of Surprise

Solar drying is considered a potential alternative sludge stabilization process due to its ability to produce Class A biosolids. However, the land intensity must be carefully considered before implementation. Solar drying together with other advanced biosolids management options are included in the SurpriseTree™ Wastewater Model as a general category for the City's further consideration. The implementation of these advanced digestion processes require the City's commitment and policy making on the environmental and social aspects beyond economical and technical considerations.

7.4.13 Incineration



- Incineration processes use high temperatures to thermally process the solids in the presence of air.
- The combustion process can be self-sustaining if solids are dewatered to approximately 30 percent solids and their heat value is sufficient. Thus, supplemental fuel is not required to sustain the process.

Incineration is combustion in the presence of air. Incineration of wastewater solids takes place in two steps. The first is drying the solids, where the temperature is raised to the point that water in the solids evaporates. The second step is the combustion of the volatile fraction of the solids.

Combustion can only take place after sufficient water is removed. Wastewater solids are dewatered to between 15 to 35 percent solids prior to incineration. The incineration process then converts biosolids into inert ash. 65 to 75 percent of the solids are combustible, and thus the volume of ash is significantly lower than that of the original biosolids. This ash can be used or disposed of more readily due to its low volume and inert nature. If solids are dewatered to approximately 30 percent solids and their heat value is sufficient, the process can be self-sustaining, and supplemental fuel is not required to sustain combustion. Nonetheless, supplemental fuel is always needed during initial startup operations and periodically throughout operations to accommodate fluctuation in feed solids characteristics.

Ash generated by incineration of wastewater solids is usually landfilled, but some facilities use other innovative methods to reuse the ash, including:

- Filler in cement and brick manufacturing;
- Subbase material for road construction;
- Daily landfill cover (must be pelletized first); and
- Ingredient in footing at athletic facilities.

Two types of incineration systems are commonly used for wastewater solids combustion: multiple hearth furnaces (MHFs) and fluidized bed furnaces (FBFs). Both use high temperatures to thermally process the solids in the presence of air. Because FBFs are generally better at meeting federal emission standards, most new installations use this technology. Some facilities with MHFs incorporate FBF technology to comply with more recent federal regulations.

Air pollution control is an integral part of any incineration facility. Equipment must be able to control particulate emissions, gases (such as nitrogen oxides, sulfur oxides, and carbon monoxide), and other characteristics such as opacity.

The advantages of incineration include:

- Volume reduction;
- Generation of stable material. Ash is a stable, sterile material, effectively eliminating storage and handling problems;
- Potential energy recovery; and
- Minimal land area required.

The disadvantages of incineration include:

- High capital investment;
- In most cases, annual operating costs depend on fuel costs;
- Consumption of non-renewable resources (oil and/or natural gas);
- Limited feasibility in nonattainment areas;
- Potential operating problems. Incinerators experience significant down time for routine maintenance and therefore require redundancy, backup, or storage. High technology instrumentation is required to comply with air pollution control permits; and
- Potential for public opposition.

Modern incineration facilities generally do not present a significant health risk to the community if they are equipped with adequately maintained process control and air pollution control equipment and are operated by trained employees.

Anticipated Performance of Incineration at the City of Surprise

Incineration is currently not an allowable process in the State of Arizona. The high capital investment, energy, and labor intensity must be carefully considered before implementation. Thermal drying together with other advanced biosolids management options are included in the SurpriseTree™ Wastewater Model as a general category for the City's further consideration. The implementation of these advanced digestion processes require the City's commitment and policy making on the environmental and social aspects beyond economical and technical considerations.

7.4.14 Summary of Biosolids Stabilization Technologies

Table WWT.50 summarizes the anticipated performance of the biosolids stabilization technologies as well as their applicability to the City of Surprise typical wastewater. Table WWT.51 summarizes the evaluation results for biosolids stabilization technologies using the implementation based criteria. Conventional aerobic digestion, ATAD, second generation ATAD, conventional anaerobic digestion, multi-phase anaerobic digestion, temperature-phased anaerobic digestion, lagoon, air drying, heat drying, composting and solar air drying are recommended for further evaluation in the SurpriseTree™ Wastewater Model.

Table WWT.50 Biosolids Stabilization Unit Operations – Performance Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operation	Performance Based Criteria		
	Volatile Solids Reduction	**Biosolids Pathogen Reduction**	**Biosolids Volume Reduction**
Aerobic Digestion	Fair.	Fair.	Fair.
Conventional Anaerobic Digestion	Good.	Good.	Good.
Multi-Phase Anaerobic Digestion	Good.	Good.	Good.
Air Drying	Good.	Good.	Good.
Heat Drying	Very good.	Very good.	Very good.
Composting	Good.	Good.	Good.
Incineration	Very good.	Very good.	Very good.

Table WWT.51 Biosolids Stabilization Unit Operations – Implementation Based Criteria
Wastewater Technology Assessment Report
City of Surprise

Unit Operations	Implementation Based Criteria																	
	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Footprint	Regulatory	Safety	Residuals	Versatility	Expand-ability	Odor	Energy Savings	Class A Biosolids	Air Quality
Aerobic Digestion	Good.	Good.	Good.	Very good.	Very good.	Good.	Good.	Good.	Fair.	Good.	Good.	Good.	Good.	Good.	Fair.	Poor.	Poor.	Good.
Conventional Anaerobic Digestion	Good.	Good.	Good.	Very good.	Fair.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Fair.
Multi-Phase Anaerobic Digestion	Good.	Good.	Very good.	Fair.	Fair.	Good.	Very good.	Good.	Very good.	Fair.	Good.	Very good.	Very good.	Very good.	Good.	Very good.	Very good.	Fair.
Air Drying	Good.	Good.	Good.	Good.	Fair.	Good.	Good.	Good.	Fair.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.
Heat Drying	Good.	Good.	Good.	Fair.	Fair.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.
Composting	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Good.	Fair.	Good.	Good.	Very good.	Good.	Good.	Good.	Good.	Good.	Good.
Incineration	Poor.	Poor.	Fair.	Fair.	Poor.	Fair.	Good.	Poor.	Very good.	N/A	Fair.	Very good.	Good.	Good.	Good.	Fair.	Good.	N/A

7.5 Biosolids Disposal Alternatives

Section 4.0 presents the City's near-term and long-term biosolids treatment standards and biosolids management standards. The biosolids quality requirements are also presented in that section.

Currently, the City is sending all biosolids to landfill. In the short term, the City would like to produce biosolids with a minimum classification of Class B, which can be both landfilled and land applied. Although it is not anticipated that Class A biosolids will become mandatory in the near future, the City's long-term plan includes treating solids onsite through thickening, advanced digestion, and dewatering processes to produce Class A biosolids that can be land-applied.

Biosolids disposed at a landfill must be dewatered and meet the TCLP test, as discussed in Section 3.5. For land application, the biosolids must be stabilized to achieve the pathogen and vector attraction reduction requirements per the different classification of biosolids. Class B, A, or EQ biosolids can be land applied. Solids can be land applied in the liquid form without thickening and/or dewatering or applied in the cake form with thickening and/or dewatering. Thickening and/or dewatering will reduce the volume, thus reducing the number of truck loads to deliver the cake to the land application site.

Land application can be a cost effective disposal option and provide potential flexibility in disposal. Implementing biosolids stabilization technologies that can achieve at least Class B biosolids requirements are an important step for the City. In the future, generation of a commercial product can be a viable alternative of landfilling through upgrading the Class B biosolids treatment facility to Class A or implementing advanced biosolids management technologies discussed in the previous section.

8.0 EVALUATIONS OF WASTEWATER TREATMENT TECHNOLOGIES USING SURPRISETREE™ WASTEWATER MODEL

As discussed throughout the Wastewater Technology Assessment Report, the optimum wastewater and biosolids treatment technology for a new WRF could depend on a variety of factors including the specific wastewater quality, the reclaimed water quality goals, and a multitude of site-specific inputs.

The quality and strength of the wastewater may vary considerably based on the impacts of industrial discharges or water conservation practices. While wastewater characteristics significantly impact the wastewater treatment technology selection, the most appropriate technology also highly depends on the end use and disposal methods of the reclaimed water. Reuse water must meet different classification requirements for the intended reuse application (i.e., Class A+ versus Class B versus Class C), each of which requires different levels of tertiary treatment and disinfection standards. Recharging water to a drinking water aquifer must be consistent with the Aquifer Protection Permit requirements. Discharge to a

surface water stream often has stringent nutrient limits depending on the designated use of the receiving stream. These factors can all impact the technology selection.

Similarly, the biosolids management goals determine the most appropriate biosolids treatment technologies and impact the liquid stream treatment. Many considerations can impact biosolids treatment alternative selection, including the biosolids end use/disposal (i.e., are biosolids sent directly to a landfill, land applied, or used in an application where achieving Class A biosolids may be desired now or in the future).

Other site-specific impacts, such as land availability, the necessity of and level of odor control, and the existing site conditions can all influence the technology selection. The interaction between various treatment processes also plays an important role in shaping the treatment train. For example, if a facility site has limited land availability, membrane bioreactors (MBR), which have a very small footprint, may be a more appropriate technology compared to an extended aeration process using oxidation ditch technologies.

There is likely no single technology that will fit the exact needs of the all of the City's future WRFs. In order to provide the City with a powerful, flexible, and consistent approach to future wastewater facilities planning and design and to foster the City's ability to assess available treatment alternatives for a given set of wastewater quality inputs and site-specific conditions, Carollo developed an innovative, advanced macro-based Microsoft Excel© model named SurpriseTree™ Wastewater Model. A copy of this model is located on a CD attached with this report.

Using the SurpriseTree™ Wastewater Model, the results of the technology alternative assessment are not limited to a single fixed set of recommendations. Instead, the model provides dynamic and customized recommendations, which assist the users in selecting the most technically feasible and cost effective treatment options in response to the wastewater quality, reclaimed water and biosolids treatment goals, and site-specific condition inputs.

The SurpriseTree™ Wastewater Model evaluates treatment technologies using criteria established by City staff and developer representatives (referred to as implementation-based criteria), which are supplemented by performance-based evaluation and capital, O&M, and lifecycle cost analysis developed by engineers. Weighting factors for the implementation-based criteria were developed by averaging the inputs from City staff and developer representatives. All weighting factors, ranking scores, and unit costs are fully adjustable by the City, providing significant flexibility to adjust to changing future conditions. The model employs a user-friendly spreadsheet structure, powered by macro-based selector buttons to make the site-specific analysis prompt and easy.

While the SurpriseTree™ Wastewater Model can provide detailed analyses for a given set of inputs, it is designed to be a master planning level tool. As with any similar application, the model and its outputs are only as accurate as the input information. For example, inputs like capital and O&M cost information included in the model are conceptual and must be updated regularly to ensure the recommendations are valid. The model is fully customizable

and can be revised to reflect the City's policy and decisions with respect to the wastewater and biosolids technology selection.

Ultimately, the model provides a practical tool to document the City's decisions and incorporate the City's institutional and technical knowledge with technical information/data provided by the engineer. Through continuing efforts by the City (assisted by the engineer when necessary), this platform can be "calibrated" and improved to meet the City's needs now and in the future.

In summary, the SurpriseTree™ Wastewater Model was created to assist in establishing a mechanism and an evaluation methodology for the City to perform site-specific evaluations when actual wastewater quality, reclaimed water treatment goals, and other site-specific information is more clearly defined for a given facility. It provides a baseline for technology selection and outlines the general required design criteria and considerations for a specific application in an effort to give the City confidence in their ultimate treatment technology selection. However, it leaves detailed design decisions, facility layouts, and other site-specific decisions to the design engineer to promote more informed and effective decision making.

8.1 Description of SurpriseTree™ Wastewater Model

The SurpriseTree™ Wastewater Model is a Microsoft Excel© spreadsheet program that uses wastewater quality, reclaimed water and biosolids treatment goals, and site-specific considerations to generate and rank treatment technologies based on specified criteria. The SurpriseTree™ Wastewater Model was customized for the City of Surprise wastewater treatment evaluation and focuses on wastewater liquid stream and biosolids treatment processes. A brief step-by-step description of the model is included in the following sections. Appendix B includes a SurpriseTree™ Wastewater Model User's Guide to assist the City in using the model for determining treatment technologies for future WRFs. Note that the screen shots from the model used throughout this Section are for reference only as screens will change based on input parameters. Please refer to the actual model for appropriate screens based on specific input parameters.

8.1.1 Introduction, Instruction Sheets and Tool Bars

Upon opening the SurpriseTree™ Wastewater Model, the initial interface the user sees is the Introduction Sheet. Clicking on the introduction image brings users to the Instruction/Help page. The "help" page is designed for first time users. Definitions of terms and symbols used throughout the model are defined as part of the sheet.

The tool bars across the top of the screen are accessible throughout the SurpriseTree™ Wastewater Model. Placing the mouse cursor over the icons displays the button's function. The user can be redirected to the associated sheet by clicking one of the tool bar options.

When closing out of the SurpriseTree™ Wastewater Model, it is recommended that the user return to the Introduction Sheet and save the associated changes. This will allow the next user to begin with the Introduction Sheet when the file is opened.

8.1.2 Step 1 – General

On the General sheet, the user enters the site-specific information for the facility. The user must enter the facility name, the construction time, location, life cycle, inflation rate, and interest rate. Based on the entered location, Surprise, Arizona, the model automatically identifies the RS Means 300 City Location factor to be 0.89. This factor is used in the model for cost analysis. The entered information for life cycle, inflation rate, and interest rate is also used in the model as part of the cost analysis.

The user can define the end use of the reclaimed water by checking all applicable boxes. These options include recharge, reuse with different classifications (e.g., Class A+, Class B, Class C, etc.), surface water discharge, etc.

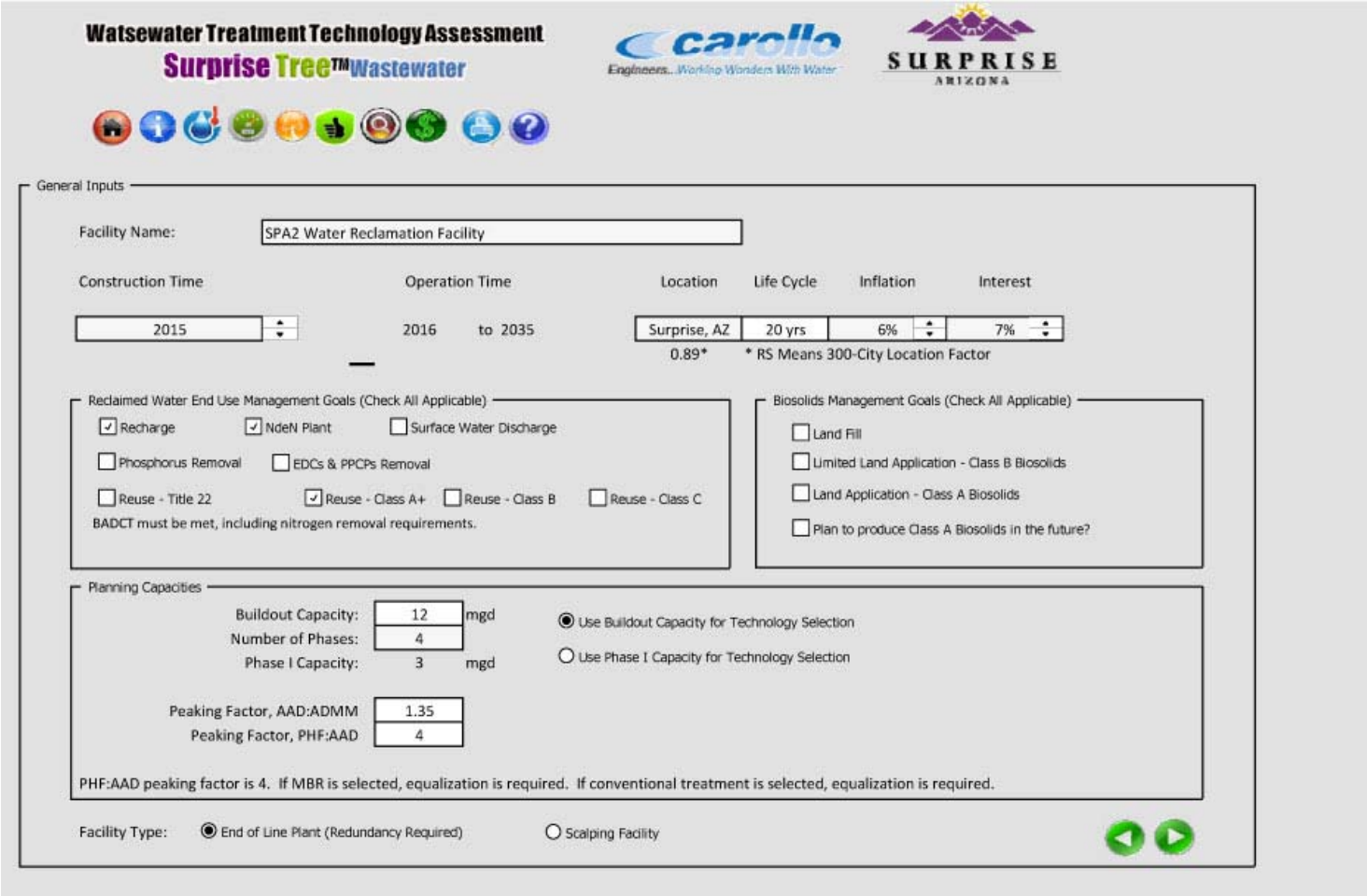
For biosolids, users can choose the intended end use/disposal options for the proposed facility (e.g., landfill, land application with Class A or Class B biosolids, etc.).

Users should check all applicable boxes for both reclaimed water and biosolids. However, the most stringent end use option will drive the treatment evaluation. For example, if both Class A+ and Class B boxes are checked, the treatment evaluation will be based on Class A+ quality. The model will provide design consideration notes addressing the differences associated with the Class B option.

The user will also input the facility build-out size, number of phases, and peaking factors on this page. The program will automatically default to selecting the technology based on the ultimate capacity of the facility. However, the user can choose to use the Phase 1 capacity for technology selection, if desired. A screen shot of the SurpriseTree™ Wastewater Model Input 1 – General is shown in Figure WWT.9.

8.1.3 Step 2 – Wastewater Qualities

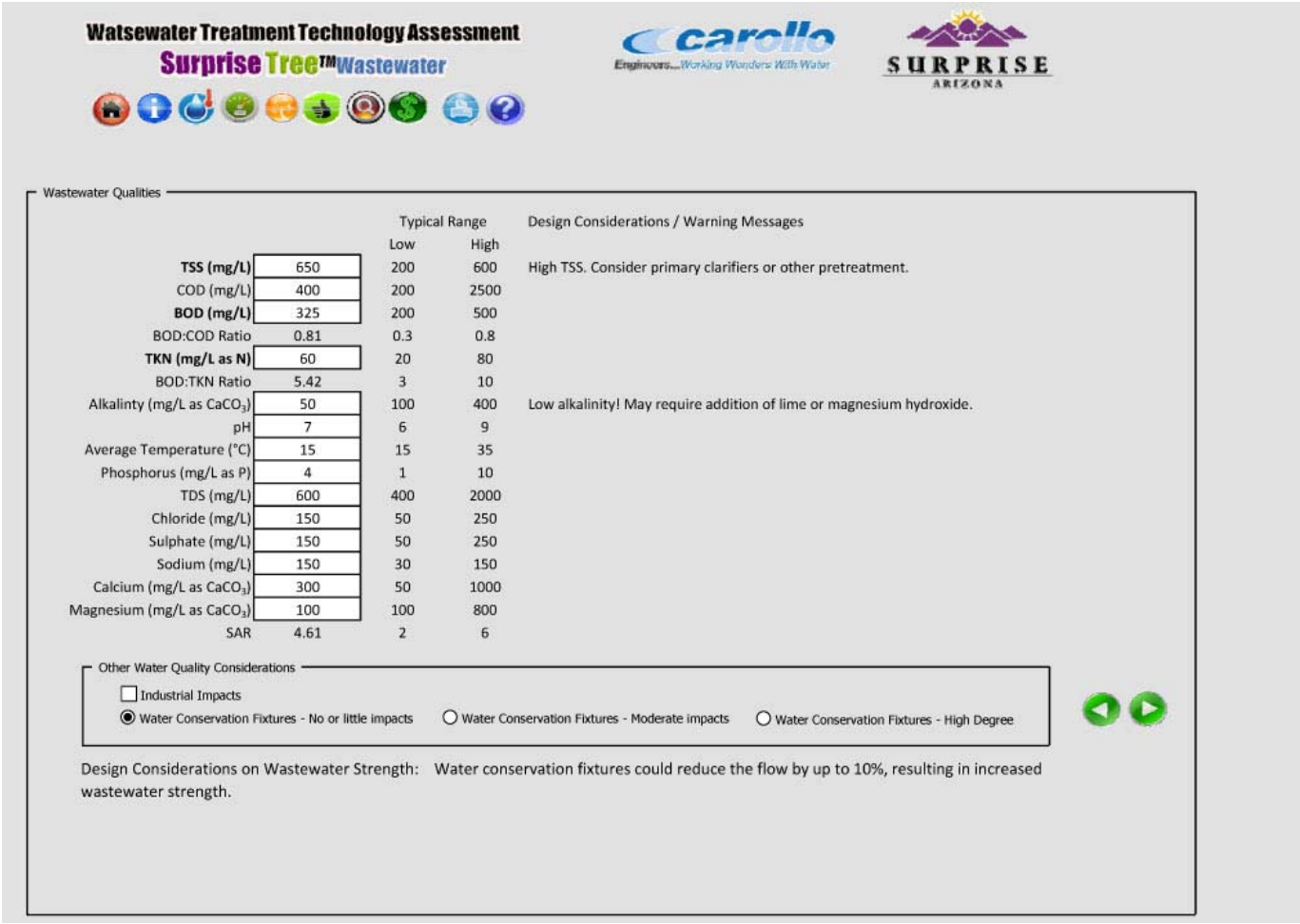
The user should input associated site-specific wastewater quality information as part of this step. Specific wastewater qualities may result in associated warning or consideration messages. The user should carefully read and consider the warning and consideration messages prior to proceeding. By checking the selection box "industrial impacts" or the option buttons for water conservation in the "Other Water Quality Considerations" box on this sheet, the SurpriseTree™ Wastewater Model will automatically generate design notes regarding the wastewater treatability for the designer's consideration. A screen shot of the SurpriseTree™ Wastewater Model Input 2 – Wastewater Qualities is shown in Figure WWT.10.



SURPRISE TREE™ WASTEWATER MODEL STEP 1 - GENERAL

FIGURE WWT.9

CITY OF SURPRISE
WASTEWATER TECHNOLOGY ASSESSMENT REPORT



SURPRISE TREE™ WASTEWATER MODEL
STEP 2 – WASTEWATER QUALITY

FIGURE WWT.10

CITY OF SURPRISE
WASTEWATER TECHNOLOGY ASSESSMENT REPORT

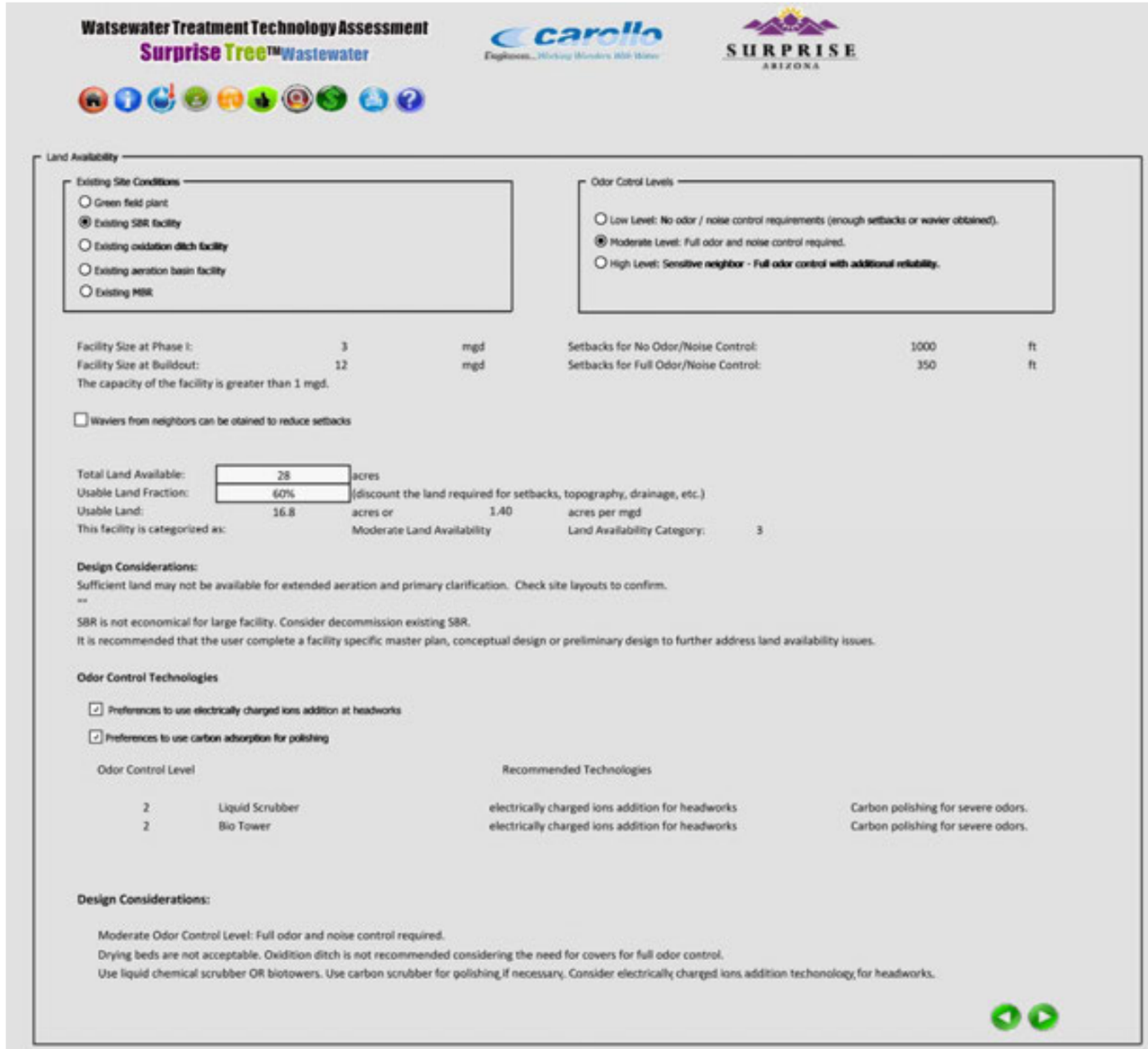
8.1.4 Step 3 – Land and Odor

The land and odor sheet allows the user to input information about the land availability and odor control requirements for the facility. Option buttons are used to define the facility type – a “Greenfield/New” Plant or “Existing Facility” to be abandoned or upgraded. This input is used by the SurpriseTree™ Wastewater Model to generate the proper design considerations and recommendations.

Users can define the required odor control levels for the facility using the option buttons. Available options include “Low Level” (no odor/noise treatment), “Moderate Level” (full odor and noise control required), and “High Level” (full odor control with additional reliability). The SurpriseTree™ Wastewater Model uses this input to generate the proper odor control recommendations. The user has the option to check the preference box to include an electrically charged ion based odor control technology for the headworks and/or carbon for polishing, if desired.

Based on the facility size inputs (in Step 1), the model will summarize the set back requirements for the proposed facility. The model allows the user to adjust the setbacks if the check box “waivers from neighbors can be obtained” is checked.

The user can input the total acreage of the site and a usable land faction in this section. The model will calculate a land availability factor (in acres per mgd) based on the land and the capacity input in Step 1. A facility land availability category will be determined by the model, with recommendations and general tips on treatment technology selection. A screen shot of the SurpriseTree™ Wastewater Model Input 3 – Land and Odor is shown in Figure WWT.11.



Watsewater Treatment Technology Assessment
Surprise Tree™ Wastewater

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Land Availability

Existing Site Conditions
- ○ Green field plant
- ◉ Existing SBR facility
- ○ Existing oxidation ditch facility
- ○ Existing aeration basin facility
- ○ Existing MBR

Odor Control Levels
- ○ Low Level: No odor / noise control requirements (enough setbacks or wavier obtained).
- ◉ Moderate Level: Full odor and noise control required.
- ○ High Level: Sensitive neighbor - Full odor control with additional reliability.

Facility Size at Phase I:	3	mgd	Setbacks for No Odor/Noise Control:	1000	ft
Facility Size at Buildout:	12	mgd	Setbacks for Full Odor/Noise Control:	350	ft

The capacity of the facility is greater than 1 mgd.

☐ Waviers from neighbors can be otained to reduce setbacks

Total Land Available:	28	acres			
Usable Land Fraction:	60%	(discount the land required for setbacks, topography, drainage, etc.)			
Usable Land:	16.8	acres or	1.40	acres per mgd	
This facility is categorized as:		Moderate Land Availability		Land Availability Category:	3

Design Considerations:

Sufficient land may not be available for extended aeration and primary clarification. Check site layouts to confirm.
"
SBR is not economical for large facility. Consider decommission existing SBR.
It is recommended that the user complete a facility specific master plan, conceptual design or preliminary design to further address land availability issues.

Odor Control Technologies

☑ Preferences to use electrically charged ions addition at headworks

☑ Preferences to use carbon adsorption for polishing

Odor Control Level		Recommended Technologies	
2	Liquid Scrubber	electrically charged ions addition for headworks	Carbon polishing for severe odors.
2	Bio Tower	electrically charged ions addition for headworks	Carbon polishing for severe odors.

Design Considerations:

Moderate Odor Control Level: Full odor and noise control required.
Drying beds are not acceptable. Oxidition ditch is not recommended considering the need for covers for full odor control.
Use liquid chemical scrubber OR biotowers. Use carbon scrubber for golishing if necessary. Consider electrically charged ions addition techonology for headworks.

SURPRISE TREE™ WASTEWATER MODEL
STEP 3 – LAND AND ODOR

FIGURE WWT.11

CITY OF SURPRISE
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8.1.5 Step 4 – Decision Making

In general, the two most important factors in the evaluation/selection of a technology are 1) The effectiveness and reliability of the technology alternative in removing the target CoC and 2) The cost effectiveness (capital and O&M) of the alternative in achieving the City's water quality standards. As outlined in Section 6.3, the Wastewater Technology Assessment was designed to address a full spectrum of evaluation factors while providing the flexibility to emphasize treatment performance and cost effectiveness, through the use of a three-tire evaluation:

- Implementation based evaluation using a comprehensive set of criteria including capital and O&M costs, technology effectiveness, operability, implementability, and to a lesser extent, the environmental, economic, and social aspects. This set of criteria and weighting factors was developed by the City and the developer representatives.
- Performance based evaluation emphasizing technical feasibility and removal efficiency of target CoCs. This evaluation was developed by the engineer and serves as an optional evaluation to supplement the primary implementation based criteria set by the City and the developer representatives.
- Financial analysis using order-of-magnitude level capital, O&M and life cycle costs. Because the implementation-based evaluation covers qualitative capital and O&M costs, this tier of evaluation can be considered as supplementary information to provide more accurate quantitative cost information.

Using the implementation and performance criteria, each treatment alternative included for further evaluation in the SurpriseTree™ Wastewater Model was ranked on a 0 to 10 scale, with 0 representing the least favorable / effective and the 10 representing the most favorable / effective. The ranking scores were developed by the Engineer based on the qualitative descriptions presented in the series of two tables at the end of each subsection of Section 6.0 (for example, Table WWT.25 for Performance Based Evaluation and Table WWT.26 for Implementation Evaluation). The City's inputs are incorporated. Users can easily make changes to these scores at any time when running the analysis. The user can also perform a sensitivity analysis by changing the water quality inputs and comparing the recommendations. The ranking scores are presented in Figure WWT.12 and displayed on the "All Options" sheet in the model.

Category	Unit Operations	Recom-mendation	Normalized Unit Capital Cost Factor	Normalized Unit O&M Cost Factor	Normalized Life Cycle Cost Factor	Unit Capital Costs ($/gpd)	Relative Unit O&M Costs ($/gal)	Simple Life Cycle ($/gal)	Normalized Performance Total	Performance Total	TSS Removal	BOD Removal	N-DeN	Turbidity	Pathogen	DBP	Volatile Solids Reduction	BS Pathogen	BS Volume Reduction	H2S Odor	Ammonia Odor	Reduced Sulfides Odor
Preliminary	Criterion Weight (CRW)	100	100	100	100				100	72	10	10	10	10	10	10	2	2	2	2	2	2
Preliminary	CoarseScrn(6mm)	95	100	100	100	0.103	0.031	0.043	38.9	70	5	2	0	0	0	0	0	0	0	0	0	0
Preliminary	StepScrn(3mm)	100	50	38	41	0.207	0.083	0.104	72.2	130	8	3	1	1	0	0	0	0	0	0	0	0
Preliminary	RotaryScrn(3mm)	92	42	25	29	0.248	0.124	0.148	83.3	150	9	4	1	1	0	0	0	0	0	0	0	0
Preliminary	FineScrn(2mm)	84	28	12	15	0.372	0.261	0.290	100.0	180	10	4	2	2	0	0	0	0	0	0	0	0
Grit	Criterion Weight (CRW)	100	100	100	100				100	72	10	10	10	10	10	10	2	2	2	2	2	2
Grit	M-VorGrit	100	80	96	92	0.099	0.050	0.059	100.0	170	8	7	1	1	0	0	0	0	0	0	0	0
Grit	FreeVorGrit	95	50	100	83	0.159	0.048	0.066	100.0	170	8	7	1	1	0	0	0	0	0	0	0	0
Grit	Aerated Grit	88	100	100	100	0.080	0.048	0.055	76.5	130	5	6	1	1	0	0	0	0	0	0	0	0
Primary	Criterion Weight (CRW)	100	100	100	100				100	72	10	10	10	10	10	10	2	2	2	2	2	2
Primary	NoPriClari	100	0	0	0	0.000	0.000	0.000	66.7	140	5	3	3	3	0	0	0	0	0	0	0	0
Primary	PriClari	80	0	0	0	0.410	0.410	0.432	100.0	210	10	5	3	3	0	0	0	0	0	0	0	0
BOD and N-DeN	Criterion Weight (CRW)	100	100	100	100				100	72	10	10	10	10	10	10	2	2	2	2	2	2
BOD and N-DeN	Extended Aeration	87	100	100	100	2.038	2.853	2.893	69.1	380	8	9	9	5	2	5	0	0	0	0	0	0
BOD and N-DeN	Aeration Basin	98	70	49	51	2.891	5.782	5.692	69.1	380	7	9	10	5	2	5	0	0	0	0	0	0
BOD and N-DeN	MBR	100	59	37	39	3.469	7.632	7.466	100.0	550	10	10	9	10	10	6	0	0	0	0	0	0
BOD and N-DeN	Trickling Filters	82	88	77	78	2.313	3.701	3.707	56.4	310	4	8	8	5	1	5	0	0	0	0	0	0
BOD and N-DeN	IFAS	82	64	41	42	3.180	6.996	6.844	63.6	350	5	9	9	5	2	5	0	0	0	0	0	0
BOD and N-DeN	SBR	85	39	32	33	5.204	8.847	8.816	61.8	340	6	8	8	5	2	5	0	0	0	0	0	0
Clarification	Criterion Weight (CRW)	100	100	100	100				100	72	10	10	10	10	10	10	2	2	2	2	2	2
Clarification	Clarification	100	100	100	100	1.311	1.443	1.501	79.4	300	7	6	6	7	2	2	0	0	0	0	0	0
Clarification	DAF	89	91	83	84	1.443	1.731	1.783	100.0	378	9	8	8	9	2	2	0	0	-1	0	0	0
Clarification	Actiflow	88	77	60	62	1.705	2.387	2.420	89.4	338	8	7	7	8	2	2	0	0	-1	0	0	0
Clarification	NoClarifier																					
Filtration	Criterion Weight (CRW)	100	100	100	100				100	72	10	10	10	10	10	10	2	2	2	2	2	2
Filtration	Disk Filters	100	94	94	94	0.836	0.501	0.574	100.0	390	8	5	5	8	8	5	0	0	0	0	0	0
Filtration	Dyna Sand	92	100	100	100	0.782	0.469	0.537	89.7	350	6	5	5	6	8	5	0	0	0	0	0	0
Filtration	Traveling Bridge	93	91	91	91	0.861	0.516	0.591	94.9	370	7	5	5	7	8	5	0	0	0	0	0	0
Filtration	Conv Sand	88	100	100	100	0.782	0.469	0.537	94.9	370	7	5	5	7	8	5	0	0	0	0	0	0
Filtration	MFUF	85	42	25	27	1.865	1.865	1.964	120.5	470	10	6	5	10	10	6	0	0	0	0	0	0
Filtration	No Filter																					
Disinfection	Criterion Weight (CRW)	100	100	100	100				100	72	10	10	10	10	10	10	2	2	2	2	2	2
Disinfection	UV	100	39	52	48	0.864	0.259	0.356	100.0	190	0	0	0	0	10	9	0	0	0	0	0	0
Disinfection	Sodium Hypo Bulk	97	70	46	51	0.486	0.292	0.334	57.9	110	0	0	0	0	9	2	0	0	0	0	0	0
Disinfection	Sodium Hypo Onsite	90	46	61	56	0.743	0.223	0.306	63.2	120	0	0	0	0	9	3	0	0	0	0	0	0
Disinfection	Gas Chlorine	65	100	100	100	0.339	0.135	0.170	63.2	120	0	0	0	0	9	3	0	0	0	0	0	0
Disinfection	Ozone+Hypo	80	33	44	40	1.036	0.311	0.427	89.5	170	0	0	0	0	9	8	0	0	0	0	0	0
Odor	Criterion Weight (CRW)	100	100	100	100				100	30	0	0	0	0	0	0	0	0	0	10	10	10
Odor	E-Ion Charged	100	21	70	61	0.439	0.263	0.302	100.0	270	0	0	0	0	0	0	0	0	0	9	9	9
Odor	Chemical Add	74	100	100	100	0.093	0.186	0.183	48.1	130	0	0	0	0	0	0	0	0	0	5	5	3
Odor	Liquid Scrubber	78	25	72	64	0.366	0.256	0.285	92.6	250	0	0	0	0	0	0	0	0	0	9	9	7
Odor	Bio Tower	75	20	79	66	0.469	0.234	0.279	81.5	220	0	0	0	0	0	0	0	0	0	9	5	8
Odor	Bio Filter	71	22	87	72	0.426	0.213	0.254	81.5	220	0	0	0	0	0	0	0	0	0	9	5	8
Odor	Carbon Adsorp	84	25	51	47	0.366	0.366	0.385	81.5	220	0	0	0	0	0	0	0	0	0	9	5	8
Thickening	Criterion Weight (CRW)	100	100	100	100				100	30	2	4	5	2	0	0	0	0	5	4	4	4
Thickening	Gravity Thickening	96	100	100	100	0.514	0.257	0.306	57.1	20	0	0	0	0	0	0	0	0	4	0	0	0
Thickening	DAF Thickening	95	80	50	55	0.642	0.514	0.559	71.4	25	0	0	0	0	0	0	0	0	5	0	0	0
Thickening	Gravity Belt	96	67	42	46	0.771	0.617	0.670	100.0	35	0	0	0	0	0	0	0	0	7	0	0	0
Thickening	RTD	97	50	25	28	1.028	1.028	1.082	100.0	35	0	0	0	0	0	0	0	0	7	0	0	0
Thickening	Centrifuge Thickening	100	40	13	15	1.284	2.055	2.058	100.0	35	0	0	0	0	0	0	0	0	7	0	0	0
Stabilization	Criterion Weight (CRW)	100	100	100	100				100	30	2	4	5	2	0	0	0	0	5	4	4	4
Stabilization	Multiphase	100	63	58	59	1.589	2.384	2.401	100.0	119	0	0	0	0	0	0	7	7	7	7	7	7
Stabilization	Lagoon	78	100	100	100	0.996	1.394	1.413	14.3	17	0	0	0	0	0	0	1	1	1	1	1	1
Stabilization	ConvAnaerobic	89	75	70	71	1.324	1.986	2.001	71.4	85	0	0	0	0	0	0	5	5	5	5	5	5
Stabilization	TempPhase	85	54	48	48	1.827	2.924	2.929	85.7	102	0	0	0	0	0	0	6	6	6	6	6	6
Stabilization	Aerboic	80	80	56	58	1.245	2.490	2.451	42.9	51	0	0	0	0	0	0	3	3	3	3	3	3
Stabilization	ATAD2	77	48	34	35	2.075	4.149	4.085	57.1	68	0	0	0	0	0	0	4	4	4	4	4	4
Dewatering	Criterion Weight (CRW)	100	100	100	100				100	30	2	4	5	2	0	0	0	0	5	4	4	4
Dewatering	DryingBeds	93	100	100	100	0.385	0.771	0.759	62.5	25	0	0	0	0	0	0	0	0	5	0	0	0
Dewatering	BeltPress	100	38	47	46	1.028	1.644	1.647	87.5	35	0	0	0	0	0	0	0	0	7	0	0	0
Dewatering	Centrifuge_Dewatering	100	30	38	37	1.284	2.055	2.058	100.0	40	0	0	0	0	0	0	0	0	8	0	0	0
Advanced BS	Criterion Weight (CRW)	100	100	100	100				100	30	2	4	5	2	0	0	0	0	5	4	4	4
Advanced BS	NoAdvBS	100	100	100	100	0.000	0.000	0.000	55.6	25	0	0	0	0	0	0	5	5	5	0	0	0
Advanced BS	AirDrying	77	80	80	80	0.887	0.887	0.934	66.7	30	0	0	0	0	0	0	6	6	6	0	0	0
Advanced BS	Composting	80	77	43	45	1.153	2.075	2.058	77.8	35	0	0	0	0	0	0	7	7	7	0	0	0
Advanced BS	SolarAirDrying	80	29	24	25	3.073	3.688	3.799	66.7	30	0	0	0	0	0	0	6	6	6	0	0	0
Advanced BS	HeatDrying	76	23	12	13	3.783	7.565	7.448	88.9	40	0	0	0	0	0	0	8	8	8	0	0	0
Advanced BS	Incineration	56	13	6	7	6.915	13.831	13.616	100.0	45	0	0	0	0	0	0	10	10	9	0	0	0

SURPRISE TREE™ WASTEWATER MODEL ALL OPTIONS TREATMENT PROCESS RANKING TABLE

FIGURE WWT.12-A

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WASTEWATER TECHNOLOGY ASSESSMENT REPORT

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Category	Unit Operations	Normalized Implementation Total	Implementation Total	O&M Costs	Capital Costs	Process Reliabilities	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Footprint	Regulatory	Safety	Residuals	Versatility	Expandability	Odor	Energy Saving	Class A Biosolids	Air Quality
Preliminary	Criterion Weight (CRW)	100	111.5	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	5.7	5.6	7.1	6.6	7.2	6.6	6.3	6.5	0.0	6.0
Preliminary	CoarseScrn(6mm)	94.5	963	8	8	5	7	7	7	4	8	5	4	5	7	5	5	5	6	0	5
Preliminary	StepScrn(3mm)	100.0	702	5	5	8	8	8	8	9	8	9	5	5	4	8	9	9	3	0	5
Preliminary	RotaryScrn(3mm)	92.4	949	4	4	7	9	9	9	8	8	9	6	5	5	7	9	7	3	0	5
Preliminary	FineScrn(2mm)	83.9	568	3	3	8	5	5	4	9	5	9	6	5	4	8	9	7	5	0	5
Grit	Criterion Weight (CRW)	100	111.5	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	5.7	5.6	7.1	6.6	7.2	6.6	6.3	6.5	0.0	6.0
Grit	M-vorGrit	100.0	948	7	9	7	8	7	9	7	5	5	5	5	5	8	8	5	5	0	5
Grit	FreevorGrit	95.3	918	8	3	8	4	9	7	7	5	5	5	5	5	9	9	5	6	0	5
Grit	Aerated Grit	86.3	872	3	6	8	7	9	8	6	6	5	5	5	5	8	8	5	5	0	4
Primary	Criterion Weight (CRW)	100	111.5	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	5.7	5.6	7.1	6.6	7.2	6.6	6.3	6.5	0.0	6.0
Primary	NoPreClari	100.0	719	10	10	0	5	5	10	5	10	10	5	5	3	5	5	5	10	0	5
Primary	PreClari	80.7	578	3	3	7	5	5	5	10	5	3	6	5	3	7	5	4	3	0	5
BOD and N-Defn	Criterion Weight (CRW)	100	111.5	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	5.7	5.6	7.1	6.6	7.2	6.6	6.3	6.5	0.0	6.0
BOD and N-Defn	Extended Aeration	87.4	646	4	3	7	8	9	8	7	8	3	8	7	5	8	2	4	8	0	4
BOD and N-Defn	Aeration Basin	98.0	724	5	5	8	9	7	7	8	7	7	8	7	5	8	7	5	4	0	5
BOD and N-Defn	MBR	100.0	739	4	6	9	9	6	4	10	4	10	9	6	5	9	10	5	4	0	5
BOD and N-Defn	Trickling Filters	82.0	606	7	6	4	8	5	6	5	6	6	5	5	5	5	8	3	6	0	4
BOD and N-Defn	IFAS	81.8	605	5	4	5	9	3	6	6	6	7	6	6	5	6	6	5	5	0	5
BOD and N-Defn	SBR	84.7	626	3	3	4	8	7	8	6	7	5	6	7	5	7	7	5	5	0	5
Clarification	Criterion Weight (CRW)	100	111.5	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	5.7	5.6	7.1	6.6	7.2	6.6	6.3	6.5	0.0	6.0
Clarification	Clarification	100.0	679	8	8	6	9	7	6	6	6	5	5	5	5	5	5	5	5	0	5
Clarification	DAF	89.3	606	5	5	8	6	4	4	7	5	7	5	5	6	6	5	5	3	0	5
Clarification	Actiflow	88.2	598	4	4	9	5	4	4	7	4	9	5	5	7	6	5	5	3	0	5
Clarification	NoClarifier																				
Filtration	Criterion Weight (CRW)	100	111.5	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	5.7	5.6	7.1	6.6	7.2	6.6	6.3	6.5	0.0	6.0
Filtration	Disk Filters	100.0	735	4	6	8	8	7	7	7	7	8	8	7	7	7	6	5	6	0	5
Filtration	Dyna Sand	92.4	680	6	7	5	8	7	6	8	6	5	5	5	7	6	5	4	7	0	5
Filtration	Traveling Bridge	92.9	683	5	5	8	7	7	6	8	6	5	7	5	7	6	5	5	6	0	5
Filtration	Conv Sand	88.2	649	5	5	5	8	7	6	8	6	4	5	5	7	6	5	4	7	0	5
Filtration	MFUF	83.5	615	1	1	10	7	5	4	5	5	9	9	6	5	8	7	8	4	0	5
Filtration	No Filter																				
Disinfection	Criterion Weight (CRW)	100	111.5	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	5.7	5.6	7.1	6.6	7.2	6.6	6.3	6.5	0.0	6.0
Disinfection	UV	100.0	679	4	4	5	8	5	6	8	6	7	9	6	5	8	5	5	4	0	7
Disinfection	Sodium Hypo Bulk	96.6	653	5	7	9	9	5	8	5	8	5	4	4	5	3	8	5	5	0	4
Disinfection	Sodium Hypo Onsite	90.0	609	5	5	7	8	5	6	6	6	5	5	7	4	3	8	5	4	0	4
Disinfection	Gas Chlorine	65.3	441	9	9	6	9	1	1	1	5	3	0	0	4	2	1	5	7	0	2
Disinfection	Ozone+Hypo	79.8	540	3	3	9	2	1	3	9	3	8	9	3	9	9	8	5	4	0	7
Odor	Criterion Weight (CRW)	100	107.3	8.4	7.8	8.1	6.9	3.8	6.1	6.6	4.6	5.3	4.9	7.1	6.8	6.8	6.3	5.5	6.5	0.0	6.0
Odor	E-Ion Charged	100.0	712	7	7	8	9	9	7	8	4	8	5	5	8	8	8	5	5	5	5
Odor	Chemical Add	74.4	530	4	9	3	8	5	5	4	8	7	5	3	3	3	3	4	8	6	3
Odor	Liquid Scrubber	77.8	554	5	6	6	8	5	5	7	5	4	4	2	4	5	6	5	5	5	5
Odor	Bio Tower	74.9	534	6	6	4	6	5	3	4	6	3	7	5	7	5	4	3	7	5	3
Odor	Bio Filter	71.4	509	5	5	4	8	3	3	4	8	1	7	5	7	5	3	3	7	5	3
Odor	Carbon Adsorp	83.8	597	5	7	4	7	5	8	6	8	5	6	5	6	4	7	4	6	5	4
Thickening	Criterion Weight (CRW)	100	107.3	8.4	7.8	8.1	6.9	3.8	6.1	6.6	4.6	5.3	4.9	7.1	6.8	6.8	6.3	5.5	6.5	0.0	6.0
Thickening	Gravity Thickening	65.7	468	6	6	6	7	7	6	5	8	2	5	5	6	5	3	4	7	5	5
Thickening	DAF Thickening	94.6	681	6	6	6	7	7	6	3	8	2	9	5	6	5	3	4	6	3	3
Thickening	Gravity Belt	96.5	693	5	5	7	7	7	5	5	9	5	5	5	9	8	9	4	5	6	5
Thickening	RTO	87.2	626	4	4	8	7	7	4	6	5	5	5	5	7	8	6	7	4	7	5
Thickening	Centrifuge Thickening	100.0	718	2	3	9	7	7	3	8	4	5	5	5	8	8	7	8	3	8	5
Stabilization	Criterion Weight (CRW)	100	107.3	8.4	7.8	8.1	6.9	3.8	6.1	6.6	4.6	5.3	4.9	7.1	6.8	6.8	6.3	5.5	6.5	0.0	6.0
Stabilization	MultiPhase	100.0	637	6	5	8	7	3	4	8	5	8	8	4	2	9	8	7	8	8	3
Stabilization	Lagoon	77.8	511	8	9	4	9	3	7	5	8	1	4	5	3	4	2	1	3	1	4
Stabilization	ConvAnaerobic	89.3	589	5	6	7	8	3	4	6	5	5	5	4	3	7	4	5	6	6	3
Stabilization	TempPhase	85.3	560	5	5	7	4	1	3	8	5	7	8	4	8	7	5	5	7	6	3
Stabilization	Aerbic	79.8	524	4	5	4	8	8	6	4	6	3	5	5	8	8	4	3	2	3	4
Stabilization	ATAD	77.4	508	5	5	4	4	8	5	4	6	4	5	5	8	8	5	4	2	7	4
Dewatering	Criterion Weight (CRW)	100	107.3	8.4	7.8	8.1	6.9	3.8	6.1	6.6	4.6	5.3	4.9	7.1	6.8	6.8	6.3	5.5	6.5	0.0	6.0
Dewatering	DryingBeds	93.4	613	8	9	4	9	5	8	8	8	3	4	5	4	3	3	2	8	6	4
Dewatering	BeltPress	100.0	657	5	5	8	9	5	5	6	6	7	6	5	7	7	7	5	4	7	6
Dewatering	CentrifUge_Dewatering	105.6	627	4	4	9	9	5	3	5	3	8	9	5	9	8	9	8	3	8	7
Advanced BS	Criterion Weight (CRW)	100	107.3	8.4	7.8	8.1	6.9	3.8	6.1	6.6	4.6	5.3	4.9	7.1	6.8	6.8	6.3	5.5	6.5	0.0	6.0
Advanced BS	NoAdvBS	100.0	657	10	10	0	5	5	10	5	10	10	5	5	5	0	10	5	10	5	5
Advanced BS	AirDrying	77.2	530	6	5	4	4	3	5	5	7	3	5	5	7	4	4	4	6	5	5
Advanced BS	Composting	79.7	548	5	5	8	8	4	4	4	7	3	5	5	8	8	4	5	5	5	5
Advanced BS	SolarAirDrying	79.8	548	7	7	4	4	3	5	5	8	3	5	5	7	4	4	4	7	5	5
Advanced BS	HeatDrying	79.5	525	4	4	7	3	3	6	6	4	5	9	5	6	5	8	5	4	5	5
Advanced BS	Incineration	55.7	382	2	2	3	3	1	3	4	2	8	6	3	9	5	5	7	3	5	8

SURPRISE TREE™ WASTEWATER MODEL ALL OPTIONS TREATMENT PROCESS RANKING TABLE

FIGURE WWT.12-B

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WASTEWATER TECHNOLOGY ASSESSMENT REPORT

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The implementation-based criteria, which were developed by the City and the developer representatives, were defined in Table WWT.23. Nine individuals (City and developer) participated in assigning weighting factors for these criteria. The averaged weighting factors were used for the final ranking evaluation as presented in Table WWT.52. It should be noted that the SurpriseTree™ Wastewater Model adjusts some weighting factors automatically using site-specific inputs entered by the user. For example, the weighting factor for footprint is adjusted using the land availability category. The more land available, the lower the weighting for footprint becomes. Similarly for biosolids, if the user input indicates that Class A biosolids are not required currently or in the future, the weighting factor for the associated category will be adjusted to zero.

Table WWT.52 Treatment Process Implementation Based Weighting Criteria as Assigned by City of Surprise and Developer Representatives Wastewater Technology Assessment Report City of Surprise

Process Screening Criteria	Liquid Stream	Odor	Biosolids
O&M costs	8.4	8.4	8.4
Capital costs	8.6	7.8	7.8
Process robustness	8.3	8.1	8.1
Maturity of technology	6.8	6.9	6.9
City of Surprise familiarity	3.7	3.8	3.8
Maintenance intensity	6.3	6.1	6.1
Operation flexibility	7.1	6.6	6.6
System complexity	4.8	4.6	4.6
Footprint	4.6 (1)	4.3 (1)	4.3 (1)
Regulatory	5.6	4.9	4.9
Risks and safety	7.1	7.1	7.1
Residuals	6.6	6.8	6.8
Versatility	7.2	6.8	6.8
Expandability/ultimate capacity	6.6	6.3	6.3
Odor	6.3	5.5	5.5
Energy saving	6.5	6.5	6.5
Class A biosolids	0	0	0 (2)
Air quality impacts	6.0	6.0	6.0

Notes:
(1) When land availability category = 2, Reasonable Land Availability
(2) When Class A biosolids is not selected.

In the SurpriseTree™ Wastewater Model, the user can place the mouse cursor over each criterion to display a definition of the associated criterion. As a supplemental evaluation focusing on technology performance, the performance based criteria evaluation is more flexible than the implementation based evaluation. The user is allowed to adjust these weighting factors. However, because developing and updating these factors requires a reasonable technical background and engineering judgment, the default (which can be reset by clicking the reset button) should be used unless the user has a specific knowledge or understanding of the associated treatment technologies.

The SurpriseTree™ Wastewater Model calculates the ranking scores using the following procedures:

- Implementation Scores for Each Technology Alternative (e.g., MBR):
  - Total Implementation Score for a technology alternative (e.g., MBR) is the weighted average (summation of the products) of the score for each alternative (e.g., MBR) for a given criterion (e.g., Footprint or Expandability) and the corresponding Weighting factor for the given criterion (e.g., 4.6 or 6.5).
  - The Total Implementation score is then normalized to 100 by multiplying by 100 and dividing by the maximum Total Implementation Score for a technology alternative (e.g., MBR) in its category (e.g., biological treatment).
  - The higher the score, the better a technology alternative is based on this comprehensive evaluation.
- Performance Scores for Each Technology Alternative (e.g., MBR):
  - Total Performance Score for a technology alternative (e.g., MBR) is the weighted average (summation of the products) of the score for each alternative (e.g., MBR) for a given criterion (e.g., BOD Removal or TSS Removal) and the corresponding Weighting factor for the given criterion (e.g., 10 or 0).
  - The Total Performance score is then normalized to 100 by multiplying by 100 and dividing by the maximum Total Implementation Score for a technology alternative (e.g., MBR) in its category (e.g., biological treatment).
  - The higher the score, the better a technology alternative is considering its performance / effectiveness in removing the target CoCs for the specific wastewater.
- Financial Scores for Each Technology Alternative:
  - Relative Capital Costs ($/gpd), O&M Costs and Life Cycle Costs ($/gal) are estimated for each alternative for the purpose of comparison.
  - The cost score is a normalized score on a 100 scale, with the least expensive alternative being 100.
  - The higher the score, the less expensive the alternative is.

- Overall Scores for Each Technology Alternative
  - The Overall Score for a technology alternative (e.g., MBR) is the weighted average (summation of the products) of the Implementation score, the Performance score, and the Capital, O&M, and Life Cycle scores for each alternative (e.g., MBR) with consideration for the corresponding slide bar setting for the given score.
  - The Overall Score is then normalized to 100 by multiplying by 100 and dividing by the maximum Overall Score for a technology alternative (e.g., MBR) in its category (e.g., biological treatment).
  - The higher the overall score, the better a technology alternative is considering its performance / effectiveness / cost in removing the target CoCs for the specific wastewater.

As illustrated in Figure WWT.13, the decision input sheet provides a quick, visual adjustment of the significance of the decision-making factors using scale bars. As the primary evaluation of the three tiers, the implementation-based evaluation can be used as a stand-alone analysis. This can be achieved by setting the scale bars for performance and capital and O&M and life cycle costs at 0 and the bar for implementation at 100. If the decision maker considers extra weighting for performance or cost effectiveness, adjustment can be made by dragging these bars accordingly. Normalized to 100, the final scores are weighted averages of:

- The normalized implementation score times the implementation scale bar setting
- The normalized performance score times the performance scale bar setting
- The capital, O&M, and life cycle costs times the scale bar settings for each costs

The higher the final score is, the better an alternative is ranked.

8.1.6 Detailed Process Ranking Sheets

The SurpriseTree™ Wastewater Model Technology Assessment Tool provides recommendations on the top treatment options for a given set of inputs (site conditions, desired reclaimed water and biosolids qualities, weighting factors, etc.). The top treatment options are recommended for further consideration. Before implementing an option, a preliminary design based on actual wastewater quality, site-specific conditions, and temporal market conditions is recommended. This will provide opportunities for process optimization and cost reduction.

The SurpriseTree™ Wastewater Model also provides more detailed results on each treatment category, such as screens, grit removal, biological treatment, disinfection, etc. These sheets can be accessed by selecting the associated workbook within the model file.

Water Treatment Technology Assessment

Groundwater Supply Treatment Evaluation

Surprise Tree™

Capital Costs		0%
O&M Costs		0%
Life Cycle Costs		0%

Performance		0%
Implemention		100%

	TSS Removal	BOD Removal	N-DeN	Turbidity	Pathogen	DBP
Liquid Stream	**10**	**10**	**10**	**10**	**10**	**10**
Odor Control	0	0	0	0	0	0
Biosolids	2	4	5	2	0	0

	Volatile Solids Reduction	Biosolids Pathogen	Biosolids Volume Reduction	H2S Odor	Ammonia Odor	Reduced Sulfides Odor
Liquid Stream	2	2	2	2	2	2
Odor Control	0	0	0	**10**	**10**	**10**
Biosolids	**0**	**0**	**5**	4	4	4

	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Familiarity	Maintenance Intensity	Operation Flexibility	System Complexity	Footprint
Liquid Stream	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	**5.7**
Odor	8.4	7.8	8.1	6.9	3.8	6.1	6.6	4.6	**5.3**
Biosolids	8.4	7.8	8.1	6.9	3.8	6.1	6.6	4.6	**5.3**

	Regulatory	Safety	Residuals & Biosolids	Versatility	Expandability	Odor	Energy Saving	Class A Biosolids	Air Quality
Liquid Stream	5.6	7.1	6.6	7.2	6.6	6.3	6.5	0.0	6.0
Odor	4.9	7.1	6.8	6.8	6.3	5.5	6.5	0.0	6.0
Biosolids	4.9	7.1	6.8	6.8	6.3	5.5	6.5	**0.0**	6.0

SURPRISE TREE™ WASTEWATER MODEL STEP 4 – DECISION MAKING

FIGURE WWT.13

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WASTEWATER TECHNOLOGY ASSESSMENT REPORT

A sensitivity analysis of the treatment option ranking can be performed by adjusting the slide bar and the weighting factors in Step 4 – Decision Making. The SurpriseTree™ Wastewater Model will recalculate the treatment option ranking when the “Update” button is clicked.

The hyperlinks for the recommended technologies will allow the user to quickly access the implementation package. Implementation packages include basis of design, process flow diagrams, and design consideration lists for the associated technology.

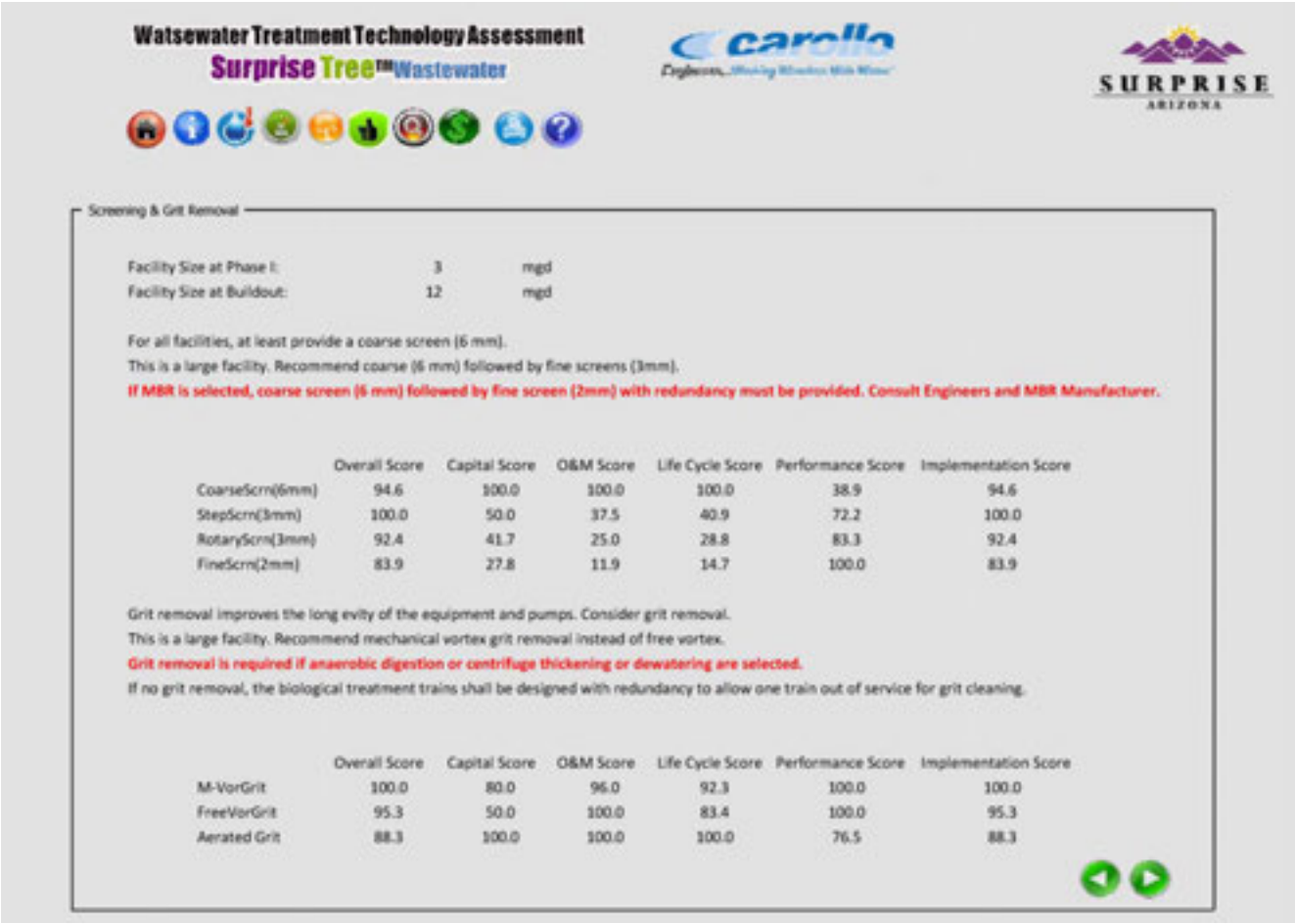
The detailed process ranking sheets summarize the model outputs associated with the recommended treatment category (i.e., screening and grit removal, primary clarifiers, disinfection, etc.). The summary includes the overall score, capital score, O&M score, life cycle score, performance score, and implementation score for a given technology. It also generates design consideration notes related to the treatment category processes based on the user input decision making settings.

An example screen shot of the SurpriseTree™ Wastewater Model Detailed Process Ranking is shown in Figure WWT.14 - Screening and Grit Removal Detailed Process Ranking. For detailed process ranking information for other treatment categories refer to the SurpriseTree™ Wastewater Model.

One of the Detailed Process Ranking sheets contains recharge methods. Many recharge methods can be used to add reclaimed water to a groundwater aquifer. These methods include surface spreading via recharge basins or alluvial infiltration and direct injection using vadose zone recharge well or aquifer storage and recovery well. The choice of recharge method depends on many factors. The Water and Wastewater Facility Guidelines provided basic design criteria for recharge methods. However, it is NOT technically feasible to capture such level of complexity using a planning level tool such as the SurpriseTree™ Wastewater Model without site-specific information and hydrogeological data. Site-specific geological data, percolation testing, water quality analyses and modeling, pilot testing, and groundwater modeling may be required to assist the selection of the appropriate methods. Land costs, distribution system configuration, location of existing recharge facilities and production wells, and public inputs must all be taken into consideration. Conducting site-specific master planning and preliminary design is required.

8.1.7 Train Generator

The SurpriseTree™ Wastewater Model train generator lists the top treatment technology options for each treatment category (i.e., preliminary treatment, grit removal, primary treatment, BOD and N-deN, etc). The technology options available in the model represent those that passed the prescreening evaluation in the Wastewater Technology Assessment Report. A total of 82,944 trains can be assembled for a given scenario, considering each of the options available for each treatment category.



	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
CoarseScrn(6mm)	94.6	100.0	100.0	100.0	38.9	94.6
StepScrn(3mm)	100.0	50.0	37.5	40.9	72.2	100.0
RotaryScrn(3mm)	92.4	41.7	25.0	28.8	83.3	92.4
FineScrn(2mm)	83.9	27.8	11.9	14.7	100.0	83.9

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
M-VorGrit	100.0	80.0	96.0	92.3	100.0	100.0
FreeVorGrit	95.3	50.0	100.0	83.4	100.0	95.3
Aerated Grit	88.3	100.0	100.0	100.0	76.5	88.3

SURPRISE TREE™ WASTEWATER MODEL SCREENING AND GRIT REMOVAL DETAILED PROCESS RANKING

FIGURE WWT.14

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WASTEWATER TECHNOLOGY ASSESSMENT REPORT

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The SurpriseTree™ Wastewater Model determines the optimal treatment trains through a combination of user inputs (associated with four primary treatment options) and the rules and programs built into the SurpriseTree™ Wastewater Model. The required user inputs specific to the four primary treatment options are:

- Is grit removal preferred or required?
- Is primary clarification preferred?
- Are both MBR and non-MBR trains acceptable?
- Is UV the preferred disinfection method?

The user can utilize the drag down menu to select the preferred options, then click on the "Train Generator" button. The SurpriseTree™ Wastewater Model will calculate the treatment trains for the given set of inputs, taking into consideration the land availability, the wastewater quality, and the intended reclaimed water and biosolids end use/disposal options.

A list of design considerations will be generated below the recommended trains. A majority of the design considerations are based on the facility specific inputs entered during Steps 1 through 4. The list is intended to provide planning level considerations. When developing future WRFs, these design considerations can be expanded or modified to include additional City inputs or updated considerations.

If the project budget is a significant constraint, the user can set the capital cost slide bar at a high percentage and a design note will be generated indicating that the "Project budget is a significant constraint. Consult engineers or designers if the user chooses not to follow the model recommendation." A screen shot of the SurpriseTree™ Wastewater Model Train Generator is shown in Figure WWT.15.

