



Primary Treatment: Sedimentation & Solids Removal

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James Markham



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Section 1: Welcome & Introductions



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SOUTHWEST
ENVIRONMENTAL
FINANCE CENTER



Who we are



SOUTHWEST
ENVIRONMENTAL
FINANCE CENTER

NM SCHOOL OF
ENGINEERING



Today's Agenda

- 01 Welcome & Introduction
- 02 Where Primary Treatment Fits in the Treatment Train
- 03 Principles of Gravity Settling, Flocculation and Floatation
- 04 Primary Clarifier Configurations & Equipment
- 05 Operational Parameters & Performance Monitoring
- 06 Routine Maintenance Practices
- 07 Why It All Matters – Plant-Wide Benefits
- 08 Conclusion, Key Takeaways & Q&A

Quick Poll: Who's in the Room?



Wastewater
Operator
/ Trainee or Plant
Staff



Utility Manager
or Director



Regulator or Other
Government
Official



Board Member /
Elected Official



Engineer
or Consultant

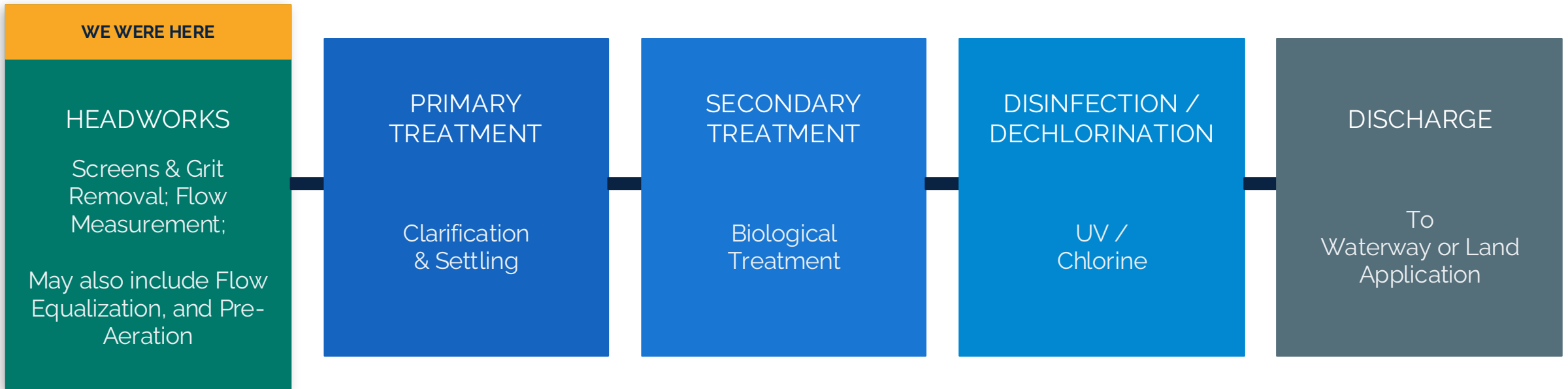


Technical
Assistance Provider

Section 2: Where Primary Treatment Fits in the Treatment Train

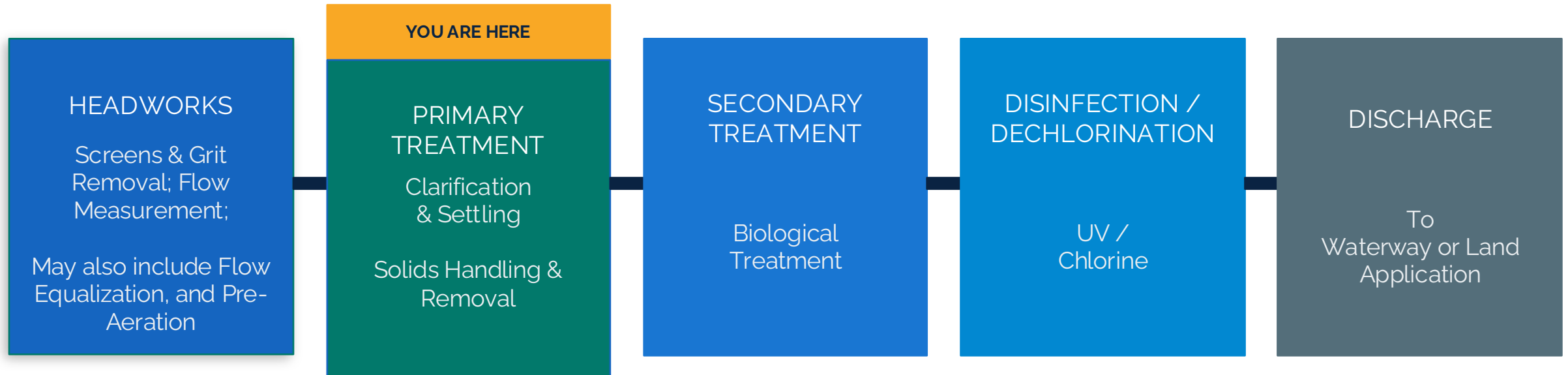


The Wastewater Treatment Train

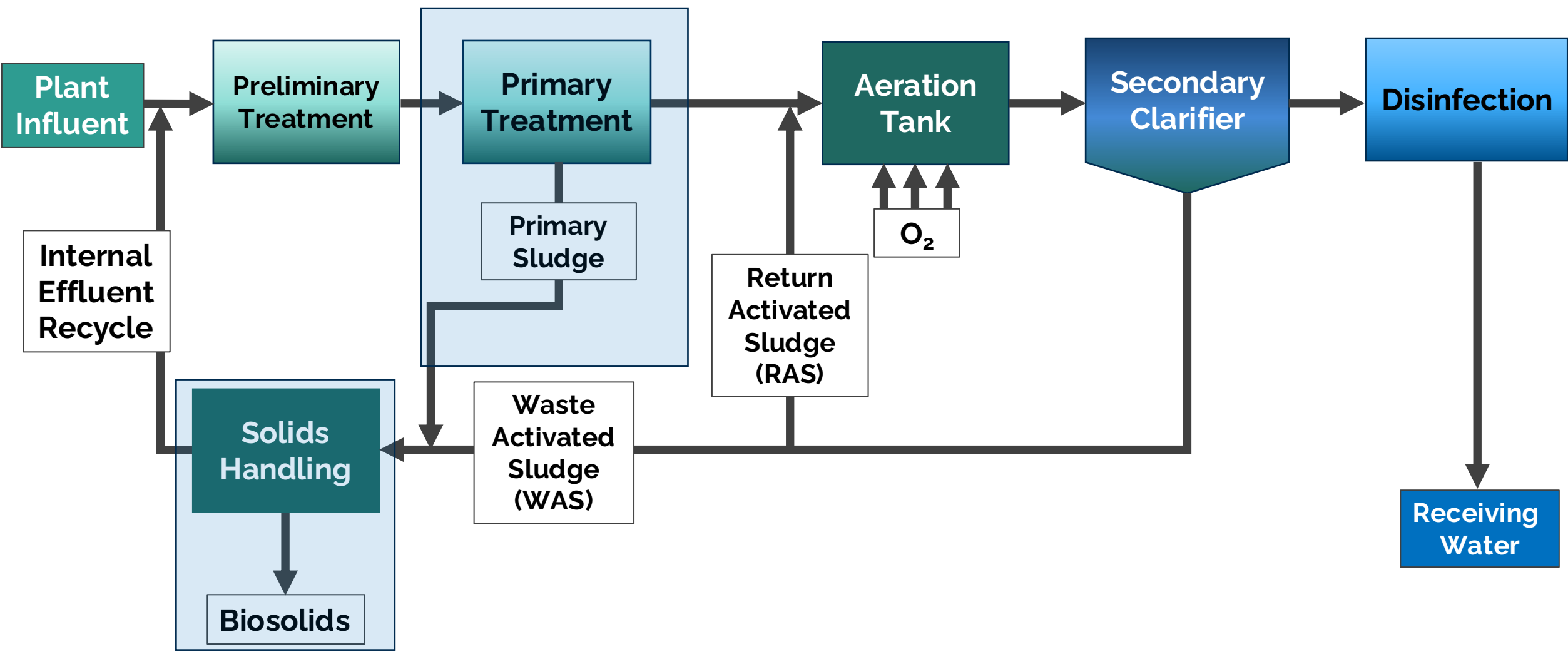


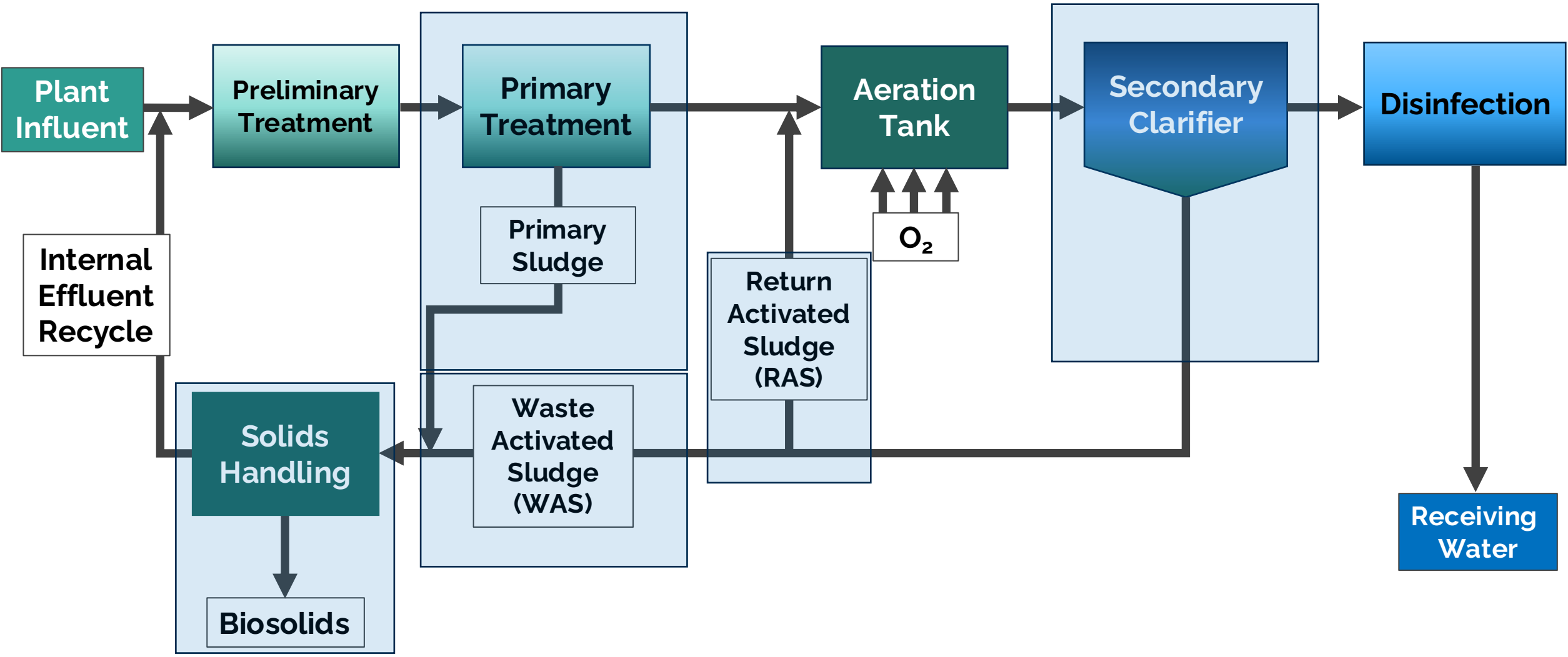
Everything downstream depends on the headworks performing well.

The Wastewater Treatment Train

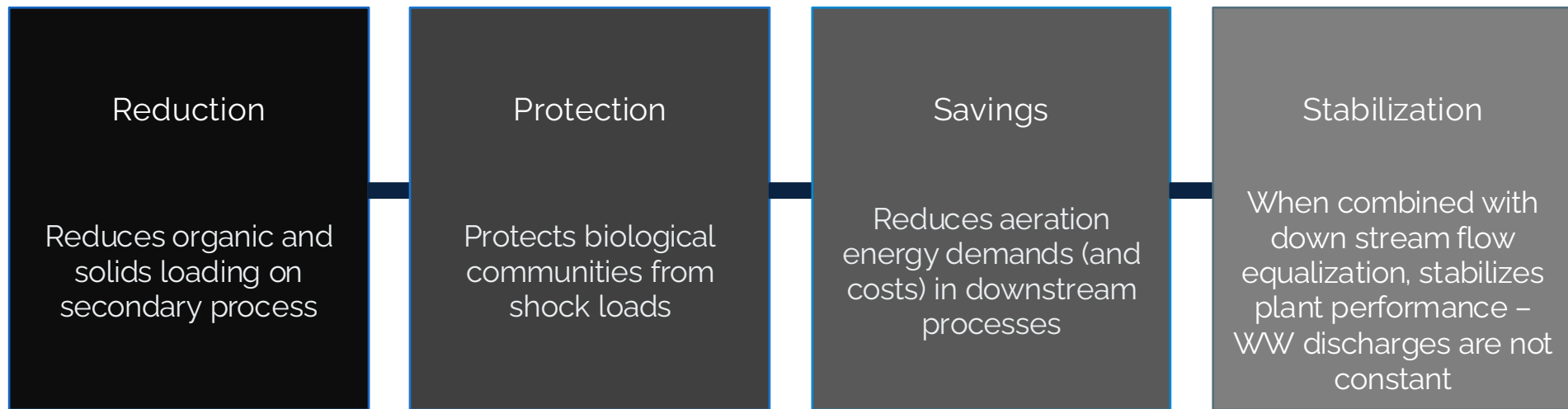


Removing biosolids through sedimentation, clarification, (and disposal of sludge)





A Typical Primary Treatment Matters



Primary treatment uses sedimentation to remove most of the biosolids left after preliminary treatment

Why Primary Treatment Matters

TSS Removal

50–70%

Under normal conditions, well-operated

BOD Removal

25–40%

Under normal conditions, well-operated

Removal rates are significant and reduce loads on later treatment stages

Regulatory Context

Clean Water Act

Establishes the federal framework for wastewater treatment standards across the United States.

NPDES Permits

Facility-specific permits set your effluent limits. Accurate flow reporting and treatment performance are direct requirements.

