Water Quality Within RAS
Water Quality Within RAS

- Water quality within RAS depends upon the water flow (Q) and efficiency of waste removal ($f_{rem}$) at each unit process:
  - Solids capture
    - filtration
    - Sedimentation
    - ozonation
  - Carbon dioxide removal
    - aeration
  - Ammonia removal
    - biofiltration
Water Quality Within RAS

- Treatment efficiency ($f_{rem}$) controls water quality!
  - Not system exchange rate!

**EXAMPLE:** @ $f_{rem} = 0.8$, $R = 0.8$ to $0.99$

\[
[waste]_{tank} = \left\{ \frac{1}{1 - R + (R \cdot f_{rem})} \right\} \cdot \frac{P_{waste}}{Q} = \{1.19 \text{ to } 1.25\} \cdot \{\text{single pass outlet conc.}\}
\]
Water Quality Within RAS

- Treatment efficiency ($f_{rem}$) controls water quality!

Best water quality if $f_{rem} \geq 60\%$
Water Quality Within RAS

BMP #1:

select unit processes that provide high waste removal efficiencies within coldwater RAS!

- Treatment efficiency ($f_{rem}$) $\geq$ 0.6
Water Quality Within RAS

BMP #1.2:

select *fluidized-sand biofilters* to remove $\geq 80\%$ of TAN each pass through coldwater RAS
Design, Management, and Applications of Fluidized Sand Biofilters

Steven Summerfelt
Freshwater Institute, Shepherdstown, WV
Outline

- Introduction
- Mechanisms for Flow Injection
- Fluidization Fundamentals
  - Sand selection guidelines
  - Calculating pressure drop
  - Calculating bed expansion
  - Experimental technique to measure bed expansion
  - Effect Of biofilm growth on fluidization
Outline

- FSB Design and Performance Criteria
  - Nitrification rate and ammonia removal efficiency
  - CO\textsubscript{2} production and O\textsubscript{2} consumption
- FSB Operation and Management Practices
  - Managing bed growth
  - Managing flow & avoiding air bubbles
  - Mechanisms to unplug the flow distribution manifold
- Applications for salmonids
Introduction to FSBs

- FSBs treat dissolved wastes.
- FSBs appear cost effective for some large RAS:
  - specific surface area of sand is high
    - 4,000-20,000 m²/m³
  - cost of sand is low
    - $70-200 per m³ delivered
  - cost for surface area is low
    - $0.05-0.004/m²
Introduction to FSBs

- FSBs are compact.
- FSBs can treat small or large flows.
  - 3 to 190 L/s
  - 50 to 3,000 gal/min
FSB Can Be More Cost Effective

- FSB are about 5 times less expensive than comparable trickling filters

(Summerfelt & Wade, 1998, *Recirc Today*)

<table>
<thead>
<tr>
<th></th>
<th>Fluidized-sand biofilter #1</th>
<th>Fluidized-sand biofilter #2</th>
<th>Plastic media trickling filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow capacity, L/min</td>
<td>1,520</td>
<td>2,280</td>
<td>2,000</td>
</tr>
<tr>
<td>Design feed load(^d), kg/day</td>
<td>58</td>
<td>64</td>
<td>59</td>
</tr>
<tr>
<td>Media specific surface area, m(^2)/m(^3)</td>
<td>11,300</td>
<td>11,300</td>
<td>180</td>
</tr>
<tr>
<td>Design TAN removal rate, g/d/m(^2)</td>
<td>0.06</td>
<td>0.06</td>
<td>0.2</td>
</tr>
<tr>
<td>Media volume, m(^3)</td>
<td>2.5</td>
<td>2.7</td>
<td>49.0</td>
</tr>
<tr>
<td>Cost of media, $</td>
<td>380</td>
<td>415</td>
<td>20,600</td>
</tr>
<tr>
<td><strong>Total biofilter cost, $</strong></td>
<td><strong>$6,000</strong></td>
<td><strong>$5,500</strong></td>
<td><strong>$28,000</strong></td>
</tr>
</tbody>
</table>
FSB Appear to be Cost Effective at Large Scales

- Capital cost estimates associated with biofilter choice for a 454 ton/yr tilapia farm.