8.1.8 Costs

The SurpriseTree™ Wastewater Model includes relative conceptual level costs for comparing the economics of each treatment technology. The costs were compiled from a wide variety of sources and are intended to represent conceptual planning level information only. These costs are NOT meant to be used for budget planning, design, or construction. If updated or site-specific cost information is available, the user can utilize the Costs sheet to override the default costs. Updated cost information can be entered into the *City's Adjustment* columns for unit capital and O&M costs. The information should be entered in $/gallon for capital cost and $/1000 gallons for O&M costs. Note that the model automatically adjusts the default costs based on inputs such as construction time, location factor, and facility size. A screen shot of the SurpriseTree™ Wastewater Model Costs is shown in Figure WWT.16.

Watsewater Treatment Technology Assessment
Surprise Tree™ Wastewater

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SURPRISE ARIZONA

All Possible Trains

Number of Trains: 82944

Preliminary	Grit Removal	Primary	BOD and N-DeN	Clarification	Filtration	Disinfection	Thickening	Stabilization	Dewatering
4	3	2	4	2	3	3	4	4	3
CoarseScrn(6mm)	M-VorGrit	PriClari	MBR			UV	Gravity Thickening	Multiphase	DryingBeds
StepScrn(3mm)	FreeVorGrit	NoPriClari	Aeration Basin	Clarification	Disk Filters	Sodium Hypo Bulk	DAF Thickening	Lagoon	BeltPress
RotaryScrn(3mm)	Aerated Grit		Extended Aeration	NoClarifier	Dyna Sand	Sodium Hypo Onsite	Gravity Belt	ConvAnaerobic	Centrifuge_Dewatering
FineScrn(2mm)			SBR		Traveling Bridge		RTD	Aerobic	

Decisions to Make

Grit Basins	Grit removal is NOT required.
Primary Clarification	Primary clarification is NOT preferred.
MBR	Both MBR and non-MBR trains are acceptable.
UV	Other disinfection options are acceptable.

Total Number of Trains: 21

MBR Trains (No Biosolids)

Number of Trains: 3

Preliminary	Grit Removal	Primary	BOD and N-DeN	Clarification	Filtration	Disinfection	Thickening	Stabilization	Dewatering
1	1	1	1	1	1	3	1	1	1
CoarseScrn(6mm) + FineScrn(2mm)	No grit removal	No Primary	MBR			UV	-	Solids Dewatering to Landfill	Belt Press
						Sodium Hypo Bulk			
						Sodium Hypo Onsite			

Non-MBR Trains (No Biosolids)

Number of Trains: 18

Preliminary	Grit Removal	Primary	BOD and N-DeN	Clarification	Filtration	Disinfection	Thickening	Stabilization	Dewatering
2	1	1	1	1	3	3	1	1	1
CoarseScrn (6 mm) + StepScrn (3 mm)	No grit removal	No Primary	Aeration Basin	Clarification	Disk Filters	UV	-	Solids Dewatering to Landfill	Belt Press
CoarseScrn (6 mm) + RotaryScrn(3mm)					Dyna Sand	Sodium Hypo Bulk			
					Traveling Bridge	Sodium Hypo Onsite			

Design Considerations

(1) BADCT must be met, including nitrogen removal requirements.
(2) Class A+ effluent. Disinfection shall be designed to meet fecal coliform 23 cfu/100 mL single sample maximum and non-detect four out of last seven daily samples.
(3) PHF:AAD peaking factor is 4. If MBR is selected, equalization is required. If conventional treatment is selected, equalization is required.
(4) The facility size may not be economical for extended aeration.
(5) The facility size may not be economical for SBR.
(6) This is a large facility. Recommend coarse (6 mm) followed by fine screens (3mm).
(7) Grit removal is not selected. The biological treatment trains shall be designed with redundancy to allow one train to be taken out of service for grit removal.
(8) Grit removal is required if anaerobic digestion or centrifuge thickening or dewatering are preferred.
(9) This is a large facility. Recommend mechanical vortex grit removal in lieu of free vortex.
(10) The influent BOD:TKN ratio is 5.42 mg/L.This is a reasonable ratio.
(11) The influent TSS is 650 mg/L.High TSS! Primary Clarification is recommended.
(12) If MBR is selected, coarse screening (6 mm) followed by fine screening (2mm) with redundancy must be provided. Consult Engineers and MBR Manufacturer.
(13) Design Considerations on Wastewater Strength: Water conservation fixtures could reduce the flow by up to 10%, resulting in increased wastewater strength.
(14) Phosphorus removal is not expected to be an issue for this facility.
(15) Requires covers for aeration tanks. Extended aeration is not recommended considering the expense to cover large basins.
(16) This facility is a NdeN plant. The biological process shall be designed to allow nitrification and denitrification.
(17) If MBR is selected, no secondary clarification is necessary.
(18) If MBR is selected, no filtration process is necessary.
(19) To meet Class A+ quality, the facility shall be capabile of feeding filter aid polymer.
(20) Microfiltration/ultrafiltration can be considered for replacing existing filtration facilities.
(21) If sodium hypochlorite is selected in lieu of UV, large chlorine contact basins are often required to meet the CT. This can be expensive and require a large land area.
(22) If UV is selected, sodium hypochlorite (bulk) is required to provide residual chlorine.
(23) Open channel UV is recommended for non-MBR trains. Pressurized UV is recommended for MBR trains.
(24) For MBR trains, the selection of UV will provide multiple barriers and better water quality.
(25) This facility is planned for recharge or has water quality goals for emerging contaminants such as EDCs and PPCPs.
(26) Selection of UV is recommended for it's compatibility with Advanced Oxidation Process (AOP).
(27) Selection of ozone or other AOP technologies is recommended for further evaluation if EDCs and PPCPs are of a concern.
(28) No thickening is required due to no need of stabilization.
(29) If MBR is selected, the use of polymer associated with DAF might be a concern, considering the potential membrane fouling.
(30) If anaerobic digestion or advanced anaerobic digestion processes are selected, primary clarifications shall be selected.
(31) If multiphase digestion is selected, centrifuge thickening is preferred to provide required high solids concentration.
(32) No thickening and no stabilization is required.
(33) There is land available for primary clarification and anaerobic digestion facilities.
(34) If extended aeration is selected, aerobic digestion is recommended and can be smaller due to the extended aeration.
(35) If extended aeration is selected, primary clarification and anaerobic digestion are not recommended.
(36) It is recommended that the user complete a facility specific master plan, conceptual design or preliminary design to further address land availability issues.

SURPRISE TREE™ WASTEWATER MODEL TRAIN GENERATOR

FIGURE WWT.15

CITY OF SURPRISE
WASTEWATER TECHNOLOGY ASSESSMENT REPORT

carollo

Watsewater Treatment Technology Assessment

Surprise Tree™ Wastewater

	facility size: 12 mgd						
	Default		City's Adjustment		LCA Analysis		
	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Life Cycle ($/1000gal)
Preliminary	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
CoarseScrn	$ 0.07	$ 0.02			$0.10	$0.03	$0.04
StepScrn(3mm)	$ 0.15	$ 0.06			$0.21	$0.08	$0.10
RotaryScrn(3mm)	$ 0.17	$ 0.09			$0.25	$0.12	$0.15
FineScrn	$ 0.26	$ 0.18			$0.37	$0.26	$0.29
Grit	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
AeratedGrit	$ 0.06	$ 0.03			$0.08	$0.05	$0.05
M-VorGrit	$ 0.07	$ 0.04			$0.10	$0.05	$0.06
FreeVorGrit	$ 0.11	$ 0.03			$0.16	$0.05	$0.07
Primary	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
PriClari	$ 0.29	$ 0.29			$0.41	$0.41	$0.43
NoPriClari	$ -	$ -			$0.00	$0.00	$0.00
BOD and N-DeN	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
Oditch	$ 1.44	$ 2.01			$2.04	$2.85	$2.89
A-Basin	$ 2.04	$ 4.08			$2.89	$5.78	$5.69
MBR	$ 2.45	$ 5.38			$3.47	$7.63	$7.47
SBR	$ 1.83	$ 3.12			$2.60	$4.42	$4.41
Trickling Filters	$ 1.63	$ 2.61			$2.31	$3.70	$3.71
IFAS	$ 2.24	$ 4.93			$3.18	$7.00	$6.84
Secondary Clarification	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
Clarification	$ 0.92	$ 1.02			$1.31	$1.44	$1.50
Filtration	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
Disk Filters	$ 0.59	$ 0.35			$0.84	$0.50	$0.57
TravelingBridge	$ 0.61	$ 0.36			$0.86	$0.52	$0.59
MFUF	$ 1.31	$ 1.31			$1.87	$1.87	$1.96
DynaSand	$ 0.61	$ 0.36			$0.86	$0.52	$0.59
ConvSand	$ 0.55	$ 0.33			$0.78	$0.47	$0.54
Disinfection	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
GasChlorine	$ 0.24	$ 0.10			$0.34	$0.14	$0.17
Sodium Hypo Bulk	$ 0.34	$ 0.21			$0.49	$0.29	$0.33
Sodium Hypo Onsite	$ 0.52	$ 0.16			$0.74	$0.22	$0.31
UV+Hypo	$ 0.61	$ 0.18			$0.86	$0.26	$0.36
Ozone+Hypo	$ 0.73	$ 0.22			$1.04	$0.31	$0.43
Odor	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
ChemicalAdd	$ 0.07	$ 0.13			$0.09	$0.19	$0.18
LiquidScrubber	$ 0.26	$ 0.18			$0.37	$0.26	$0.28
BioFilter	$ 0.30	$ 0.15			$0.43	$0.21	$0.25
BioTower	$ 0.33	$ 0.17			$0.47	$0.23	$0.28
CarbonAdsorp	$ 0.26	$ 0.26			$0.37	$0.37	$0.39
E-IonCharged	$ 0.31	$ 0.19			$0.44	$0.26	$0.30
Thickening	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
DAFThicken	$ 0.45	$ 0.36			$0.64	$0.51	$0.56
CentrifugeT	$ 0.91	$ 1.45			$1.28	$2.06	$2.06
GravityThicken	$ 0.36	$ 0.18			$0.51	$0.26	$0.31
RTD	$ 0.72	$ 0.72			$1.03	$1.03	$1.08
GravityBelt	$ 0.54	$ 0.43			$0.77	$0.62	$0.67
Stabilization	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
Aerobic	$ 0.88	$ 1.76			$1.24	$2.49	$2.45
ATAD2	$ 1.46	$ 2.93			$2.07	$4.15	$4.08
ConvAnaerobic	$ 0.93	$ 1.40			$1.32	$1.99	$2.00
Multiphase	$ 1.12	$ 1.68			$1.59	$2.38	$2.40
TempPhase	$ 1.29	$ 2.06			$1.83	$2.92	$2.93
Lagoon	$ 0.70	$ 0.98			$1.00	$1.39	$1.41
Dewatering	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
CentrifugeD	$ 0.91	$ 1.45			$1.28	$2.06	$2.06
BeltPress	$ 0.72	$ 1.16			$1.03	$1.64	$1.65
DryingBeds	$ 0.27	$ 0.54			$0.39	$0.77	$0.76
Advanced Biosolids Treatment	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
NoAdvBS	$ -	$ -			$0.00	$0.00	$0.00
Composting	$ 0.81	$ 1.46			$1.15	$2.07	$2.06
Incineration	$ 4.88	$ 9.75			$6.92	$13.83	$13.62
AirDrying	$ 0.63	$ 0.63			$0.89	$0.89	$0.93
SolarAirDrying	$ 2.17	$ 2.60			$3.07	$3.69	$3.80
HeatDrying	$ 2.67	$ 5.33			$3.78	$7.57	$7.45
Disposal	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
LandApp	$ -	$ -			$0.00	$0.00	$0.00
Landfill	$ -	$ -			$0.00	$0.00	$0.00
LandApp&Fill	$0.00	$0.00			$0.00	$0.00	$0.00

References:

References for the costs include, but may not be limited to, the Carollo Planning-Level Cost Estimating Software (PCES), the Surprise SPA 2 RWRF Conceptual Design Report and Detailed Design costs, the City of Phoenix WWTP Alternative Disinfection Studies, the City of Sedona Biosolids Management Study, the City of Phoenix 23rd Avenue WWTP Multiphase Digestion Study, and the Casa Grande WRF expansion project.

Disclaimer:

1) Costs presented above are for relative technology alternative evaluation. They shall NOT be used for CIP planning or construction purpose.
2) This is relative costs for comparing treatment alteratives in each treatment category. The costs shall not be misused in lieu of preliminary design or detailed design cost estimates.
3) Costs do not include preliminary and final design expenses, permitting costs,land acquisition costs for well sites, well development costs, construction admin & inspection costs, commissioning costs, and associated contingency on these costs.
4) Capital costs are expressed in $/gpd, costs to build a 1 gpd facility. O&M costs are expressed in $/1000 gallon, costs to produce 1000 gallon of water. Life cycle costs are expressed in $/1000 gallon, costs to produce one thousand gallon of water
5) Adjustment by users are encouraged. Users are responsible for the accuracy of the adjusted costs and the validation of all costs once adjusted.

SURPRISE TREE™ WASTEWATER MODEL COSTS

FIGURE WWT.16

CITY OF SURPRISE
WASTEWATER TECHNOLOGY ASSESSMENT REPORT

8.1.9 Additional Considerations

Once input is provided to all input sheets and the train generator is used to update the treatment options, the SurpriseTree™ Wastewater Model can produce a report containing all input information along with the model results. The report is a simple and convenient way to summarize and interpret the model output. An example SurpriseTree™ Wastewater Model Report is included in Appendix C. The report can be easily customized to include additional notes and decisions.

The SurpriseTree™ Wastewater Model uses sound engineering judgment and City/developer representative input to characterize the relative treatment capabilities of various wastewater treatment technologies for the City of Surprise. This tool is designed to assist the user in making decisions on treatment technology selection without dictating the decisions or eliminating flexibility or engineering judgment from the design process. In general, it is intended for internal use within the City of Surprise only.

8.2 Most Favorable Wastewater Treatment Technologies

To provide the City and the developer with useful planning level design information, the Wastewater Technology Assessment Report includes a series of Implementation Packages, which represent the most likely treatment alternatives to be implemented at the City's future WRFs. These treatment alternatives are viable options for the City's facilities, considering their technical feasibility and cost effectiveness. They generally represent the top two to three most favorable treatment technologies of each treatment category (e.g., primary treatment, secondary treatment, disinfection). Generally speaking, these treatment technologies can be utilized to achieve the City's treatment standards in a cost effective manner.

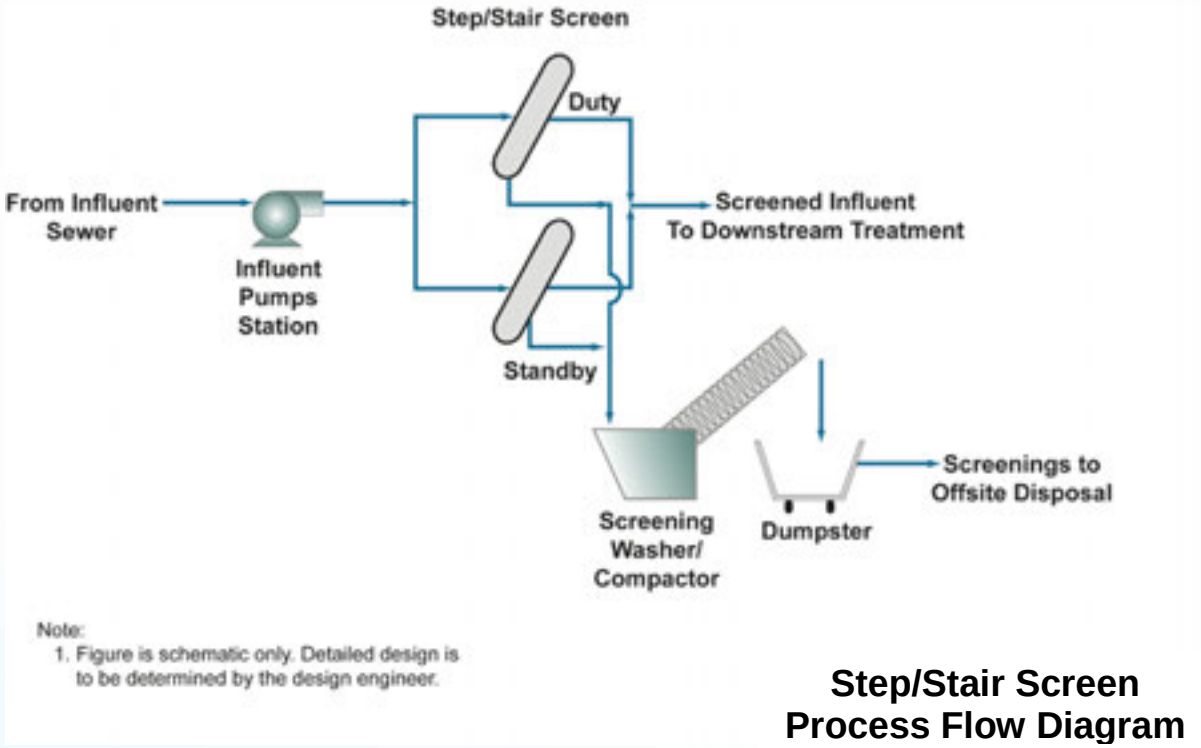
The process flow diagrams, basis of design, and design considerations for each of the recommended wastewater and biosolids treatment technologies are presented on the associated single or double-sided Implementation Package. Each separate Implementation Package provides information on one technology. When the City makes decisions for a new WRF, they can choose to use the SurpriseTree™ Wastewater Model to assist in the decision making or to check the decisions made by the developer/engineer during the planning of a new WRF. The City can access the Implementation Packages from the model and provide them to the developer to assist in ensuring the planning and design is consistent with the City's standards for the associated technologies. The developer should use the Implementation Packages as the basis for the design of the new WRF.

The user should always carefully review the SurpriseTree™ Wastewater Model outputs prior to using the Implementation Packages as certain technologies should or should not be implemented when another technology is selected, based on specific engineering and policy reasons . For example, when MBR is selected as the biological treatment process, fine screens must be used for preliminary treatment (in lieu of other preliminary treatment technologies).

This section presents the Implementation Packages for the following technology alternatives:

- Preliminary Treatment: Step/stair screen (Implementation Package [IP]-1), rotary screen (IP-2), fine screens (IP-3)
- Grit Removal: Mechanical vortex (IP-4), free vortex (IP-5).
- Primary Treatment: Primary clarifiers (IP-6).
- Biological Treatment: Extended aeration (IP-7), MBR (IP-8), MLE activated sludge (IP-9).
- Clarification: Secondary clarifier (IP-10).
- Filtration: Traveling bridge filter (IP-11), cloth type disk filter (IP-12), continuous upflow granular media filter (IP-13).
- Disinfection: UV (IP-14), sodium hypochlorite bulk (IP-15), sodium hypochlorite onsite (IP-16).
- Biosolids Thickening: Rotary drum thickening (IP-17), gravity belt thickening (IP-18), centrifuge thickening (IP-19).
- Biosolids Stabilization: Conventional anaerobic digestion (IP-20), conventional aerobic digestion (IP-21), multi-phase anaerobic digestion (IP-22).
- Biosolids Dewatering: Centrifuge dewatering (IP-23), belt filter press (IP-24).
- Odor Control: Liquid chemical scrubber (IP-25), BioTower (IP-26), carbon adsorption (IP-27), electrically charged ion addition (IP-28).

8.3 Implementation Packages

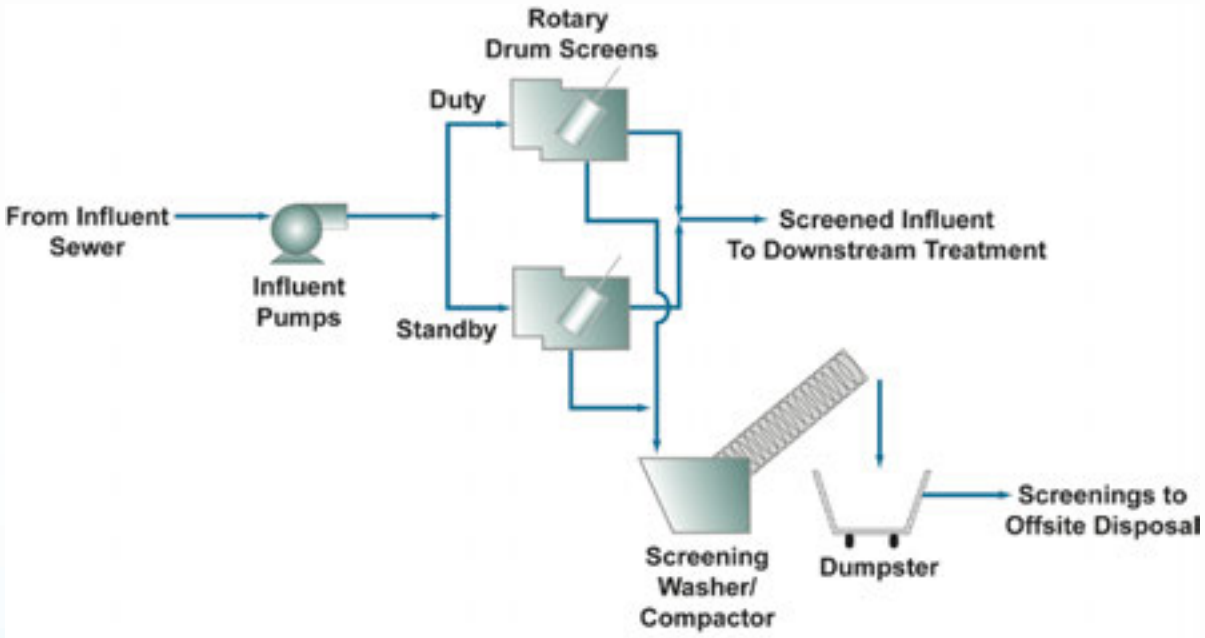


Step/Stair Screen Process Flow Diagram

Step/Stair Screen Design Criteria			
	Unit	**Value**	**Notes**
Type	Mechanical step/stair screen		
Design Flow Condition	Peak Hour Flow		
Process Redundancy			
Operating Screens	No.	n	n = number of screens required to accommodate design flow
Standby Screens	No.	1	Mechanically cleaned type
Opening Size	mm	4 - 6	
Angle of Inclination	degrees	40-57	Varies based on manufacturer
Operation	--	Mechanically Cleaned	
Screenings Handling	--	Screenings washer/ compactor	Screenings require landfill disposal and must comply with the requirements of 40.CFR 264.134 (pass the Paint Filter Liquids Test, EPA Method 9095B).
Type of Conveyor	--	Shaft-less, screw	

Design Considerations for Step/Stair Screens

- All duty and stand-by screens shall be mechanically cleaned.
- Material removed through the screening process shall be further processed through a screenings washer/compactor system designed to wash any removed organic material and reduce the water content of the screenings. Washed/compacted screening material shall be disposed of in a landfill and therefore must comply with the requirements of 40.CFR 264.134 (pass the Paint Filter Liquids Test, EPA Method 9095B).
- Preliminary treatment will generate odors. Step/stair screens must be fully enclosed to promote easy drawn off of foul air for odor control directly from the source, unless the units are located inside a building provided with odor control.
- Screenings handling shall be designed for containment and treatment of odors.
- Step/Stair screens shall not be used as the only screening process in combination with a MBR biological treatment process.



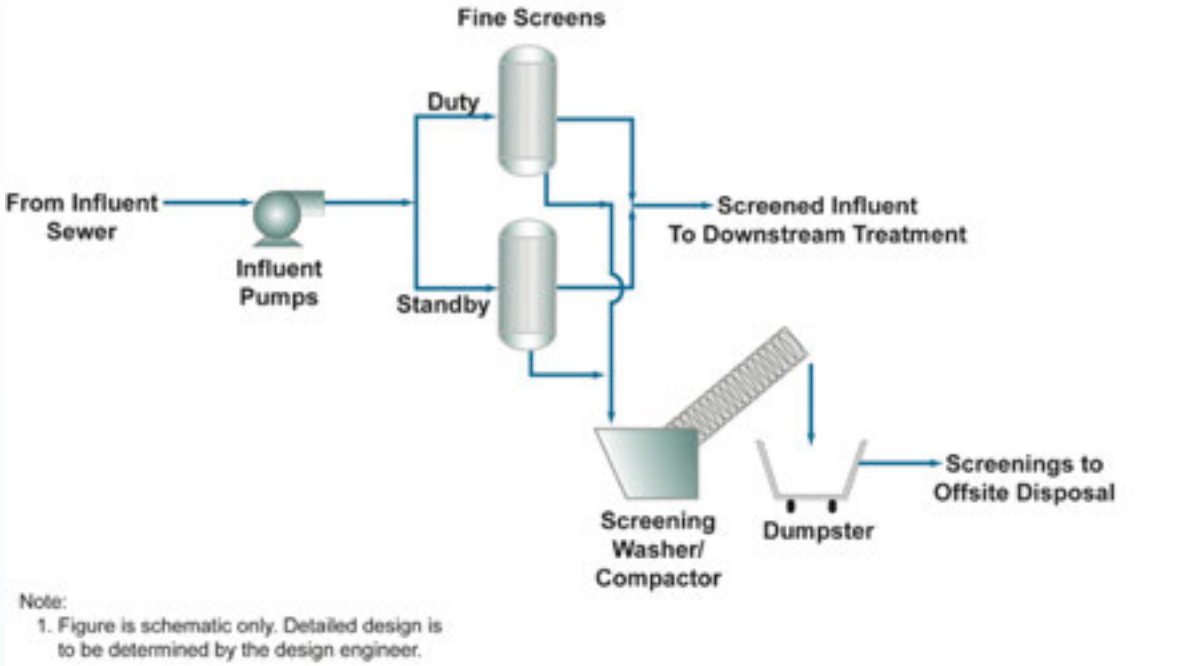
Note:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

Rotary Drum Screen Process Flow Diagram

Rotary Drum Screen Design Criteria			
	Unit	**Value**	**Notes**
Type	Mechanical rotary drum screen		
Design Flow Condition	Peak Hour Flow		
Process Redundancy			
Operating Screens	No.	n	n = number of screens required to accommodate design flow
Standby Screens	No.	1	Mechanically cleaned type
Opening Size	mm	1 - 6	
Operation	--	Mechanically Cleaned	
Screenings Handling	--	Screenings washer/ compactor	Screenings require landfill disposal and must comply with the requirements of 40.CFR 264.134 (pass the Paint Filter Liquids Test, EPA Method 9095B).
Type of Conveyor	--	Shaft-less, screw	

Design Considerations for Rotary Drum Screens

- All duty and stand-by screens shall be mechanically cleaned.
- Material removed through the screening process shall be further processed through a screenings washer/compactor system designed to wash any removed organic material and reduce the water content of the screenings. Washed/compacted screening material shall be disposed of in a landfill and therefore must comply with the requirements of 40.CFR 264.134 (pass the Paint Filter Liquids Test, EPA Method 9095B).
- Preliminary treatment will generate odors. Rotary drum screens must be fully enclosed to promote easy drawn off of foul air for odor control directly from the source unless the units are located inside a building provided with odor control .
- Screenings handling shall be designed for containment and treatment of odors.

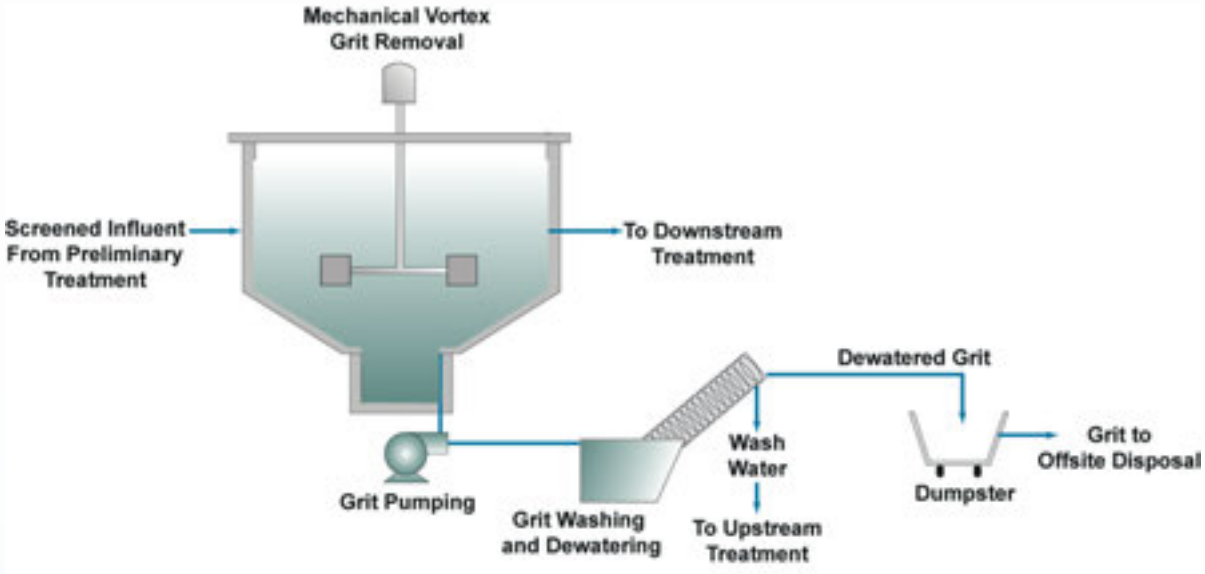


Fine Screen Process Flow Diagram

Fine Screen Design Criteria			
	Unit	**Value**	**Notes**
Type	Mechanical Fine Screen		
Design Flow Condition	Peak Hour Flow		
Process Redundancy			
Operating Screens	No.	n	n = number of screens required to handle design flow
Standby Screens	No.	1	Mechanically cleaned type
Opening Size	mm	1 - 2	
Operation	--	Mechanically Cleaned	
Screenings Handling	--	Screenings washer/ compactor	Screenings require landfill disposal and must comply with the requirements of 40.CFR 264.134 (pass the Paint Filter Liquids Test, EPA Method 9095B).
Screenings Handling Process Redundancy	--	Redundant units are required	
Type of Conveyor	--	Shaft-less, screw	

Design Considerations for Fine Screens

- A fine screen can provide the required protection for MBR/membrane pretreatment, provided that the opening size meets the membrane manufacturer's requirements.
- All duty and stand-by screens shall be mechanically cleaned.
- Material removed through the screening process shall be further processed through a screenings washer/compactor system designed to wash any removed organic material and reduce the water content of the screenings. Washed/compacted screening material shall be disposed of in a landfill and therefore must comply with the requirements of 40.CFR 264.134 (pass the Paint Filter Liquids Test, EPA Method 9095B).
- Preliminary treatment will generate odors. Fine screens must be fully enclosed to promote easy drawn off of foul air for odor control directly from the source unless the units are located inside a building provided with odor control .
- Screenings handling shall be designed for containment and treatment of odors.
- Perforated plate type fine screen is required for MBR pretreatment (wedge wire shall not be used).



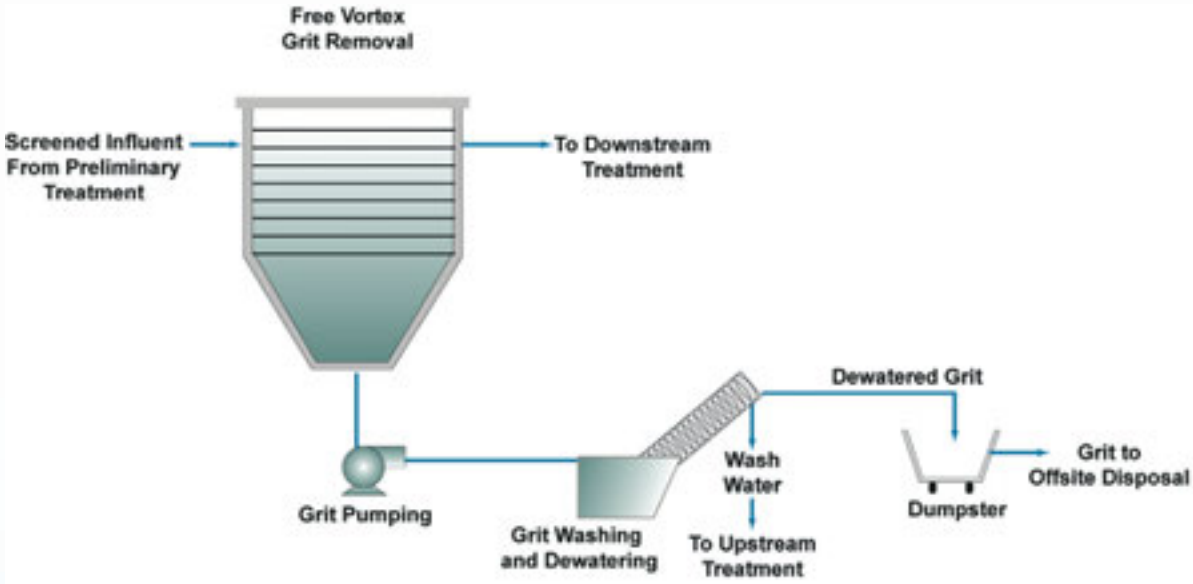
Note:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

Mechanical Vortex Grit Removal Process Flow Diagram

Mechanical Vortex Grit Removal Design Criteria			
	Unit	**Value**	**Notes**
Type	Mechanical Vortex		
Design Flow Condition	Peak Hour Flow		
Process Redundancy	Redundant units are not required but a process bypass must be provided.		
Detention Time at Peak Hour Flow Rate	sec	30	
Removal Rates			
Greater than 50-mesh	%	95	Range 92-98
50-Mesh to 70-Mesh	%	85	Range 80-90
70-Mesh to 100-Mesh	%	65	Range 60-70
Design Size	Micron	100	
Grit Handling	--	Grit pumping, washing and dewatering	Removed Grit requires landfill disposal and must comply with the requirements of 40.CFR 264.134 (pass the Paint Filter Liquids Test, EPA Method 9095B).

Design Considerations for Mechanical Vortex Grit Removal

- Grit removed by the process shall be further processed through a grit pumping, washing and dewatering system. The system shall be designed to wash organic material off the removed grit and reduce the water content of the materials. Washed/dewatered grit materials shall be disposed of in a landfill and therefore must comply with the requirements of 40.CFR 264.134 (pass the Paint Filter Liquids Test, EPA Method 9095B).
- All open-tank grit removal facilities will require covers for odor containment and control. Grit handling shall be designed for containment and treatment of odors.
- Grit removal is required when anaerobic digestion is selected as the solids stabilization process, or when centrifuges are used for solids dewatering or thickening.



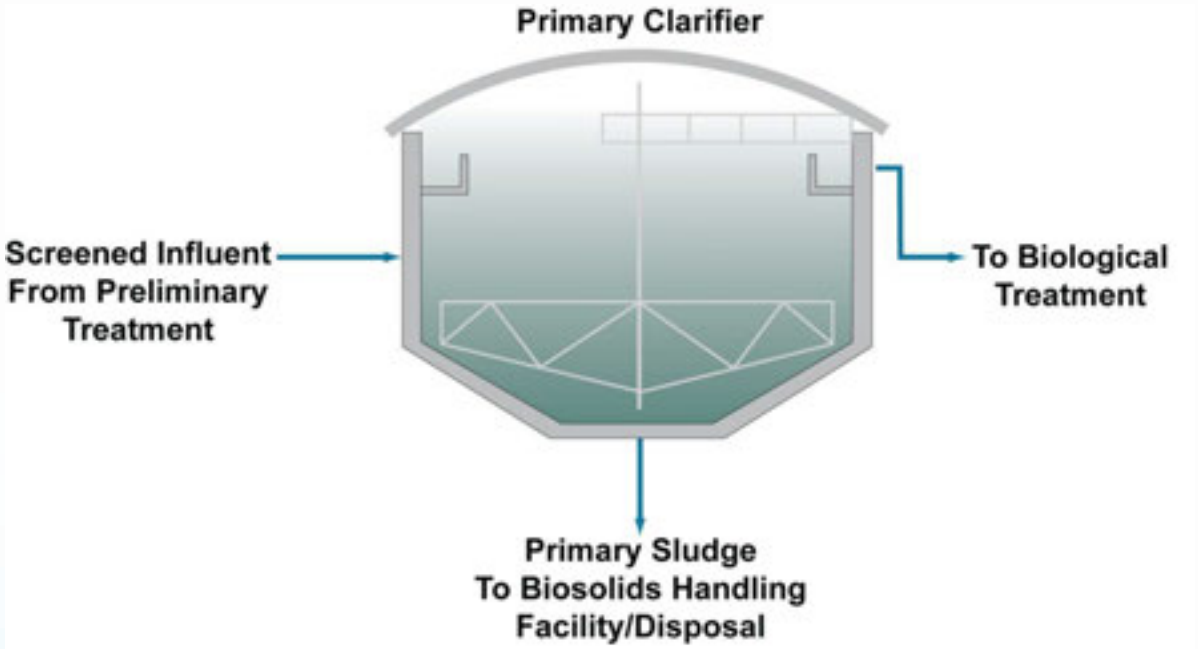
Note:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

Free Vortex Grit Removal Process Flow Diagram

Free Vortex Grit Removal Design Criteria			
	Unit	**Value**	**Notes**
Type	Free Vortex		
Design Flow Condition	Peak Hour Flow		
Process Redundancy	Redundant units are not required but a process bypass must be provided.		
Detention Time at Peak Hour Flow Rate	seconds	30	
Removal Rates			
Greater than 50-mesh	%	95	Range 92-98
50-Mesh to 70-Mesh	%	85	Range 80-90
70-Mesh to 100-Mesh	%	65	Range 60-70
Design Size	Micron	100	
Grit Handling	--	Grit pumping, washing and dewatering	Removed Grit requires landfill disposal and must comply with the requirements of 40.CFR 264.134 (pass the Paint Filter Liquids Test, EPA Method 9095B).

Design Considerations for Free Vortex Grit Removal

- Grit removed by the process shall be further processed through a grit pumping, washing and dewatering system. The system shall be designed to wash organic material off the removed grit and reduce the water content of the grit material. Washed/dewatered grit materials shall be disposed of in a landfill and therefore must comply with the requirements of 40.CFR 264.134 (pass the Paint Filter Liquids Test, EPA Method 9095B).
- All open-tank grit removal facilities will require covers for odor containment and control. Grit handling shall be designed for containment and treatment of odors.
- Grit removal is required when anaerobic digestion is selected as the solids stabilization process, or when centrifuges are used for solids dewatering or thickening.
- Free vortex grit systems shall not be used for treatment plants master planned to treat greater than 6 mgd.
- Free vortex systems are preferred when variable flow rates are anticipated.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

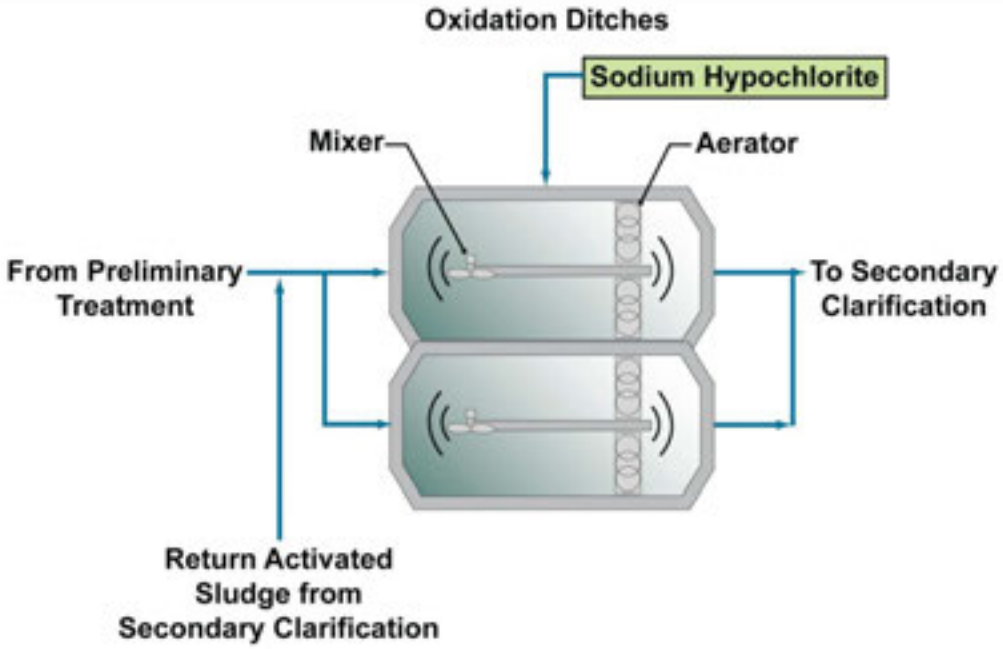
Primary Clarification Process Flow Diagram

Primary Clarifier Design Criteria			
	Unit	**Value**	**Notes**
Type	Circular/Rectangular Basin with surface scum and bottom sludge scrapers		
Design Flow Condition	Maximum month average day flow or peak hour flow. (Surface overflow rates with the clarifier surface area provided shall not to exceed the maximum values provided below).		
Process Redundancy	Redundant units are not required but a process bypass must be provided.		
Maximum Surface Overflow Rates			
Maximum Month Average Day Flow	gpd/ft^2	1,000 when followed by secondary treatment	Range of 800 - 1,200 when followed by secondary treatment
Minimum Hydraulic Retention Time at Maximum Month Average Day Design Flow	hours	2.0	

Primary Clarifier Design Criteria			
	Unit	**Value**	**Notes**
Minimum Side Water Depth	feet	12	Range: 12 - 16
Design BOD Removal	Percent	< 35	
Design Total Suspended Solids Removal	Percent	< 65	

Design Considerations for Primary Clarification

- Circular clarifiers are preferred and shall be considered as a first option. However, rectangular primary clarification basins can be considered for facilities with limited land and can take advantage of common wall construction.
- Surface skimming provides an effective scum control and shall be included on all primary clarifier designs.
- Primary clarification is recommended for influent wastewater containing TSS greater than 500 mg/L. However, if the BOD to TKN ratio is less than 3, primary clarification is not recommended.
- Primary clarification may be necessary when preceding activated sludge for BOD and nutrient removal. Primary clarification can also be used with other biological treatment processes when there is a high influent TSS or a need to reduce the loading on the downstream processes.
- The sludge produced in the primary clarifiers provides readily available biomass for digestion. Anaerobic digestion is the most applicable digestion process for primary sludge. Primary sludge also improves dewaterability of digested sludge.
- The primary clarification process will generate odors. All clarifiers will require covers for odor containment and control, unless adequate site set backs are available.
- Sludge collector bearings and gears shall not be below process liquid surface or in contact with process liquid.



Note:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

Extended Aeration Process Flow Diagram

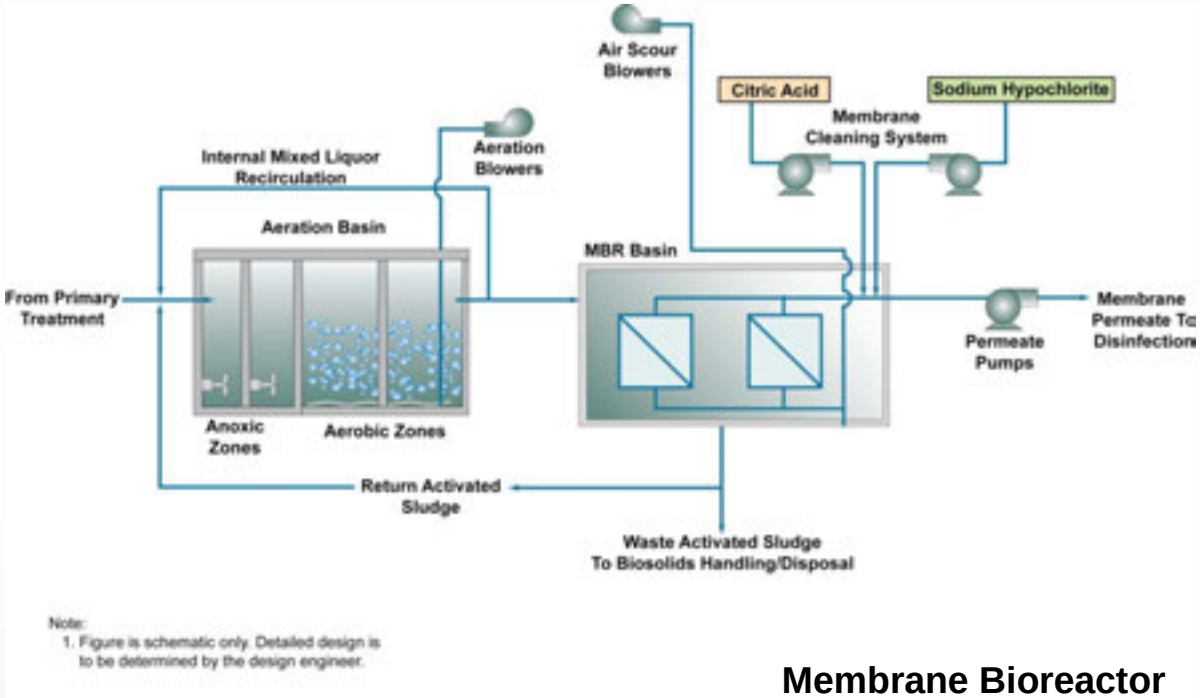
Extended Aeration Design Criteria			
	Unit	**Value**	**Notes**
Type	Extended Aeration - Oxidation Ditch Type		
Design Flow Condition	Maximum Month Average Day Loadings [lb/day]. (MMAD Load [lb/day] = AAD Load [lb/day] x PF)		
Process Redundancy	Treat MMAD Loadings with all basins in service. Treat AAD Loadings with one basin out of service.		
Hydraulic Retention Time at Maximum Month Average Day Flow	hours	18-30	
Anoxic Volume Fraction	%	20-40	To be determined by process design and wastewater characteristics

Extended Aeration Design Criteria			
	Unit	**Value**	**Notes**
Aerobic Volume Fraction	%	60-80	To be determined by process design and wastewater characteristics
Aerator Type	--	Dual impeller aerator or brush aerators	
Dissolved Oxygen Average Setpoint Concentration	mg/L	2.0	Range: 1.0 – 3.0
Anoxic Mixing Type	--	Submersible propeller mixer	
Solids Retention Time at Maximum Month Average Day Loadings	days	20 - 30	Extended aeration mode
Mixed Liquor Suspended Solids Concentration	mg/L	2,000 - 4,000	
Maximum Organic Loading Rate	lb BOD / 1,000 ft^3•d	20	Range: 10 - 20 (extended aeration mode)
Design Return Activated Sludge Flow	% of Influent Maximum Month Average Day Flow	150	Operating range: 50 - 150

Design Considerations for Extended Aeration (Oxidation Ditch Type)

- The use of oxidation ditches generally eliminates the need for primary treatment and anaerobic digestion from the process train.
- A relatively large footprint and basin volume is required due to longer required SRTs. Large volume provides good flow equalization under high flow and loading conditions.
- The extended aeration process can achieve nitrification and denitrification using an automatic control system, or using separate anoxic zones.
- The use of surface brush aerators limits the allowable basin depth to 10-12 feet to achieve optimum operating conditions. Dual impeller aerators allow operating with side water depths of approximately 16-18 feet. Oxygen transfer efficiency of the proposed aeration system configuration shall be supported by engineering data and operating experience.
- Covering oxidation ditches to provide full odor control (if required based on available setbacks) typically represents a high capital cost. Because of the large footprint required for extended aeration, it is difficult to achieve full odor control for the process.

- Covering basins increases the potential for deck and tank wall corrosion. A corrosion-resistant coating is required.
- Anaerobic digestion (conventional or multi-phase) is not recommended when using the oxidation ditch process due to the long SRT requirements associated with the oxidation ditch process.
- Because of the large footprint requirements, oxidation ditch technology is typically not recommended for large capacity facilities.
- A velocity of 1 to 2 ft/sec should be maintained through the basins to maintain the MLSS in suspension.



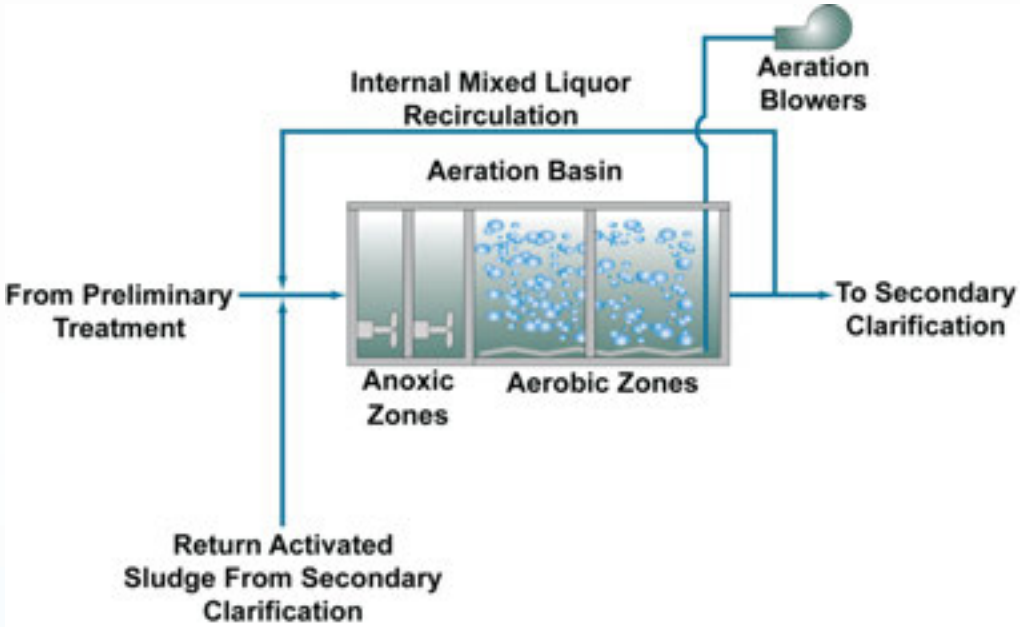
Membrane Bioreactor Process Flow Diagram

Membrane Bioreactor Design Criteria			
Parameter	**Unit**	**Value**	**Notes**
Type of Basins	Activated Sludge / MBR		
Design Flow Condition	Maximum Month Average Day Loadings [lb/day]. (MMAD Load [lb/day] = AAD Load [lb/day] x PF)		
Process Redundancy	Treat MMAD Loadings with all basins in service. Treat AAD Loadings with one basin out of service.		
Minimum Aerobic Hydraulic Retention Time at Maximum Month Average Day Flow	hours	4	
Minimum Solids Retention Time at Maximum Month Average Day Loadings	days	10	Coordinate with MBR manufacturer.
Return Activated Sludge Flow	% of Influent Maximum Month Average Day Flow	300 - 500	Dependent on process design and wastewater characteristics.

Membrane Bioreactor Design Criteria			
Parameter	**Unit**	**Value**	**Notes**
Activated Sludge Process Basins			
Anoxic Volume Fraction	Percent	20 - 40	Dependent on process design and wastewater characteristics.
Aerobic Volume Fraction	Percent	60 - 80	Dependent on process design and wastewater characteristics.
MLSS Concentration	mg/L	6,000 – 8,300	Dependent on process design.
Dissolved Oxygen Average Setpoint Concentration	mg/L	2.0	Range: 1 – 3 mg/L
Type of Air Diffuser System	--	Fine Bubble Membrane Disc	
Type of Mixer (Anoxic Zone)	--	Submersible Propeller Mixers	
Membrane Filtration System			
Design Flow Condition	Provide sufficient membrane surface area to avoid exceeding maximum allowable fluxes under AADF, MMADF, and PDF.		
Process Redundancy	Shall be able to filter MMAD Flow with one train out of service. Shall be able to filter Peak Day Flow with all trains in service.		
MLSS Concentration in Membrane Tanks	mg/L	8,000-10,000	
Membrane Type	--	Hollow fiber or flat sheet	
Maximum Allowable Design Fluxes			
Annual Average Day Flow	gal/ft^2•day	12 (one train out of service)	Design fluxes vary depending on manufacturer.
Maximum Month Average Day Flow	gal/ft^2•day	16 (one train out of service)	
Peak Day Flow	gal/ft^2•day	22 (all trains in service)	
MBR Permeate Turbidity	NTU	$\leq$ 0.5	
Minimum Dissolved Oxygen Requirement	mg/L	0.5	
Membrane Pore Size	µm	0.1 or smaller	

Design Considerations for MBR

- MBR replaces secondary clarification and filtration unit processes.
- MBRs operate at a higher MLSS and therefore reduce the required aeration basin volume. However, at high MLSS concentration, the oxygen transfer rate decreases. Maintaining an MLSS concentration in the membrane basins between 8,000 and 10,000 mg/L and between 6,000 and 8,000 mg/L in the aeration basins is required to optimize operation of the aeration system.
- Odor control can be feasibly achieved by covering process basins. Covering basins increases the potential for deck and tank wall corrosion. A corrosion-resistant coating is required.
- Membrane fouling control is critical for efficient MBR operation. The following are considerations relative to fouling control:
  - Adequate pretreatment of the influent (maximum 2 mm perforated plate type screening with sufficient redundancy, microsieving, combined grit, oil, sand, and hair removal)
  - Sustainable operation at low permeate flux values (12-22 gal/ft^2-d)
  - Introduction of turbulent conditions and fluid motion near the membrane surface through aeration (depending on manufacturer) is required.
  - Physical cleaning techniques (membrane relaxation, membrane backwashing) are required.
  - Chemical membrane cleaning (maintenance wash, clean-in-place) is required. Cleaning waste disposal must be considered and addressed appropriately.
- Lifting equipment (e.g., bridge crane) is required above the membrane tank to facilitate removal of membrane cassettes and associated appurtenances for maintenance or replacement.
- Equalization is an important consideration due to the relatively small MBR tank size. Adequate peaking factors for peak hydraulic and loading events must be considered and accounted for through either separate, dedicated equalization or equalization built in to the biological process.
- The anoxic reactors in the activated sludge treatment basins shall be divided into a minimum of two stages in series with baffle walls to increase denitrification efficiency.
- Promoting plug flow by compartmentalizing the treatment tankage enhances plant performance, both through increased nitrification rates and through improved settleability. A minimum of two anoxic stages and two aerobic stages shall be considered in the design.
- Aeration system shall have means for automated DO control.
- Aeration basins shall have a free surface over the entire basin with a means to remove and suppress scum.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

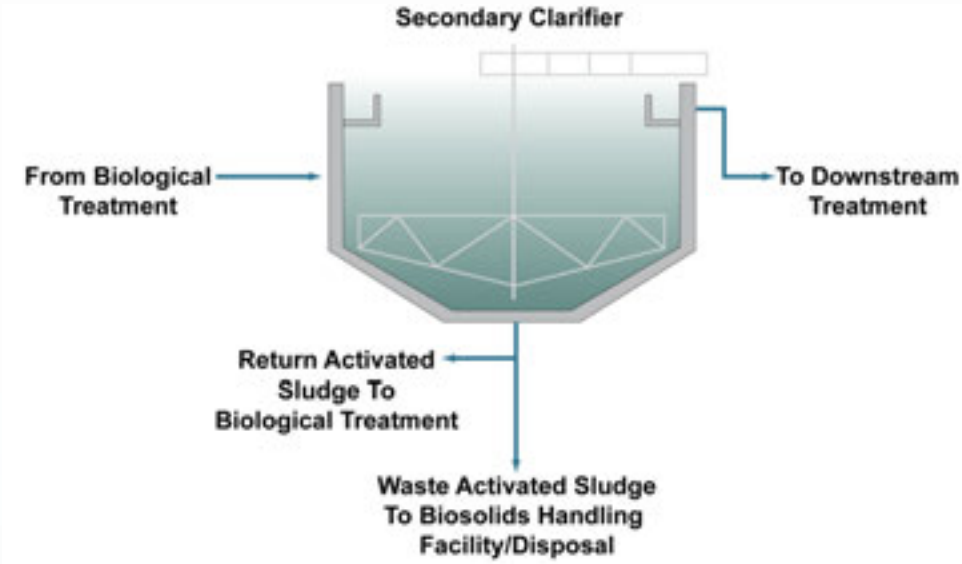
Aeration Basin - MLE Process Flow Diagram

MLE Activated Sludge Process Design Criteria			
Parameter	**Unit**	**Value**	**Notes**
Type of Basin	Modified Ludzak-Ettinger (MLE) Activated Sludge		
Design Flow Condition	Maximum Month Average Day Loadings [lb/day]. (MMAD Load [lb/day] = AAD Load [lb/day] x PF)		
Process Redundancy	Treat MMAD Loadings with all basins in service. Treat AAD Loadings with one basin out of service.		
Anoxic Volume Fraction	%	20 – 40	
Aerobic Volume Fraction	%	60 – 80	
MLSS Concentration	mg/L	2,000- 3,500	
Minimum Aerobic Hydraulic Retention Time at Maximum Month Average Day Flow	hours	4	
Minimum Solids Retention Time at Maximum Month Average Day Loadings	days	7	Range: 7 – 20. SRT is temperature dependant.
Internal Mixed Liquor Recirculation Flow	Percent of Influent Maximum Month Average Day Flow	300 – 500	Dependent on process design and wastewater characteristics.

MLE Activated Sludge Process Design Criteria			
Parameter	**Unit**	**Value**	**Notes**
Return Activated Sludge Flow	Percent of Influent Annual Average Day Flow	100	Operating range: 50 - 100
Dissolved Oxygen Average Setpoint Concentration	mg/L	2.0	Range: 1 – 3 mg/L
Type of Air Diffuser System	--	Fine Bubble Membrane Disc	
Type of Mixer (Anoxic Zone)	--	Submersible Propeller Mixers	

Design Considerations for MLE Activated Sludge

- The Modified Ludzak-Ettinger (MLE) activated sludge process consists of anoxic zones ahead of aerobic zones in an activated sludge basin. The process includes an internal mixed liquor recycle from the end of the aerobic zones to the head of the anoxic zones.
- The internal mixed liquor recycle (IMLR) provides the majority of the nitrates to the anoxic zones for enhanced denitrification and nitrogen removal efficiency. The IMLR provides operational flexibility to address varying influent organic loadings.
- A minimum BOD/TKN ratio of 4:1 is required for effective nitrate reduction by preanoxic processes such as MLE. When the BOD:TKN ratio is less than 4, an external carbon source may be required. When the BOD:TKN ratio is higher than 10, the biological process can still perform well, but a low-cost pretreatment (aerated pond) should be considered to reduce the main aeration requirement.
- The anoxic reactor shall be divided into a minimum of two stages in series with baffle walls to increase denitrification efficiency.
- Promoting plug flow by compartmentalizing the treatment tankage enhances plant performance, both through increased nitrification rates and through improved settleability. A minimum of two anoxic stages and two aerobic stages shall be considered in the design.
- Full odor control can be effectively achieved by covering the process basins. Covering basins increases the potential for deck and tank wall corrosion. A corrosion-resistant coating is required.
- Aeration system shall have means for automated DO control.
- Aeration basins shall have a free surface over the entire basin with a means to remove and suppress scum.



Notes:
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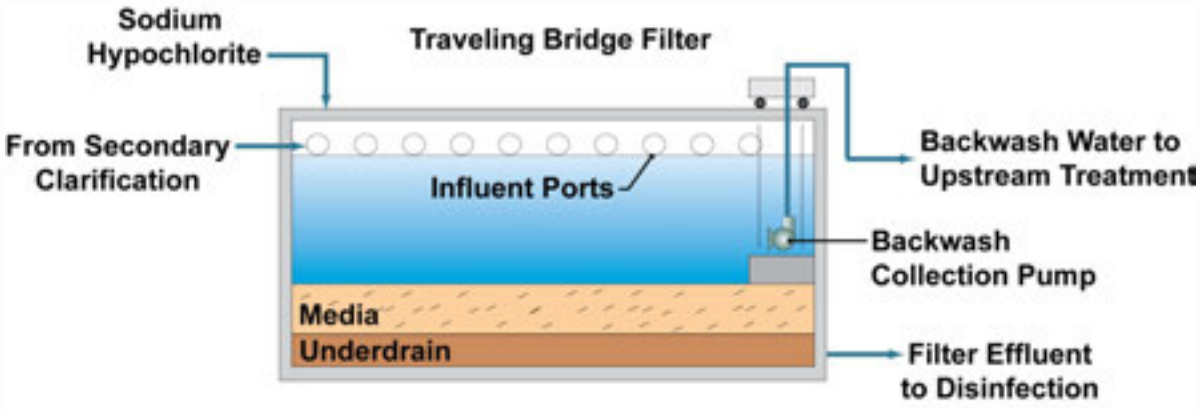
Secondary Clarification Process Flow Diagram

Secondary Clarifier Design Criteria			
	Unit	**Value**	**Notes**
Type	Circular basins with surface and bottom scum/sludge scrapers		
Design Flow Condition	Maximum month average day flow (MMADF) and peak day flow (PDF), in conjunction with design MLSS concentration		
Process Redundancy	One redundant basin at MMADF. All basins in service at PDF.		
Clarifier Sizing Methodology	State Point Analysis (flux theory).		
Clarifier Sizing Approach	State Point Analysis of proposed clarifier sizes shall demonstrate an “underloaded” condition (state point and underflow rate line below the solids flux curve) under all flow conditions. The design shall provide the following minimum safety factors over “critical loading” conditions (state point on the solids flux curve, underflow rate line below the solids flux curve): • 15 percent at peak day flow conditions. • 100 percent at maximum month average day flow conditions.		

Secondary Clarifier Design Criteria			
	Unit	**Value**	**Notes**
Minimum Design Sludge Volume Index (SVI)	mL/g	150	Minimum stated value shall be used for all new plants. When using SVI to select settleability constants for the flux curve in the State Point Analysis, designer shall specify which correlation (Daigger, Pitman, Wahlberg, etc.) is used. For plant expansions, different SVI values and/or settleability parameters may be used if supported by process operational data.
Maximum Surface Overflow Rates			
Maximum Month Average Day Flow	gpd/ft^2	600 - 800	Maximum allowable SOR varies with plant size, per ADEQ Engineering Bulletin No. 11.
Peak Hour Flow	gpd/ft^2	1,200	
Solids Loading Rate at Maximum Month Average Day Flow	lb/day•ft^2	30	
Minimum Side Water Depth	feet	14	
Minimum Hydraulic Retention Time at Maximum Month Average Day flow	hr	3 - 4	

Design Considerations for Secondary Clarification

- Secondary clarification is required following activated sludge processes (MLE or extended aeration processes) utilized for BOD and nutrient removal. Secondary clarification is not required if MBR technology is utilized for BOD and nutrient removal.
- Secondary clarifier performance for the proposed design shall be modeled utilizing the Flux Theory and the State Point Analysis technique. The clarifier surface overflow rates, solids loadings, weir loadings, and sludge settling characteristics shall be evaluated to ensure that the requirements presented herein are met.
- Surface skimming provides an effective scum control method and must be included in all clarifier designs.
- Bottom scrapers with hoppers and hydraulic suction designs provide effective means to remove settled solids from the process.
- Sludge collector bearings, and gears shall not be below process liquid surface or in contact with process liquid.



Notes:
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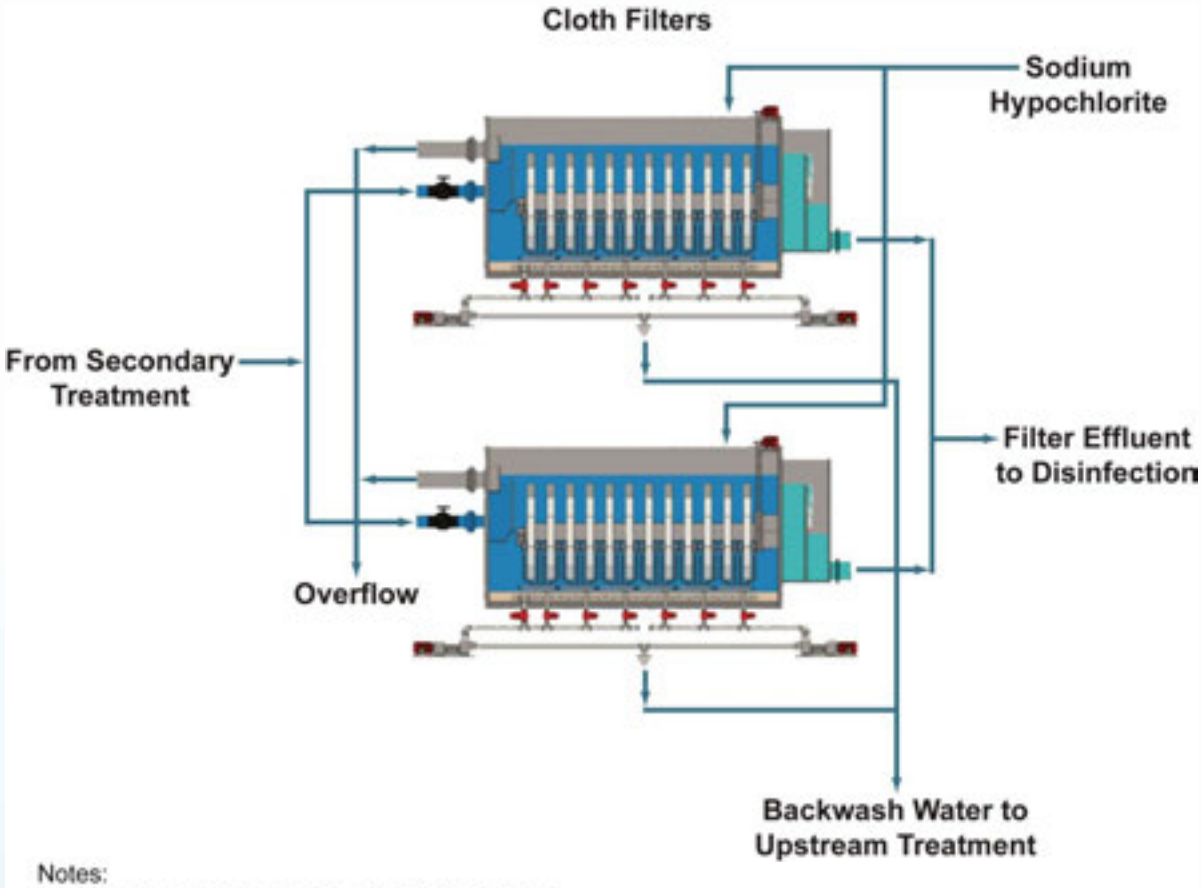
Traveling Bridge Filter Process Flow Diagram

Traveling Bridge Filter Design Criteria			
	Unit	**Value**	**Notes**
Type	Traveling Bridge		
Design Flow Condition	Peak Day Flow and Maximum Month Average Day Flow		
Process Redundancy	Filters must be sized for: • PDF with one unit out of service. • MMADF with one unit out of service		
Maximum Hydraulic Loading Rates			
Maximum Month Average Day Flow	gpm/ft^2	2.0	With one unit out of service
Peak Day Flow	gpm/ft^2	4.0	With one unit out of service
Average Influent Suspended Solids Concentration	mg/L	15	
Maximum Intermittent Suspended Solids Concentration	mg/L	30	
Type of Backwash	--	Automatic, continuous	
Type of Media	--	Mono Granular Media, Sand	
Media Depth, Minimum	inches	16	Range: 16 - 24

Traveling Bridge Filter Design Criteria			
	Unit	**Value**	**Notes**
Media Requirements	--	Silica Sand per AWWA Standard B-100 with D_{10} 0.9mm and C_u $D_{60}/D_{10} \leq 1.5$	
Filter Effluent Water Quality			
Maximum Effluent Suspended Solids under Average Day Hydraulic Loading Rates (less than 2 gpm/ft^2)	mg/L in 24-hour composite sample	5.0	
Maximum Effluent Suspended Solids under Peak Hydraulic Loading Rates (less than 4 gpm/ft^2)	mg/L in grab sample	8.0	
Average Turbidity	NTU based on 24-hour average	2.0	
Maximum Turbidity	NTU based on grab sample	5.0	

Design Considerations for Traveling Bridge Filters

- Each filter shall include the compartmental filter bottom, underdrain system, filter media, and a cleaning and backwash mechanism.
- The traveling bridge filter system shall be suitable for filtering secondary clarified effluent. Each filter shall be designed to operate in a continuous operation mode, designed to backwash while receiving flows.
- The traveling bridge filter shall be of the two-pump type (i.e., a separate backwash and washwater pump shall be supplied on each carriage). Each pump shall be the submersible type.
- There is a potential for high algae growth in filter basins if exposed to sunlight. Filters shall be designed with chlorine dosing to prevent algae growth.



