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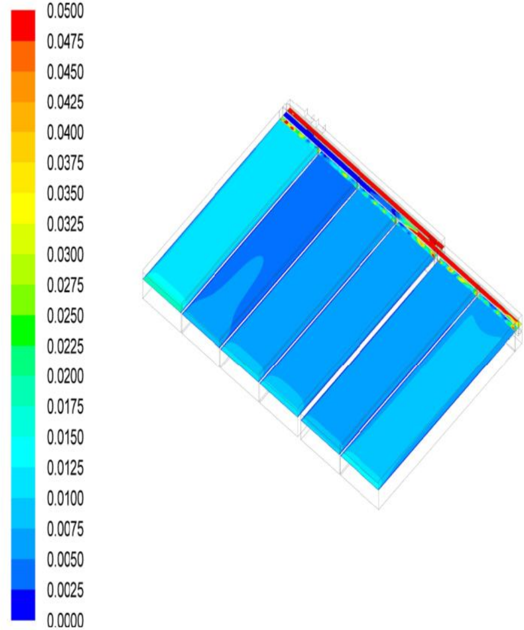
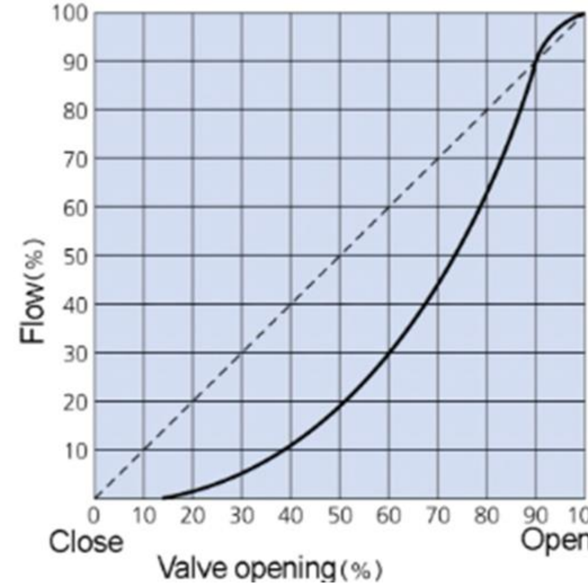




Informing Water Treatment Plant Design with Localized Hydraulic Models

Henry Ricca, PE

Agenda

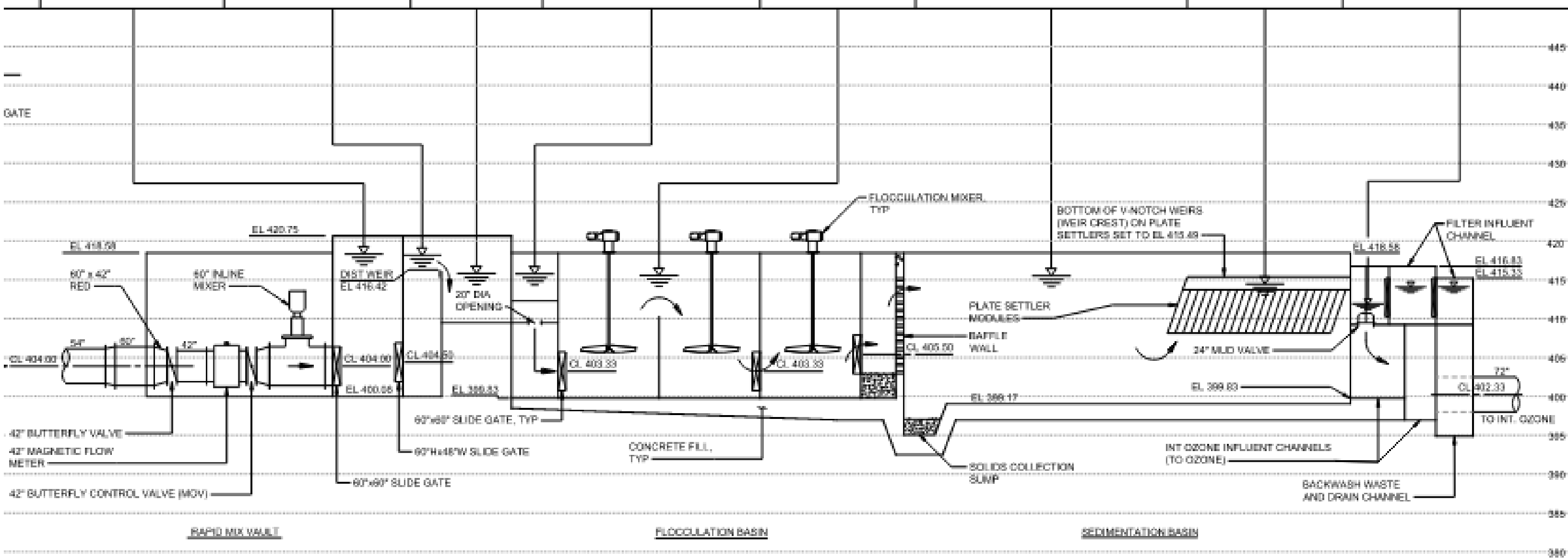
- Importance of Hydraulics in Treatment Plant Design
    - General Overview
    - Flow Distribution
- Practical Examples of Design Decisions Informed by Hydraulics
- Q&A

Importance of Hydraulics in Treatment Plant Design

What is a Hydraulic Profile?

Determine headloss as water flows through each process

Establish Hydraulic Grade Lines (HGLs) through the treatment process (water level)



	Rapid Mix Effluent Channel (FT., MSL)	Mixed Water Collection Box (FT., MSL)	Mixed Water Channel (FT., MSL)	Flocculation Influent Channel (FT., MSL)	Flocculation (FT., MSL)	Sedimentation Basin (FT., MSL)	Plate Settler Effluent Trough (FT., MSL)	Settled Water Channel (To Int. Ozone Influent Channels)
	418.7	418.5	416.1	416.0	415.7	415.6	414.4	412.0
	418.1	418.0	415.9	415.8	415.7	415.6	414.3	412.0
	418.4	418.2	415.9	415.9	415.7	415.6	414.4	412.0

Reasons for Preparing Hydraulic Profiles

- To ensure the hydraulic gradient is adequate for flow through the treatment facility
- To prevent facility overflows during peak flow events
- To establish head requirements for pump design
- To ensure equal flow distribution between processes