<table>
<thead>
<tr>
<th>(Timmons et al., 2000)</th>
<th>Farm Cost</th>
<th>Cost, $/kg/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBC</td>
<td>$668,000</td>
<td>$1.5</td>
</tr>
<tr>
<td>Trickling Biofilter</td>
<td>$620,000</td>
<td>$1.36</td>
</tr>
<tr>
<td>Pressurized Bead Filter</td>
<td>$296,000</td>
<td>$0.66</td>
</tr>
<tr>
<td>Conventional FSB</td>
<td>$124,000</td>
<td>$0.26</td>
</tr>
<tr>
<td>Cyclo Bio FSB</td>
<td>$76,000</td>
<td>$0.18</td>
</tr>
</tbody>
</table>
Flow Distribution Mechanisms

- Flow distribution methods vary, but are all important!

- false-floor w/ orifice distribution plate
  - orifices distributed across false-floor (controlling $\Delta P$)

- pipe-manifold w/ orifices on lateral pipes
  - orifices distributed across pipe-manifold (controlling $\Delta P$)

- CycloBio w/ inlet slot about bottom perimeter
  - slotted inlet about circumference (NO controlling $\Delta P$)
Flow Distribution by Vertical Probes

- Widely applied in many RASs.
- FI purchased this FSB in 1989 from Dallas Weaver
Distribution Through False Floor

- Eric Swanson reported (Aqua Expo, 1992) flow injection underneath a false floor.

Influent Manifold → False Floor → Effluent Weir

false-floor distribution plate
Pipe-Lateral Distribution

- Modified pipe-lateral distribution manifold.
Pipe-Lateral Distribution

- Modified pipe-lateral distribution manifold above abrasion resistant floor
Pipe-Lateral Distribution

- Example FSB in salmon smolt RASs at Marine Harests Big Tree Creek Hatchery (BC)

(system designed by PRAqua Tech.)
Pipe-Lateral Distribution

➢ To create uniform flow distribution:

✓ Pressure drop ($\Delta P$) across orifice should be $\geq$ headloss through the sand bed (i.e., $\geq$ depth of static sand):

$$\Delta P_{orif} = \left[ \frac{Q_{orif}}{C \cdot A_{orif}} \right]^2 \cdot \frac{1}{2 \cdot g}$$

- $Q_{orif}$ = flowrate in m$^3$/s
- $A_{orif}$ = orifice area in m$^2$
- $C = 0.6$ and $g = 9.81$ m/s$^2$
Cyclo Biofilter™

- Water injected tangentially into circular plenum and through slotted inlet about its base.
- Developed by Marine Biotech Inc. (Beverly, MA)
Cyclo Biofilter™

➢ USDA ARS National Cold Water Marine Aquaculture Center, Franklin, ME

✓ compact trt system
  • 2.74 m dia x 6.4 m tall

✓ 101 kg feed/day sustained capacity
  • lightly loaded
  • 5000 L/min RAS flow
Cyclobio FSB @ NCWMAC

- Height of Cyclobio was set at 6.4 m (21 ft):
  - Elevation required to gravity flow
    - from top of cyclobio,
    - through CO2 stripper,
    - through LHO unit,
    - through LHO head tank,
    - through fish culture tanks,
    - through drum filter, and
    - back to pump sump
Cyclobio FSB @ NCWMAC

- Requirement to provide height > 2*Dia of cyclobio
  - Static sand depth of 1.8-2.4 m (6-8 ft)
  - Total expanded bed depth of 4.3-5.5 m (14-18 ft)
  - Minimizes turbulence in bed of cyclobio
  - Pump Total Dynamic Head of 7.6 m (25 ft)
    - Two 7.5 HP pumps
    - 5.0 m³/min RAS Flow
Cyclobio FSB @ Freshwater Inst.

