# Repair and Protection of Concrete Structures at Wastewater Treatment Facilities

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# Repair and Protection of Concrete Structures at Wastewater Treatment Facilities

- Overview of the Wastewater Treatment Process
- Concrete structures that make up a WWTP
- Potential issues with concrete elements and structures
- Methods for repair and protection of concrete elements
- Important Considerations

# Repair and Protection of Concrete Structures at Wastewater Treatment Facilities

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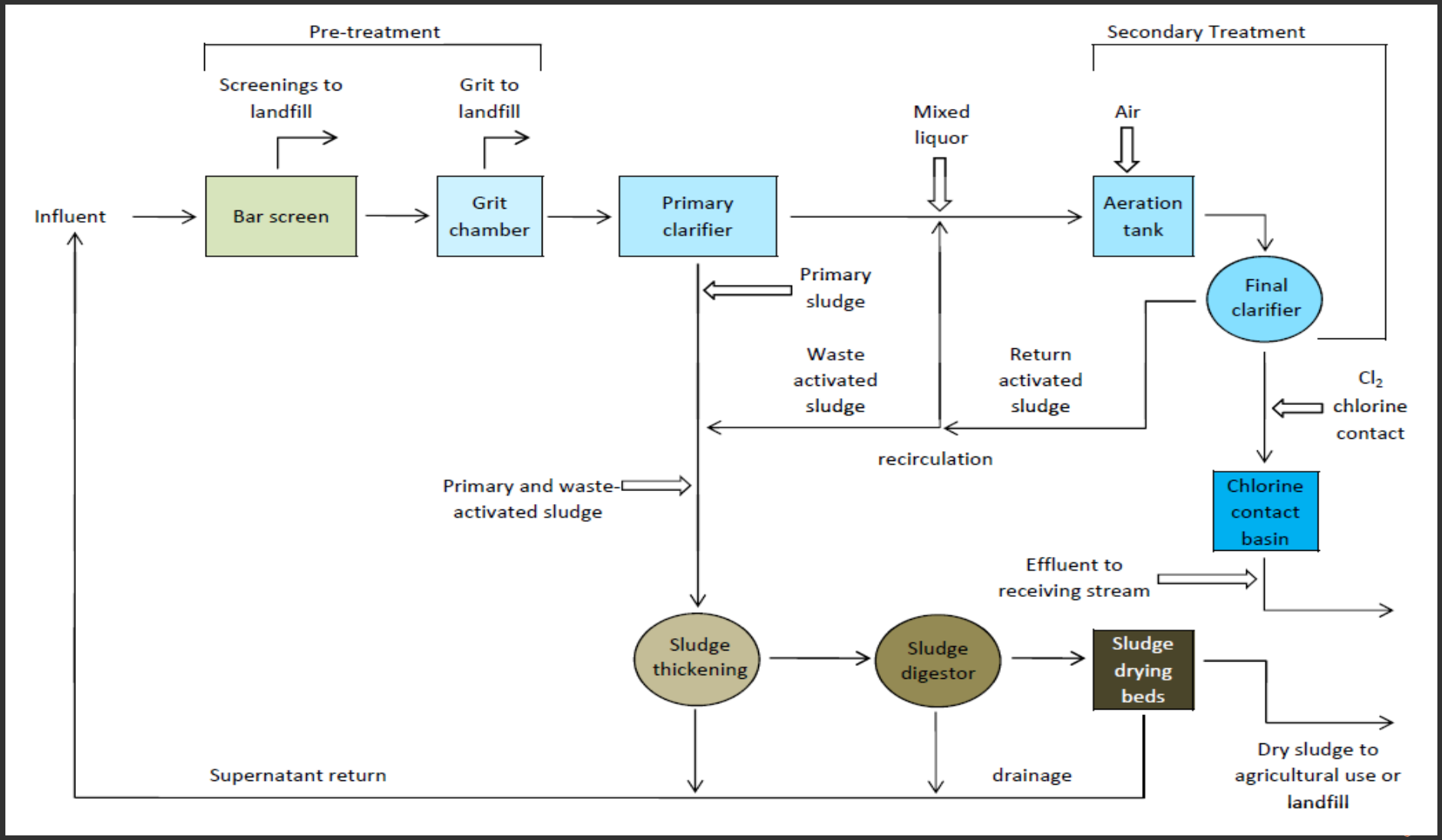
# Overview of the WWT Process



# Concrete Structures

## Large Conduits:

- Older pipes – Reinforced Concrete (RCP), unlined
- Newer pipes might be lined RCP or glass-fiber reinforced plastic (GRP)
- Subject to scouring, chemical attack and joint leaks

# Concrete Structures

## Junction Boxes:

- Located at changes in flow (splitting flows, combining flows, diversions, etc.)
- Turbulent flow conditions
  - Scouring
  - Increased chemical attack

# Concrete Structures

## Pump stations / wet wells:

- Pumps required to move water or sludge on to next process

- Varying water levels
  - Encourage bacteria growth
  - Increased chemical attack
  - Increased freeze-thaw effects

# Concrete Structures

## Equalization Basins:

- Allow for regulating flow rates during peaks
- Typically large ponds or lagoons
- Not always in use (load / unload)
- Bottom slabs may need to resist back pressure from groundwater

# Concrete Structures

## Pre-Treatment:

- Headworks:
  - Bar Screen removes larger solids such as rocks, vegetation, trash, or rags
  - Removes solids larger than 5/8”

# Concrete Structures

## Pre-treatment:

- Headworks:
  - Grit chambers allow abrasive grit to settle out
  - Wastewater is at its most abrasive before large solids and grit are removed

# Concrete Structures

## Primary Treatment:

- Primary clarifiers
  - Solids settle to bottom
  - Sludge is scraped to hopper at one end (or center, if clarifier is round), then pumped to sludge treatment facility

# Concrete Structures

## Primary Treatment:

- Primary clarifiers
  - Typically remove 50-70% of suspended solids

# Concrete Structures

## Primary Treatment:

- Primary clarifiers
  - Grease and oils float to top and are skimmed off

# Concrete Structures

## Secondary Treatment:

- Activated Sludge System
  - Dissolved oxygen in aeration tank promotes growth of microbial organisms
  - Microbes break down organic solids and promote coagulation of small solids into larger floc for improved settling

# Concrete Structures

## Secondary Treatment:

- Secondary (Final) Clarifiers
  - Microbes and floc sludge settle to the bottom, where it is collected
  - Some sludge is re-circulated to maintain microbe population
  - Remaining sludge sent for processing

# Concrete Structures

Tertiary Treatment:

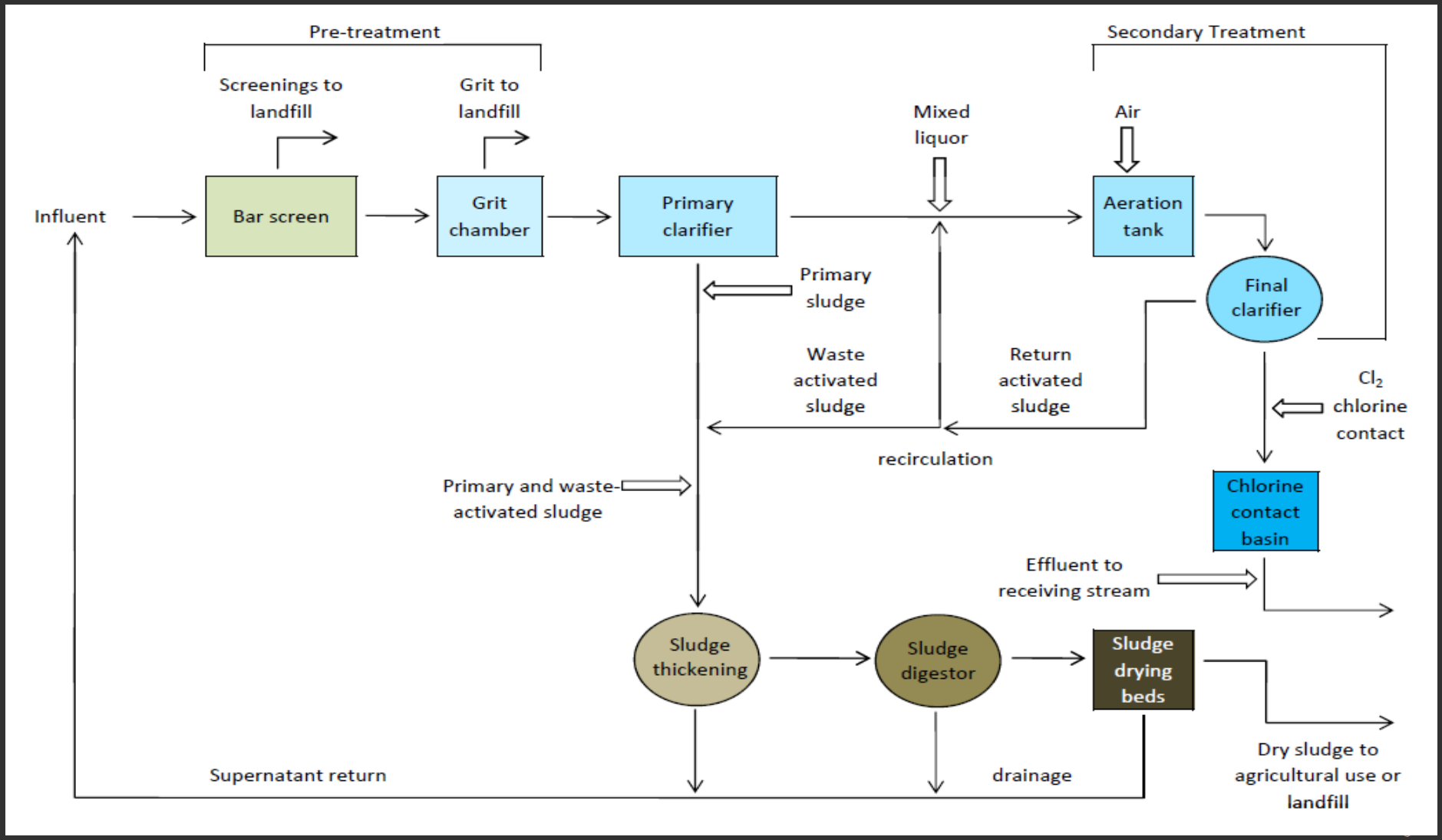
- Chlorination / De-chlorination
- Ultra-violet high-intensity light disinfection
- Phosphorus removal
- Nitrogen / Ammonia removal
- Additional filtering

# Concrete Structures

## Discharge:

- Treated water discharged to a river or stream

# Overview of the WWT Process



# Concrete Structures

## Sludge Processing:

- Sludge thickeners
  - De-waters sludge to reduce volume
  - Gravity thickening in sedimentation tanks

# Concrete Structures

## Sludge Processing:

- Sludge thickeners
  - De-waters sludge to reduce volume
  - Gravity thickening in sedimentation tanks
  - Dissolved air flotation thickening uses fine air bubbles to float solids to surface

# Concrete Structures

## Sludge Processing:

- Sludge digesters
  - Reduces the amount of organic matter and harmful organisms

# Concrete Structures

## Sludge Processing:

- Sludge digesters
  - Aerobic – open top
  - Bacterial - Bacteria rapidly consume organic matter and convert it to carbon dioxide
  - Diffuser system – Jet aerators oxidize the sludge

# Concrete Structures

## Sludge Processing:

- Sludge digesters
  - Anaerobic – closed, fixed or floating top
  - Carried out in absence of oxygen

# Concrete Structures

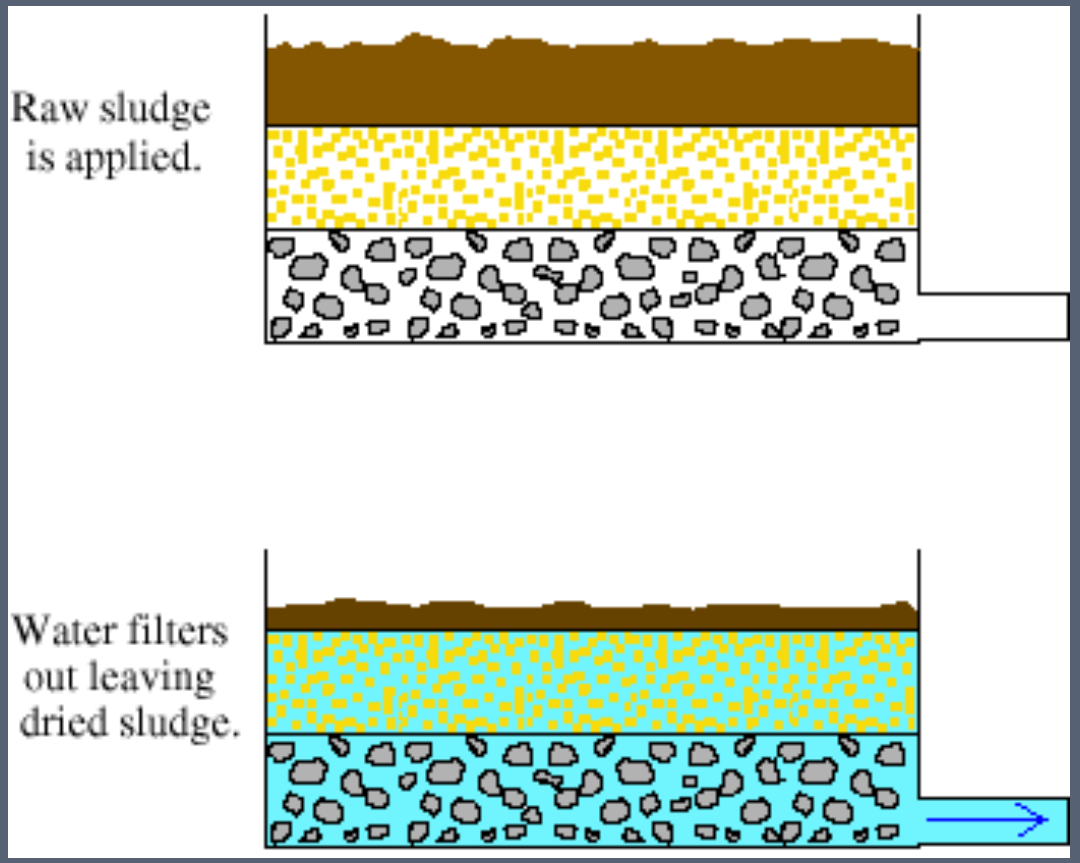
## Sludge Processing:

- Sludge digesters
  - Anaerobic digestion
  - Thermophilic – Sludge is fermented at 55° C (131° F)
  - Mesophilic – 36° C (97° F)
  - Produces biogas
  - Methane most useful

# Concrete Structures

## Sludge Processing:

- Sludge drying beds



# Concrete Structures

## Sludge Processing:

- Sludge drying beds
- Filter presses
- Belt filter presses

# Concrete Structures

## Sludge Processing:

- Sludge may be disposed of by burying (landfill), or incineration
- Incineration not used much unless in conjunction with a waste-to-energy process

# Concrete Structures

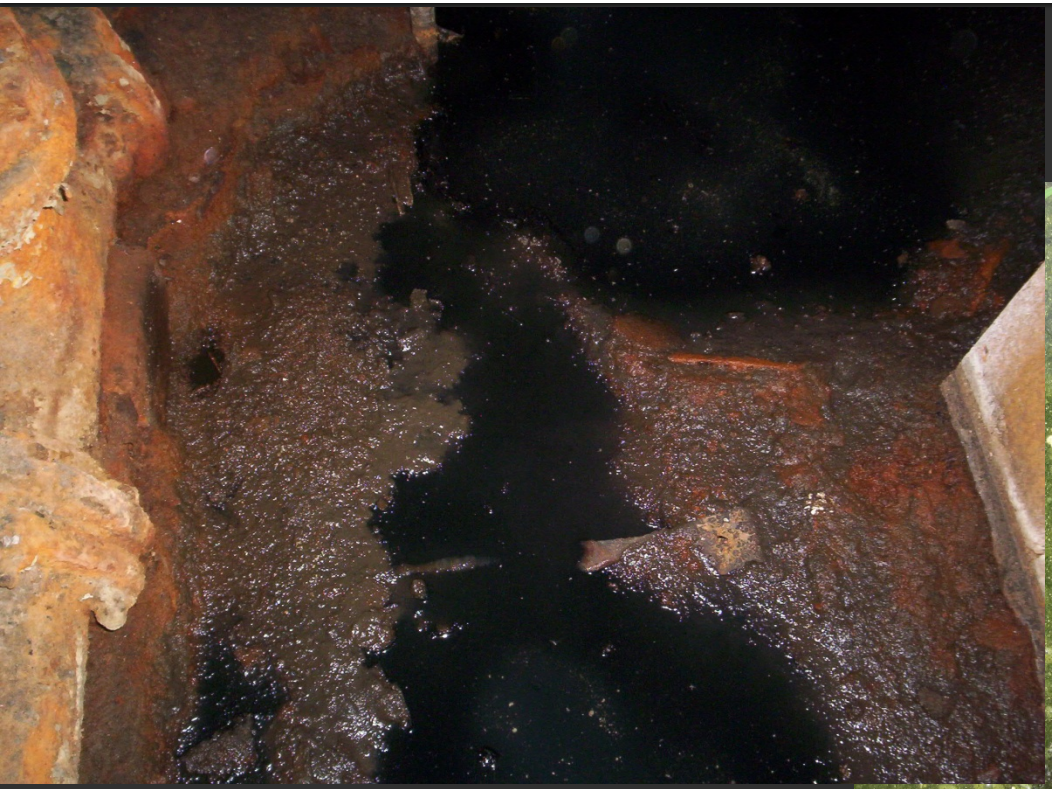
## Sludge Processing:

- Sludge can be superheated
- Convert into small pelletized granules, high in nitrogen and other organic materials
- Commercial and industrial sludge may be too contaminated

# Potential Issues with Concrete Elements and Structures

- Chemical Attack
- Scour
- Joint Issues
- Cracks
- Damage at Water Surfaces & Boundary Zones
- Delaminations
- Spalls
- Unconsolidated Concrete

# Potential Issues with Concrete Elements and Structures



# Potential Issues with Concrete Elements and Structures

## Chemical Attack:

- Chemical damage includes:
  - Concrete loss – can be severe (3”-6” or more)
  - Exposed aggregate and aggregate damage
  - Corroded steel reinforcing

# Potential Issues with Concrete Elements and Structures

## Chemical Attack:

- $H_2S$
  - Bacteria oxidize $H_2S$ and produce sulfuric acid
  - Acid dissolves the cement paste, creating a layer of "fluff" which can wash away, exposing the next layer of concrete
  - Worst at front end of plant

# Potential Issues with Concrete Elements and Structures

## Chemical Attack:

- Chlorine
  - Hypochloric acid
  - Acid reduces the alkalinity of the concrete, leading to corrosion of the steel reinforcing
  - Worst at application point
- Other chemicals
  - Ferric chloride, $CO_2$, aluminum sulfate,etc.

# Potential Issues with Concrete Elements and Structures

## Surface Erosion:

- Scour
  - Damage caused by the movement of process fluids over surface
  - Affects conduits, junction boxes, effluent structures, and other elements

# Potential Issues with Concrete Elements and Structures

## Surface Erosion:

- Scour
  - Wastewater can contain abrasive materials (sand, rocks, broken glass, etc.)
  - Even clean water can cause scour
  - Worst at front end of plant, but can happen throughout plant

# Potential Issues with Concrete Elements and Structures

Joints:

- Construction Joints
  - Leaking
    - Groundwater
    - Process fluids

# Potential Issues with Concrete Elements and Structures

Joints:

- Expansion Joints

# Potential Issues with Concrete Elements and Structures

## Joints:

- Expansion Joints
- Sub-grade wall/slab joints in empty basins may be under pressure from groundwater
- Unsealed joints could be allowing process fluid to leach into subgrade

# Potential Issues with Concrete Elements and Structures

## Cracks:

- Elastic shortening (shrinkage)

# Potential Issues with Concrete Elements and Structures

## Cracks:

- Movement
  - Sub-grade shrink/ swell
  - Load/unload walls and slabs

# Potential Issues with Concrete Elements and Structures

## Damage at Water Surfaces and Boundary Zones:

- Intermittent wetting encourages bacteria growth
- Turbulence releases more $H_2S$ and other gasses
- Freeze-thaw

