



# Converting Sioux City WWTP to Modified Ludzak-Ettinger Process (MLE)

**AWWA & KWEA Joint Annual Meeting**



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# Presentation Outline

- **Project Background**
- **Hydraulic Considerations**
- **Nitrogen Removal Basics**
- **MLE Conversion Design**
- **Questions**



# Project Background

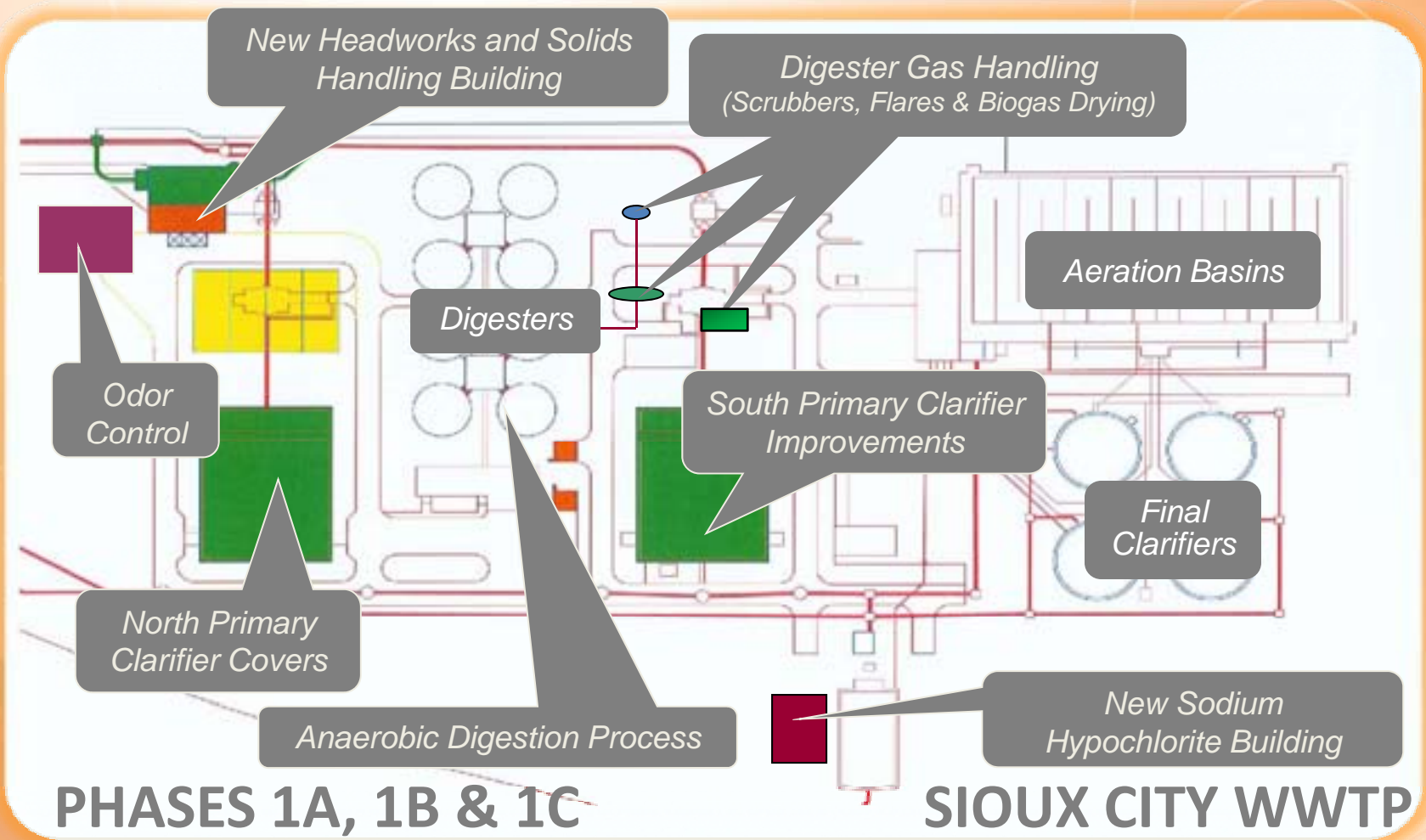
- City Owns One Regional WWTP
  - 11 Pump Stations
  - 320 Miles of Sewers
- WWTP Highly Visible
- Original WWTP Constructed in 1961
- Major Upgrade in 1978
- Since Then, Only Minor Upgrades and Aging Infrastructure