State Programs

State discharge permits also have specific effluent limits and requirements for solids handling. Your state may require headworks as part of facility design standards. Requirements vary — know yours.

As is the case with Headworks performance, effective primary treatment performance is foundational to meeting permit limits — it's not optional, it's expected.

Section 3: Principles of Gravity Settling

Sedimentation • Flocculation • Floatation (the Opposite of Sedimentation)



How Settling Works: Stoke's Law

$$V_s = g(\rho_s - \rho_f)d^2 / 18\mu$$

Settling Velocity Formula

Key Takeaway: BIGGER +
DENSER particles in WARMER
water = FASTER settling

g

Gravitational acceleration
(constant)

$\rho_s - \rho_f$

Density difference between
particle and fluid

d^2

Particle diameter (squared –
size matters most!)

μ

Dynamic viscosity of the fluid
(affected by temperature)

Types of Settling – What Happens in Clarifiers

Type I	Discrete Particle:	Individual particles fall at constant velocity – the idealized model (Stokes' Law applies directly).
Type II	Flocculent Settling:	Particles collide and combine as they fall, forming larger flocs that settle faster. THIS is what happens in primary clarifiers.
Type III	Zone / Hindered:	High solids – particles settle as a mass. More relevant to secondary clarifiers and thickeners.
Type IV	Compression:	Bottom layers compress under weight above. Relevant to sludge thickening operations.

Sedimentation is Analogous to Snowfall



Look at What Happens in a Snowglobe



Horizontal Flow Design Criteria for Sedimentation

Item	Typical Horizontal Grit Channel	Typical Primary Settling Tank
Detention Time	1 to 3 min	2 to 3 hours
Horizontal Flow Velocity	0.7 to 1.4 ft/s	1 to 2 ft/min
Specific Gravity of Particles	~ 2.5 to 2.6	<1 to 1.25

Primary Sedimentation (a little math)

Targeting particles with Specific Gravity between **1.01 and 1.05**

Assume settling rate of 0.167 ft/min or 0.0028 ft/sec

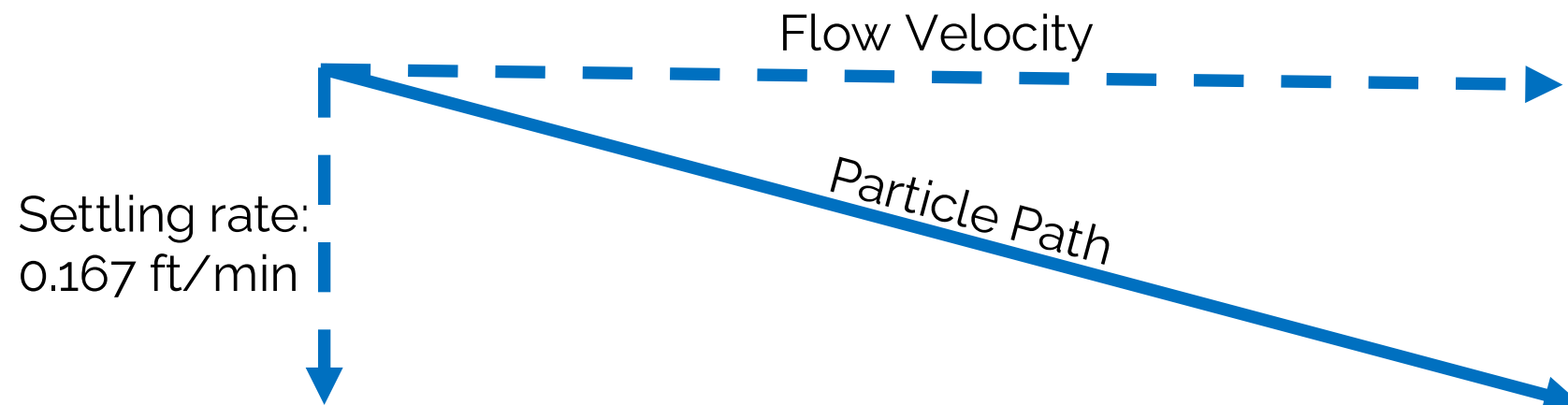
Assume horizontal flow velocity of 2 ft/min or 0.033 ft/sec