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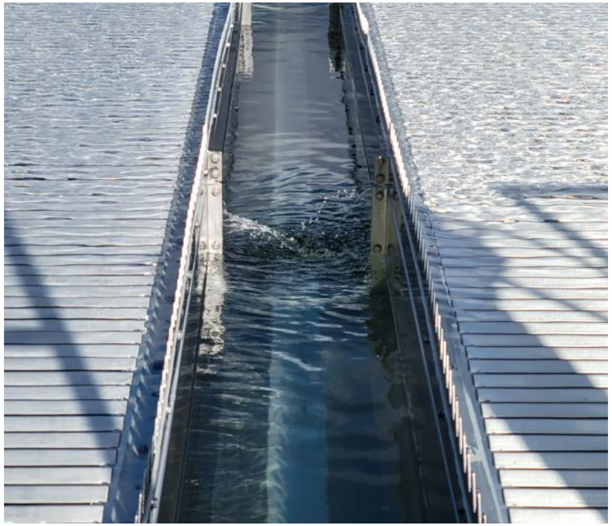
Design Flows

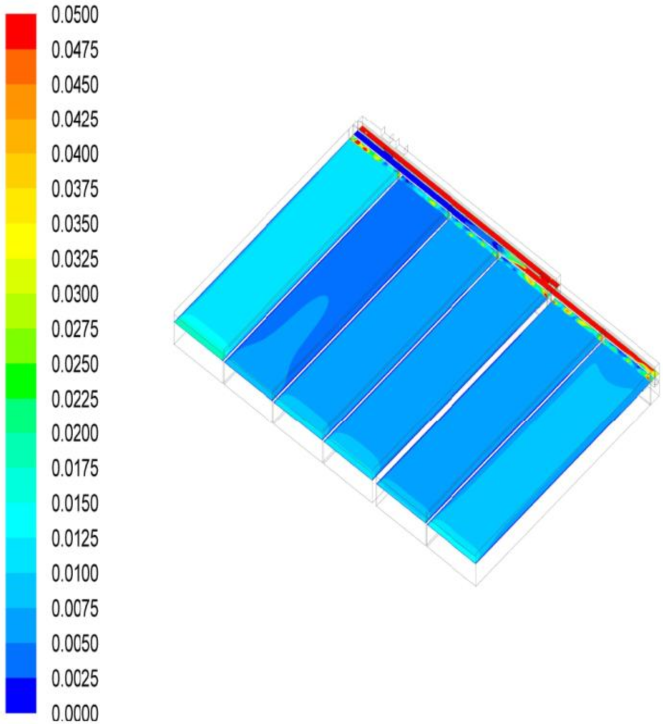
- Minimum Flow
  - Consider minimum velocities to be maintained
  - Consider for control valve and pump operation
- Average Flow
  - Sets typical depths and volumes
- Rated Plant Capacity
  - Used to design wall elevations and contain water levels within tanks and channels
  - Consider “worst case” condition
    - Process unit out of service?
    - Peak instantaneous flow?



COMPLETE HYDRAULIC CALCULATIONS FOR ALL PERTINENT FLOW CONDITIONS

Flow Distribution and Control

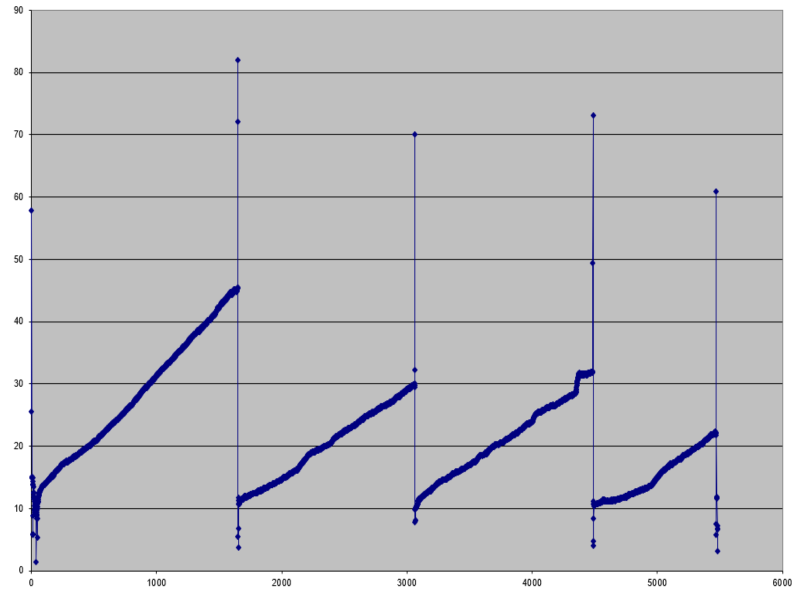
- Benefits of uniform flow distribution:
  - Best use of available hydraulic capacity
  - Improves process performance and reliability
  - Contributes to consistent compliance with tighter effluent limits
- Symmetry, although helpful, does not ensure proper flow distribution
- Maintaining flow distribution
  - Inducing headloss at points of desired distribution (i.e. orifices/ports, weirs, rate-of-flow controller)



Additional Hydraulic Considerations

- Provide adequate detention/contact times and loading rates in process units
- Consider plans for future expansion (ex. sizing of pipes and channels for future flows)
- Variable headloss conditions (clean/dirty filters, screens, etc.)