# Project Background

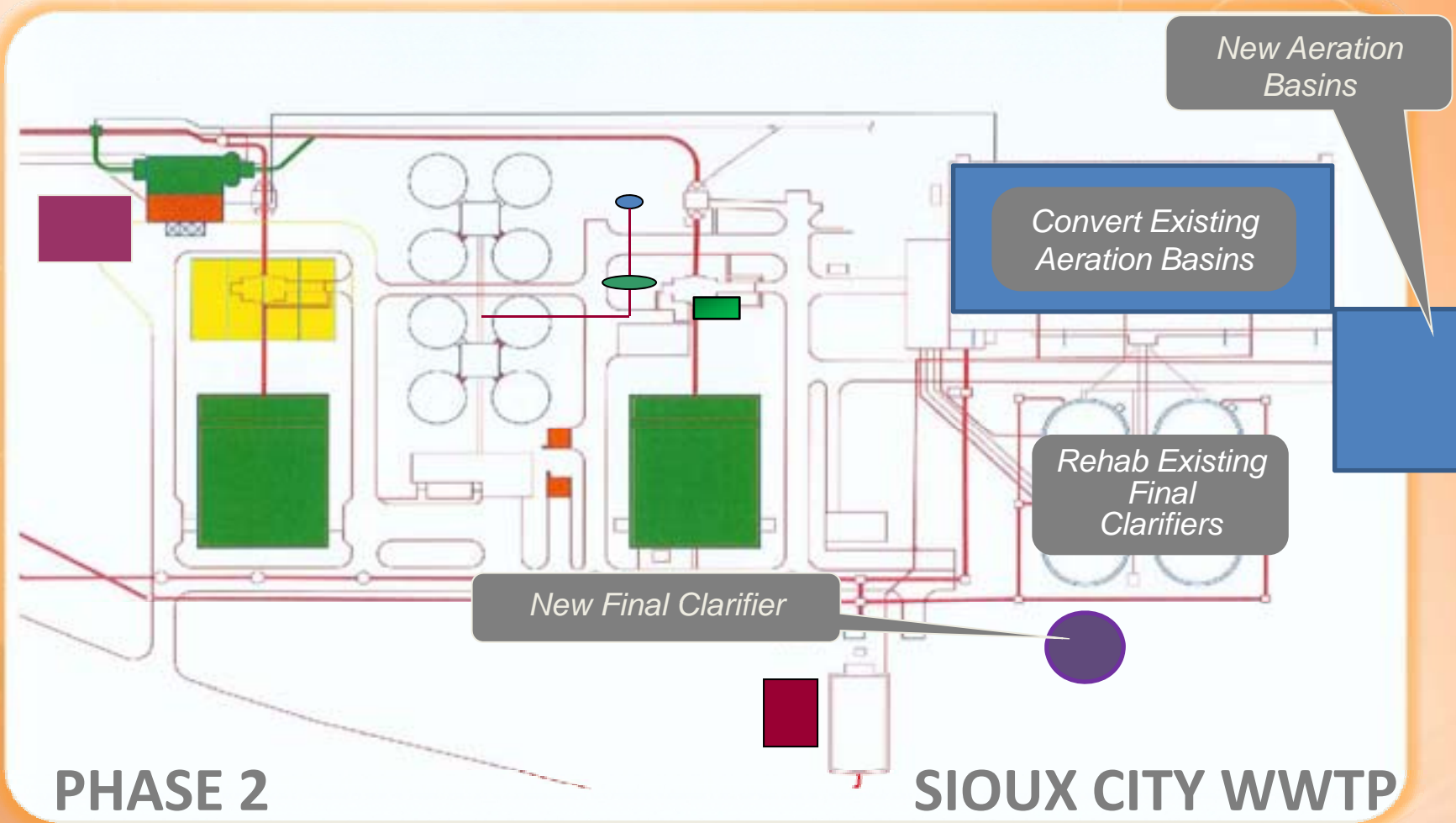
- **Unique Features of Sioux City WWTP Project**
  - *Design / Operate: American Water / CDM Team*
  - *Significant high strength industrial flow*
    - *BOD >600 mg/L and TKN >100 mg/L*
  - *Odor Control Guarantee*
  - *Project Phasing: 1A, 1B/1C, 2*