Basin is 200 ft long with 10 ft of water in it

$$\text{settling time} = \frac{\text{depth}}{\text{settling rate}}$$

$$\text{settling time} = \frac{10 \text{ ft}}{0.167 \text{ ft/min}}$$

$$\text{settling time} = 60 \text{ min}$$



Primary Sedimentation

Targeting particles with Specific Gravity between **1.01 and 1.05**

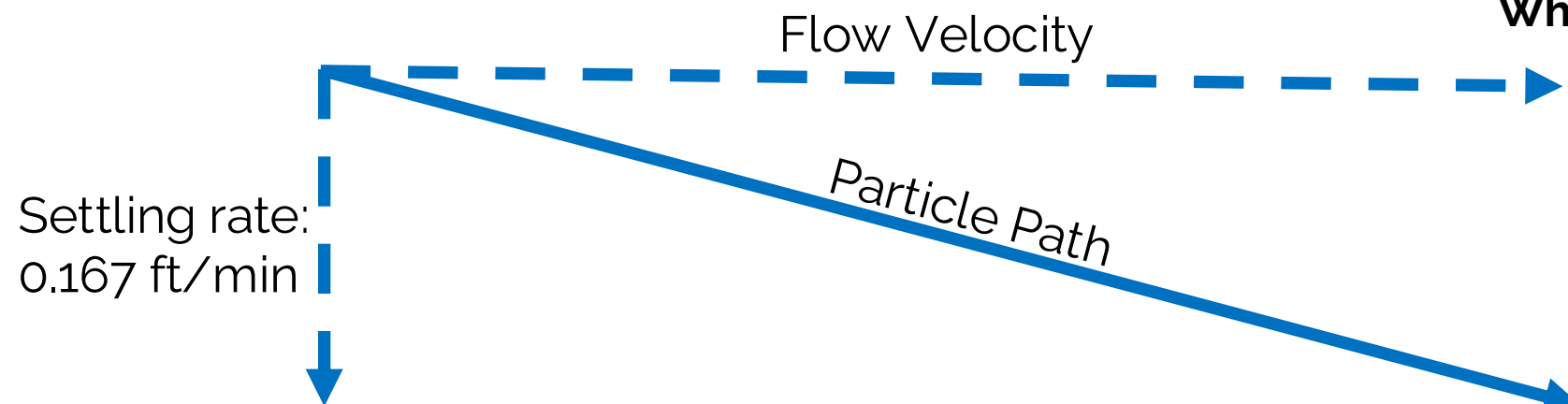
Assume settling rate of 0.167 ft/min or 0.0028 ft/sec

Assume horizontal flow velocity of 2 ft/min or 0.033 ft/sec

Basin is 200 ft long with 10 ft of water in it

settling time = 60 min

What's the horizontal distance traveled?



horizontal velocity = 2 ft/min

$$velocity = \frac{length}{time}$$

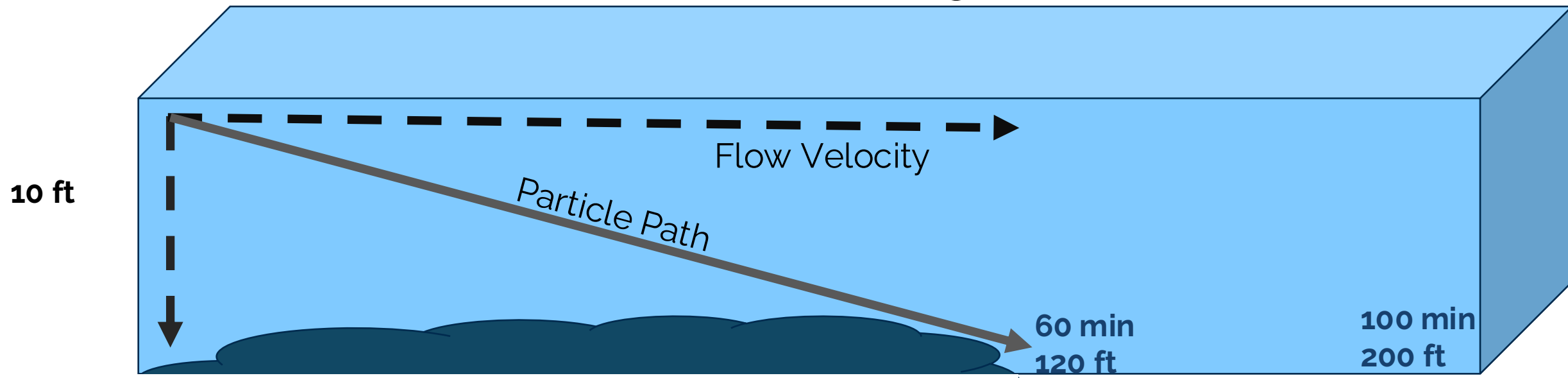
$$velocity \times time = length$$

$$2 \frac{ft}{min} \times 60 \cancel{min} = 120 ft$$

Primary Sedimentation

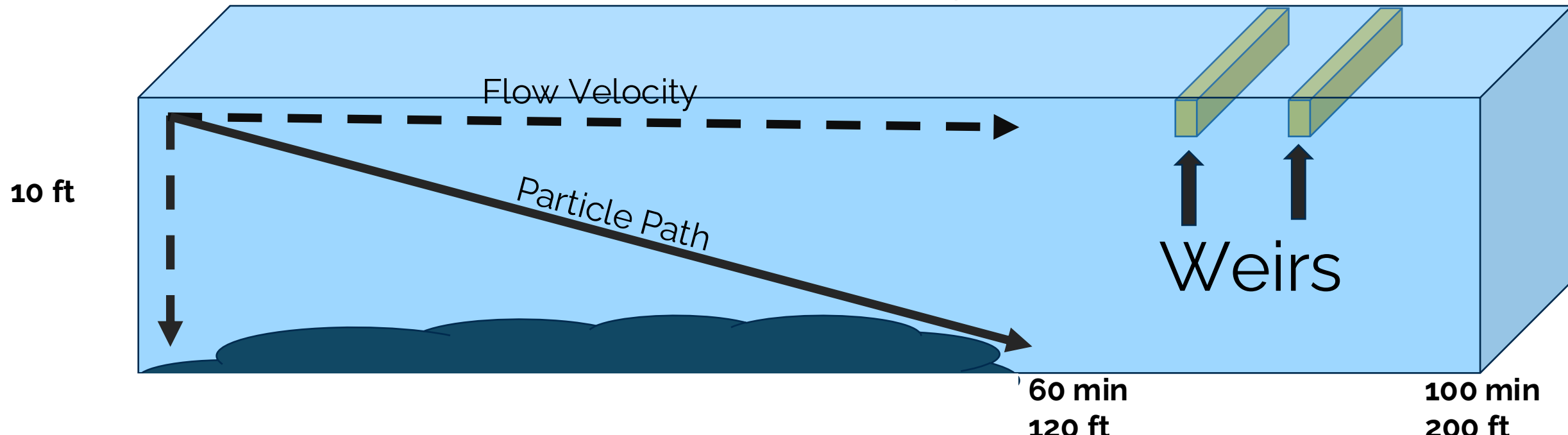
So, what does that mean?

Particles settling at this rate will settle within first 120 ft of 200 foot tank (first 60% from inlet) and water exiting will be clearer



Primary Sedimentation

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Floataction (the Opposite of Sedimentation)



SCUM

Scum & Floatables Removal

What Floats?

Oils, fats, greases, and low-density materials (plastics, soaps) don't settle — they rise to the water surface and must be actively removed to prevent carryover into the effluent.

Scum Baffle

A submerged or partially submerged barrier near the effluent end that traps surface material and prevents it from flowing out with clarified water.

Skimmer Arm

Slowly sweeps the water surface, pushing accumulated scum toward a collection box or trough for removal and co-processing with primary sludge.