Notes:
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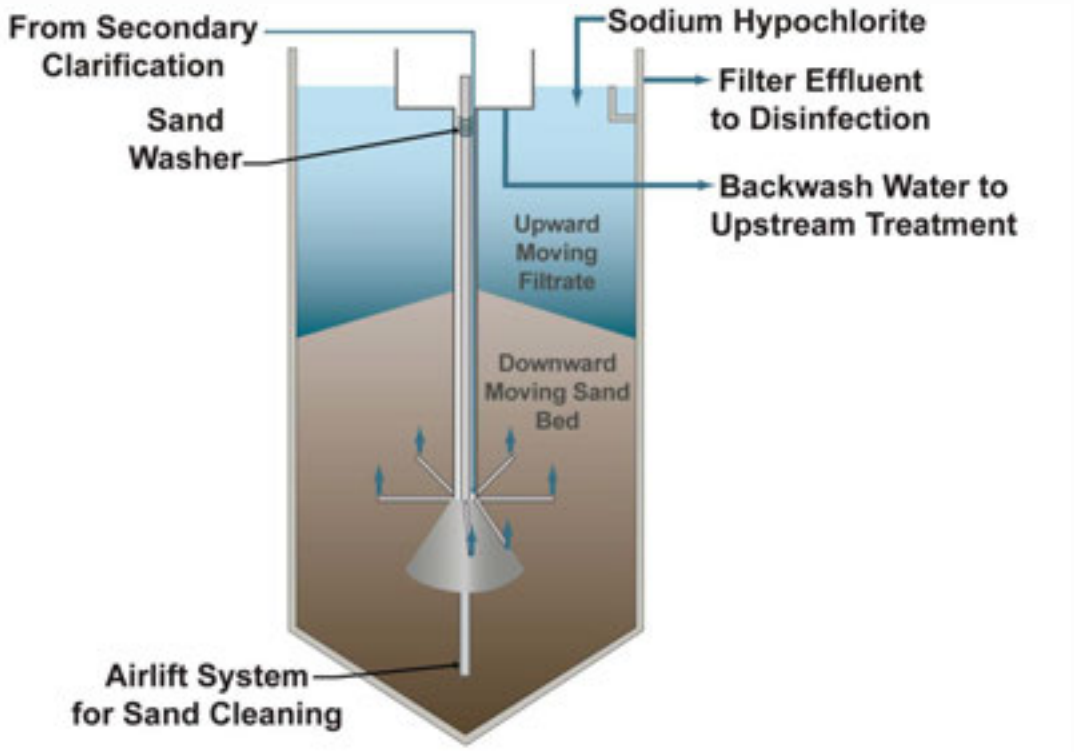
Cloth Filter - Disk Type Process Flow Diagram

Cloth Filter-Disk Type Design Criteria			
	Unit	**Value**	**Notes**
Type	Disk Type Cloth Media		
Design Flow Condition	Peak Day Flow and Maximum Month Average Day Flow		
Process Redundancy	Filters must be sized for: • PDF with one unit out of service. • MMADF with one unit out of service		
Maximum Hydraulic Loading Rates			
Maximum Month Average Day Flow	gpm/ft^2	3	With one unit out of service
Peak Day Flow	gpm/ft^2	5	With one unit out of service

Cloth Filter-Disk Type Design Criteria			
	Unit	**Value**	**Notes**
Maximum Solids Loading Rate	Lb TSS / sf / day	3.0	At peak flow and maximum influent TSS
Average Influent Suspended Solids Concentration	mg/L	15	
Maximum Intermittent Suspended Solids Concentration	mg/L	30	
Type of Backwash	--	High Pressure, intermittent	
Nominal Filter Pore Size	µm	10	
Type of Media	--	Synthetic Pile Fabric Cloth or Woven Polyester	Media shall be resistant to chlorine concentrations up to 10 mg/L.
Filter Effluent Water Quality			
Maximum Effluent Suspended Solids under Average Day Hydraulic Loading Rates (less than 3 gpm/ft^2)	mg/L in 24-hour composite sample	5.0	
Maximum Effluent Suspended Solids under Peak Hydraulic Loading Rates (less than 5 gpm/ft^2)	mg/L in grab sample	8.0	
Average Turbidity	NTU based on 24-hour average	2.0	
Maximum Turbidity	NTU based on grab sample	5.0	

Design Considerations for Cloth Filters (Disk Type)

- Filter media shall be resistant to intermittent chlorine dosing resulting in chlorine concentrations of up to 10 mg/L.
- Disk filters are available in inside-out and outside-in configurations. The outside-in option is preferred but inside-out option can also be considered.
- There is a potential for high algae growth in filter basins if exposed to sunlight. Filters shall be designed with chlorine dosing to prevent algae growth.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

Continuous Upflow Granular Media Filter Process Flow Diagram

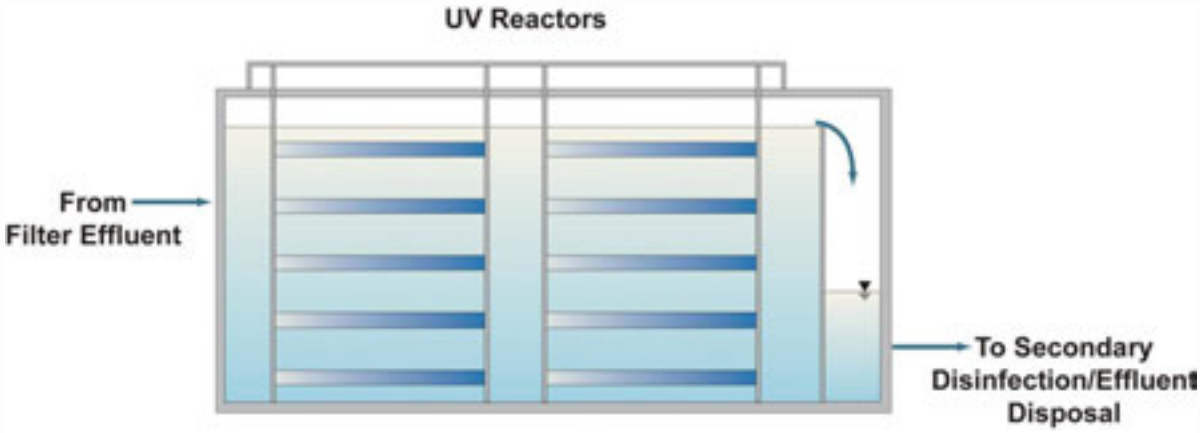
Continuous Upflow Granular Media Filter Design Criteria			
	Unit	**Value**	**Notes**
Type	Continuous upflow granular media		
Design Flow Condition	Peak Day Flow and Maximum Month Average Day Flow		
Process Redundancy	Filters must be sized for: • PDF with one unit out of service. • MMADF with one unit out of service		
Maximum Hydraulic Loading Rates			
Maximum Month Average Day Flow	gpm/ft^2	3	With one unit out of service
Peak Day Flow	gpm/ft^2	5	With one unit out of service
Average Influent Suspended Solids Concentration	mg/L	15	

Continuous Upflow Granular Media Filter Design Criteria			
	Unit	**Value**	**Notes**
Maximum Intermittent Suspended Solids Concentration	mg/L	30	
Type of Media	--	Mono-Granular Media, Sand	
Media Requirements	--	Silica Sand per AWWA Standard B-100 with D_{10} 0.9mm and C_u $D_{60}/D_{10} \leq 1.5$	
Media Depth	inches	36 - 72	
Filter Depth	feet	10 - 25	
Type of Backwash	--	Continuous, Upflow	
Air Scouring	$scfm/ft^2$	> 100	
Backwash Surface Loading Rate to achieve scouring and cleaning of the sand	gpm/ft^2	> 50	
Sand redistribution rate on top of the sand bed due to continuous backwash	number per day	4-6	
Filter Effluent Water Quality			
Maximum Effluent Suspended Solids under Average Day Hydraulic Loading Rates (less than 3 gpm/ft^2)	mg/L in 24-hour composite sample	5.0	
Maximum Effluent Suspended Solids under Peak Hydraulic Loading Rates (less than 5 gpm/ft^2)	mg/L in grab sample	8.0	
Average Turbidity	NTU based on 24-hour average	2.0	
Maximum Turbidity	NTU based on grab sample	5.0	

Design Considerations for Continuous Upflow Granular Media Filters

- Continuous backwash, upflow filters consist of a standard bed, with a single media. Mixed or multiple media shall not be allowed.
- Filter shall operate countercurrent; feed shall be upflow with sand moving downward.
- Filter shall not contain any moving parts and shall not contain any screens, wedge wires, grids, etc., to retain the media in place.

- Flow between filter cells shall be self equalizing. No flow controls, regulators, etc. shall be required.
- Filter shall produce a continuous filtrate stream and a continuous reject stream and shall not be shut down for any backwash cycles. Backwash valves, pumps or instrumentation shall be required for backwash cycles.
- Sand bed shall be continuously backwashed internally and redistributed on top of the sand bed. No external sand movement or washing will be allowed.
- An airlift system is necessary to achieve media cleaning. This process requires air compressors, air dryers, receiving tank and airlift pump.
- There is a potential for high algae growth in filter basins if exposed to sunlight. Filters shall be designed with chlorine dosing to prevent algae growth.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

Ultraviolet Disinfection Process Flow Diagram

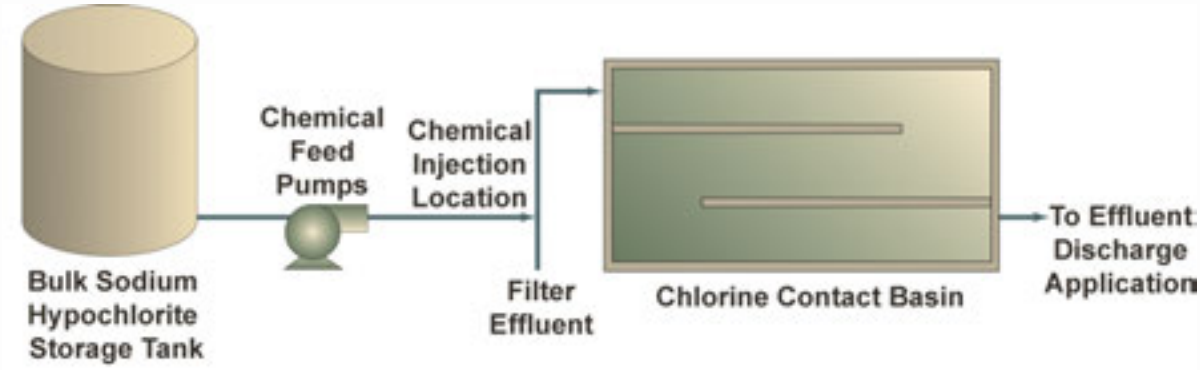
Ultraviolet Disinfection Design Criteria			
	Unit	**Value**	**Notes**
Type	Low Pressure / High Output, In-vessel or in-channel		
Design Flow Condition	Peak Day Flow		
Process Redundancy	A minimum of two parallel trains shall be provided. Full redundancy at peak day flow must be provided by including either a redundant reactor per train, or a completely redundant train.		
Lamp Output Wavelength	nm	254	
Design UV Transmittance (UVT)			
When using non-membrane filtration as a part of the treatment process upstream	%	≤ 55	Higher values may be used for plant expansions if supported by plant historical UVT data.
When using membrane filtration as a part of the treatment process upstream	%	≤ 65	Higher values may be used for plant expansions if supported by plant historical UVT data.

Ultraviolet Disinfection Design Criteria			
	Unit	**Value**	**Notes**
When using Reverse Osmosis as a part of the treatment process upstream	%	≤ 90	
Design UV Dose			
When using non-membrane filtration upstream of disinfection	$mW \cdot s/cm^2$	≥ 100	At peak day flow conditions with full redundancy
When using membrane filtration upstream of disinfection	$mW \cdot s/cm^2$	≥ 80	At peak day flow conditions with full redundancy
When using Reverse Osmosis upstream of disinfection	$mW \cdot s/cm^2$	≥ 50	At peak day flow conditions with full redundancy
UV Lamp Cleaning System	--	Mechanical / Chemical Wipers	
Minimum Lamp Life	hours	9,000	
UV Disinfection Influent Water Quality			
BOD_5	mg/L	≤ 5.0	
TSS	mg/L	≤ 5	
Disinfection Effluent Water Quality to meet Arizona Class A+			
Fecal Coliforms in 4 of last 7 samples	cfu/100 mL	Non-detect	
Fecal Coliforms 7 sample mean	cfu/100 mL	2.2	
Fecal Coliforms single sample maximum	cfu/100 mL	23	

Design Considerations for Ultraviolet Disinfection

- UV provides primary disinfection. For some effluent applications, a secondary disinfectant is required to maintain a residual. Bulk or onsite generated sodium hypochlorite is recommended for secondary disinfection. If no residual chlorination is required, dechlorination following UV disinfection is not necessary.
- In-vessel alternatives are preferred over in-channel alternatives for UV systems following membrane filtration processes. Utilizing in-vessel UV disinfection configurations following MBR or membrane filtration processes takes advantage of the pressure from the membrane permeate pumps to pump the water through the UV disinfection process.
- Background water characteristics, such as hardness and iron, also correlate to the fouling potential and resulting lamp cleaning demands.

- If the proposed facility will produce a Class A+ effluent, the designer shall comply with the Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse by the National Water Research Institute and American Water Works Association Research Foundation.
- The lamp array configuration must be the uniform array with all lamps parallel to each other and to the flow. The lamps shall be evenly spaced in horizontal and vertical rows with centerline spacing equal in both directions. The single array pattern shall be continuous and symmetrical throughout the reactor.
- The system shall be designed for complete immersion of the UV lamps including both electrodes and the full length of the lamp tube in the effluent. Both lamp electrodes shall operate at the same temperature and be cooled by the effluent.
- The UV dose produced by the system shall not be less than the design dose at the end of the design time period with the specified factors applied.
- A passive overflow must be provided for all in-channel UV disinfection applications.



Notes:
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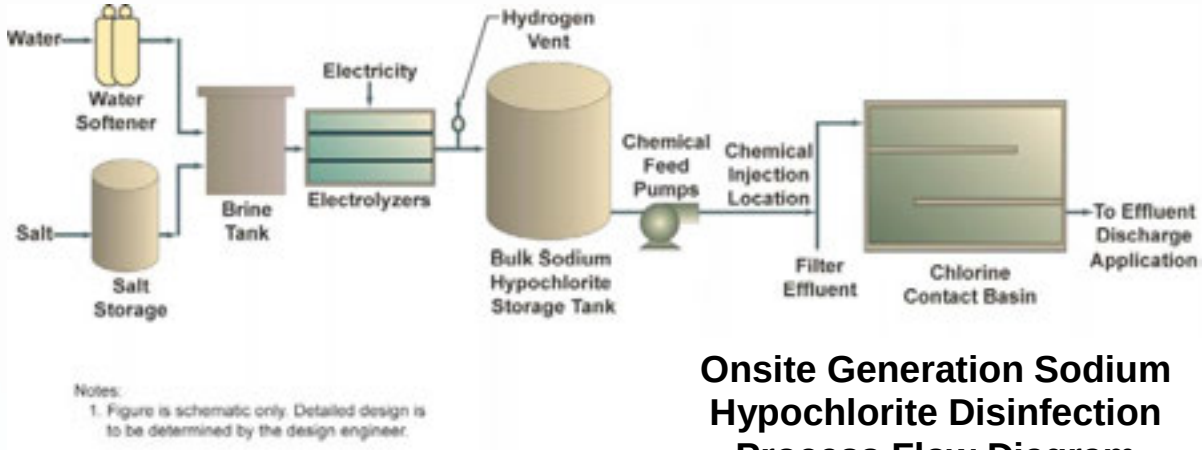
Bulk Sodium Hypochlorite Disinfection Process Flow Diagram

Bulk Sodium Hypochlorite Design Criteria			
	Unit	**Value**	**Notes**
Chemical Feed System			
Type	Bulk sodium hypochlorite		
Design Flow Condition	Pumping: Peak Chlorine Dose at Peak Hour Flow Storage: Average Chlorine Dose at Annual Average Day Flow		
Process Redundancy	Pumping: system shall be able to deliver peak dose at peak hour flow with one unit out of service. Storage: A minimum of two storage tanks shall be provided (see required storage time below).		
Chemical Storage under Average Day Demand	Minimum of 30 days of storage		
Type of Chemical	--	Liquid, 12.5% solution as chlorine	
Chlorine Degradation	--	8% solution as chlorine after 30 days of storage at 30° C	
Chemical Feed Pump Type	--	Positive displacement, variable speed driver	
Chlorine Contact Basin			
Design Flow Condition	Peak Hour Flow		
Process Redundancy	No redundant basins are required.		

Bulk Sodium Hypochlorite Design Criteria			
	Unit	**Value**	**Notes**
CT (Dose Concentration x Contact Time) Requirement	mg-minutes/L	≥ 360	
Minimum Contact Time	minutes	≥ 30	
Minimum Length to Width Ratio	L:W	40:1	
Depth to Width Ratio	D:W	1:1	
Chemical Injection Type	--	Chemical Injection Diffuser	
Disinfection Effluent Water Quality to meet Arizona Class A+			
Fecal Coliforms in 4 of last 7 samples	cfu/100 mL	Non-detect	
Fecal Coliforms 7 sample mean	cfu/100 mL	2.2	
Fecal Coliforms single sample maximum	cfu/100 mL	23	

Design Considerations for Bulk Chlorine Disinfection

- Chemical feed facilities must be designed to meet the criteria outlined in the Water and Wastewater Facility Guidelines, Chapter 6 Chemical Facilities (Carollo Engineers, 2010).
- Depending on reuse application, dechlorination may be required after disinfection with sodium bisulfite. For effluent alternatives that require a chlorine residual, dechlorination is not necessary.
- Design dosages provided herein (CT) are for primary disinfection only. Additional sodium hypochlorite necessary for other process areas within the WRF shall be considered separately from primary disinfection when determining pumping and storage requirements. When centralizing chlorine storage for primary disinfection and for ancillary purposes, the minimum required storage time of 30 days (based on average day demands) shall be maintained. Additional uses for sodium hypochlorite other than primary disinfection include, but are not limited to control of activated sludge bulking and foaming, reduction of biological growth on filters, shocking of process or reclaimed water pipelines, and odor control.
- The stability of hypochlorite is affected by heat, light, pH and the presence of heavy metal cations. Sodium hypochlorite solutions are vulnerable to significant loss of available chlorine over time. Solution deterioration shall be minimized by limiting exposure to sunlight by installing bulk sodium hypochlorite storage tanks under shade structures.
- Sodium hypochlorite shall be used as a secondary disinfectant when combined with UV disinfection as the primary disinfectant.



Onsite Generation Sodium Hypochlorite Disinfection Process Flow Diagram

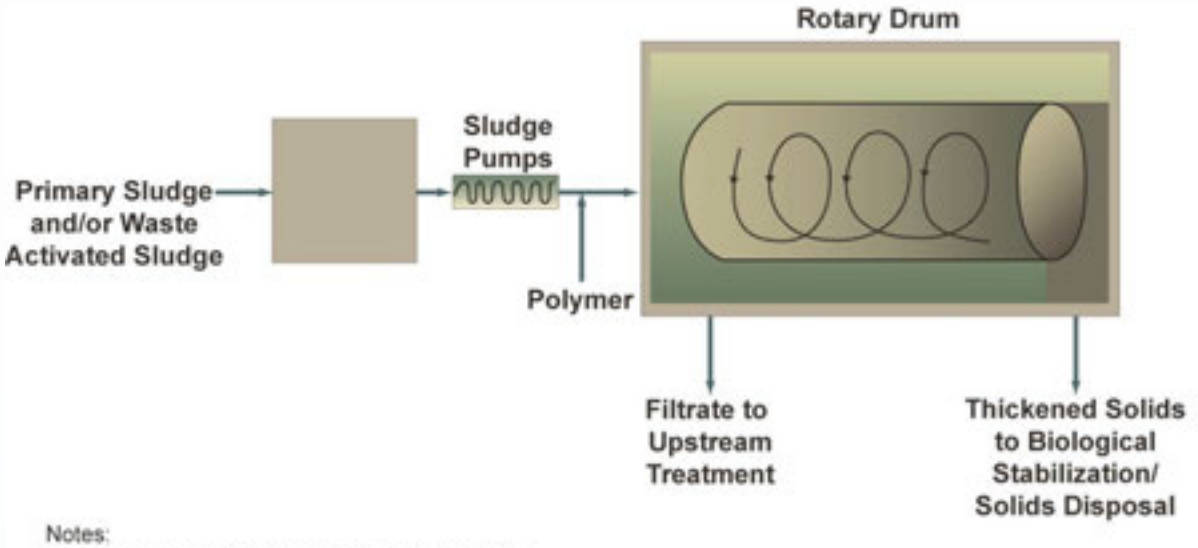
On-site Generation Sodium Hypochlorite Design Criteria			
	Unit	**Value**	**Notes**
Chemical Feed System			
Type	Onsite generated sodium hypochlorite		
Design Flow Condition	Pumping: Peak Chlorine Dose at Peak Hour Flow Storage: Average Chlorine Dose at Annual Average Day Flow		
Process Redundancy	Pumping: system shall be able to deliver peak dose at peak hour flow with one unit out of service. Storage: No redundancy is required for storage tanks (see required storage time below).		
Chemical Storage under Average Day Demand	Minimum of 5 days of storage		
Chemical Storage under Peak Day Demand	Minimum of 1 days of storage		
Generator Type	--	Electrolytic cell	
Type of Chemical Generated	--	Liquid, 0.8% solution as chlorine	
Chlorine Degradation	--	negligible after 5 days of storage	
Water Consumption	gallons / lb of available chlorine produced	15	
Salt Consumption	gallons / lb of available chlorine produced	3	

On-site Generation Sodium Hypochlorite Design Criteria			
	Unit	**Value**	**Notes**
Chemical Feed Pump Type	--	Positive displacement, variable speed driver	
Chlorine Contact Basin			
Design Flow Condition	Peak Hour Flow		
Process Redundancy	No redundant basins are required.		
CT (Dose Concentration x Contact Time) Requirement	mg-minutes/L	≥ 360	
Minimum Contact Time	minutes	≥ 30	
Minimum Length to Width Ratio	L:W	40:1	
Depth to Width Ratio	D:W	1:1	
Chemical Injection Type	--	Chemical Injection Diffuser	
Disinfection Effluent Water Quality to meet Arizona Class A+			
Fecal Coliforms in 4 of last 7 samples	cfu/100 mL	Non-detect	
Fecal Coliforms 7 sample mean	cfu/100 mL	2.2	
Fecal Coliforms single sample maximum	cfu/100 mL	23	

Design Considerations for Onsite Generation Chlorine Disinfection

- Chemical feed facilities must be designed to meet the criteria outlined in the Water and Wastewater Facility Guidelines, Chapter 6 Chemical Facilities (Carollo Engineers, 2010).
- Depending on the reuse application, dechlorination may be required after disinfection with sodium bisulfite. For effluent alternatives that require a chlorine residual, dechlorination is not necessary.
- Design dosages provided herein (CT) are for primary disinfection only. Additional sodium hypochlorite necessary for other process areas within the WRF shall be considered separately from primary disinfection when determining pumping and storage requirements. When centralizing chlorine storage for primary disinfection and for ancillary purposes, the minimum required storage time of 5 days (based on average day demands) shall be maintained. Additional uses for sodium hypochlorite other than primary disinfection include, but are not limited to control of activated sludge bulking and foaming, reduction of biological growth on filters, shocking of process or reclaimed water pipelines, and odor control.

- Design of onsite generation systems must incorporate provisions for the potential off-gassing from the generation system, to assist in optimizing system operation and minimizing operational safety concerns. Venting of by-product hydrogen must be addressed for safety reasons.
- Sodium hypochlorite shall be used as a secondary disinfectant when combined with UV disinfection as the primary disinfectant.
- Sodium Hypochlorite onsite generation shall be installed inside a building to house the equipment and the electrical system. The electrical service capacity must be considered.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

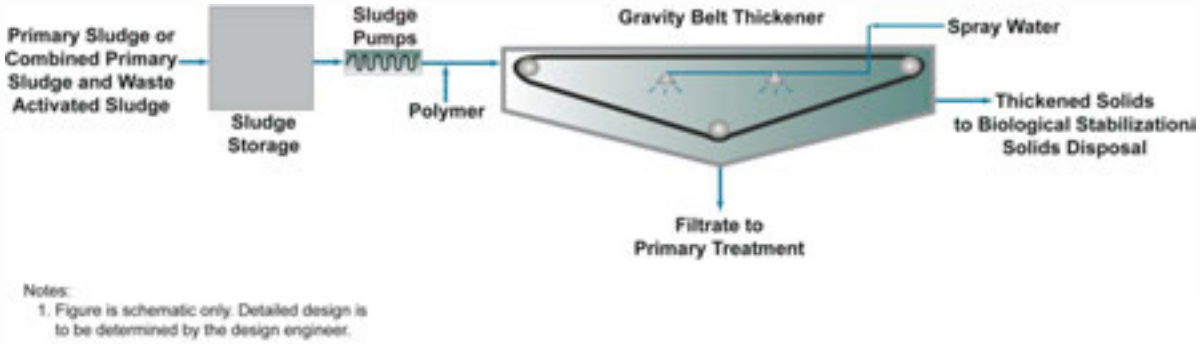
Rotary Drum Thickening Process Flow Diagram

Rotary Drum Thickener Design Criteria			
	Unit	**Value**	**Notes**
Type	Rotary Drum Thickener		
Design Flow Condition	Sludge production (primary sludge and/or waste activated sludge) at Maximum Month Average Day Influent Loadings [lb/day]. (MMAD Load [lb/day] = AAD Load [lb/day] x PF)		
Process Redundancy	One fully redundant thickener unit at MMAD loadings		
Type of Sludge	Primary sludge and/or waste activated sludge (WAS)		
Operating Schedule			
Days per Week, Not to Exceed	days	5	Longer operating schedules must be approved by the City on a case-by-case basis
Hours per Day, Not to Exceed	hr/day	8	Longer operating schedules must be approved by the City on a case-by-case basis.

Rotary Drum Thickener Design Criteria			
	Unit	**Value**	**Notes**
Feed Solids	Percent total suspended solids	0.5 to 3.0	
Volatile Feed Solids Content	Percent of total suspended solids	60 to 80	
Maximum Solids Size	inches	1	
Conditioning System	--	Polymer	
Thickened Solids Concentration	Percent on a dry weight basis at 0.5-3.0 percent feed solids	5.0	
Minimum Solids Capture Rate	Percent	≥ 90	
Sludge Storage Tank Minimum Holding Time (Upstream of RDT)	days	2	At MMAD loadings

Design Considerations for Rotary Drum Thickeners

- The drum wash system shall be designed to boost pressure as required by manufacturer and provide a continuous flow of plant service water to the spray header designed to keep the thickening drum orifices clear of solids.
- All wetted parts and the support structure of the rotary drum thickener shall be constructed of 316 stainless steel.
- A conditioning polymer system is required to optimize the thickened solids concentration. Polymer feed facilities must be designed to meet the criteria outlined in the Water and Wastewater Facility Guidelines, Chapter 6 Chemical Facilities (Carollo Engineers, 2010).
- Sludge is odorous and rotary drum thickeners will require containment and an odor control system.
- Rotary drum thickeners can treat both primary and waste activated sludge (WAS). The thickening process can be designed to treat primary sludge alone, WAS alone or co-thicken primary and WAS together.
- If co-thickening of primary sludge and WAS is performed, a blending tank shall be installed upstream of the thickening process to blend the two sludge types together prior to thickening. Sludge storage basins can serve as a blending tank.
- When thickening one type of sludge (primary sludge or WAS), a storage tank shall be installed upstream of the thickening process to provide flexibility for the thickening operations.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

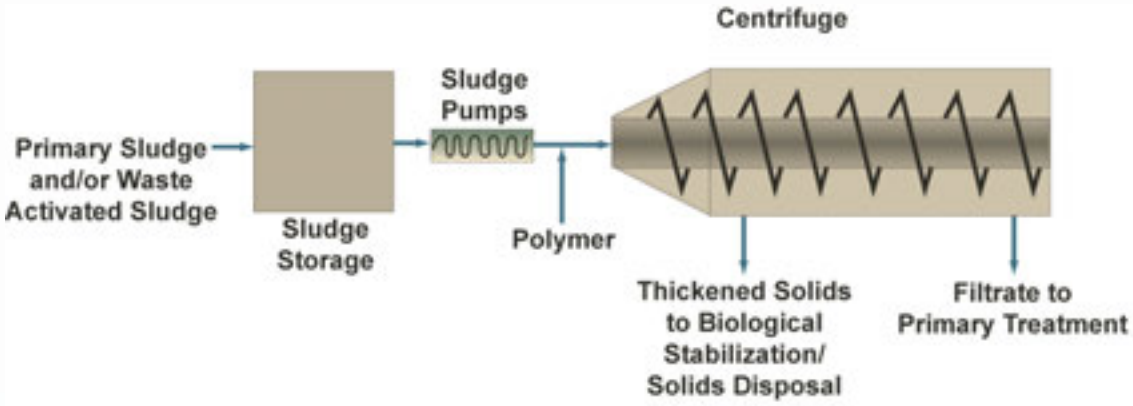
Gravity Belt Thickening Process Flow Diagram

Gravity Belt Thickener Design Criteria			
	Unit	**Value**	**Notes**
Type	Gravity Belt Thickener		
Design Flow Condition	Sludge production (primary sludge and/or waste activated sludge) at Maximum Month Average Day Influent Loadings [lb/day]. (MMAD Load [lb/day] = AAD Load [lb/day] x PF)		
Process Redundancy	One fully redundant thickener unit at MMAD loadings		
Type of Sludge	Primary sludge and/or waste activated sludge (WAS)		
Operating Schedule			
Days per Week, Not to Exceed	days	5	Longer operating schedules must be approved by the City on a case-by-case basis
Hours per Day, Not to Exceed	hr/day	8	Longer operating schedules must be approved by the City on a case-by-case basis.
Feed Solids	Percent total suspended solids	0.5 to 3.0	
Volatile Feed Solids Content	percent of total suspended solids	60 to 80	
Maximum Solids Size	inches	1	
Conditioning System	--	Polymer	
Thickened Solids Concentration	Percent	5.0	

Gravity Belt Thickener Design Criteria			
	Unit	**Value**	**Notes**
Minimum Solids Capture Rate	Percent	≥ 90	
Sludge Storage Tank Minimum Holding Time (Upstream of GBT)	days	2	At MMAD loadings

Design Considerations for Gravity Belt Thickeners

- Gravity belt thickeners are more suitable for primary sludge or co-thickening primary sludge and WAS. If co-thickening is performed, a blending tank is required upstream of the thickening process to blend the two sludge types together. Sludge storage basins can serve as a blending tank.
- Provide each gravity belt thickener with separate sludge conditioning device capable of efficiently mixing sludge with dilute polymer solution prior to discharge to gravity dewatering section of thickener. Sludge conditioning devices shall include in-line, non-clog, venturi-type sludge / polymer mixer and aging flocculation tank for polymer mixing and flocculation of feed sludge.
- Polymer feed facilities must be designed to meet the criteria outlined in the Water and Wastewater Facility Guidelines, Chapter 6 Chemical Facilities (Carollo Engineers, 2010).
- Sludge is odorous and gravity belt thickeners will require containment and an odor control system.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

Centrifuge Thickening Process Flow Diagram

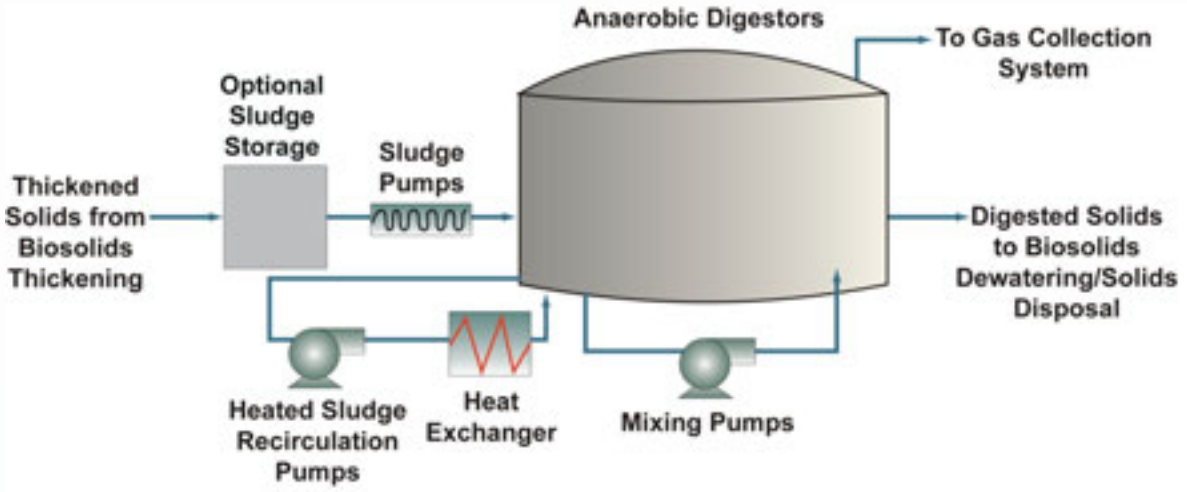
Centrifuge Thickener Design Criteria			
	Unit	**Value**	**Notes**
Type	Centrifuge Thickening		
Design Flow Condition	Sludge production (primary sludge and/or waste activated sludge) at Maximum Month Average Day Influent Loadings [lb/day]. (MMAD Load [lb/day] = AAD Load [lb/day] x PF)		
Process Redundancy	One fully redundant thickener unit at MMAD loadings		
Type of Sludge	Primary sludge and/or waste activated sludge (WAS)		
Operating Schedule			
Days per Week, Not to Exceed	days	5	Longer operating schedules must be approved by the City on a case-by-case basis
Hours per Day, Not to Exceed	hr/day	8	Longer operating schedules must be approved by the City on a case-by-case basis.
Feed Solids	Percent total suspended solids	0.5 to 3.0	

Centrifuge Thickener Design Criteria			
	Unit	**Value**	**Notes**
Volatile Feed Solids Content	Percent of total suspended solids	60 to 80	
Maximum Solids Size	inches	1	
Conditioning System	--	Polymer	
Thickened Solids Concentration	Percent on a dry weight basis at 0.5-3.0 percent feed solids	5	Range 5 - 8
Minimum Solids Capture Rate	Percent	≥ 90	
Sludge Storage Tank Minimum Holding Time (Upstream of Centrifuge)	days	2	At MMAD loadings
Noise suppression to maintain the average noise level measured at 3 feet around the periphery of centrifuge assembly without feed	decibels	≤ 88	
Vibration Displacement at pillow blocks when running without feed	mils	≤ 2	
Centrifuge Configuration	--	high speed, horizontal, cylindrical-conical, solid bowl, scroll type designed for continuous operation	
Acceleration due to gravity at the bowl wall at maximum design operating speed	Multiples of acceleration	≥ 3,000	

Design Considerations for Centrifuge Thickener

- All wetted parts of the centrifuge rotating assembly shall be AISI Type 316 stainless steel, except for the “O” rings, seals, and abrasion-resistant material. Frame shall be fabricated of cast iron and casing shall be fabricated of stainless steel.
- Bowl drive system shall consist of an electric motor and a belt drive system. Belt drive system shall consist of multiple belts as required to provide full load capacity and also to withstand the full starting torque of the system.
- In order to minimize wear due to abrasive materials in the feed, replaceable hard surfacing shall be provided at all points where the abrasive action of the sludge will cause wear on the metal parts of the centrifuge.

- Grit removal is required for facilities using centrifuges.
- Sludge is odorous and centrifuge thickeners will require containment and an odor control system.
- A conditioning polymer system is required to optimize the thickened solids concentration. Chemical feed facilities must be designed to meet the criteria outlined in the Water and Wastewater Facility Guidelines, Chapter 6 Chemical Facilities (Carollo Engineers, 2010).
- Centrifuge thickeners can treat both primary and waste activated sludge (WAS). The thickening process can be designed to treat primary sludge alone, WAS alone or co-thicken primary sludge and WAS together.
- If co-thickening of primary sludge and WAS is performed, a blending tank shall be installed upstream of the thickening process to blend the two sludge types together. Sludge storage basins can serve as a blending tank.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

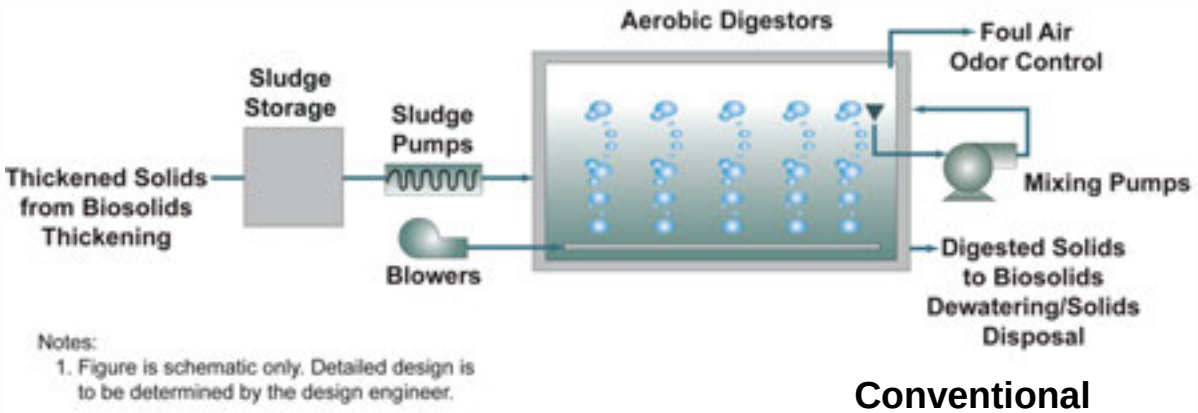
Conventional Anaerobic Digestion Process Flow Diagram

Conventional Anaerobic Digestion Design Criteria			
	Unit	**Value**	**Notes**
Type	Conventional Anaerobic Digestion		
Design Flow Condition	Sludge production (primary sludge and/or waste activated sludge) at Maximum Month Average Day Influent Loadings [lb/day]. (MMAD Load [lb/day] = AAD Load [lb/day] x PF)		
Process Redundancy	One fully redundant digester at MMAD loadings		
Type of Sludge	Thickened sludge (primary sludge and waste activated sludge)		
Solids Retention Time (with one digester out of service) at Maximum Month Average Day Loadings	days	≥ 15	Required to achieve Class B biosolids quality. Calculation of active volume shall consider grit accumulation (5 to 10 percent).
Temperature	°F	95	Mesophilic range (95 - 97 °F)
Feed Solids Concentration	Percent	3 - 5.5	
Digested Sludge Concentration	Percent	1 - 2	

Conventional Anaerobic Digestion Design Criteria			
	Unit	**Value**	**Notes**
Maximum Solids Loading Rate at Maximum Month Average Day Loading Conditions	lb VSS / ft^3•d	0.16	
Volatile Solids Destruction	Percent	40 - 55	
Gas Yield	ft^3/lb of Volatile Solids Destroyed	15	
Digester Mixing	No. of tank turn-overs in one day	8	
Optional Digested Sludge Storage Tank Retention Time	days	4	

Design Considerations for Conventional Anaerobic Digestion

- Conventional anaerobic digestion can be operated at both mesophilic (95 degrees Fahrenheit) or thermophilic (132 degrees Fahrenheit). The higher temperature is not recommended due to odor problems of the dewatering process.
- Components of the conventional digestion facility include digesters, sludge transfer system, mixing system, heating system (boiler and heat exchangers), gas handling system (piping, storage, flares and optional gas utilization equipment).
- Primary clarification is recommended if conventional anaerobic digestion is selected.



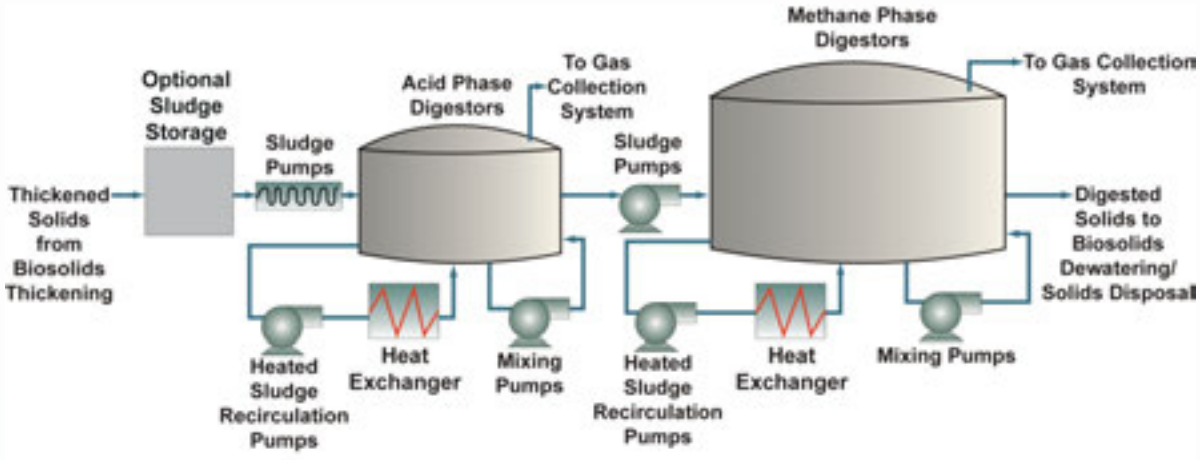
Conventional Aerobic Digestion Process Flow Diagram

Aerobic Digestion Design Criteria			
	Unit	**Value**	**Notes**
Type	Aerobic Digestion		
Design Flow Condition	Sludge production (primary sludge and/or waste activated sludge) at Maximum Month Average Day Influent Loadings [lb/day]. (MMAD Load [lb/day] = AAD Load [lb/day] x PF)		
Process Redundancy	One fully redundant digester at MMAD loadings		
Type of Sludge	Thickened sludge (primary sludge and waste activated sludge)		
Feed Solids Concentration	Percent	≤ 2.5	Range: 0.5 - 2.5
Solids Retention Time at Maximum Month Average Day Loadings, multiple compartments	Days at 68°F	40	Required to achieve Class B biosolids quality, include multiple compartments to allow one compartment out of service and still meet HRT

Aerobic Digestion Design Criteria			
	Unit	**Value**	**Notes**
	Days at 60°F	60	Required to achieve Class B biosolids quality, include multiple compartments to allow one compartment out of service and still meet HRT
Type of Aeration	--	Diffused Air, Fine or Coarse Bubble	
Air Requirements	--	Maximum of mixing air requirements (0.18 scfm/ft^2), or process air demand per oxygen demand calculations	
Dissolved Oxygen Residual in Liquid	mg/L	1 - 2	
Reduction of Volatile Suspended Solids	Percent	35-50	
Digested Sludge Storage Tank Retention Time	days	4	

Design Considerations for Aerobic Digestion

- Effective DO control is critical to the performance of the aerobic digestion and may help to reduce the electricity costs.
- Process design shall include process oxygen demand calculations based on endogenous respiration demands and nitrification. Alkalinity demands due to nitrification shall also be included in the design to determine whether a supplemental alkalinity system is required.
- Aerobic digestion often has odors and foam issues and requires an odor control system.
- Aerobic digestion is available in different forms such as Autothermal Thermophilic Aerobic Digestion (ATAD) and 2nd generation ATAD. These technologies operates at higher temperature through self-heated aerobic digestion and reduces HRT to 15 to 20 days. They have potential to achieve Class A biosolids, however, the foaming control, temperature control, and off-gas odor treatment have not been proven reliable.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

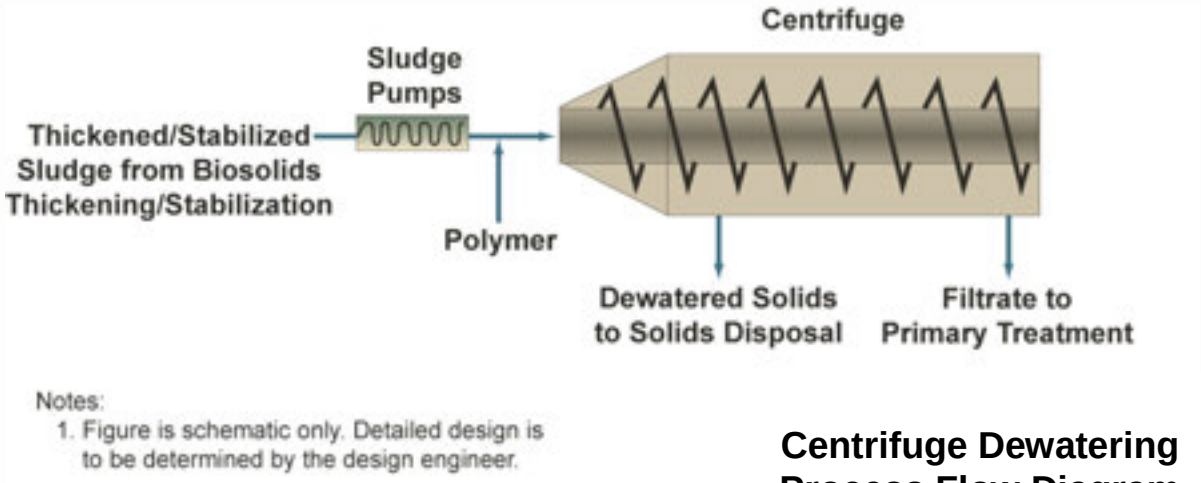
Multi-Phase Anaerobic Digestion Process Flow Diagram

Multi-Phase (Acid/Methane) Anaerobic Digestion Design Criteria			
	Unit	**Value**	**Notes**
Type	Multi-Phase Anaerobic Digestion with Mesophilic Acid phase and / Mesophilic or Thermophilic Methane Phase		
Design Flow Condition	Sludge production (primary sludge and/or waste activated sludge) at Maximum Month Average Day Influent Loadings [lb/day]. (MMAD Load [lb/day] = AAD Load [lb/day] x PF)		
Process Redundancy	One fully redundant digester (acid and methane) at MMAD loadings		
Type of Sludge	Thickened sludge (primary sludge and waste activated sludge)		
Solids Retention Time			
Acid Phase	days	1 - 2	
Methane Phase (Mesophilic)	days	15 days with all digesters in service, 12 days with 1 digester out of service	

Multi-Phase (Acid/Methane) Anaerobic Digestion Design Criteria			
	Unit	**Value**	**Notes**
Methane Phase (Thermophilic)	days	12 days with all digesters in service, 10 days with 1 digester out of service	
Temperature			
Mesophilic Stage	°F	95	Range (95 - 97 °F)
Thermophilic Stage	°F	125	Range (125 - 130 °F)
Feed Solids Concentration	Percent	6 - 8	
Digested Sludge Concentration	Percent	2 - 4%	
Acid Phase Solids Loading Rate	lb VSS / ft^3•d	1 - 3	
Acid Phase Volatile Solids Reduction	Percent	5	
Methane Phase Volatile Solids Destruction	Percent	50 - 70	
Acid Phase Gas Yield	ft^3/lb of Volatile Solids Destroyed	0.8	Very low heating value
Methane Phase Gas Yield	ft^3/lb of Volatile Solids Destroyed	15	
Digester Mixing	No. of tank turn-overs in one day	8	
Optional Digested Sludge Storage Tank Retention Time	days	4	

Design Considerations for Multi-Phase Anaerobic Digestion

- Multi-phase digestion can be operated stably at thermophilic temperature. The thermophilic methane digester may be followed with a small third phase transfer digester, which will reduce the potential of odor problems.
- Components of the multi-phase digestion facility are similar to the conventional anaerobic digestion, which include digesters (acid phase and methane phase), sludge transfer system, mixing system, heating system (boiler and heat exchangers), gas handling system (piping, storage, flares and optional gas utilization equipment).
- Primary clarification is recommended if multi-phase anaerobic digestion is selected.
- Sludge thickening to the specified feed solids concentration is required prior to multi-phase digestion.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

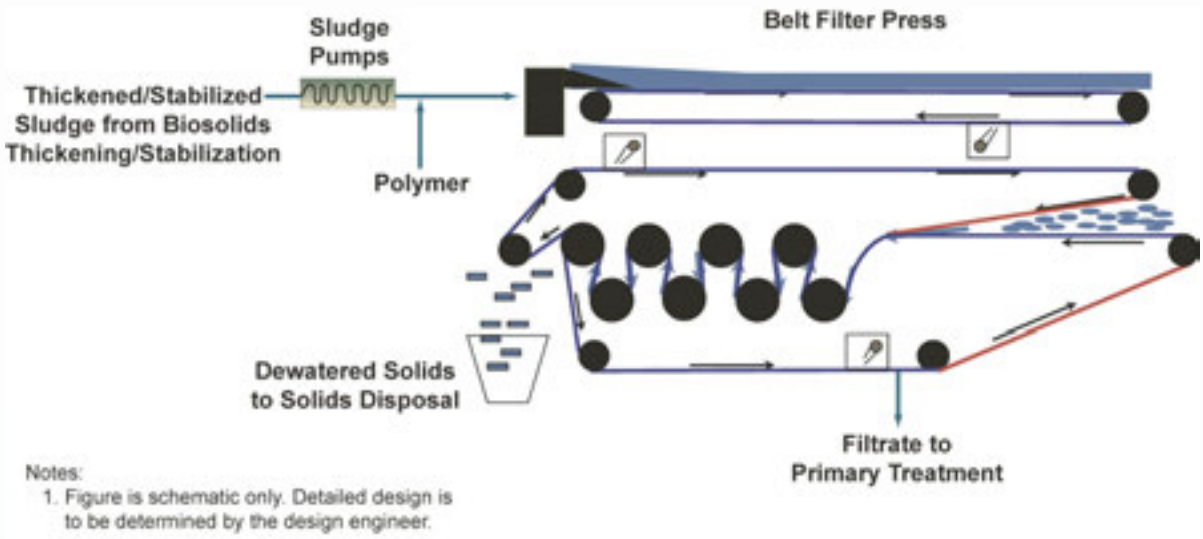
Centrifuge Dewatering Process Flow Diagram

Centrifuge Dewatering Design Criteria			
	Unit	**Value**	**Notes**
Type	Centrifuge Dewatering		
Type of Sludge	Digested Biosolids or Undigested Secondary Sludge (WAS)		
Design Flow Condition	Sludge production at Maximum Month Average Day Influent Loadings [lb/day]. (MMAD Load [lb/day] = AAD Load [lb/day] x PF)		
Process Redundancy	One fully redundant unit at MMAD loadings		
Operating Schedule			
Days per Week, Not to Exceed	days	5	Longer operating schedules must be approved by the City on a case-by-case basis.
Hours per Day, Not to Exceed	hr/day	8	Longer operating schedules must be approved by the City on a case-by-case basis.
Feed Solids	percent total suspended solids	Undigested WAS: 0.5 to 1.5 Digested biosolids: 1.5 to 4.0	
Maximum Solids Size	inches	1	
Conditioning System	--	Polymer	
Dewatered Solids Concentration	Percent	≥ 20	

Centrifuge Dewatering Design Criteria			
	Unit	**Value**	**Notes**
Solids Capture	Percent	95	
Sludge Storage Tank Minimum Holding Time (Upstream of Centrifuge)	days	3	At MMAD loadings. May be combined with digested sludge volume
Noise suppression to maintain the average noise level measured at 3 feet around the periphery of centrifuge assembly without feed	decibels	≤ 88	
Vibration Displacement at pillow blocks when running without feed	mils	≤ 2	
Centrifuge Configuration	--	high speed, horizontal, cylindrical-conical, solid bowl, scroll type designed for continuous operation	
Acceleration due to gravity at the bowl wall at maximum design operating speed	Multiples of acceleration	≥ 3,000	

Design Considerations for Centrifuge Dewatering

- All wetted parts of the centrifuge rotating assembly shall be AISI Type 316 stainless steel, except for the “O” rings, seals, and abrasion-resistant material. Frame shall be fabricated of cast iron and casing shall be fabricated of stainless steel.
- Bowl drive system shall consist of an electric motor and a belt drive system. Belt drive system shall consist of multiple belts as required to provide full load capacity and also to withstand the full starting torque of the system.
- In order to minimize wear due to abrasive materials in the feed, replaceable hard surfacing shall be provided at all points where the abrasive action of the sludge will cause wear on the metal parts of the centrifuge.
- Grit removal is required for facilities using centrifuges.
- Sludge is odorous and centrifuge dewatering will require containment and an odor control system.
- A conditioning polymer system is required to optimize the dewatered solids concentration. Chemical feed facilities must be designed to meet the criteria outlined in the Water and Wastewater Facility Guidelines, Chapter 6 Chemical Facilities (Carollo Engineers, 2010).



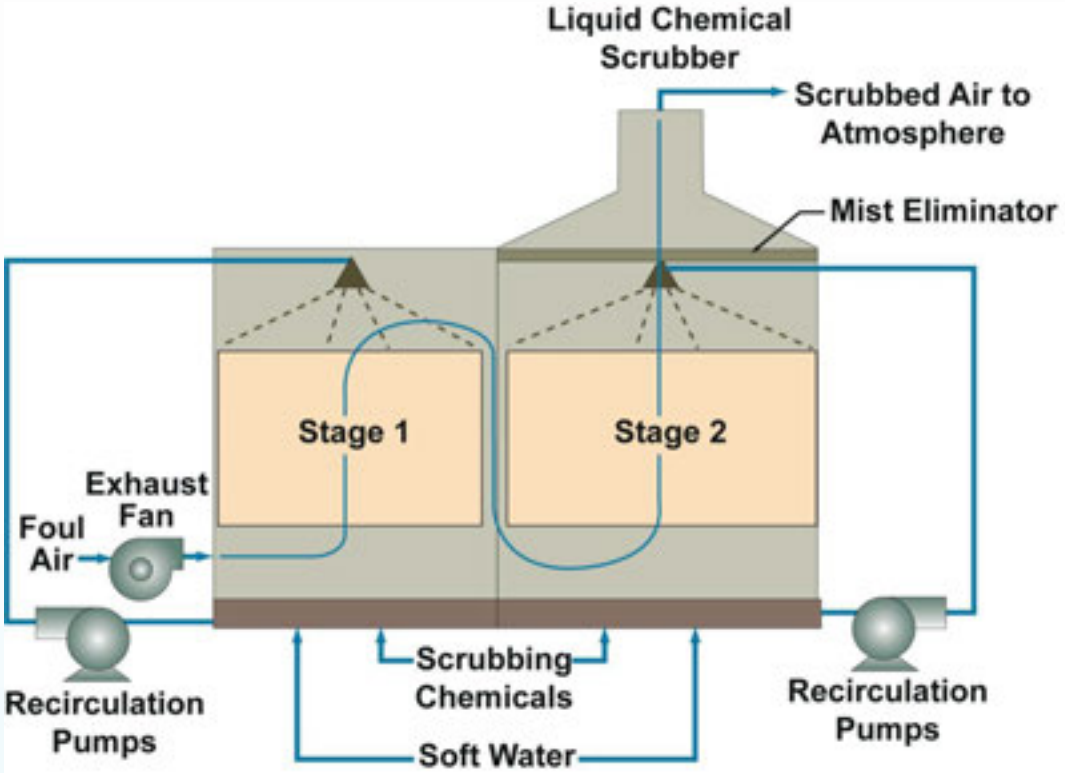
Belt Filter Press Dewatering Process Flow Diagram

Belt Filter Press Dewatering Design Criteria			
	Unit	**Value**	**Notes**
Type	Belt Filter Press Dewatering		
Design Flow Condition	Sludge production at Maximum Month Average Day Influent Loadings [lb/day]. (MMAD Load [lb/day] = AAD Load [lb/day] x PF)		
Process Redundancy	One fully redundant unit at MMAD loadings		
Type of Sludge	Digested Biosolids or Undigested Secondary Sludge (WAS)		
Operating Schedule			
Days per Week, Not to Exceed	days	5	Longer operating schedules must be approved by the City on a case-by-case basis
Hours per Day, Not to Exceed	hr/day	8	Longer operating schedules must be approved by the City on a case-by-case basis.
Feed Solids Concentration	Percent	Undigested WAS: 0.5 to 1.5 Digested biosolids: 1.5 to 4.0	

Belt Filter Press Dewatering Design Criteria			
	Unit	**Value**	**Notes**
Maximum Solids Size	inches	1	
Conditioning System	--	Polymer	
Polymer Injector Ring	--	Capable of splitting polymer flow and injection into minimum 4 separate points within sludge flow cross section.	
Source of Washwater	--	Reclaimed water	
Solids Capture	Percent	95	
Dewatered Cake Concentration	Percent	≥ 18	
Belt Service Life	hours	≥ 3,000	
Belt Dewatering Zones	--	Three zones: gravity, wedge and pressure/shear.	

Design Considerations for Belt Filter Press Dewatering

- Design system to allow belt replacement without disassembly of machine components or changes to belt pressure or alignment settings.
- Sludge is odorous and belt filter press dewatering will require containment and an odor control system.
- A conditioning polymer system is required to optimize the dewatered solids concentration. Chemical feed facilities must be designed to meet the criteria outlined in the Water and Wastewater Facility Guidelines, Chapter 6 Chemical Facilities (Carollo Engineers, 2010).



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

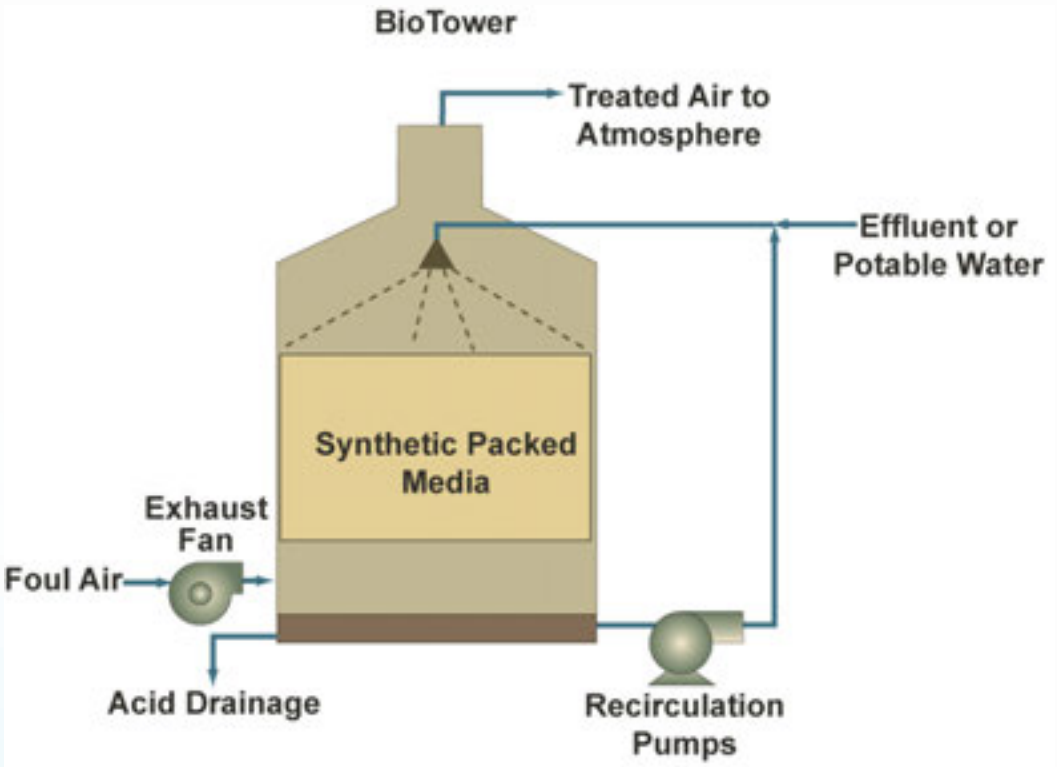
Liquid Chemical Scrubber Odor Control Process Flow Diagram

Liquid Chemical Scrubber Odor Control Design Criteria			
	Unit	**Value**	**Notes**
Type	Two or Three Stage Liquid Chemical Scrubber		
Design Flow Condition	Design for air changes per hour requirement and the amount of odor contaminant to remove, specific to each process area		
Process Redundancy	One fully redundant unit		
Air Changes per Hour		> 12	Requirement depends upon the process area being treated. Refer to NFPA 820.
Typical Scrubbing Chemicals	--	12.5% NaOCl, 25% NaOH	
Packing Material	--	corrosion resistant polypropylene	

Liquid Chemical Scrubber Odor Control Design Criteria			
	Unit	**Value**	**Notes**
Minimum H_2S Removal Efficiency	Percent	99.0	
Vessel Material	--	FRP	

Design Considerations for Liquid Chemical Scrubber Odor Control

- A liquid distribution header shall be provided to uniformly distribute the scrubbing liquid onto the packing material.
- The gases shall pass through a high efficiency mist eliminator prior to discharging into the stack. The spray nozzles shall be specifically designed to be clog resistant.
- A water softener system must be provided to meet the required make-up water flow.
- If NaOCl and NaOH are available on site, the chemical system can be sized to provide these chemicals for the scrubber. Dedicated pumps for the odor control system will be required.
- Liquid chemical scrubbers must be placed in a contained area.



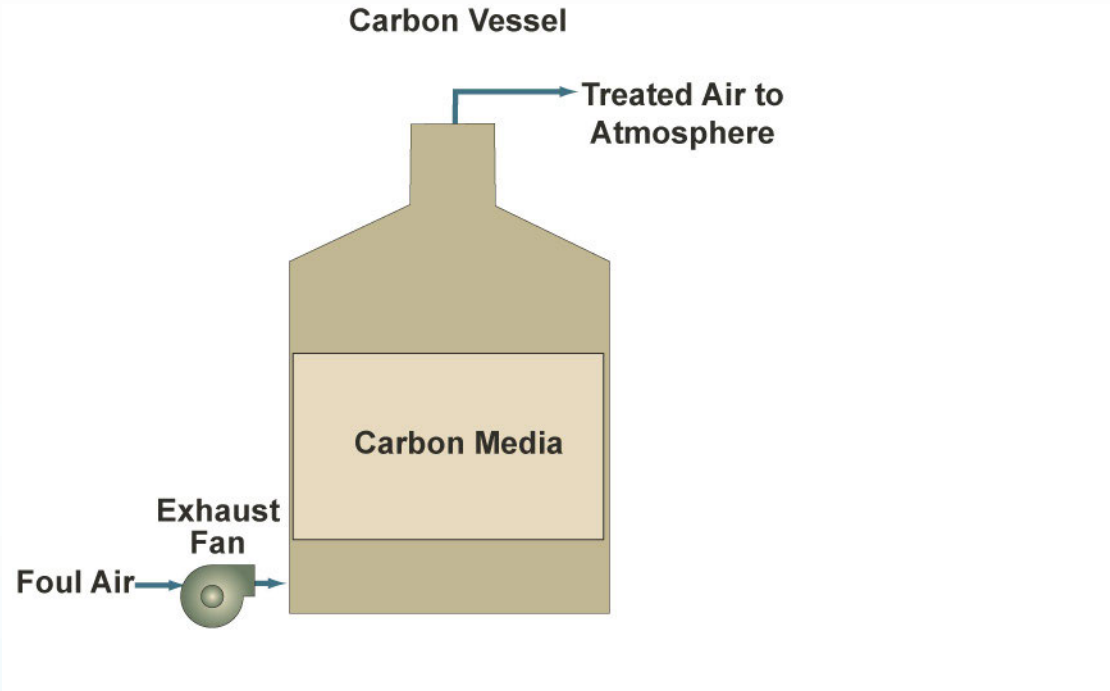
Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

BioTower Odor Control Process Flow Diagram

BioTower Odor Control Design Criteria			
	Unit	**Value**	**Notes**
Type	BioTower		
Design Flow Condition	Design for air changes per hour requirement and the amount of odor contaminant to remove, specific to each process area		
Process Redundancy	One fully redundant unit required		
Air Changes per Hour		> 12	Requirement depends upon the process area being treated. Refer to NFPA 820.
Packing Media	--	synthetic media (foam, lava rock, plastic, etc.)	
Residence Time	seconds	30 - 60	
Recirculation Rate	gpm/ft^2	0.35 - 0.7	
Pressure Drop of Conventional Biofilters	inches of water	8 to 12	
H_2S Removal Efficiency	%	90 to 99	

Design Considerations for BioTower Odor Control

- A BioTower odor control system requires a rectangular or circular vessel, air distribution system, medium, and a means of maintaining minimum moisture content in the medium.
- The media must be split into layers to eliminate compaction.
- The scrubbing solution shall be evenly distributed over the top of the media.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

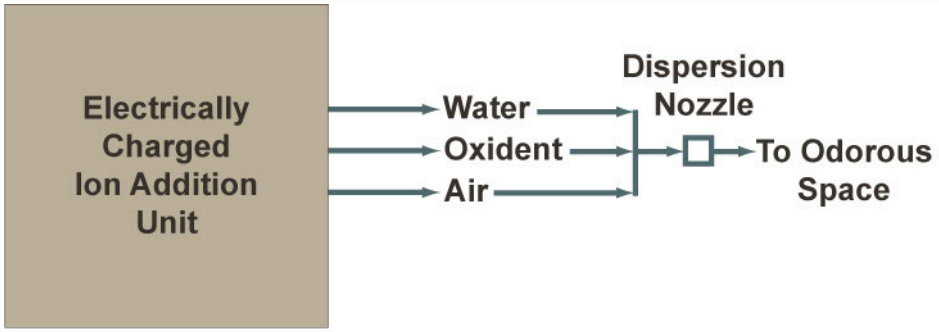
Carbon Odor Control Process Flow Diagram

Carbon Adsorption Odor Control Design Criteria			
	Unit	**Value**	**Notes**
Type	Dual Bed Carbon Adsorption		
Design Flow Condition	Design for air changes per hour requirement and the amount of odor contaminant to remove, specific to each process area		
Process Redundancy	One fully redundant unit		
Air Changes per Hour		> 12	Requirement depends upon the process area being treated. Refer to NFPA 820.
Vessel Material	--	FRP	
Packing Material Type	--	Activated Carbon, virgin, palletized, derived from high-grade bituminous coal, vapor phase type	
Packing Material Mean Particle Diameter	mm	3.9 to 4.1	

Carbon Adsorption Odor Control Design Criteria			
	Unit	**Value**	**Notes**
Packing Material Apparent Density	g/L	460 to 520	
Face Velocity through System	ft/min	40 to 50	
Media depth	ft	3	
Pressure Drop for a new, loosely packed (upflow) 3-foot deep bed	inches of water	6 to 12	
H_2S Removal Efficiency	%	99.0	

Design Considerations for Carbon Adsorption Odor Control

- The life of a carbon adsorption bed is limited, so the carbon must be regenerated or replaced regularly for continued odor removal.
- Activated carbon absorbers shall be used as a polishing filter, following a liquid chemical scrubber or BioTower. This configuration provides a robust odor control alternative and helps prolong the life of the carbon.



Notes:
1. Figure is schematic only. Detailed design is to be determined by the design engineer.