- **Dimensions:**
  - 2.7 m (9 ft) dia
  - 6.1 m (20 ft) tall

- **Static sand capacity:**
  - 1.5 m (5 ft) depth
  - 8.5 m³ (300 ft³) volume
  - assimilates TAN from 160 kg feed/day
  - $1000-1500 for sand

- **4700 L/min RAS flow**
  - Two 5-HP pumps

(courtesy of Marine Biotech Inc.)
Cyclo Biofilter™

- Pressure drop across the piping, sand, & cyclo bio

(Summerfelt et al., 2004)  
(1 cm/s = 14.7 gpm/ft2)
Cyclo Biofilter™ Advantage

- Cyclo Bio requires less pressure to operate.
  - 0.1-0.3 bar (2-4 psig) less pressure was required to operate a cyclo bio compared to a modified-pipe manifold FSB.
    - assuming a similar fluidized-sand biofilter height.
  - CycloBio has lower ΔP of piping and inlet orifice
Cyclo Biofilter™

- Effluent collection launder

To stripping column
Sand Selection Guidelines

- Purchase silica filter sand from supplier listed by American Water Works Association Sourcebook (AWWA)
Sand Selection Guidelines

- Filter sand is characterized by a sieve analysis
  - Effective size ($D_{10}$) is size where 10% of sand is finer
  - Also need to estimate $D_{50}$, $D_{60}$, and $D_{90}$
    - $D_{50}$ is mean size of sand
    - $D_{90}$ is largest 10% of sand, which must expand at design velocity
  - Sand uniformity coefficient, $UC = D_{60}/D_{10}$

- Sieve analysis is plotted on log-probability axis.
Sand Selection Guidelines

- Determine $D_{10}$, $D_{50}$, $D_{60}$, $D_{90}$, and UC from sieve analysis
Characterizing Sand: $D_{10}$

- The "effective size" ($D_{10}$) is defined as the opening size which will pass only the smallest 10%, by weight, of the granular sample.
- $D_{10}$ provides an estimate of the smallest sand in the sample and is the size used to estimate the maximum expansion at a given superficial velocity.
Characterizing Sand: $D_{90}$

- $D_{90}$ provides an estimate of the largest sand in the sample and is the size to estimate the minimum expansion at a given velocity.
- $D_{90}$ can be estimated from the $D_{10}$ and the UC:

\[
D_{90} = D_{10} \cdot \left(10^{1.67 \cdot \log(UC)}\right)
\]
Characterizing Sand: $D_{50}$

- The “mean size” ($D_{50}$) is the sieve size for which approximately 50% of the grains by weight are smaller.
- $D_{50}$ provides an estimate of the average size of the sand in the sample and is the value used during design to estimate the average bed expansion at a given superficial velocity:

$$D_{50} = D_{10} \cdot \left(10^{0.83 \cdot \log(UC)}\right)$$
Characterizing Sand: $S_b$

- The “bed specific surface area” is the specific surface area available per unit of bed volume ($S_b$); this can be estimated using estimates for the static bed void fraction ($\varepsilon \approx 0.45$) and sand sphericity ($\Psi \approx 0.75$):

$$S_b = \frac{6 \cdot (1 - \varepsilon)}{\Psi \cdot D_{50}}$$
Calculating Bed Expansion

- Buoyant force of rising water lifts sand bed when velocity exceeds minimum fluidization velocity ($v_{mf}$).