Skimmer Speed

Too fast = surface turbulence that disrupts settling. Too slow = thick crust that may freeze or become unmanageable. Finding the right balance matters.

Scum Disposal

Typically co-processed with primary sludge — pumped to digesters or combined with the solids stream for downstream handling.

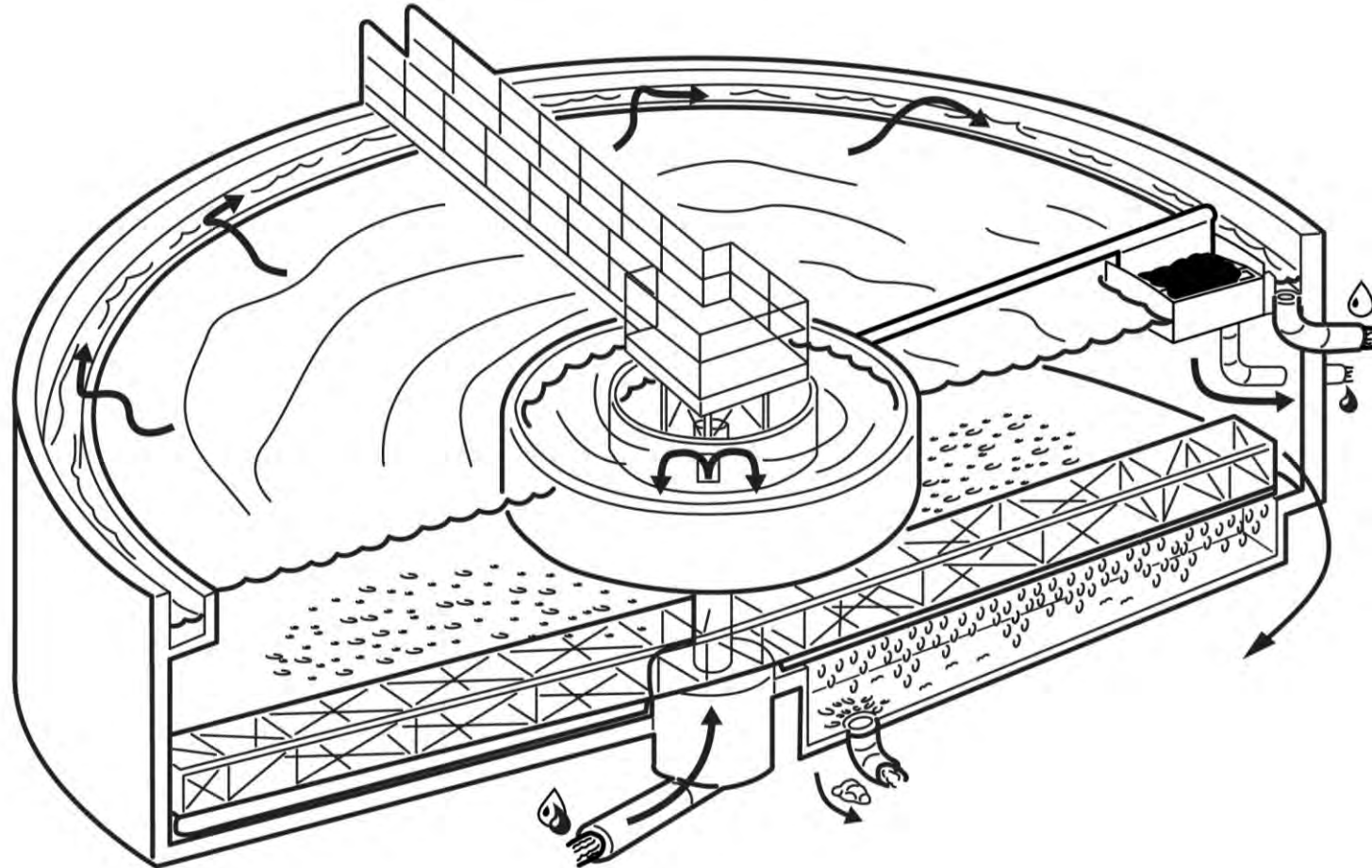
Section 4: Primary Clarifier Configurations & Equipment

Circular • Rectangular • Alternative Designs



Circular

- Most common configuration in the US
- Typical diameters: 20–200 ft
- Center-feed or peripheral-feed designs
- Rotating sludge scraper mechanism
- Advantages: simpler mechanism, lower maintenance, good for variable flows
- Better hydraulic performance for smaller facilities



CIRCULAR CLARIFIER COMPONENTS



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Circular Clarifiers

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Rectangular

- More common at larger or older facilities
- Chain-and-flight sludge collection mechanism
- Better land-use efficiency for very large flows
- Easier to cover for odor control — rectangular roof structures are simpler
- Advantages: good for large plants, industrial applications
- Key challenge: achieving even flow distribution across full basin width



Key Components in Depth

Feed Well / Inlet

Dissipates incoming flow energy and distributes flow evenly. A damaged feed well creates turbulence from the very start.

Effluent Weirs & Launderers

Must be level — even slight unevenness causes short-circuiting and reduces effective basin volume. Check regularly.

Scum Baffles & Skimmers

Trap floatable material and sweep it to collection boxes. Speed must be balanced to avoid turbulence.

Sludge Scrapers / Flights

Move settled solids from the floor toward the hopper for withdrawal. Regular inspection of wear is essential.

Sludge Hopper & Drawoff

Collect and transport withdrawn sludge. Frequent blockages signal a scheduling or grit problem.

Torque / Shear Limiter

Protects the drive unit from overload. Frequent trips are a warning sign — investigate the root cause immediately.

Chemical-Assisted Primary Treatment (CEPT)



Performance: TSS removal 80–90% | BOD removal 50–60%

When Used

Wet weather events, industrial influent, phosphorus removal requirements, or when primary performance needs a boost.

Trade-offs

Chemical cost, need for storage and feed systems, and sludge volume increase (up to 2×) must be factored into overall solids management.

Applications

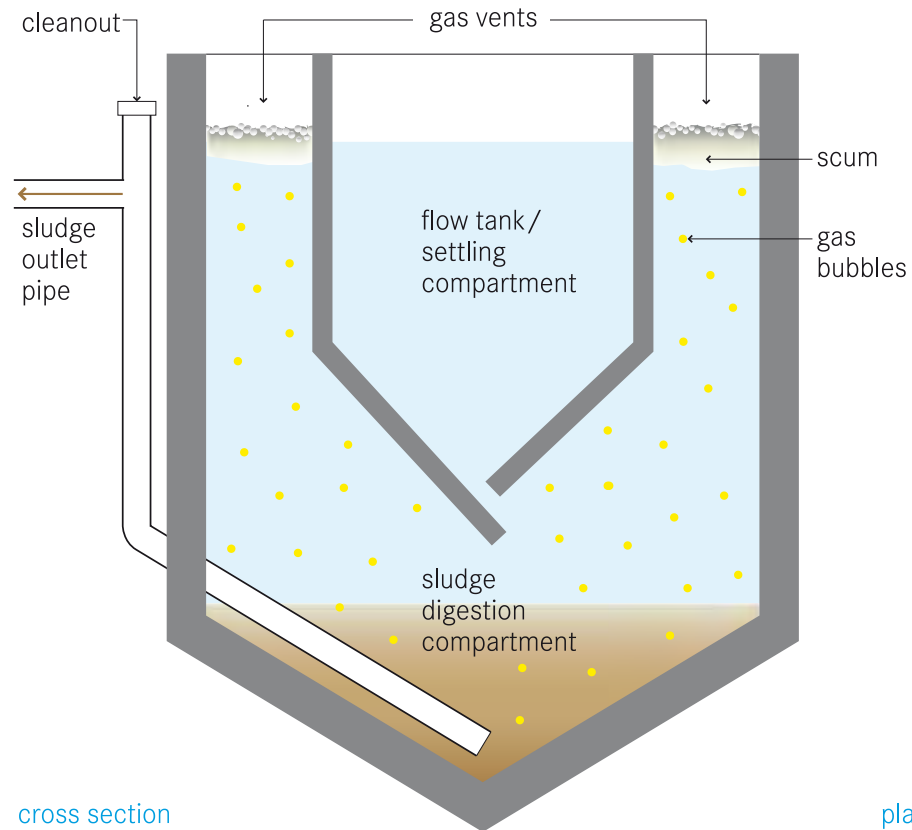
Some facilities use CEPT seasonally or on-demand during high-flow conditions. Others use it continuously for phosphorus compliance. Phosphorus removal rates can be as high as 90%

