

# Low Cost, Scalable, Water Clarification

**Meng H. Lean, Ph.D.**

**Principal Scientist & Area Manager**

**HSL/Microfluidic Systems**

**Palo Alto Research Center**

**[mlean@parc.com](mailto:mlean@parc.com)**

***NASA Urban Planning Workshop***

**NASA Research Park, Moffett Field, CA**

**January 10, 2009**

# 2005 Entry into Cleantech

- Program started as a “grassroots,” researcher-driven activity with management support
- Researchers organized a speaker series →
- These events generated many new connections and insights



**Science and Technology  
for a  
Sustainable World**

**Thursday, February 10, 4:00pm**  
**Nathan S. Lewis**  
George L. Argyros Professor and Professor of Chemistry  
California Institute of Technology

**Wednesday, February 16, 1:00pm**  
**Michael Braungart**  
Co-author of *Cradle to Cradle:  
Remaking the Way We Make Things*

**Thursday, March 10, 4:00pm**  
**David Gottfried**  
President, WorldBuild Technologies  
Founder, Green Building Council and  
Author of *Green to Green*

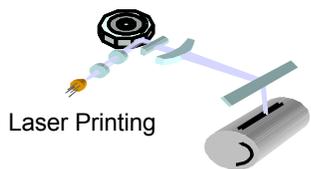
**Thursday, March 24, 4:00pm**  
**Barbara Waugh**  
HP, Co-founder World inclusion and  
Author of *The Soul in the Computer*

**Thursday, April 7, 4:00pm**  
**Tim Woodward**  
Managing Director, Nth Power

All presentations will take place at  
George E. Pake Auditorium  
Palo Alto Research Center  
3333 Coyote Hill Road  
Palo Alto, CA 94304  
[www.parc.com/sustainability](http://www.parc.com/sustainability)

Agilent Technologies EPRC hp parc UNIVERSITY OF CALIFORNIA UCMERCED ENERGY RESEARCH INSTITUTE XEROX. arc Palo Alto Research Center

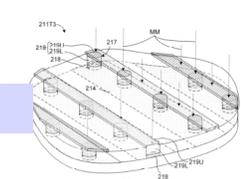
# Deep Competencies Support Cleantech Agenda



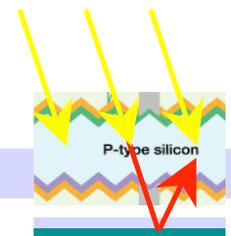
## Optical Design



Solar concentrators



Laser processing of PV wafers

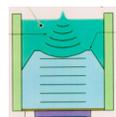


Novel light capture methods



Solid state lighting

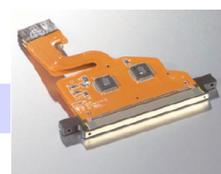
Inkjet



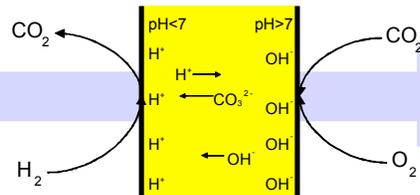
## Direct Printing



High Aspect Ratio PV Gridlines

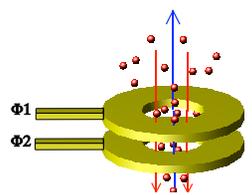


Inkjet to Form Silicide PV Contacts



Low cost membranes for CO<sub>2</sub> extraction

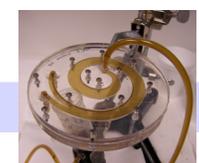
Toner Powder Control



## Particle Manipulation



Bioagent concentrator



Membrane-less spiral flow water filter

Model Based Printer Control



## Adaptive Control



Data Center Optimization



Demand Response



# Sustaining Water Supply

- **Meeting Water Needs**
  - Conserving use
  - Recycling waste water
  - Desalination of seawater
- **PARC Clean Water Technology**
  - Low power
  - Small footprint
  - Scalable
  - Continuous flow
  - Low maintenance
  - Rapid process
  - Versatile – generic capability



# PARC Clean Water Technology

- **Hydrodynamic Separation** without a physical barrier
  - Modular, configurable, continuous flow
  - Scalable from mL/min to 100s L/min
  - Designed size cut-off separation of neutrally buoyant particles down to 1-3  $\mu\text{m}$  and to desired efficiency
- **Spiral Mixer**
  - Effective turbulent mixing
  - Custom shear rate  $\rightarrow$  dense, uniform-sized floc
- **In-line Coagulation, Flocculation, & Separation**
  - Address sub-micron particles
  - Reduce coagulant dosage by 50%
  - Rapid aggregation of pin floc
  - Replace sedimentation with pin floc separation
  - Rapid process time: hours down to minutes