Electrically Charged Ion Addition Odor Control Process Flow Diagram

Electrically Charged Ion Addition Odor Control Design Criteria			
	Unit	**Value**	**Notes**
Type	Electronically Charged Ion Addition		
Design Flow Condition	Design for air changes per hour requirement and the amount of odor contaminant to remove, specific to each process area		
Process Redundancy	One fully redundant unit		
Air Changes per Hour		> 12	Requirement depends upon the process area being treated. Refer to NFPA 820.
H_2S Removal Efficiency	%	99.0	

Design Considerations for Electrically Charged Ion Addition Odor Control

- Control of odors using ion addition occurs at the source of the odor, and uses the odorous space as the reactor to oxidize the odors and stop corrosion. One unit is required for each process area requiring treatment.
- Electrically charged ion addition type odor control is best suited for small pump stations and wet well applications.
- Electrically charged ion addition can serve as a supplementary system odor control system to liquid chemical scrubbers to knock down odors prior to reaching the main odor control system.

9.0 SUMMARY AND CONCLUSIONS

This Wastewater Technology Assessment project was completed to accomplish the following:

- Provide the foundation for uniformity in approach to future City of Surprise wastewater treatment facilities and infrastructure.
- Provide a mechanism to obtain consensus from all sectors and levels of City management on City wastewater treatment and infrastructure policy.
- Provide technically feasible, cost effective, and reliable approaches to meet the regulatory requirements for wastewater treatment facilities and infrastructure.
- Establish a position which enhances the City's control over the planning and implementation process for its future wastewater treatment facilities and infrastructure.
- It was critical that the City establish reasonable policies and defensible design criteria and guidelines, which promote the timely and cost effective construction of new water reclamation facilities. This project provides the City of Surprise with a series of documents that outline design guidelines and standards for future wastewater facilities and infrastructure for the community.

The Wastewater Technology Assessment identifies and discusses technologies for treating the City's future wastewater. Current, proposed, and future regulations were reviewed and Reclaimed Water Quality Standards were established based on input from City staff and developer representatives. The City of Surprise Reclaimed Water Quality Standards establish treatment standards for all future water reclamation facilities within the City. BOD, TSS, nitrification-denitrification, turbidity, pathogens, and DBP control were identified as CoCs by the City. Viable wastewater treatment technologies were reviewed and recommendations were made regarding the most appropriate/applicable treatment processes to address the established CoCs.

A customized tool called SurpriseTree™ Wastewater was created for the City to compare wastewater treatment technologies. This tool allows the City to input future site-specific information to assist in identifying the best alternative for wastewater treatment. All treatment processes recommended meet the City's Reclaimed Water Quality Standards and biosolids disposal requirements.

Based on general ranking results as presented in the SurpriseTree™ Wastewater Model, the most favorable treatment technologies recommended to achieve the City's reclaimed water treatment standards include:

- Preliminary Treatment: Step/stair screen, rotary screen, fine screens
- Grit Removal: Mechanical vortex, free vortex.
- Primary Treatment: Primary clarifiers.
- Biological Treatment: Extended aeration, MLE activated sludge, MBR.

- Clarification: Secondary clarifiers.
- Filtration: Cloth type disk filter, continuous upflow granular media filter, traveling bridge filter.
- Disinfection: UV, sodium hypochlorite bulk, sodium hypochlorite onsite.

Based on general ranking results from the SurpriseTree™ Wastewater Model, the most favorable treatment technologies identified to address the City's biosolids treatment standards (volatile solids reduction, pathogen reduction and volume reduction) include:

- Biosolids Thickening: Rotary drum thickening, gravity belt thickening, centrifuge thickening.
- Biosolids Stabilization: Conventional anaerobic digestion, conventional aerobic digestion, multi-phase anaerobic digestion.
- Biosolids Dewatering: Centrifuge dewatering, belt filter press.

Liquid chemical scrubber, BioTower, carbon and electrically charged ion addition are the most favorable odor control alternatives, as identified by the SurpriseTree™ Wastewater Model.

The treatment alternatives outlined above were recommended for the City's further consideration based on their general performance and cost effectiveness. More detailed treatment train recommendations based on site-specific inputs, are available through the use of the SurpriseTree™ model.

Implementation Packages were developed for each of the noted technologies. The City can choose to use the SurpriseTree™ Wastewater Model to assist in selecting the most appropriate technology for a new WRF, or to check the decisions made by a developer/engineer during the planning for a new WRF. The City can then access the Implementation Packages from the model and provide them to the developer to assist in ensuring the planning and design is consistent with the City's standards for the associated technologies. The developer should use the Implementation Packages as the basis for the design of the new WRF. The user should always carefully review the SurpriseTree™ Wastewater Model outputs prior to using the Implementation Packages as certain technologies should or should not be implemented when another technology is selected, based on specific engineering and policy reasons.

At the final stages of the Wastewater Technology Assessment project the following items were identified to be evaluated during the future updates of the Wastewater Technology Assessment report:

1) Further evaluation is necessary to clarify that the facility design should be based on the end use of the reclaimed water (recharge technology, uses of reuse water, etc.).

2) Further evaluation is necessary on the reduction of TOC or DBP precursors. Since disinfection alone will not help us to deal with the TTHM issue, additional process to reduce precursors should be evaluated.
3) Future evaluation should review upcoming regulation changes, emerging contaminants and technologies, and their applicability to the City.
4) Future evaluation should coordinate with the Integrated Water Master Plan updates.
5) The City's current experience with wastewater treatment is mainly associated with the SPA 1 WRF, which is an oxidation ditch plant. SPA 2 WRF, the City's first MBR plant, was recently commissioned. In the future update, raw and treated water quality data from SPA 2 WRF should be analyzed and used as important planning basis for future facilities. This may play an important role in assessing TOC / DBP mitigation as it is expected that the chlorine demand for the membrane product water will be different from the oxidation ditch plant effluent.

This project also includes a Water Technology Assessment Report and Water and Wastewater Facility Guidelines. Refer to Water Technology Assessment Report (Carollo Engineers 2011) for an assessment of water treatment technologies for the City of Surprise. Refer to Water and Wastewater Facility Guidelines Volumes I, II, III (Carollo Engineers 2011) for guidelines associated with the design of water and wastewater treatment support facilities.

WORKSHOP TA3
WASTEWATER TREATMENT TECHNOLOGY EVALUATION

SURPRISE
ARIZONA

Wastewater Design Standards and Technology Assessments

Workshop No. TA4: Wastewater Treatment Technology Evaluation

February 11th, 2010, 9:30 AM – 5:00 PM

carollo
Engineers...Working Wonders With Water™

Agenda

1. Introduction (9:30 - 9:35 AM)
2. WW Treatment Unit Process Evaluation (9:35 AM –11:30 AM)
3. Odor Control Unit Process Evaluation (11:30 – 12:00 PM)
4. Lunch Break (12:00 – 1:00 PM)
5. Biosolids Treatment Unit Process Evaluation (1:00 – 3:00 PM)
6. WW Treatment Technology Screening Analysis (3:00 – 4:00 PM)
7. Next Steps (4:00 – 5:00 PM)

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Progress Since Workshop TA3

Technology Assessment

- Conducted Water Quality Standards Meeting Held
  - City and Developer Representative Comments Incorporated
- New Version of SurpriseTree™ Model Released
- Water Technology Assessment Basis of Design, Process Flow Diagrams and Design Considerations presented for City Review
- Water TAR Report Developed and in Internal Review
- Conducted Initial Discussion on Wastewater Treatment Technology Assessment Deliverable Format

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Workshop TA4 Objectives

- Present Wastewater Treatment Technology Evaluation
- Present Odor Control Technology Evaluation
- Present Biosolids Treatment Technology Evaluation
- Achieve Consensus on Wastewater TAR Deliverable Format and Directions for Next Steps

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City's Wastewater Treatment Status and Standards

1. The City's wastewater treatment facility shall be designed to meet, at a minimum, the alert levels defined in the APP permit, the BADACT requirement and the Class A+ reclaimed water quality standards.
2. Alert Levels (AL) defined in APP Permit often govern the design of the treatment facility.
   a. 80% of the discharge limits for discharge monitoring
   b. 80% of the Aquifer Quality Limit (AQL) for groundwater monitoring
   c. Flow Alert Level as 95% of the Flow Limit (Capacity in average month flow permitted)

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City's Wastewater Treatment Standards (See Handout) 1 of 3

Parameter	BADCT Effluent Limits	Class A+ Effluent Limits	Aquifer Protection Permit SPA-1 WRF[1]					Recommended City of Surprise Reclaimed Water Quality Standards
			Discharge Monitoring[2]		Reclaimed Water Monitoring[2]	Groundwater Monitoring[2]		
			Alert Level	Discharge Limit	Discharge Limit	Alert Level	Aquifer Quality Limit	
Effluent Quality Class Requirement	-	-	-	-	Class A+	-	-	Class A+
pH (std)	6.0 - 9.0	-	-	-	-	-	-	6.0 - 9.0
DO (mg/L)	-	-	-	-	-	-	-	2.0[3]
BOD_5 (mg/L)	< 30	-	-	-	-	-	-	< 30
TSS (mg/L)	< 30	-	-	-	-	-	-	< 10[4]
Total Nitrogen (mg/L as N)[5]	< 10	< 10	8	10	10	8	10	< 8
Nitrate (mg/L as N)	-	-	-	-	-	8	10	< 8
Nitrite (mg/L as N)	-	-	-	-	-	8	10	< 8
Turbidity (NTU)								
Daily (24-hour) average	-	2	-	-	2	-	-	2
Single sample maximum	-	5	-	-	5	-	-	5
Total Coliform (cfu/100 mL)	-	-	-	-	-	Non-detect	Non-detect	-
Fecal Coliform (cfu/100 mL)								
Single sample maximum	23	23	Not Established	23	23	-	-	23
Seven sample median	2.2	-	-	-	-	-	-	-
Four out of last seven daily samples	-	Non-Detect	Not Established	Non-Detect	Non-Detect	Non-detect	Non-detect	Non-Detect
TDS (mg/L)	-	-	-	-	-	-	-	1000[6]
Chloride (mg/L)	-	-	-	-	-	-	-	250[6]
Sodium (mg/L)	-	-	-	-	-	-	-	150[6]

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City's Wastewater Treatment Standards (See Handout) 2 of 3

Parameter	BADCT Effluent Limits	Class A+ Effluent Limits	Aquifer Protection Permit SPA-1 WRF[1]					Recommended City of Surprise Reclaimed Water Quality Standards
			Discharge Monitoring[2]		Reclaimed Water Monitoring[2]	Groundwater Monitoring[2]		
			Alert Level	Discharge Limit	Discharge Limit	Alert Level	Aquifer Quality Limit	
Antimony (mg/L)	-	-	0.0048	0.006	-	0.0048	0.006	0.0048
Arsenic (mg/L)	-	-	0.04	0.05	-	0.04	0.05	0.04
Barium (mg/L)	-	-	1.60	2.00	-	1.60	2.00	1.60
Beryllium (mg/L)	-	-	0.0032	0.004	-	0.0032	0.004	0.0032
Cadmium (mg/L)	-	-	0.004	0.005	-	0.004	0.005	0.004
Chromium (mg/L)	-	-	0.08	0.1	-	0.08	0.1	0.08
Cyanide (mg/L)	-	-	0.16	0.2	-	0.16	0.2	0.16
Fluoride (mg/L)	-	-	3.2	4.0	-	3.2	4.0	3.2
Lead (mg/L)	-	-	0.04	0.05	-	0.04	0.05	0.04
Mercury (mg/L)	-	-	0.0016	0.002	-	0.0016	0.002	0.0016
Nickel (mg/L)	-	-	0.08	0.1	-	0.08	0.1	0.08
Selenium (mg/L)	-	-	0.04	0.05	-	0.04	0.05	0.04
Thallium (mg/L)	-	-	0.0016	0.002	-	0.0016	0.002	0.0016
Benzene (mg/L)	-	-	0.004	0.005	-	0.004	0.005	0.004
Carbon tetrachloride (mg/L)	-	-	0.004	0.005	-	0.004	0.005	0.004
o-Dichlorobenzene (mg/L)	-	-	0.48	0.6	-	0.48	0.6	0.48
para-Dichlorobenzene (mg/L)	-	-	0.06	0.075	-	0.06	0.075	0.06
1,2-Dischloroethane (mg/L)	-	-	0.004	0.005	-	0.004	0.005	0.004
1,1-Dichloroethylene (mg/L)	-	-	0.0056	0.007	-	0.0056	0.007	0.0056
cis-1,2-Dichloroethylene (mg/L)	-	-	0.05	0.07	-	0.05	0.07	0.05
trans-1,2-Dichloroethylene (mg/L)	-	-	0.08	0.1	-	0.08	0.1	0.08

City's Wastewater Treatment Standards (See Handout) 3 of 3

Parameter	BADCT Effluent Limits	Class A+ Effluent Limits	Aquifer Protection Permit SPA-1 WRF[1]					Recommended City of Surprise Reclaimed Water Quality Standards
			Discharge Monitoring[2]		Reclaimed Water Monitoring[2]	Groundwater Monitoring[2]		
			Alert Level	Discharge Limit	Discharge Limit	Alert Level	Aquifer Quality Limit	
Dichloromethane (mg/L)	-	-	0.004	0.005	-	0.004	0.005	0.004
1,2-Dichloroproane (mg/L)	-	-	0.004	0.005	-	0.004	0.005	0.004
Ethylbenzene (mg/L)	-	-	0.56	0.7	-	0.56	0.7	0.56
Monochlorobenzene (mg/L)	-	-	0.08	0.1	-	0.08	0.1	0.08
Styrene (mg/L)	-	-	0.08	0.1	-	0.08	0.1	0.08
Tetrachloroethylene (mg/L)	-	-	0.004	0.005	-	0.004	0.005	0.004
Toluene (mg/L)	-	-	0.8	1.0	-	0.8	1.0	0.8
Trihalomethanes (total) (mg/L)	-	-	0.08	0.1	-	0.08	0.1	0.08
1,1,1-Trichloroethane (mg/L)	-	-	0.16	0.2	-	0.16	0.2	0.16
1,2,4-Trichlorobenzene (mg/L)	-	-	0.056	0.07	-	0.056	0.07	0.056
1,1,2-Trichloroethane (mg/L)	-	-	0.004	0.005	-	0.004	0.005	0.004
Trichloroethylene (mg/L)	-	-	0.004	0.005	-	0.004	0.005	0.004
Vinyl Chloride (mg/L)	-	-	0.0016	0.002	-	0.0016	0.002	0.0016
Xylenes (Total) (mg/L)	-	-	8.0	10.0	-	8.0	10.0	8.0

Notes:
(1) State of Arizona Aquifer Protection Permit No. P-102478, July 2009
(2) Sampling and Reporting Frequency is Daily, Weekly, Monthly, or Quarterly, as outined in the APP.
(3) For secondary treatment process control.
(4) Based on a Turbidity < 2 NTU
(5) Based on a 5 sample rolling geometric mean.
(6) Based on City of Phoenix and City of Scottsdale Reclaimed Water Quality Goals. High salinity and sodium will impact the reuse potential as irrigaiton water. High chloride causes effluent toxicity and could limit the discharge capability.

Achieving the City's Wastewater / Biosolids Treatment Standards Requires Multiple Treatment Categories

Liquid Stream

Category	TSS Removal	BOD Removal	N-DeN	Turbidity	Pathogen	DBP
Preliminary	X	X	X	X		
Grit	X	X	X	X		
Primary	X	X	X			
BOD and N-DeN	X	X	X	X		
Clarification	X	X	X	X		
Filtration				X	X	
Disinfection					X	X

Odor Control

Category	H_2S Odor	Ammonia Odor	Reduced Sulfides Odor
Odor	X	X	X

Biosolids

Category	Volatile Solids Reduction	Biosolids Pathogen	Biosolids Volume Reduction
Thickening			X
Stabilization	X	X	X
Dewatering			X
Advanced Biosolids Treatment	X	X	X
Disposal	X	X	X

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Wastewater Treatment Technology Assessment

Preliminary Treatment

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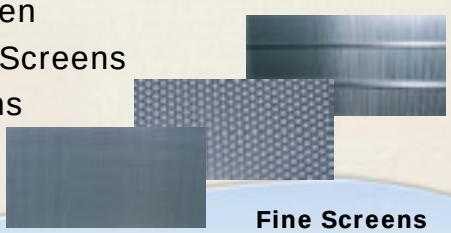
Preliminary Treatment - Available Options

1. Coarse Screens (6 mm / 0.25 in or larger)
   a. Trash Rack
   b. Manual Screen
   c. Mechanically Cleaned Bar Screen

Coarse Screen

2. Fine Screens (6 mm / 0.25 in or smaller)
   a. Rotary Drum Screen
   b. Step / Stair Screen
   c. Band / Belt Fine Screens
   d. Ultra Fine Screens



Fine Screens

Trash Racks are Designed to Capture Large Debris

1. 38 to 150 mm / 1.5 - 6 in
2. Designed to prevent logs, timbers, and other large debris from entering pumping equipment or treatment processes.

Manually Raked Coarse Screens are Not Recommended

1. Manually Cleaned Bar Screen (30 to 50 mm / 1 to 2 in)
   a. Designed to remove large solids, rags, and debris.
   b. Bars set at 30 to 45 degrees from vertical to facilitate cleaning.
   c. Primarily used in older or smaller treatment facilities, or in **bypass channels.**

Recommendation on Redundancy
- N+1 automatic screens
- 1 bypass channel with manually raked screen

Mechanically Cleaned Coarse Screening

- Openings 6 mm / 0.25 in or larger
- Self cleaning
- Deep channels
- High screenings loads and fast removal rates
- Low head loss and high flows

Chain Driven Catenary & Rake

Climber Screens

Continuous Belt

Curved Screen

About Equipment Manufacturers

- For most of the products being reviewed, there are multiple manufacturers.

- This presentation may include some manufacturer's products as examples.
- The TAR recommendation focuses on what type/category of screen to select, but does not intend to select/lock-in a specific manufacturer.

Mechanically Cleaned
Catenary and Chain Driven Rake

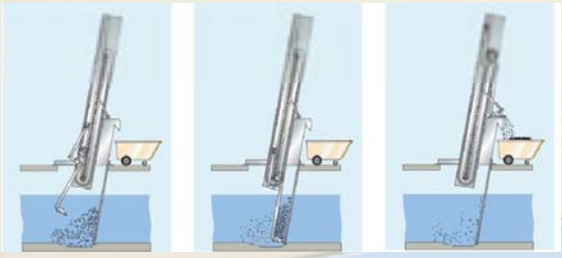
Catenary	Chain Driven Rake
Front Clean, Front Return	Front clean, front return; Front clean, back return; Back clean, back return
Heavy chain design; Difficult to handle	Submerged moving parts may require dewatering of the channel
	May have screenings carryover or rake jam
Large footprint; May emit odor	
Inexpensive	

Mahr®

RakeMax®

Mechanically Cleaned
Reciprocating Rake (Climber)

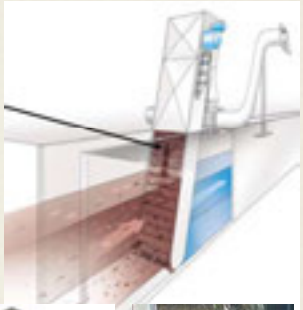
- Imitates the movement of manually raking the screen
- No submerged moving parts
- Can handle large objectives (grit accumulation may impede rake movement)
- Requires more headroom than other screens

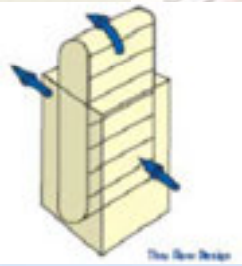


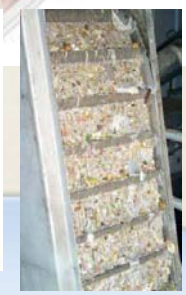
ClimbMax® Mensch Crawler™

Mechanically Cleaned
Continuous Belt

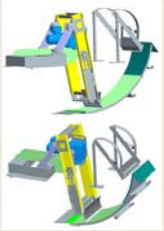
- **Flow passes through screens twice**
- **Screen cleaning is critical to performance**
- **Perforated plates**
- Compact design and **low installation height**
- Completely encased for odor withdrawal







Coarse Screen Comparison

RakeMax®	ClimbMax®	EscaMax®	CurveMax®
			
•Very high screenings discharge capacity •Low headloss •**Low installation height** above ground level even in deep channels •Control-independent safety system •Completely encased for odor withdrawal	•**All moving parts above water** •Rake guidance •**Reliable & low maintenance** •High flow rates •Low head loss •Easy to retrofit •Channel width: 0.6 to 4 m •Discharge height: ≥ 1.8 m + (a multiple of 0.5 m) •Max impoundage up to 2.6m •Bar spacing: Front cleaned screen: ≥ 6 mm; Back cleaned screen: ≥ 15 mm	•Belt Screen using **perforated plates** •Reliable cleansing with a rotating brush •Easy-to-retrofit into existing channels •Compact design and **low installation height** • Completed odor encased	•No submerged driving parts •Low headloss due to the large effective bar rack surface •Bar or non-blocking wedge wire profile

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Mechanically Cleaned
Spiral Screen

ESS Spiral Screen

- Economical screening with integral compaction
- Steel or stainless steel shaftless screw available
- 3 mm, 6 mm or 9 mm openings available
- Fully enclosed
- 45 or 35 degree or less setting angle
- Channel mounted or tank mounted units are available

Filename.ppt

Fine Screening – Available Alternatives

1. Fine Screens (1.5 to 6 mm / 0.06 to 0.25 in)
   a. Inclined (Static)
   b. Rotary Drum Screen
   c. Step / Stair Screen
   d. Belt / Band
2. Ultra Fine Screens (0.2 to 1.5 mm / 0.01 to 0.06 in)
   a. Placed after coarse or fine screens
   b. Can reduce suspended solids to levels near those achieved by primary clarification
   c. Ideal for membrane bioreactor pretreatment

Fine Screens
Perforations

V or Wedge Wire

Perforated Plate

Woven Mesh

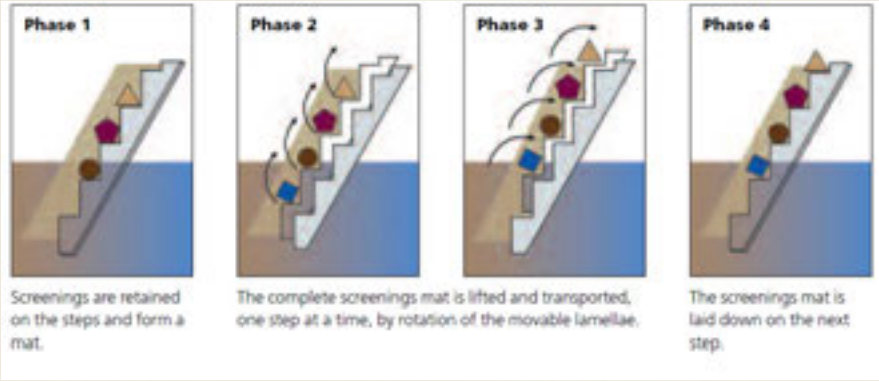
Fine Screens
Step / Stair Screens

- Size down to 3-mm
- Screenings provide additional screening
- Screenings are stepped up to discharge point
- Best for deep channels
  - Installation angle of 40° - 53°
  - Vertical Version up to 75° for space saving
- High flows and low head loss
- High screenings loads
- Reliable operation and long life
- Linkage system with lubrication-free bearings avoids use of difficult-to-maintain chains and sprockets

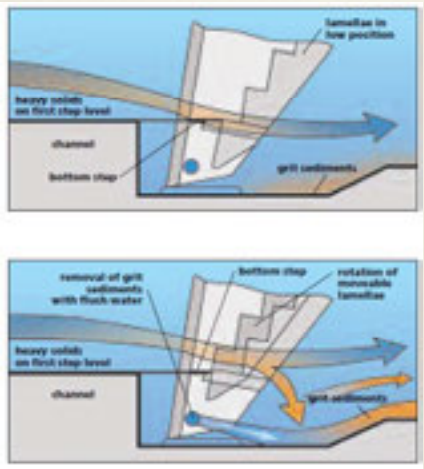
STEP SCREEN®

ESR Stair Screen

Fine Screens
Step / Stair Screens



Flush Bottom Base Plate Design Addresses Solids Accumulation



STEP SCREEN® with optimal bottom step design. The channel floor is flush with the top of the lowest step.

Flexible 0.08" (2 mm) thick lamellae at the bottom of the SSF-HF

Fine Screens

Rotary Drum Screens

- Rotating Screen
- 0.5 to 6-mm wedge wire or perforated plate
- External feed or internal feed
- Economical fine screen
- Can be fully enclosed
- Designed for pumped flow applications
- Blinding of the screen surface generates additional filtering
- In channel or in vessel
- All in One Unit Available: Screening – washing – transport – dewater

ROTAMAT®

Liqui-Fuge Rotary Drum Screen

Fine Screens
Band / Belt Screen

- Band screen protection for membrane pretreatment
- Openings as fine as 2 mm
- Center feed design eliminates carryover
- Small footprint

Headworks

Eliminator™ Band Screen

Fine Screens
Inclined (Static)

- For small plants and low screenings loading
- Economical with no mechanical components
- 0.01-inch (0.2 mm) to 0.2-inch (5 mm) wedge wire openings
- Require manual cleaning using high pressure hot water, steam or a degreaser
- Designed for pumped flow applications

NOT RECOMMENDED

VULCAN INDUSTRIES INCORPORATED

Ultra fine screens open up new fields of application

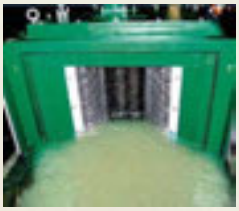
- 0.2 to 1.5 mm / 0.01 to 0.06 in
- Reliable separation of hairs and fibrous material for MBR pretreatment
- Reduce COD/BOD/organics discharged into a receiving water course at a river / ocean outfall
- Coagulants can be added for further improvement of the screen's efficiency (up to 95% filterable solids, 65% COD/BOD and 60% phosphorus)

Screening Handling

1. Conveyance
   a. Conveyor
      1) Belt
      2) Shafted
      3) Shaftless
   b. Sluice
2. Washing / Compaction
   a. Dewatering performance up to 60 % DR
   b. Weight reduction up to 80 %
   c. Increases the thermal value of screenings

Other Considerations: Comminutors and Grinders

- In line or in channel
- Minimize clogging and protect process equipment
- Used on bypass channel for non-MBR facility



Recommendations for Screening Equipment

- Fine screens with a maximum opening size of 3 mm
- If membrane treatment process is used, use fine screens (2 mm maximum opening) or follow the membrane manufacture's recommendation
- Recommended Type of Screens for Further Evaluation
  - Coarse Screens
  - Step/Stair Fine Screens
  - Rotary Drum Fine Screens (recommended for membranes)
  - Band / Belt Fine Screens

Wastewater Treatment Technology Assessment

Grit Removal

Role of Grit Removal

1. **Remove wastewater abrasives from flow stream to:**
   a. Reduce downstream deposition
   b. Reduce equipment wear & maintenance
   c. Reduce solids handling

Grit Removal – Available Alternatives

- Aerated Grit Chambers
- Vortex-Type Grit Chambers
  - Free Vortex
  - Mechanical Vertex

Mectan®

Smith and Loveless

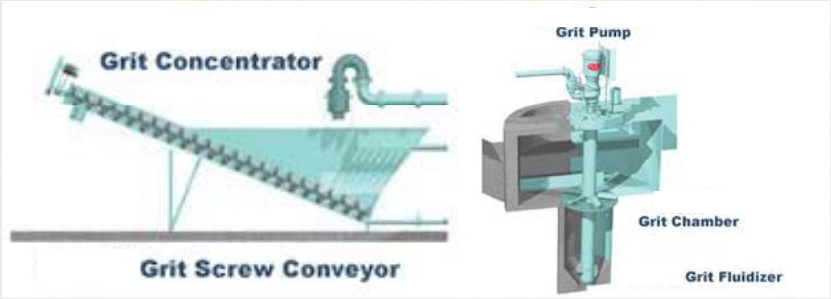
Vortex Grit Removal System XGT

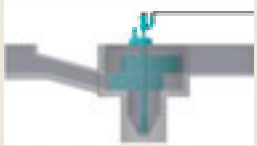
Grit King®

Grit Removal
Aerated Grit Chambers

- Low cost
- Extremely simple mechanical design
- No moving parts below the water surface
- Can use the blower air for air-lift grit pumping as well
- Could eliminate septic conditions of the plant influent (if applicable)

Grit Removal
Mechanical Vortex Grit Chambers





360° Grit Chamber with Flow Control Baffle

360° Grit Chamber without Flow Control Baffle

270° Grit Chamber

Grit Removal
Free Vortex Type Grit Chambers

- Modular, multiple-tray settleable solids concentrator
- Captures 95% of all grit 50 micron and larger
- Minimal headloss
- High efficiency flow distribution
- Tangential feed establishes vortex (without moving parts)
- Solids pumped to Grit Washer / Separator, Classifier, and dewatering system
- Large surface area in a small footprint
- Compact, yet expandable design

Grit Removal

Free Vortex Type Grit Chambers

TEACUP™

- Increasing performance as flows (grit loading) increase (conventional grit basins perform worst at peak flow)
- All hydraulic, non-mechanical design with no internal moving parts
- Prefabricated modular components
- Simple, low maintenance operation
- Compact design requires up to 80% less area than other grit systems
- Discharges a clean (low organic) grit slurry
- Emits fewer odors
- Requires only dewatering

Casa Grande

Recommendations on Grit Removal Equipment

- Mechanical Vortex Grit Chambers
- Free Vortex Type Grit Chambers

Wastewater Treatment Technology Assessment

Primary Clarification

Role of Primary Clarification

1. Remove readily settable solids and floating materials from flow stream to:
   a. Reduce suspended solids content by 50 to 65%
   b. Reduce BOD by 25 to 40%
   c. Reduce and equalize load to the biological treatment

City of San Diego PLWTP Primary Clarifiers

EWA WPCF Primary Clarifiers

NSD Soscol WRF Primary Clarifiers

Primary Clarification May be Eliminated

With Primary Clarification

- Provide readily available biomass for digestion
- Reduce biological treatment loading and aeration costs
- Improve dewaterability of digested sludge
- Enhance bio-P removal

Without Primary Clarification

- Not required with proper preliminary treatment (without imported solids)
- Save on capital
- Save on odor control and covers
- Save on primary sludge pumping and handling
- Save on footprint and yard piping

Primary Clarification can be Achieved Using Fine Screens

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Wastewater Treatment Technology Assessment

BOD Removal and Nutrient Removal

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Role of BOD and Nutrient Removal

- Remove BOD, COD and TSS
- Remove suspended and non-settleable colloidal solids
- Remove Nitrogen and phosphorous (if needed) to meet effluent standards

BOD and Nutrient Removal – Available Alternatives

1. Oxidation Ditch
2. Sequencing Batch Reactor (SBR)
3. Trickling Filters
4. Aeration Basin (MLE)
5. Integrated Fixed Film Activated Sludge (IFAS)
6. Membrane Bioreactor (MBR)

Casa Grande Oxidation Ditch

Cave Creek WRF Aeration Basins

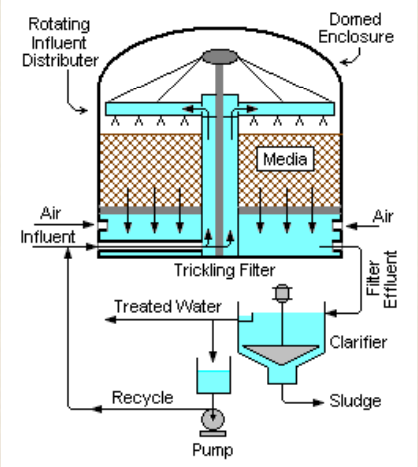
Redlands Recycled WTF Membrane Bioreactor

Attached Growth Processes vs. Suspended Growth

- Suspended Growth:
  - Oxidation Ditch
  - Sequential Batch Reactor
  - Activated Sludge / MLE
  - MBR
- Attached Growth:
  - Trickling Filters
  - Rotating Biological Contactor
  - Packed Bed Reactors
- Combining Suspended and Attached Growth
  - IFAS

BOD and Nutrient Removal

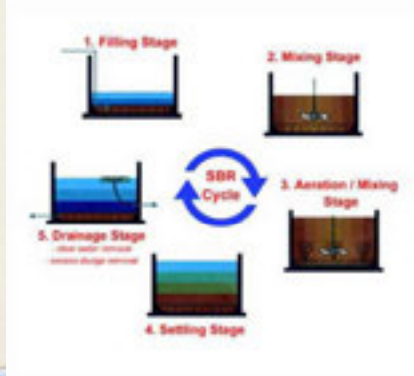
Trickling Filters



- Consists of a fixed bed of rocks, gravel, plastic media
- Sewage flows downward
- Film of microbial slime grow on the media
- Aerobic conditions are maintained by splashing, diffusion, forced or natural air
- Slime layer builds up until sloughs off
- Typically followed by a clarifier

BOD and Nutrient Removal
Sequencing Batch Reactor (SBR)

- Relatively high quality effluent at widely varying flows and loadings
- Nutrient removal
- No sludge recycle system
- No clarifiers
- Optimum energy efficiency
- Small footprint
- Flexible design
- Proven technology



BOD and Nutrient Removal
Oxidation Ditch

- Proven technology
- Low energy consumption
- Relatively good effluent quality
- Low equipment costs but high concrete costs
- Large footprint

BOD and Nutrient Removal

Oxidation Ditch

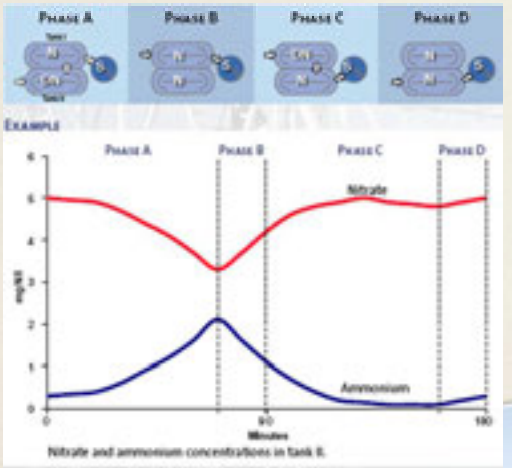
EWT® Carrousel®

- City is familiar with technology
- Aerator design allows deep basin and smaller footprint
- ACE automatic control system

BOD and Nutrient Removal

Oxidation Ditch

Kruger BioDenitro®

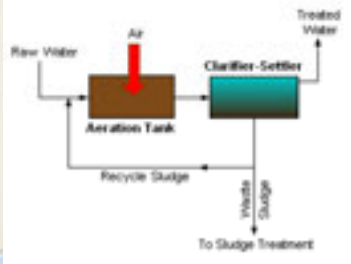


- Familiar technology
- Flexible interplay of the two process steps (nitrification and denitrification) is time-controlled
- Raw wastewater introduced with denitrification eliminates the need for an external carbon source
- Consist of 2 to 4 process tanks
- Surface aerator limits basin depth

BOD and Nutrient Removal

Activated Sludge Process

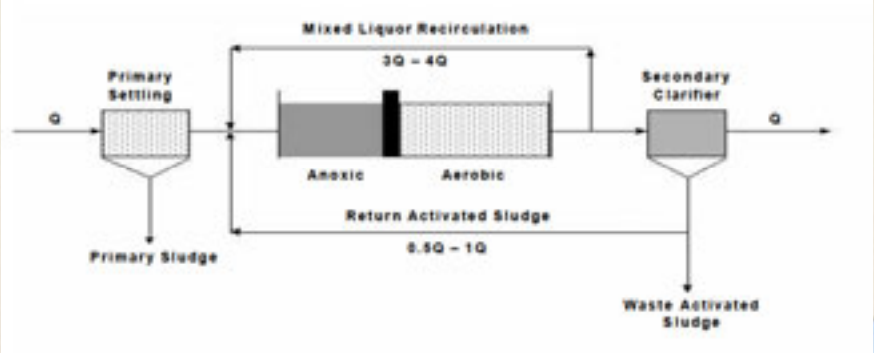
- Suspended growth process
- Common, proven process with long history
- Many variations available:
  - Conventional
  - Step Feed
  - Contact Stabilization
  - High Purity Oxygen
  - Extended Aeration



BOD and Nutrient Removal

Modified Ludzack-Ettinger (MLE)

•Process Provides Enhanced Nitrogen Removal



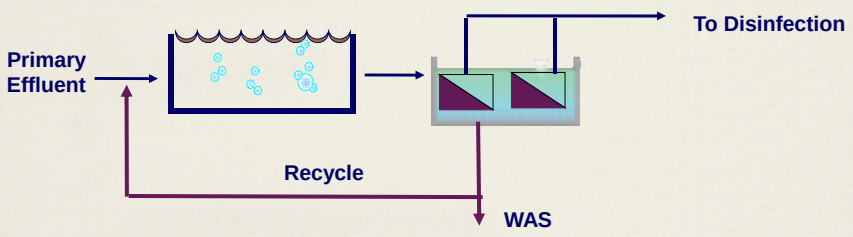
BOD and Nutrient Removal

MBR

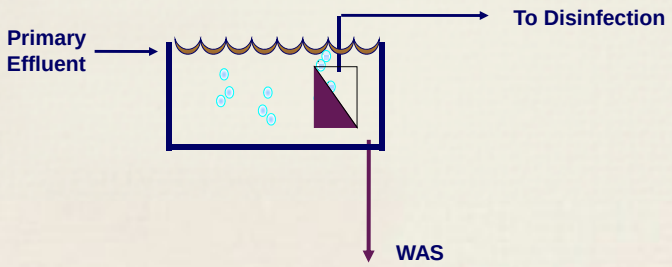
1. Membrane Bioreactor (MBR)
   a. Modified Activated Sludge Process
   b. UF/MF membrane

2. Two Configurations
   a. External (EMBR)
   b. Submerged/Integral (SMBR)

External Membrane Tank



Submerged / Integral Membrane System



MBR Process

1. MBRs combine activated sludge process with mechanical filtration to expand normal operating range
2. MBRs operate at a higher MLSS
   a. Longer SRT, shorter HRT
3. MBRs produce a low turbidity effluent which eliminates the need for tertiary filtration

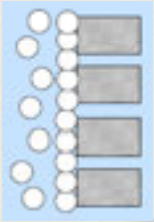
MBR Advantages

1. An overall high quality effluent regardless of sludge's settling characteristics
2. Complete retention of slow-growing nitrifying bacteria resulting in removal of both organic matter and nitrogen
3. Complete retention of suspended matter
4. Effluent disinfection through rejection of both bacteria and viruses
5. Lower UV dosage needed
6. High operational reliability
7. No Clarifiers. No filters. Less space.

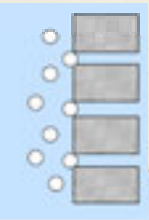
Membrane Fouling

- Inevitable deterioration in filtration performance and increase in pressure loss
- Three main phenomena that can occur simultaneously:

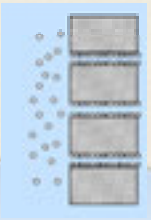
Cake Development



Pore Blockage



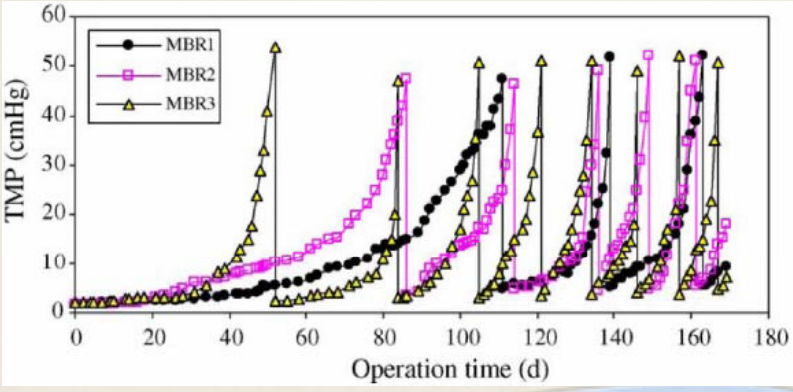
Pore Constriction



Membrane Fouling Control

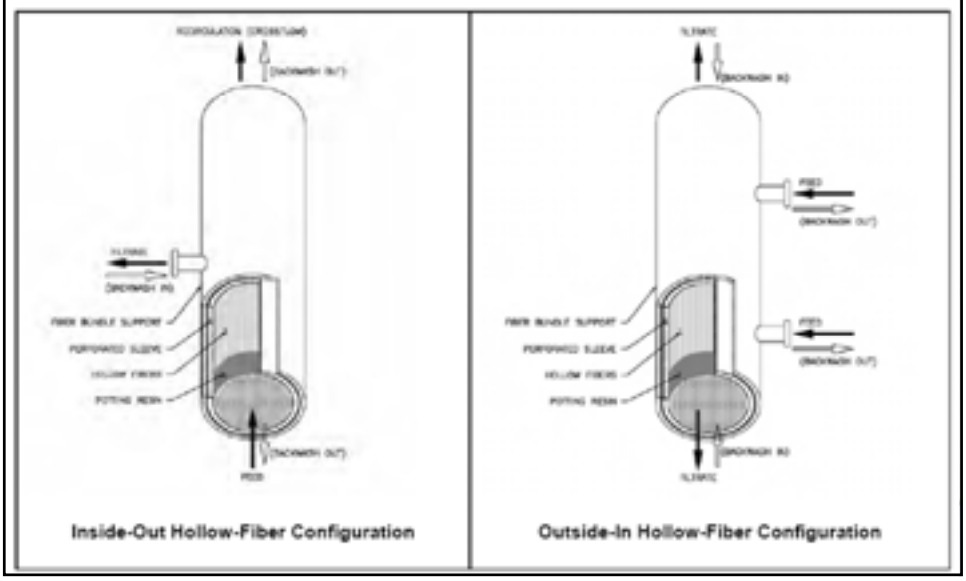
- Pretreatment of the influent (screening, microsieving, combined grit, oil, sand and hair removal)
- Sustainable operation at low permeate flux values (20 - 35 L/m^2-h)
- Induction of turbulent conditions and fluid motion near the membrane surface through aeration
- Physical cleaning techniques (membrane relaxation, membrane backwashing)
- Chemical membrane cleaning (maintenance wash, Clean-In-Place)

Periodic Chemical Cleaning is Necessary to Restore Membranes Permeability



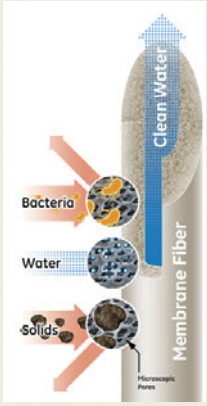
Adopted from: Lei Ji & Jiti Zhou, "Influence of aeration on microbial polymers and membrane fouling in submerged membrane bioreactors", Journal of Membrane Science

Inside-Out versus Outside-In Membrane Filtration

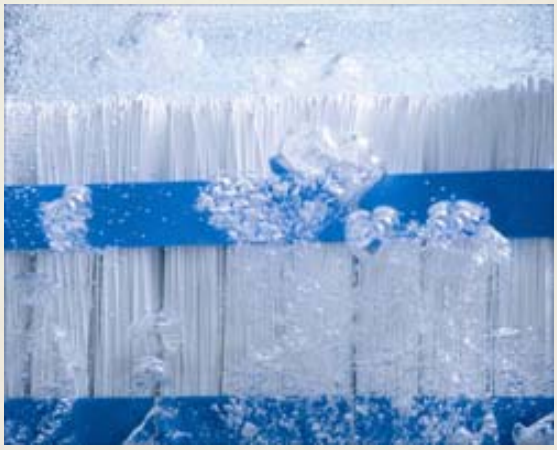


Types of Membranes: Zenon

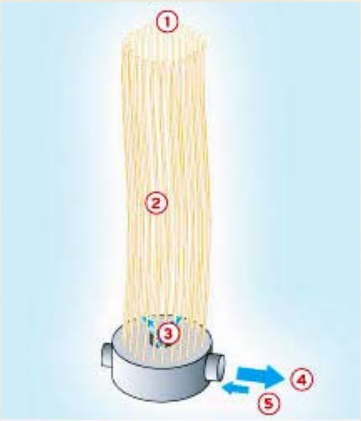
ZeeWeed 500



Types of Membranes: Koch



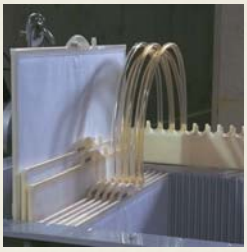
Koch Membranes are Sealed on One End Only

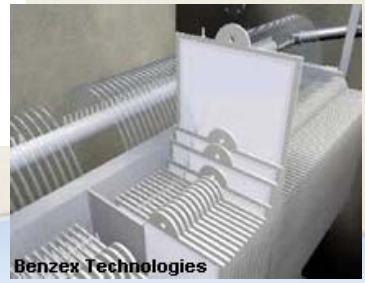


Legend: (1) sealed ends (2) one-sided freely movable membrane filters (3) central aeration (4) filtrate removal (5) backwashing

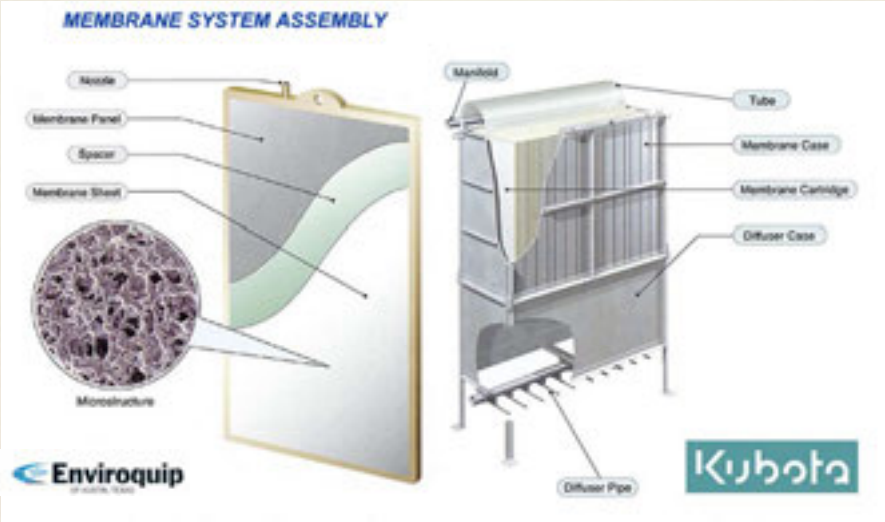
Legend: (1) air (2) filtrate removal via collector line (3) filtrate removal of the module rows (4) air supply line

Types of Membrane: Kubota





Flat Sheet Membrane Configurations



Flat Sheet MBR

Benefits:

- Easier to operate
- Gravity Filtration
- Less Screening Requirement
- No Backpulsing Equipment
- Less cleaning; Less automation
- No cleaning chemicals (no tank liners)
- Proven performance at MLSS concentrations from 8,000 mg/l - 18,000 mg/l

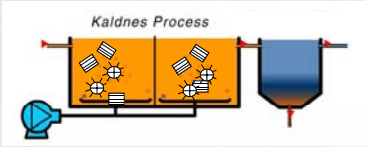
Enviroquip
OF AUSTIN, TEXAS

Challenges:

- Single-Source
- Less History/Experience

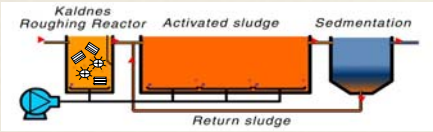
Introduction to Moving Bed Biofilm Reactor (MBBR) Process

Many Variations: MBBR vs. BAS vs. IFAS



MBBR Process

Stand-alone system. No RAS



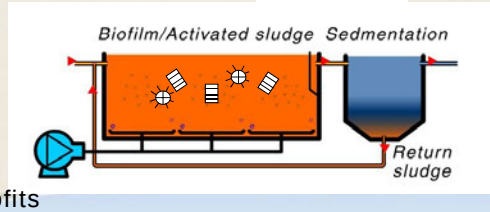
BAS™ Process

BAS = biofilm-activated sludge

Upgrade to denitrification

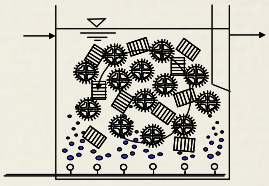
IFAS Process (HYBAS™)

Best for Existing System Retrofits

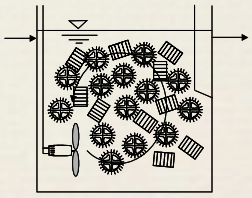


Operation of the MBBR & HYBAS Process

- Aeration for oxygen & mixing in BOD & nitrification
- Slow speed mixers for mixing in post-denitrification applications
- Screens used to retain media in each reactor
- Multiple reactors used to specialize bacteria for each application

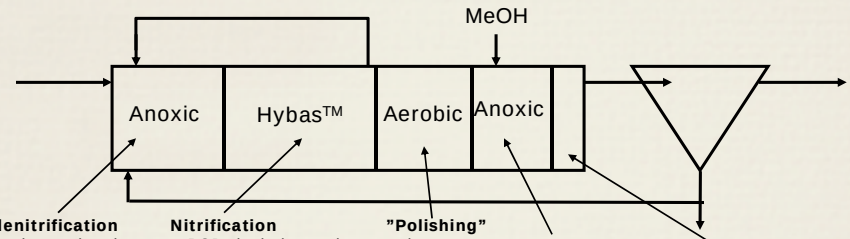


Aerobic reactor



Anoxic reactor

AnoxKaldnes Design Philosophy: The right bugs in the right place with conditions to maximize kinetics



Pre-denitrification
- Uses internal carbon
- Alkalinity produced
- BOD reduction
- Maximize rates by:
  - C/N ratio
  - Redox optimization using plug-flow
  - Short SRT (viable sludge)

Nitrification
- BOD-depletion and partial nitrification by suspended biomass
- High-rate nitrification by attached biomass
- Maximize rates by:
  - Low BOD load on attached biomass
  - Non-ammonia limited conditions
  - DO control
  - Seeding of nitrifiers from biofilm to suspended phase

"Polishing" reduces ammonia to required level through nitrification with suspended biomass.

Post-denitrification
- Uses external carbon
- Reduces nitrate to required level
- Decreasing internal recirculation to avoid instability and hydraulic issues

Post-aerobic
Removal of excess carbon
Oxygenation of effluent

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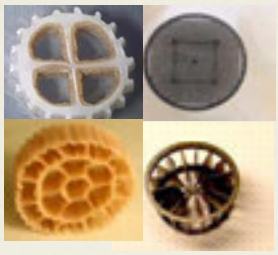
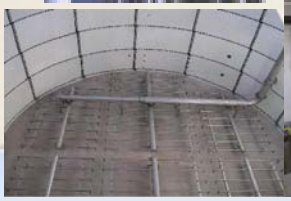
Components of the Aerobic HYBAS™

- Tank
- Media
- Aeration System
- Blowers
- Instrumentation & Controls





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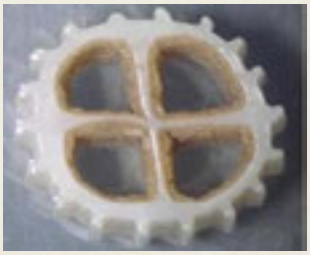
90% of All Installation Use K1 Biofilm Carrier Elements

500 m^2/m^3 in bulk
(152.4 ft^2/ft^3)
10 mm (>3/8") diam
7 mm (>1/4") length

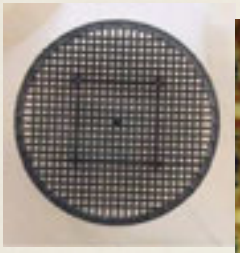


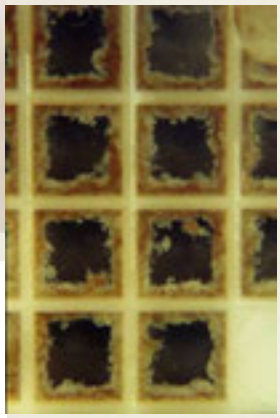
New Media Has the Same Surface Area But 25% Less Plastic per Unit Volume

K3™

500 m^2/m^3 in bulk
(152.4 ft^2/ft^3)
25 mm (~1") diameter
9 mm (>0.33") length

Media with Large Surface Area is Ideal for Retaining Nitrifiers





BIOFILM CHIP™ - M

1,200 m^2/m^3 in bulk

(365 ft^2/ft^3)

48 mm diameter x 2.2 mm thick

BIOFILM CHIP™ - P

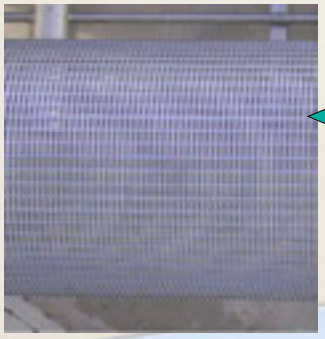
900 m^2/m^3 in bulk

(274 ft^2/ft^3)

45 mm diameter x 3 mm thick

Sieve Assembly for Media Retention

- Fixed-in place stainless steel sieve assemblies.
- Additional (~2 inch) head loss at peak hydraulic flows.
- Additional costs.



IFAS Summary

- An IFAS system would be viable for existing treatment plants that have:
  - Tight sight constraints
  - Marginal final clarifier performance and significant risk for washout
  - Adequate leniency in the existing plant hydraulic profile
- Not economical compared to MLE for a greenfield design in a spacious setting
- Smaller footprint desirable if the basins need to be covered to minimize visual or odor problems
- Generally less expensive than biological aerated filters, and MBRs

Filename.ppt

Recommendations for BOD and Nutrient Removal

1. Membrane Bioreactor (MBR)
2. Aeration Basins (MLE)
3. Oxidation Ditch

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Wastewater Treatment Technology Assessment

Clarification

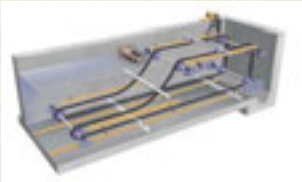
Clarification – Available Alternatives

1. Primary Clarification
   a. Primary Clarifiers
   b. No Primary Clarifiers
2. Secondary Clarifiers
   a. Conventional Secondary Clarifiers
   b. Coagulation and Chemical Enhanced Clarification
   c. Dissolved Air Floatation (discussed in thickening)
   d. No Secondary Clarifiers (MBR Option)

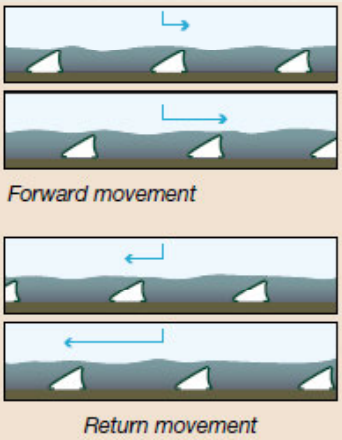
Rectangular Clarifiers Conserve Space but May Be Harder to Maintain

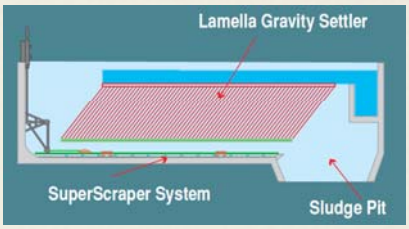
Chain & Scraper Sludge Collector

SIEMENS Envirex®



SuperScraper® is simple to install and easy to maintain, but is not ideal for high solids loading





SuperScraper® Parkson

Rectangular Clarifiers

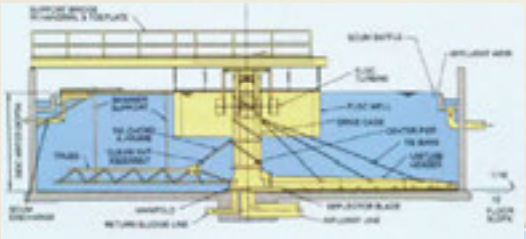
- Benefits
  - Smaller footprint
  - Reduced construction cost using common wall construction
  - Longer flow path reduces chance of short circuiting
- Disadvantages
  - Less effective at high solids loading rates
  - High maintenance requirements associated with the sludge removal mechanism (with chains and sprockets)

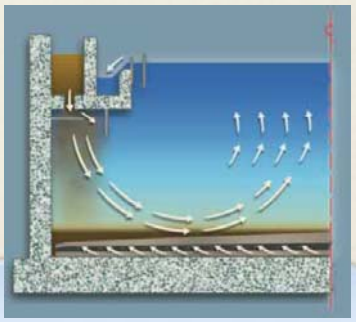
Circular Clarifier Configurations

- Mixed liquor density currents moved away
- Effective Surface and Channel Skimming

SIEMENS

Rim-Flo® Clarifiers



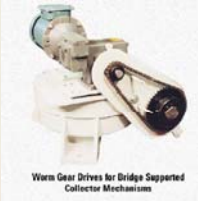


MultiDraw Suction Nozzle Collectors

Suction Pipe Clarifier

Spiral Rake Clarifier

Segmented Plow Rake



Circular Clarifiers

- Benefits
  - Simple sludge collecting system
  - Low maintenance requirement
  - Good for high solids loading
- Disadvantages
  - Higher chance for short-circuiting
  - Require more land; Cannot use common wall construction
  - Uneven distribution of sludge loads on the collecting devices

Recommendations for Secondary Clarification

1. Clarification required if the following BOD and Nutrient Removal Processes are Selected:
   a. Aeration Basins
   b. Oxidation Ditch
   c. Trickling Filters
2. Not required for MBR

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Wastewater Treatment Technology Assessment

Tertiary Filtration

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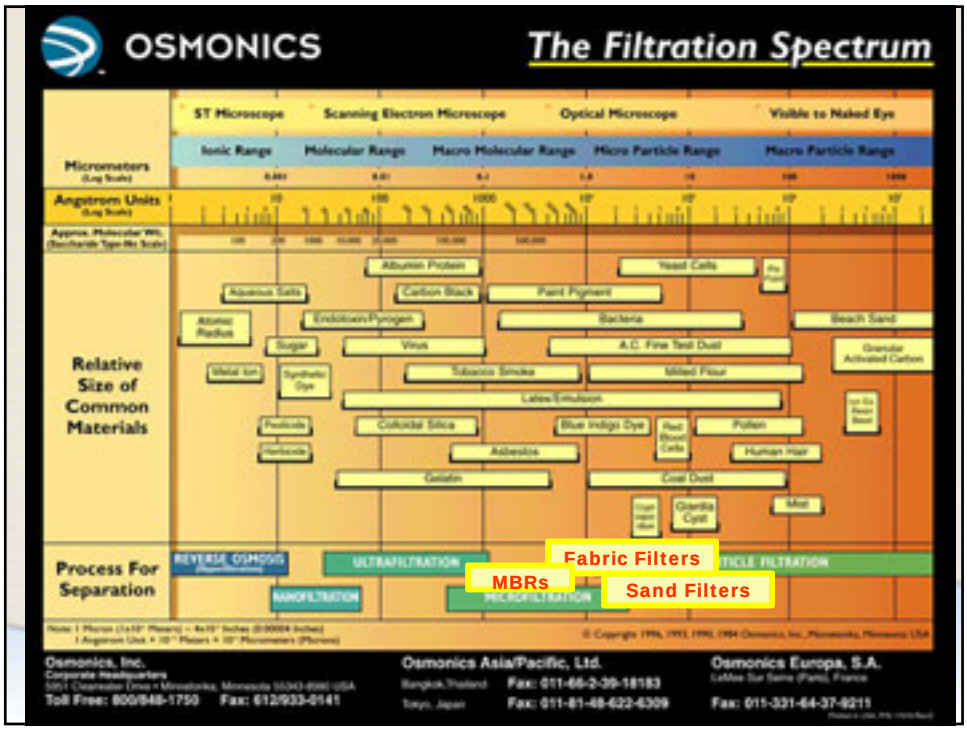
Tertiary Filtration – Available Alternatives

1. Granular Media Filter
   a. Conventional Down Flow
   b. Traveling Bridge
   c. Automatic Backwashing Filters
2. Cloth Media
   a. Disc Filters
   b. Drum Filters
3. Microfiltration / Ultrafiltration



Granular Media Filters

Benefits

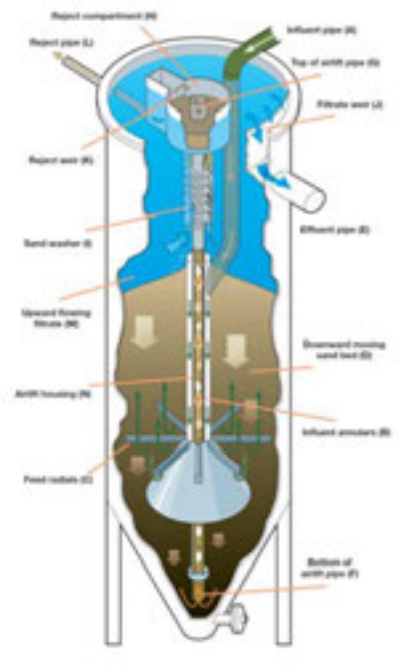
- Continuous filtration available
- Low (~ 6”) headloss through filter
- Large pipe galleries not required

Challenges

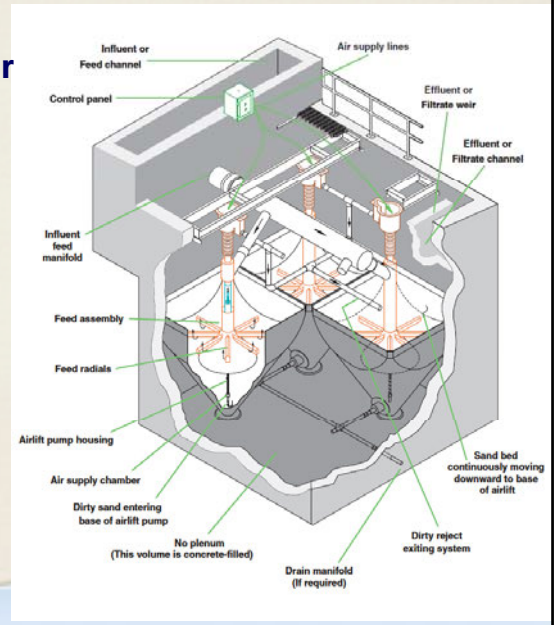
- Requires underdrain
- Poorer filtrate quality
- Media replacement/O&M

DynaSand® Continuous, Upflow, Granular Media Filter

- Continuously cleaned sand bed
- No underdrains or screens
- Sand washed with filtrate
- No level control
- Internal, vertical airlift
- Low power requirements
- Self-cleaning filters



DynaSand® Continuous, Upflow, Granular Media Filter



Tertiary Filtration:

- 3-5 gpm/sf
- 20-50 ppm influent TSS
- 5-10 ppm effluent TSS

Continuous Backwashing Upflow Filter

Benefits:

- No shutdown for backwash cycles
- Eliminates ancillary backwash equipment (simpler system and smaller footprint)
- No flow control valves, splitter boxes, or backwash controls
- Optimum sand-washing efficiency
- Good filtrate quality
- Reduces operator attention
- Reduces potential for plugging
- Minimizes overall pressure-drop
- Significantly reduces wear/maintenance
- Can be easily maintained without filter shutdown

Challenges:

- Lack of media size distribution
- Poor particle size distribution

Traveling Bridge Filters

Manufacturers:

- Aqua-Aerobic Systems, Inc., Rockford, Illinois.
- Infilco Degremont, Inc., Richmond, Virginia.
- Agency Environmental, Inc., Hanover, Maryland.