Alternative & Specialty Configurations

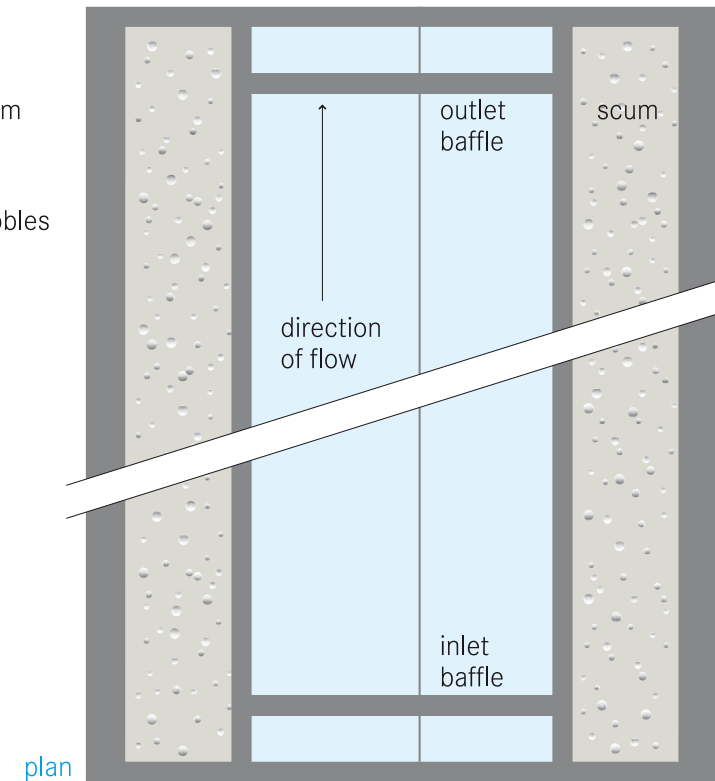
Imhoff Tanks

Small Communities

- Two-zone design — settling chamber above, anaerobic digestion chamber below.
- No energy or mechanical sludge pumping required.
- Limited capacity and performance.



cross section



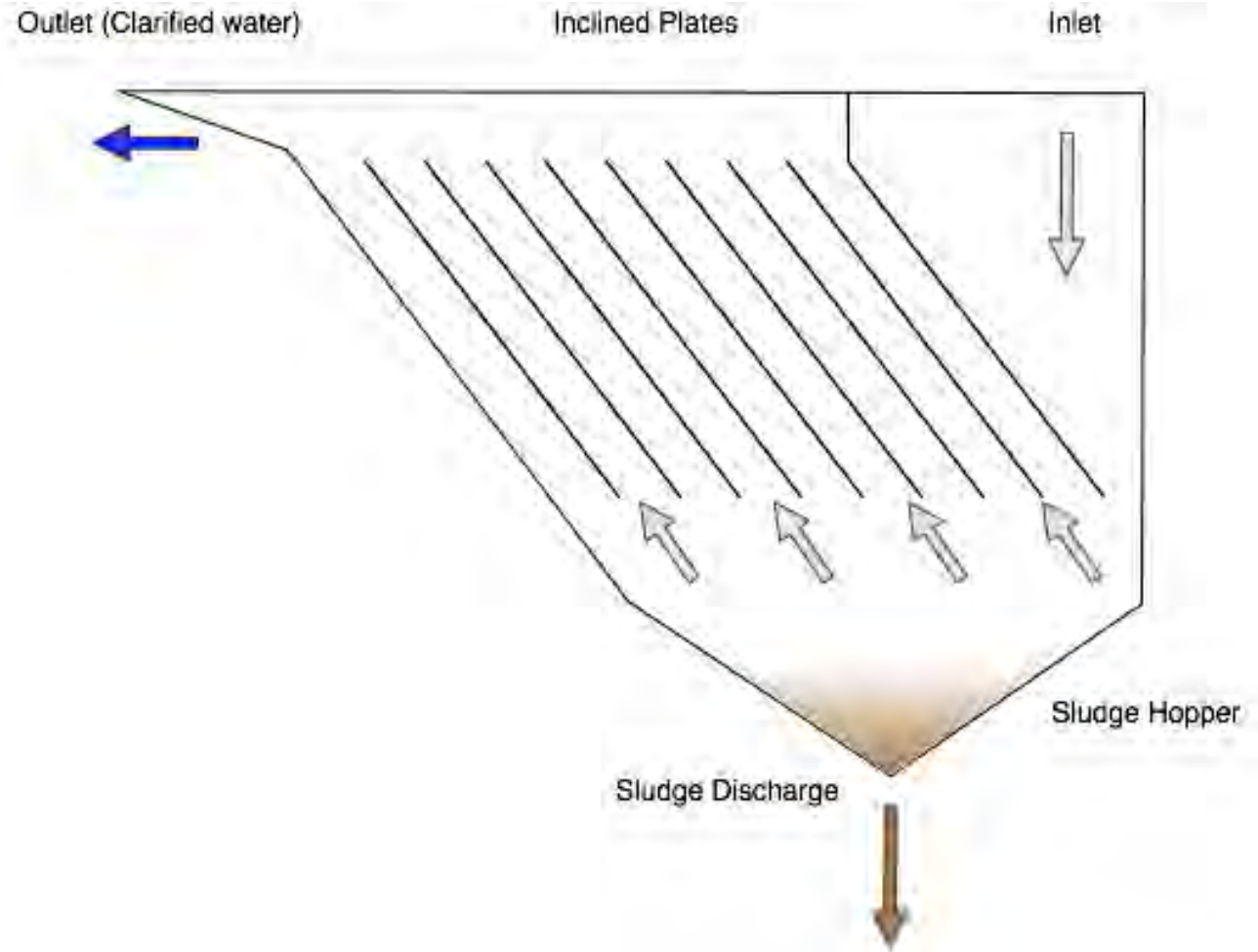
plan

Alternative & Specialty Configurations

Lamella / Plate Settlers

High-Rate Alternative

- Inclined plates dramatically increase effective settling area without adding tank volume.
- Handles 3-5× the flow of conventional clarifiers per footprint
- Ideal for expansion projects.



Alternative & Specialty Configurations

Package Plant Primaries

Small/Rural Facilities

- Pre-manufactured or built on site compact units,
- Often combined with secondary treatment.
- Appropriate for facilities with limited flows where conventional construction is cost-prohibitive.



Secondary Clarification Uses The Same Principles



Section 5: Operational Parameters & Performance Monitoring

Key Parameters • Performance Targets • Factors Impacting Efficiency



Key Operational Parameters

Parameter	Formula	Typical Range	If Exceeded...
Surface Loading Rate (SLR)	$\text{Flow (gpd)} \div \text{Surface Area (ft}^2\text{)}$	300–1,200 gpd/ft ² avg	Particles carried out before settling; low rates can result in excessive detention time & septicity
Detention Time (DT)	$\text{Volume (gal)} \div [\text{Flow Rate (gpd)} \times \text{d}/24\text{hrs}]$	2–3 hours target	Insufficient settling time; reduced removal efficiency
Weir Loading Rate	$\text{Flow (gpd)} \div \text{Weir Length (ft)}$	10,000–20,000 gpd/ft	Near-weir turbulence, solids resuspension, short circuiting
Removal Efficiency	$[(C_{\text{in}} - C_{\text{out}}) \div C_{\text{in}}] \times 100$	TSS: 50-70% BOD: 25-40%	Low removal efficiency will increase loads downstream

Expected Removal Efficiency Calculation

Typical Parameters for BOD and TSS removal:

- **50 to 70% of TSS**
- **25-40% of BOD**

$$R = \frac{t}{a + bt}$$

R = expected removal efficiency
 t = nominal detention time (hrs)
 a, b = empirical constants

Item	a	b
BOD	0.018	0.020
TSS	0.0075	0.014

$$R_{BOD} = \frac{2}{0.018 + 0.020(2)} = 35.5\% \quad R_{TSS} = \frac{2}{0.0075 + 0.014(2)} = 56.3\%$$

Typical Performance Targets

TSS Removal

50–70%

Under normal conditions, well-operated

BOD Removal

25–40%

Under normal conditions, well-operated

Reduces Performance:

High hydraulic loading · Cold temperatures · Industrial shock loads · Equipment failures · Infrequent sludge withdrawal

Improves Performance:

Chemical addition (CEPT) · Consistent sludge withdrawal · Regular maintenance · Good preliminary treatment performance



Factors Affecting Settling Efficiency

Surface Loading Rate

Too high → not enough time for particles to settle before being carried out

Detention Time

Target 3–3 hours; peak flows reduce effective DT significantly

Turbulence & Short-Circuiting

Disrupts settling paths; flow may bypass portions of the clarifier volume

Water Temperature

Cold water is more viscous — settling slows in winter; plan seasonally

Particle Characteristics

Small particles with density just above that of water. Size, density, and origin all affect settling velocity directly (Stokes' Law)