# Phases 1A, 1B & 1C Project Treatment Processes *(anticipated completion Fall 2009)*



# Phase 2 Project Treatment Processes

*(anticipated completion Spring 2011)*



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# Hydraulic Considerations

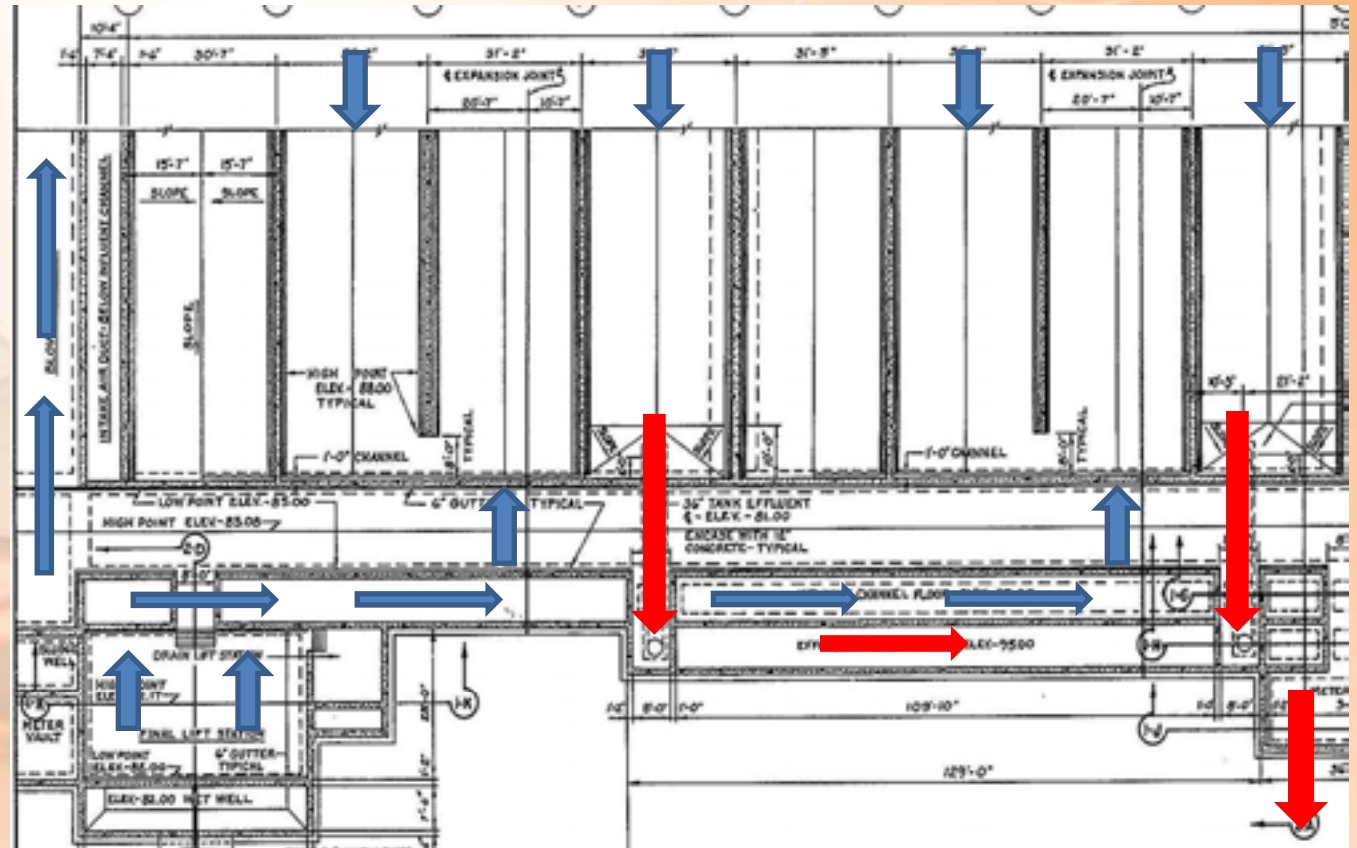
- Design Flows to Sioux City WWTP
  - *Significant increase in peak flow capacity*

	Existing Flows (MGD)	Design Flows (MGD)	Difference
Average Daily (ADW)	12.0	16.0	33% increase
Maximum Monthly (AWW)	N/A	17.6	---
Peak (PHWW)	28.0	56.5	102% increase

- IDNR Requirements
  - *Minimum 18-inch freeboard at peak flows*
  - *No weir submergence at peak flows*

# Hydraulic Considerations (cont.)

- Retrofitting Existing Structures
  - *Converting 4 existing step feed Aeration Basins to MLE*
  - *Avoid adding wall height*
- Proper Flow Splitting
  - *Replace throttling valves that split flow to Final Clarifiers*



# Hydraulic Profile Development

- Utilized Visual Hydraulics Software
  - *Graphical interactive interface*
  - *Allows user to build profiles by components*
    - *Pipes, channels, fittings, junctions*
    - *Weirs, gates, orifices, flumes*
    - *Pumps, screens, filters, tank launders*
  - *Enter main forward flow, plus return flows*
  - *Uses standard hydraulic equations*
    - *Hazen-Williams, Manning's, Darcy-Weisbach*
    - *Critical depth step method*
    - *Weir, orifice, other equations*
  - *Standard fitting minor loss table - customizable*

# Visual Hydraulics Software

File Profile Summaries Mode Options Help

Updated Hydraulic Profile

Section Description	Water Surface Elevation	Operating Condition
Starting water surface elevation-100-yr MD River Stage	85.61	Normal
River Outfall to MH 43	86.44	Normal
Manhole 43	86.53	Normal
MH 43 to MH 44	87.05	Normal
Manhole 44	87.74	Normal
MH 44 to MH 45	89.11	Normal
Manhole 45	89.2	Normal
MH 45 to Chlorine Contact Basin	90.49	Normal
Chlorine Contact Effluent Weir	91.82	Normal
Chlorine Contact Channel	91.84	Normal
Entrance to Contact Channel	91.95	Normal
Chlorine Contact Basin Splitter	91.94	Normal
Chlorine Contact Basin to MH 31	92.21	Normal
Manhole 31	92.25	Normal
MH 31 to MH 30	92.69	Normal
Manhole 30	92.78	Normal
MH 30 to MH 29 Sewer	94.83	Normal
Manhole 29	94.91	Normal
MH 29 to Final Clarifier #5	95.19	Normal
Final Clarifier #5 Effluent Launder	99.47	Normal
Final Clarifier #5 V-Notch Weirs	100.77	Normal
Final Clarifier #5 to North Splitter Structure	101.76	Normal
North Splitter Structure Weir	103.14	Normal
N Splitter Structure to AB Effluent Channel Pools	103.23	Normal
AB Effluent Channel	103.24	Normal
AB Effluent Channel to AB #3	103.57	Normal
Aeration Basin #3	103.57	Normal
AB #3 to AB Influent Channel	103.78	Normal
AB Influent Channel	103.79	Normal
Pump Discharge Slide Gate	104.2	Normal
Primary Eff PS Discharge Pipe	109.22	Normal
Primary Effluent Pumps	89.25	Normal
Primary Eff PS Suction Pipe	91.42	Normal
Primary Eff PS to MH 42	91.45	Normal
MH 42 Sluice Gate	91.86	Normal
Manhole 42	91.91	Normal
MH 42 to MH 23	92.31	Normal
MH 23 Sluice Gate	92.72	Normal
Manhole 23	92.81	Normal
MH 23 to MH 22	93.25	Normal
Manhole 22	93.29	Normal
MH 22 to MH 14	93.7	Normal
Manhole 14	93.74	Normal