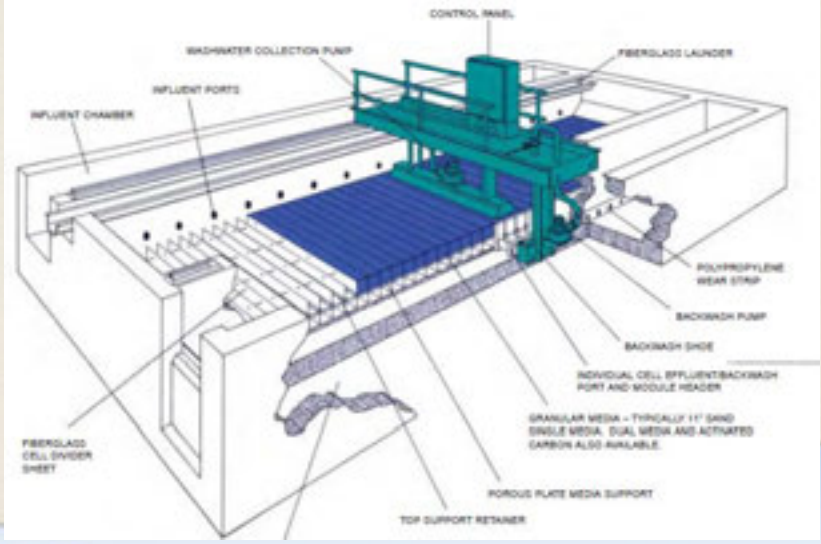
Benefits:

- Filter water and backwash filter cells simultaneously
- Divided horizontally into cells
- Feed flows through multiple inlet ports, the media and porous plate.
- Backwashing occurs under the hood below the traveling carriage
- The carriage and hood move slowly across the filter bed
- Backwash pump draws filtered water from the effluent chamber
- Separate pump picks up the washwater in the hood
- Backwash initiation based on headloss or timer

Challenges:

- Being replaced by other technology (e.g. AquaDiamond)
- Poor particle size distribution

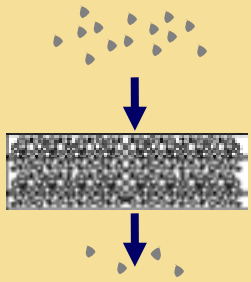
AquaABF® Automatic Backwashing Filters



Traveling Bridge Filters

Depth Filtration

Sand filters



Cloth Media Filter

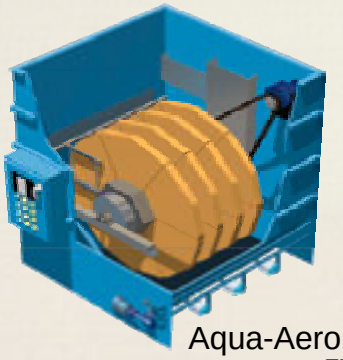
Benefits

- Continuous filtration available
- No underdrain
- Better filtrate quality (even during peak flow and turbidity events)
- Better particle size distribution (better pretreatment for UV)
- Lower backwash rates
- No media replacement

Challenges

- More susceptible to fouling, wear and tear

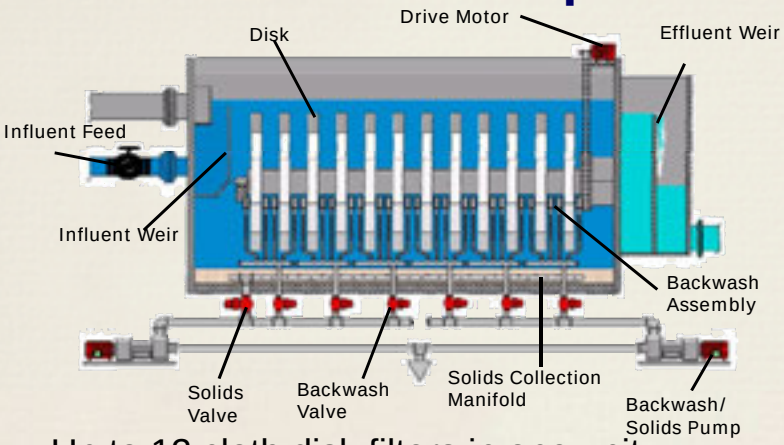
Two Major Disc Filter Manufacturers



Aqua-Aerobics
AquaDisk™

Krüger
Hydrotech Disc filter

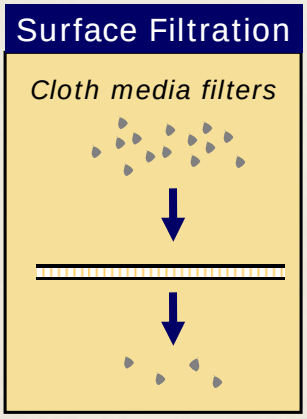
Cloth Filter Unit - AquaDisk



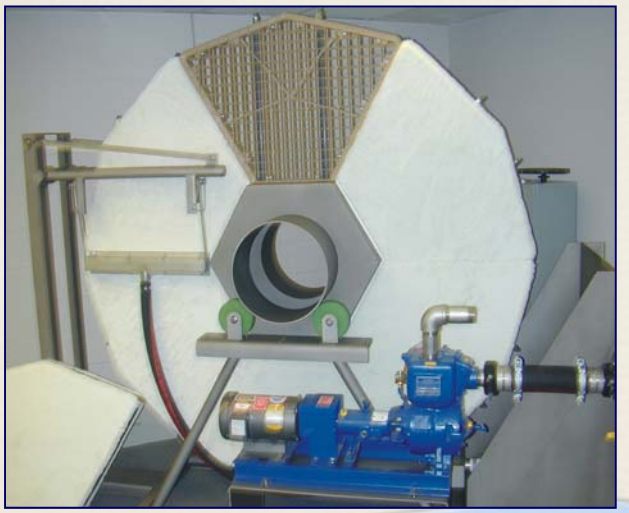
- Up to 12 cloth disk filters in one unit
- Influent enters from the inlet weir, goes through the Cloth Disks and exits at the outlet weir.
- Automatic backwash using two backwash pumps

Disk Filters Solve Site Space Constraints

- Easy modular expansion
- Operation flexibility
- High hydraulic loading rate
- Low operating head
- Low maintenance



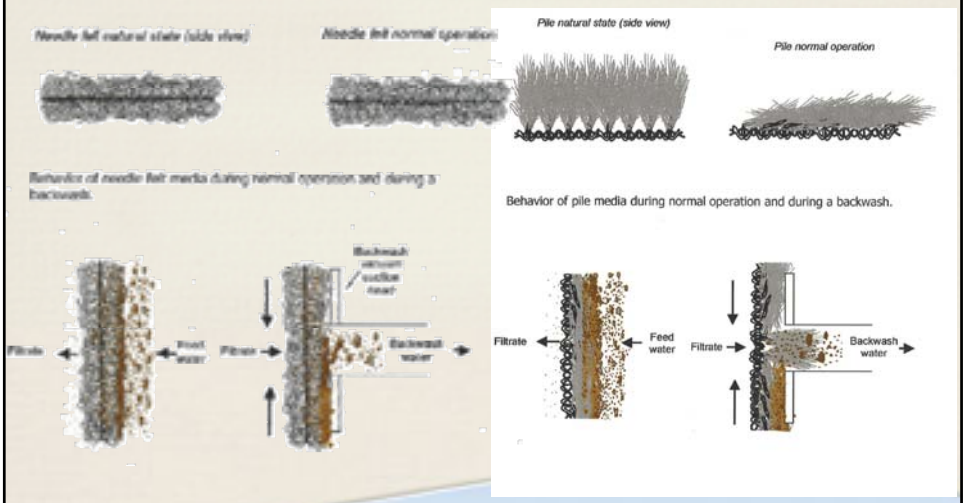
AquaDisk®: Cloth Filter Section



Filter Cloth Degradation

- Cloth available in three types of material
  - Nylon
  - Acrylic
  - Polyester
- Compared with acrylic and / or polyester, nylon fabric is slightly cheaper but has lower chlorine resistance (< 1 - 1.5 mg/L chlorine on a constant basis)

Pile Fabric is Recommended over Needle Felt



AquaDisk®: Installations

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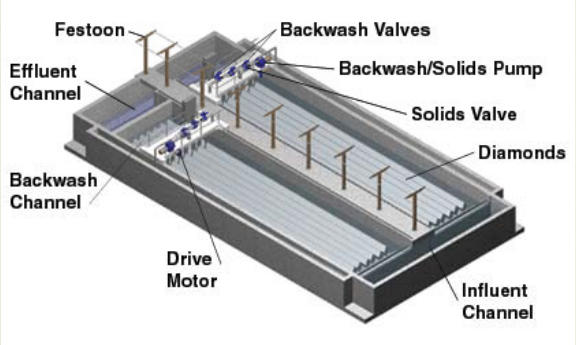
AquaDiamond® Filters Combines Traveling Bridge and Cloth Media Filtration



- 2.5 - 3 times the flow capacity of a traveling bridge filter with an equivalent footprint
- Ideal for retrofit

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AquaDiamond® Filters

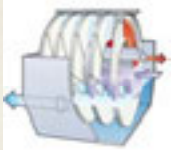
Benefits

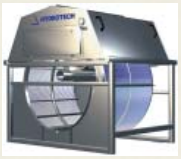
- Up to 8 vertically oriented, diamond shaped cloth media laterals per unit
- Gravity flow operation
- Available in concrete tanks
- Reuse quality effluent
- Higher solids loading per square foot of media
- Reduced backwash water volume
- Higher hydraulic loadings and reduced footprint

Challenges

- Unique pile cloth media

Kruger Discfilter has an inside-out flow pattern





Hydrotech Discfilter **Hydrotech Drumfilter**

Recommendations for Tertiary Filtration

1. Membrane Bioreactor (MBR)
2. Disk Filters
3. Granular Media/Sand Filters

Wastewater Treatment Technology Assessment

DISINFECTION

Disinfection Alternatives

1. Gaseous Chlorine
2. Liquid Chlorine (Bulk)
3. Liquid Chlorine (Onsite)
4. Chloramines
5. UV
6. Ozone

Gaseous and Liquid Chlorine have Essentially the Same Chemistry

Gaseous Chlorine

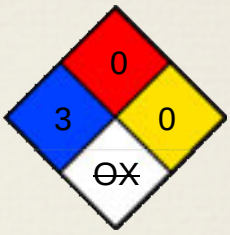
Sodium Hypochlorite (Bulk)

Sodium Hypochlorite (Onsite Generation)

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

$$HClO \rightarrow H^+ + ClO^-$$

Disinfection - Gaseous Chlorine



- Gaseous form
- Available in 150 pound cylinders, one-ton containers, 17-ton tanker trucks, and rail cars

Gaseous Chlorine - Benefits and Challenges

Benefits:

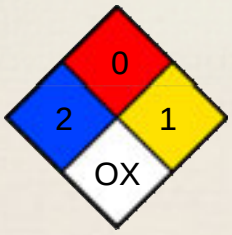
- Long history of successful operation
- Readily available and economical chemical
- Experienced and trained personnel

Challenges:

- Operation and maintenance intensive
- Safety concerns of accidental release during transportation and operation
- Require risk management plan (Clean Air Act Section 112(r): >2500 lb)

Sodium Hypochlorite (Bulk)

- 12.5% sodium hypochlorite is a hazardous material
- Also referred to as “Bleach”



Sodium Hypochlorite (Bulk) - Benefits and Challenges

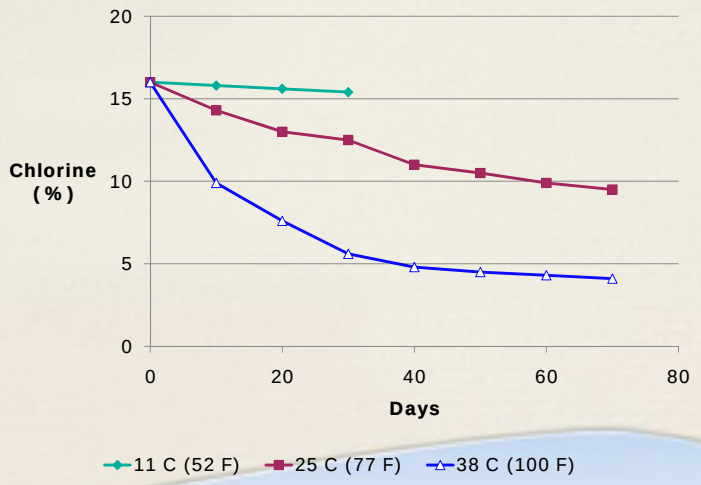
Benefits:

- Safer to transport, store & handle than gaseous Cl_2
- Personnel experienced with chemical feed systems
- Relatively easy to operate and maintain

Challenges:

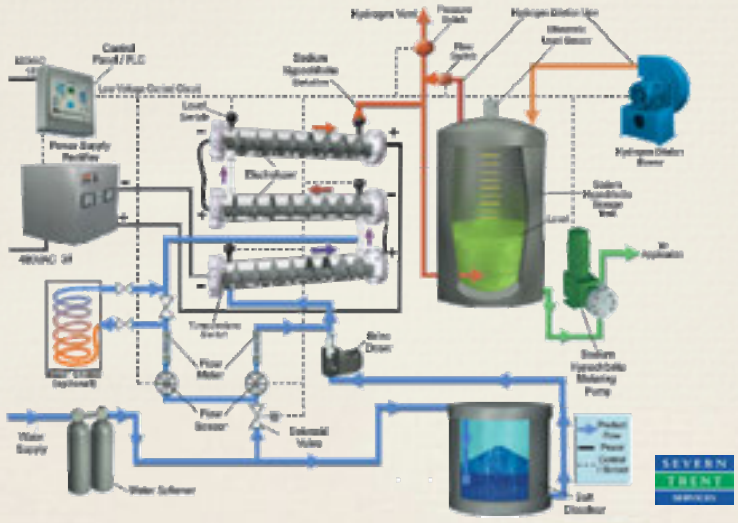
- Large Contact Basin
- Higher chemical costs than gaseous chlorine
- Potential for air binding, plugging and mechanical malfunction
- Precipitation of calcium may result in solids in the solution feed lines
- UV and Heat Degradation - Must be protected and used in timely manner (chlorate and chlorite)

Sodium Hypochlorite Degrades, Especially under High Temperature



Building / climate control?

Sodium Hypochlorite Onsite Generation (OSG)



$NaCl + H_2O + 2e = NaOCl + H_2$

Salt + Water + Electrical Energy = Sodium Hypochlorite + Hydrogen

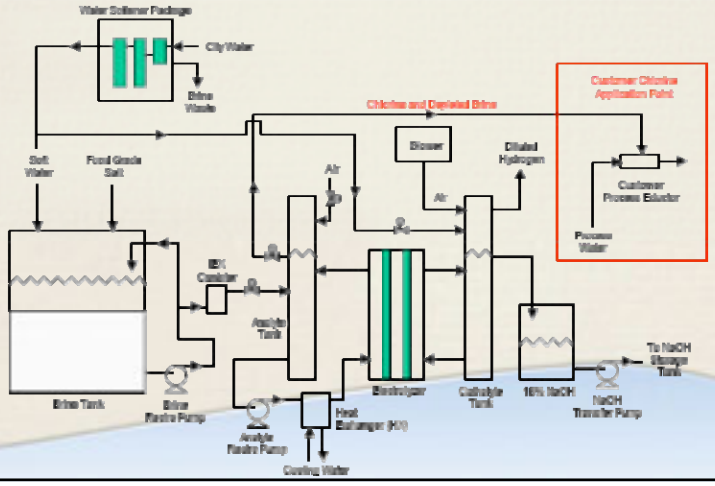
Onsite Chlorine Generation

Electrolytic Technologies Corporation

Klorigen™ M-Series

$2NaCl + H_2O + Power = Cl_2 + NaOH + H_2$

$Cl_2 + 2NaOH = NaOCl + NaCl + H_2O$ (Optional)



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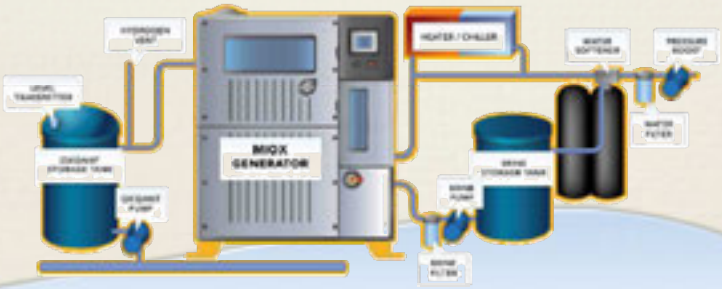
MIOX Onsite Hypochlorite Generation and Mixed Oxidant Solution Generation



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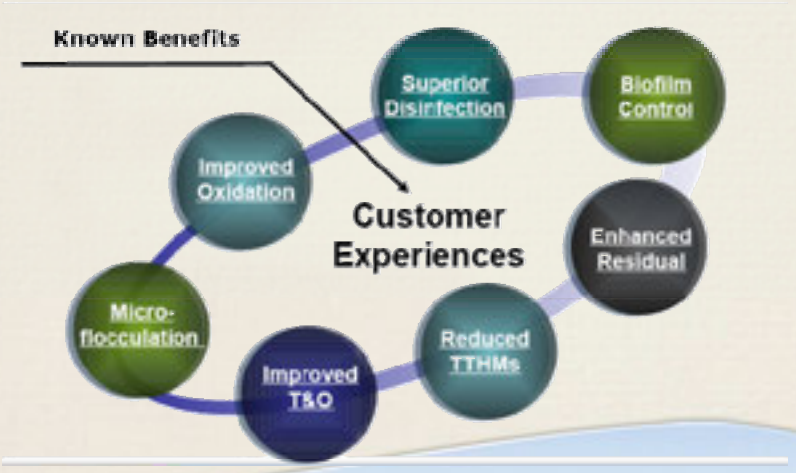
Manufacturer Claims Superior Chemistry for Mixed Oxidants



Onsite Generation – Benefits and Challenges

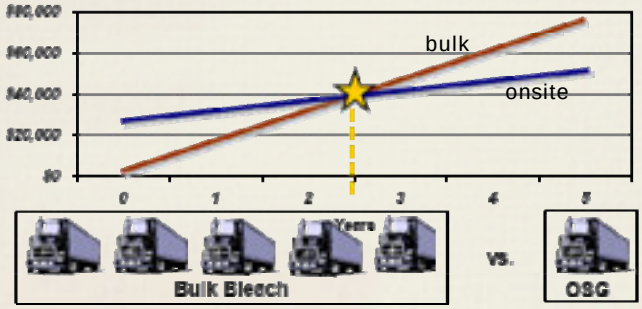
Benefits

- <1% Sodium Hypochlorite is a non-hazardous chemical
- Safer to store and handle than chlorine gas
- Less degradation
- On-demand production and flexible operation (produce extra during off-peak)
- Reduced operational costs
- Consistent solution strength
- Less truck traffic compared to bulk

Challenge

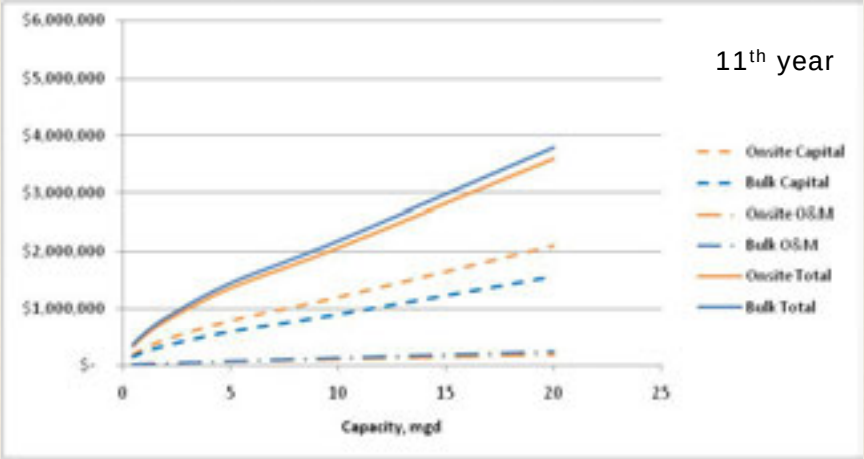
- Large Contact Basin
- High capital costs
- Replace electrolytic cells every 5 to 10 years
- High power consumption
- May require operation staff training
- Addition of TDS (10 – 14 mg/L increase) & sodium (5 – 6 mg/L)
- H_2 gas must be force vented and monitored

OSG Manufacturers Claim Payback Period as Short as 2 to 3 Years



- Size of Facility and Chlorine Usage
- Building? 100% Redundancy? Finance?

Payback Calculator



Conflicting Regulatory Requirements for Effluent Disinfection Pose Challenges to Arizona WW Utilities

- Use gaseous or liquid chlorine is requried to achieve the Class A+ Effluent Reuse requirement of "Non Detect" for fecal coliform. However, their use may trigger noncompliance with current or future DEQ recharge guidelines (on DBPs) when effluent is used for groundwater recharge.
- APP requirements are being applied to **all** new WWTPs and significant modifications, *and to reuse and discharge projects.*

Arizona WWTP Effluent: Several Possible Destinations

Effluent Destination	Regulations	Disinfection Technologies	Consideration
Direct Reuse	Class A+; No numerical THM Standards yet;	Chlorination; **UV + Chlorination**	UV provides flexibility.
Indirect Reuse: Recharge	**APP**	**UV (Still need some chlorine for well maintenance)**	Use UV; Onsite better than remote; Use basins for THM dissipation
Effluent Discharge	AzPDES; Surface Water Quality Standards; APP	Chlorination – Dechlorination; **UV (No Cl2 Residual Requirement)**	UV makes sense with no Cl2 residual requirement.

Chlorine Dosages for A+ Reclaimed Water

- Handbook of Chlorination and Alternative Disinfectants, Fourth Edition

$$Ct = \frac{\sqrt[3]{\frac{y_0}{y}}}{0.23} - 1$$

- y_0 = initial coliform MPN/100 mL
- y = final coliform MPN/100mL
- C = chlorine residuals, mg/L, at the end of contact time t
- t = contact time in minutes

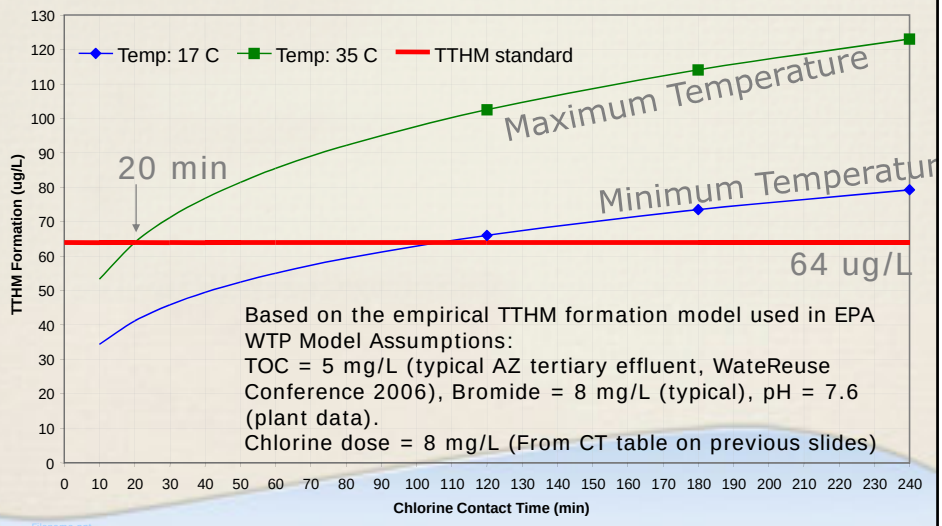
Chlorine Dose for A+ Reclaimed Water

Based on combined chlorine unless otherwise noted; **Contact time 30-min**

Type of Wastewater	Initial Coliform Count MPN/100 mL	Chlorine Dose, mg/L			
		Effluent Standard, MPN/100 mL			
		1000	200	23	≤ 2.2
Raw wastewater	10^7 - 10^9	15 - 40			
Primary effluent	10^7 – 10^9	10 - 30	20 - 40		
Trickling filter effluent	10^5 – 10^6	3 - 10	5 - 20	10 - 40	
Activated-sludge effluent	10^5 – 10^6	2 - 10	5 - 15	10 - 30	
Filtered activated-sludge effluent	10^4 – 10^6	4 - 8	5 - 15	6 - 20	8 - 30
Nitrified effluent	10^4 – 10^6	4 - 12	6 - 16	8 - 18	8 - 20
Filtered nitrified effluent	10^4 – 10^6	4 - 10	6 - 12	8 - 14	8 - 16
Microfiltration effluent	10^1 – 10^3	1 - 3	2 - 4	2 - 6	4 - 10
Reverse osmosis*	~ 0	0	0	0	0 - 2
Septic tank effluent	10^7 – 10^9	20 - 40	40 - 60		
Intermittent sand filter effluent	10^2 - 10^4	1 - 5	2 - 8	5 - 10	8 - 18

* Based on free chlorine. Wastewater Engineering, 4th Edition

Chlorine Disinfection TTHM Formation vs. Contact Time (Modeling Results confirmed by Recent Sampling)



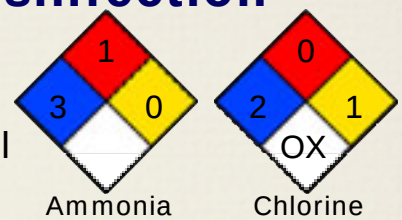
TTHM Reduction Strategies

- Coordinate closely with ADEQ on a case-by-case basis
- TOC Removal Processes (GAC, MIEX, RO, etc.) are expensive
- Alternative Disinfection
  - Chloramine is not recommended (nitrosodimethylamine (NDMA))
  - Ultraviolet (UV) is recommended for the best flexibility
  - Still use some chlorine - Use intermittent chlorine shocking to control regrowth and well fouling
  - Consider other new alternative disinfection technologies (pasteurization and pressurized ozone)
- Recharge basins dissipate THM (Volatilization perhaps metabolization)
- Reduce recharge water pipeline and retention time (Onsite versus remote)

Chloramine Disinfection

Benefits

a. Maintain a persistent and effective residual
b. Ability to penetrate biofilms similar to chlorine
c. Tendency to form lower levels of TTHMs and HAAs
d. Ability to minimize chlorine-related taste and odors

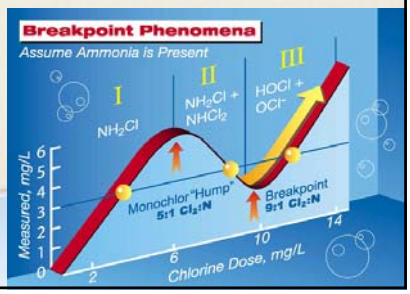


Ammonia Chlorine

$NH_3 + HOCl = NH_2Cl + H_2O$

$NH_3 + 2HOCl = NHCl_2 + 2H_2O$

$NH_3 + 3HOCl = NCl_3 + 3H_2O$



Chloramine Disinfection

Challenges

a. Additional costs associated with two chemical feed systems
b. Requires handling two hazardous chemicals
c. Formation of chloramine-related DBPs (such as NDMA)
d. Potential for nitrate to exceed MCLs through nitrification in the reuse water system
e. Toxic to fish and amphibians at levels used

About NDMA

a. NDMA = N-Nitrosodimethylamine
b. Very high lifetime cancer risk
c. Results in liver cancer, lung cancer, non-cancerous liver damage, and internal bleeding and death
d. EPA recommended level of NDMA for lakes and streams: 0.00069 ppb
e. Not currently regulated by EPA, but is listed in Unregulated Contaminant Monitoring Rule 2 (UCMR2), proposed rule for 2007 - 2010
f. Regulated in California (DHS notification level: 10 ng/L)

Ultraviolet Disinfection

1. Benefits:
   a. Safe access and operation
   b. No in-stream chemicals required for primary disinfection or dechlorination
   c. No truck traffic except for residual chlorine
   d. No byproducts
   e. NDMA destruction potential
   f. Short treatment time allows compact foot print
   g. Better upgradeability
   h. Future utility in treating EDCs, PCPs, etc.

Ultraviolet Disinfection

1. Challenges:
   a. No residual provided - still need residual chlorine for reclaimed water conveyance systems
   b. Complex on-line intensity validation equipment
   c. Higher electrical power consumption
   d. Mercury bulbs – potential water quality & bulb disposal issues
   e. Higher maintenance requirements

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Medium Pressure vs. Low Pressure Lamps

- Low Pressure High Output (Trojan 3000+)
  - 5 MGD to 60 MGD
  - Requires 14 lamps per 1 MGD for secondary effluent
  - High output, low pressure cost-saving amalgam lamps
  - Auto chemical/mechanical cleaning system
- Medium Pressure High Output (Trojan 4000+)
  - 10 MGD to 1000 MGD
  - Requires 2.5 lamps per 1 MGD for secondary effluent
  - Module removal mechanism
  - Medium pressure, high intensity lamps
  - Auto chemical/mechanical cleaning system

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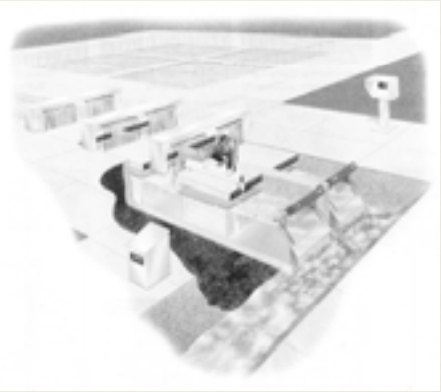
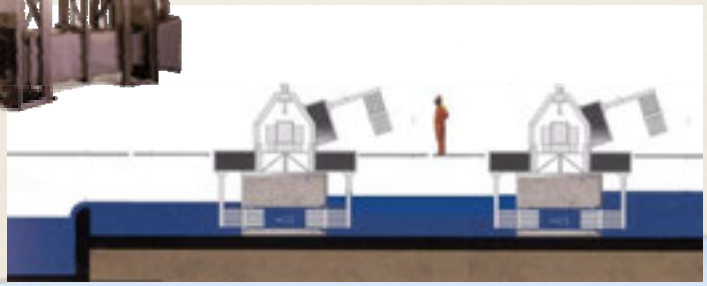
Low Pressure High Output Unit - Trojan 3000 Plus



Medium Pressure High Output Unit Trojan 4000



Ultraviolet Design Considerations

- Total/Fecal coliform 2.2 CFU/100mL (5 sample geometric mean);
- Total/Fecal coliform 25 CFU/100mL (single sample maximum)
- Filter Effluent UV Transmittance
  - o Typically 55-65% (secondary effluent)
  - o 65-75% (granular media filtered effluent)
  - o 75-80% (MBR effluent)
- Filter Effluent Total Suspended Solids (TSS)
  - 5 mg/L

Pasteurization for Reclaimed Water

Research shows:

1. Rapid coliform disinfection
2. Rapid virus disinfection
3. Equal in energy use to UV disinfection without using pre-existing waste heat

Contact: Andrew Salveson, WCO

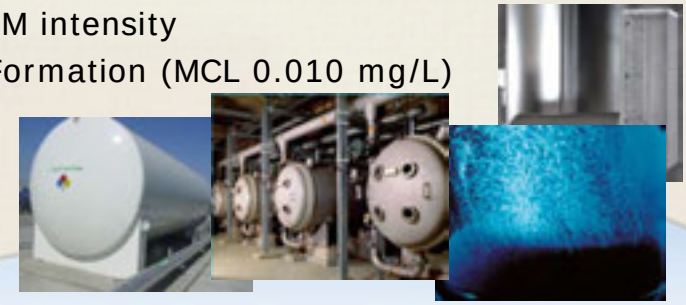
Ozone – Benefits and Challenges

Benefits

- Strong oxidant and disinfectant
- Lower TTHM Formation (Not a main driver)

Challenges

- Still need residual disinfection
- High capital and O&M costs
- Increased safety concern of liquid oxygen
- Higher O&M intensity
- Bromate Formation (MCL 0.010 mg/L)



Ozone for Reclaimed Water

Research shows:

1. Low CT for coliform (1 mg-min/L)
2. Even lower CT for virus (0.16 mg-min/L)
3. Impact of ozone injection methods
4. Impact of peroxide

Contact: Andrew Salveson, WCO

Innovative Wastewater Pressurized Ozone System was Title 22 Certified

HiPOx®

Applied Process Technology, Inc.

- Future pilot testing for T&O, micro-pollutants
- Competitive costs for implementing ozone

Contact: A. Salveson, WCO

Recommendations for Disinfection

1. UV Disinfection
   a. Requires Secondary Disinfection
2. Liquid Chlorine (Bulk)
3. Liquid Chlorine (Onsite)

Wastewater Treatment Technology Assessment

Odor Control

Odor & Noise Control: Arizona Administrative Code R18-9-B201

Sewage Treatment Facility Design Flow (gallons per day)	No Noise, Odor, or Aesthetic Controls (feet)	Full Noise, Odor, and Aesthetic Controls (feet)
3000 to < 24,000	250	25
24,000 to < 100,000	350	50
100,000 to < 500,000	500	100
500,000 to < 1,000,000	750	250
1,000,000 or greater	1000	350

- Full noise, odor, and aesthetic controls means that all treatment components are fully enclosed, odor scrubbers are installed on all vents, and fencing aesthetically matched to that in the area surrounding the facility
- The owner or operator may decrease setbacks if setback waivers are obtained from affected property owners in which the property owner acknowledges awareness of the established setbacks, basic design of the sewage treatment facility, and the potential for noise and odor.

Odor / Noise Control Concept

- Assume typically insufficient room for a 1,000-foot setback between the plant process units and the nearest property line
- Difficult to obtain setback waivers
- 350 ft setbacks & full odor control are both required

Expected Odor Producing Areas

- Headworks and preliminary treatment (influent pumping, screening, grit removal, and flow splitter structure)
- Secondary treatment (oxidation ditch, secondary clarifier, and splitter structure)
- Solids handling (thickening, digestion, dewatering, loading and storage)

Wastewater Odor Producing Compounds

- Small, relatively volatile molecules with MW between 15 and 150
- Low in concentration, but high in volume
- Result from anaerobic decomposition of organic matter containing sulfur and nitrogen

Wastewater Odor Producing Compounds

- Type of odors
  - Inorganic gases (H_2S, NH_3)
  - Organic vapors (mercaptans, indoles, skatoles, and nitrogen-bearing organics)
- Primary offensive odors
  - Hydrogen sulfide - “rotten eggs” and sensed at low concentration (1 – 10 ppb)
  - Methyl mercaptan - “decayed cabbage”
  - Dimethyl sulfides - “decayed vegetables”

Type of Odors and Odor Controls

Odor Producing Area	Type of Odorous Compounds	Type of Full Odor Control
Headworks	Hydrogen sulfide (1 – 50 ppm)	Covered wet well; Enclosed screens; Wet Scrubber or Bio Towers.
	Reduced sulfur organic odors	
Oxidation Ditches / Aeration Basins	Hydrogen sulfide (< 0.1 ppm)	Covered basins / Wet Scrubbers or Bio Towers.
	Reduced sulfur organic odors	
Secondary Clarifiers	Hydrogen sulfide (None)	Covered clarifiers
	Weak organic musty odors	
Sludge process and Storage	Hydrogen sulfide (1 – 100 ppm)	Enclosed in solids handling building; Wet Scrubber or Bio Towers.
	Strong reduced sulfur organic odors; Ammonia odor from digested sludge dewatering	

Note:
Hydrogen sulfide (H_2S) – "rotten eggs"
Reduced sulfur organics include mercaptan and dimethyl sulfides – "decayed cabbage"

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Available Odor Control Technologies

- Chemical (e.g., Ferric Chloride, Ferrous chloride) addition
- Wet chemical scrubber
- BioFilters
- BioTowers
- Carbon absorption
- Odor removal through ion addition
  - Electrical charged
  - VAPEX

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Odor Control – Chemical Addition

- Advantage
  - Moderately effective
  - Effective backup and supplemental odor control
- Disadvantage
  - Impossible to cost-effectively treat all odor compounds
  - Effectiveness is very site-specific
  - Not as effective as air stream treatment alternatives
  - Results in high chemical costs
  - Some chemicals (e.g. ferric) classified as hazardous
  - pH drop and increase corrosion potential if overdosed
  - Increases sludge volume and impacts solids handling and disposal alternatives
  - May introduce undesirable metals
  - Can decrease effectiveness of other process such as UV

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Odor Control – Wet Scrubbers

- USFilter/Davis and USFilter RJ Environmental both used at South Plant

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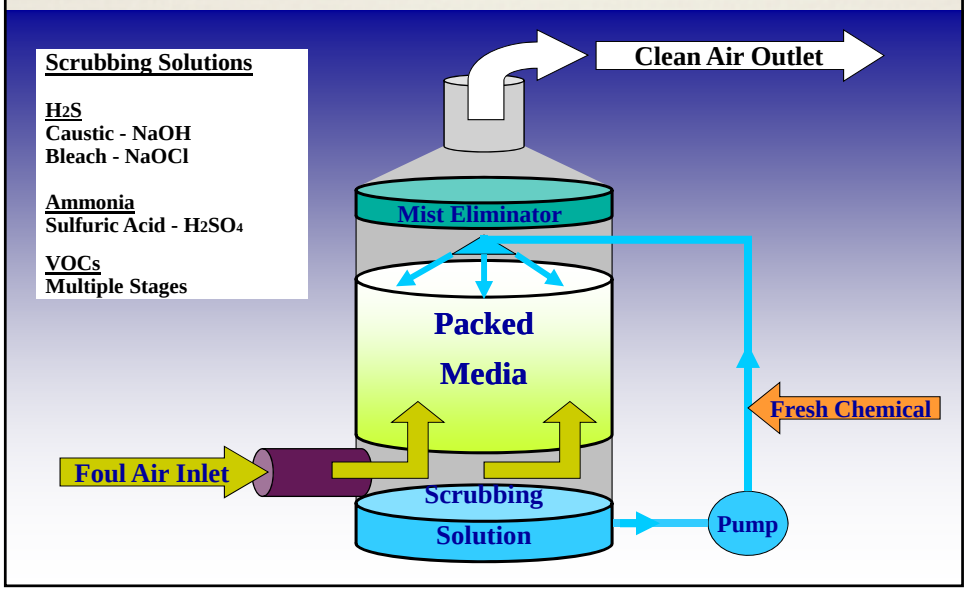
Chemical Scrubber Towers



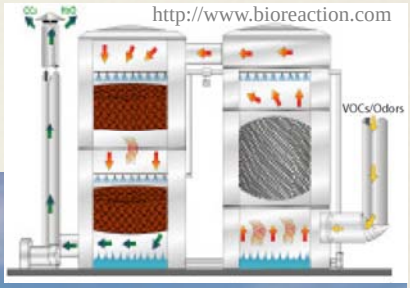
Applications

Odor Control – Wet Scrubbers

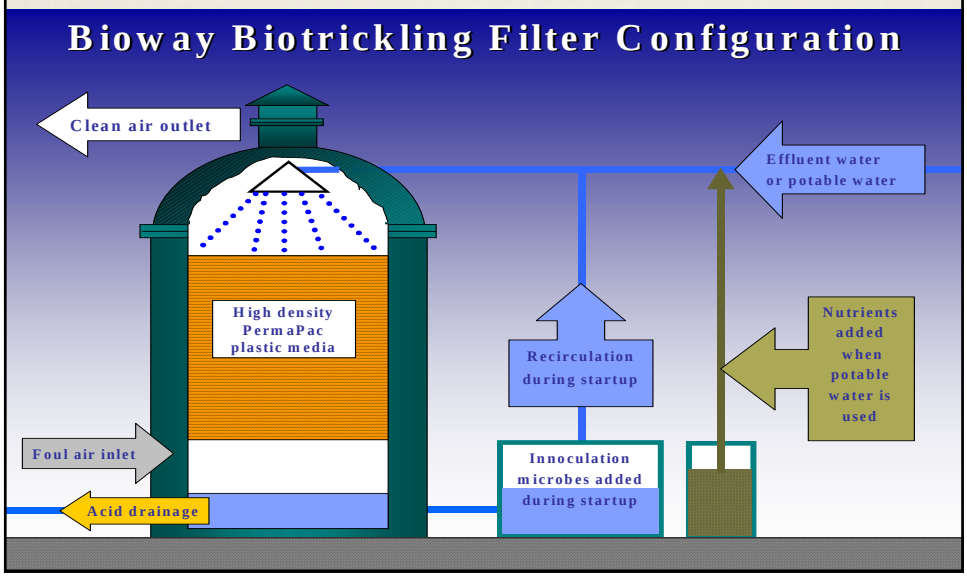
- Advantages:
  - Capable of handling high air flow rates and high odor concentrations
  - Removing as much as 99.9 percent of the H_2S content.
  - Respond well to variable inlet concentrations
- Disadvantages:
  - Low removal efficiency on some organic compounds
  - High chemical requirements
  - High electrical consumption (Pressure drops of 8 to 12 in W.C. depending on the number of stages)
  - High noise and high corrosion potential
  - Safety concerns with the handling of hazardous chemicals

Odor Control – BioTowers

- Natural media with indigenous microorganisms
- For low to moderate odor
- No chemical use
- City has unfavorable experience



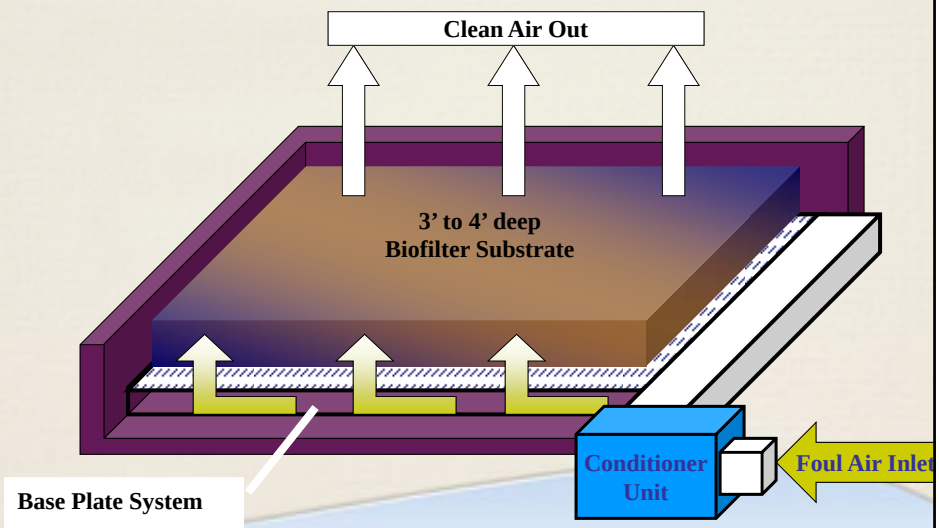
Bio-Towers



Bio Filters

- Advantages
  - Low Cost
  - Remove VOC's, NH_3, H_2S
  - Low Head Requirements
- Disadvantages
  - Large Footprint
  - Biological System
  - Requires Humidity and Aerobic Conditions

Bio Filter Elements

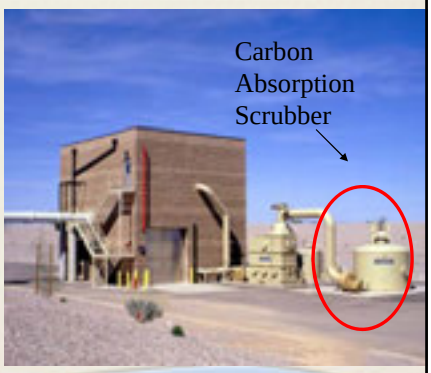


Small Package Systems - BioFilters

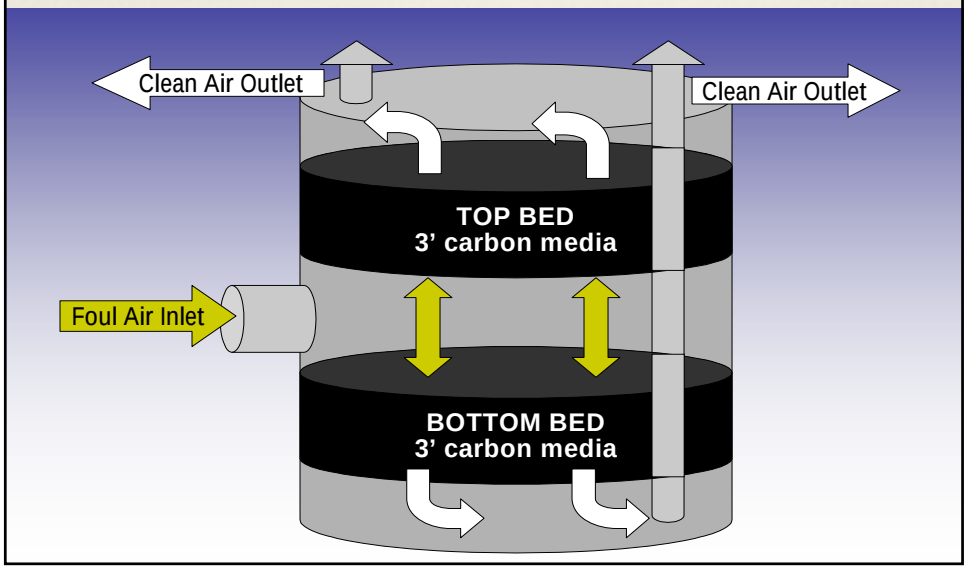
Large Systems - BioFilters

Odor Control – Carbon Absorption

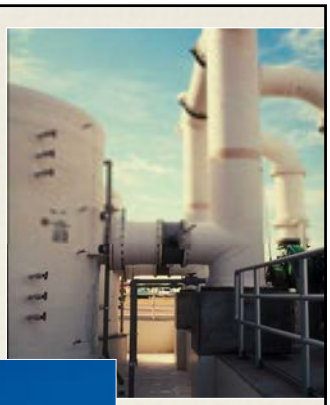
- Advantages:
  - Reliable and easy to operate
  - Good for secondary odor polishing
- Disadvantages:
  - Carbon sites consumed rapidly at high odor concentrations
  - Need regeneration and replacement of carbon
  - Difficult to predict carbon breakthrough for multiple odor components



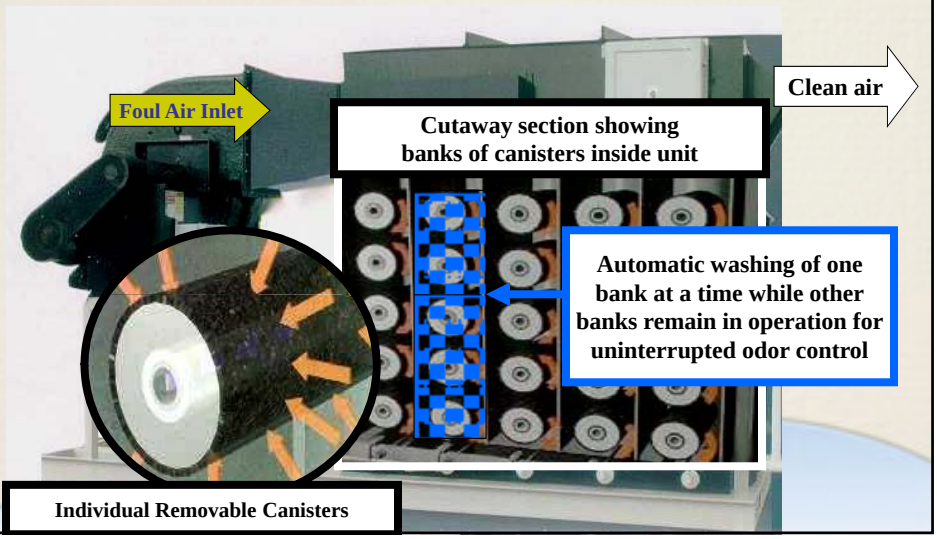
Dual Bed Configuration



Applications



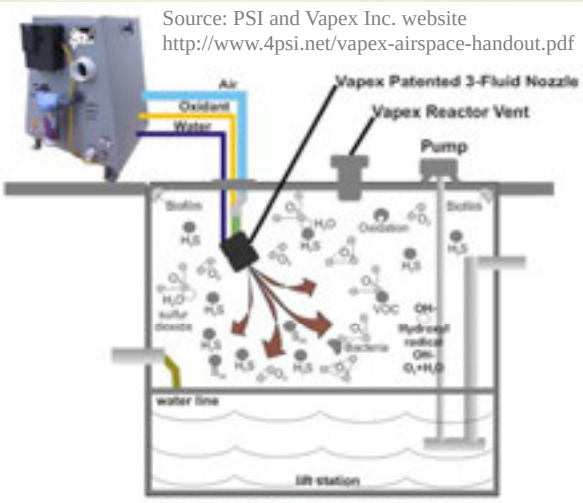
Calgon's Phoenix Package Systems



Odor Control – VAPEX (Hydroxyl Ion Fog)

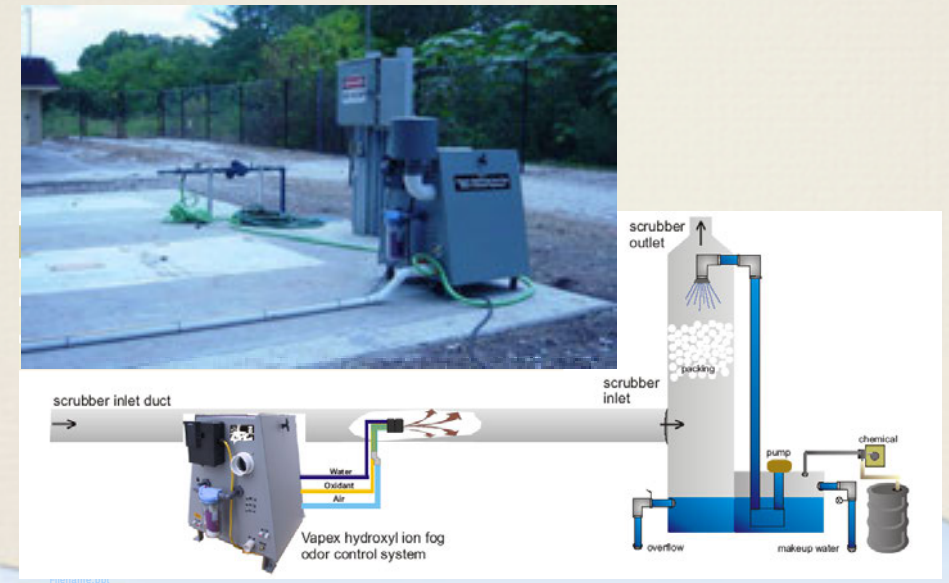
1. Remove both VOC and H_2S
2. Neutralize pH corrosion
3. No chemicals
4. Generate hydroxyl ion fog from air water and power
5. Chemical oxidation
6. No separate reactor

Source: PSI and Vapex Inc. website http://www.4psi.net/vapex-airspace-handout.pdf



Vapex Hydroxyl Ion Reactive Fog

VAPEX



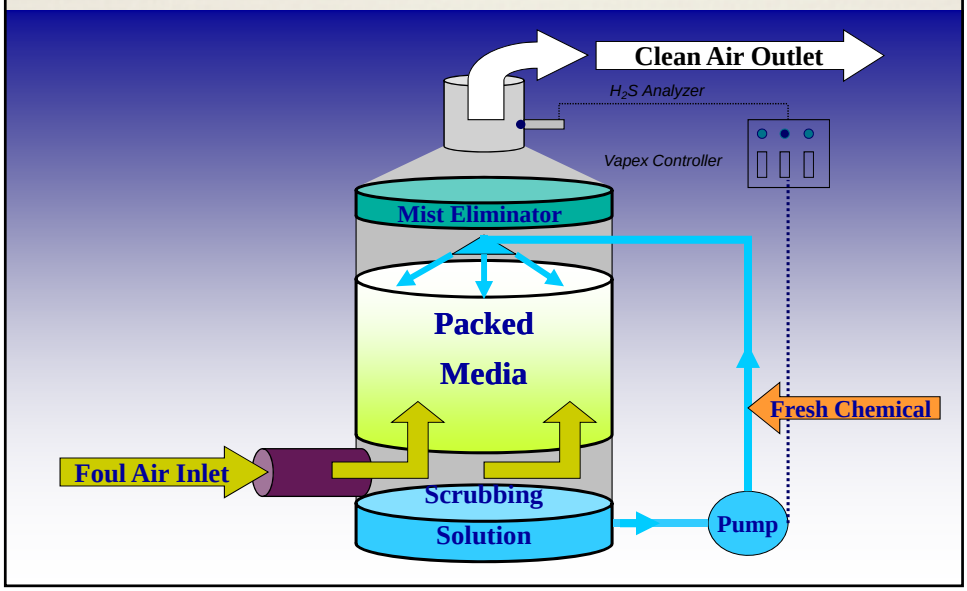
Electrically Charged Ion Addition

Ion Generating Modules

High Performance Air Filters

Intake Air System

Vapex Sentinel Control System



Odor Control Performance

Parameter	Chemical Tower Removal Efficiency%	Packed Carbon Tower Removal Efficiency %	Bio-Tower Removal Efficiency %	Bio Filter Removal Efficiency %
Hydrogen Sulfide	99	99	99	99
Carbonyl Sulfide	99	99	99	99
Methyl Mercaptan	<50	99	99	99
Ethyl Mercaptan	ND	ND	ND	ND
Dimethyl Sulfide	99	99	99	99
Carbon Disulfide	99	98	98	98
Isopropyl Mercaptan	<50	ND	ND	ND
N-Propyl Mercaptan	<50	ND	ND	ND
Dimethyl Disulfide	99	ND	ND	ND
Methane	<10	<50	<50	<50
TGNMO	<10	95	95	95
Ammonia	99	50	50	50

Odor Control Recommendations

- Headworks
  - Covered / enclosed influent pumping, screening and grit removal
  - VAPEX or Electrically Charged
  - Two-Stage Packed-Tower Wet Chemical Scrubber (Sodium Hypochlorite & Sodium Hydroxide) or Biotowers
- Secondary treatment
  - Covered oxidation ditch, clarifiers and flow splitter structure
- Solids handling
  - Enclosed in building
  - Two-Stage Packed-Tower Wet Chemical Scrubber (Sodium Hypochlorite & Sodium Hydroxide) or Biotowers

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For Sensitive Neighborhoods

- Use carbon polishing
- Multiple Barrier Approach
  - Consider bio-tower followed by chemical scrubber or carbon polishing

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Noise Control Requirement

- Noise control goals
  - Health and safety of operations personnel
  - Comfort and acceptance of the surrounding community
- Noise attenuation requirement: < 50 dBA at the property boundary
  - (ADEQ recommended limit per Bulletin 11)

Noise Attenuation Recommendations

- Headworks
  - Below grade wet wells
  - Submersible pumps and motors
  - Enclosed screens and grit removal tanks
- Oxidation Ditches / Aeration Basins
  - Covered ditches / Basin
  - Aerator / Blower noise attenuation
- RAS/WAS Pumping
  - Motor shroud / increased level of motor insulation
- Tertiary Filtration
  - Motor shroud / increased level of motor insulation
- Effluent Pumping
  - Motor shroud / increased level of motor insulation

Noise Attenuation Recommendations

- Solids Handling
  - Enclosed in building with interior acoustical treatment on walls
  - Motor shroud / increased level of motor insulation
- Odor Control Systems
  - Inlet / outlet silencer on blowers
- VFDs
  - Enclosed in building(s)
- Plant Alarm/Intercom System
  - Minimize audible alarms plant-wide to only those required by code

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Wastewater Treatment Technology Assessment

Biosolids - Thickening

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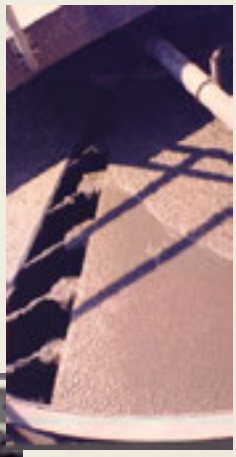
Thickening – Available Alternatives

- Dissolved Air Flotation (DAF)
- Gravity Thickener (GT)
- Gravity Belt Thickener (GBT)
- Rotary Drum Thickener (RDT)
- Centrifuge Thickening



Gravity Thickening and Dissolved Air Flotation

Gravity Thickener

Dissolved Air Flotation

Gravity Thickening

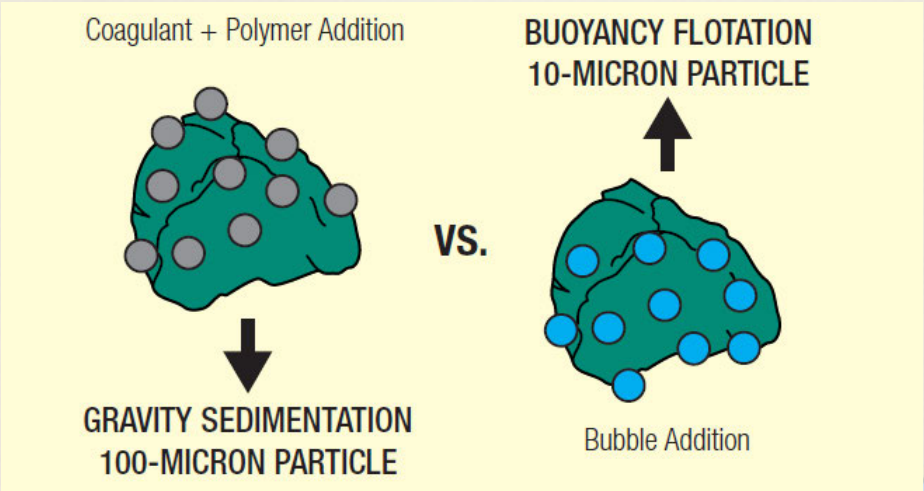
Benefits

- Simple operation
- Low operating costs
- Low maintenance
- Ideal for dense particles that settle rapidly
- Provide some thickened sludge storage

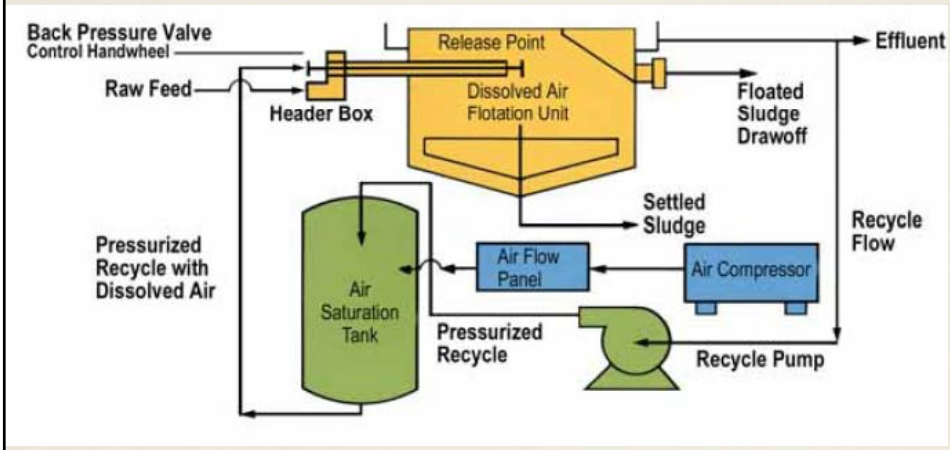
Challenges:

- Odor potential
- Not good for WAS thickening
- Limited thickened sludge concentration

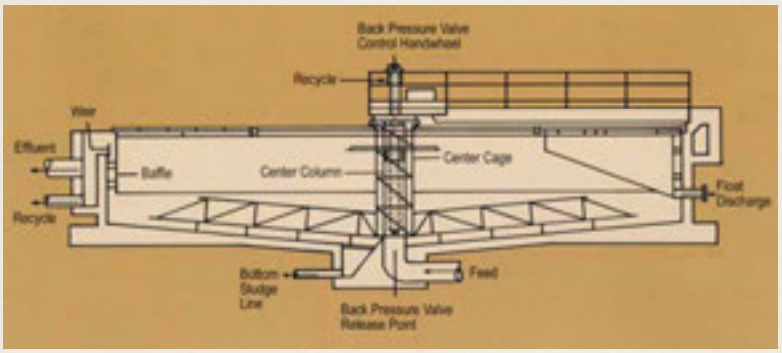
GT / DAF is Based on the Principle of Buoyancy Flotation



DAF System Components

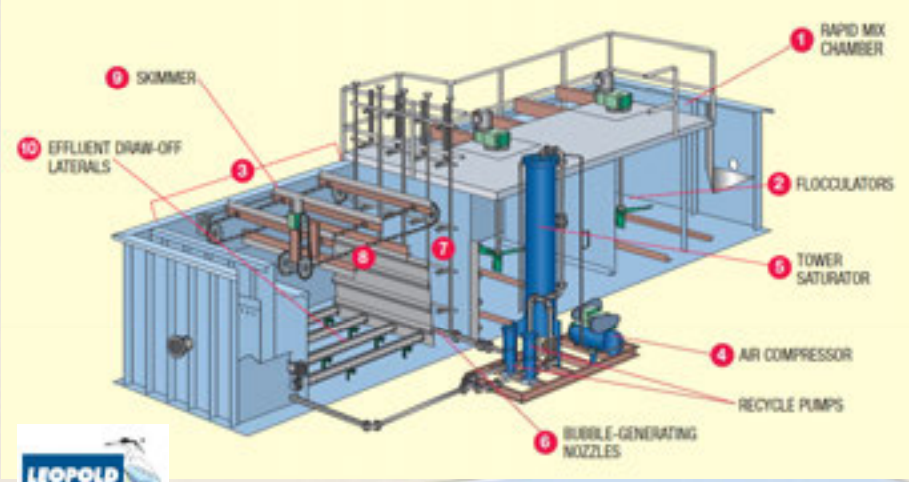


DAF System Components



EIMCO WATERTECHNOLOGIES

DAF System Components



DAF Thickening

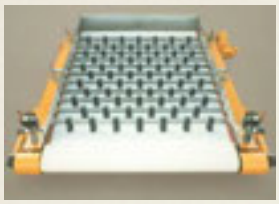
Benefits

- Effective for WAS
- Relatively simple and low operating costs
- Good for fats, oils, and grease removal

Challenges:

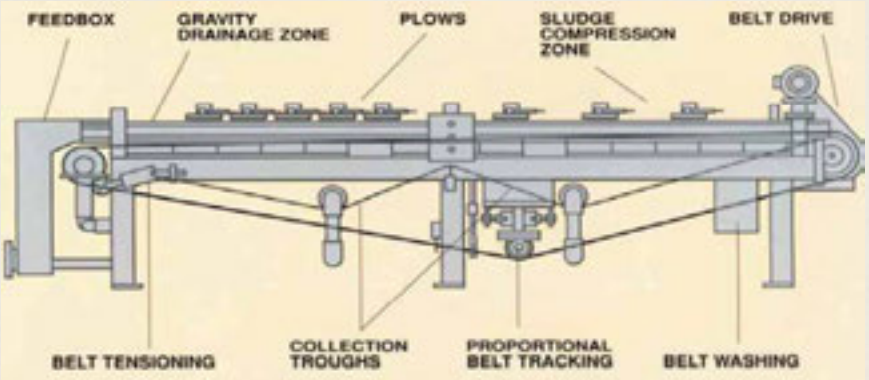
- Requires use of polymer or conditioning chemicals
- Odor potential
- Limited thickened sludge concentration (3 - 5%)
- If enclosed, building corrosion potential

Gravity Belt Thickener



Andritz

Gravity Belt Thickener

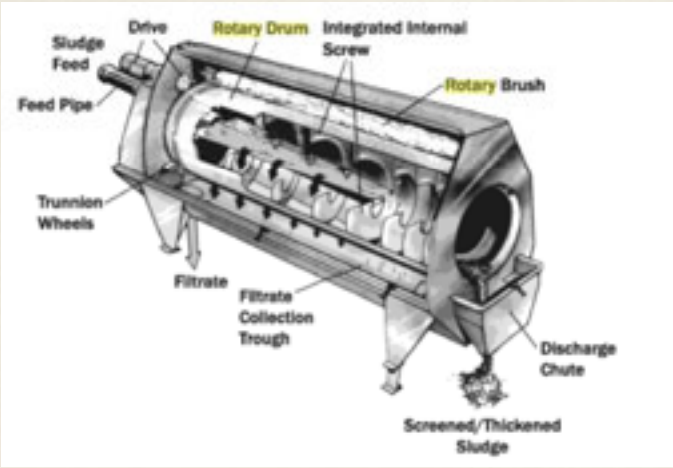


- Developed through application of belt filter press for sludge dewatering.
- Conditioned sludge applied to water permeable belt.

Gravity Belt Thickener

- Advantages
  - Less space requirements
  - Control capability for process performance
  - Relatively low power consumption
  - High solids capture with minimum polymer
  - Low operational skills required
  - High solids concentration (6-8%)
- Disadvantages
  - Polymer dependent
  - High humidity and odor potential
  - Building corrosion potential, if enclosed

Rotary Drum Thickener

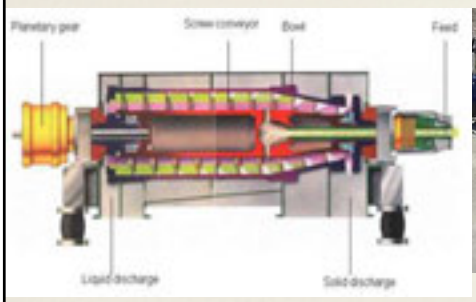


Separate solids from liquid by initial coagulation and flocculation (polymer usage) and then drainage of free water through rotating porous media

Rotary Drum Thickener

- Benefits
  - Less space requirementss
  - Low capital cost
  - Relatively low power consumption
  - High solids capture
  - Flexible operation for varying sludge characteristics
- Challenges
  - Polymer dependent
  - Sensitivity to polymer type
  - Housekeeping
  - Moderate operator attention required

Centrifuge Thickening



- Used for both thickening and dewatering
- Settling of sludge particles under the influences of centrifugal forces

Thickening Centrifuges

Benefits:

- Less space requirements
- Effective for primary sludge and WAS
- High thickened sludge concentration potential (critical for some advanced digestion process)
- Ability to control process performance
- Minimizes odor

Challenges:

- High capital and O&M
- Sophisticated maintenance requirements
- Best suited for continuous operation

Wastewater Treatment Technology Assessment

Biosolids - Dewatering

Dewatering – Available Alternatives

- Drying Beds
- Belt Filter Press
- Centrifuges

Sludge Drying Beds

- Dry solids on open concrete beds
- Solids removed manually after drying

Sludge Drying Beds

Benefits:

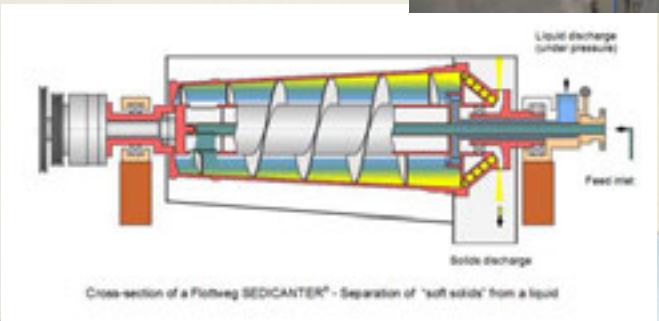
- Lowest capital cost where land is readily available
- Small amount of operator attention and skill required
- Very low energy consumption
- Less sensitive to sludge variability

Challenges:

- Potential odor and vector problems
- Require large land area
- Require stabilized sludge
- Design requires consideration of climatic effects
- Sludge removal is labor intensive

Centrifuge Dewatering

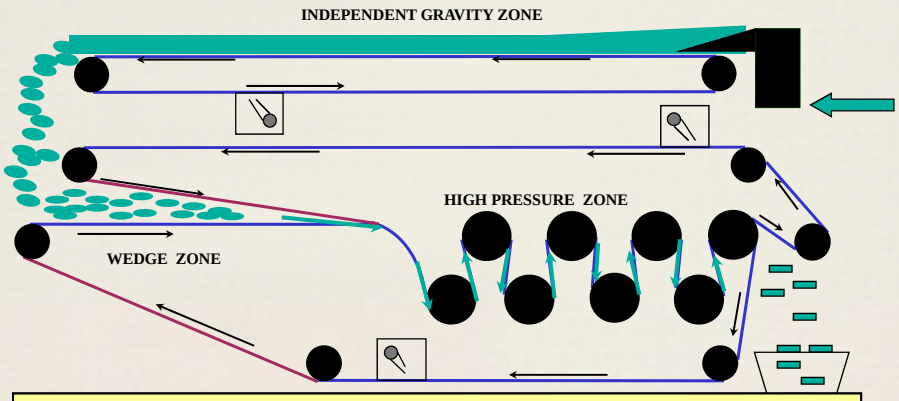
- Under influences of centrifugal force
- Solids bowl centrifuge



Centrifuge Dewatering

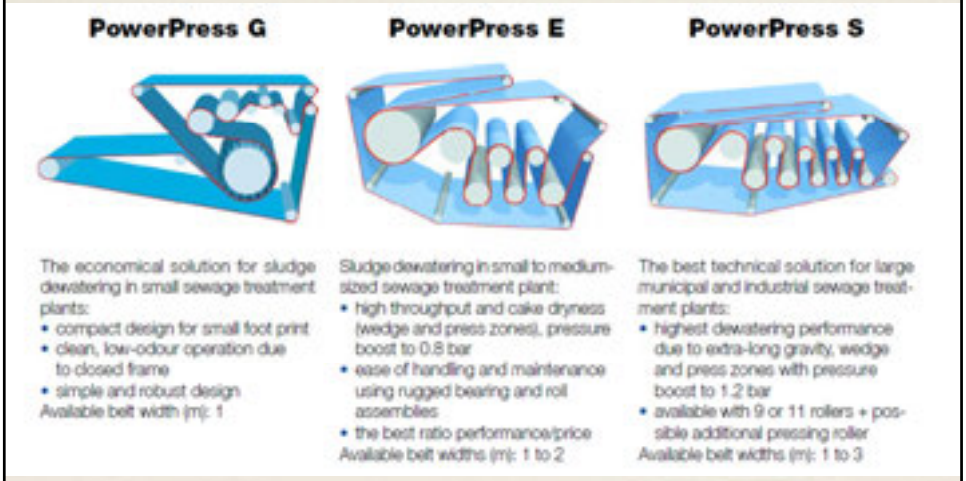
- Benefits:
  - Less odor potential and housekeeping
  - Fast start-up and shut-down
  - Produce dry sludge cake
  - Low capital cost to capacity ratio
  - Small footprint
- Challenges:
  - High maintenance
  - Require grit removal to reduce wear
  - Skilled maintenance personnel required
  - Centrate handling/treatment concerns

Belt Filter Press



Thinner Sludges Require a 3 Belt Unit

Types of BFP



Belt-filter Press Dewatering

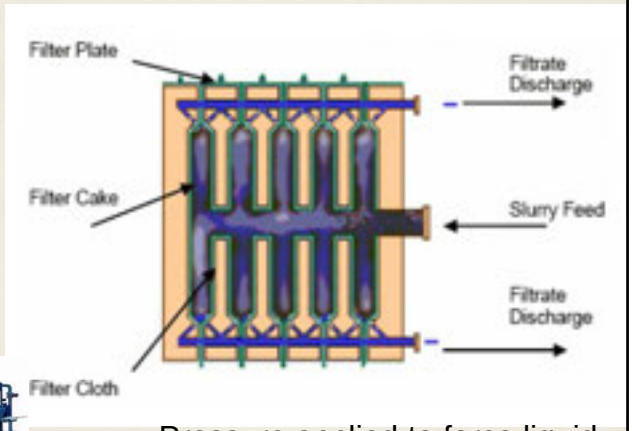
Benefits:

- Relatively low energy requirements
- Relatively low capital and operating costs
- Less complex and easier to maintain
- High-pressure presses are capable of producing dry cake
- Minimal effort required for system shutdown
- Continuous feed

Challenges:

- High odor potential
- May require sludge grinder in feed stream
- Sensitive to incoming sludge feed characteristics
- Need operator attention / semi-automatic operation

Plate Filter Press



- Pressure applied to force liquid through filter cloth and plate outlet ports
- Plates separated to remove sludge

Plate Filter Press

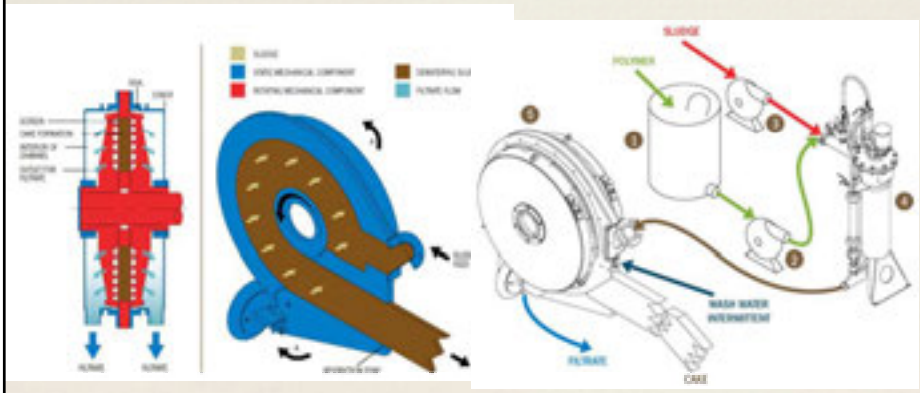
Benefits:

- Highest cake solids concentration
- Low suspended solids in filtrate

Challenges:

- Batch operation
- High equipment and O&M costs
- Large footprint
- Skilled maintenance personnel required
- Additional solids due to large chemical addition

Fournier Rotary Press



- Sludge rotated between two parallel revolving screens
- Filtrate passes through the screens
- Frictional force of the slow moving screens and controlled outlet restriction produce dry cake

Rotary Press

Benefits:

- Continuous operation
- Totally enclosed
- High cake dryness
- Simpler than centrifuge (less maintenance)
- Lower power usage and lower noise levels than centrifuge
- Easy to start and stop
- Low wash water

Challenges:

- Relatively new technology
- More expensive than belt press

Wastewater Treatment Technology Assessment

Biosolids Management

City's Biosolids Treatment Status and Goals

- **Currently:** Sending biosolids to landfill
- **Near Term:** The City would like to achieve Class B biosolids. This will allow the City to do utilize landfill and land application.
- **Long Term:** Although it is not anticipated that producing Class A Biosolids will become mandatory in the near future, the City's long-term plan includes treating biosolids onsite through thickening, advanced digestion and dewatering processes to produce Class A biosolids.

