APPENDIX B

Summary of Pond Characteristics

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	FACULTATIVE	AEROBIC			ANAEROBIC
		Partial Mix	***Complete Mix***	***High Performance***	
Description	Earthen impoundment less than 2.5m deep. O^{2-} saturated water at surface supports aerobic biodegradation. Aerobic and anaerobic degradation processes occur mid-depth. Bottom anaerobic water supports methanogenesis. Performance depends on O_2 from algae.	Earthen impoundment in which aeration (mechanical surface mixing or submerged diffusion) is used to meet O_2 needs. No solids suspended. Performance depends on aeration.	Earthen impoundment in which mechanical mixing introduces air for BOD removal and to suspend solids. Performance depends on aeration.	Dual-power, multi-cellular systems (DPMC) designed for maximum BOD conversion efficiency.	A deep earthen basin not mixed or aerated. The organic load exceeds any naturally occurring dissolved $O_{2.}$ Degradation takes place anaerobically.
Common Modifications	***Controlled Discharge*** – during winter or peak algal growth periods in summer ***Hydrograph Controlled Release -*** *discharge* when conditions in the receiving stream are suitable. ***Plastic Curtains -*** used as baffles to divide lagoon into cells. ***Floating Plastic Grids -*** **s**upporting the Growth of plants to reduce algal growth.	***Plastic curtains -*** with floats, anchored to bottom dividing lagoons into multiple cells to improve hydraulic conditions. ***Submerged diffusers*** - suspended from flexible floating booms which move in a cyclic pattern during aeration activity. Treats a larger volume with	*High Performance BIOLAC™ Nitrogen Removal Nitrification and de-nitrification.*	None known at this time.	***Placement -*** in front of facultative lagoon as part of design or retrofitted to existing system.

		each aeration line. ***Effluent recirculation*** -within the system to enhance oxygen levels.			
	FACULTATIVE	**AEROBIC**			**ANAEROBIC**
		Partial Mix	***Complete Mix***	***High Performance***	
Performance	**BOD: to** <30mg/L 95% of the time. **TSS:** to <100 mg/L. **NH_3:** up to 90% removal in summer. **P:** up to 50% removal. **Pathogen and fecal coliform removal:** varies with temperature and detention time.	**BOD: to** <30 mg/L 95% of the time with settling at end of system. **TSS:** to < 60 mg/L. **NH_3:** nitrified during summer.	Not available.	**TSS: to** < 15mg/L. **NH_3:** 90%removal.	**BOD:** reduced by 60%; less in cold climates.
Costs	**See Ch. 8**	**See Ch. 8**	**See Ch. 8**	**See Ch. 8**	**See Ch. 8**

	FACULTATIVE	**AEROBIC**			**ANAEROBIC**
		Partial Mix	***Complete Mix***	***High Performance***	
Applicability	Raw municipal wastewater effluent from *Primary treatment* *Trickling filters* *Aerated ponds* *Anaerobic ponds* *Biodegradable industrial wastewater*	Municipal and industrial wastewaters of low to medium strength.	Municipal and industrial applications where space is limited. Raw, screened or primary settled municipal wastewater. Biodegradable industrial wastewaters.	Screened municipal and industrial wastewater in areas where space is limited.	Pretreatment of municipal and industrial wastewater with high organic loading.
Advantages	Removes BOD, TSS, bacteria and NH_3. Low energy requirements. Easy to operate.	Smaller plant footprint than facultative ponds. Discharge acceptable under all climatic conditions.	Small footprint. Discharge acceptable under all conditions. No ice formation in cold weather.	Small footprint Removes BOD, TSS and bacteria when used with a settling basin Effective at converting NH_3 to NO_3^-.	Treats high organic loadings. Produces methane for energy recovery. Produces less sludge than other processes. Low energy requirements.
Disadvantages	Higher sludge accumulation in cold climates; removal required. Mosquitoes, other insect vectors, and burrowing animals may be a problem. Odors can occur with spring and fall pond turnover. Larger footprint. Difficult to control or predict ammonia levels in winter.	Requires energy input. Not as effective at removing N and P as facultative ponds. Ice formation. Mosquitoes and other vectors. Sludge removal required. Routine maintenance and cleaning required to maintain design aeration rates.	Agitation must be sufficient to suspend all solids. High energy requirement for aeration and solids suspension. Increased solids disposal. Settling basin needed to facilitate solids separation.	Solids removal is greater than other options. High energy requirements. Relatively little experience with this type of system.	Large footprint. Odors. Long retention times. Process may not be effective in colder climates.