Current Forward Flow = 56.54 mgd  
 Current Return I Flow = 15.98 mgd  
 Current Return II Flow = mgd  
 Current Return III Flow = mgd

Current Hydraulic Profile Diagram

94.83 94.91 95.19 99.47 100.77 101.76 103.14 103.23 103.24 103.57

MH 30 to MH 29 Sewer Manhole 29 MH 29 to Final Clarifier #5 Final Clarifier #5 Effluent Launder Final Clarifier #5 V-Notch Weirs Final Clarifier #5 to North Splitter Structure North Splitter Structure Weir N Splitter Structure to AB Effluent Channel Pools AB Effluent Channel AB Effluent Channel to AB #3

Pipe characteristics - River Outfall to MH 43

River Outfall to MH 43

General Fittings Flows Diagram Summary

Pipe/conduit shape Conduit diagram

Circular  
 Rectangu  
 Other

Pipe size and len

Diameter

Width, if re

Length o

File

Pipe Summary Diagram

Head loss graph - River Outfall to MH 43

Headloss Graph

Flow (mgd)	Headloss (ft)
11.3	0.0
22.6	0.1
33.9	0.3
45.2	0.5
56.5	0.8
67.8	1.1
79.2	1.5
90.5	2.0
101.8	2.5
113.1	3.5

S. = 85.68

IAMS EQUATION:  
 solids loss  
 $(\text{Flow}^{2.63})^{1.85 * 152} + 0 = 0.02 \text{ ft.}$

ic feet per second (cfs)

Graph flow increment

**Change current graph flow increment**

Current flow increment:  mgd

Current graph flow range (mgd):  to

Update Graph Close Help

# Software Benefits/Limitations

- **Benefits**

- *Easy to change parameters, add components – automatic profile update*
- *Operating condition status: normal, submerged, etc.*
- *Analyze flow splits & taking units off-line*
- *Eliminates spreadsheet incorrect cell references*
- *Various graphs, reports available*
- *Consistency of results between projects*

- **Limitations**

- *Static hydraulic condition, not a dynamic model*
- *Open channel versus pressure pipe – must manually check conditions*

# Hydraulic Solutions

- **New Splitter Structures**
  - *Attached to Aeration Basin effluent channel*
  - *36-inch orifices to eliminate pipe losses*
  - *20-foot wide weir gates*
- **Aeration Basin Retrofit**
  - *Designed anoxic zone baffles to limit headloss*
  - *Increased influent pipe diameter*
- **IDNR Variance**
  - *Freeboard at peak flows:*
    - *14.5 inches in Aeration Basin Influent Channel*
    - *11/17 inches in Aeration Basins (internal/external walls)*

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# Nitrogen Removal Basics

## Ammonia Removal (*Nitrification*) – Required

- Ammonia compliance schedule August 2011
  - *Monthly Average 26 to 92 mg/L*
  - *Daily Maximum 53 to 97 mg/L*
- Phase 2 Design ~ 5 mg/L Effluent Ammonia-N

## Nitrogen Removal (*Denitrification*) – Not Required

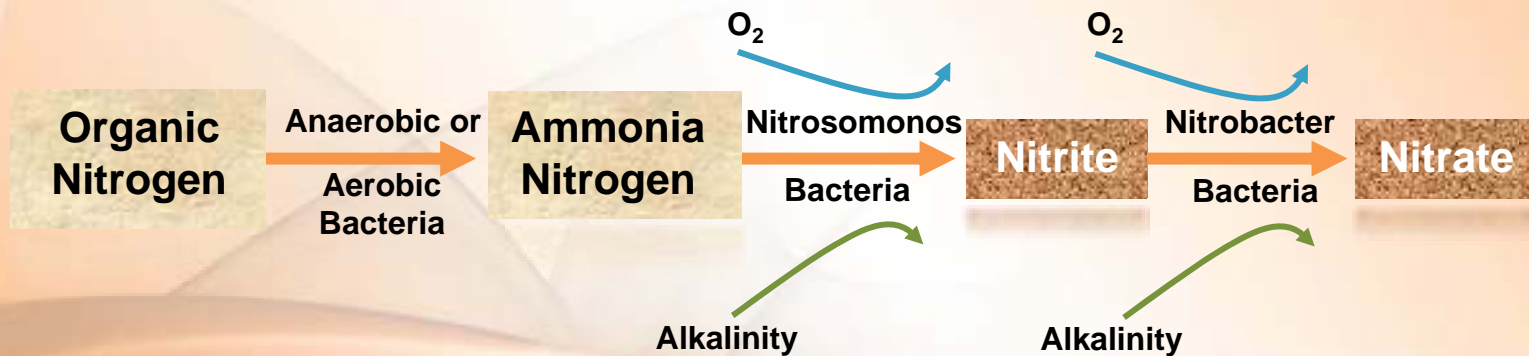
- Benefits to Environment
- Benefits to Plant Operation

# Why Remove Nitrogen?

- Ammonia is highly toxic to aquatic life
- Ammonia exerts high oxygen demand in surface waters
- Ammonia increases chlorine demand
- Nitrates interfere with biological P removal
- Nitrogen stimulates growth of aquatic plants and algae