Two Primary Issues Drive Most Biosolids Management Decisions

Biosolids Quality

- Exceptional Quality (EQ)
- Class A
- Class B
- Other

Disposal Options

- Land Application
  - Agricultural Land
  - City Owned Land
- Landfill
  - No beneficial reuse
  - Alternative Daily Cover
- Commercial Product

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Biosolids Classification is the Baseline for Technology Selection / Disposal Options

	Exceptional Quality	*Class A*	*Class B*
Requirement	Fecal coliform density <1000 MPN/g total dry solids **or** *Salmonella* density <3 MPN/4 g total dry solids. Reduce pathogen levels to below detectable limits Achieve vector attraction reduction via limited options. Must meet monthly average metal concentration limits.	Fecal coliform density <1000 MPN/g total dry solids **or** *Salmonella* density <3 MPN/4 g total dry solids. Reduce pathogen levels to below detectable limits Achieve vector attraction reduction. Must meet ceiling metal concentration limits and metal loading rates.	Achieve pathogen and vector attraction reduction.
Can be applied to…	Anywhere.	Nurseries, gardens, golf courses, parks, and areas where contact with general public is possible.	Agriculture, landfill, & areas with no potential contact with general public.

Various Methods are Available to Achieve Pathogen Reduction

- Subject to various time-temperature regimes
- Treat in high pH, high temperature process
- Treat with approved Process to Significantly Reduce Pathogens (Class B) or Process to Further Reduce Pathogens (Class A/EQ)

Various Methods are Also Available to Achieve Vector Attraction Reduction

- Achieve 38% reduction in volatile solids
- Aerobic or anaerobic digestion
- Chemical addition to raise pH
- Dry biosolids
- Incorporation of biosolids into soil, or direct injection of biosolids beneath soil surface
- Cover biosolids with soil

Land Application Can Be a Cost Effective Disposal Option

Local Agriculture

- Advantages
  - Minimal City involvement (equipment, bookkeeping, etc.)
  - Potential elimination of dewatering
- Disadvantages
  - Limited Control (costs, shared liability, etc.)
  - No "City" beneficial reuse

City Owned Property

- Advantages
  - Direct benefit from reuse
  - Promotes cost savings and improved public services across City
  - Potential elimination of dewatering
- Disadvantages
  - Additional capital, operating and maintenance costs
  - Assumed liability

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Landfill Application Can Provide Potential Flexibility in Disposal

Direct Disposal

- Advantages
  - Minimal City involvement (equipment, bookkeeping, etc.)
- Disadvantages
  - No "City" beneficial reuse
  - High cost

Alternative Daily Cover

- Advantages
  - Beneficial reuse
  - Potential reduction in gate fees
- Disadvantages
  - No "City" benefit from reuse
  - High cost
  - Continued dewatering required

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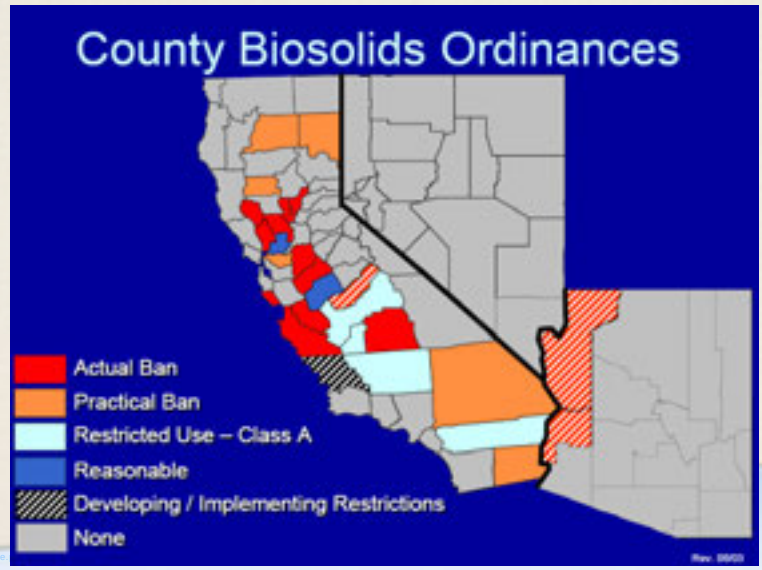
Generation of a Commercial Product Can be a Viable Alternative

- Benefits
  - Beneficial reuse options
  - Potential cost savings (on disposal or revenue generation)
  - Can be coupled with other disposal options
- Challenges
  - Requires Class A or EQ product
  - Requires sludge drying equipment/Compost
  - High capital/O&M costs

Ultimate Process Selection is Influenced by Regulations

- Recent industry opinion - No "hot" regulatory issues related to biosolids management
  - However, recent studies indicate centrifuge dewatering may lead to pathogen regrowth
- "Incineration" is difficult to permit in Arizona (may include emerging thermal technologies, i.e., pyrolysis/gasification, glassification)

CA Ordinances Provide a Good Example of Current Trends



There are a Multitude of Potential Biosolids Stabilization Alternatives

1. Aerobic Digestion
   a. Conventional
   b. Autoregulating Thermophilic (ATAD) & ATAD 2nd Generation
2. Anaerobic Digestion
   a. Conventional
   b. Temperature-Phased
   c. Multi-Phase
      - Mesophilic-Thermophilic
      - Mesophilic-Mesophilic
   d. Thermophilic
3. Heat Treatment
   a. Zimpro®
   b. Ver-Tech®
   c. Cambi®
4. Pasteurization
   a. Ashbrook ECOTherm Process®
5. Chemical Addition
   a. Alkaline Stabilization
   b. N-Viro Corp
   c. RDP EnVessel Pasteurization®

1. Air Drying
   a. Conventional Air Drying
   b. Parkson THERMO-SYSTEM™ Drying
   c. Vacuum Assisted Drying
2. Composting
   a. Windrow
   b. Aerated Piles
   c. In-vessel
3. Heat Drying
   a. Rotary Dryers
      - Swiss Combi®
      - Andritz®
   b. Carver Greenfield®
   c. Flash Dryers
   d. Paddle Dryers
4. Incineration
5. Gasification
6. Other Proprietary Processes
   a. US Filter – Cannibal®
   b. Vitrification – Minergy Corp®

A Variety of Stabilization Alternatives Can be Eliminated Based on Goals

- *Aerobic Digestion (ATAD)*
  - Not sustainable
  - Difficult to regulate/operate (temperature, foaming)
  - Odor potential (requires scrubbing)
- *Heat Treatment (Zimpro®, Ver-Tech®, Cambi®)*
  - Not sustainable (Energy Intensive)
  - Produce odors, colors, organic sidestreams, etc.
- *Pasteurization (Ashbrook ECO-Therm Process®)*
  - Potential regrowth of pathogens
  - Produces Odors
  - Post treatment required

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A Variety of Stabilization Alternatives Can be Eliminated Based on Goals

- *Chemical Addition (Alkaline Stabilization, N-Viro Corp, RDP EnVessel Pasteurization®)*
  - Increase volume of biosolids for disposal
  - Potentially not suitable for all land types
  - High O&M Costs (chemicals)
- *Incineration/Vitrification – Minergy Corp®*
  - Prohibited in Arizona

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Digestion, Stabilization and Disposal – Remaining Alternatives

Digestion and Stabilization

- Aerobic Digestion
- 2nd Generation ATAD
- Conventional Anaerobic Digestion
- Temperature Phased Anaerobic Digestion
- Multiphase (Acid / Gas) Anaerobic Digestion
- Multistage Thermophilic

Biosolids Disposal – Remaining Alternatives

Advanced Stabilization

- Cannibal Process
- Air Drying
- Heat Drying
- Composting

Biosolids Disposal

- Land Fill
- Land Application

Wastewater Treatment Technology Assessment

Biosolids Technology – Digestion, Stabilization and Disposal

Additional Sludge Screening / Conditioning May Be Considered

- Improves the Aesthetic value of biosolids by removing
  - Plastics
  - Personal care products
  - Visible debris

- Enhances the Hydrolysis rate of sludge
- Enhances the fluid properties of thickened sludge
- Reduces the amount of debris in the sludge

What's in The Sludge???

- Primary Sludge (PS)
  - *Raw organics, undigested carbohydrates, simple sugars, fats, oils, grease.*
  - *Rule of 10%*
- Secondary Sludge or Waste Activated Sludge (WAS)
  - *Complex Organics, Proteins, Aminoacids, long chained sugars (cellulose materials)*
  - *Living Organisms (Death and Decay)*
- If no primary, secondary treatment decomposes easy "food"

Comparing Aerobic and Anaerobic Digestion

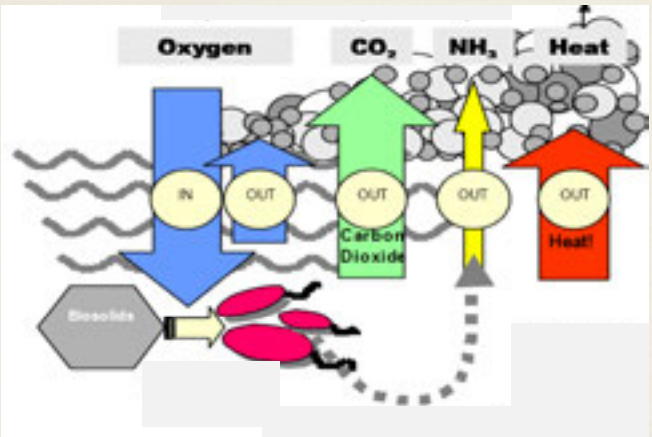
Aerobic

- Oxidizes organics and cell tissues aerobically to CO_2, water and ammonia
- Limited by oxygen transfer

Anaerobic

- Accept shigh strength waste
- Oxygen transfer is not a limiting factor
- Generates methane
- Higher volatile solids reduction

Simplified Process Summary for Aerobic Digestion



Limited by oxygen transfer; Accept low and moderate feed solids concentration; 30 to 50% volatile solids reduction.

Simplified Process Summary for Anaerobic Digestion

Hydrolysis Formation		*Acid Formation*		*Methane*
Insoluble Organics	→	**Soluble Organics**	→	**Organic Acids** → **Methane CO_2**

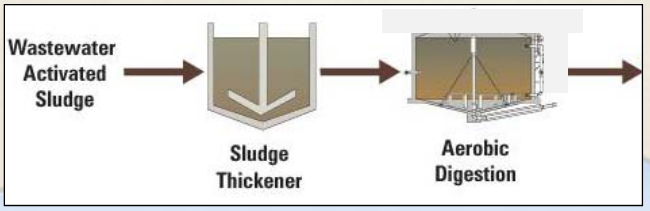
Extracellular Enzymes		*Acid Producers*	*Methanogens*
Cellulose	**Glucose**	**Acetic**	**Cells**
Proteins	**Amino Acids**	**Propionic**	**Stabilized**
Organics			
Lipids	**Fatty Acids**	**Latic + Cells**	
Phosphorylated	**PO_4^{-3}**		
		Organics	

No oxygen; Generate Methane; Higher volatile solids reduction;

Conventional Aerobic Digestion

- Air introduced to maintain aerobic conditions
- Meets vector attraction reduction requirements by +38% destruction of VS
- Produces a Class B Biosolids
- Meets Process to Significantly Reduce Pathogens by time-temperature relationship
  - Between 40 days at 20°C and 60 days at 15°C

Components needed: tank, diffuser system, blowers, mixing



Conventional Aerobic Digestion

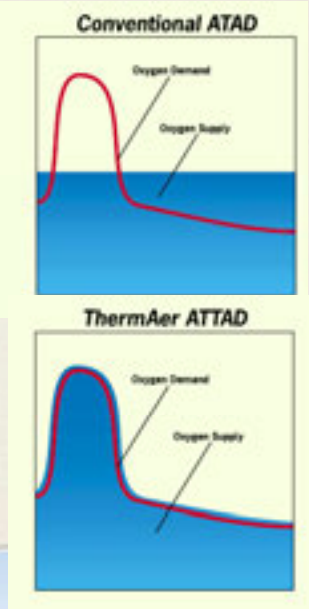
- Benefits:
  - Produces Class B biosolids
  - Compatible with existing processes
  - Low Capital Cost
- Challenges:
  - Long retention time (Requires large digester capacity)
  - Produces Class B biosolids
  - Energy intensive (relative to other technologies)
  - No energy recovery / Not compatible with cogeneration
  - Potential for odors and foam

Autothermal Thermophilic Aerobic Digestion (ATAD)

- Self-heated aerobic digestion
- Higher temperature (132 - 150 ^{o}F) than conventional aerobic digestion
- 10 – 15 day retention time

2nd Generation ATAD

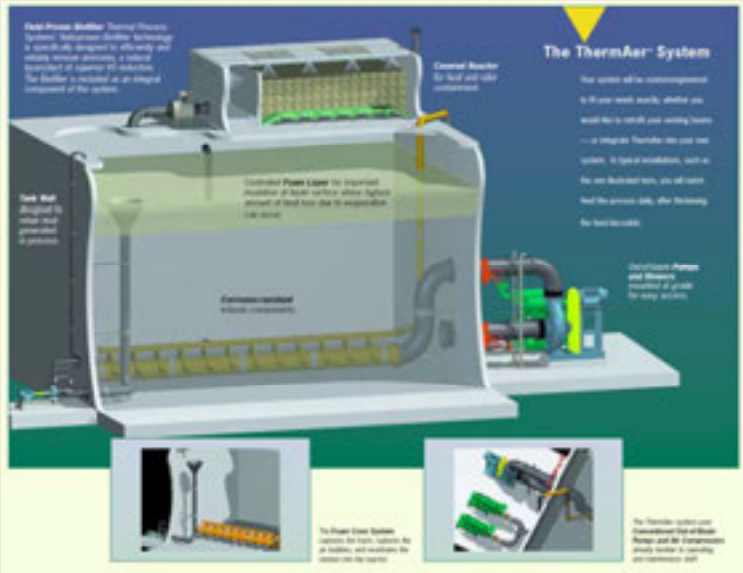
2nd Generation: Automatic control based on ORP instruments



2nd Generation ATAD

Components

- Reactor
- Mixing Pump / Blower
- Foam control cone
- Off-gas treatment (biotowers)



2nd Generation ATAD

Benefits

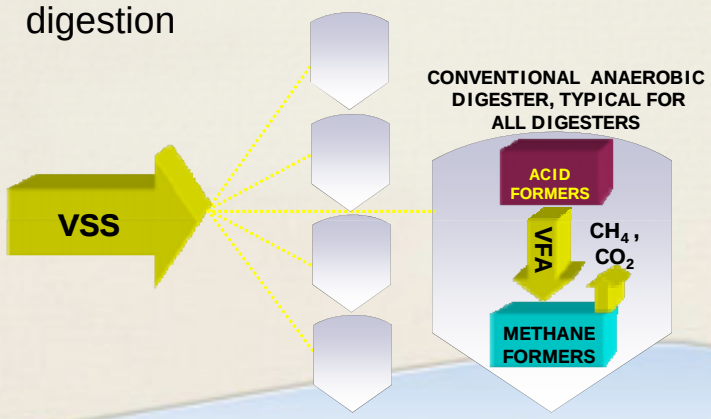
- Relatively Simple
- High / Moderate VSS Reduction (~40 – 50%)
- No extra heating
- Class A Biosolids

Challenges

- Foaming Control Is a Challenge
- Off-Gas and Odor Control Issues Have Not Been Proven Reliable
- Performance Relies Highly on DO and ORP Control
- Temperature Control through Off-gas is Not Effective
- No Energy Recovery

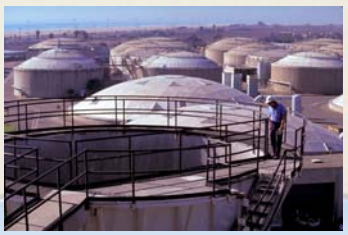
Conventional Anaerobic Digestion

Biosolids treated in absence of air for a specific amount of time at a specific temperature depending on type of anaerobic digestion



Conventional Anaerobic Digestion

- Lack of oxygen promotes fermentative state and degradation of organics through fermentation
- Can typically achieve ~50% destruction of VS
- 15 days at 35-55 °C (95-132 °F) minimum required
- Can be operated at both mesophilic (95 °F) or thermophilic (132 °F)



Conventional Anaerobic Digestion

Benefits:

- Compatible with cogeneration in larger facilities
- Operational costs low if methane is used – Low net energy requirements
- Accepts thicker solids
- Lower tank volume required compared to aerobic digestion

Challenges

- High initial cost
- Increased complexity
- Potential for odors and foam
- Requires operator training
- Recovers slowly from upset
- Supernatant is strong in COD, BOD, SS, and NH_4
- Struvite deposit potential

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Conventional Anaerobic Digestion

Components:

- Digester(s) and covers
- Sludge transfer piping
- Mixing system
- Heating system (boiler and heat exchangers)
- Gas handling system (piping and flares)

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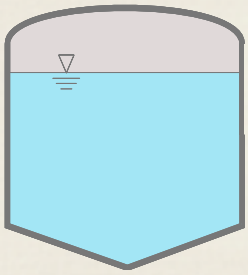
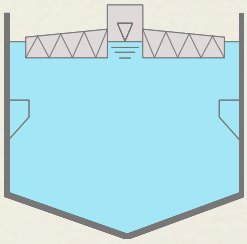
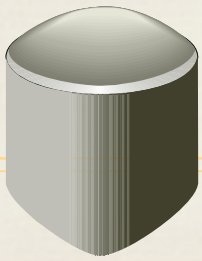
Anaerobic Digester Cover Designs

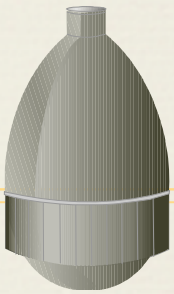




Fixed **vs.** **Floating**

Anaerobic Digester Designs





Classic **vs.** **Egg-Shaped**

Egg Shaped Digester Provides Better Mixing and Performance

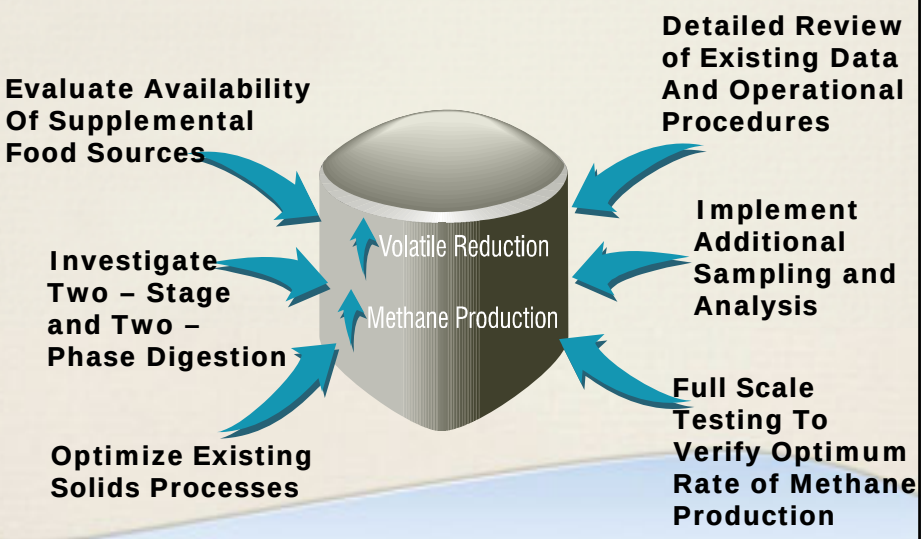
Benefits:

- Minimum grit accumulation
- Reduced foam formation
- Higher mixing efficiency
- Lower O&M Costs
- Reduced cleaning frequency
- Smaller footprint

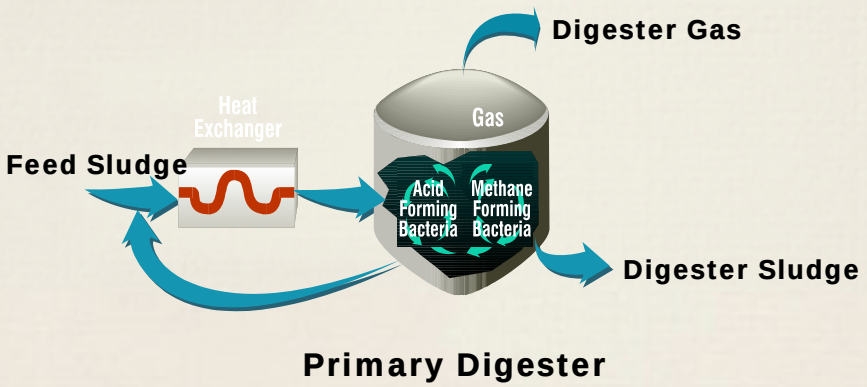
Challenges:

- Expensive construction
- Little gas storage volume

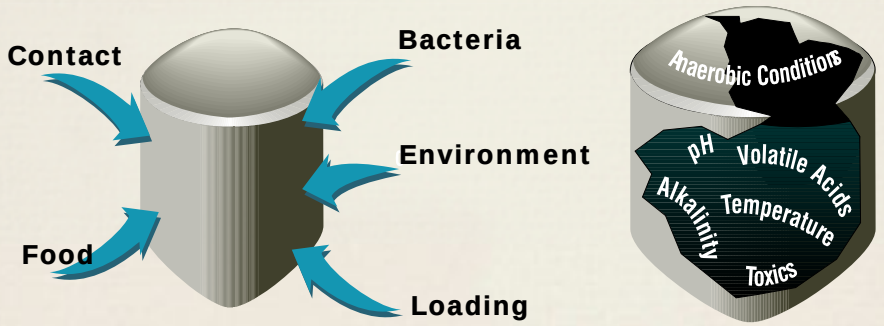
Maximize Digester Process Performance



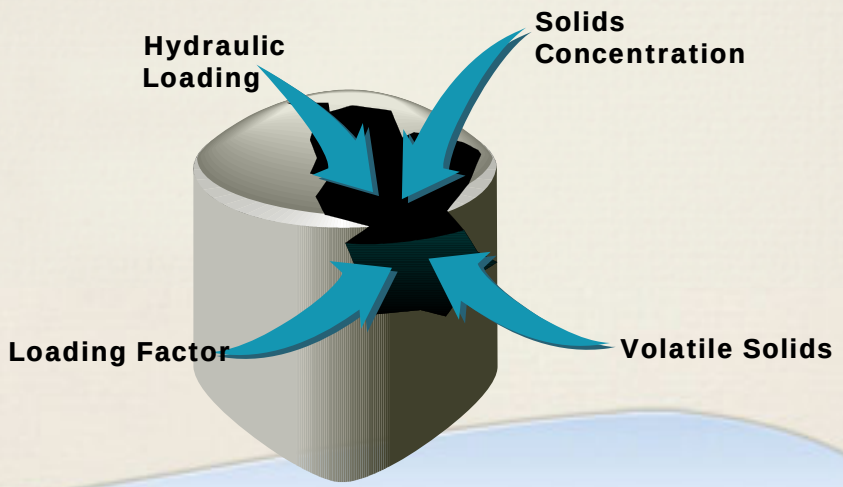
Single Stage High Rate Anaerobic Digester System



Factors Affecting Anaerobic Digestion



Loading Factors Affecting Digestion

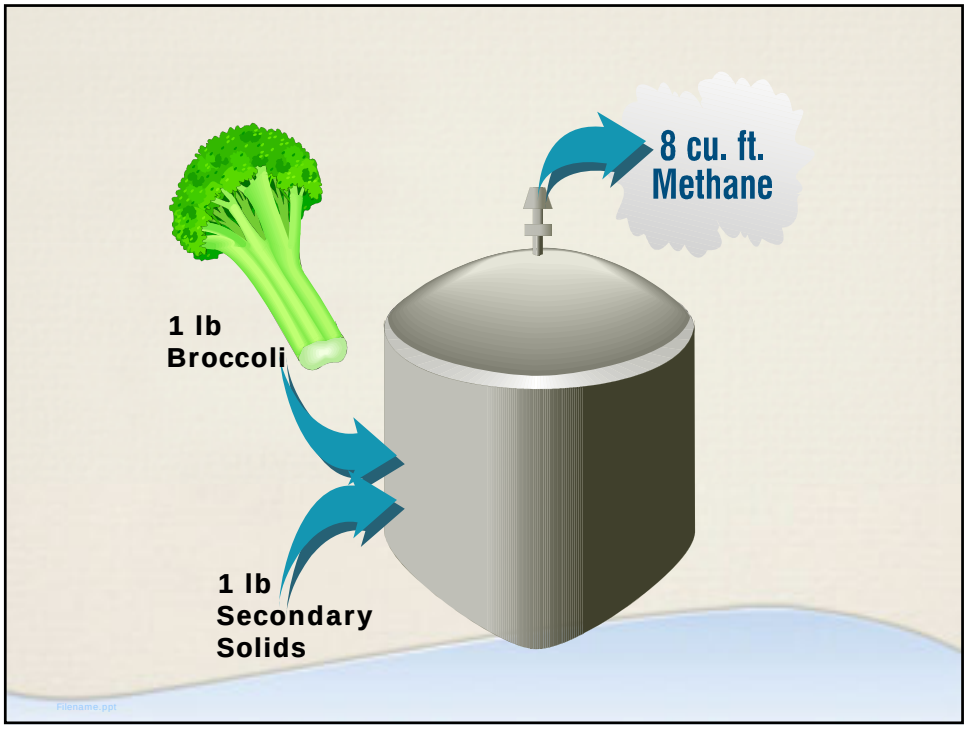


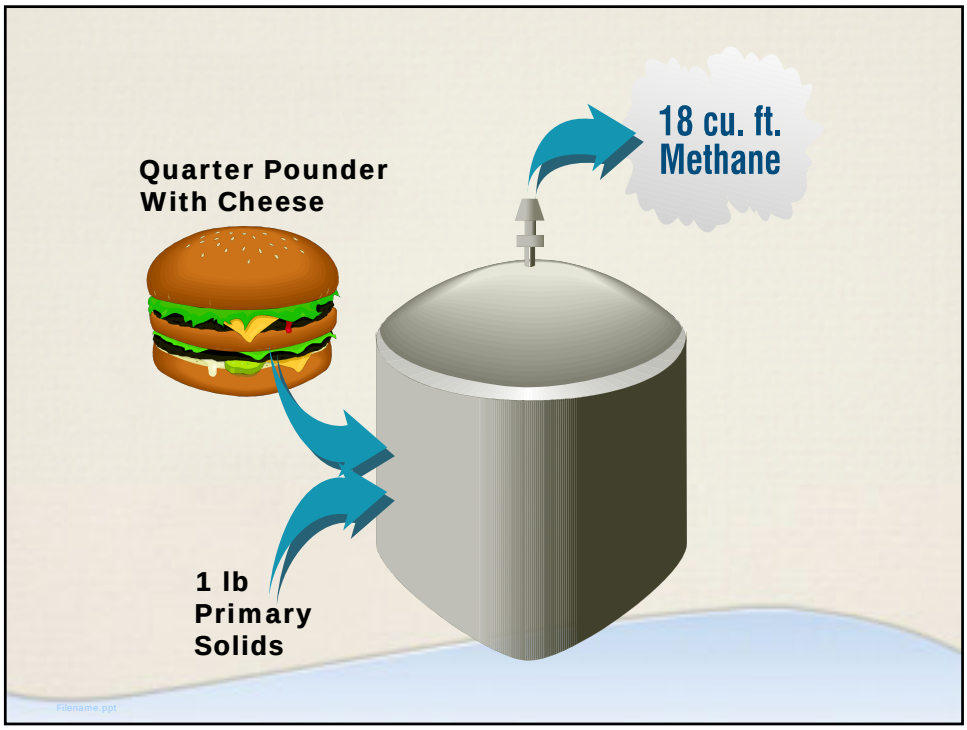
Effect of Anaerobic Digestion Feed Solids Concentration

% Solids	Organic Loading @ 15 day HRT Lbs VSS/ft3-d[1]	Limiting Criteria [1]
1	0.03	Hydraulic Limited
2	0.07	Hydraulic Limited
3	0.10	Hydraulic Limited
4	0.13	Hydraulic Limited
5	0.17	Solids Limited
6	0.20	Solids Limited
7	0.23	Solids Limited
8	0.27	Solids Limited
9	0.30	Solids Limited
10	0.33	Solids Limited

1. Assumes 80% Volatile Suspended Solids

Conventional digester accepts 4% solids


8 cu. ft.
Methane
1 lb
Broccoli
1 lb
Secondary
Solids


18 cu. ft.
Methane
Quarter Pounder
With Cheese
1 lb
Primary
Solids

Gas Production for Compounds Found in Wastewater Solids

Material	Specific Gas Production (cu Ft/lb Fed)	CH_4 Content (Percent)
Fats	18 - 23	62 - 72
Scum	14 - 16	70 - 75
Grease	17	68
Crude Fibers	13	45 - 50
Protein	12	73
Cells	8	65 - 70

Typical Characteristics of Conventional Anaerobic Digester Gas

	Typical Constituent Concentration, %
Methane	55 - 75
Carbon Dioxide	25 - 45
Hydrogen Sulfide	0.01 - 1
Nitrogen	2 - 6
Hydrogen	0.1 - 2

Digester Gas is a Renewable Energy Source

- Green Energy
- APS/SRP Incentives available
- Does not rely on petroleum products
- Has high energy content and value
  - 60-70% Methane = 600-700 BTU/cuft @ $1.00/ therm = 6-7 cents/cuft
- Can be used as fuel
  - Boilers to heat the Digesters
  - Burners in Sludge Driers
  - Engines for Cogeneration

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Issues Specific to Using Digester Gas to Generate Power

- Gas composition and pressure
  - Typical 40% CO_2
  - Typical 60% CH_4
  - Water vapor (saturated)
  - Trace levels of contaminants including H_2S and siloxanes, greases, dirt, etc.
  - Typically generated at 8-12 inches w.c.
  - H_2S Treatment Options
    - Iron sponge (adsorption)
    - Ferric Chloride into process
- Advanced digestion process improves gas production and quality

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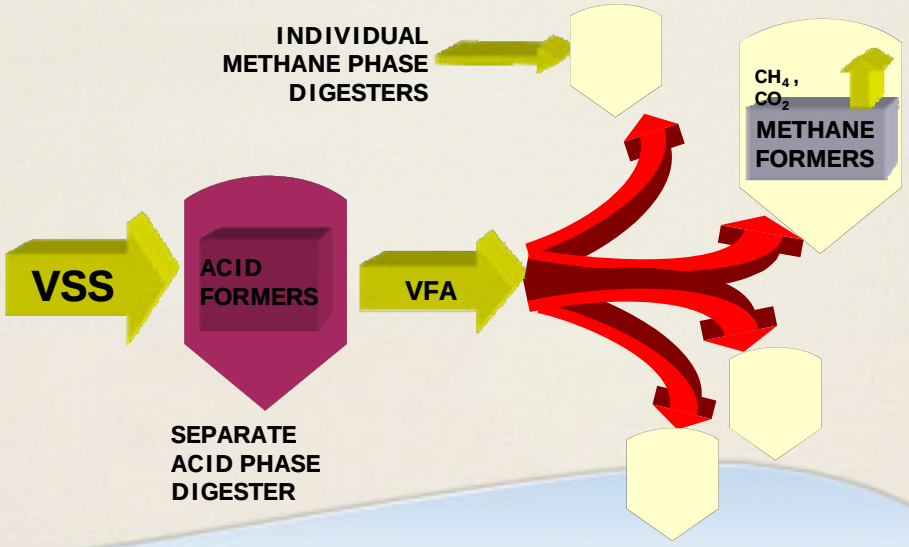
Multi-Phase Digestion Concept



Multi-Phase Process: Right Bugs Live in the Right Environment

Acid Phase Digester

- Degradation of celluloid materials (lignins) commonly undegradable in conventional anaerobic digestion.
- Destruction of foam causing microorganisms
- Enhanced destruction of pathogenic organisms.
- Destruction of Floc "Structure" increases dewaterability

Methane Phase Digester

- Released carbonate alkalinity (7,000-9,000 mg/L as $CaCO_3$) provides outstanding stability to changes.
- pH controlled by carbonate alkalinity not VFA's;
- Over 90% of the gas is produced in this phase
- Methane concentration around 70%.
- Acid gases H_2S and CO_2 suppressed due to pH conditions.

Multi-Phase Digestion Benefits

Multi-Phase Digestion

Capital Expenditure
- Reduced Expansion Costs
- Increased Dewaterability
- Class "A" Biosolids

Operation
- Enhanced Pathogen Kill
- Stable Operation at Thermophillic Temp.
- Eliminates "SOUR" digester concerns from Operators
- Increased Gas Quality
- Reduced Foam Generation
- Reduced Engine Maintenance
- Increased Dewaterability

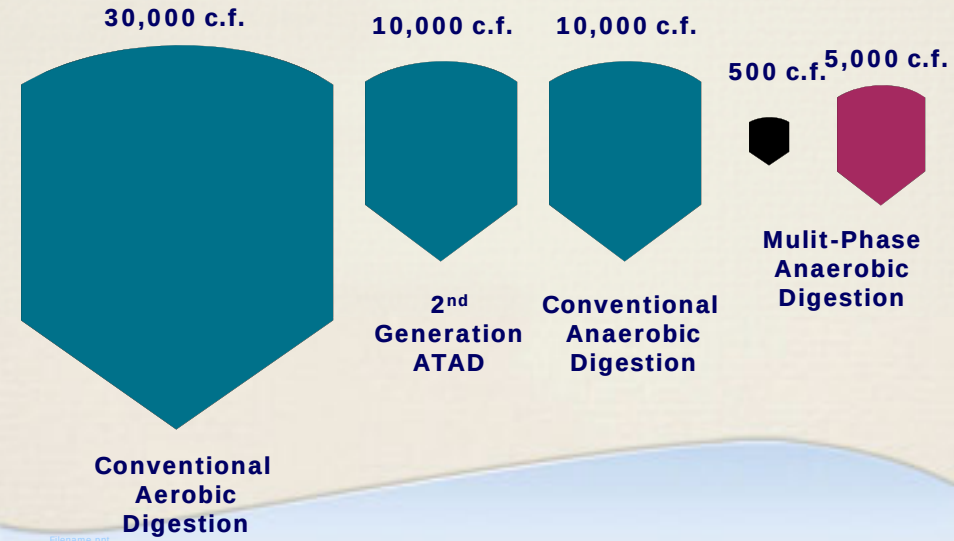
Revenue
- Reduced Heating Costs
- Increased Gas Quantity
- Reduced Engine Maintenance
- Increased Dewaterability
- Class "A" Biosolids

Reuse
- Enhanced Destruction of VSS
- Increased Dewaterability
- Class "A" Biosolids

Multi-Phase Anaerobic Digestion

- Benefits
  - High VSS reduction (55 – 75%)
  - Can produce Class A biosolids if needed (Lower heating requirements when not needed)
  - Recover energy (Use Methane Gas) and lower life cycle cost
  - Improved digester gas production and quality
  - Reduced foam; Resistant to oil and grease
  - Full scale applications locally and world wide
- Challenges
  - Impact of ammonia-laden concentrate return
  - High initial costs

Multiphase Digestion Advantages: Reduce Digester Volume



Multiphase Digestion Advantages: Accept High Loading

- Acid Phase Digester operates with High VSS loading.
  - Conventional Digesters must limit VSS loading therefore limiting % solids in feed
  - Acid Phase Digesters can be fed more concentrated solids to accomplish acid conditions.
    - Approximately 6-8% TSS feed to Acid Phase Digester
    - Can accept scum, oil and grease

Multi-Phase Digestion Advantages: Improve Gas Production and Quality

	Conventional Anaerobic Digestion	Acid Phase	Methane Phase
Specific Methane Yield per lb of VSS Added	6.12	0.40	9.48
Methane Content %	65	< 30	~70
H_2S Content ppm (No FeCl3 addition)	2,000	1500	150

- Separation of phases and pH generates a much cleaner gas from the methane phase as compared to the gas produced from the conventional digester.
- Increased Gas Yield represents better utilization of available VSS.

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Multi-Phase Digestion Process Comparison

Assuming 1,000 lbs of Biodegradable VSS per day fed to Mesophilic Digesters

	Conventional High Rate Digester	Acid Phase	Methane Phase
Sludge Concentration % VSS	3%	5%	
Solids Loading lbs VSS/ft^3 d	0.1	1.81	
Digester Size ft^3	10,000	550	5,000
HRT days	19	2	13
Expected VSS Destruction %	60%	5%	70%
Methane Produced SCFD	6,120	800	9,500
Effluent VFA mg/L	30	~10,000	30
Ammonia Nitrogen lbs/day	80-100		120-150

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2nd Generation ATAD vs. Multiphase Digestion

	2nd Generation ATAD	Multiphase
Process	1-stage aerobic	2 to 3 stages, anaerobic
VSS Reduction	40-50 %	50-65%
Operating Temperature	132 - 150 ºF	97 ºF for Acid Phase, 125 ºF Thermo Methane Phase
Retention Time (Day)	10 - 15	2 + 10~12 (thermo) or 12~15 (meso)
Heating	Self-heated. Temperature controlled by off-gas. Hard to maintain.	Heated using energy recovered. Proven heat exchanger and temperature control technologies.
Mixing Energy	Limited by Oxygen Transfer	Much more efficient.
Gas Production	Off-gas is a waste & must be treated	Digestion gas is an energy source for heating and more
Thickening	Required. 6-8%	Required. 6-8%
Cake Solids	~ 25%	20% +
Ammonia Load	High Ammonia in Off-gas	High Ammonia in Centrate
Odor Control	2-stage biofilter	Not Required
Costs (Further Evaluation Required)	Lower Capital	Lower Life Cycle if consider energy savings

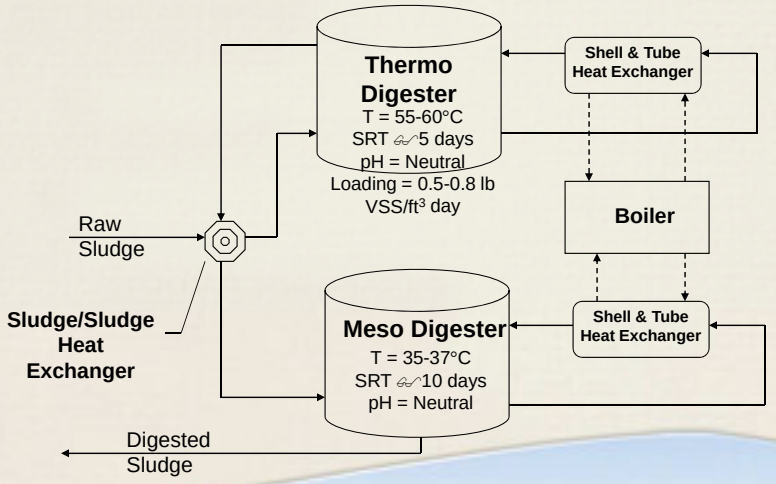
2nd Generation ATAD vs. Multiphase Digestion

Bio-Solids Management Process Comparison Matrix

PROCESS	Class A Product	Recycle Stream: Significant Nutrient	Recycle Stream: Low COD	High Volatile Solids Reduction	Low to Moderate Energy Use	Off-Gas: Ammonia	Off-Gas: Methane	Off-Gas: Reduced Sulfur	Retrofit Potential	Simple Operation
Thermofor	•	•	•	•	•	•			•	•
Conventional ATAD	•	•			•	•		•		
Anaerobic Digestion		•			•		•	•		
Lime Stabilization	•				•	•		•		
Thermal Drying	•							•		
Composting	•			•	•			•		•
APAD		•	•	•	•			•	•	•
D4PAD	•	•	•	•	•		•	•	•	•

APAD = Acid Phase Anaerobic Digestion (Meso-Meso)
D4PAD = Meso-Thermo-Meso Multiphase Anaerobic Digestion

Temperature-Phased Anaerobic Digestion



Temperature-Phased Anaerobic Digestion

Benefits

- High reaction rates
- Additional VS reductions
- Improved dewaterability
- Class A compliance potential (based on pathogen kill)

Challenges

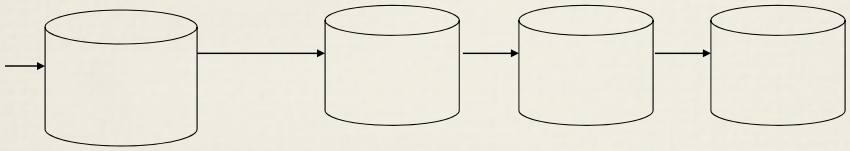
- More complicated **heat exchanger** system design and operation
- The only patented advanced digestion process (Royalty fee)

Full-scale TPAD Operation in US

Plant	Sturgeon Bay, WI	Neenah-Menasha Neenah, WI	Papillion Creek Omaha, NE	Newton, IA	Independence, IA	New Hampton, IA
Years	3~4	2	6	> 5	2	4

Staged Thermophillic Anaerobic Digestion

All reactors at 55 C; reactors operate as methane reactors
pH = 7.2 - 7.8
Batch Operation for Class A



SRT in 1st Stage = > 5-8 days
Loading to 1st Stage = 0.1 lb VSS/ft3 day

Variable HRT in remaining stages

- Multiple reactors reduces short circuiting
- Achieve Class A biosolids
- VSR up to 65%

Staged Thermophillic Anaerobic Digestion

Benefits

- Improved VSR
- Ease in achieving Class A
- Heat recovery not required
- "One" biological system
- Improved dewaterability

Challenges

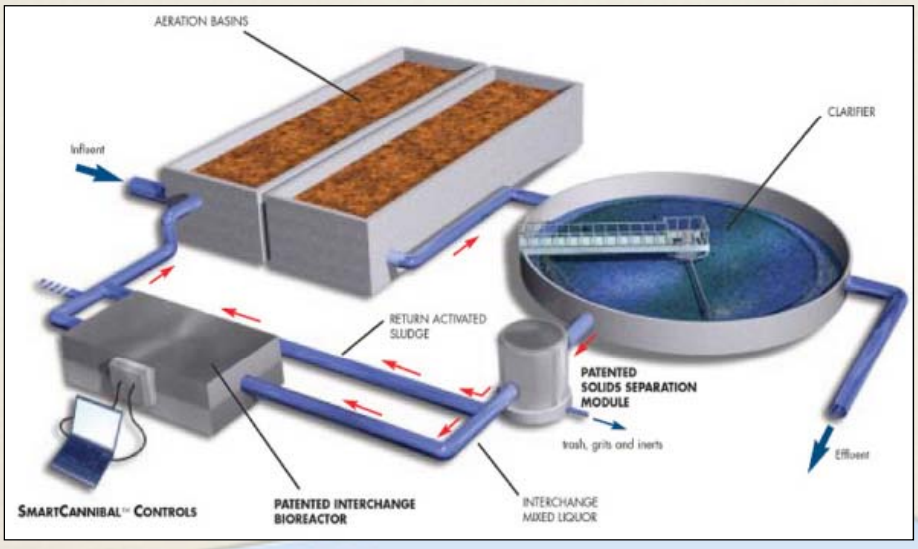
- Some product odor and VFA content
- Reduced HRT not yet proven
- Added heat required over meso digestion

3 full scale facilities operating in North America, including 130 mgd at Vancouver. Several POTWs testing/evaluating staged thermophillic.

Cannibal® Solids Reduction Process

- Sludge typically wasted in conventional plants is pumped to sidestream bioreactor
- Non-aerobic sidestream bioreactor selects low-growth facultative bacteria and destroys aerobic bacteria breaking down their cells
- Remaining facultative bacteria returned to aeration basins where broken down by aerobic bacteria
- Produces little/no biological residuals

Cannibal® Solids Reduction Process



Cannibal® Pros/Cons

Benefits:

- Significantly reduces amount of biosolids
- Solids content 40-50%
- Reduced footprint
- Low energy and labor

Challenges:

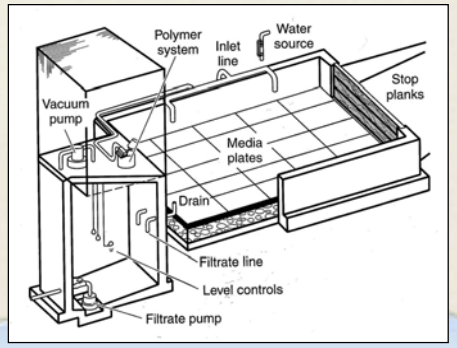
- Proprietary Technology
  - Requires Licensing Fee
- Limited installations
- Produces inert material, which does not provide beneficial reuse

Conventional Air Drying

- Prolonged exposure to sunlight and air
- Benefits:
  - Produces Class A biosolids
  - Reduces the amount of material for disposal
  - Low Capital Cost
- Challenges:
  - Land intensive
  - Effectiveness impacted by climate changes
  - Potential for high odors at processing site
  - Cannot be land applied unless re-wetted
  - Dust control and buffer zones

Vacuum Assisted Drying

- Sludge initially dewatered by gravity drainage
- Vacuum applied to further dewater
- Biosolids air dried for additional 24 to 48 hours
- Polymer added to aid in dewatering
- Not recommended due to reported operational issues



Vacuum Assisted Drying

Benefits:

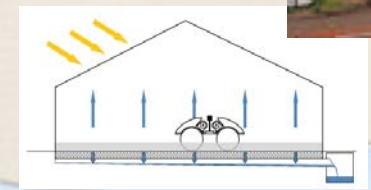
- Smaller footprint required (vs. air drying beds)
- Reduces the amount of material for disposal

Challenges:

- Energy and labor intensive
- Media has tendency to clog regularly
- Polymer intensive
- Optimal polymer dosage needed in order to operate correctly

THERMO-SYSTEM™ Solar Sludge Dryer

- Sludge dried in drying beds enclosed by greenhouse-like structure.
- Sludge tilled by computerized “mole”, aerating the sludge



THERMO-SYSTEM™

Benefits:

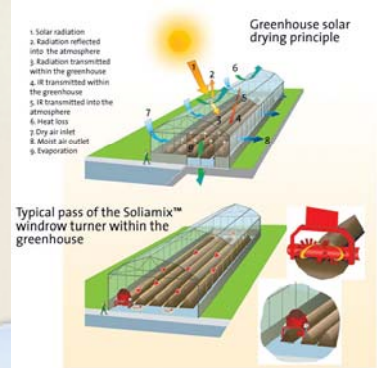
- Produces Class A biosolids
- Up to 50-90% solids content can be achieved
- Low energy and operating costs
- Can retrofit to existing sludge drying beds
- Minimizes odor
- Not affected by inclement weather

Challenges:

- Land intensive
- “Mole” can experience mechanical problems

SOLIA™ Sludge Dryer

- Sludge dried in drying beds enclosed by greenhouse-like structure.
- Solar radiation evaporates water from sludge
- Windrow turner (SOLIAMIX™), aerates biosolids and digests



SOLIA™

Benefits:

- Produces Class A biosolids
- 60-80% reduction in biosolids volume
- Low energy and operating costs
- Can retrofit to existing sludge drying beds
- Minimizes odor
- Not affected by inclement weather
- Windrow turner provides effective aeration

Challenges:

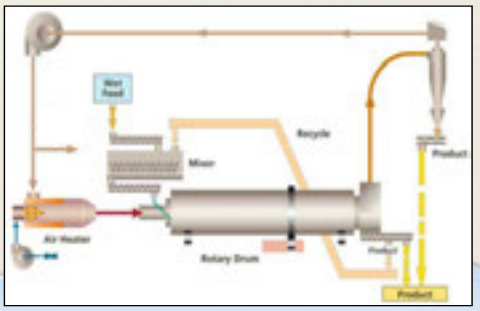
- Land intensive
- Requires “dry” biosolids

Heat Drying

- Sludge is dried by direct or indirect contact with hot gases
  - Temperature of sludge to exceed 80°C or wet bulb temperature of gas to exceed 80°C
- Resulting moisture content of biosolids is typically 10% or lower

Heat Drying

- Rotary dryers
  - Swiss Combi®
  - Andritz®
- Carver Greenfield
- Flash dryers
- Paddle dryers

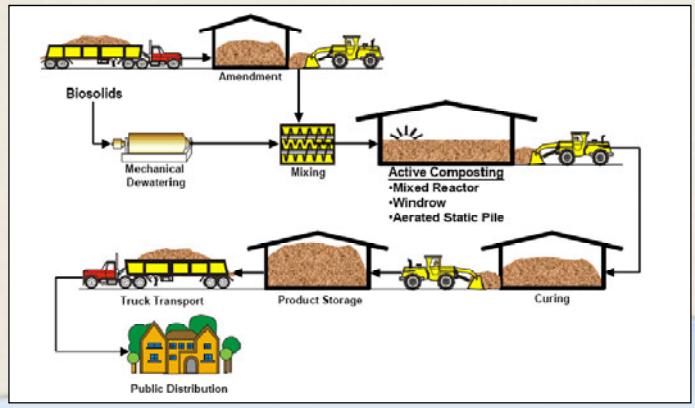


Heat Drying

- Benefits:
  - Produces Class A biosolids
    - Can be land applied or marketed commercially
  - Substantial volume reduction
  - Can be started quickly (not a biological process)
- Challenges:
  - Energy and labor intensive
  - Odors, emissions
  - Land application limitations due to moisture content

Composting

- Windrows
- Static aerated piles
- In-Vessel



Composting Requirements

- In-Vessel and static aerated pile
  - Minimum sludge temperature of 55°C maintained for 3 days
- Windrow
  - Minimum sludge temperature of 55°C maintained for 15 days (windrow turned minimum 5 times)

Composting can be a viable alternative if a product market is available

- Benefits:
  - Produces Class A biosolids
  - May produce marketable product
  - Suitable for land application
  - Can be combined with other processes
- Challenges:
  - Requires 18-30% dewatered solids
  - Requires bulking agent and carbon source
  - Land intensive (less for in-vessel)
  - Odor potential (less for in-vessel)
  - Fire danger (in-vessel)

Wastewater Treatment Technology Assessment

RECOMMENDED TRAINS

Filename.ppt

Post-Prescreening Technology Assessment Includes Three Tiers

- Evaluation using Performance Based Criteria

Normalized Performance Total	Performance Total	TSS Removal	BOD Removal	N-DeN	Turbidity	Pathogen	DBP	Volatile Solids Reduction	BS Pathogen	BS Volume Reduction	H2S Odor	Ammonia Odor	Reduced Sulfides Odor
100	72	10	10	10	10	10	10	2	2	2	2	2	2
72.2	130	8	3	1	1	0	0	0	0	0	0	0	0
83.3	150	9	4	1	1	0	0	0	0	0	0	0	0
100.0	180	10	4	2	2	0	0	0	0	0	0	0	0

- Evaluation using Implementation Based Criteria

Normalized Implementation Total	Implementation Total	Unit Ops	Unit Ops Cost	Process Complexity	Maturity of Technology	City or Surplus Property	Maintenance Complexity	Operations Complexity	System Complexity	Odors	Aesthetics	Noise	Footprint	Expandability	Flexibility	Energy Costs	Class A Complexity	Life Cycle Costs
100	111.4	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	4.6	5.6	7.1	6.6	7.2	6.6	6.3	6.5	6.0
66.0	66	5	5	5	6	3	5	5	5	5	5	5	5	5	5	5	5	5
62.3	64	4	4	7	6	6	6	6	6	5	5	5	5	7	5	7	5	6	5
52.7	59	3	3	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
51.7	58	3	4	5	7	7	7	5	5	5	5	5	5	5	5	5	5	5	5
100	111.4	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	4.6	5.6	7.1	6.6	7.2	6.6	6.3	6.5	1.0	6.0

- Financial Evaluation using Capital, O&M & Life Cycle Costs

Category	Unit Operations	Recom-mendation	Normalized Unit Capital Cost Factor	Normalized Unit O&M Cost Factor	Normalized Life Cycle Cost Factor	Unit Capital Costs ($/gpd)	Relative Unit O&M Costs ($/gal)	Simple Life Cycle ($/gal)
Preliminary	Criterion Weight (CRW)	100	100	100	100			
Preliminary	StepScrn	198	50	38	40	0.146	0.058	0.084
Preliminary	RotaryScrn	196	42	25	28	0.175	0.087	0.120
Preliminary	BeltScrn	196	28	12	14	0.262	0.184	0.237
Preliminary	CoarseScrn	194	100	100	100	0.073	0.022	0.034

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City and Developer Representatives Assigned Weighting Factors for the Implementation Based Criteria

	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Farmilarity	Maintenance Intensity	Operation Flexibility	System Complexity	Footprint
Liquid Stream	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	4.6
Odor	8.4	7.8	8.1	6.9	3.8	6.1	6.6	4.6	4.3
Biosolids	8.4	7.8	8.1	6.9	3.8	6.1	6.6	4.6	4.3

	Regulatory	Saftety	Residuals	Versatility	Expandability	Odor	Energy Saving	Class A Biosolids	Air Quality
Liquid Stream	5.6	7.1	6.6	7.2	6.6	6.3	6.5	1.0	6.0
Odor	4.9	7.1	6.8	6.8	6.3	5.5	6.5	4.5	6.0
Biosolids	4.9	7.1	6.8	6.8	6.3	5.5	6.5	4.5	6.0

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Recommended Unit Processes

Preliminary	Grit	Primary	BOD / NDeN	Clarification	Filtration	Disinfection
Step Screen (3mm)	Free Vortex	Clarifier	Oxidation Ditch	Clarifier	Disk Filter	UV + Hypo (Bulk)
Rotary Screen (3mm)	Mechanical Vortex	No Clarifier	Aeration Basin	DAF	DynaSand Filter	Sodium Hypo (Bulk)
Fine Screen			MBR			Sodium Hypo (Onsite)

Thickening	Stabilization	Dewatering	Advanced	Disposal
Centrifuge	Multiphase Anaerobic	Centrifuge		Land Application
DAF	Conventional Anaerobic	Belt Press		Land Fill
RTD	Aerobic / ATAD II	Drying Beds	Composting	Land Fill & Land Application

Odor Control
Chemical Scrubber
VAPEX / Electrically Charged Ion
Biotower

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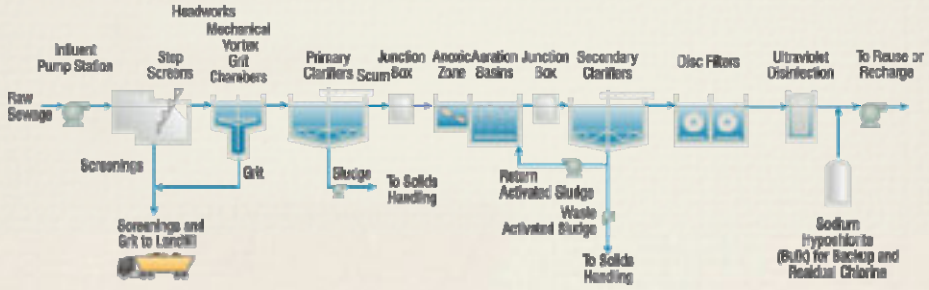
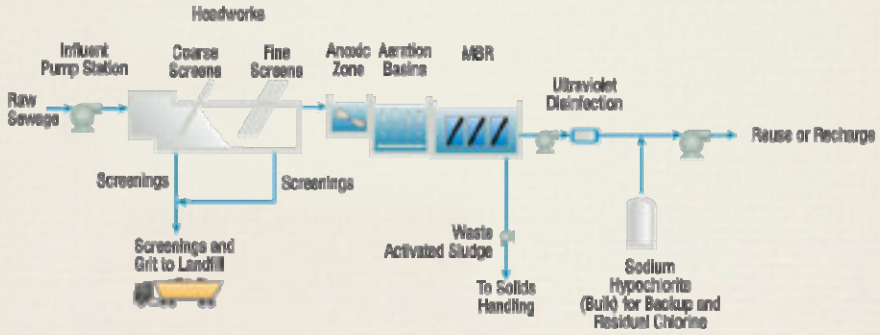
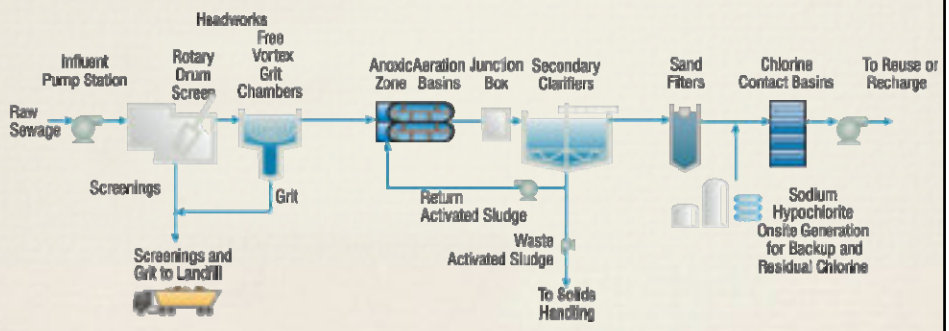
Recommended Liquid Stream Train 1



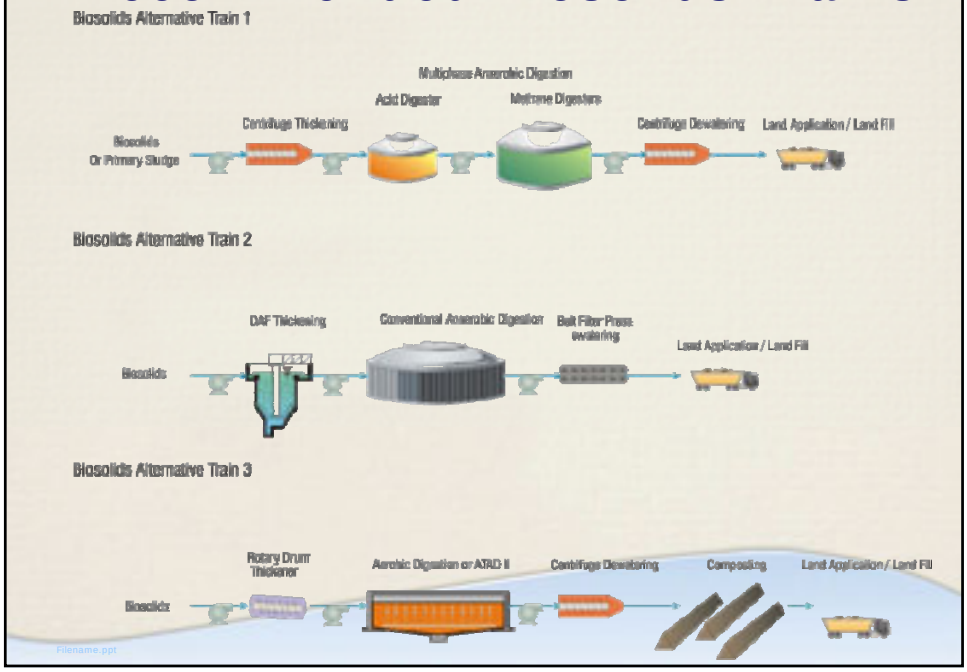
Recommended Liquid Stream Train 2



Recommended Liquid Stream Train 3



Recommended Biosolids Trains



Recommended Liquid Stream Trains

1. Step Screen – Mechanical Vortex Grit Removal – Primary Clarifier – Aeration Basin – Clarifier – Disk Filter – UV – Sodium Hypochlorite (Bulk)
2. Coarse Screen – Fine Screen – MBR – UV - Sodium Hypochlorite (Bulk)
3. Rotary Drum Screen – Free Vortex Grit Removal – Oxidation Ditch or Aeration Basin – Clarifier – Conventional Sand Filter – UV – Sodium Hypochlorite Onsite Generation

Recommended Biosolids Trains

1. Centrifuge Thickening - Multiphase Anaerobic Digestion – Centrifuge Dewatering – Land Fill / Land Application
2. DAF - Conventional Anaerobic Digestion – Belt Filter Press -Dewatering – Land Fill / Land Application
3. Rotary Drum Thickening – Aerobic Digestion / ATAD II – Centrifuge Dewatering – Composting – Land Application

Recommended Odor Control

1. Liquid/Wet Chemical Scrubbers
2. VAPEX / Electrically Charged Ion Addition (for Headworks)
3. Biotowers
4. Carbon Scrubber (polishing) for sensitive neighborhoods

Next Steps

1. Further develop the top three liquid streams and biosolids trains
2. Develop basis of design, process flow diagram, design considerations for each train/unit process

SURPRISETREE™ WASTEWATER MODEL USER'S GUIDE

City of Surprise

Design Guidelines and Technology Assessments

SurpriseTree™ Wastewater Model User's Guide

FINAL
April 2011

4600 East Washington, Suite 500 • Phoenix, Arizona 85034 • P. 602.263.9500 • F. 602.265.1422

City of Surprise

Design Guidelines and Technology Assessments

SurpriseTree™ Wastewater Model User's Guide

TABLE OF CONTENTS

Page

1.0 SURPRISETREE™ WASTEWATER MODEL 1

1.1 Purpose of the SurpriseTree™ Wastewater Model 1

1.2 Intended Use of the SurpriseTree™ Wastewater Model 3

2.0 QUICK GUIDE FOR SURPRISETREE™ WASTEWATER MODEL 4

2.1 Introduction, Instruction Sheets and Tool Bars 4

2.2 Step 1 – General Information 5
2.2.1 Quick Guide 5
2.2.2 Facility Inputs 5
2.2.3 Intended Reclaimed Water and Biosolids End Use 6
2.2.4 Facility Size and Phasing 6
2.2.5 Other Items of Note 6

2.3 Step 2 – Water Quality 6
2.3.1 Quick Guide 6

2.4 Step 3 – Land and Odor 8
2.4.1 Quick Guide 8
2.4.2 Input Existing Site Conditions 8
2.4.3 Input Odor Control Levels 8
2.4.4 Setbacks 9
2.4.5 Land Availability 9
2.4.6 Other Items of Note 10

2.5 Decision Making 10
2.5.1 Quick Guide 10
2.5.2 Set Overall Weighting Using Slide Bars 10
2.5.3 To Consider Extra Weighting for Costs 11
2.5.4 To Consider Extra Weighting for Performance 11

2.6 Detailed Process Ranking Sheets 11

2.7 Train Generator 12
2.7.1 Quick Guide 12
2.7.2 All Treatment Trains 12
2.7.3 User Inputs/Decisions 13

2.8 Update Costs 14
2.8.1 Quick Guide: 14
2.8.2 To Update the Cost Information 15

2.9 Print a Report 15

2.10 Help 15

3.0 ADVANCED USE 16

3.1 Step 1 – General Information 16
3.1.1 Effluent End Use 16

3.2 Step 2 – Wastewater Quality 18
3.2.1 Critical Wastewater Quality Parameters 18
3.2.2 Phosphorus Removal 19
3.2.3 Salinity and Inorganics 19
3.2.4 Industrial Impacts and Water Conservation 20

3.3 Step 3 – Land and Odor 21
3.3.1 Land Availability 21
3.3.2 Setbacks 21
3.3.3 Odor Control 23

3.4 Step 4 – Decision Making 24
3.4.1 Implementation-Based Criteria Evaluation 24
3.4.2 Performance-Based Criteria Evaluation 26
3.4.3 Weighting Factor Automatic Adjustment 27
3.4.4 Weighting Factor Manual Adjustment 28
3.4.5 To Reset Weighting Factors 28
3.4.6 Set Overall Weighting using Slide Bars 28
3.4.7 To Consider Extra Weighting for Costs 29
3.4.8 To Consider Extra Weighting for Performance 29

3.5 Detailed Process Ranking Sheets 29
3.5.1 Score and Ranking Calculation 29
3.5.2 Screening and Grit 31
3.5.3 Primary Clarification 33
3.5.4 BOD and Nutrient Removal 33
3.5.5 Disinfection and AOP 35
3.5.6 Biosolids 36
3.5.7 Technology Implementation Package 38

3.6 Train Generator 39
3.6.1 Train Generator..... 39
3.6.2 Rules..... 40
3.6.3 Preferences..... 41
3.6.4 Design Notes 43

3.7 Cost Evaluation 43
3.7.1 Relative Unit Costs 43
3.7.2 How to Perform Cost Analysis 45

3.8 Disclaimer.....47

REVISION ADDENDUM

1.0 SURPRISETREE™ WASTEWATER MODEL

This document provides instructions to the City of Surprise and other users to assist in navigating and utilizing the SurpriseTree™ Wastewater Model. The SurpriseTree™ Wastewater Model is intended for use by the City of Surprise in determining the most technically feasible and economically acceptable wastewater treatment technology options for its future regional water reclamation facilities (RWRFs). Preliminary basis of design, process flow diagrams, and design considerations included in the Wastewater Technology Assessment Report establish the typical design parameters and configurations for the recommended technology options. They represent the minimum acceptable requirements for implementing these treatment technologies at the City's future RWRFs and provide a documented starting point for the City and developer's Engineer.

1.1 Purpose of the SurpriseTree™ Wastewater Model

Many factors could impact the wastewater treatment technology selection for a facility. As discussed throughout the Wastewater Technology Assessment Report, the optimum wastewater and biosolids treatment technology for a new RWRF could depend on a variety of factors including the specific wastewater quality, the reclaimed water quality goals, and the site-specific inputs.

The quality and strength of the wastewater may vary considerably based on the impacts of industrial discharges or the water conservation practices. While wastewater characteristics significantly impact the wastewater treatment technology selection, the most appropriate technology also highly depends on the end use and disposal methods of the reclaimed water. Reuse water must meet different classification requirements for the intended reuse application (i.e. Class A+ versus Class B versus Class C), each of which requires different levels of tertiary treatment and disinfection standards. Recharging water to a drinking water aquifer must be consistent with the Aquifer Protection Permit requirements. Discharge to a surface water stream often has stringent nutrient limits depending on the designated use of the receiving stream. These factors can all impact the technology selection.

Similarly, the biosolids management goals determine the most appropriate biosolids treatment technologies and impact the liquid stream treatment. Many considerations can impact biosolids treatment alternative selection, including the biosolids end use/disposal (i.e. are biosolids sent directly to a landfill, land applied, or used in an application where achieving Class A biosolids may be desired now or in the future).