# Potential Issues with Concrete Elements and Structures

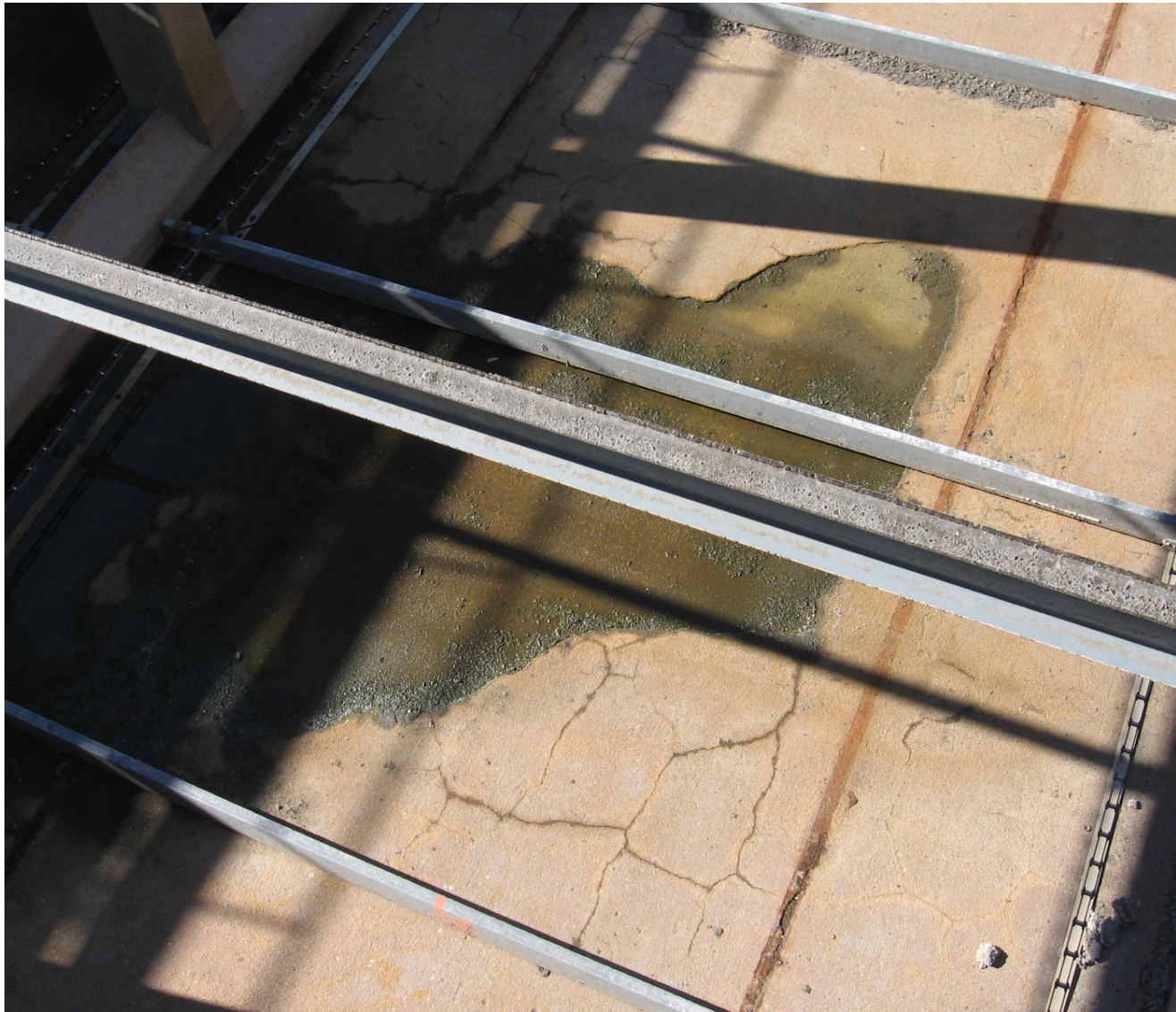
## Damage at Water Surfaces and Boundary Zones:

- Intermittent wetting encourages bacteria growth
- Turbulence releases more $H_2S$ and other gasses
- Freeze-thaw

# Potential Issues with Concrete Elements and Structures

## Delaminations:

- Inadequate surface preparation
- Improper material placement



# Potential Issues with Concrete Elements and Structures

## Spalls:

- Inadequate cover over reinforcing steel

# Potential Issues with Concrete Elements and Structures

## Unconsolidated Concrete:

- Improper placement of reinforcing steel
- Inadequate vibration during placement

# Repair & Protection Methods

- Repair Methods
  - Repair mortars
    - Hand-applied
    - Spray-applied
    - Form and pour/pump
  - Crack injection
    - Epoxy
    - Polyurethane
  - Expansion joint systems
    - Within the joint
    - Surface-applied

# Repair & Protection Methods

- Repair Methods
  - Contractor's means and methods
  - Performance-based specified by Design Engineer

# Repair & Protection Methods

## Repair Mortar:

- Hand-applied
  - Small, isolated areas

# Repair & Protection Methods

## Repair Mortar:

- Hand-applied
  - Small, isolated areas
  - Tight work areas

# Repair & Protection Methods

## Repair Mortar:

- Spray-applied
  - Large areas

# Repair & Protection Methods

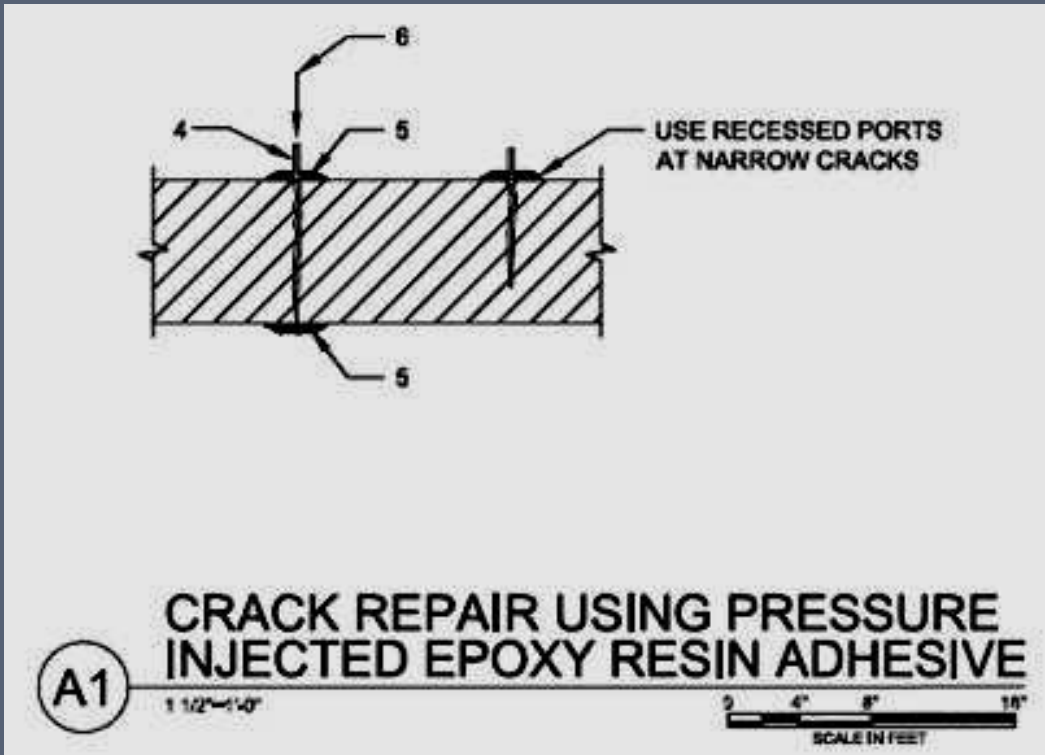
## Repair Mortar:

- Formed and poured or pumped
  - Deep areas
  - Flowable material to encapsulate reinforcing

# Repair & Protection Methods

## Crack injection:

- Structural - epoxy



# Repair & Protection Methods

## Crack injection:

- Leaking cracks in water-containing structures – flexible polyurethane

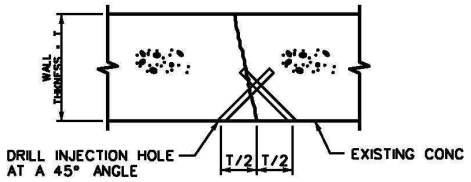
# Repair & Protection Methods

## Crack injection:

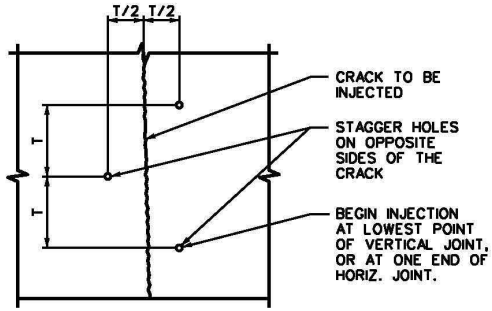
- Leaking cracks in water-containing structures – flexible polyurethane