# Environmental Conditions for Biological Nitrification

Adequate oxygen and alkalinity will result in ammonia conversion to Nitrate




# Results of Nitrification

- TKN  $\longrightarrow$   $\text{NO}_3^-$  (Nitrate)
- $\text{O}_2$  demand  $\cong 4.5 \text{ mg O}_2 / \text{mg Ammonia}$
- Alkalinity demand  $\cong 7.1 \text{ mg CaCO}_3 / \text{mg Ammonia}$
- Nitrification contributes little to waste biosolids
  - *BOD solids yield  $\cong 0.7 \text{ mg /mg BOD}$*
  - *Nitrifier solids yield  $\cong 0.1 - 0.15 \text{ mg /mg Ammonia}$*

# Environmental Conditions for Biological Denitrification

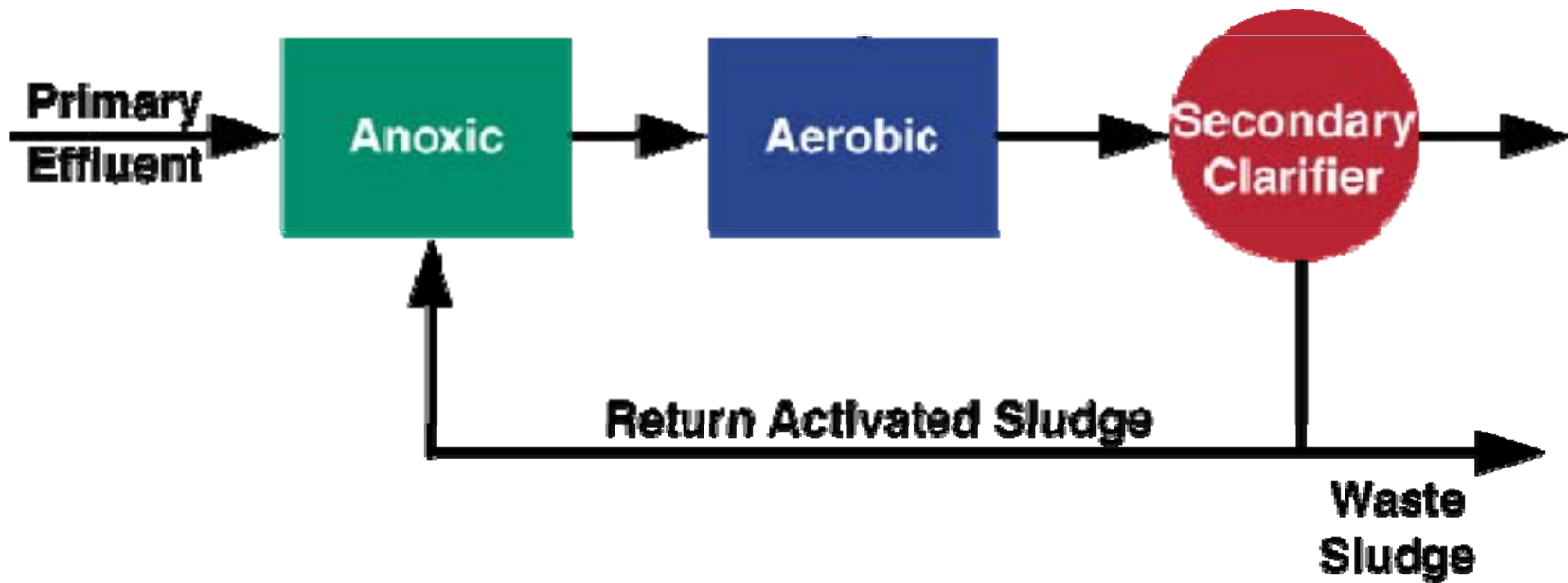
- Occurs in the absence of molecular oxygen
  - *Anoxic Zones*
- $\text{NO}_3$  used instead of  $\text{O}_2$  as an electron acceptor
- Carbon source is required for denitrification
- Anoxic contact time (2 to 4 hours)
- Mixing

# Results of Denitrification

- Nitrate  $\text{NO}_3^-$   Nitrogen Gas
- $\text{O}_2$  recovery  $\cong 2.8 \text{ mg O}_2 / \text{mg NO}_3^-$  reduced
- Alkalinity recovery  $\cong 3.0 \text{ mg CaCO}_3 / \text{mg NO}_3^-$
- Solids yield  $\cong 0.4 \text{ mg VSS} / \text{mg COD}$  removed