![Diagram showing static and expanded bed with interface between clear fluid and static bed, water distribution, and media support mechanism.](image)
Calculating Bed Expansion

- Bed expansion terminology:
  - 50% expansion, e.g., 1 m of static sand depth expands to 1.5 m
  - 100% expansion, e.g., 1 m of static sand depth expands to 2.0 m
  - 200% expansion, e.g., 1 m of static sand depth expands to 3.0 m
Calculating Pressure Drop

- Pressure drop across a sand bed
  - increases according to Ergun’s equation until bed begins to expand.
  - remains constant at all water velocities after the expansion begins.
  - remains constant for all sand sizes,
    - 1 m of static sand requires about 1 m of water head to expand.

\[ \frac{h}{L} = (S_{G_p} - S_{G_w}) \cdot (1 - \varepsilon) \]

- see Summerfelt and Cleasby (1996)
Calculating Bed Expansion

- Estimate bed expansion for a given sand as a function of water velocity, using:
  - water viscosity and density
  - sand size, sphericity
  - void space of the loose static bed
- see Dharmarajah and Cleasby (1986)
Experimental Measurement of Sand Expansion

- Filter sand sample should be obtained & tested in a 10-cm dia column
  - validate relationship between sand bed expansion and superficial water velocity
  - conduct this test before completing design of FSB
Bed Expansion in Test Columns vs. Full-Scale FSBs

Sand Expansion Tests

US Silica sand
\(D_{10} = 0.275\) mm

Parry Company sand
\(D_{10} = 0.23\) mm
Bed Expansion

- Seawater vs freshwater at 4.4°C and 26.7°C

(courtesy of Thomas Lauttenbach, Marine Biotech)
Biofilm in Fine Sand Biofilters

- biofilms grow on the expanded sand
Biofilm Development in Fine Sand Biofilters

- biofilms thicken with time:
  - decreasing particle density,
  - increasing bed expansion,
  - migrating to top of bed.
Biofilm in Fine Sand Biofilters

- Water velocities (0.7-1.4 cm/s) do not flush larger sheared pieces from the bed;
  - such pieces accumulate & continue to grow.
Vertical Stratification

- The beds are vertically stratified in:
  - sand size
  - bed expansion
  - biofilm thickness and biofloc size
  - nitrification rate
Biofilter bed depth increases with time (about 8 cm/wk @ FI):
- bio-particles accumulate;
- bed expansion increases,
  - as thickening biofilm reduces particle densities.
**TAN Removal Rate & Efficiency**

- **Warm-water & cold-water FSB applications:**

<table>
<thead>
<tr>
<th></th>
<th>g TAN removed per day</th>
<th>TAN Removal Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>per m² surface area</td>
<td>per m³ expand bed volume</td>
</tr>
<tr>
<td><strong>COLD-WATER BIOFILTER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fine sand, ~11,500 m²/m³</td>
<td>0.06</td>
<td>170</td>
</tr>
<tr>
<td>D₁₀ = 0.18-0.24 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WARM-WATER BIOFILTER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>coarse sand, ~5,000 m²/m³</td>
<td>0.2</td>
<td>600-1000</td>
</tr>
<tr>
<td>D₁₀ = 0.5-0.7 mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Nitrification in Coldwater Applications

- Fine sands ($D_{10} = 0.18-0.24$ mm) are used:
  - controls nitrite-nitrogen at very low levels
    - generally $< 0.1-0.2$ mg/L
  - produce higher TAN removal efficiencies
    - 80-95% TAN removal each pass
  - provide excess nitrification capacity
    - 200% excess can be achieved
Tank Water Quality in 6 Replicate Trout RAS with out Ozone