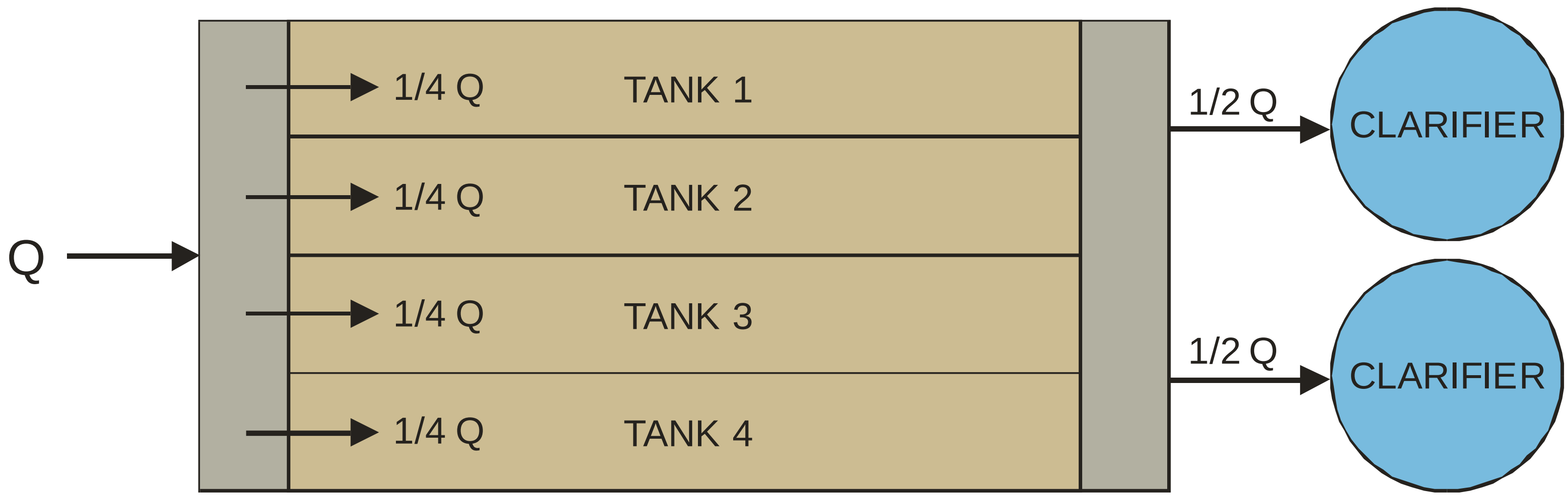
Filter HL vs. Time



Hydraulic Overview:
Flow Distribution

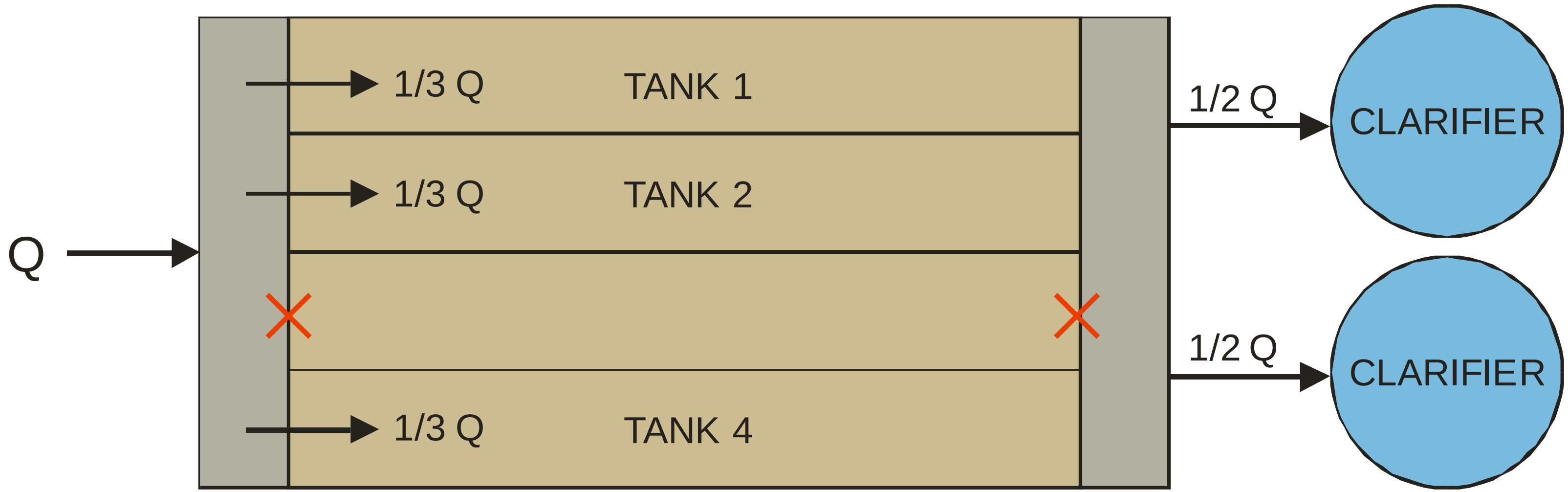
Flow Distribution - Objectives

- Flow Distribution – 95% distribution to all units



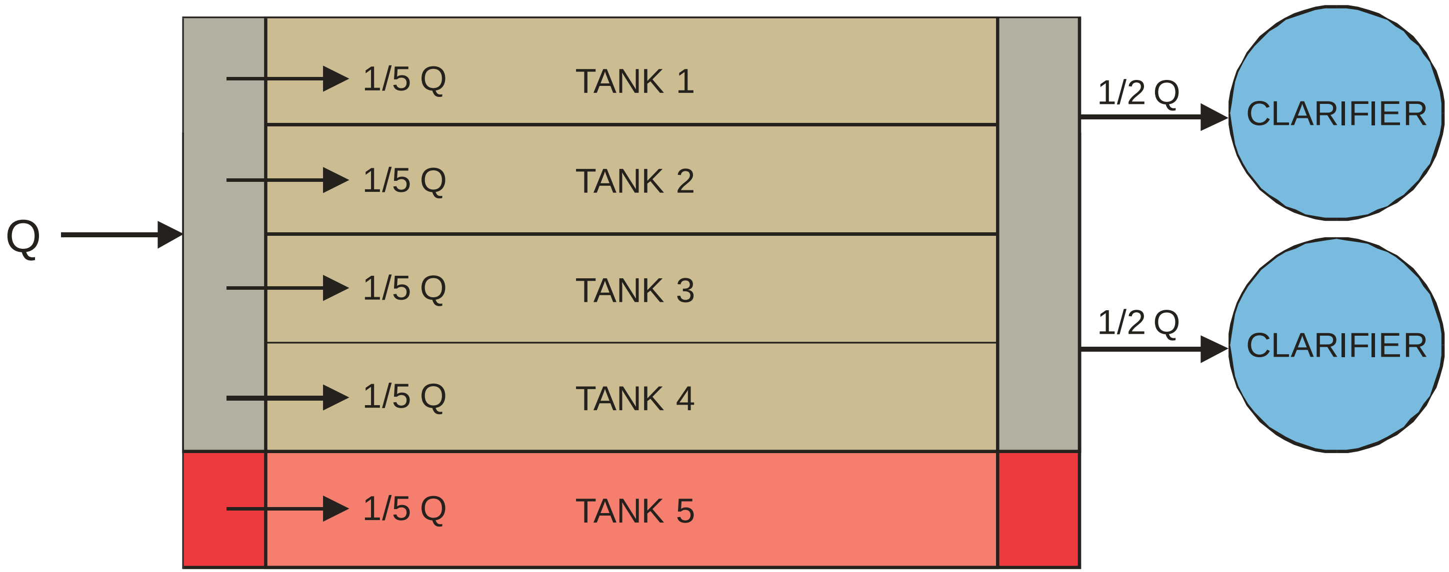
Flow Distribution - Objectives

- Flow Distribution – 95% distribution to all units
  - Ease of operation



Flow Distribution - Objectives

- Flow Distribution – 95% distribution to all units
  - Expandability



Maintaining Flow Distribution