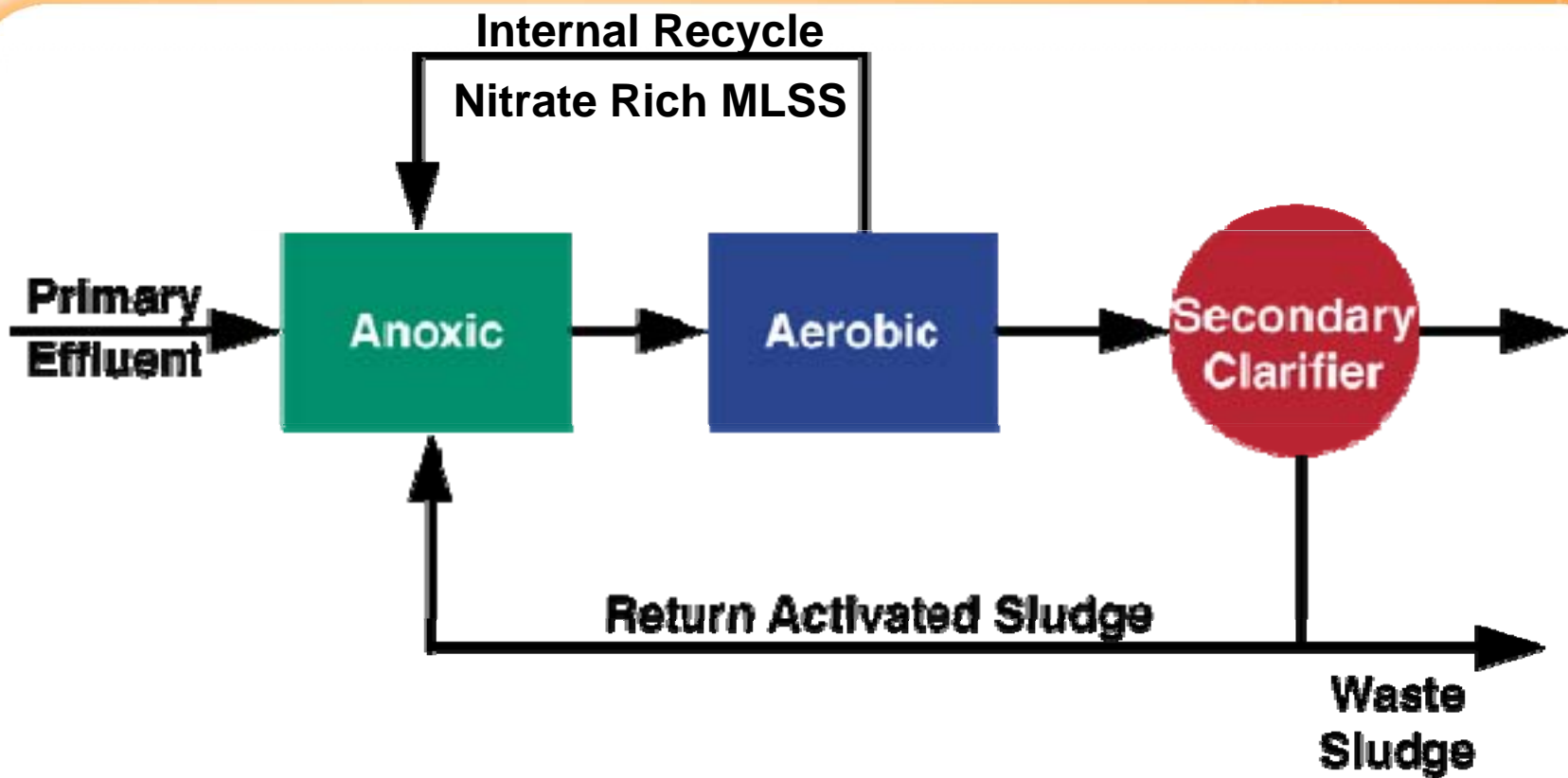
# Ludzack-Ettinger (1962)

*First pre-anoxic Biological Nutrient Removal (BNR) concept*



# Modified Ludzack-Ettinger (1973)

MLE



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# MLE Conversion Design (Phase 2)

## Secondary Treatment Facilities

- Ammonia compliance schedule August 2011
- Facility Plan Updated, 2008 (Veenstra & Kimm, Inc.)
- MLE Selected
  - *Lowest capital cost alternative*
  - *Meet ammonia scheduled effluent permit limits*
  - *Minimize future projects by meeting possible total nitrogen limits*
  - *Lower oxygen use and power cost (compared to nitrification alone)*