<table>
<thead>
<tr>
<th>Parameters</th>
<th>High Exchange (2.6% makeup)</th>
<th>Low Exchange (0.26% makeup)</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg Feed per m³ makeup</td>
<td>0.53</td>
<td>5.3</td>
</tr>
<tr>
<td>TAN (mg/L)</td>
<td>0.47 ± 0.02</td>
<td>0.84 ± 0.09</td>
</tr>
<tr>
<td>Nitrite (mg/L)</td>
<td>0.03 ± 0.005</td>
<td>0.013 ± 0.005</td>
</tr>
<tr>
<td>Nitrate (mg/L)</td>
<td>14 ± 0</td>
<td>99 ± 3</td>
</tr>
<tr>
<td>cBOD₅ (mg/L)</td>
<td>3 ± 0</td>
<td>13 ± 1</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>3 ± 0</td>
<td>14 ± 0</td>
</tr>
<tr>
<td>CO₂ (mg/L)</td>
<td>11 ± 0</td>
<td>13 ± 1</td>
</tr>
<tr>
<td>O₂ (mg/L)</td>
<td>9.8 ± 0.1</td>
<td>9.2 ± 0.2</td>
</tr>
<tr>
<td>True Color (Pt-Co units)</td>
<td>16 ± 1</td>
<td>103 ± 5</td>
</tr>
<tr>
<td>UV Transmittance (%)</td>
<td>86 ± 0</td>
<td>45 ± 1</td>
</tr>
</tbody>
</table>
Results: Biofilter Nitrification

- #1 Mapleton Sand, $D_{10}=0.19$ mm
- 2,700 L/min flow through CycloBio (60% of total)

<table>
<thead>
<tr>
<th></th>
<th>6.4% Makeup</th>
<th></th>
<th>1.1% Makeup</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DOC = 2.7 mg/L</td>
<td>NO$_2$-N (mg/L)</td>
<td>DOC = 7.4 mg/L</td>
<td>NO$_2$-N (mg/L)</td>
</tr>
<tr>
<td>Biofilter inlet</td>
<td>1.18 ± 0.04</td>
<td>0.06 ± 0.00</td>
<td>1.49 ± 0.04</td>
<td>0.28 ± 0.03</td>
</tr>
<tr>
<td>Biofilter outlet</td>
<td>0.09 ± 0.01</td>
<td>0.02 ± 0.00</td>
<td>0.25 ± 0.01</td>
<td>0.25 ± 0.07</td>
</tr>
<tr>
<td>Change</td>
<td>-1.09 ± 0.10</td>
<td>1.24 ± 0.03</td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Removal Eff.</td>
<td>92%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Results: Biofilter Respiration

- **#1 Mapleton Sand, D_{10}=0.18 mm**
- **2,700 L/min flow through CycloBio (60% of total)**

<table>
<thead>
<tr>
<th></th>
<th>6.4% Makeup DOC = 2.7 mg/L</th>
<th>1.1% Makeup DOC = 7.4 mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO(_2)</strong> (mg/L)</td>
<td>20 ± 2</td>
<td>25 ± 0</td>
</tr>
<tr>
<td><strong>O(_2)</strong> (mg/L)</td>
<td>10.9 ± 0.4</td>
<td>9.4 ± 0.1</td>
</tr>
<tr>
<td><strong>Biofilter inlet</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biofilter outlet</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Change</strong></td>
<td>8 ± 1</td>
<td>4 ± 1</td>
</tr>
<tr>
<td></td>
<td>-6.4 ± 0.3</td>
<td>-6.9 ± 0.3</td>
</tr>
</tbody>
</table>
## CBOD Removal in FSB’s Treating Intensive Fish Farm Effluent

<table>
<thead>
<tr>
<th>Sand D&lt;sub&gt;10&lt;/sub&gt; (mm)</th>
<th>Bed Management</th>
<th>Inlet CBOD (mg/L)</th>
<th>Outlet CBOD (mg/L)</th>
<th>CBOD Removal Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.11</td>
<td>siphon</td>
<td>11.5 ± 2.7</td>
<td>4.1 ± 1.0</td>
<td>64</td>
</tr>
<tr>
<td>0.11</td>
<td>siphon</td>
<td>11.0 ± 2.6</td>
<td>4.2 ± 1.3</td>
<td>62</td>
</tr>
<tr>
<td>0.19</td>
<td>siphon</td>
<td>8.7 ± 2.3</td>
<td>3.4 ± 1.2</td>
<td>60</td>
</tr>
<tr>
<td>0.11</td>
<td>shear</td>
<td>6.8 ± 1.0</td>
<td>1.2 ± 0.3</td>
<td>82</td>
</tr>
<tr>
<td>0.11</td>
<td>shear</td>
<td>6.7 ± 1.1</td>
<td>1.5 ± 0.4</td>
<td>77</td>
</tr>
<tr>
<td>0.19</td>
<td>shear</td>
<td>7.1 ± 1.2</td>
<td>2.4 ± 0.5</td>
<td>66</td>
</tr>
</tbody>
</table>
## TAN Removal in FSB’s Treating Intensive Fish Farm Effluent