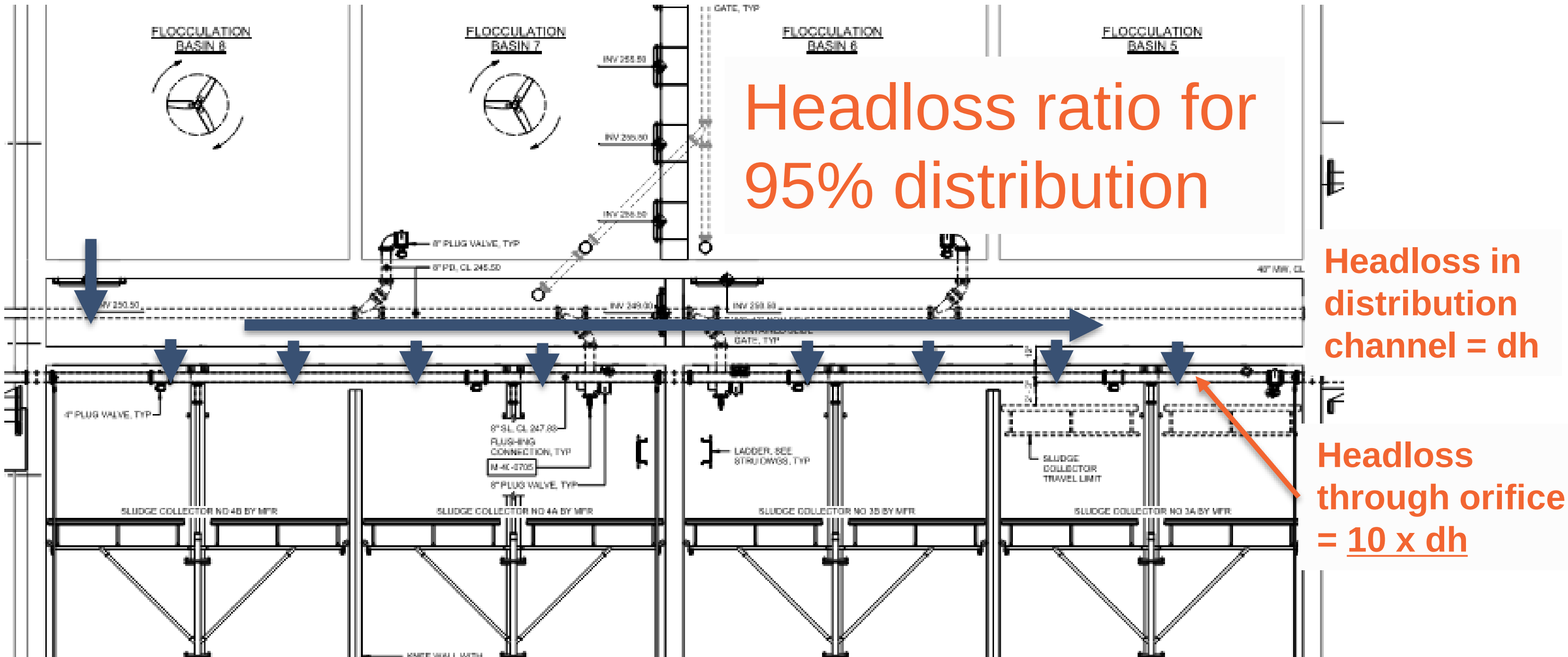
- Basic Principle – Induce Headloss!

  Provide a high enough headloss at points where equal flow distribution is required so that the head differential acting against equal flow distribution is relatively small in comparison.

- Common ways to induce headloss
  - Weirs (splitter boxes, etc.)
  - Ports (distribution from channel to process units)
  - Rate Controllers (valves, etc.)
    - Not always desirable in processes other than filters
    - Additional equipment cost and maintenance required