PRESSURE INJECTED POLYURETHANE GROUT

1. EXPANDING POLYURETHANE GROUT SHALL BE IN ACCORDANCE WITH SPECIFICATION SECTION 03930.
2. GROUT SHALL BE LOW-VISCOSITY, HYDROPHOBIC POLYURETHANE, FLEXIBLE WHEN CURED, AND DESIGNED FOR USE IN HAIRLINE CRACKS. SUBMIT PROPOSED MATERIAL FOR REVIEW AND APPROVAL. POLYURETHANE GROUTS OFFERED BY THE FOLLOWING MANUFACTURERS ARE ACCEPTABLE:
   A. SIKA CORPORATION
   B. DENEEF CONSTRUCTION CHEMICALS
3. ALL SURFACES OF CRACKS TO RECEIVE POLYURETHANE GROUT SHALL BE FREE OF ALL LOOSE AND UNSOUND MATERIAL, OIL, GREASE, WAX, OR OTHER BOND INHIBITING AGENTS. USE SANDBLAST OR WATERBLAST TO CLEAN SURFACE. ACID ETCHING SHALL NOT BE USED. SEAL FACE OF CRACKS USING EPOXY PASTE ADHESIVE.
4. DRILL AND INSTALL INJECTION PORTS (PACKERS) AT A 45 DEGREE ANGLE TO THE SURFACE IN ORDER TO INTERSECT THE CRACK AT THE MID-DEPTH OF THE STRUCTURAL MEMBER. STAGGER HOLES ON OPPOSITE SIDES OF THE CRACK. PORT SPACING IS DEPENDENT UPON CRACK WIDTH, AND MAY VARY FROM 6" TO 24".
5. FLUSH CRACKS WITH CLEAN WATER PRIOR TO PRESSURE INJECTION WITH POLYURETHANE GROUT. IF WATER DOES NOT TRAVEL TO ADJACENT PORTS, DRILL AND PORT ADDITIONAL HOLES.
6. BEGIN INJECTION OF POLYURETHANE GROUT AT THE INJECTION PORT OF LOWEST ELEVATION OR AT ONE END OF HORIZONTAL CRACK. INJECT GROUT IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS UNTIL ENTIRE CRACK IS FILLED.
7. FOLLOW POLYURETHANE GROUT INJECTION WITH WATER INJECTION AS RECOMMENDED BY MANUFACTURER.
8. ANY INJECTED CRACK THAT CONTINUES TO EXHIBIT SIGNS OF LEAKS OR SEEPAGE SHALL BE RE-INJECTED.
9. AFTER COMPLETION OF INJECTION, REMOVE EXCESS GROUT AND ALL INJECTION PORTS, SLEEVES, ETC. CLEAN AND PATCH HOLES USING NON-SHRINK GROUT. GRIND SURFACE SEALER FLUSH WITH SURROUNDING CONCRETE.
10. THE NOTES PROVIDED ABOVE ARE FOR GENERAL INFORMATION ONLY. IN CASE OF CONFLICT BETWEEN THE REPAIR MATERIAL MANUFACTURER'S APPLICATION GUIDELINES AND THE NOTES PROVIDED ABOVE, THE MANUFACTURER'S GUIDELINES SHALL GOVERN.




WALL PLAN OR SLAB SECTION




WALL ELEVATION OR SLAB PLAN

TYPICAL REPAIR

DETAIL 3
NTS SE-04

# Repair & Protection Methods

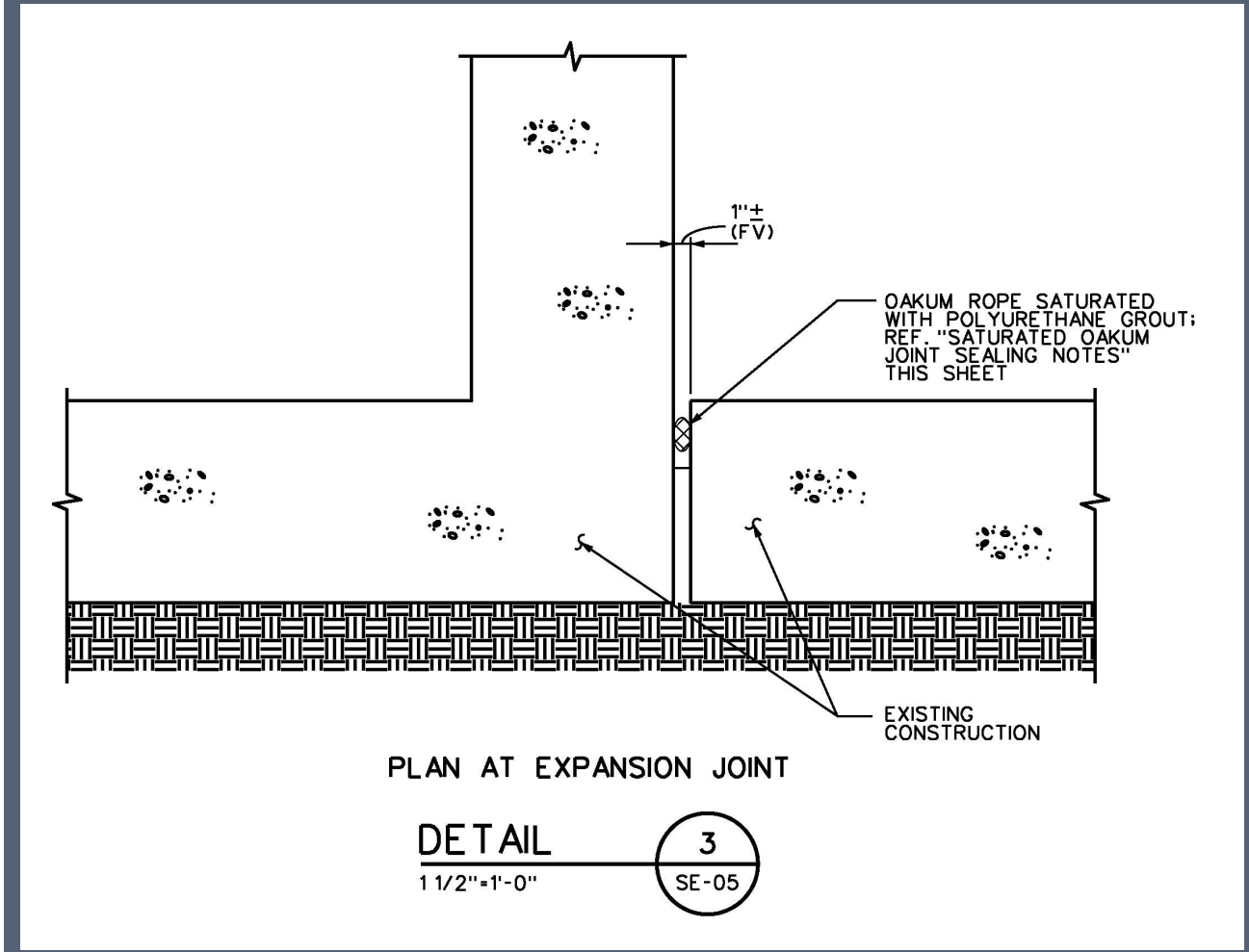
## Crack injection:

- Leaking cracks in water-containing structures – flexible polyurethane

# Repair & Protection Methods

## Expansion Joints:

- Remove existing joint material and install new inside the joint



# Repair & Protection Methods

## Expansion Joints:

- Existing joint material to remain inside joint
- Provide new surface-applied joint system

# Repair & Protection Methods

## Surface Preparation:

- Most important aspect of any repair
- Mechanical means

# Repair & Protection Methods

- Protection Methods – Process related
  - Ventilation to limit moisture and chemical exposure
  - Controlling turbulence
  - Controlling concentrations of chemicals

- Protection Methods - Constructible
  - RCP conduit liners
  - PVC liners
  - Epoxy coating systems

# Repair & Protection Methods

## RCP Conduit Liners:

- RCP can be outfitted with an inner liner (slipped in)

# Repair & Protection Methods

## RCP Conduit Liners:

- RCP can be outfitted with an inner liner (slipped in)
- Existing RCP can be repaired and lined
  - PVC liner

# Repair & Protection Methods

## RCP Conduit Liners:

- RCP can be outfitted with an inner liner (slipped in)
- Existing RCP can be repaired and lined
  - PVC liner
  - GFRP
  - CFRP

# Repair & Protection Methods

PVC liners:

- Concrete basins, channels, tunnels, flumes, etc.

# Repair & Protection Methods

Epoxy overlay systems:

- Trowel-applied
- Basins, tunnels, channels, flumes, troughs, etc.

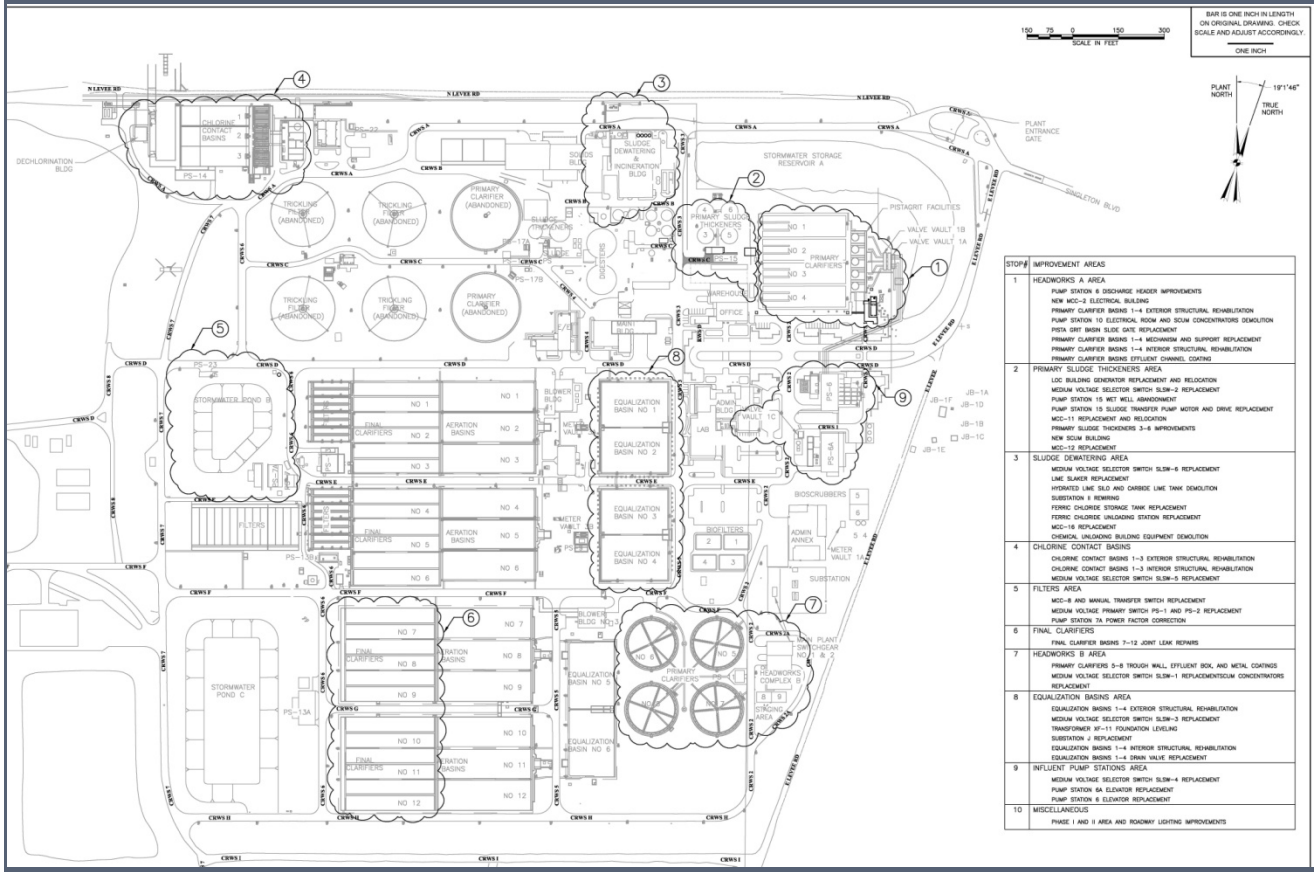
# Repair & Protection Methods

- Protection Methods - Constructible
  - Exposure
  - Age and condition of the concrete substrate
  - Life expectancy of the structure
  - Impact of repairs on plant operations

# Important Considerations

## Coordination with On-Going Plant Operations:

- Pre-planned shutdown(s)
- Date(s) and duration(s)



# Important Considerations

## Coordination with On-Going Plant Operations:

- Pre-planned shutdown(s)
- Date(s) and duration(s)

Table 01310-1 Calendar Days from Notice-To-Proceed

| Facility/Activity | Calendar Days From Notice-To-Proceed |
|---|---|
| Headworks A Complete Shutdown (Effluent PC 4) | ~~75~~ *60* Days From NTP *(Add. #1)* |
| Headworks A Partial Shutdown (Effluent PC 1-3) | ~~150~~*135* Days From NTP *(Add. #1)* |
| Headworks A MCC-2 Building | 14 Months From NTP |
| PS-6 Discharge Header A | 14 Months From NTP |
| PS-6 Discharge Header B | 14 Months From NTP |
| Primary Clarifier Basin 1 | 14 Months From NTP |
| Primary Clarifier Basin 2 | 14 Months From NTP |
| Primary Clarifier Basin 3 | 14 Months From NTP |
| Primary Clarifier Basin 4 | 14 Months From NTP |
| Headworks A Scum Building | 14 Months From NTP |
| Demolish Hydrated Lime Silos and Carbide Tank | 60 Days From NTP |

# Important Considerations

## Coordination with On-Going Plant Operations:

- Pre-planned shutdown(s)
- Date(s) and duration(s)
- Maximum duration of shutdowns for various structures