<table>
<thead>
<tr>
<th>Sand D$_{10}$ (mm)</th>
<th>Bed Management</th>
<th>Inlet TAN (mg/L)</th>
<th>Outlet TAN (mg/L)</th>
<th>TAN Removal (%)</th>
<th>Outlet Nitrite (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.11</td>
<td>siphon</td>
<td>1.01 ± 0.16</td>
<td>0.37 ± 0.10</td>
<td>63</td>
<td>0.17 ± 0.02</td>
</tr>
<tr>
<td>0.11</td>
<td>siphon</td>
<td>0.99 ± 0.13</td>
<td>0.38 ± 0.11</td>
<td>62</td>
<td>0.17 ± 0.02</td>
</tr>
<tr>
<td>0.19</td>
<td>siphon</td>
<td>0.94 ± 0.14</td>
<td>0.66 ± 0.11</td>
<td>30</td>
<td>0.20 ± 0.04</td>
</tr>
<tr>
<td>0.11</td>
<td>shear</td>
<td>0.83 ± 0.06</td>
<td>0.10 ± 0.04</td>
<td>88</td>
<td>0.07 ± 0.02</td>
</tr>
<tr>
<td>0.11</td>
<td>shear</td>
<td>0.82 ± 0.06</td>
<td>0.11 ± 0.04</td>
<td>87</td>
<td>0.09 ± 0.02</td>
</tr>
<tr>
<td>0.19</td>
<td>shear</td>
<td>0.81 ± 0.06</td>
<td>0.11 ± 0.04</td>
<td>86</td>
<td>0.15 ± 0.03</td>
</tr>
</tbody>
</table>
# Total Coliform Removal in FSB

## Treating Intensive Fish Farm Effluent

<table>
<thead>
<tr>
<th>Sand D$_{10}$ (mm)</th>
<th>Bed Management</th>
<th>Inlet Total Coliform (counts/100 mL)</th>
<th>Outlet Total Coliform (counts/100 mL)</th>
<th>Total Coliform Removal Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.11</td>
<td>shear</td>
<td>4.7 x 10$^5$</td>
<td>1.3 x 10$^4$</td>
<td>97</td>
</tr>
<tr>
<td>0.11</td>
<td>shear</td>
<td>4.2 x 10$^5$</td>
<td>6.5 x 10$^3$</td>
<td>98</td>
</tr>
<tr>
<td>0.19</td>
<td>shear</td>
<td>1.8 x 10$^5$</td>
<td>1.1 x 10$^4$</td>
<td>94</td>
</tr>
</tbody>
</table>
O\textsubscript{2} demand due to Nitrification

- Approximately 60% of O\textsubscript{2} consumed across FSB goes towards nitrification;
- Every 1 mg/L of TAN removed requires approximately 7.7 mg/L (= 4.6 mg/L DO ÷ 0.6) of dissolved O\textsubscript{2}
- O\textsubscript{2} limitations can become a problem when the desired removal of TAN is high
  - i.e., ≥ 1.2 mg/L of TAN removed per pass
Managing Bed Growth

- Siphon biosolids bed as needed to prevent them from overtopping biofilter.
Managing Bed Growth

- Siphon biosolids from the bed:
  - maintain a maximum bed depth;
  - remove biosolids from the top,
    - removes thickest and oldest biofilm;
  - also remove some sand,
    - lost sand must be replaced on occasion.
Managing Bed Growth