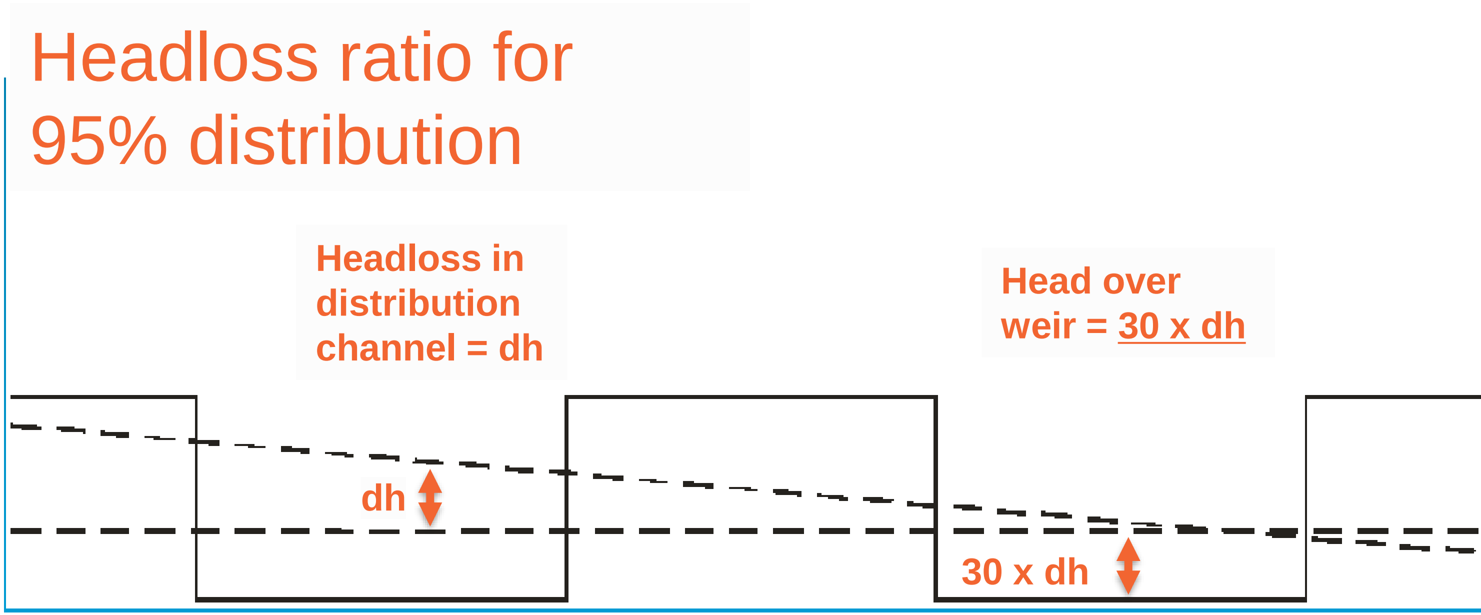
Flow Distribution

- Orifices
  - Headloss in channel between orifices (dh)
  - Headloss through orifice: 10 x dh



Flow Distribution

- Weirs
  - Headloss in channel between weirs (dh)
  - Head over weir: 30 x dh



Practical Examples

Hydraulics Calculations – Real World Examples

Example – Williams WTP

Identifying hydraulic capacity of aging WTP

Hydraulics Calculations – Real World Examples

Example – Williams WTP

Identifying hydraulic capacity of aging WTP

Developed hydraulic model of existing plant with record drawings

- Model calibrated with field measured water elevations

Results of Existing WTP Hydraulic Model Calibration at 6.5 mgd Flow

Process	Measured WSE (ft)	Hydraulic Profile WSE (ft)	Model Error (ft)
Flocculation Basins (West Train)	389.80	389.79	0.01
Sedimentation Basin (West)	389.68	389.72	0.04
Sedimentation Basin (East)	389.72	389.72	0.00
Sedimentation Basin Effluent Channel (West)	389.33	389.30	0.03
Sedimentation Basin Effluent Channel (East)	389.27	389.27	0.00
Filter Influent Channel (West)	389.27	389.26	0.01
Filter Influent Channel (East)	389.20	389.26	0.06
Filters	388.63	388.63	0.00

Hydraulics Calculations – Real World Examples

Example – Williams WTP

Defined freeboard at various flow rates up to permitted capacity of 22 MGD. Red cells mean < 12” freeboard

Existing WTP Model Results – Freeboard[1] Throughout WTP Processes (ft)

Flow (mgd)	Filtered Water Collection Box	Filters	Filter Influent Weirs	Sed Basin Effluent Weirs	Sed Basins	Sed Basin Influent Channel	Flocculation Basins	Rapid Mix
8	3.8	2.2	0.4	**0.2** [2]	1.1	1.0	2.1	2.1
10	3.5	2.2	0.4	**0.1** [2]	1.1	**0.9** [2]	2.1	2.1
12	3.2	2.2	**0.3** [2]	**0.0** [2]	1.0	**0.8** [2]	2.0	2.0
14	2.8	2.2	**0.2** [2]	**-0.1** [2]	1.0	**0.7** [2]	1.9	1.9
22	**0.8** [2]	2.2	**0.0** [2]	**-0.3** [2]	**0.9** [2]	**0.4** [2]	1.4	1.4

[1] Freeboard is defined as the distance between water level and top of concrete or downstream water level and weir elevation.

[2] Red shaded cells indicate less than 12 inches of freeboard from top of concrete elevation or less than 4 inches of downstream freeboard from the weir elevation.

Hydraulics Calculations – Real World Examples

Example – Williams WTP

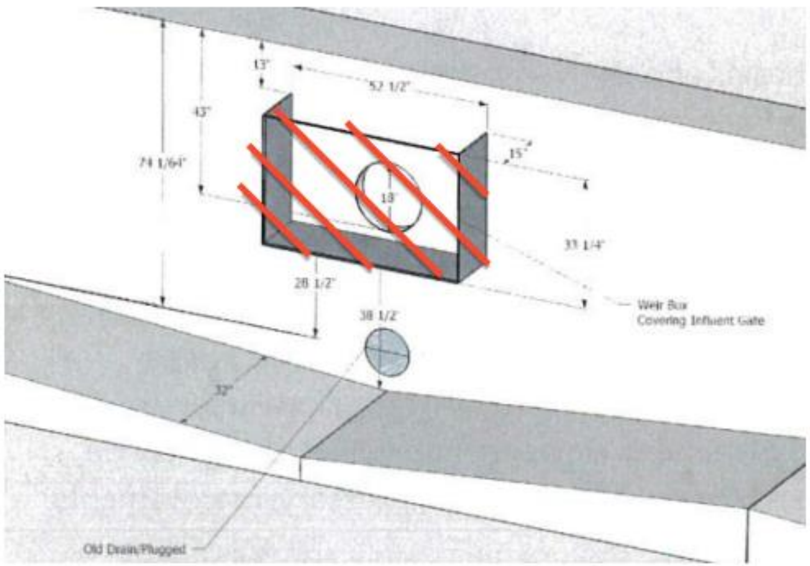
Limited freeboard!

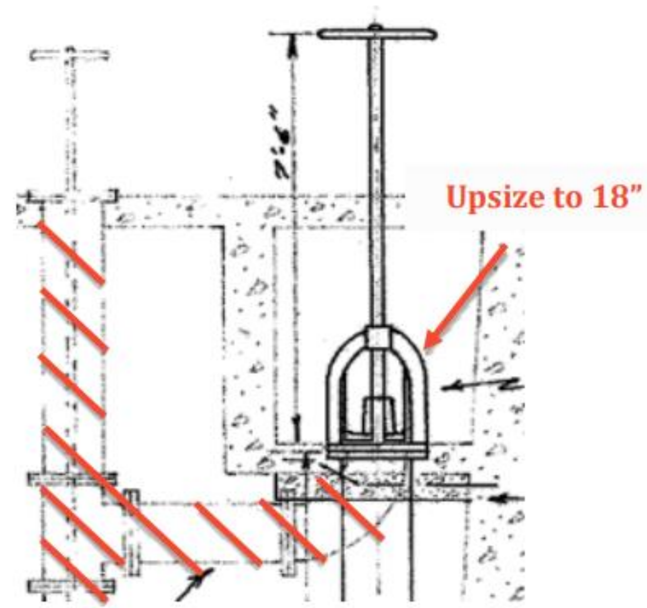
Hydraulics Calculations – Real World Examples