Other site specific impacts, such as land availability, the necessity of and level of odor control and the existing site conditions can all influence the technology selection. The interaction between various treatment processes also plays an important role in shaping the treatment train. For example, if a facility site has limited land availability, membrane bioreactors (MBR), which have a very small footprint, may be a more appropriate technology compared to an extended aeration process using oxidation ditch technologies. When MBR is selected, neither secondary clarifiers nor filters are required.

To provide a useful tool for the City that could assess available treatment alternatives for a given set of wastewater quality inputs and site-specific conditions, Carollo developed an innovative, advanced macro-based excel model named SurpriseTree™ Wastewater. A copy of this model is located on a CD attached with this report.

Using SurpriseTree™ Wastewater, the results of the technology alternative assessment are not limited to a single fixed set of recommendations. Instead, the model provides a dynamic and customized solution, which automatically generates the most technically feasible and cost effective treatment options in response to the wastewater quality, reclaimed water treatment goals, and site-specific condition inputs.

The SurpriseTree™ Wastewater Model evaluates treatment technologies using criteria established by City staff and developer representatives (referred to as implementation-based criteria), which are supplemented by performance-based evaluation and capital, O&M and lifecycle cost analysis developed by engineers. Weighting factors for the implementation-based criteria were developed by averaging the inputs from City staff and developer representatives. All weighting factors, ranking scores, and unit costs are fully adjustable by the City, providing significant flexibility to adjust to changing future conditions. The model employs a user-friendly spreadsheet structure, powered by macro-based selector buttons to make the site-specific analysis prompt and easy.

While the SurpriseTree™ Wastewater Model can provide detailed analyses for a given set of inputs, it is designed to be a master planning level tool. As with any similar application, the model and its outputs are only as accurate as the input information. For example, inputs like capital and O&M cost information included in the model are conceptual and must be updated regularly to ensure the recommendations are valid. Ultimately, the model provides a practical tool to document the City's decisions and incorporate the City's institutional and technical knowledge with technical information/data provided by the engineer. Through continuing efforts by the City (assisted by the engineer when necessary), this platform can be "calibrated" and improved to meet the City's needs now and in the future.

In summary, the SurpriseTree™ Wastewater Model was created to assist in establishing a mechanism and an evaluation methodology for the City to perform site-specific evaluations when actual wastewater quality, reclaimed water treatment goals, and other site specific information is more clearly defined for a given facility. It provides a baseline for technology selection and outlines the general required design criteria and considerations for a specific application in an effort to give the City confidence in their ultimate treatment technology selection. However, it leaves detailed design decisions, facility layouts, and other site-specific decisions to the design engineer to promote more informed and effective decision making.

1.2 Intended Use of the SurpriseTree™ Wastewater Model

The SurpriseTree™ Wastewater Model provides the City of Surprise with a means to identify the most applicable treatment technologies for a RWRF based on the wastewater quality inputs, the intended end use of reclaimed water and biosolids, and other site-specific conditions.

As the intent of the model is to provide a master planning level tool, it is recommended that the City consider the top three to five ranked treatment processes for a new RWRF. Once the treatment processes have been selected, the City can provide the developer with the corresponding implementation package from the Wastewater Technology Assessment Report to use as a baseline for preliminary design.

This approach provides the developer with the flexibility to select the treatment technology that best fits their application. The approach also helps to ensure that the City receives a facility that meets agreed upon performance and implementation based standards as well as minimum baseline design criteria for the associated technology. Finally, the approach provides opportunities for process optimization and promotes cost reduction for the City.

In general, the SurpriseTree™ Wastewater Model is intended for use directly by the City of Surprise or their designated representatives. However, at the City's discretion, the model may be used/adapted by developer representatives to assist in determining applicable treatment technologies for a new RWRF.

2.0 QUICK GUIDE FOR SURPRISETREE™ WASTEWATER MODEL

The following section contains a quick reference/demonstration guide for the SurpriseTree™ Wastewater Model. The basis for this demonstration is the City of Surprise SPA 2 RWRF. Water quality data and site-specific information from the SPA 2 RWRF was used to outline the purpose and functionality of the various sections of the model. Refer to Section 3.0 for more detailed descriptions associated with how to use the model.

2.1 Introduction, Instruction Sheets and Tool Bars

Upon opening the SurpriseTree™ Wastewater Model, the first interface the users see is the Introduction Sheet. Clicking on the introduction image brings users to the Instruction/Help page. The "help" page is designed for first time users. Definitions of terms and symbols used throughout the model are defined as part of the sheet.

The tool bars across the top of the screen are accessible throughout the SurpriseTree™ Wastewater Model. Placing the mouse cursor over the icons displays the button's function. The user can be redirected to the associated sheet by clicking one of the tool bar options. The tool bar is shown in the table below. The green arrows on each sheet can also be used to navigate to the next or previous page.

Home	**General Information**	**Water Quality Inputs**	**Decision Making (Weighting Factors)**	**Land Availability and Odor Control**	**Train Generator**	**Scores (for all treatment options)**	**Report**	**Costs**	**Help / Instruction**
SurpriseTree™ Wastewater Model Tool Bar									

When closing out of the SurpriseTree™ Wastewater Model, it is recommended that the user return to the Introduction Sheet and save the associated changes. This will allow the next user to begin with the Introduction Sheet when the file is opened.

2.2 Step 1 – General Information

2.2.1 Quick Guide

When the user clicks on the introduction screen, the SurpriseTree™ Wastewater Model will navigate to its Step 1 – General sheet.

Clicking on the facility information icon will also take the user directly to the Step 1 – General sheet.

The user should input associated facility information in the activated cells.

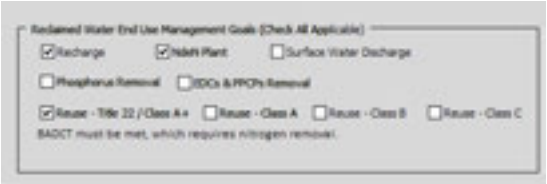
Clicking the right arrow will proceed to the next page.

2.2.2 Facility Inputs

On the Step 1 – General sheet, the user enters the site-specific information for the facility as shown in the example screen capture above. The user must enter the facility name, the construction time, location, life cycle, inflation rate, and interest rate. Based on the entered location, Surprise, Arizona, the model automatically identifies the RS Means 300 City Location factor to be 0.89. This factor is used in the model for cost analysis. The entered information for life cycle, inflation rate, and interest rate is also used in the model as part of the cost analysis.

2.2.3 Intended Reclaimed Water and Biosolids End Use

The user can define the end use of the reclaimed water by checking all applicable boxes. These options include recharge, reuse with different classifications (e.g. Class A+, Class B, Class C, etc.), surface water discharge, etc.



For biosolids, users can choose the intended end disposal options for the proposed facility (e.g. land fill, land application with Class A or Class B biosolids).

Users should check all applicable boxes. However, the most stringent end use option will drive the treatment evaluation. For example, if both Class A+ and Class B boxes are checked, the treatment evaluation will be based on Class A+ quality. The model will provide design consideration notes addressing the differences associated with the Class B option.

2.2.4 Facility Size and Phasing

The users will also input the facility build-out size, number of phases and peaking factors on this page. In the example below (SPA 2 RWRF), the RWRF capacity size was assumed to be 16 mgd at build-out, and be constructed in 4 equal phases. The capacity of Phase 1 was assumed to be 4 mgd. The program will automatically default to selecting the technology based on the ultimate capacity of the facility. However, the user can choose to use the Phase 1 capacity for technology selection, if desired.

The selection of “end of line plant” versus “scalping facility” will generate different design notes in the SurpriseTree™ Wastewater Model report for the designer’s consideration.

2.2.5 Other Items of Note

Refer to Section 3.2 for additional details.

2.3 Step 2 – Water Quality

2.3.1 Quick Guide

The user can navigate to the Step 2 – Water Quality sheet by clicking on the associated tab

or by clicking on the water quality icon .

The user should input associated site specific wastewater quality information in the activated cells.

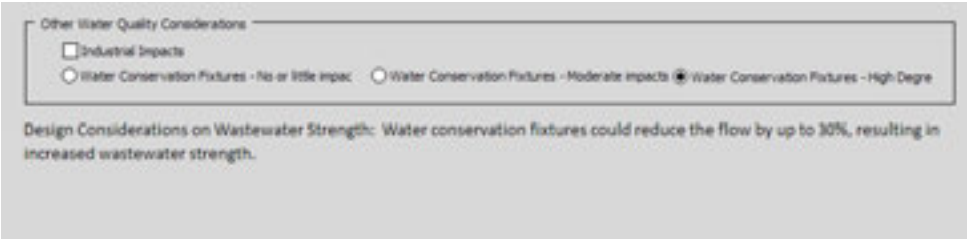
		Typical Range	
		Low	High
TSS (mg/L)	200	200	600
COD (mg/L)	340	200	2500
BOD (mg/L)	320	200	500
BOD:COD Ratio	0.94	0.3	0.8
TKN (mg/L as N)	62	20	80
BOD:TKN Ratio	5.16	3	10
Alkalinty (mg/L as $CaCO_3$)	250	100	400
pH	7	6	9
Average Temperature (°C)	21	15	35
Phosphorus (mg/L as P)	1.5	1	10
TDS (mg/L)	600	400	2000
Chloride (mg/L)	150	50	250
Sulphate (mg/L)	150	50	250
Sodium (mg/L)	150	30	150
Calcium (mg/L as $CaCO_3$)	300	50	1000
Magnesium (mg/L as $CaCO_3$)	100	100	800
SAR	4.61	2	6

Specific wastewater qualities may result in associated warning or consideration messages.

Warnings / Considerations

The user should carefully read and consider the warning and consideration messages prior to proceeding. Check the entered data when warning messages such as the screen capture below appear. In this example, the user may have attempted to enter a COD value that is unrealistic or less than the BOD value. Click on Retry to reenter the data. Click on Cancel to go back to the previous entry or the model default.

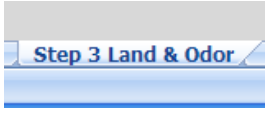
By checking the selection box “industrial impacts” or the option buttons for water conservation in the “Other Water Quality Considerations” box on this sheet, SurpriseTree™ Wastewater will generate design notes regarding the wastewater treatability for the designer’s consideration.



Clicking on the right arrow will proceed to the next page.

2.4 Step 3 – Land and Odor

2.4.1 Quick Guide

The user can navigate to the Step 3 – Land and Odor sheet by clicking on the associated tab 

or by clicking on the Land and Odor icon .

The user can follow the instructions on the page to provide inputs regarding land availability and odor control levels.

Clicking on the right arrow will proceed to the next page.

2.4.2 Input Existing Site Conditions

Use the option buttons to define the facility type – a "Greenfield/New" Plant or Existing Facility to be abandoned or upgraded. This input is used by the SurpriseTree™ Wastewater Model to generate the proper design considerations and recommendations. For SPA 2, the existing site is equipped with an SBR facility.

2.4.3 Input Odor Control Levels

Users can define the required odor control levels for the facility using the option buttons. Available options include "Low Level" (no odor/noise treatment), "Moderate Level" (full odor and noise control required) and "High Level" (full odor control with additional reliability).

The SurpriseTree™ Wastewater Model uses this input to generate the proper odor control train / recommendations. For the SPA2 example, it was determined that the appropriate odor control level was "Moderate Level". In this case, the model would recommend either a liquid scrubber or BioTower biofilters. The user has the option to check the preference box to include an electrically charged ion technology odor control unit for the headworks and/or carbon for polishing, if desired.

Odor Control Technologies

☑ Preferences to use electrically charged ions addition at headworks

☐ Preferences to use carbon adsorption for polishing

Odor Control Level		Recommended Technologies
2	Liquid Scrubber	VAPEX or other ion addition for headworks
2	Bio Tower	VAPEX or other ion addition for headworks

2.4.4 Setbacks

Based on the facility size inputs (in Step 1), the model will summarize the set back requirements for the proposed facility. The model allows the users to adjust the setbacks if the check box "waivers from neighbors can be obtained" is checked.

Facility Size at Phase I:	2	mgd	Setbacks for No-Odor/Noise Control:	1000	ft
Facility Size at Buildout:	8	mgd	Setbacks for Full Odor/Noise Control:	350	ft

The capacity of the facility is greater than 1 mgd.

☐ Waivers from neighbors can be obtained to reduce setbacks

2.4.5 Land Availability

The user can input the total acreage of the site and a usable land faction in this section. The model will calculate a land availability factor (in acres per mgd) based on the land and the capacity input in Step 1. A facility land availability category will be determined by the model, with recommendations and general tips on treatment technology selection.

For the SPA 2 example, it was assumed that a total of 28 acres was available with a usable land fraction of 60% (considering the odor setbacks). Based on such inputs, the calculated land availability is around 1.4 acres per mgd – falling into a land availability category of 3 – moderate land availability. The model notifies the user that there may not be enough land available for extended aeration (i.e. using oxidation ditch) and/or primary clarifiers and suggests verifying site layouts for various technologies.

Regarding the existing site condition, the model states that SBR is not economical for large facility. Consider decommission existing SBR.

Total Land Available:	28	acres			
Usable Land Fraction:	60%	(discount the land required for setbacks, topography, drainage, etc.)			
Usable Land:	16.8	acres or	1.40	acres per mgd	
This facility is categorized as:		Moderate Land Availability		Land Availability Category:	3

Design Considerations:

May not have enough land for extended aeration and primary clarifiers. Check site layouts.

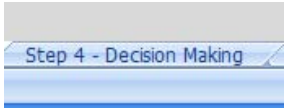
SBR is not economical for large facility. Consider decomission existing SBR.

2.4.6 Other Items of Note

Refer to Section 3.3 for additional details.

2.5 Decision Making

2.5.1 Quick Guide

The user can navigate to the Step 4 – Decision Making sheet by clicking on the associated tab 

or by clicking on the Decision Making icon .

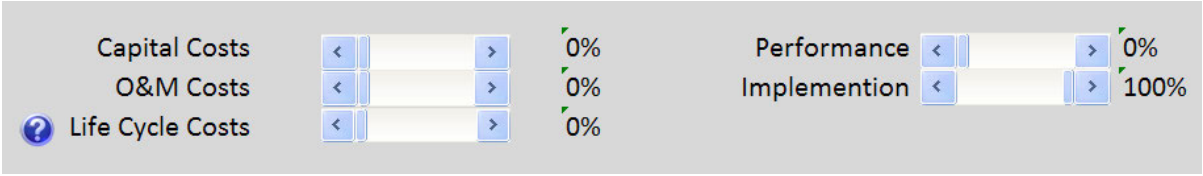
The user can choose to utilize the default weighting factors or can adjust the factors accordingly.

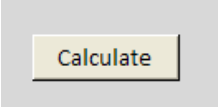
Clicking on the right arrow will proceed to the next page.

It is recommended that the default weighting factors be maintained as originally specified in the model. Refer to Section 3.4 for details regarding modification of the weighting factors, the definitions of each criteria, how the default weighting factors were assigned, and how to reset the default.

2.5.2 Set Overall Weighting Using Slide Bars

The implementation based weighting factors represent a stand-alone comprehensive evaluation incorporating costs, process reliability, operational issues, regulatory and safety issues, etc. To use the City assigned default weighting factors, the user should set the slide bars for performance, capital, O&M, and life cycle costs at 0% and the slide bar for implementation at 100%.



Click the calculate button 

and review the top recommended treatment processes for the specific wastewater quality, reclaimed water quality goals, biosolids end uses, and site specific inputs and weighting factors.

Costs and performance are two major factors that could influence the technology selection. The user can performing a sensitivity analysis by assigning extra weighting for costs or performance by dragging the slide bars as described below.

2.5.3 To Consider Extra Weighting for Costs

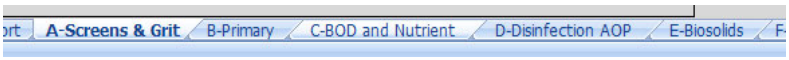
Keep the implementation slide bar at the 100% level and the performance slide bar at 0%. Drag one of the capital, O&M or life cycle bars to the appropriate weighting. Click the calculate button to determine changes in the recommendation. Change the setting and calculate again, if desired.

2.5.4 To Consider Extra Weighting for Performance

Keep the implementation slide bar at the 100% level and reset the slide bars for costs to 0%. Drag the performance bar to the appropriate weighting. Click the calculate button to determine changes in the recommendation. Change the setting and calculate again, if desired.

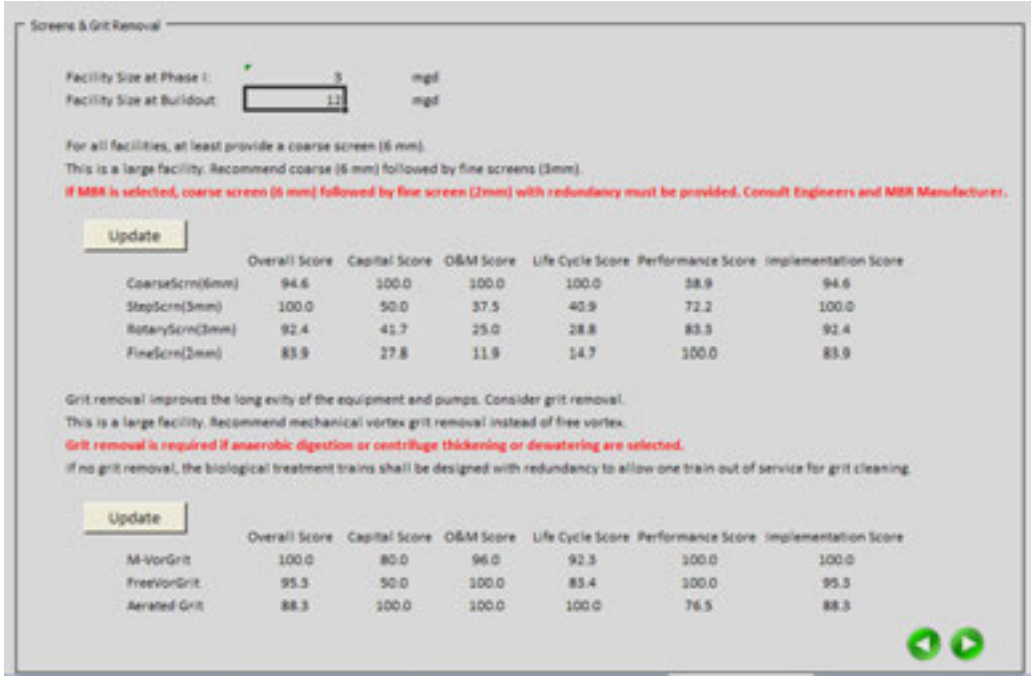
2.6 Detailed Process Ranking Sheets

The SurpriseTree™ Wastewater Model provides more detailed results on each treatment category, such as screens, grit removal, biological treatment, disinfection, etc. These sheets can be accessed by selecting the associated workbook within the model file:



A screen capture of the detailed sheet for the “screen and grit removal” process can be found below for the SPA2 example. Sensitivity analysis of the treatment option ranking can be performed by adjusting the slide bar and the weighting factors on Step 4 – Decision Making. The SurpriseTree™ Wastewater Model will recalculate the treatment option ranking when the “Update” button is clicked.

The user can also choose to skip these detailed process ranking sheets and go directly to the train generator sheet (Section 2.7).



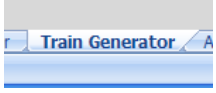
Clicking on the hyperlinks for the recommended technologies will allow the user to quickly access the implementation package. Implementation packages include basis of design, process flow diagrams, and design consideration lists for the associated technology

.

Clicking on the right arrow will proceed to the next page.

2.7 Train Generator

2.7.1 Quick Guide

The user can navigate to the Train Generator sheet by clicking on the associated tab 

or by clicking on the Train Generator button .

The user can follow the instructions on the page to generate treatment trains for the liquid and biosolids treatment processes.

2.7.2 All Treatment Trains

On this page, the SurpriseTree™ Wastewater Model lists the top two to four treatment technology options for each treatment category (i.e. preliminary treatment, grit removal, primary treatment, BOD and N-deN, etc). The technology options available in the model represent those that passed the prescreening evaluation in the Wastewater Technology

Assessment Report. As shown in the screen capture below (see the upper right hand corner of the table), a total of 82,944 trains can be assembled for the given scenario, by multiplying the number of options available for each treatment category.

2.7.3 User Inputs/Decisions

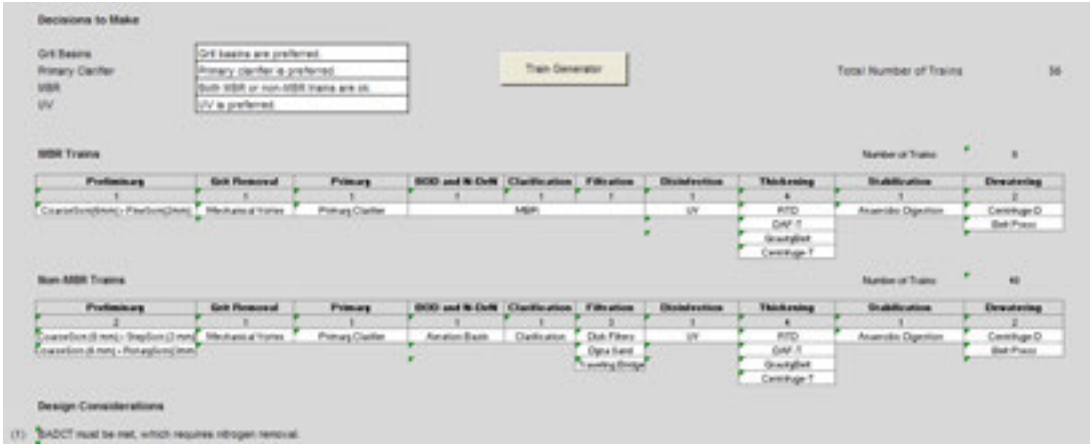
The SurpriseTree™ Wastewater Model determines the optimal treatment trains through a combination of user inputs (associated with four primary treatment options) and the rules and programs built in to the SurpriseTree™ model. The required user inputs specific to the four primary treatment options are:

- Is grit removal preferred or required?
- Is primary clarifier preferred?
- Are both MBR or non-MBR trains acceptable?
- Is UV the preferred disinfection method?

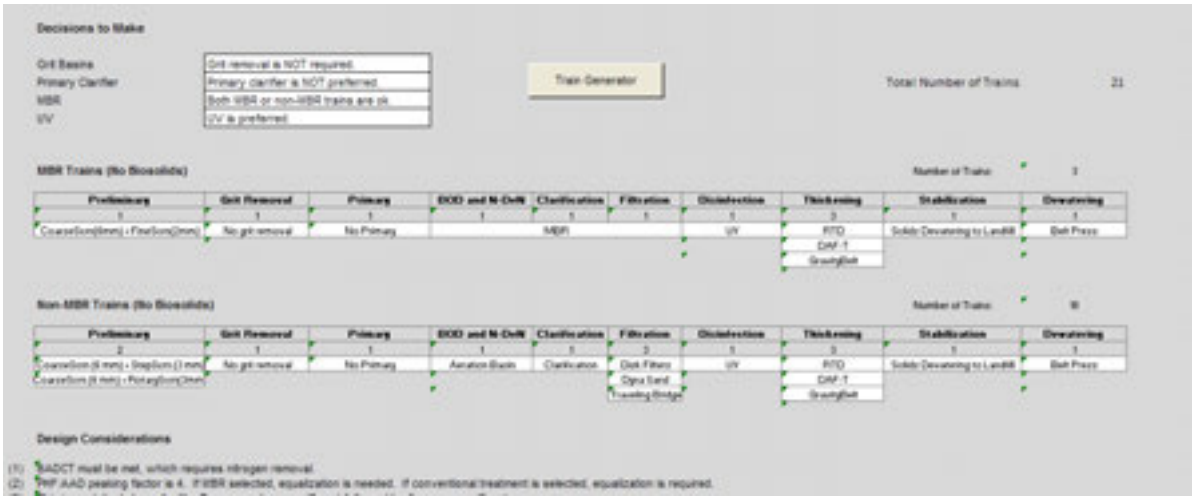
The user can utilize the drag down menu to select the preferred options, then click on the "Train Generator" button. The SurpriseTree™ Wastewater Model will calculate the treatment trains for the given set of inputs, taking into consideration the land availability, the wastewater quality and the intended reclaimed water and biosolids end use/disposal options.

A list of design considerations will be generated below the recommended trains. A majority of the design considerations are based on the facility specific inputs entered during Steps 1 through 4. The list is intended to provide planning level considerations. When developing future RWRFs, these design considerations can be expanded or modified to include additional City inputs or updated considerations.

For the SPA2 example, land area was not sufficient for extended aeration and UV was the preferred disinfection method based on reducing DBP formation potential. Under these conditions, a total of 56 potential trains were recommended, including 8 MBR trains and 48 non-MBR trains.



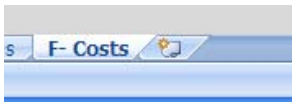
If the project budget is a significant constraint, the user can set the capital cost slide bar at a high percentage and a design note will be generated to say “Project budget is a significant constraint. Consult engineers or designers if the user chooses not to follow the model recommendation.” To accommodate budget constraints, the user could choose to eliminate grit basins and primary clarifiers and delay the biosolids digestion process. If these adjustments are made to the inputs and the Train Generator in rerun, the revised model will recommend 21 trains, including 3 MBR trains and 18 non-MBR trains.



2.8 Update Costs

2.8.1 Quick Guide:

The user can navigate to the F – Costs sheet by clicking on the associated tab



or by clicking on the Costs icon .

The user can choose to utilize the default cost information or can adjust accordingly based on current market conditions, etc.

2.8.2 To Update the Cost Information

The SurpriseTree™ Wastewater Model includes relative conceptual level costs for comparing the economics of each treatment technology. These costs are NOT meant to be used for budget planning, design, or construction. If updated or site specific cost information is available, the user can utilize the F – Costs sheet to override the default costs. Updated cost information can be entered into the *City's Adjustment* columns for unit capital and O&M costs.

	facility size: 16 mgd						
	Default		City's Adjustment		LCA Analysis		
	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Life Cycle ($/1000gal)
Preliminary	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
CoarseScrn	$ 0.07	$ 0.02			$0.10	$0.03	$0.04
StepScrn(3mm)	$ 0.15	$ 0.06			$0.21	$0.08	$0.10
RotaryScrn(3mm)	$ 0.17	$ 0.09			$0.25	$0.12	$0.15
FineScrn	$ 0.26	$ 0.18			$0.37	$0.26	$0.29
Grit	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
AeratedGrit	$ 0.06	$ 0.03			$0.08	$0.05	$0.05
M-VorGrit	$ 0.07	$ 0.04			$0.10	$0.05	$0.06
Free'VorGrit	$ 0.11	$ 0.03			$0.16	$0.05	$0.07
Primary	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
PriClar	$ 0.26	$ 0.26			$0.37	$0.37	$0.39

The information should be entered in $/gallon for capital cost and $/1000 gallons for O&M costs. For the purposes of this demonstration, the costs are maintained as those developed by the engineer. Refer to Section 3.7 for additional information.

2.9 Print a Report

Once the preferred settings are input into Step 1 - 4 and the train generator is used to update the treatment options, the user can generate a report by clicking on the Print Report icon on the SurpriseTree™ model toolbars on any page.

To customize the report, fill in the appropriate cells in the model and/or edit the Report pages as appropriate. Users can change the format or edit the text cells as long as such edits do not change the formulas.

2.10 Help

Help can be accessed from any page, by clicking the by clicking on the associated tab Instruction or the Question icon on the SurpriseTree™ tool bar. The user will automatically be redirected to the Help / Instruction page.

3.0 ADVANCED USE

The SurpriseTree™ Wastewater Model is a Microsoft Excel© spreadsheet program that uses user wastewater quality, reclaimed water and biosolids treatment goals, and site specific considerations to generate and rank treatment technologies based on specific criteria. The SurpriseTree™ Wastewater program was customized for the City of Surprise wastewater treatment evaluation and focuses on wastewater liquid stream and biosolids treatment processes. Section 2 presented a step by step example associated with how to use the model. A more detailed description focusing on the advanced use of the model is included in the following sections.

3.1 Step 1 – General Information

3.1.1 Effluent End Use

The user can define the end use of the reclaimed water by checking all applicable boxes. These options include recharge, reuse with different classifications (e.g. Class A+, Class B, Class C, etc.), surface water discharge, etc.

For biosolids, users can choose the intended end disposal options for the proposed facility (e.g. land fill, land application with Class A or Class B biosolids).

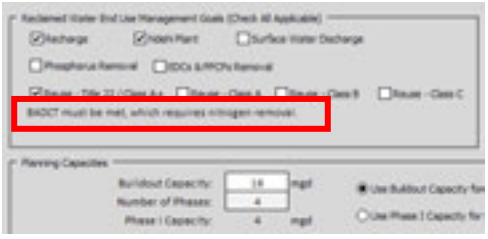
Users should check all applicable boxes. The most stringent end use option will drive the treatment evaluation. For example, if both Class A+ and Class B boxes are checked, the treatment evaluation will be based on Class A+ quality. The model will provide design consideration notes addressing the differences associated with the Class B option

3.1.1.1 BADCT

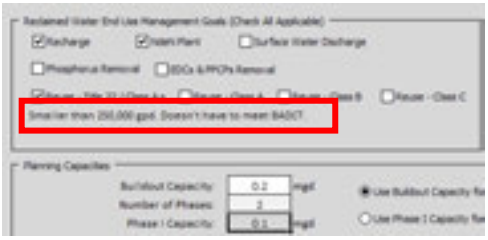
The SurpriseTree™ Wastewater Model incorporates the ADEQ rules regarding Best Available Demonstrated Control Technology (BADCT) and generates design consideration messages based on user inputs in the Reclaimed Water End Use Management section.

The ADEQ rules require that a wastewater treatment plant with a capacity greater than 250,000 gpd must meet the conditions of BADCT. Treated effluent must (at a minimum) meet or exceed the current standards set forth in the Arizona Administrative Code (A.A.C.), as specifically defined in R18-9 and R18-11.

If the facility size input is larger than 0.25 mgd, a message will be generated to inform the user that BADCT requirements must be met.



If the facility size input on the Step 1 – General Sheet is less than 0.25 mgd, a message will be generated indicating “Smaller than 250,000 gpd. Facility does not have to meet BADCT.”



3.1.1.2 Class C Effluent

If the user selects Class C effluent and the facility is smaller than 250,000 gpd, stabilization ponds with a 20-day detention time can be used without denitrification and filtration. On the Train Generator sheet, the recommended Class C train generated will include a coarse screen and a stabilization pond.

If the user select Class C effluent but the facility is larger than 250,000 gpd, BADCT requirements must be met - including the total nitrogen requirement and more stringent disinfection requirements. On the Train Generator sheet, the recommended Class C train generated will, at a minimum, include a coarse screen, conventional aeration or extended aeration, clarification, and disinfection.

3.1.1.3 Peaking Factors

The SurpriseTree™ Wastewater Model requires the user to input two peaking factors - one for annual average day (AAD) to average day maximum month (ADMM), the other for peak hour (PHF) to AAD. These peaking factors will be included in the SurpriseTree™ model report and provided to the designer.

When the peaking factor for PHF:AAD is greater than a stage 1 preset value (default = 2), the SurpriseTree™ Wastewater Model will recommend equalization basins if MBR technology is selected. If this peaking factor is greater than a stage 2 preset value (default = 3), the model will recommend equalization basins for conventional aeration and MBR technologies, but not for extended aeration.

3.2 Step 2 – Wastewater Quality

On the Step 2 – Water Quality sheet, the user should input associated site specific wastewater quality information in the activated cells. The SurpriseTree™ Wastewater Model provides a typical range for each parameter as a reference. Values entered do not have to be within the typical range.

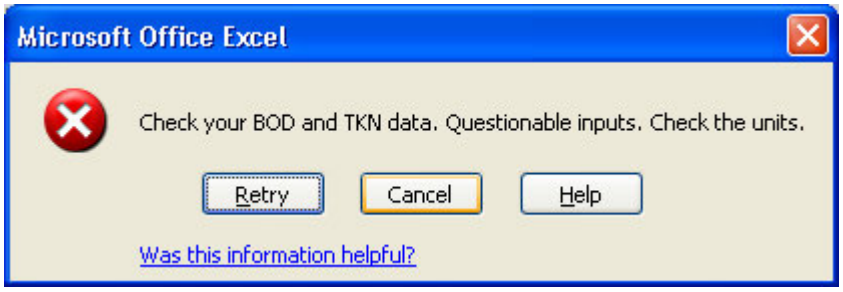
The SurpriseTree™ Wastewater Model automatically generates warning messages when preset conditions are met. The user should carefully read and consider any warning and consideration messages prior to proceeding.

3.2.1 Critical Wastewater Quality Parameters

Several examples of the warning/design consideration messages associated with critical wastewater quality parameters (such as BOD, TKN, TSS, etc.) are outlined below:

- When the input TSS is higher than a preset value (default = 600 mg/L), a warning message will be displayed indicating “High TSS. Consider primary clarifiers or other pretreatment.”
- When the input COD is higher than a preset value (default = 1000 mg/L), a warning message will be displayed indicating “High COD! Caution! Industrial impacts.”
- When the input BOD is higher than a preset value (default = 500 mg/L), a warning message will be displayed indicating “High BOD!”
- When the calculated BOD:COD ratio is below a preset value (default = 0.2), a warning message will be displayed indicating “Low BOD:COD ratio! Industrial Impact!”
- When the input TKN is higher than a present value (default = 80 mg/L), a warning message will be displayed indicating “High TKN!”
- When the calculated BOD:TKN ratio is below a preset value (default = 3), a warning message will be displayed indicating “Low BOD:TKN ratio! Need additional carbon sources!”
- When the calculated BOD:TKN ratio is higher than a preset value (default = 10), a warning message will be displayed indicating “High BOD:TKN ratio! A low cost pretreatment pond is recommended!”

- When the input alkalinity is less than a preset value (default = 100 mg/L), a warning message will be displayed indicating “Low alkalinity! May require addition of lime or magnesium hydroxide.”
- When the input pH is higher than 9 or lower than 6, a warning message will be displayed indicating “High (or low) pH! Verify industrial pretreatment.”
- When the input critical wastewater quality parameters (such as BOD, COD, TSS and TKN) are unrealistic, a pop up message will provide a “Check Input” alert and ask the user to reenter the numbers. Click on “Retry” to reenter. Click on “Cancel” to keep the original value.



3.2.2 Phosphorus Removal

When (1) “surface discharge” is NOT selected as one effluent end use/disposal options on the Step 1 – General Information sheet, OR (2) the input phosphorus value is lower than a preset value (default = 5 mg/L), the SurpriseTree™ Wastewater Model will not consider phosphorus removal necessary for the associated facility.

When (1) “surface discharge” is selected as a potential effluent end use/disposal option on Step 1 – General Information sheet, and (2) the input phosphorus value is higher than a preset value (default = 5 mg/L), the SurpriseTree™ Wastewater Model will determine that phosphorus removal is required. The model will further recommend the user consider biological phosphorus treatment, enhanced filtration with ferric salts, biological filtration processes, softening, RO or EDR.

Design considerations regarding phosphorus removal will be generated in the SurpriseTree™ Wastewater Model report.

3.2.3 Salinity and Inorganics

When the input TDS is higher than a preset value (default = 1000 mg/L), a warning message will be displayed indicating “High TDS! May impact reuse.” Similarly, individual ions such as sodium, chloride, calcium, etc. will trigger similar warning messages when the preset values are exceeded.

If the input TDS or concentrations of individual ions are higher than the presets, and if "surface discharge" is selected as a potential effluent end use/disposal option on Step 1 – General Information sheet, the warning message will also include "Potential WET failure!" – reminding the user of potential concerns associated with failing the whole effluent toxicity test when discharging this effluent to a surface water stream. The model will also generate design notes/considerations related to salinity management and treatment.

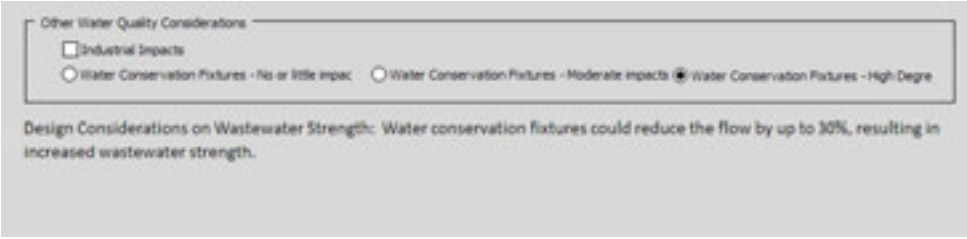
The SurpriseTree™ Wastewater Model calculates the Sodium Adsorption Ratio (SAR) – a measure of the suitability of water for use in agricultural irrigation. In general, the higher the SAR, the less suitable the water is for irrigation. Irrigating with high SAR water may require soil amendments to prevent long-term damage to the soil. Design considerations will be generated by the model if TDS, individual ions, or SAR levels exceed the preset values.

The SurpriseTree™ Wastewater Model will also check the input TDS in comparison to the summation of the input concentrations for the major ions. If the TDS is less than the summation of input values for calcium, magnesium, chloride, sulfate and sodium, an error message will request the user check the inputs.

3.2.4 Industrial Impacts and Water Conservation

The SurpriseTree™ Wastewater Model will generate design notes/considerations regarding the impacts of industrial discharge on wastewater treatability for the designer's consideration when (1) the selection box "industrial impacts" is checked, OR (2) the BOD:COD ratio is less than a preset value (default = 0.3).

Many rapidly growing communities have encountered increases in wastewater strength potentially resulting from the use of low-flow plumbing fixtures (i.e., low-flush toilets, low-flow showerheads, faucet aerators, etc.) in residential housing and other water conservation measures/changes in lifestyle. The SurpriseTree™ Wastewater Model will provide design considerations regarding the impacts of the wastewater treatability when the user selects one of the option buttons for water conservation. The following screen shots provide examples of the impacts of such selections.



3.3 Step 3 – Land and Odor

3.3.1 Land Availability

The user can input the total acreage of the site and a usable land faction in this section. The model will calculate a land availability factor (in acres per mgd) based on the land and the capacity input in Step 1. A facility land availability category will be determined by the model, with recommendations and general tips on treatment technology selection.

Total Land Available:	16	acres			
Usable Land Fraction:	60%	(discount the land required for setbacks, topography, drainage, etc.)			
Usable Land:	9.6	acres or	0.60	acres per mgd	
This facility is categorized as:		Very Limited Availability		Land Availability Category:	5

Design Considerations:

Land is not sufficient. Consider advanced high rate technologies (e.g. MBR) and buildings with multiple stories. Primary clarifier and O-Ditch are not recommended.

3.3.2 Setbacks

Arizona Administrative Code Title 18, Ch. 9 requires that the owner or operator of a new sewage treatment facility, or one that is undergoing a major modification, shall provide setbacks from the nearest adjacent property line using the following information.

Sewage Treatment Facility Design Flow (gallons per day)	No Noise, Odor, or Aesthetic Controls (feet)	Full Noise, Odor, and Aesthetic Controls (feet)
3,000 to less than 24,000	250	25
24,000 to less than 100,000	350	50
100,000 to less than 500,000	500	100
500,000 to less than 1,000,000	750	250
1,000,000 or greater	1000	350

Notes:

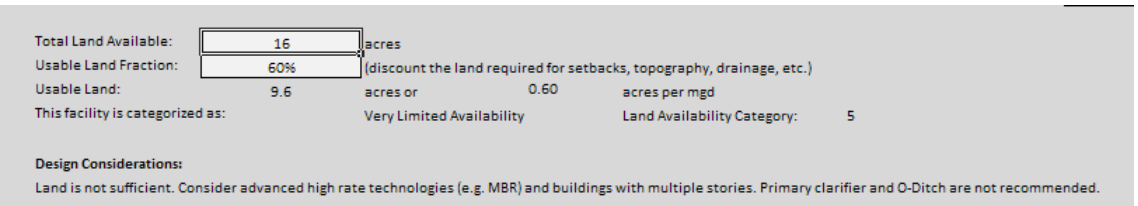
1. Full noise, odor, and aesthetic controls represents that all treatment components are fully enclosed, odor scrubbers are installed on all vents, and fencing is installed around the facility.
2. The owner or operator may decrease setbacks if setback waivers are obtained from affected property owners in which the property owner acknowledges awareness of the established setbacks, basic design of the treatment facility, and the potential for noise and odor.

The SurpriseTree™ Wastewater Model incorporates the setback requirements. The facility capacity entered on the General Information sheet will be automatically used to determine the setback requirements.

Facility Size at Phase 1:	2	mgd	Setbacks for No Odor/Noise Control:	1000	ft
Facility Size at Buildout:	16	mgd	Setbacks for Full Odor/Noise Control:	350	ft
The capacity of the facility is greater than 1 mgd.					

When the check box “waivers from neighbors can be obtained” is checked, the model will allow the users to adjust the setbacks.

The user then proceeds to the land availability section and enters the land available and the usable land fraction. The usable land fraction discounts the land required for setbacks, topography, storm retention ponds, etc.



Based on the facility capacity and the land availability, the SurpriseTree™ Wastewater Model will determine the land availability category of the proposed facility. This is accomplished by dividing the available land by the facility capacity (in acres per mgd) with a series of adjustable preset values - an example is presented in the table below.

Land Availability Category	Small Facility (< 5 mgd)	Large Facility (<20 mgd)	Implications
1 High Land Availability	>6	>4	Sufficient land. No restrictions on technology selection.
2 Reasonable Land Availability	>4	>3	Land availability does not limit technology selection. Extended aeration and primary clarifiers can be considered.
3 Moderate Land Availability	>2	>1.3	Sufficient land may not be available for extended aeration and primary clarifiers. Check site layouts.
4 Limited Land Availability	>1	>0.8	Land is limited. Consider technologies that do not require large land areas, such as MBR. Land is likely not available for primary clarifiers or extended aeration.
5 Very Limited Availability	<1	<0.8	Land is not sufficient. Consider advanced high rate technologies (e.g. MBR) and buildings with multiple stories. Primary clarifier and extended aeration are not recommended.

3.3.3 Odor Control

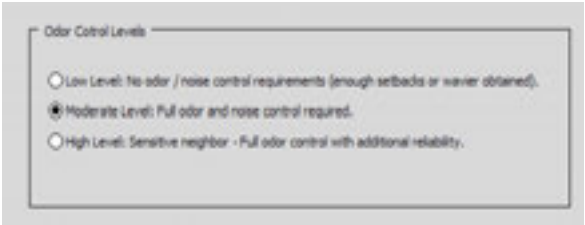
Several types of odor control technologies were evaluated as part of the Wastewater Technology Assessment Report, including chemical scrubbers, Bio-Tower filters, carbon adsorption, and ion addition technologies such as VAPEX/Oxy-Phogg.

The SurpriseTree™ Wastewater Model recommends the best odor control strategies based on user inputs and preferences, including:

- Odor control levels
- Preference to use electrically charged ion addition technology at the Headworks
- Preference to use carbon adsorption for polishing

Users can define the odor control levels for the facility using the option buttons. Available options include:

- Low Level: No odor treatment required
- Moderate Level: Full odor and noise control required
- High Level: Highly sensitive neighborhood – Full odor control with additional reliability



The SurpriseTree™ Wastewater Model will generate recommendations based on user inputs. Several examples illustrating the model outputs are included below.

When the selected odor control level is “low,” and there is no preference to use the electrically charged ions addition system or carbon scrubber, the model states that no odor or noise control is required.

Odor Control Level	Recommended Technologies
1	No odor and noise control is required. The facility has enough setbacks or waviers from neighbors. .

When the selected odor control level is “moderate”, and the user checks the preference boxes to use the electrically charged ions addition technology, the model recommends use of a liquid scrubber or BioTower, with the electrically charged ions addition technology for the Headworks.

Odor Control Level		Recommended Technologies
2	Liquid Scrubber	electrically charged ions addition for headworks
2	Bio Tower	electrically charged ions addition for headworks

When the selected odor control level is “high,” and the user checks the preference boxes to use the electrically charged ions addition and carbon scrubber, the model recommends the use of a BioTower followed by chemical scrubber, with the electrically charged ions addition technology for the Headworks.

Odor Control Level		Recommended Technologies	
2	Liquid Scrubber	electrically charged ions addition for headworks	Carbon polishing for severe odors.
2	Bio Tower	electrically charged ions addition for headworks	Carbon polishing for severe odors.

3.4 Step 4 – Decision Making

The user can adjust all weighting factors used in the SurpriseTree™ evaluation on the sheet titled “Step 4 – Decision Making.” As explained in the Wastewater Technology Assessment Report, the decision making is a three-tier process, including:

- Evaluation using implementation based criteria
- Supplemental evaluation emphasizing performance
- Supplemental evaluation emphasizing costs

3.4.1 Implementation-Based Criteria Evaluation

The implementation based evaluation criteria from the Wastewater Technology Assessment Report are represented as “orange” in the model. These criteria are defined in the following table. In the SurpriseTree™ Wastewater Model, placing the mouse cursor over each criterion displays the associated definition.

Water Process Screening Criteria	Definition / Description
O&M Costs	What are the annual operation and maintenance cost for the alternative?
Capital Costs	What are the equipment costs, initial installation costs, and construction costs for the alternative?
Process Robustness	Does the alternative provide sufficient treatment stability with expected wastewater quality variations? Is it more reliable than the other alternatives?
Maturity of Technology	Is the alternative mature in design and operation?
City of Surprise Familiarity	Does the City of Surprise have operational experience with this alternative? Is the City’s operation staff familiar with the process of this alternative?

Water Process Screening Criteria	Definition / Description
Maintenance Intensity	What are the maintenance requirements for the alternative?
Operation Flexibility	Does the alternative allow flexible operation to meet process control goals?
System Complexity	How complex is the equipment and required operation of the alternative?
Process Footprint	How much land area is required for the alternative?
Regulatory Requirements	How much regulatory coordination effort is associated with implementation & operation of the alternative?
Risks and Safety	Does the alternative have concerns associated with process safety such as hazardous material handling and process risk management?
Residuals and Biosolids	What volume/type of biosolids are produced by the alternative? How can the biosolids generated by this alternative be treated compared to other alternatives? Does the alternative produce low ammonia content in digested sludge, (i.e. low ammonia concentration in centrate after dewatering)? Can the additional load of centrate ammonia be accommodated by the plant liquid stream treatment process, when returned to the headworks?
Versatility	Is the alternative versatile in removing multiple contaminants, including emerging concerns?
Expandability/Ultimate Capacity	Does the alternative provide a configuration that allows easy future expansion using a module design concept (to accommodate the ultimate treatment capacity on the site)?
Odor Control	Does the alternative require an odor control facility? How is the efficiency of the odor control system associated with the alternative?
Energy Savings	Does the alternative have any energy saving features or produce reusable energy by-products?
Air Quality Impacts	What volume/type of air pollutants/emissions does the alternative generate?
Class A Biosolids	Will the alternative be capable of producing Class A biosolids?

Weighting factors for the implementation based criteria were assigned by nine individuals (City and developer representatives). The averaged weighting factors are used as the default inputs in the model (as illustrated in the table below). For example, the *O&M costs* and the *capital costs* criteria have the highest weighting factors among all factors, implying that costs are the most important implementation factor to the City and developers. The *City of Surprise Familiarity* with a treatment technology has the lowest weighting factor, implying that familiarity is the least important implementation factor to the City and developers.

	O&M Costs	Capital Costs	Process Robustness	Maturity of Technology	City of Surprise Farmilarity	Maintenance Intensity	Operation Flexibility	System Complexity	Footprint
Liquid Stream	8.4	8.6	8.3	6.8	3.7	6.3	7.1	4.8	4.6
Odor	8.4	7.8	8.1	6.9	3.8	6.1	6.6	4.6	4.3
Biosolids	8.4	7.8	8.1	6.9	3.8	6.1	6.6	4.6	4.3

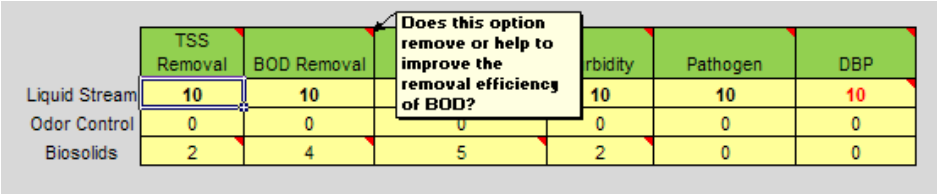
	Regulatory	Saftety	Residuals	Versatility	Expandability	Odor	Energy Saving	Class A Biosolids	Air Quality
Liquid Stream	5.6	7.1	6.6	7.2	6.6	6.3	6.5	1.0	6.0
Odor	4.9	7.1	6.8	6.8	6.3	5.5	6.5	4.5	6.0
Biosolids	4.9	7.1	6.8	6.8	6.3	5.5	6.5	0.0	6.0

3.4.2 Performance-Based Criteria Evaluation

The performance based criteria are designed to provide more specific information on how a technology compares with other alternatives in terms of target constituent removal. The weighting factors were assigned to each performance based criterion on a 0 to 10 scale, with 0 representing the least important/applicable and 10 representing the most important/applicable. The weighting factors were assigned by the engineer and can be adjusted to reflect the relevance of different treatment categories to a specific target constituent.

Performance Criteria	Definition / Description
TSS Removal	Does this option remove or help to improve the removal efficiency of TSS?
BOD Removal	Does this option remove or help to improve the removal efficiency of BOD?
Nitrification – Denitrification Processes	Does this option assist or help to assist in the nitrification and denitrification processes?
Turbidity Removal	Does this option remove or help to improve the removal efficiency of particles? Is it subject to fouling by particles?
Pathogen Removal	Does this option provide log-removal credits for pathogens? Does this option help to improve the pathogen kill by other processes?
DBP Control	Does this option reduce the formation of chlorinated DBPs? Does this option produce other non-chlorinated DBPs (e.g. bromated) and emerging (non-regulated) DBPs?
Volatile Solids Reduction	Does this option provide volatile solids reduction in the biosolids?
BS Pathogens	Does this option provide biosolids pathogen reduction?
BS Volume Reduction	Does this option provide biosolids volume reduction?
H_2S Odor	Does this option remove or help to improve H_2S odors?
Ammonia Odor	Does this option remove or help to improve ammonia odors?
Reduced Sulfides Odor	Does this option remove or help to improve sulfide odors?

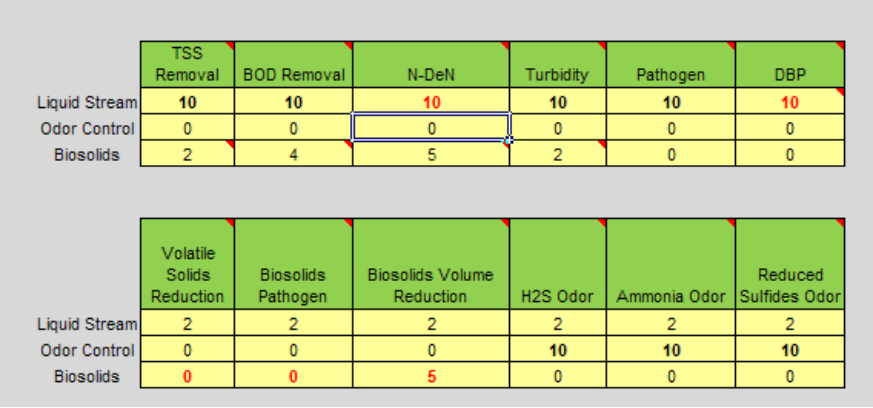
The performance based evaluation criteria from the Wastewater Technology Assessment Report are represented as “green” in the model. These evaluation criteria are associated with the capability of the technologies to remove contaminants. The associated weighting factors were assigned by the engineer and can be adjusted to reflect the relevance of different treatment categories to a specific target Contaminant of Concern (CoC). Placing the mouse cursor over each criterion displays a definition of the associated criterion.



	TSS Removal	BOD Removal		rbidity	Pathogen	DBP
Liquid Stream	10	10		10	10	10
Odor Control	0	0	0	0	0	0
Biosolids	2	4	5	2	0	0

Weighting factors for TSS removal, BOD removal, nitrogen removal, turbidity removal, pathogen removal, and disinfection byproduct formation potential were included as “10s” for liquid stream treatment processes but “0” for solids treatment processes. This default is consistent with the fact that these categories are only relevant to the liquid stream treatment – not to biosolids treatment.

Weighting factors for volatile solids reduction, biosolids pathogen, and biosolids volume reduction were included as “10s” for biosolids treatment processes and “2s” for liquid stream processes. This default setting is consistent with the fact that these categories are the primary treatment objectives for biosolids treatment and that liquid stream treatment processes can also impact biosolids production and characteristics. Similarly, the weighting factors for the H_2S odor, ammonia odor, and reduced sulfides odor categories are set at “10” for odor control treatment processes. The default weighting factors are presented in the screen capture below for reference.



	TSS Removal	BOD Removal	N-DeN	Turbidity	Pathogen	DBP
Liquid Stream	10	10	10	10	10	10
Odor Control	0	0	0	0	0	0
Biosolids	2	4	5	2	0	0

	Volatile Solids Reduction	Biosolids Pathogen	Biosolids Volume Reduction	H2S Odor	Ammonia Odor	Reduced Sulfides Odor
Liquid Stream	2	2	2	2	2	2
Odor Control	0	0	0	10	10	10
Biosolids	0	0	5	0	0	0

3.4.3 Weighting Factor Automatic Adjustment

The SurpriseTree™ Wastewater Model adjusts some weighting factors automatically using site specific inputs entered by the user. For example, the weighting factor for footprint is adjusted using the land availability category. The more land available, the lower the weighting for footprint becomes. Similarly for biosolids, if the user input indicates that

Class A biosolids are not required currently or in the future, the weighting factor for the associated category will be adjusted to zero.

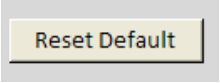
For performance-based criteria, some weighting factors are also preprogrammed to respond to user inputs. For example, if the user selects the Class A+ or N-DeN option in the effluent end use section in Step 1, the N-DeN weighting factor will be set at a high default value of “10”. Otherwise (i.e. when nutrient removal is not required for the facility), the weighting factor will be set at a lower default value of “0”. Similarly, if the recharge or emerging contaminant removal option is selected in Step 1, the DBP Removal criterion will receive a high default weighting factor of “10”.

3.4.4 Weighting Factor Manual Adjustment

The user should review the weighting factors, as previously identified by the engineer, and as shown in the screen capture in Section 3.4.2. The weighting factors were assigned to each performance based criterion on a 0 to 10 scale, with 0 representing the least important/applicable and 10 representing the most important/applicable.

3.4.5 To Reset Weighting Factors

The user can adjust weighting factors as required. Adjusting the weighting factors may also be helpful when performing a sensitivity analysis. However, because the default weighting factors were assigned as part of a collaborative effort between the Engineer, City, and developers, the default settings should be utilized unless the user has a specific and justifiable reason to change the weighting factor. For example, a new SPA with low population density may justify a lower weighting associated with the “footprint” criterion. In this case, changes can be made by typing the new weighting factor in the “footprint” cell.

The default settings can be restored by clicking the reset button 

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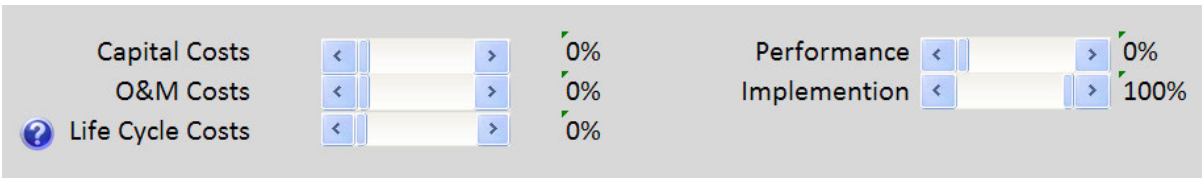
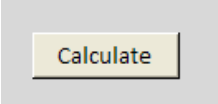
3.4.6 Set Overall Weighting using Slide Bars

The implementation based weighting factors represent a stand-alone comprehensive evaluation incorporating costs, process reliability, operational issues, regulatory and safety issues, etc. To use the default weighting factors assigned by the Engineer, City and Developer, the user should set the slide bars for performance, capital, O&M, and life cycle costs at 0% and the slide bar for implementation at 100%.



Click the calculate button 

and review the top recommended treatment processes for the specific wastewater quality, reclaimed water and biosolids quality goals, site specific inputs and weighting factors. The results will be shown on the detailed unit process sheets (see Section 3.5).

Costs and performance are two major categories that could influence the technology selection. The user can consider performing a sensitivity analysis by assigning extra weighting for costs or performance by dragging the slide bars as described below.

3.4.7 To Consider Extra Weighting for Costs

Keep the implementation slide bar at the 100% level and the performance slide bar at the 0% level. Drag the capital, O&M, or life cycle bars to the appropriate weighting. Click the calculate button to determine changes in the recommendation. Change the setting and calculate again, if desired.

3.4.8 To Consider Extra Weighting for Performance

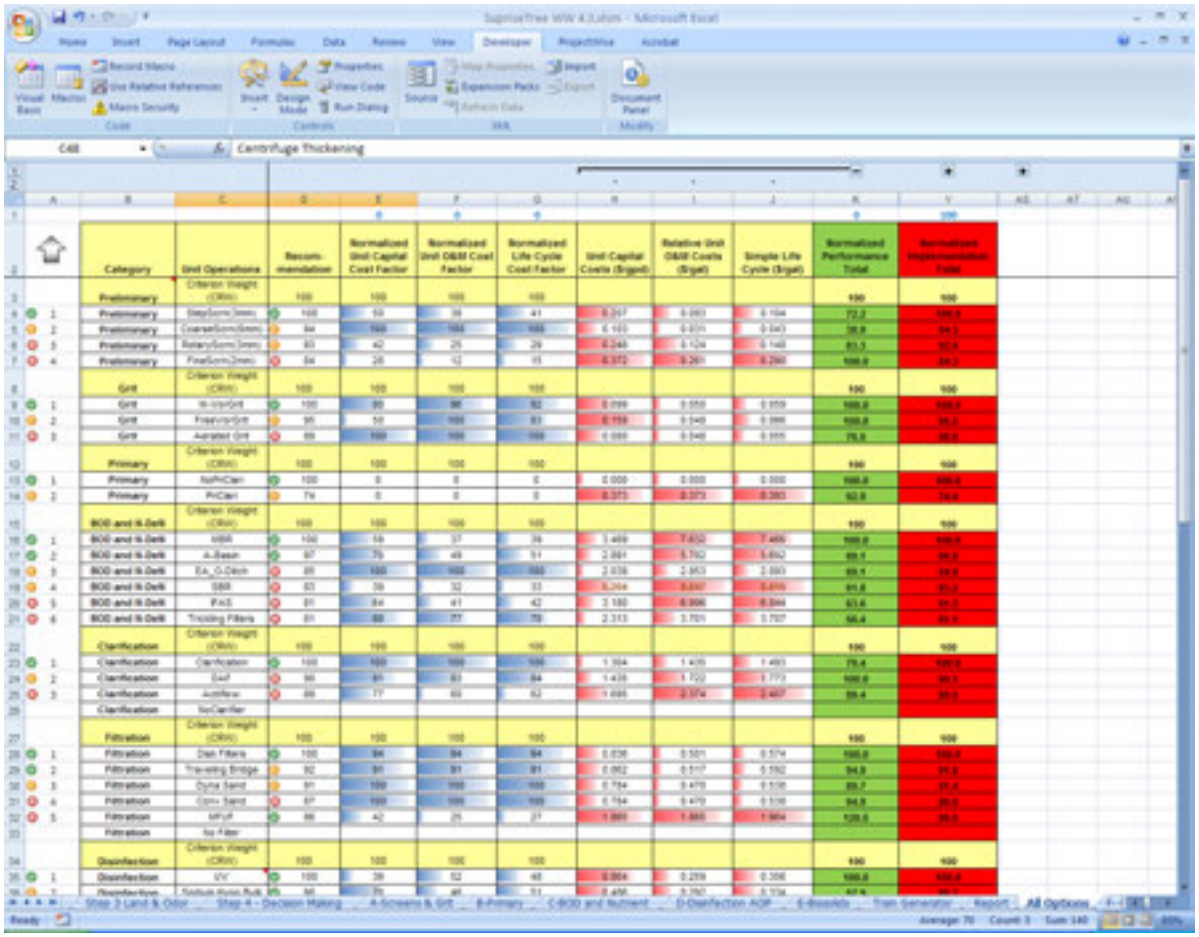
Keep the implementation slide bar at the 100% level and reset the slide bars for costs to 0%. Drag the performance bar to the appropriate weighting. Click the calculate button to determine changes in the recommendation. Change the setting and calculate again, if desired.

3.5 Detailed Process Ranking Sheets

The SurpriseTree™ Wastewater Model provides more detailed results associated with each treatment category, such as screens, grit removal, biological treatment, disinfection, etc. The user can choose to skip these detailed process ranking sheets and proceed directly to the Train Generator by clicking on the icon.

3.5.1 Score and Ranking Calculation

As described in the Wastewater Technology Assessment report, the SurpriseTree™ Wastewater Model utilizes a logical, three-tier evaluation to rank the treatment technology options. The ranking scores are presented in the following screen captures and can be found on the “All Options” sheet in the model.



The SurpriseTree™ Wastewater Model calculates the ranking scores using the following procedures:

- Implementation Scores for Each Technology Alternative (e.g., MBR):
  - Total Implementation Score for a technology alternative (e.g., MBR) is the weighted average (summation of the products) of the score for each alternative (e.g., MBR) for a given criterion (e.g., Footprint or Expandability) and the corresponding Weighting factor for the given criterion (e.g., 4.6 or 6.5).
  - The Total Implementation score is then normalized to 100 by multiplying by 100 and dividing by the maximum Total Implementation Score for a technology alternative (e.g., MBR) in its category (e.g., biological treatment).
  - The higher the score, the better a technology alternative is based on this comprehensive evaluation.
- Performance Scores for Each Technology Alternative (e.g., MBR):
  - Total Performance Score for a technology alternative (e.g., MBR) is the weighted average (summation of the products) of the score for each alternative (e.g., MBR) for a given criterion (e.g., BOD Removal or TSS Removal) and the corresponding Weighting factor for the given criterion (e.g., 10 or 0).

  - The Total Performance score is then normalized to 100 by multiplying by 100 and dividing by the maximum Total Implementation Score for a technology alternative (e.g., MBR) in its category (e.g., biological treatment).
  - The higher the score, the better a technology alternative is considering its performance / effectiveness in removing the target CoCs for the specific wastewater.
- Financial Scores for Each Technology Alternative:
  - Relative Capital Costs ($/gpd), O&M Costs and Life Cycle Costs ($/gal) are estimated for each alternative for the purpose of comparison.
  - The cost score is a normalized score on a 100 scale, with the less expensive alternative being 100.
  - The higher the score, the less expensive the alternative is.
- Overall Scores for Each Technology Alternative
  - The Overall Score for a technology alternative (e.g., MBR) is the weighted average (summation of the products) of the Implementation score, the Performance score, and the Capital, O&M and Life Cycle scores for each alternative (e.g., MBR) with consideration for the corresponding slide bar setting for the given score.
  - The Overall Score is then normalized to 100 by multiplying by 100 and dividing by the maximum Overall Score for a technology alternative (e.g., MBR) in its category (e.g., biological treatment).
  - The higher the overall score, the better a technology alternative is considering its performance / effectiveness in removing the target CoCs for the specific wastewater.

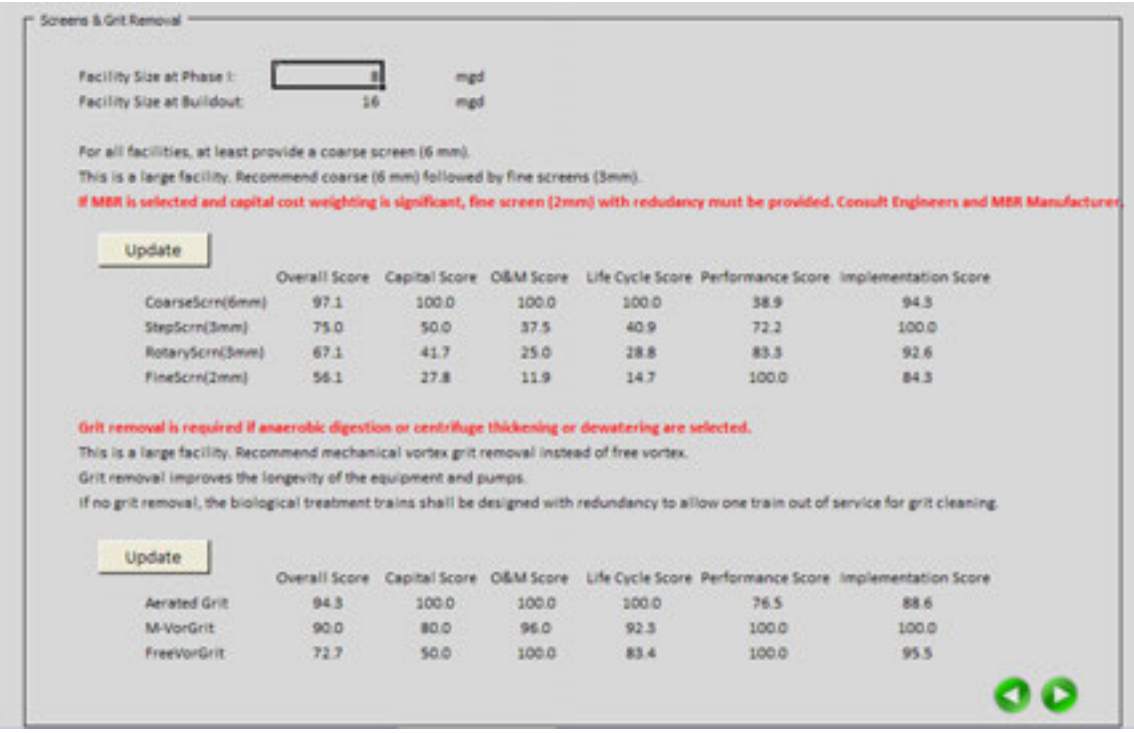
3.5.2 Screening and Grit

This sheet summarizes the model outputs associated with the recommended screening and grit removal technology options. The summary includes the overall score, capital score, O&M score, life cycle score, performance score and implementation score for a given technology. It also generates design consideration notes related to the screening and grit removal processes based on the user input decision making settings.

As described in Section 3.4, the use of the weighing slide bars provides users with a quick/visual adjustment to determine the significance of the decision-making factors. By clicking on the update button, the SurpriseTree™ Model will quickly update the treatment option ranking based on the given weighting factor and the slide bar settings.

When setting the Implementation bar at 100%, and the Performance and Cost bars at 0% on the Step 4 sheet, the overall score (which equals the implementation score), represents the Engineer, City, and Developer assigned default weighting factors for decision making. A screen capture of the screening and grit removal detailed output is presented below.

The user can choose to emphasize financial or performance categories by following the instructions provided in Section 3.4.6. The following example illustrates the sensitivity of the model. If the user keeps the Implementation slide bar at its full position and moves the slide bar setting for capital cost to the full position, the overall score represents an average of the implementation score and the capital cost score with equal weighting (50% of each). When the “Update” button is clicked, the SurpriseTree™ Wastewater Model will recalculate the treatment option ranking based on these settings. The revised results are presented in the following screen shot.



Screens & Grit Removal

Facility Size at Phase I: 8 mgd
Facility Size at Buildout: 16 mgd

For all facilities, at least provide a coarse screen (6 mm).
This is a large facility. Recommend coarse (6 mm) followed by fine screens (3mm).
If MBR is selected and capital cost weighting is significant, fine screen (2mm) with redudancy must be provided. Consult Engineers and MBR Manufacturer.