- **Biofilm Shearing with Pump**
  - Top of bed pumped back into inlet.
  - Creates shearing effect on biofilm
  - Sand bed maintains constant height
  - Minimal sand loss
Management Practices: Water Flow

- To maintain proper bed expansion, a FSB must operate within a fairly narrow water flow range, i.e., within about ± 10-30% of its design flow.
- Water flow cannot cease for more than approximately 6-24 hrs, to prevent anaerobic conditions and resulting loss in the nitrification capacity of the FSB.
Management Practices: Prevent Air Bubbles

- Prevent air bubbles from being pumped into fluidized-sand biofilters. Bubbles washout sand!

Bubbles from leaky pipe fittings or entrained air at pump intake.
Management Practices: Clean Outs

- Clean-outs must be provided to remove debris that could plug the flow distribution manifold.
Practical Considerations: Check Valves

- Reliable swing check valves (or foot valves) are critical to prevent backflow!
Practical Considerations: Sand Blasting

- Installation of an abrasion resistant floor is critical.
Practical Considerations: Installing New Sand

- Load sand pneumatically (14 m³ in 2-3 hrs)
- Wash fine clay found in new sand out of system before recirculating water to fish.
Applications of FSB’s

- Used widely in N. America for salmonid RAS.
  - some in Chile.
Nutreco’s Big Tree Creek Hatchery (BC)

- Fluidized-sand biofilters used in many salmonid RAS’s.
  - Remove TAN & cBOD efficiently & do not generate NO₂,
  - Low cost, compact, and robust.

(designed by PRAqua Tech)
Nutreco’s Big Tree Creek Hatchery (BC)

- Three recirc systems (~12 m³/min/system) for chinook salmon smolt production.

(designed by PRAqua Techn.)
Nutreco’s Big Tree Creek Hatchery (BC)

- Chinook salmon fry RAS (~4,000 L/min)
Target Marine Hatcheries

- Two recirc modules for coho salmon smolt production (Sechelt, BC)

Pre-existing flow-through systems (typically used circular tanks for salmon production)
Target Marine Hatcheries

- Compact layout of a RAS module.

(designed by PR Aqua Technologies)
Target Marine Hatchery (BC)

- Salmon smolt

(system designed by PRAqua Tech.) Courtesy of PRAqua Technologies (BC)
Target Marine Hatcheries (BC)

- Salmon smolt

(system designed by PRAqua Tech.)
USDA ARS, Franklin, ME

- Temporary 1200 L/min RAS for Atlantic salmon fry,
  - used for 3 yrs before new facility was ready
- 7 new RAS’s for broodstock development program.
Penobscot Smolt Hatchery

- Currently *Center for Cooperative Aquaculture Research* (Franklin, ME)

(Designed by Eric Swanson)
Oak Bay Hatchery, Cooke Aquaculture (NB)

- Atlantic salmon smolt
- Distribution through false floor

(Swanson-type design)
WV Aqua (West Virginia)

- Arctic char grow-out farm
- 12 m³/min in each of three RAS

(system designed by PRAqua Tech.)
CONCLUSIONS

- Fine sand fluidized biofilters are used in many large-scale recycle systems, because they:
  - can be scaled to treat flows > 10,000 L/min
  - provide high TAN removal efficiencies
  - maintain low nitrite-nitrogen levels
  - are compact
  - are capital cost efficient
    - high specific surface areas (4,000-45,000 m²/m³)
    - low media cost ($40-70/m³ of sand)
  - are reliable if well designed, non-plugging.
CONCLUSIONS

- Disadvantages:
  - design not well understood until recently
  - moderate operating pressure (0.34-0.68 bar; 5-10 psig)
    - elevation at top of biofilter usually designed to provide gravity flow back through remaining treatment processes
  - must be operated at +/- 20% of design flow
  - cannot be shut-down for ~ 6 hrs w/o losing nitrification
  - biofilm on the sand may require management
Thank you for your attention!