Influent Variability

Industrial inputs or wet weather events can change particle properties rapidly

Temperature – Seasonal Settling Rate Changes

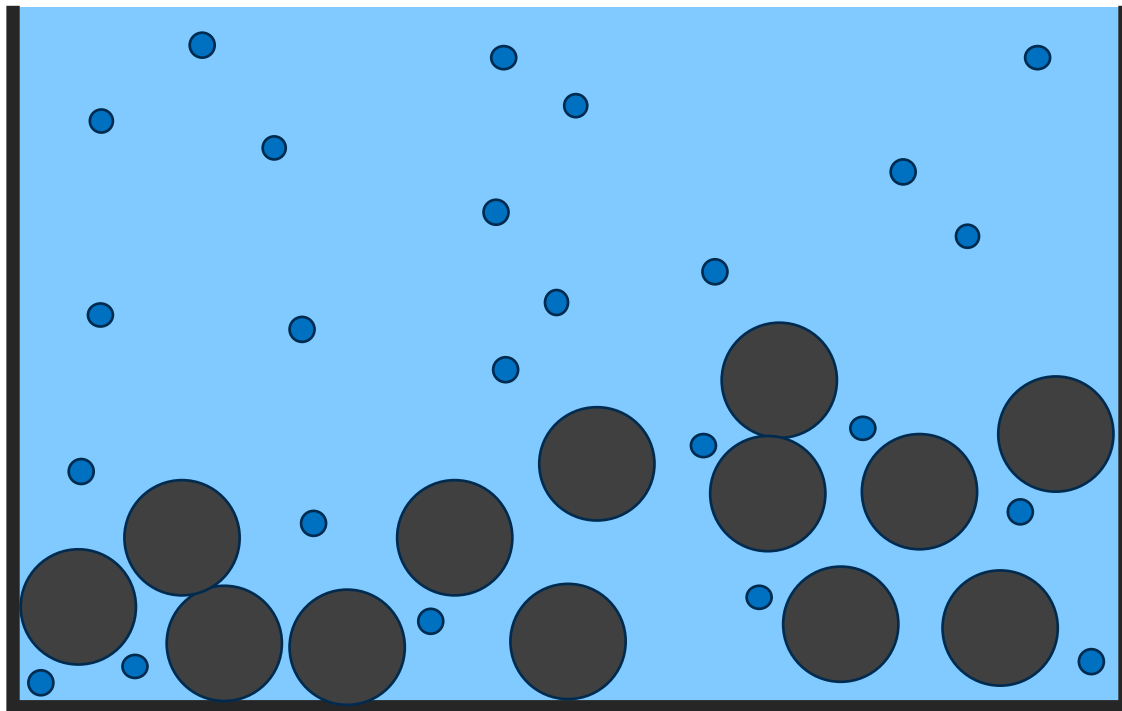


Temperature – Easier Settling in Warm Weather

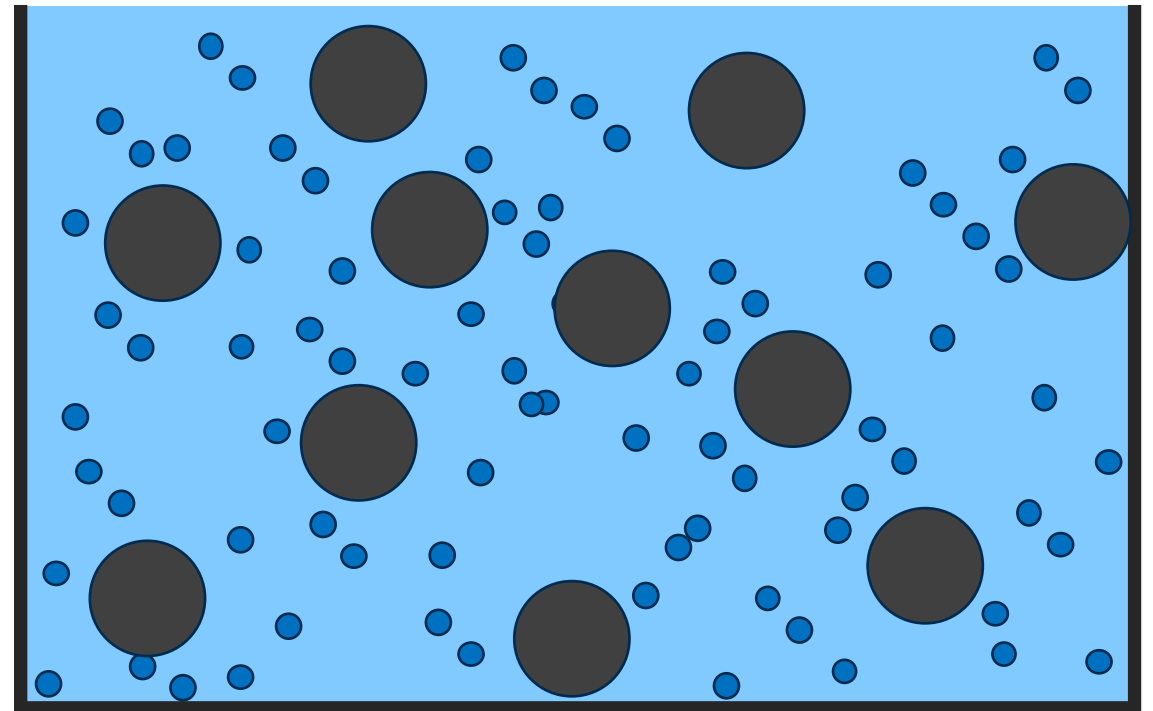
Particles tend to settle easier in warmer water – because it becomes less viscous

● = Water Molecule

● = Particles



Warm water 100 Degrees F

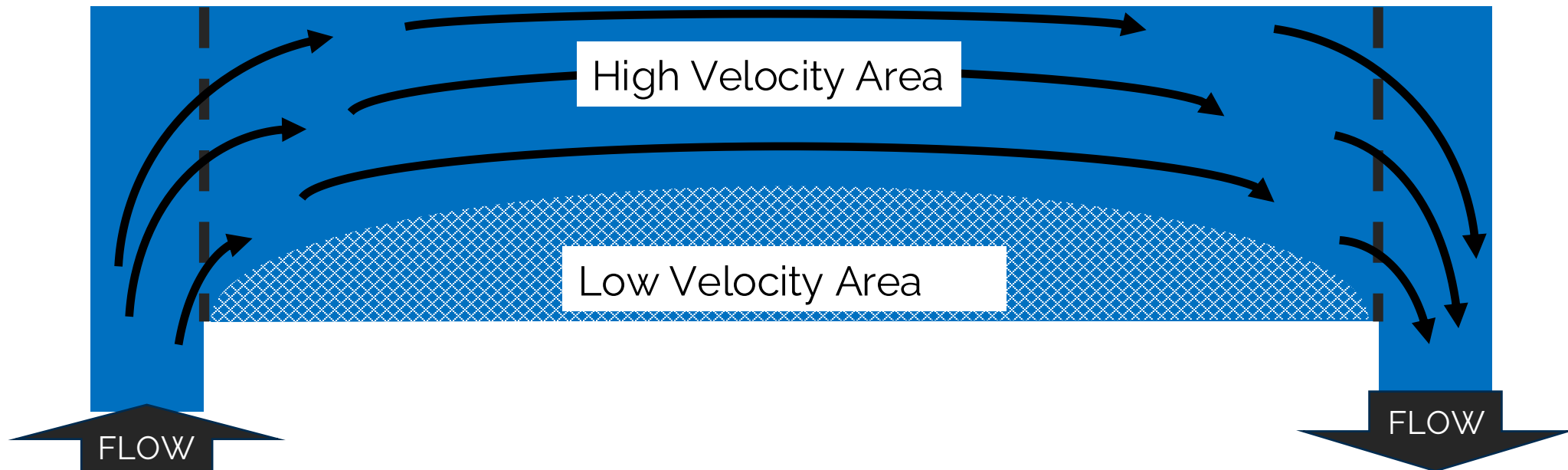


Cold water 40 Degrees F

Short Circuiting

When water isn't evenly disbursed across the tank area and velocity is much faster in some parts than others

In the high velocity area detention time is reduced and particles escape before settling; in the low velocity area septic conditions and odor can arise.