Example – Williams WTP

Recommended improvements to remedy hydraulic bottlenecks

- Upsize sedimentation basin influent mud valves
- Remove unnecessary filter influent weirs





Hydraulics Calculations – Real World Examples

Example – Williams WTP

Resulting freeboard predicted by model with recommended improvements

WTP with Recommended Improvements Model Results – Freeboard[1] Throughout WTP Processes (ft)

Flow (mgd)	Filtered Water Collection Box	Filters	Filter Influent Weirs	Sed Basin Effluent Weirs	Sed Basins	Sed Basin Influent Channel	Flocculation Basins	Rapid Mix
8	3.8	1.7	N/A	0.3	1.1	1.0	2.2	2.2
10	3.5	1.9	N/A	0.3	1.1	1.0	2.2	2.2
12	3.2	2.0	N/A	0.3	1.0	1.0	2.2	2.1
14	2.8	2.2	N/A	0.3	1.0	1.0	2.1	2.1
22	0.8 [2]	3.0	N/A	0.3	1.0	0.9 [2]	1.9	1.9

[1] Freeboard is defined as the distance between water level and top of concrete or downstream water level downstream and weir elevation.

[2] Red shaded cells indicate less than 12 inches of freeboard from top of concrete elevation or less than 4 inches of freeboard from weir elevation.

Hydraulics Calculations – Real World Examples

Example – Cooleemee WTP

Replacing aging WTP with greenfield 3.5 MGD WTP

New WTP is up a hill from existing WTP

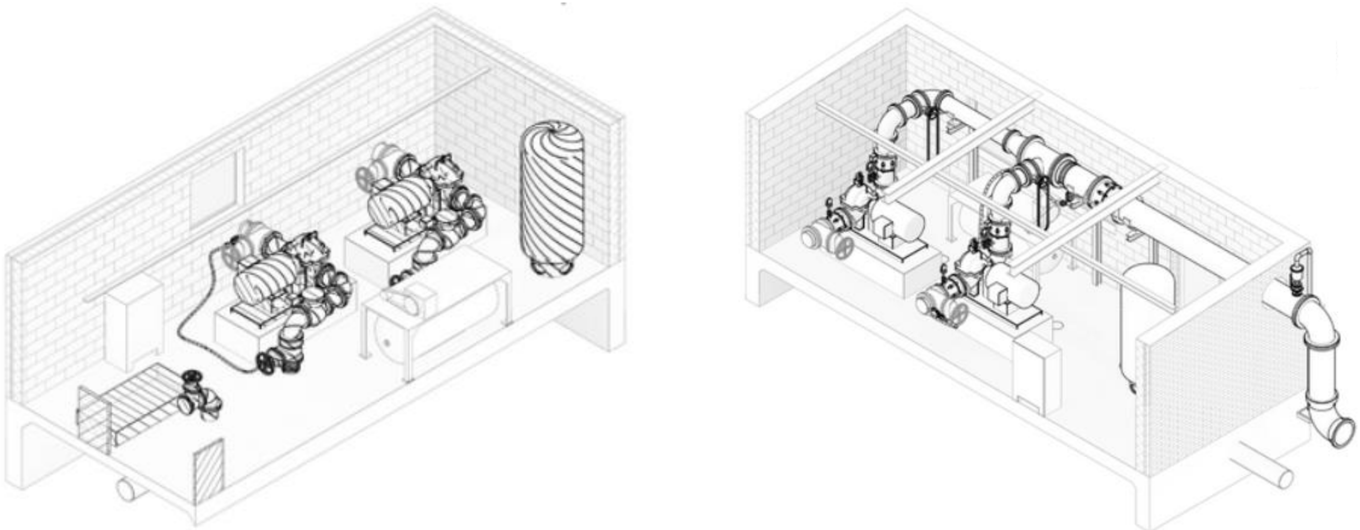
- Need new raw water (RW) pumps with more TDH to get water from river to plant

Hydraulics Calculations – Real World Examples

Example – Cooleemee WTP

KYPIPE model to develop system curve for new RW pumping system

- Increased static head
- New, larger RW transmission pipeline

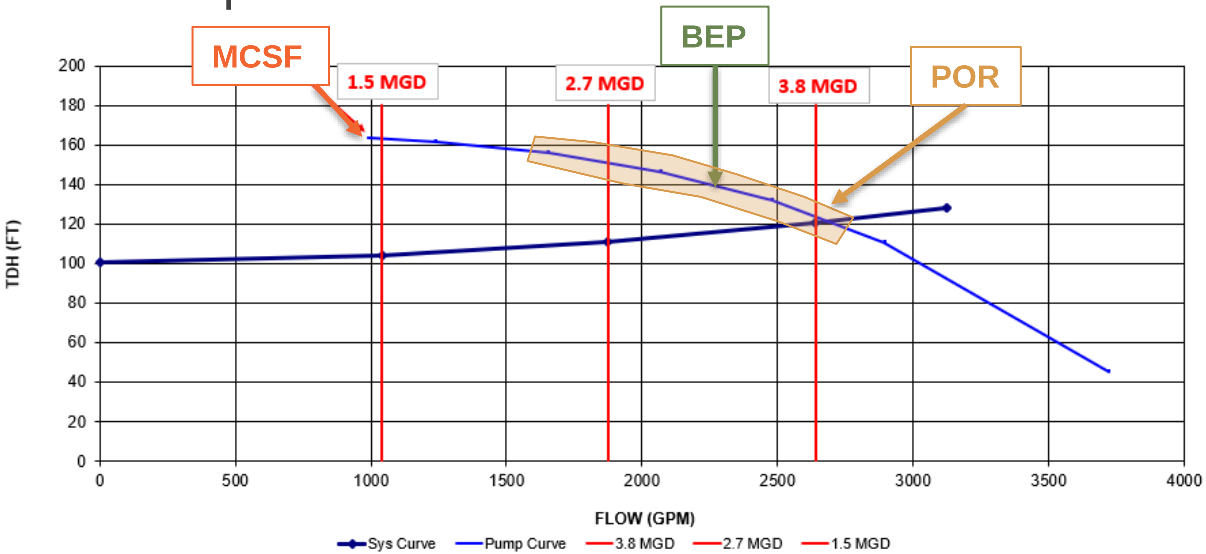


Hydraulics Calculations – Real World Examples

Example – Cooleemee WTP

Select new pumps to meet design points

- Minimum flow point – keep above min. continuous stable flow
- Average flow point – want very good efficiency here
- Maximum flow point – be able to meet this w/ reasonable efficiency



Hydraulics Calculations – Real World Examples

Example – Cooleemee WTP

How to control flow rate to meet our 1.5 - 3.8 MGD range?