**Table 01310-2 Maximum Duration of Shutdown**

| Critical Operation | Maximum Duration of Shutdown |
|---|---|
| PC 4 Effluent Channel Coating | 75 Days |
| Scum Chopper Pump Connection to Scum Concentrator 1 | 3 Days |
| Scum Chopper Pump Connection to Scum Concentrator 2 | 3 Days |
| Primary Clarifier 1 | 6 Weeks |
| Primary Clarifier 2 | 6 Weeks |
| Primary Clarifier 3 | 6 Weeks |
| Primary Clarifier 4 | 6 Weeks |
| Primary Clarifier 5 | 6 Weeks |
| Primary Clarifier 6 | 6 Weeks |
| Primary Clarifier 7 | 6 Weeks |
| Primary Clarifier 8 | 6 Weeks |
| Lime System Without Delivered Slaked Lime | 8 Hours/Day |
| Installation of CCB 1-3 Effluent Channel Bulkhead | 4 hours |
| Chlorine Contact Basin 1 | 2 Weeks |
| Chlorine Contact Basin 2 | 2 Weeks |
| Chlorine Contact Basin 3 | 2 Weeks |
| Primary Sludge Thickener 3 | 12 Weeks |

# Important Considerations

## Coordination with On-Going Plant Operations:

- Pre-planned shutdown(s)
- Date(s) and duration(s)
- Maximum duration of shutdowns for various structures

| Critical Operation | Maximum Duration of Shutdown |
|---|---|
| Primary Sludge Thickener 4 | 12 Weeks |
| Primary Sludge Thickener 5 | 12 Weeks |
| Primary Sludge Thickener 6 | 12 Weeks |
| Demolish 18-S-PVC at Primary Sludge Thickener 2 | 2 Hours |
| Equalization Basin 1 | 4 Weeks |
| Equalization Basin 2 | 4 Weeks |
| Equalization Basin 3 | 4 Weeks |
| Equalization Basin 4 | 4 Weeks |
| Final Clarifier 7 | 3 Weeks |
| Final Clarifier 8 | 3 Weeks |
| Final Clarifier 9 | 3 Weeks |
| Final Clarifier 10 | 3 Weeks |
| Final Clarifier 11 | 3 Weeks |
| Final Clarifier 12 | 3 Weeks |
| Scum Concentrator 3 | 2 Weeks |
| Scum Concentrator 4 | 2 Weeks |
| ~~MCC-8 (Stormwater PS-23)~~ | ~~3 Days~~ *(Add. #4)* |
| MCC-11 (PS-15, Primary Sludge Thickeners) | 4 Hours |
| MCC-12 (DAFT, Blend Tanks) | 2 Hours |
| SLSW-1 (Headworks B, PS-13A) | 4 Hours |
| SLSW-2 (LOC, Office/Warehouse, Solids) | 4 Hours |
| SLSW-3 (PS-7A, E/E, Maintenance, Dechlor) | 4 Hours |
| SLSW-4 (Lab, PS-6A) | 4 Hours |
| SLSW-5 (PS-7A, E/E, Maintenance, Dechlor) | 4 Hours |
| SLSW-6 (LOC, Solids) | 4 Hours |
| PS 1 and 2 (PS-7A, E/E, Maint, Dechlor) | 4 Hours |
| ~~Substation J Switch (Blower Building 2, EQ Basins)~~ | ~~4 Hours~~ *(Add. #4)* |
| Transformer XF11 (E/E) | 4 Hours |
| Ferric Chloride Unloading Station | ~~1 Month~~*60 Days (Add. #3)* |
| *Grit Snail Control Panel* | *8 Hours (Add. #3)* |

# Important Considerations

## Coordination with On-Going Plant Operations:

- Clearly defining responsibilities

2. The CONTRACTOR is responsible for notifying the OWNER's Representative prior to commencing work on any of the critical operations listed in Table 01310-1 or 01310-2. The OWNER will operate all gates/valves. The CONTRACTOR will be responsible for draining all internal piping including portable pumps. The OWNER does not guarantee gates/valves are leak-tight or hold at all. The CONTRACTOR shall be responsible for the control of flow through the gates/valves if they are not leak-tight or hold at all, at no additional cost to the OWNER. ***The OWNER will be responsible for draining the basins only. It is the CONTRACTOR's responsibility to clean the basins to the extent necessary to perform the work in accordance with the Contract Documents. The CONTRACTOR may use the OWNER's non-potable water source and hoses to wash the sludge down the basin drain for PC 1-4,5-8, and CCB 1-3. CONTRACTOR shall remove all debris from EQ 1-4 basin floors and haul offsite. All cleaning activities shall be coordinated with the OWNER in accordance with Specification 01040 Project Administration. (Add. #3)***

3. The allowable shutdowns and required restriction times stated in the above Table 01310-2 are the maximum permitted, not including the time required for OWNER to open or close gates/valves, drainage times, and electrical load transfer.

# Important Considerations

## Coordination with On-Going Plant Operations:

- What will happen if….

4. In the event that any time limit established in Table 01310-1 or 01310-2 are exceeded, the CONTRACTOR shall be responsible for any additional costs incurred by the OWNER as a result of that time period being exceeded. Such expenses may include, but not be limited to:

   a. Additional personnel costs incurred by the OWNER as a result of that time period being exceeded.

   b. Additional costs incurred by the OWNER to rent equipment necessary as a result of the CONTRACTOR's failure to complete the work within the allotted time.

   c. Penalties imposed on the OWNER by any regulatory agency, which penalties were incurred by reason of a plant failure attributed in whole or part to the delay in completion of a task listed in Table 01310-1 or 01310-2.

   d. OWNER may withhold from the CONTRACTOR's compensation the actual costs for any such expenses incurred.

# Important Considerations

## Coordination with On-Going Plant Operations:

- Required sequencing of the work

5. Prior to commencing the next step in sequence following a shutdown for the installation of new mechanical equipment, the following equipment will need to complete one (1) week of successful operation:
   a. Primary Sludge Thickeners 3-6
   b. Headworks A Scum Concentrators
   c. Headworks B Scum Concentrators

# Important Considerations

## Coordination with On-Going Plant Operations:

- Mandatory construction sequence constraints

C. Mandatory Construction Sequence Constraints

1. Headworks A

   a. PC 4 effluent channel shall be coated prior to PC 1-3 effluent channel.

   b. No partial or complete shutdown of Headworks A will be allowed during any partial or complete shutdowns of Headworks B by OWNER or others.

   c. Pump Station 6 Header A or Header B shall be in service at all times. Both headers cannot be out of service at the same time.

   d. New Headwork A Scum Building, foul air blower, and new MCC-2 must be fully operational before demolishing existing MCC-2 and Headworks A Scum System.

   e. Temporary relocation of the filtrate lines shall be completed prior to PC 1-4 effluent channel coating.

   f. Only one connection between new primary clarifier scum piping and new scum chopper pumps can be completed at a time. Before making the remaining connection the new scum concentrator must be completed, tested, and ready for operation.

   g. A primary clarifier basin shall not be in operation without a functioning scum collection system.

   h. At all times, either all of Primary Clarifiers 5-8 or all of Primary Clarifiers 1-4 shall be available to the OWNER for use.

   i. Grit Snail control panel relocation must be coordinated with Headworks A complete shutdown.

   j. Switchover to new MCC-2 and new PLC-2 will be on a system by system basis.