<table>
<tr><th rowspan="2"></th><th rowspan="2">FACULTATIVE</th><th colspan="3">AEROBIC</th><th rowspan="2">ANAEROBIC</th></tr>
<tr><th>Partial Mix</th><th>Complete Mix</th><th>High Performance</th></tr>
<tr>
<td>Design Considerations and Criteria</td>
<td>Systems with at least three cell in series are recommended.

Inlet and outlet structure design should maximize volume to avoid short circuiting.

<u>Typical criteria:</u>
Loading Rate
22-67kg BOD_5/ha-d.
Detention Time
25-180 d.
Depth 1.5m – 2.5m.
Surface Area 4-60 ha.

Average organic loading rate and detention time relative to ambient temperature:
<table>
<tr><th>T, ^oC</th><th>BOD, kg/ha/d</th><th>t_{det},d</th></tr>
<tr><td>>15</td><td>18-36</td><td>?</td></tr>
<tr><td>0-10</td><td>9-18</td><td>?</td></tr>
<tr><td><0</td><td>4.5-9</td><td>120-180</td></tr>
</table>
Maximum loading rate for the 1st cell in multi-cell systems relative to temperature:
<table>
<tr><th>T, ^oC</th><th>BOD, kg/ha/d</th></tr>
<tr><td>>15</td><td>40</td></tr>
<tr><td><0</td><td>16</td></tr>
</table>
Lining may be required.</td>
<td>1.8 - 6 m (6 to 20 ft), 3 m (10 ft).

Submerged diffusion 3.7 to 4 kg O_2/kW-hour (6 to 6.5 lbs O_2/hphour).

Mechanical surface aerators 1.5 to 2.1 kg O_2/kW-hour (2.5 to 3.5 lbs O_2/hp-hour).

System should have at least three lined cells in series depending on soil conditions.

Detention Times 10 – 30d [20 days most common].

The design of aerated lagoons for BOD removal is based on first-order kinetics and the complete mix hydraulics model. Even though the system is not completely mixed.

Ponds should be rectangular with a 3:1 or 4:1 length to width ratio</td>
<td>Three cell systems are recommended.

Agitation must be sufficient to suspend all solids.

Detention time: 1.5 < 3d.

The design for BOD removal is based on first-order kinetics and the complete mix hydraulics model.</td>
<td>$\geq$ 6W/m^3 needed for primary basin, 1.8W/m^3 for settling basin.

Detention Time <1.5d.

Not appropriate for $CBOD_5$<100mg/L</td>
<td>BOD loading rate: 0.04 -0.30 kg/m^3/d (2.5- 18.7 lb /10^3 ft^3/d).

Detention time: 1-50d.

Depth: 2.4-6m [Deeper is better.]

Surface area: 0.2-0.8 ha.

Minimum freeboard: 0.9m.

Liners recommended to prevent seepage.

Surface runoff should be diverted from lagoon surface.</td>
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</table>

	FACULTATIVE	AEROBIC			ANAEROBIC
		Partial Mix	*Complete Mix*		
Design Models and Equations [See Appendix C for example calculations]	**Areal Loading Rate Method –** Simple to use when impoundment will not be mixed. **Gloyna Model –** Assumes a BOD_5 removal efficiency of 89-90%. **Complete Mix Kinetics –** Marias and Shaw model (also assumes first order degradation kinetics). [NOTE: This model is not widely accepted as a complete mix kinetic model; assumptions have not proven to be valid for facultative ponds.] **Plug Flow** **Intermediate Flow (between complete mix and plug flow) –** Wehner-Wilhlem Equation accounts for both biodegradation kinetics and dispersion.	Use **complete mix kinetic** model.		Use **complete mix kinetics** model.	Design based on volumetric loading rate, water temperature and hydraulic detention time. See **Advanced Integrated Pond System** Design (Oswald 1999).