- Control valve – *changes system curve*
- Variable Frequency Drives (VFDs) on pumps – *changes pump curve*

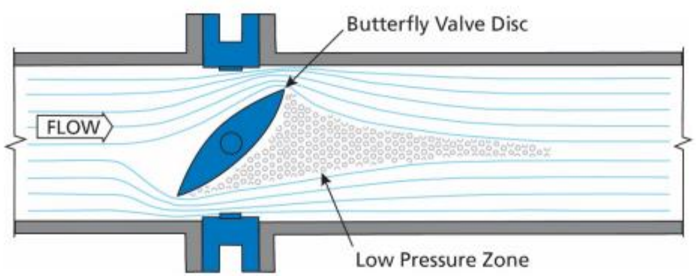
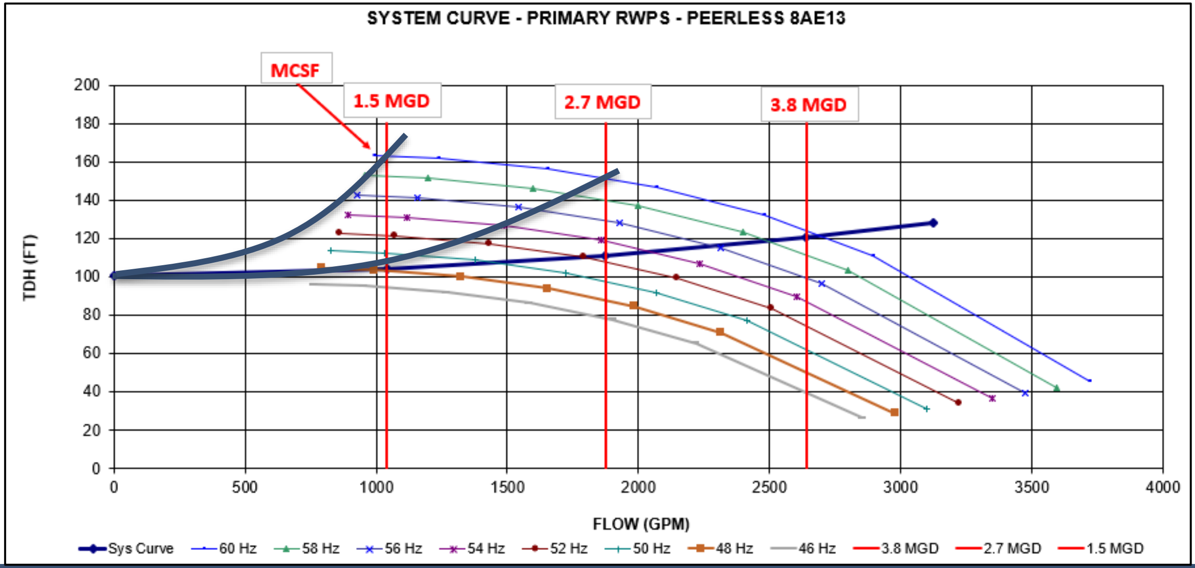


FIGURE 1. Cavitation

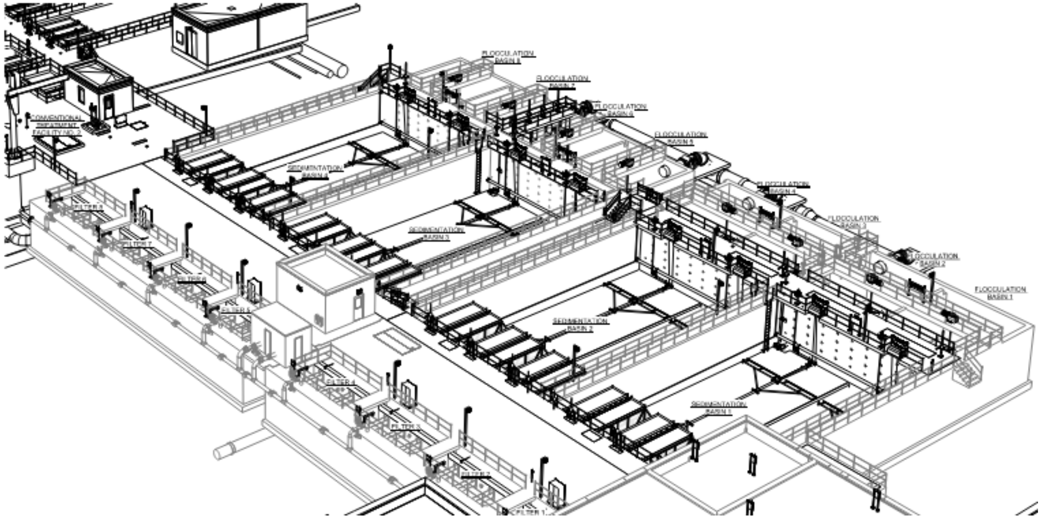


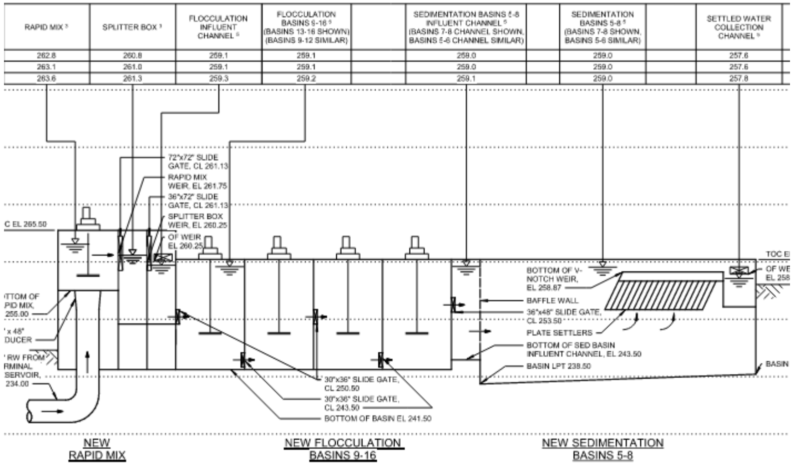
Hydraulics Calculations – Real World Examples