# Design Flows and Loadings

## FLOWS

*ADW: 16.0 MGD*

*AWW: 17.6 MGD*

*MWW: 28.7 MGD*

*PHWW: 56.5 MGD*

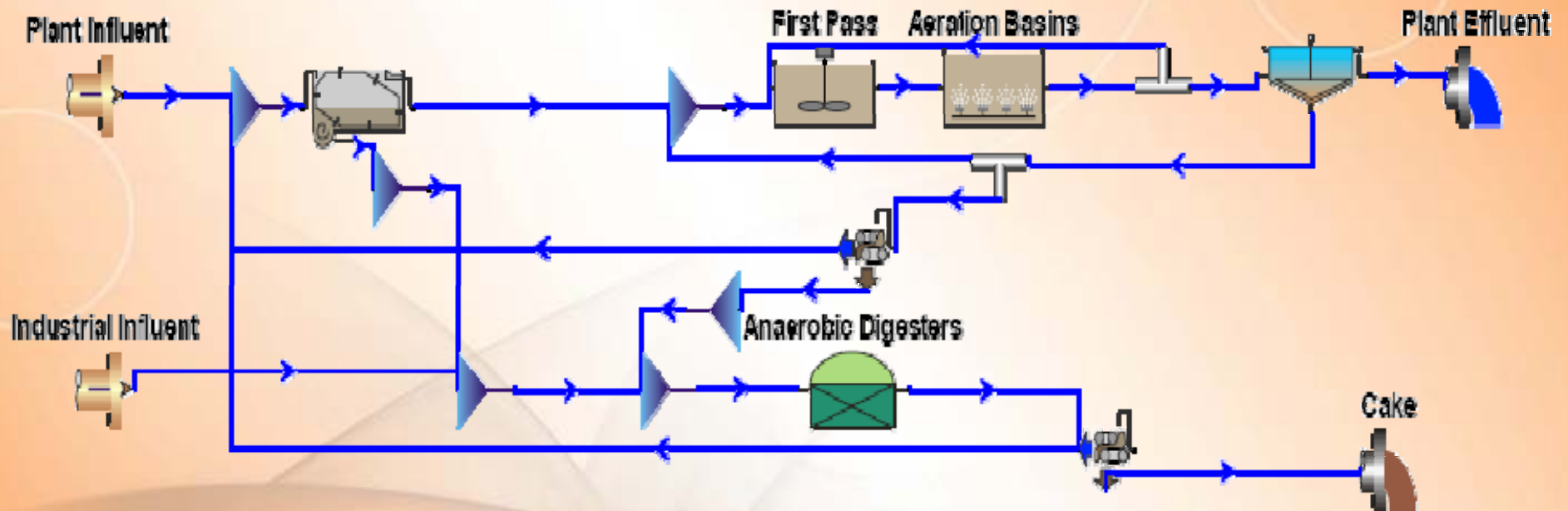
## LOADINGS

*BOD: 74,000 – 90,000 ppd  
~600 mg/L*

*TSS: 52,000 – 75,000 ppd  
~450 mg/L*

*Total Kjeldahl Nitrogen:  
10,000 – 12,400  
~ 100 mg/L*

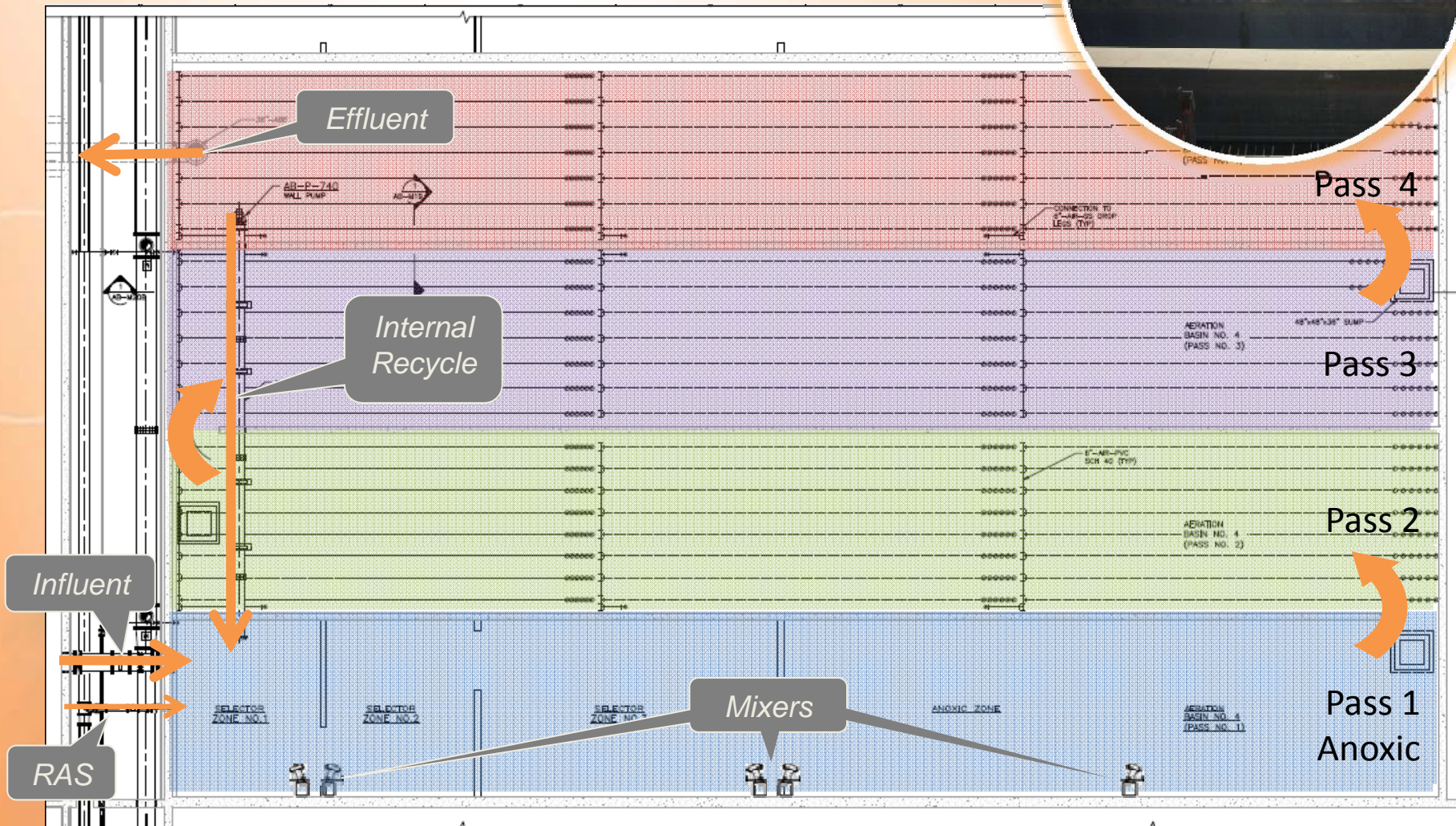
# BioWin Process Flow Chart



# BioWin Simulation Results

Flow SRT		BOD mg/L	TSS mg/L	Ammonia – N mg/L	TKN mg/L
<b>16.0 MGD</b> <b>7.8 days</b>	Influent	550	400	55	73
	Effluent	2.7	5.0	0.9	16.9
	<b>% Removal</b>	<b>99.5</b>	<b>98.8</b>	<b>98.4</b>	<b>77</b>
<b>17.6 MGD</b> <b>6.8 days</b>	Influent	690	560	73.5	98
	Effluent	2.9	5.7	1.0	22.3
	<b>% Removal</b>	<b>99.6</b>	<b>99.0</b>	<b>98.7</b>	<b>77</b>
<b>28.73 MGD</b> <b>6.8 days</b>	Influent	376	312	55.5	74
	Effluent	4.5	10.3	0.1	29.6
	<b>% Removal</b>	<b>98.8</b>	<b>96.7</b>	<b>99.7</b>	<b>60</b>