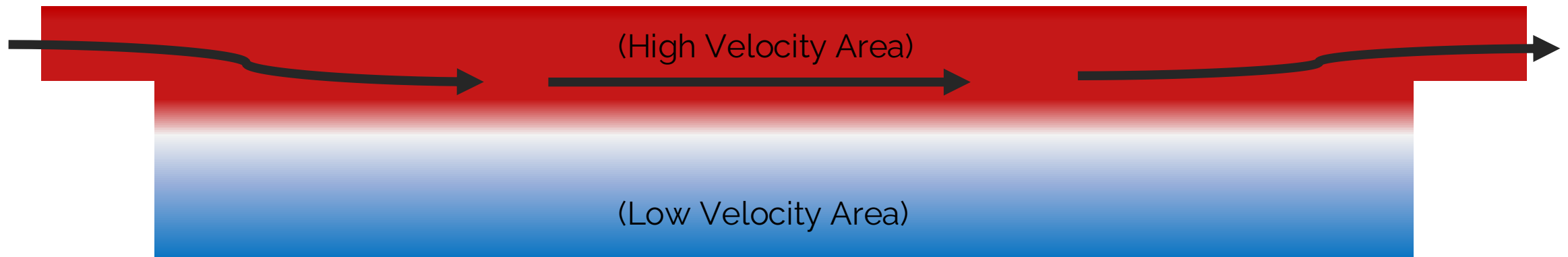


Short Circuiting - Temperature

Temperature stratification can cause short circuiting too.

Cold water is denser, warmer water tends to float on top.

If the basin is cold and the influent is very warm, it may flow along the top and cause septic conditions at the bottom

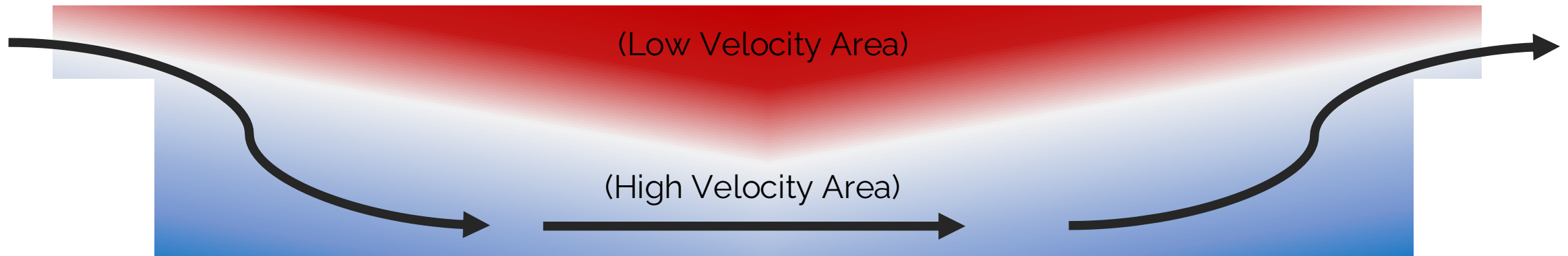


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Cold water is denser, warmer water tends to float on top.

If the basin is warm and the influent is very cold, it may flow along the bottom, and cause septic conditions at the top



Diagnosing Poor Performance

Effluent Carryover

Cause: Hydraulic overloading (check SLR & DT first) or damaged mechanism components

Action: Verify DT and SLR are within design range; inspect feed well and weirs; evaluate flow equalization

Short-Circuiting

Cause: Density currents, wind, or damaged inlet structure creating preferential flow paths

Action: Dye tracer test to map flow; inspect feed well; check baffles

Rising Sludge

Cause: Anaerobic conditions in hopper — sludge sitting too long produces gas that floats flocs

Action: Increase sludge withdrawal frequency immediately; review withdrawal schedule

Excessive Scum

Cause: High fats, oils, and greases from food service or industrial contributors

Action: Investigate influent sources – evaluate pre-treatment options; increase skimmer frequency; evaluate CEPT

Section 6: Routine Maintenance Practices

Daily • Weekly • Monthly • Quarterly • Annual



Recordkeeping Best Practices

- Log every inspection — including 'no issues noted' entries
- Track: flow rate, SLR, DT, sludge blanket depth, withdrawal volumes
- Log all sampling results: influent and effluent TSS and BOD
- Date and sign all entries — regulatory inspectors will review these
- Flag anomalies and document corrective actions taken
- Trend data monthly — graphs reveal gradual changes invisible day-to-day

Why Records Matter

- Regulatory: Compliance reports and inspection readiness
- Diagnostic: Trends visible in graphs, invisible day-to-day
- Legal: Documentation of due diligence
- Planning: Data drives preventive maintenance scheduling
- Institutional: Knowledge preserved when staff turn over

Example Maintenance & Monitoring

DAILY

- Check and record sludge blanket depth
- Inspect scum removal and skimmer arm; clear debris
- Observe effluent weirs for even flow and short-circuiting
- Verify drive unit — noise, torque/ampage, rotation
- Record influent/effluent flow, TSS, BOD, color, odor

WEEKLY

- Clean effluent weirs and baffles (algae, grease, solids)
- Lubricate drive unit, collector chains, and sprockets
- Exercise sludge pumps, valves, and telescoping valves
- Adjust scum equipment & scum pump cycle times
- Inspect handrails, walkways, and safety equipment

MONTHLY

- Inspect drive unit oil level; sample oil if due
- Check chain tension and flight/scrapper condition
- Calibrate flow meters
- Inspect and clean influent gates and splitter boxes
- Review sludge pumping rates and blanket trends

Example Maintenance & Monitoring

QUARTERLY

- Drain and inspect scum pit, sludge hopper, and wet wells
- Change drive unit oil and inspect gear wear
- Service sludge pumps — impellers, seals, and packing
- Evaluate TSS/BOD removal vs. design criteria
- Inspect concrete above waterline for cracks and spalling

ANNUAL

- Drain, clean, and fully inspect clarifier internals
- Inspect and recoat corrosion protection as needed
- Full drive unit service — seals, torque overload testing
- Survey weir levelness and adjust as needed
- Review annual performance; update O&M and capital plans

These are examples. Exact tasks and intervals should always be cross-referenced with your specific equipment manufacturer's O&M manual and your state's operator requirements, since some tasks (especially drive unit servicing) vary by equipment type

Process Control Tests for Primary Clarifiers

Test	Frequency	Location	Common Range
Dissolved Oxygen (DO)	Daily	Effluent	0-3 mg/L
pH	Daily	Influent Effluent	6.5-8.0 6.5- 8.0 (Depends on region, water supply and discharges into collection system)
Temperature	Daily	Influent	50F to 80F (Depends on region, water supply and discharges into collection system)
Biological Oxygen Demand (BOD)	At least daily (composite)	Influent Effluent	150-400 mg/L 50-150 mg/L
Total Suspended Solids (TSS)	At least daily (composite)	Influent Effluent	150-400 mg/L 50-150 mg/L

Common Failure Modes & Early Warning Signs

Failure Mode	Warning Sign	Possible Root Cause / Response
Torque Limiter Trips	Mechanism stops; alarm activates	Excess sludge buildup, grit, or foreign object. Investigate & clean before restarting.
Drive Unit Failure	No mechanism movement; no cleaning cycle	Ignored lubrication schedule or age. Build proactive and preventive maintenance into your schedule.
Flight / Scraper Wear	Reduced sludge collection efficiency	Gradual wear caught at annual inspection; sudden from grit or debris impact.
Scum Valve Blockage	Scum accumulates; skimmer ineffective	Cold weather, thick grease, or infrequent operation. Exercise valves regularly.
Drawoff Line Blockage	Sludge withdrawal impaired or stopped	Grit, rags, or scale. Keep runs short and direct; know your cleanout access points.

Safety at the Primary Clarifier



Primary clarifiers can be dangerous. The hazards below demand strict adherence to safety procedures.

Falls, Drowning & Entanglement

- Open tanks with low or no railings present serious fall hazards; clarifier water can have currents pulling toward sludge withdrawal points. Ensure that floatation devices and other PPE are available
- Sludge collector mechanisms, drive shafts, and chain-and-flight assemblies can entangle clothing, tools, or limbs — even at slow rotation speeds.
- Algae and grease on weirs, walkways, and launders make slip hazards severe, especially in wet weather.