Example – Sanford WTF Expansion

12 MGD → *30 MGD (with future 42 MGD in mind)*

1. Excel-based hydraulic model of existing plant
2. Calibrate model with field measurements
3. Expand model to include proposed facilities and higher flow rates

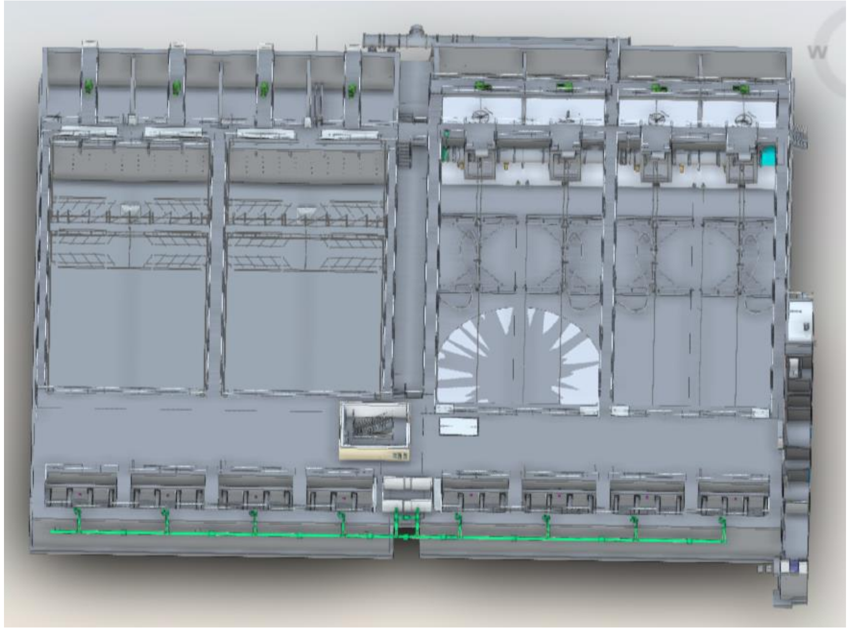




Hydraulics Calculations – Real World Examples

Example – Sanford WTF Expansion

12 MGD → *30 MGD (with future 42 MGD in mind)*



Sizing for wide range of flows!

- Pipes
- Channels
- Basins
- Pumps

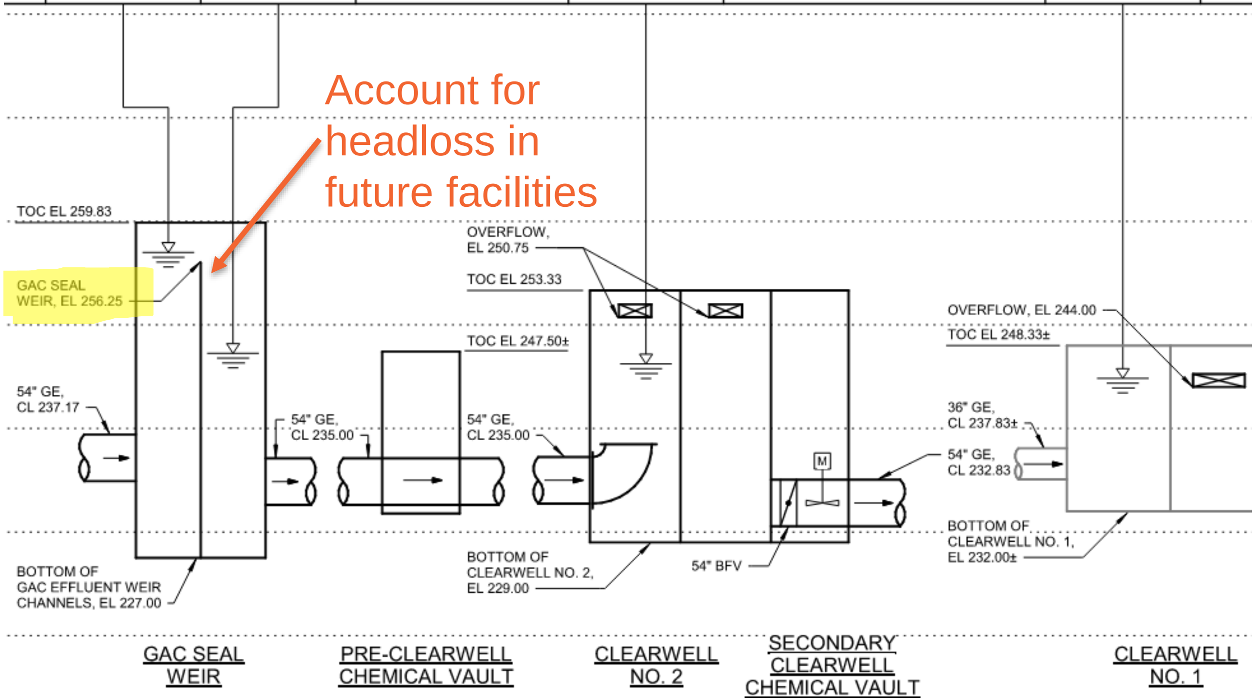
Ensure solids don't settle out at low flows

Avoid floc shear and excessive headloss at high flows

Hydraulics Calculations – Real World Examples

Example – Sanford WTF Expansion

	GAC SEAL WEIR FLUME [3]	GAC EFFLUENT FLUME [3]		CLEARWELL NO. 2 [3]		CLEARWELL NO. 1 [3]	
	256.7	244.4		244.1		243.5	
	256.8	245.3		244.7		243.5	
	257.0	247.6		246.2		243.5	



Hydraulics Calculations – Real World Examples

Example – Sanford WTF Expansion

Flow control valves operate best between 20%-80% open.

Size valves to keep operations in that range for worst-case scenarios

Maximum headloss to induce at filters (closed valve)

- Min flow, clean bed, all in service

Minimum headloss to induce at filters (open valve)

- Max flow, dirty bed, 2 out of service