Update

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
CoarseScrn(6mm)	97.1	100.0	100.0	100.0	38.9	94.3
StepScrn(3mm)	75.0	50.0	37.5	40.9	72.2	100.0
RotaryScrn(3mm)	67.1	41.7	25.0	28.8	83.3	92.6
FineScrn(2mm)	56.1	27.8	11.9	14.7	100.0	84.3

Grit removal is required if anaerobic digestion or centrifuge thickening or dewatering are selected.
This is a large facility. Recommend mechanical vortex grit removal instead of free vortex.
Grit removal improves the longevity of the equipment and pumps.
If no grit removal, the biological treatment trains shall be designed with redundancy to allow one train out of service for grit cleaning.

Update

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
Aerated Grit	94.3	100.0	100.0	100.0	76.5	88.6
M-VorGrit	90.0	80.0	96.0	92.3	100.0	100.0
FreeVorGrit	72.7	50.0	100.0	83.4	100.0	95.5

As noted in the screen capture, when capital cost is assigned a higher importance in decision making, less expensive options, such as the coarse screen and the aerated grit removal, rank higher than when implementation criteria carry 100% of the weight.

It is important to read the associated notes/considerations prior to selecting a technology. For example, when no extra weighting factor is assigned to the capital costs (implementation slide bar = 100%, all other slide bars = 0%), the model recommends coarse screening (6 mm) followed by fine screening (2 mm) with redundancy for an MBR application. However, if the capital cost weighting is more significant (e.g. capital cost slide bar = 50%), the model will allow fine screening (2 mm) with redundancy for MBR.

Facility size inputs could also change the model recommendation. For example, single fine screens (3 mm) are recommended for a small facility while coarse screening (6 mm) followed by fine screening (3 mm) is recommended for larger, non MBR facility.

3.5.3 Primary Clarification

This sheet summarizes considerations associated with primary clarifier technology options including their overall score, capital score, O&M score, life cycle score, performance score and implementation score. The sheet also summarizes the applicability of the technology based on user inputs/model defaults associated with whether primary clarification is required, is a user "preference", or if primary clarification is not recommended.

The SurpriseTree™ Wastewater Model generates design considerations based on the user's input. For primary clarification, these design considerations may include:

- **Land:** Depending on the land availability entered on Step 3, the model will either indicate that land is sufficient and primary clarification can be considered, or the land is not sufficient and primary clarification is not recommended.
- **Wastewater Quality:** If the influent TSS is higher than a preset value (default = 500 mg/L), the model will recommend primary clarification. If the influent BOD:TKN ratio is less than a preset value (default = 3), the model will not recommend primary clarification.

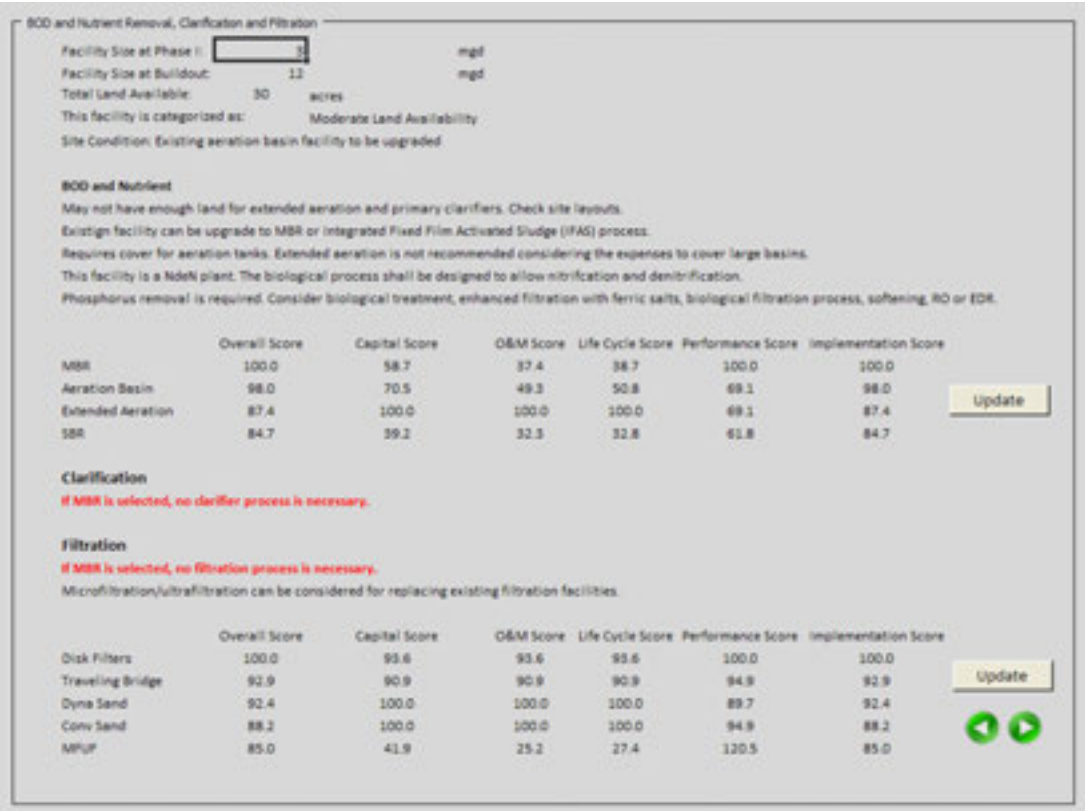
Other considerations address the synergy between primary clarifiers and the selection of other technologies in different treatment categories. For example, if anaerobic digestion or advanced anaerobic digestion processes are selected, primary clarifiers will be automatically selected. If extended aeration is selected, primary clarifier are not recommended. An example screen capture is presented below.

3.5.4 BOD and Nutrient Removal

This sheet summarizes the model outputs associated with the recommended biological treatment and filtration technology options including their overall score, capital score, O&M score, life cycle score, performance score, and implementation score. It also generates design consideration notes related to the biological treatment and filtration process based on the user input decision making settings.

The SurpriseTree™ Wastewater Model generates design considerations based on the user's input. For biological treatment, these design considerations may include:

- **Land Availability:** The model will automatically indicate whether land availability will impact/limit the selection of specific biological treatment technologies. For example, if the land availability factor for the site is 3 (Moderate Land Availability), the model will remind the user that there may not be sufficient land available for processes such as extended aeration. In these cases, the model will suggest the user confirm site layouts to verify sufficient land is available.
- **Existing Site Conditions:** The model will generate recommendations based on the existing site conditions input in Step 3. For example:
  - If the proposed site is a "greenfield" plant, site conditions will likely not affect the technology selection – if sufficient land is available.
  - If the existing site is equipped with an aeration basin facility, the existing facility can be maintained and expanded or upgraded to an MBR facility.
  - If the existing site is equipped with an oxidation ditch facility, the existing facility can be maintained and expanded or upgraded to a conventional aeration facility or MBR facility.
  - If the existing site is equipped with an SBR facility and the facility size is less than a preset value (default = 3 mgd), the model will recommended that SBR technology be maintained. If the facility size is larger than 3 mgd, the model will recommend decommissioning the SBR and proceeding with a new technology.
- **Odor Control:** If odor control requirements are stringent, the model will consider the costs to provide odor control as a factor in technology selection. For example, if the odor control level is 2 or 3 (full odor control is required), extended aeration may not be recommended considering the expense required to cover large basins.
- **Nutrient Removal:** The model will summarize the nitrification, denitrification, and phosphorus removal requirements based on the effluent end use and wastewater strength.



BOD and Nutrient Removal, Clarification and Filtration

Facility Size at Phase I: 3 mgd
Facility Size at Buildout: 12 mgd
Total Land Available: 30 acres
This facility is categorized as: Moderate Land Availability
Site Condition: Existing aeration basin facility to be upgraded

BOD and Nutrient

May not have enough land for extended aeration and primary clarifiers. Check site layouts.
Existign facility can be upgrade to MBR or Integrated Fixed Film Activated Sludge (IFAS) process.
Requires cover for aeration tanks. Extended aeration is not recommended considering the expenses to cover large basins.
This facility is a NdeN plant. The biological process shall be designed to allow nitrification and denitrification.
Phosphorus removal is required. Consider biological treatment, enhanced filtration with ferric salts, biological filtration process, softening, RO or EDR.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
MBR	100.0	58.7	37.4	38.7	100.0	100.0
Aeration Basin	98.0	70.5	49.3	50.8	69.1	98.0
Extended Aeration	87.4	100.0	100.0	100.0	69.1	87.4
SBR	84.7	39.2	32.3	32.8	61.8	84.7

Update

Clarification

If MBR is selected, no clarifier process is necessary.

Filtration

If MBR is selected, no filtration process is necessary.
Microfiltration/ultrafiltration can be considered for replacing existing filtration facilities.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
Disk Filters	100.0	93.6	93.6	93.6	100.0	100.0
Traveling Bridge	92.9	90.9	90.9	90.9	94.9	92.9
Dyna Sand	92.4	100.0	100.0	100.0	89.7	92.4
Conv Sand	88.2	100.0	100.0	100.0	94.9	88.2
MPUF	85.0	41.9	25.2	27.4	120.5	85.0

Update

For secondary clarification, secondary clarifiers are the only viable option evaluated as part of the SurpriseTree™ Wastewater Model. Advanced clarification processes such as DAF or Actiflo are evaluated in the Wastewater Technology Assessment report but are not recommended for the City's RWRFs. If MBR is the selected technology, clarifiers and/or filters are not required.

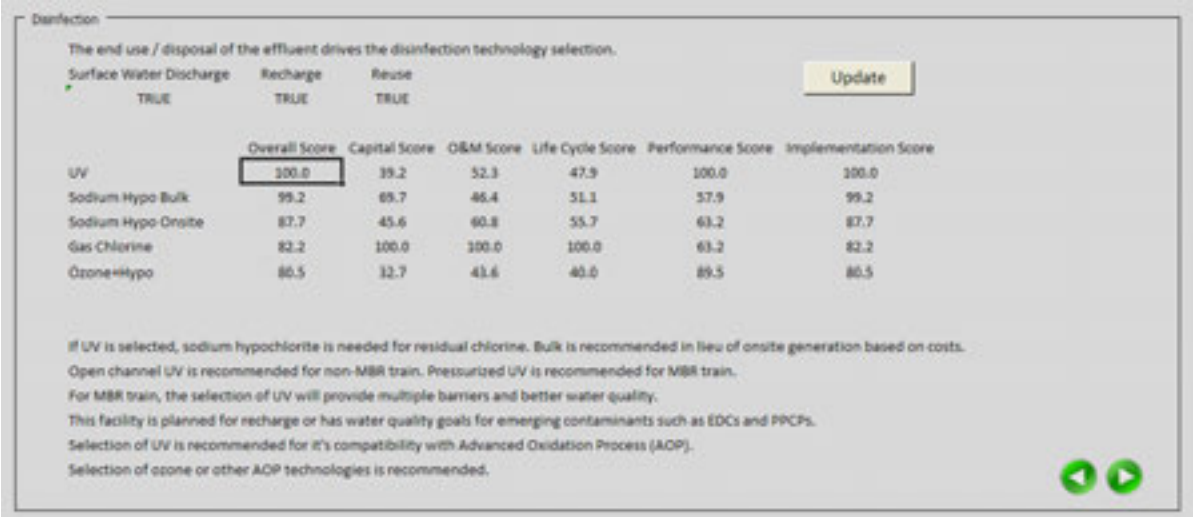
The user can choose to emphasize financial or performance categories by following the instructions provided in Section 3.4.6. For example, if the user keeps the implementation slide bar at its full (100%) position but moves the slide bar setting for capital cost to the full position, technology options with lower capital costs will rank higher on the list.

3.5.5 Disinfection and AOP

This sheet summarizes the model outputs associated with the recommended disinfection technology options including their overall score, capital score, O&M score, life cycle score, performance score, and implementation score. It also generates design consideration notes related to the disinfection process and the advanced oxidation process based on user input decision making setting.

The SurpriseTree™ Wastewater Model generates design considerations based on the user's input. For disinfection, these design considerations may include:

- If UV is selected, sodium hypochlorite is required to provide chlorine residual. Bulk sodium hypochlorite is recommended in lieu of onsite generation based on current costs.
- Open channel UV is recommended for non-MBR trains. Pressurized UV is recommended for MBR trains.
- For MBR trains, the selection of UV will provide multiple barriers and better water quality.



If reclaimed water from the facility is intended for recharge, or the user checked the EDCs and PPCPs removal box in the effluent end use management goals in Step 1, the model will reiterate these goals. The model will recommend UV for its compatibility with future Advanced Oxidation Processes (AOP). The model will also suggest technologies such as RO and AOP in the form of UV / H_2O_2, ozone / H_2O_2 or UV / TiO_2.

The user can choose to emphasis financial or performance categories by following the instructions provided in Section 3.4.6. For example, if the user keeps the implementation slide bar at its full position and moves the slide bar setting for capital cost to the full position, options with lower capital costs will rank higher on the list.

3.5.6 Biosolids

This sheet summarizes the model outputs associated with the recommended thickening, biosolids stabilization, and dewatering technologies including their overall score, capital score, O&M score, life cycle score, performance score and implementation ranking scores. It also generates design consideration notes related to the biosolids treatment process and the advanced biosolids handling technologies based on user input decision making settings.

The SurpriseTree™ Wastewater Model generates design considerations based on the user's input. For solids thickening, these design considerations may include:

- If solids stabilization is not required, thickening may not required. If stabilization is required, (either Class B or Class A biosolids), thickening is typically required depending on the selected stabilization technology.
- If MBR technology is selected, polymer use for DAF or other technologies may be a potential fouling concern in the recycled stream.
- If grit basins are not selected, centrifuge thickening is not recommended considering the abrasive nature of the biosolids without grit removal.
- If multiphase digestion is selected, centrifuge thickening is preferred to provide the required high solids concentrations.

Design considerations associated with solids stabilization processes may include:

- To produce Class A or Class B biosolids, stabilization is required. For landfilling sludge, stabilization is not required.
- When land availability is limited, the SurpriseTree™ Wastewater Model notifies the user that there may not be sufficient land to implement primary clarification and anaerobic digestion facilities. The model recommends the user complete a facility specific master plan, conceptual design or preliminary design to address these issues.
- If extended aeration is selected, aerobic digestion is recommended. The associated digester size can be reduced due to the extended aeration process.

Some examples of the design considerations associated with dewatering may include:

- Dewatering is required for landfill.
- Land application can be accomplished with liquid or dewatered biosolids (depending on the City's contracts). Dewatering is recommended to reduce hauling costs.
- If grit basins are not selected, centrifuge dewatering is not recommended considering the abrasive nature of the biosolids without grit removal.

Biosolic

Thickening

No thickening is required due to no need of stabilization.

If MBR is selected, the use of polymer associated with DAF might be a concern, considering the potential fouling of polymer on membranes.

Update

If grit basins are not selected, no centrifuge thickening.

If multiphase digestion is selected, centrifuge thickening is preferred for the need of high solids concentration.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
Centrifuge Thickening	100.0	40.0	12.5	14.9	100.0	100.0
RTD	97.2	50.0	25.0	28.3	1.0	1.0
Gravity Belt	96.5	66.7	41.7	45.6	0.8	0.6
Gravity Thickening	95.7	100.0	100.0	100.0	0.5	0.3
DAF Thickening	94.6	80.0	50.0	54.7	0.6	0.5

Stabilization

Update

No thickening and no stabilization is required.

There is land available for primary clarifier and anaerobic digestion facility.

If extended aeration is selected, aerobic digester is recommended and can be smaller due to the extended aeration.

If extended aeration is selected, primary clarifier and anaerobic digestion are not recommended.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
Multiphase	100.0	62.7	58.5	58.9	100.0	100.0
ConvAnaerobic	89.3	75.2	70.2	70.6	71.4	89.3
TempPhase	85.3	54.5	47.7	48.3	85.7	85.3
Aerboic	79.8	80.0	56.0	57.7	42.9	79.8
ATAD2	77.4	48.0	33.6	34.6	57.1	77.4
Lagoon	77.9	100.0	100.0	100.0	14.3	77.9

Dewatering

Dewatering is required for landfill.

If grit basins are not selected, no centrifuge dewatering.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
BeltPress	100.0	37.5	46.9	46.1	87.5	100.0
Centrifuge_Dewatering	95.2	30.0	37.5	36.9	100.0	95.2
DryingBeds	93.4	100.0	100.0	100.0	62.5	93.4

Advanced Biosolids Management Options

☐ Is advanced biosolids management (solids drying, composting, etc.) a preference?

The SurpriseTree™ Wastewater Model considers advanced biosolids management options as a preference of the owner. Advanced biosolids management may not be mandatory to achieve biosolids goals and many social, political, environmental, and economic aspects drive the decision.

3.5.7 Technology Implementation Package

The detailed process ranking sheets include hyperlinks indicating “Click here for implementation package”. Clicking on these links will allow the user to quickly access the implementation packages for the recommended technologies. These packages include basis of design, process flow diagrams, and design consideration lists for the associated technology.

3.6 Train Generator

3.6.1 Train Generator

After completing the inputs on Steps 1 through 4 and reviewing the detailed process ranking sheets for individual treatment technologies, the user can proceed to the Train Generator sheet to review the complete treatment trains assembled by the model.

The following table summarizes the top options for each treatment category recommended by the Wastewater Technology Assessment report for further consideration. All of these options are considered technically feasible and economically acceptable for the City of Surprise RWRFs. Theoretically 4 X 3 X 2 X 4 X 2 X 3 X 3 X 3 X 4 X 3 = 82,944 permutations (treatment trains) can be assembled using these options.

Preliminary	Grit Removal	Primary	BOD and N-DeN	Clarifi-cation	Filtration	Disin-fection	Thickening	Stabilization	Dewatering
4	3	2	4	2	3	3	4	4	3
Step Screen (3 mm)	Mechanical Vortex Grit	Primary Clarifier	MBR			UV	Centrifuge Thickening	Multiphase	Belt Press
Coarse Screen (6 mm)	Free Vortex Grit	No Primary Clarifier	Aeration Basin	Clarifi-cation	Disk Filters	Sodium Hypo Bulk	RTD	Conventional Anaerobic	Centrifuge Dewatering
Rotary Screen (3 mm)	Aerated Grit		Extended Aeration	No Clarifier	Traveling Bridge	Sodium Hypo Onsite	Gravity Belt	Temperature Phase	Drying Beds
Fine Screen (2 mm)			SBR		DynaSand		Gravity Thickening	Aerobic	

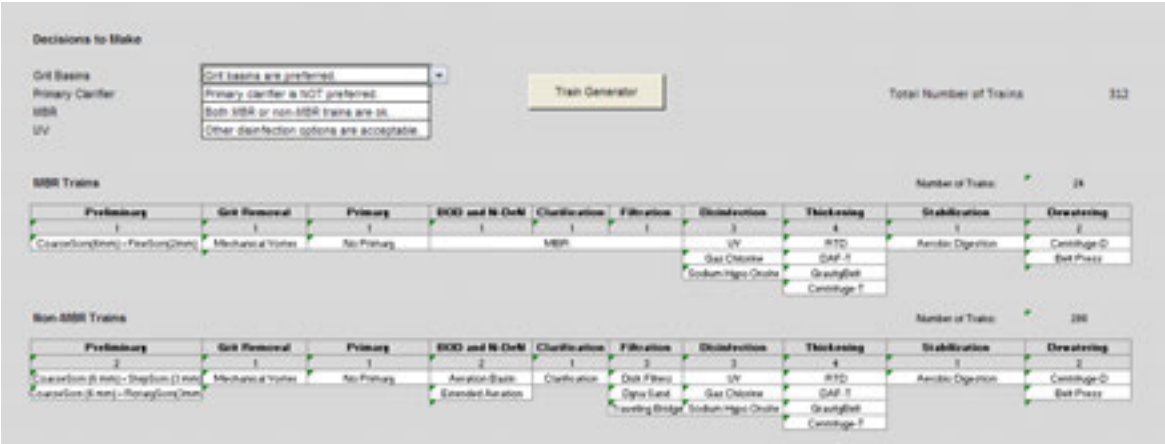
Obviously, evaluating all potential treatment trains is not practical. Without the model, users would have to select the top one or two options in each category by preference and assemble treatment trains based on preferences and engineering judgment. More detailed evaluations (facility master plan or conceptual design) would have to be performed to compare the pros and cons, the capital, O&M and life cycle costs for each train. Considerations such as the site specific impacts, synergy between the technologies being considered, market conditions at the time, etc. must all be considered before the final treatment train could be selected for a proposed site.

The SurpriseTree™ Wastewater Model offers the City a new mechanism to expedite treatment train evaluation and assist in ensuring minimum treatment goals, design criteria and capital and O&M costs are incorporated. Although it cannot replace a facility master plan, conceptual design, or engineering judgment, it provides a fully adjustable platform to gather site specific facility planning information and owner's preferences and incorporate engineering principles and rules in wastewater treatment technology selection.

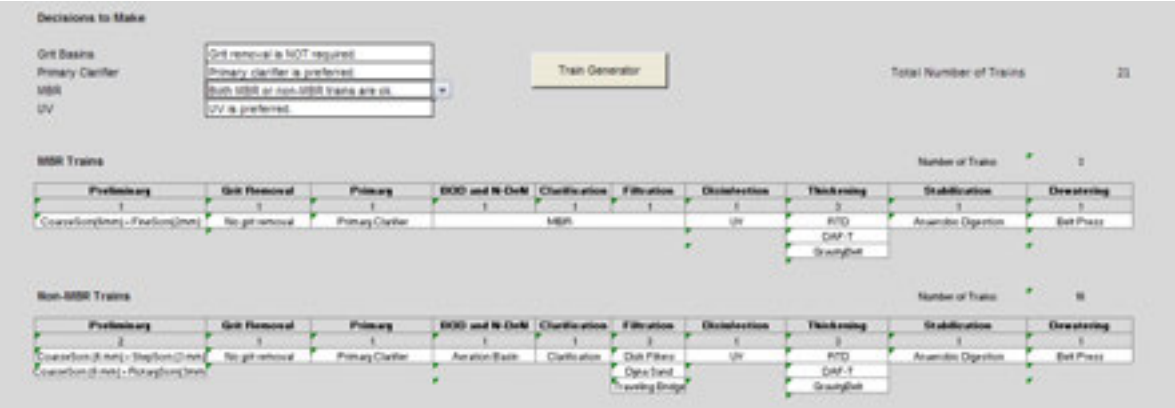
The SurpriseTree™ Wastewater Model incorporates many engineering rules and considerations in wastewater treatment technology selection. It also considers the impacts of wastewater quality (BOD:TKN ratio, TSS concentrations, etc.), effluent end use options,

biosolids management options, flow capacity and peaking factors, odor control requirements and land availability in the treatment technology selection.

By applying these rules and considerations, the SurpriseTree™ Wastewater Model quickly eliminates unviable treatment trains and allows the user to focus on the optimum technologies for the specific application. For instance, in the SPA 2 example, the 82,944 permutations are quickly filtered down to 24 MBR trains and 288 non-MBR trains for additional consideration as shown in the screen capture below, if the user chose “grit basins are preferred” and “primary clarifiers are not preferred”.



In the screen capture below, the number of viable treatment trains further reduced to 3 MBR or 18 non-MBR trains if the user chose “primary clarifier is preferred”.



3.6.2 Rules

The SurpriseTree™ Wastewater Model incorporates many engineering rules and considerations in wastewater treatment technology selection as highlighted in the sections above. Many of these inputs directly impact the treatment technology selection. Some are used by the model to generate design considerations and notes for the City, the developer and the designers.

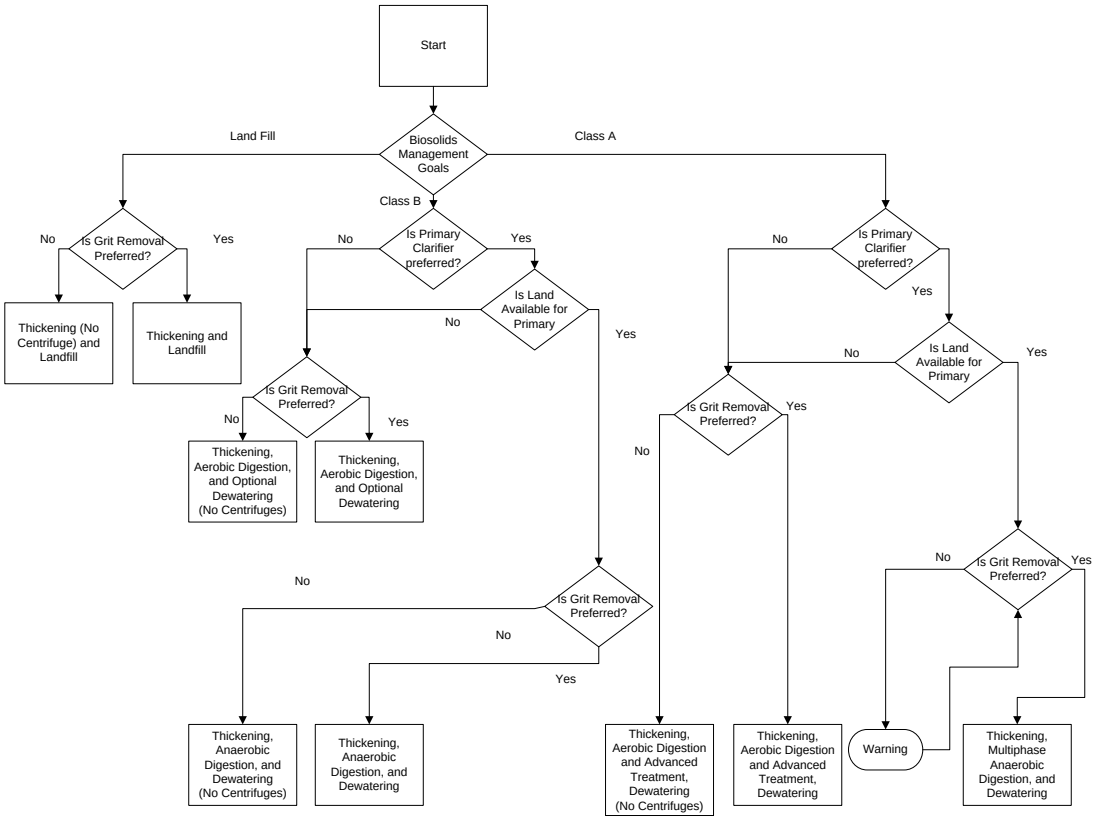
3.6.3 Preferences

As part of the Train Generator sheet, the user is asked to answer four preference questions:

- Is grit removal preferred or required?
- Is primary clarifier preferred?
- Are both MBR or non-MBR trains acceptable?
- Is UV the preferred disinfection method?

Responses to these four questions are critical as they represent preferences associated with the primary treatment categories, influence the selection of technologies under other treatment categories, and greatly reduce the total number of viable trains. This section illustrates how answers to these four questions could impact the technology selection using the SPA 2 RWRF example.

Assuming the user has completed the required inputs in Steps 1 through 4 similar to the examples presented in Section 2.0, the following logic flow diagram illustrates the selection basis for the selection of grit basins or primary clarifiers as preferred biosolids management technologies.

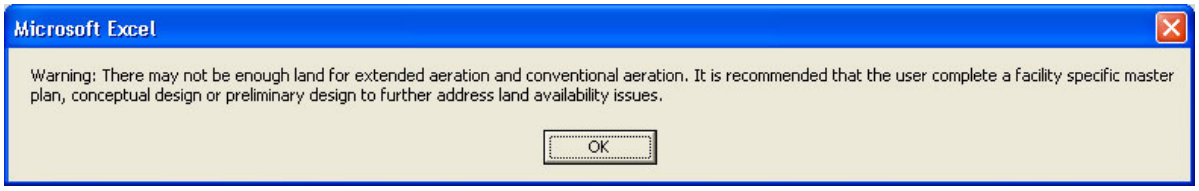


If the user indicates a preference for no grit basins, centrifuge thickening or centrifuge dewatering will not be recommended by the model, considering the abrasiveness of the biosolids without grit removal. Grit removal is required by the model if anaerobic digestion or centrifuge thickening or dewatering are selected.

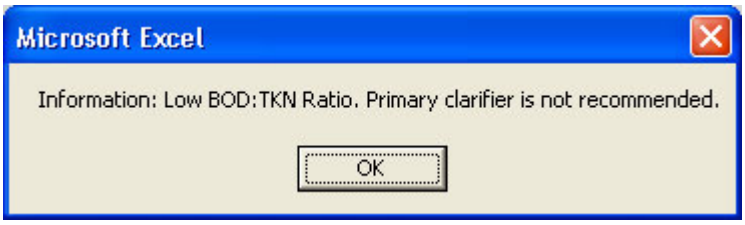
For example, if the user elects to achieve Class A biosolids using a multiphase digestion process, but attempts to select “no grit basins”, a warning message will indicate that grit basins are required under such conditions.

If the biosolids management goal is “landfill only”, no digestion process is required. If the user attempts to select primary clarifiers as a preference, an information box will indicate that primary clarification is not necessary under such conditions.

Similarly, if land availability may not be sufficient for primary clarifiers, a message will indicate such if user attempts to select primary clarifier as a preference.



Water quality can also impact whether primary clarifiers are a viable technology for the proposed treatment facility. For instance, if the raw water BOD:TKN ratio is low, an information box will indicate that primary clarification is not recommended under such conditions.



If the user chooses “MBR is preferred”, the SurpriseTree™ Wastewater Model will only generate MBR trains. If the user selects “Both MBR and non-MBR trains are acceptable”, the model will consider MBR, conventional aeration, extended aeration, and SBR technologies. The model will use land availability (See Section 3.3) and facility capacity cutoff to further refine the technology options as indicated below.

- For SBR to be a preferred option, the facility size shall be less than an adjustable preset value (default = 3 mgd);
- For the extended aeration basins technology to be economical, the facility size shall be less than an adjustable preset value (default = 10 mgd).

If the user chooses “UV is preferred”, the SurpriseTree™ Wastewater Model will consider UV with sodium hypochlorite (bulk) for residual chlorine (given the City’s concerns associated with the safety issues of gaseous chlorine). If the user chooses “Other disinfection options are acceptable”, the model will consider UV with sodium hypochlorite (bulk) for residual chlorine, bulk sodium hypochlorite and sodium hypochlorite onsite generation.

3.6.4 Design Notes

In addition to the treatment train assembly functions, the Train Generator sheet will also automatically generate a list of site specific design notes when the user clicks on the “Train Generator” button.

3.7 Cost Evaluation

This section presents information associated with the cost evaluation included in the SurpriseTree™ Wastewater Model. An example is provided to illustrate how to use the F – Cost sheet to perform cost sensitivity analysis for treatment technologies.

3.7.1 Relative Unit Costs

The SurpriseTree™ Wastewater Model includes relative conceptual level costs for comparing the economics of each treatment technology. The included costs are NOT intended to be used for budget planning, design, or construction.

The model automatically adjusts the costs based on inputs such as construction time, location factor, and facility sizes. The following table presents a snap shot of the costs associated with a 12 mgd facility with relative costs in 2010 dollars.

	Relative Unit Capital Costs ($/gpd)	Relative O&M Costs ($/1,000 gal)
Preliminary		
Coarse Screen	$0.07	$0.02
Step Screen (3 mm)	$0.15	$0.06
Rotary Screen (3 mm)	$0.17	$0.09
Fine Screen	$0.26	$0.18
Grit		
Aerated Grit	$0.06	$0.03
M-Vortex Grit	$0.07	$0.04
Free Vortex Grit	$0.11	$0.03
Primary		
Primary Clarifier	$0.29	$0.29
BOD and N-DeN		
Oxidation Ditch	$1.44	$2.01
Aeration Basin	$2.04	$4.08
MBR	$2.45	$5.38
SBR	$1.83	$3.12
Trickling Filters	$1.63	$2.61
IFAS	$2.24	$4.93
Secondary Clarification		
Clarification	$0.92	$1.02
Filtration		
Disk Filters	$0.59	$0.35
Traveling Bridge	$0.61	$0.36
MF/UF	$1.31	$1.31
DynaSand	$0.61	$0.36
Conventional Sand	$0.55	$0.33
Disinfection		
Gas Chlorine	$0.24	$0.10
Sodium Hypo Bulk	$0.34	$0.21
Sodium Hypo Onsite	$0.52	$0.16
UV + Hypo	$0.61	$0.18
Ozone + Hypo	$0.73	$0.22
Odor		
Chemical Addition	$0.07	$0.13
Liquid Scrubber	$0.26	$0.18
Biofilter	$0.30	$0.15
BioTower	$0.33	$0.17
Carbon Adsorption	$0.26	$0.26
Electrically Ion Charged	$0.31	$0.19

	Relative Unit Capital Costs ($/gpd)	Relative O&M Costs ($/1,000 gal)
Thickening		
DAF Thicken	$0.45	$0.36
Centrifuge Thickening	$0.91	$1.45
Gravity Thicken	$0.36	$0.18
RTD	$0.72	$0.72
Gravity Belt	$0.54	$0.43
Stabilization		
Aerobic Digestion	$0.88	$1.76
ATAD2	$1.46	$2.93
Conventional Anaerobic	$0.93	$1.40
Multiphase	$1.12	$1.68
Temperature Phase	$1.29	$2.06
Lagoon	$0.70	$0.98
Dewatering		
Centrifuge Dewatering	$0.91	$1.45
Belt Press	$0.72	$1.16
Drying Beds	$0.27	$0.54
Advanced Biosolids Treatment		
Composting	$0.81	$1.46
Incineration	$4.88	$9.75
Air Drying	$0.63	$0.63
Solar Air Drying	$2.17	$2.60
Heat Drying	$2.67	$5.33

References for the costs include, but are not be limited to, the Carollo Engineers, Inc. Planning-Level Cost Estimating Software (PCES), the Surprise SPA 2 RWRF Conceptual Design Report and Detailed Design costs, the City of Phoenix WWTP Alternative Disinfection Studies, the City of Sedona Biosolids Management Study, the City of Phoenix 23rd Avenue WWTP Multiphase Digestion Study, and the Casa Grande WRF expansion project.

3.7.2 How to Perform Cost Analysis

As discussed previously, the implementation based weighting factors represent a stand-alone comprehensive evaluation incorporating qualitative costs (scores on 1 to 10 scale), process reliability, operational issues, regulatory and safety issues, etc. If the user sets the slide bars for performance, capital, O&M, and life cycle costs at 0% and the slide bar for implementation at 100%, the City assigned default weighting factors will govern in the evaluation.

Capital Costs	0%	Performance	0%
O&M Costs	0%	Implemention	100%
Life Cycle Costs	0%		

Calculate

Using the disinfection technologies as an example, under this default setting condition, the technology ranking is shown below (D-Disinfection AOP Sheet), with bulk sodium hypochlorite ahead of sodium hypochlorite onsite generation.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
UV	100.0	39.2	52.3	47.9	100.0	100.0
Sodium Hypo Bulk	96.6	69.7	46.4	51.1	57.9	96.6
Sodium Hypo Onsite	90.0	45.6	60.8	55.7	63.2	90.0
Ozone+Hypo	79.8	32.7	43.6	40.0	89.5	79.8
Gas Chlorine	66.1	100.0	100.0	100.0	63.2	66.1

	facility size: 12 mgd						
	Default		City's Adjustment		LCA Analysis		
	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Life Cycle ($/1000gal)
MFLIF	$ 1.31	$ 1.31			$1.87	$1.87	$1.96
NoFilter	$ -	$ -			$0.00	$0.00	$0.00
DymaSand	$ 0.61	$ 0.36			$0.86	$0.52	$0.59
ConvSand	$ 0.55	$ 0.33			$0.78	$0.47	$0.54
Disinfection	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
GasChlorine	$ 0.24	$ 0.10			$0.34	$0.14	$0.17
Sodium Hypo Bulk	$ 0.34	$ 0.21			$0.49	$0.29	$0.33
Sodium Hypo Onsite	$ 0.52	$ 0.16			$0.74	$0.22	$0.31

To utilize the cost information in the evaluation by emphasizing the financial aspects in decision making, users shall adjust the slide bars for capital, O&M or life cycle. Assume the O&M cost category represents 30% in the decision making process and the implementation 70%.

Capital Costs	0%	Performance	0%
O&M Costs	30%	Implemention	70%
Life Cycle Costs	0%		

Calculate

Under these conditions, the technology ranking is shown below (D-Disinfection AOP Sheet), with bulk sodium hypochlorite still ahead of sodium hypochlorite onsite generation.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
UV	85.7	39.2	52.3	47.9	100.0	100.0
Sodium Hypo Bulk	81.5	69.7	46.4	51.1	57.9	96.6
Sodium Hypo Onsite	81.2	45.6	60.8	55.7	63.2	90.0
Gas Chlorine	76.3	100.0	100.0	100.0	63.2	66.1
Ozone+Hypo	68.9	32.7	43.6	40.0	89.5	79.8

If updated or site specific cost information is available, the user can utilize the F – Costs sheet to override the default costs. Updated cost information can be entered into the *City's Adjustment* columns for unit capital and O&M costs. The information should be entered in $/gallon for capital cost and $/1000 gallons for O&M costs.

Assuming the user has more recent O&M costs for the bulk sodium hypochlorite and onsite generation technologies, the information can be input into the O&M costs column, as shown below.

	facility size: 12 mgd						
	Default		City's Adjustment		LCA Analysis		
	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Unit Capital Costs ($/gpd)	O&M Costs ($/1000 gal)	Life Cycle ($/1000gal)
MFUF	$ 1.31	$ 1.31			$1.87	$1.87	$1.96
NoFilter	$ -	$ -			$0.00	$0.00	$0.00
DynaSand	$ 0.61	$ 0.36			$0.86	$0.52	$0.59
ConvSand	$ 0.55	$ 0.33			$0.78	$0.47	$0.54
Disinfection	Enter new costs in the white cells to replace the Default Costs. (e.g. =0.022 or =C12*1.1).						
GasChlorine	$ 0.24	$ 0.10			$0.34	$0.14	$0.17
Sodium Hypo Bulk	$ 0.34	$ 0.21		0.3	$0.49	$0.43	$0.46
Sodium Hypo Onsite	$ 0.52	$ 0.16		0.15	$0.74	$0.21	$0.30

Assuming the O&M cost category represents a 30% weighting and the implementation category represents a 70% weighting (as show below) the model output can be revised to reflect updated recommendations by clicking the calculate button or the update button on the D-Disinfection AOP Sheet.

Capital Costs	0%	Performance	0%	Calculate
O&M Costs	30%	Implemention	70%	
Life Cycle Costs	0%			

Under these conditions, the technology ranking is shown below (D-Disinfection AOP Sheet), with onsite generation of sodium hypochlorite moving ahead of bulk sodium hypochlorite in the ranking matrix.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
UV	85.7	39.2	52.3	47.9	100.0	100.0
Sodium Hypo Onsite	82.1	45.6	63.7	57.5	63.2	90.0
Sodium Hypo Bulk	77.1	69.7	31.8	37.4	57.9	96.6
Gas Chlorine	76.3	100.0	100.0	100.0	63.2	66.1
Ozone+Hypo	68.9	32.7	43.6	40.0	89.5	79.8

3.8 Disclaimer

The SurpriseTree™ Wastewater Model is a customized technology assessment tool developed to assist the City of Surprise in selecting the optimum wastewater and biosolids treatment technologies for its future water reclamation facilities. It incorporates the impacts of site specific conditions on technology selection, wastewater engineering principles and design considerations, and the City and developer's agreed upon preferences for a variety of selection criteria. It allows City staff to perform quick internal assessments for planning purpose and generate site specific reports, which can be given to developers and designers to expedite the planning and implementation and assist in ensuring minimum criteria are met.

While the model is designed to be a comprehensive assessment tool, the City may encounter specific situations in new SPAs which are not addressed in the model. However, the model was developed to serve as a “living document” - fully customizable and easy to modify to accommodate these new challenges. As the City continues to use this tool and adjust the scores, costs, weighting factors, etc., to meet current conditions, the model will be better “calibrated” to meet the City’s goals and will continue serve as an excellent platform to accumulate the City’s institutional knowledge and policies.

The costs included in the SurpriseTree™ Wastewater Model are relative costs for comparing the technology options in the same treatment categories. They are NOT intended to be used for budget planning, design, or construction.

REVISION ADDENDUM

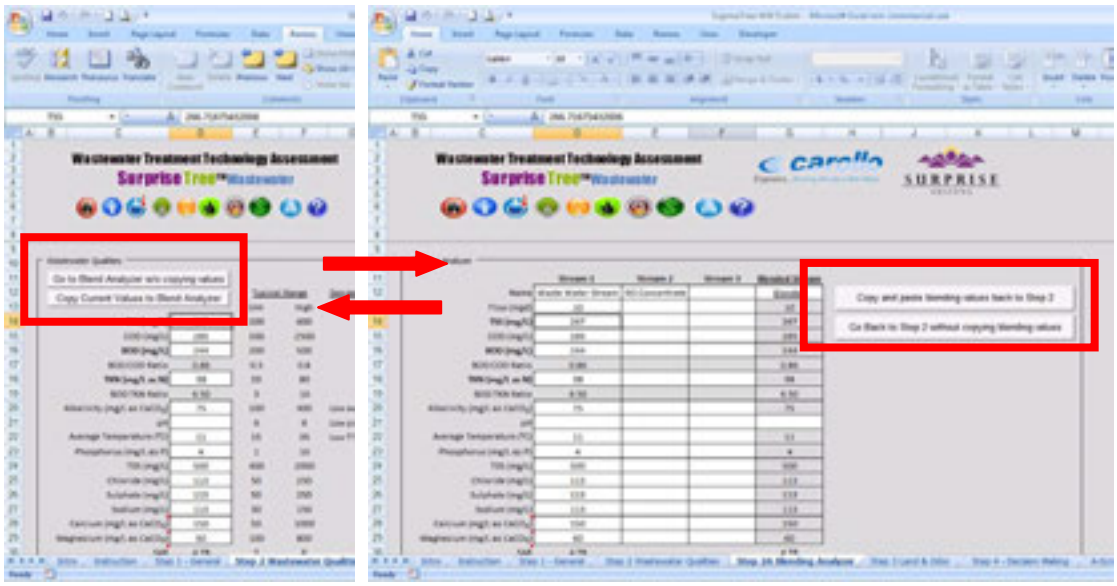
This addendum summarizes the major revisions made to SurpriseTree™ Wastewater model after the final project meeting with respect to two main model features: (1) blending analyzer and (2) algorithms associated with the disinfection and THM reduction. The revisions are included in Version 5.0 of the model.

BLENDING ANALYZER

A feature was added to allow users to conduct blending analysis and consider the impacts on wastewater characteristics of discharging specific wastewater streams (such as RO concentrate from a small desalination facility) into sewer and the potential implications on treatment technology selection.

On Step 2 Wastewater Qualities, click on the "Go to Blend Analyzer w/o coping values" Button or the "Copy Current Values to Blend Analyzer" Button to go to the Blend Analyzer page. The user can add up to three streams by entering the name, the flow, and the water quality data of the streams. SurpriseTree™ will calculate the blended stream flow and water quality. To proceed, the user can click on the "Copy and paste blending values back to Step 2" Button or the "Go back to Step 2 without copying blending values" Button.

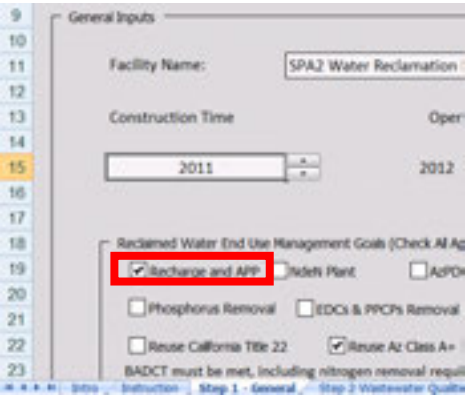
Note: To simplify the model, pH calculation of two or more blending streams is not included in this model. The user will need to determine the estimated pH for the blended streams by alternative means and enter it manually.



DISINFECTION AND THM ALGORITHMS

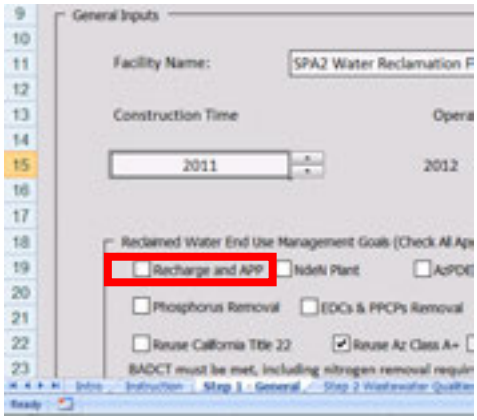
Based on the discussion at the final project meeting, the SurpriseTree™ recommendations regarding disinfection technologies and THM mitigation were revised to consider THM mitigation as a requirement instead of an option.

On the Train Generator sheet, when “UV is preferred” is selected, sodium hypochlorite (onsite or bulk) is not recommended as primary disinfectant in the SurpriseTree™ model. However, when UV is selected, sodium hypochlorite is still needed for secondary disinfection and maintenance uses (see design notes section).

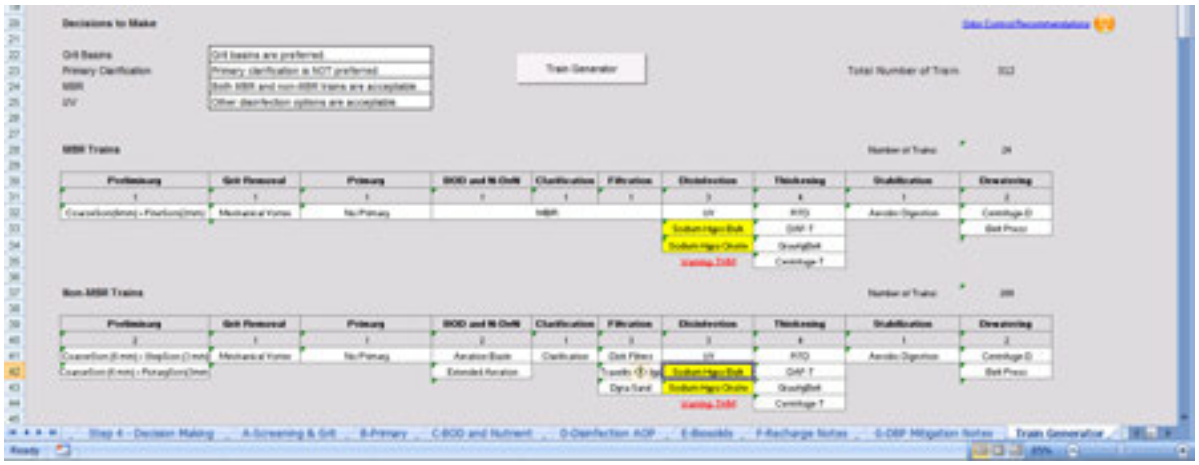


When the “Recharge and APP” box on “Step 1 - General” is checked, and the option “Other disinfection options are accepted” is selected on the Train Generator page, SurpriseTree™ will allow sodium hypochlorite bulk or onsite as a primary disinfectant for an MBR train. However, these cells are highlighted in yellow as a warning. A link to the “DBP mitigation notes” sheet will appear, linking to more customizable discussions on this topic. This indicates that even though the MBR product water quality is better than that from conventional treatment (which may result in lower chlorine demand and provide some disinfection credits); MBR trains are not immune to THM compliance problems. Measures to minimize THM formation are required, including conducting site-specific studies, or implementing aeration, coagulation, or other means that are demonstrated to be effective through testing.

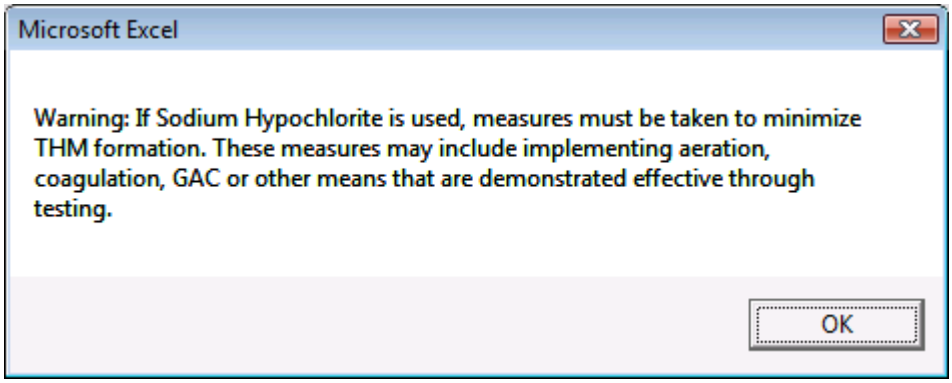
For conventional technologies (aeration basin or extended aeration with tertiary filtration other than membrane filtration), sodium hypochlorite (bulk or onsite) is NOT allowed under such conditions, unless a site specific study can prove that THM compliance is not expected to be an issue.



When the “Recharge and APP” box on “Step 1 - General” is NOT checked, and the option “Other disinfection options are accepted” is selected on the Train Generator page, SurpriseTree™ will allow sodium hypochlorite bulk or onsite as a primary disinfectant for both MBR and conventional trains. However, these cells are highlighted in yellow as a warning. A link to the “DBP mitigation notes” sheet will appear, linking to more customizable discussions on this topic. Measures to minimize THM formation are required, including conducting site-specific studies, or implementing aeration, coagulation, or other means that are demonstrated to be effective through testing.

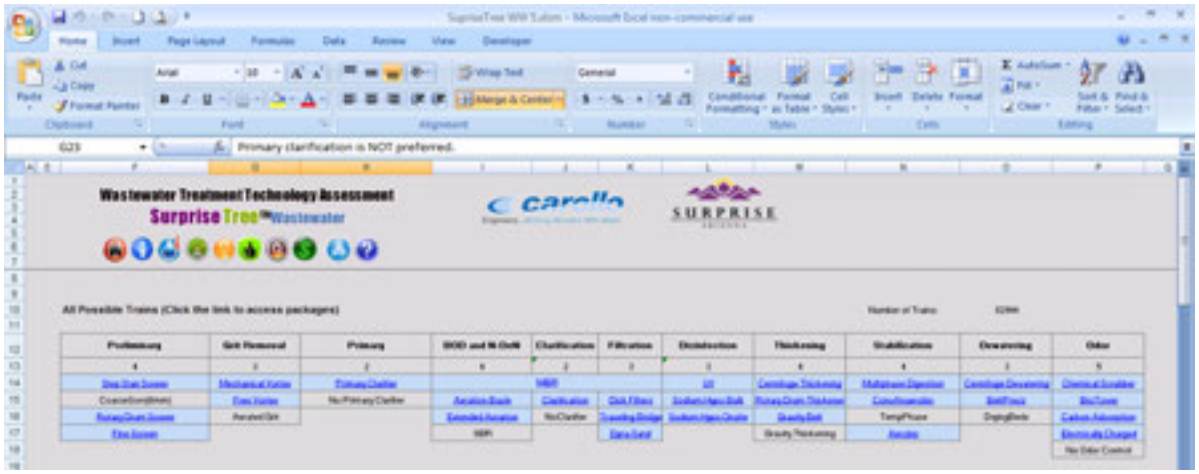


In addition, warning messages like the one shown below will pop up to warn the user regarding the importance of and requirement for THM mitigation.

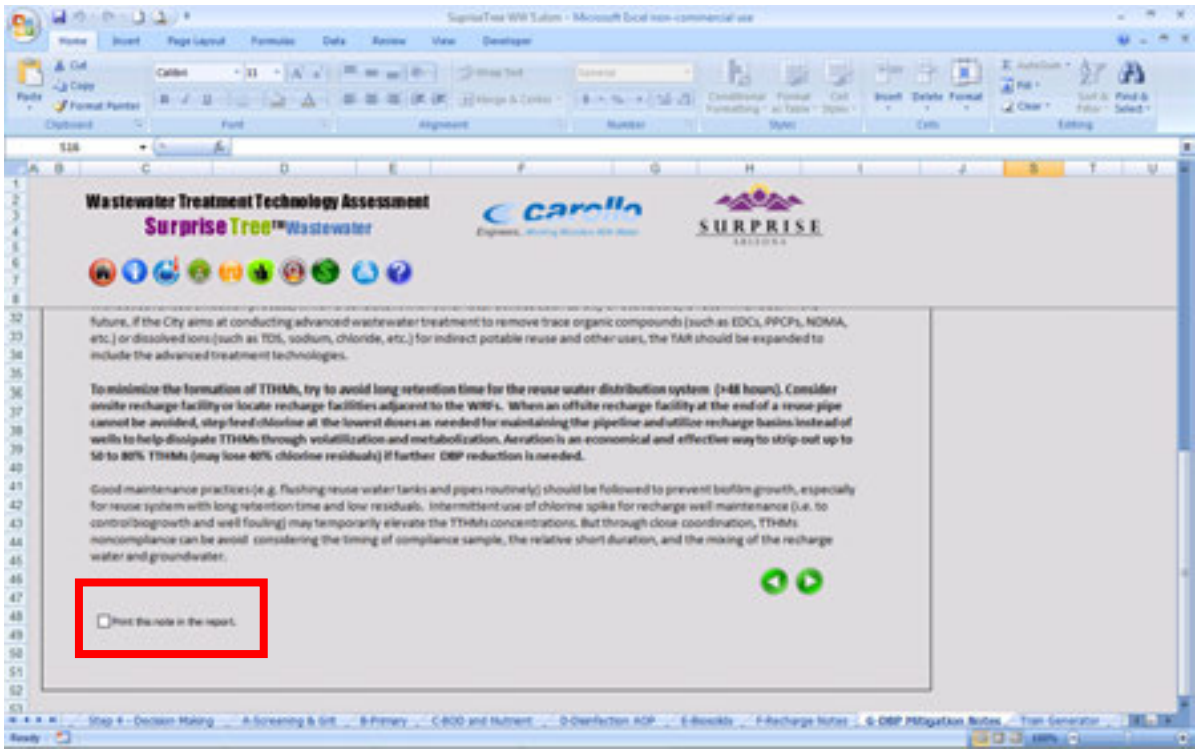


OTHER MODIFICATIONS

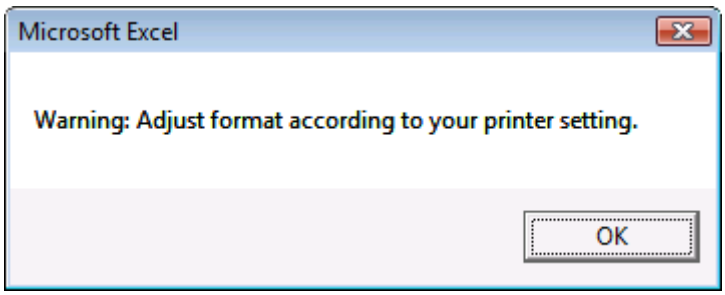
Links to implementation packages were added to 28 treatment technologies. Clicking on the links in SurpriseTree™ will lead the user to a summary of the basis of design, process flow diagram, and design considerations associated with these technologies.



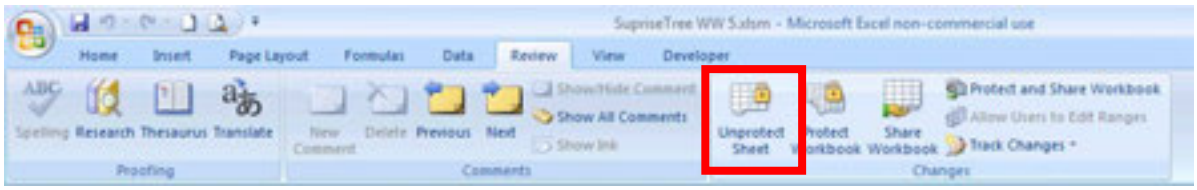
The user can include additional considerations, recommendations, and City policies easily through the Note Pages. The user can delete or edit the notes, as appropriate. These notes can be included or excluded in the final report by using the check boxes located at the end of the note sheets.



The user should adjust the format of the report page (and other pages if necessary) based on the local computer and printer setting prior to generating a final report by clicking on the Printer button. A reminder message will pop up.



The City Users can unprotect the spreadsheet to make edits and format adjustments by clicking on Unprotect Sheet on the Review tool bar. The default password is left blank. After making adjustments, it is recommended the user protect the sheet again to avoid unintentional edits of the program codes.



SURPRISETREE™ WASTEWATER MODEL REPORT

Watsewater Treatment Technology Assessment
Surprise Tree™ Wastewater

Date: 11/15/2010 14:06

General Information

Facility Name: SPA2 Water Reclamation Facility
Construction Time: 2015
Location: Surprise, AZ (RS Means 300-City Location Factor = 0.89)
Interest Rate: 7% Inflation Rate: 6% Life Cycle Length: 20 yrs

Capacity and Land Availability

Facility Size at Phase I:	3 mgd	Peaking Factor, AAD:ADMM	1.35
Facility Size at Buildout:	12 mgd	Peaking Factor, PHF:AAD	3.1

Total Land Available: 28 acres
Usable Land Fraction: 0.6 (discount the land required for setbacks)
Usable Land: 16.8 acres or 1.4 acres per mgd
This facility is categorized as: Moderate Land Availability
Sufficient land may not be available for extended aeration and primary clarification. Check site layouts to confirm.
Site Condition: Existing SBR facility
PHF:AAD peaking factor is 4. If MBR is selected, equalization is required. If conventional treatment is selected, equalization is required.

Water Quality

	Input	Typical Range Low	Typical Range High	Design Considerations / Warning Messages
TSS (mg/L)	650	200	600	High TSS. Consider primary clarifiers or other pretreatment.
COD (mg/L)	400	200	2500	
BOD (mg/L)	325	200	500	
BOD:COD Ratio	0.81	0.3	0.8	
TKN (mg/L as N)	60	20	80	
BOD:TKN Ratio	5.42	3	10	
Alkalinty (mg/L as CaCO3)	50	100	400	Low alkalinity! May require addition of lime or magnesium hydroxide.
pH	7	6	9	
Average Temperature (°C)	15	15	35	
Phosphorus (mg/L as P)	4	1	10	
TDS (mg/L)	600	400	2000	
Chloride (mg/L)	150	50	250	
Sulphate (mg/L)	150	50	250	
Sodium (mg/L)	150	30	150	
Calcium (mg/L as CaCO3)	300	50	1000	
Magnesium (mg/L as CaCO3)	100	100	800	
SAR	4.61	2	6	

Design Considerations on Wastewater Strength: Water conservation fixtures could reduce the flow by up to 10%, resulting in increased wastewater strength.

End Use and Regulations

The end use / disposal of the effluent drives the disinfection technology selection.

Surface Water Discharge	Recharge	Class A+	Class B	Class C	BADCT
NO	Yes	Yes	NO	NO	Yes

Odor Control

Moderate Odor Control Level: Full odor and noise control required.
Drying beds are not acceptable. Oxidition ditch is not recommended considering the need for covers for full odor control.

Use liquid chemical scrubber OR biotowers. Use carbon scrubber for polishing if necessary. Consider electrically charged ions addition techonology for headworks.

BOD and Nutrient

Land Availability: Sufficient land may not be available for extended aeration and primary clarification. Check site layouts to confirm.
""
Existing Site Conditions: SBR is not economical for large facility. Consider decommission existing SBR.
Odor ControlRequires cover for aeration tanks. Extended aeration is not recommended considering the expense to cover large basins.
Nutrient Removal: This facility is a NdeN plant. The biological process shall be designed to allow nitrification and denitrification.
Phosphorus removal is not expected to be an issue for this facility.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
Extended Aeration	87.4	100.0	100.0	100.0	69.1	87.4
Aeration Basin	98.0	70.5	49.3	50.8	69.1	98.0
MBR	100.0	58.7	37.4	38.7	100.0	100.0
Trickling Filters	82.0	88.1	77.1	78.0	56.4	82.0

Clarification

If MBR is selected, no secondary clarification is necessary.

Filtration

If MBR is selected, no filtration process is necessary.
Microfiltration/ultrafiltration can be considered for replacing existing filtration facilities.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
Disk Filters	100.0	93.6	93.6	93.6	100.0	100.0
Dyna Sand	92.4	100.0	100.0	100.0	89.7	92.4
Traveling Bridge	92.9	90.9	90.9	90.9	94.9	92.9
Conv Sand	88.2	100.0	100.0	100.0	94.9	88.2
MFUF	85.0	41.9	25.2	27.4	120.5	85.0

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
UV	100.0	39.2	52.3	47.9	100.0	100.0
Sodium Hypo Bulk	96.6	69.7	46.4	51.1	57.9	96.6
Sodium Hypo Onsite	90.0	45.6	60.8	55.7	63.2	90.0
Gas Chlorine	65.3	100.0	100.0	100.0	63.2	65.3
Ozone+Hypo	79.8	32.7	43.6	40.0	89.5	79.8

If sodium hypochlorite is selected in lieu of UV, large chlorine contact basins are often required to meet the CT. This can be expensive and require a large land area.
If UV is selected, sodium hypochlorite is needed to provide residual chlorine. Bulk is recommended in lieu of onsite generated sodium hypo. based on capital costs.
Open channel UV is recommended for non-MBR train. Pressurized UV is recommended for MBR train.
For MBR train, the selection of UV will provide multiple barriers and better water quality.
This facility is planned for recharge or has water quality goals for emerging contaminants such as EDCs and PPCPs.
Selection of UV is recommended for its compatibility with Advanced Oxidation Process (AOP).
Consider advanced water treatment such as RO and AOP such as UV / H2O2, ozone / H2O2 or UV / TiO2 or other AOP technologies.

Thickening

The biosolids management goal is as follows:

Dewatering and Land Fill	Class A Biosolids	Class B Biosolids	Future Class A Biosolids
No	No	No	No

Thickening may not be required if solids stabilization is not required.
If MBR technology is selected, polymer use for DAF or other technologies may be a potential fouling concern in the recycled stream.
If grit basins are not selected, centrifuge thickening is not recommended considering the abrasive nature of the biosolids without grit removal.
If multiphase digestion is selected, centrifuge thickening is preferred to provide the required high solids concentrations.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
Gravity Thickening	95.7	100.0	100.0	100.0	57.1	95.7
DAF Thickening	94.6	80.0	50.0	54.7	0.6	0.5
Gravity Belt	96.5	66.7	41.7	45.6	0.8	0.6
RTD	97.2	50.0	25.0	28.3	1.0	1.0
Centrifuge Thickening	100.0	40.0	12.5	14.9	1.3	2.1

Stabilization

For landfilling sludge, stabilization is not required.
There is land available for primary clarification and anaerobic digestion facilities.

If extended aeration is selected, aerobic digestion is recommended. The associated digester size can be reduced due to the extended aeration process.
If extended aeration is selected, primary clarification and anaerobic digestion are not recommended.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
Multiphase	100.0	62.7	58.5	58.9	100.0	100.0
Lagoon	77.9	100.0	100.0	100.0	14.3	77.9
ConvAnaerobic	89.3	75.2	70.2	70.6	71.4	89.3
TempPhase	85.3	54.5	47.7	48.3	85.7	85.3
Aerboic	79.8	80.0	56.0	57.7	42.9	79.8
ATAD2	77.4	48.0	33.6	34.6	57.1	77.4

Dewatering

If grit basins are not selected, centrifuge dewatering is not recommended considering the abrasive nature of the biosolids without grit removal.

	Overall Score	Capital Score	O&M Score	Life Cycle Score	Performance Score	Implementation Score
DryingBeds	93.4	100.0	100.0	100.0	62.5	93.4
BeltPress	100.0	37.5	46.9	46.1	87.5	100.0
Centrifuge_Dewatering	100.0	30.0	37.5	36.9	100.0	100.0

Preferences

Grit removal is NOT required.
Primary clarification is NOT preferred.
Both MBR and non-MBR trains are acceptable.

Other disinfection options are acceptable.

Recommendations

Total Number of Trains: 21

MBR Trains (No Biosolids) Number of Trains: 3

Preliminary	Grit Removal	Primary	BOD and N-DeN	Clarification	Filtration	Disinfection	Thickening	Stabilization	Dewatering
1	1	1	1	1	1	3	1	1	1
CoarseScrn(6mm) + FineScrn(2mm)	No grit removal	No Primary	MBR			UV	-	Solids Dewatering to Landfill	Belt Press
						Sodium Hypo Bulk			
						Sodium Hypo Onsite			

Non-MBR Trains (No Biosolids) Number of Trains: 18

Preliminary	Grit Removal	Primary	BOD and N-DeN	Clarification	Filtration	Disinfection	Thickening	Stabilization	Dewatering
2	1	1	1	1	3	3	1	1	1
CoarseScrn (6 mm) + StepScrn (3 mm)	No grit removal	No Primary	Aeration Basin	Clarification	Disk Filters	UV	-	Solids Dewatering to Landfill	Belt Press
CoarseScrn (6 mm) + RotaryScrn(3mm)					Dyna Sand	Sodium Hypo Bulk			
					Traveling Bridge	Sodium Hypo Onsite			

Design Considerations

(1) BADCT must be met, including nitrogen removal requirements.
(2) Class A+ effluent. Disinfection shall be designed to meet fecal coliform 23 cfu/100 mL single sample maximum and non-detect four out of last seven daily samples.
(3) PHF:AAD peaking factor is 4. If MBR is selected, equalization is required. If conventional treatment is selected, equalization is required.
(4) The facility size may not be economical for extended aeration.
(5) The facility size may not be economical for SBR.
(6) This is a large facility. Recommend coarse (6 mm) followed by fine screens (3mm).
(7) Grit removal is not selected. The biological treatment trains shall be designed with redundancy to allow one train to be taken out of service for grit removal.
(8) Grit removal is required if anaerobic digestion or centrifuge thickening or dewatering are preferred.
(9) This is a large facility. Recommend mechanical vortex grit removal in lieu of free vortex.
(10) The influent BOD:TKN ratio is 5.42 mg/L.This is a reasonable ratio.
(11) The influent TSS is 650 mg/L.High TSS! Primary Clarification is recommended.
(12) If MBR is selected, coarse screening (6 mm) followed by fine screening (2mm) with redundancy must be provided. Consult Engineers and MBR Manufacturer.
(13) Design Considerations on Wastewater Strength: Water conservation fixtures could reduce the flow by up to 10%, resulting in increased wastewater strength.
(14) Phosphorus removal is not expected to be an issue for this facility.
(15) Requires covers for aeration tanks. Extended aeration is not recommended considering the expense to cover large basins.
(16) This facility is a NdeN plant. The biological process shall be designed to allow nitrification and denitrification.
(17) If MBR is selected, no secondary clarification is necessary.
(18) If MBR is selected, no filtration process is necessary.
(19) To meet Class A+ quality, the facility shall be capabile of feeding filter aid polymer.
(20) Microfiltration/ultrafiltration can be considered for replacing existing filtration facilities.
(21) If sodium hypochlorite is selected in lieu of UV, large chlorine contact basins are often required to meet the CT. This can be expensive and require a large land area.
(22) If UV is selected, sodium hypochlorite (bulk) is required to provide residual chlorine.
(23) Open channel UV is recommended for non-MBR trains. Pressurized UV is recommended for MBR trains.
(24) For MBR trains, the selection of UV will provide multiple barriers and better water quality.
(25) This facility is planned for recharge or has water quality goals for emerging contaminants such as EDCs and PPCPs.
(26) Selection of UV is recommended for it's compatibility with Advanced Oxidation Process (AOP).
(27) Selection of ozone or other AOP technologies is recommended for further evaluation if EDCs and PPCPs are of a concern.
(28) No thickening is required due to no need of stabilization.
(29) If MBR is selected, the use of polymer associated with DAF might be a concern, considering the potential membrane fouling.
(30) If anaerobic digestion or advanced anaerobic digestion processes are selected, primary clarifications shall be selected.
(31) If multiphase digestion is selected, centrifuge thickening is preferred to provide required high solids concentration.
(32) No thickening and no stabilization is required.
(33) There is land available for primary clarification and anaerobic digestion facilities.
(34) If extended aeration is selected, aerobic digestion is recommended and can be smaller due to the extended aeration.
(35) If extended aeration is selected, primary clarification and anaerobic digestion are not recommended.
(36) It is recommended that the user complete a facility specific master plan, conceptual design or preliminary design to further address land availability issues.