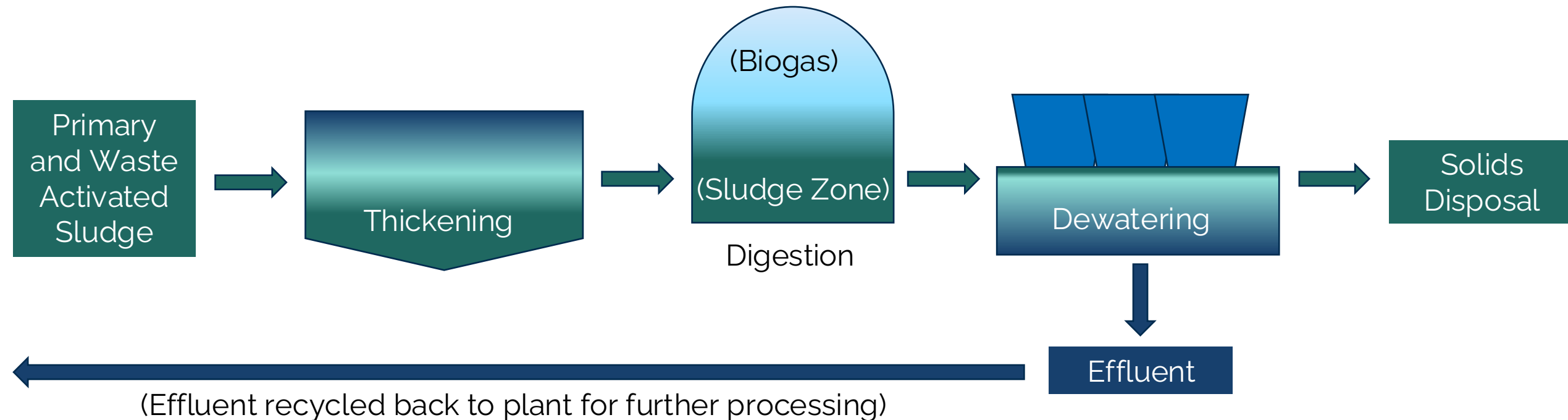
Hazardous Gasses & Confined Spaces

- H₂S accumulates in scum pits, sludge hoppers, sample wells, and below covered launders. Heavier than air, odor-deadening, and rapidly fatal at high concentrations.
- Methane and oxygen-deficient atmospheres can also be present in any below-grade clarifier structure.
- Confined space entry requires permits, atmospheric monitoring, trained attendants, ventilation, and a documented rescue plan — no exceptions.

Mechanical, Electrical & Biological

- Electrical shocks from live equipment can kill you. Lockout/tagout is mandatory before any work on drives, pumps, gates, or scrapers — including for clearing jams or rags.
- Pinch points exist at sprockets, chain returns, and skimmer arms. Never reach into a moving mechanism to clear debris.
- Pathogen exposure from raw wastewater requires gloves, eye/face protection, and immediate hand washing. Avoid splashing during sampling.

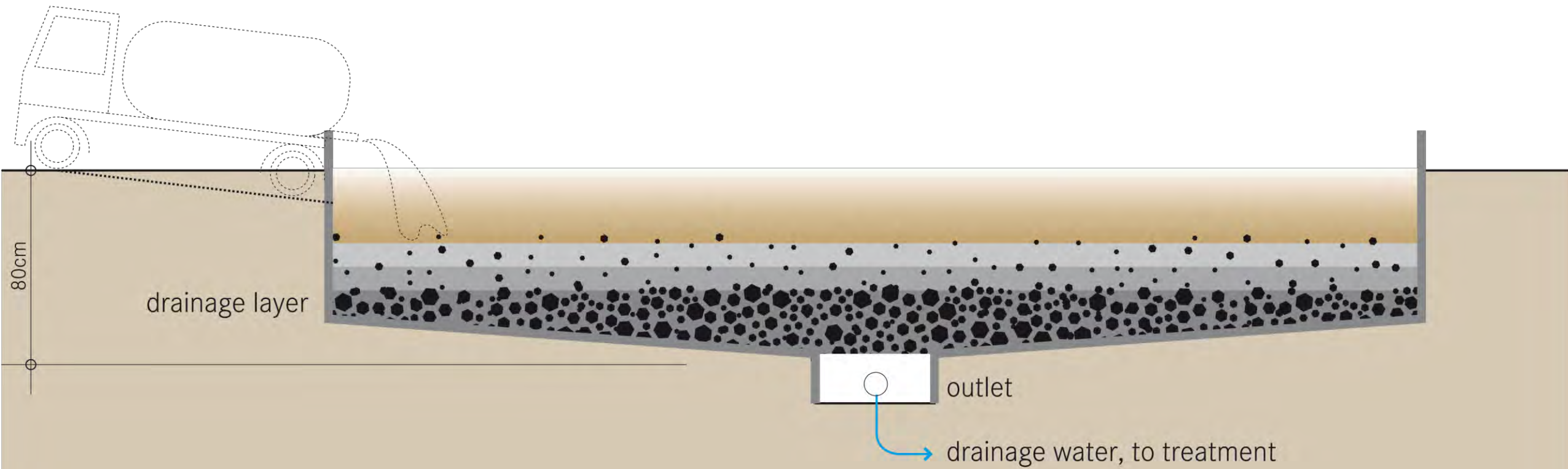
A Typical Solids Removal Process Flow



Solids must be removed or treatment basins will fill up and/or go septic .



Sludge Drying Bed



Sludge Drying Bed



Section 7: Why It All Matters – Plant-Wide Benefits

Key takeaways – Q & A



Protecting the Biological Process

Aeration Basin Stability

Lower BOD loading = more stable dissolved oxygen management and more consistent biological community behavior.

Secondary Clarifier Load

Lower TSS carryover reduces solids burden on secondary clarifiers and lowers the risk of solids washout events.

Filamentous Bulking Risk

Consistent F:M ratio reduces conditions that favor filamentous organisms — the cause of bulking sludge that won't settle.

The Bottom Line for Operators:

Operators who run stable primary treatment give their biological system a consistent diet — and biology doesn't like surprises. Good primary performance is upstream protection for everything downstream.

Energy & Cost Impacts

50–60%

of total plant energy
might be used for aeration

Every pound of BOD removed in primary treatment is a pound your blowers don't have to process in secondary.

- Rule of thumb: ~1 lb O₂ required per lb BOD removed in secondary treatment
- Improving primary BOD removal by 50 mg/L at a 1-MGD plant saves ~417 lbs BOD/day from secondary aeration
- Over a year, this represents significant blower runtime and electricity cost reduction
- Primary treatment is not just a regulatory requirement — it's an energy cost management tool

Biosolids Management Benefits

Primary Sludge Quality

3–8% solids content — significantly easier to thicken and dewater than secondary sludge (0.5–1.5% solids). Requires less energy to process.

Blend Ratio Optimization

Blending primary and secondary sludge improves overall dewaterability. More primary sludge = better blend ratio for downstream handling.

Digester Performance

Primary sludge is high in volatile solids — excellent biogas feedstock. Better primary performance = more biogas yield if anaerobic digesters are in use.

Regulatory Compliance & Community Confidence

Wet Weather Buffer

Primary treatment and downstream flow equalization tanks can absorb some of the surge during high-flow events before it reaches secondary — protecting your permit compliance during the most challenging conditions.

Compliance Documentation

Consistent primary monitoring data is part of compliance reporting. A well-documented record demonstrates due diligence and builds a strong permit compliance history.

Infrastructure Investment

Well-maintained primary infrastructure means lower risk of costly emergency repairs, fewer unplanned outages, and more predictable capital planning.

Community Trust

Your ratepayers and neighbors care about what goes into local waterways. Reliable, compliant operation builds public trust — and failures erode it in ways that extend well beyond the plant fence line.

Section 8: Conclusions, Key Takeaways, Q&A

Wrapping it all up



Key Takeaways

01

Primary treatment removes 50–70% TSS and 25–40% BOD — an essential foundation for everything downstream.

02

Gravity settling is simple in principle but is sensitive to hydraulics, temperature, & particle characteristics.

03

Equipment, hydraulics, and operations all interact — a failure in any area affects the others.

04

Consistent monitoring and recordkeeping are the foundation of good performance and regulatory compliance.

05

Good primary performance protects your biology, reduces energy costs, and supports permit compliance.

06

The best operators treat primary treatment with the same rigor as secondary and tertiary systems.

Practical Next Steps

For Operators

- Calculate your current SLR and DT and other parameters — compare to your design specifications
- Review your sludge withdrawal schedule — is it based on actual blanket depth data?
- Make sure your O&M Manual is up to date
- Audit your monitoring frequency and compare to today's recommendations
- Make sure you're following safety protocols and logging relevant and required data

For Managers

- Request a primary treatment performance summary at your next staff meeting
- Review your PM schedule for primary clarifier mechanisms and drive units
- Evaluate your preventive maintenance budget against reactive repair history
- Start assessing CIP needs based on O&M

For Board Members & Leadership

- Ask for a performance summary — TSS removal, BOD removal, any maintenance events
- Ask how primary treatment performance connects to secondary energy costs
- Ensure infrastructure plans include primary treatment equipment lifecycle costs

Funding Opportunities for Improvements

State Revolving Fund (SRF)

Low-Interest Loans

EPA Clean Water SRF — low-interest loans for eligible wastewater infrastructure. Headworks improvements almost always qualify.

USDA Rural Development

Grants & Loans

Water & Environmental Program — particularly valuable for rural utilities. Offers both grant and loan financing for water and wastewater projects.

State-Specific Programs

Varies by State

Many states have additional funding mechanisms beyond federal programs. Contact your state program office early in the planning process.

Start conversations with your state SRF program office early — before designs are finalized. Favorable financing can significantly reduce the burden on your ratepayers.



Q & A

CONTACT INFORMATION



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