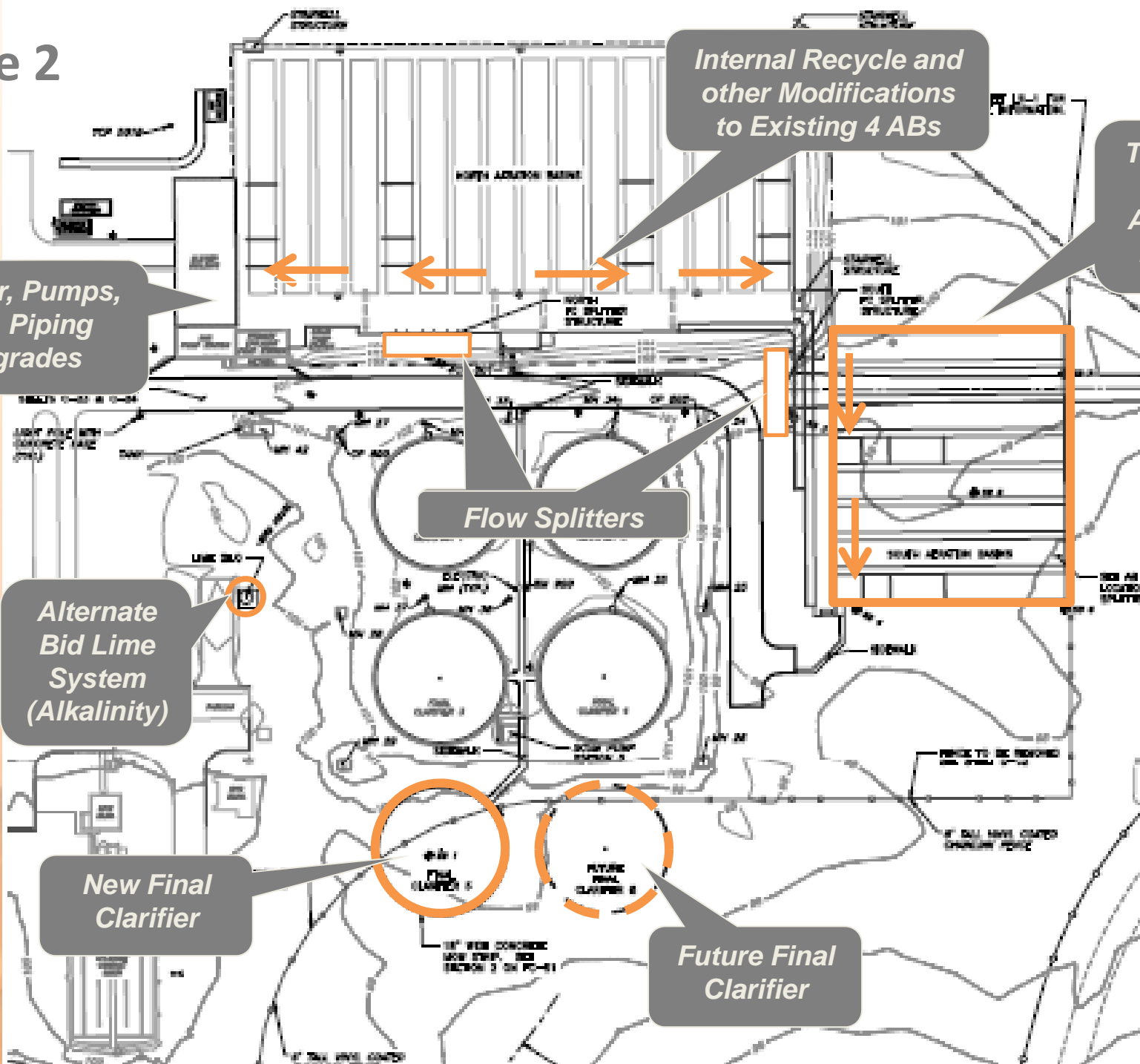
# Sioux City MLE Process Aeration Basins



# Existing Aeration Basin



# Phase 2



Blower, Pumps, and Piping Upgrades

Internal Recycle and other Modifications to Existing 4 ABs

Two New MLE Aeration Basins

Flow Splitters

Alternate Bid Lime System (Alkalinity)

New Final Clarifier

Future Final Clarifier

# Design Challenges

- Existing Facility
  - *Geometry of ABs is fixed*
  - *Hydraulic constraints*
- Construction scheduling and maintaining plant in operation during 20 month construction period
- Concurrent construction
  - *Phase 1A*
  - *Phase 1B/1C*
  - *Phase 2*

# Questions



**CDM**  
listen. think. deliver.