# Important Considerations

## Coordination with On-Going Plant Operations:

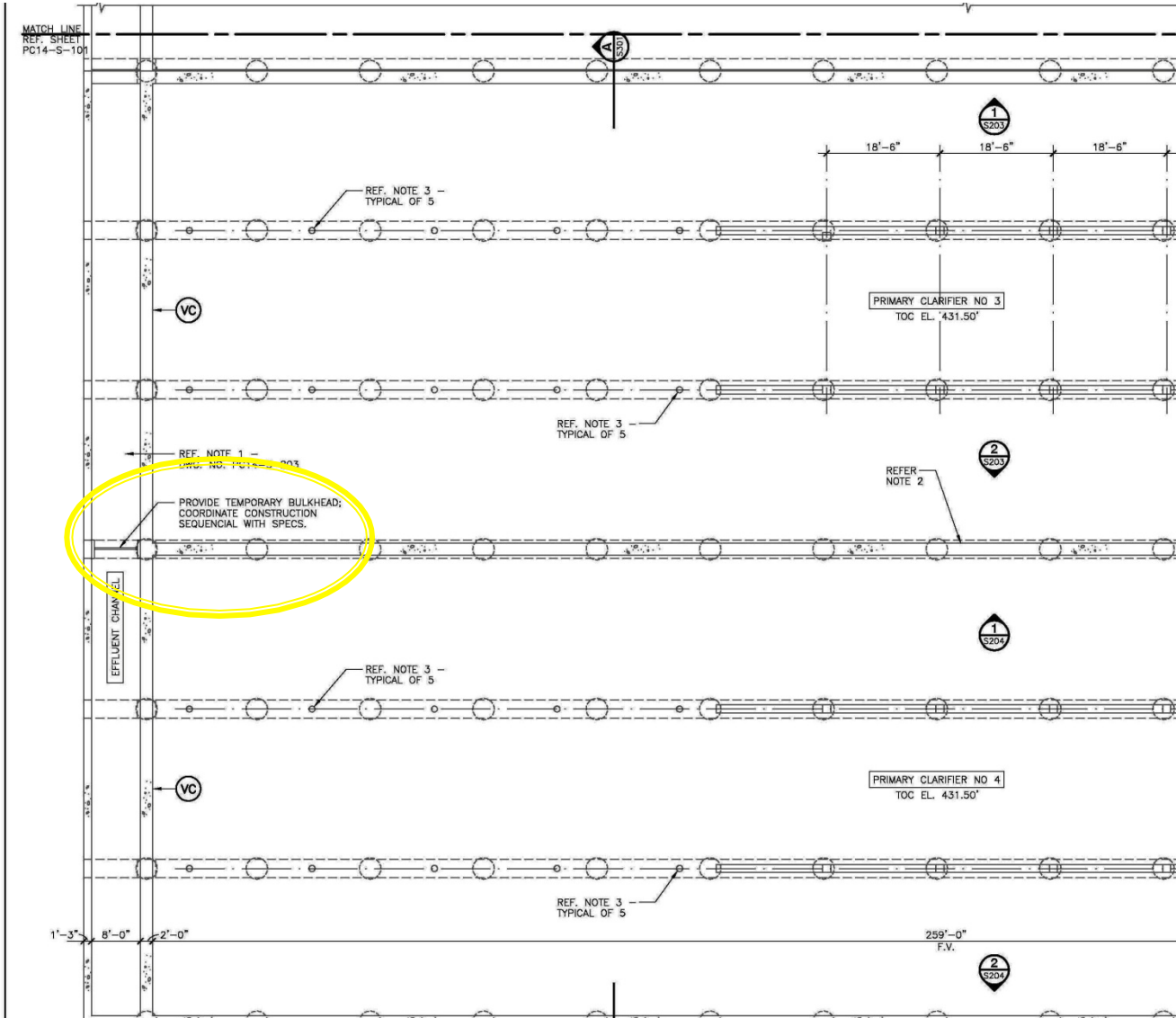
- Mandatory construction sequence constraints

7. Miscellaneous
   a. Only one chlorine contact basin can be taken out of service at a time, except for 4 hour total shutdown to install common effluent channel bulkhead.
   b. Only one equalization basin can be taken out of service at a time.
   c. Only one final clarifier can be taken out of service at a time.
   d. Only one Headworks B scum concentrator can be taken out of service at a time.

# Important Considerations

## Coordination with On-Going Plant Operations:

- Isolation of processes



# Important Considerations

## Coordination with On-Going Plant Operations:

- Recommended construction sequencing

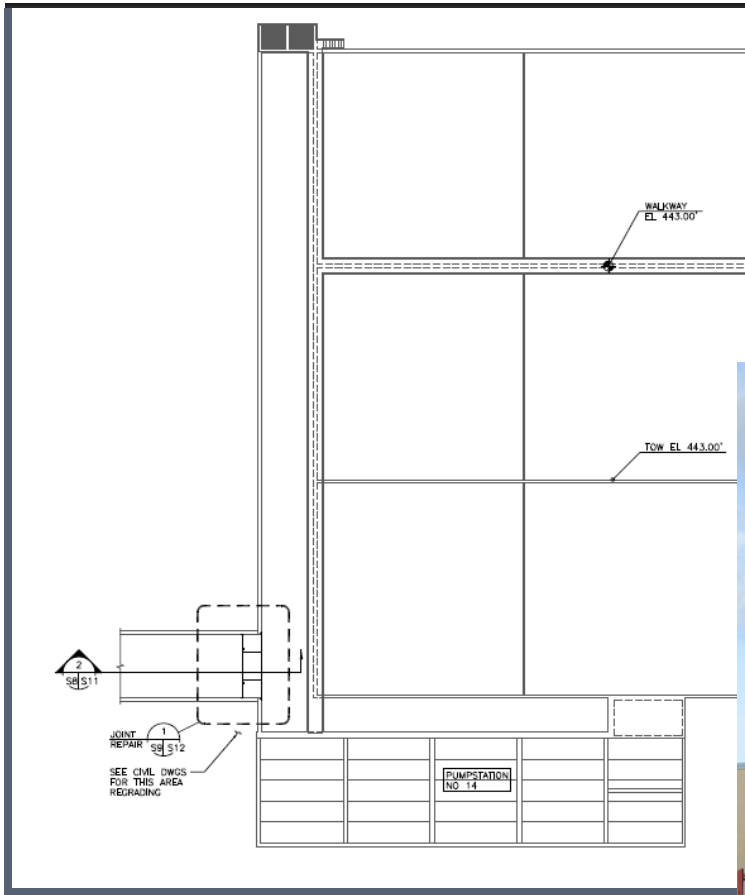
C. Primary Clarifiers 1-4 effluent channel coating.

1. Install filtrate bypass piping
2. Shutdown Headworks A completely and drain effluent channel.
3. Install temporary plug in the 96" effluent pipe and drain PC 1-4.
4. Coat the PC 4 effluent channel.
5. Install temporary bulkhead between PC 4 and PC 3.
6. Remove temporary plug in the 96" effluent pipe and place Headworks A back into service utilizing only PC 4.
7. Coat the PC 1-3 effluent channel.
8. Remove bulkhead between PC 4 and PC 3.
9. Restore filtrate piping to preconstruction conditions.
10. Place PC 1-3 back into service.

# Important Considerations

## Coordination with On-Going Plant Operations:

- Isolation of work areas




# Important Considerations

## Coordination with On-Going Plant Operations:

- Isolation of work areas

# Repair and Protection of Concrete Structures at Wastewater Treatment Facilities

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Questions?