# Scalable from Microscale to Macroscale

## – Many Other Potential Applications

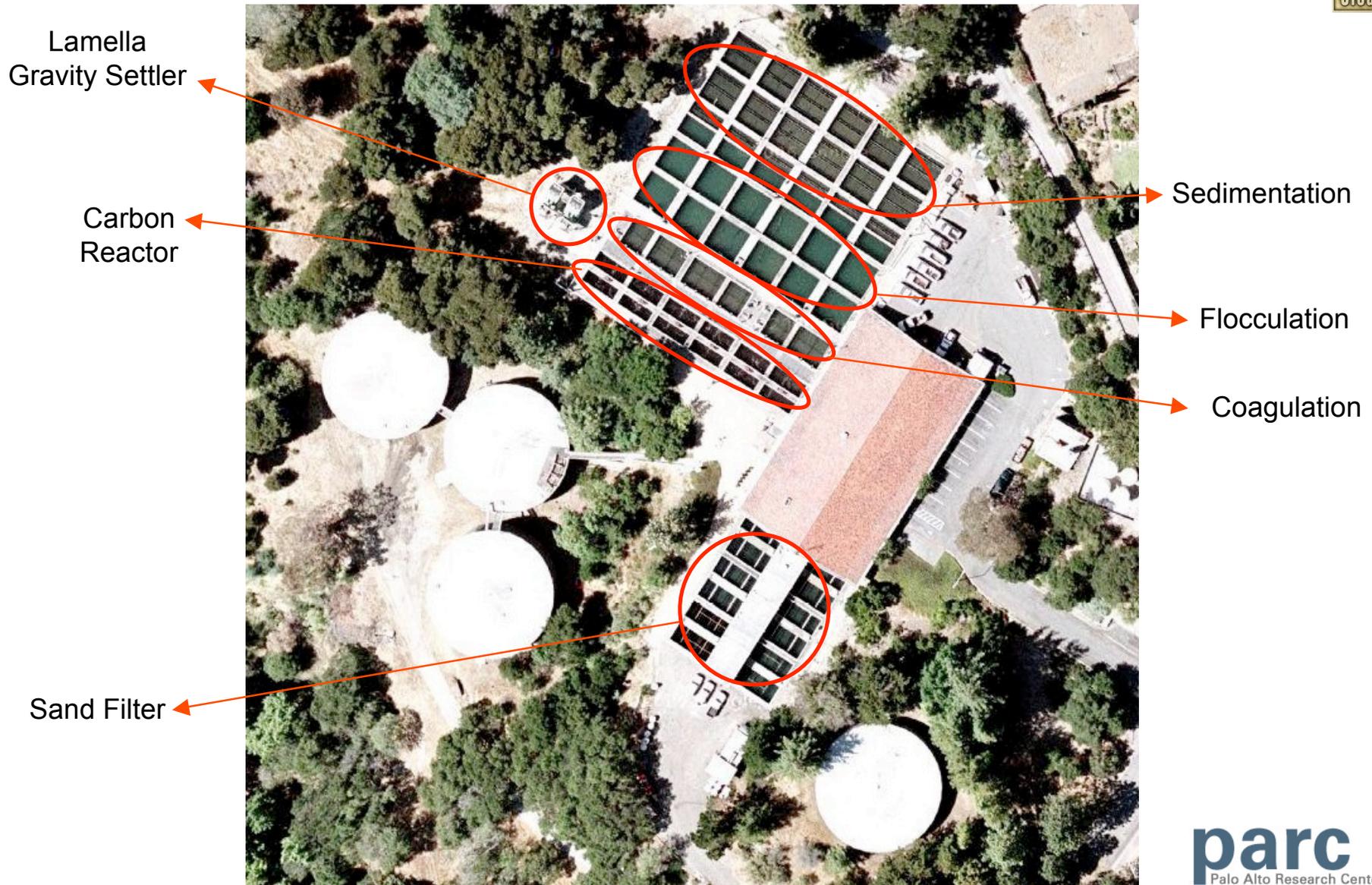


- **PRIMARY FOCUS:**  
Municipal Water Treatment
- **Other Water Applications**
- Industrial water purification
  - CMP slurry reclaim, ....
- Waste water remediation
  - In-line, low dosage, coagulant and spiral separation for removal of dissolved materials
- Power plant cooling tower
  - Minimize chemical scaling
- Pre-treatment for RO
  - Lighten organic loading for RO membranes
- Petroleum refining
  - Separation of immiscible fluids
- Produced waters
  - Prior to reinjection
- Ballast Water
- Agricultural water

Generic capability: platform technology for separation of particles from a moving fluid

- **Other Application Areas**
- Bio medical
  - Plasma separation and lab-on-chip devices
- Auto & jet fuel refinement
  - Particle (grit) removal
- Chemical (colloid) industry
  - Particle screening
- Food & Beverage Industry
  - Pathogen screening, water purification
- Mineral processing
- High Throughput Screening (HTS) for waterborne pathogens
- Algae Dewatering for bio fuels
  - Increase harvest

# Conventional Water Treatment Plant



MH Lean, January 2009

Santa Cruz, Ca Facility



# Conventional Water Treatment Plant



Lamella Gravity Settler

PARC technology aims to replace this

Reduce CapEx by \$ 2-3 million  
for 20 MGD plant

Eliminate flocculation &  
sedimentation:

Reduce time from *hrs* to *mins*  
Reduce area reqts *up to 70%*  
Estimated \$300,000-\$400,000  
annual savings

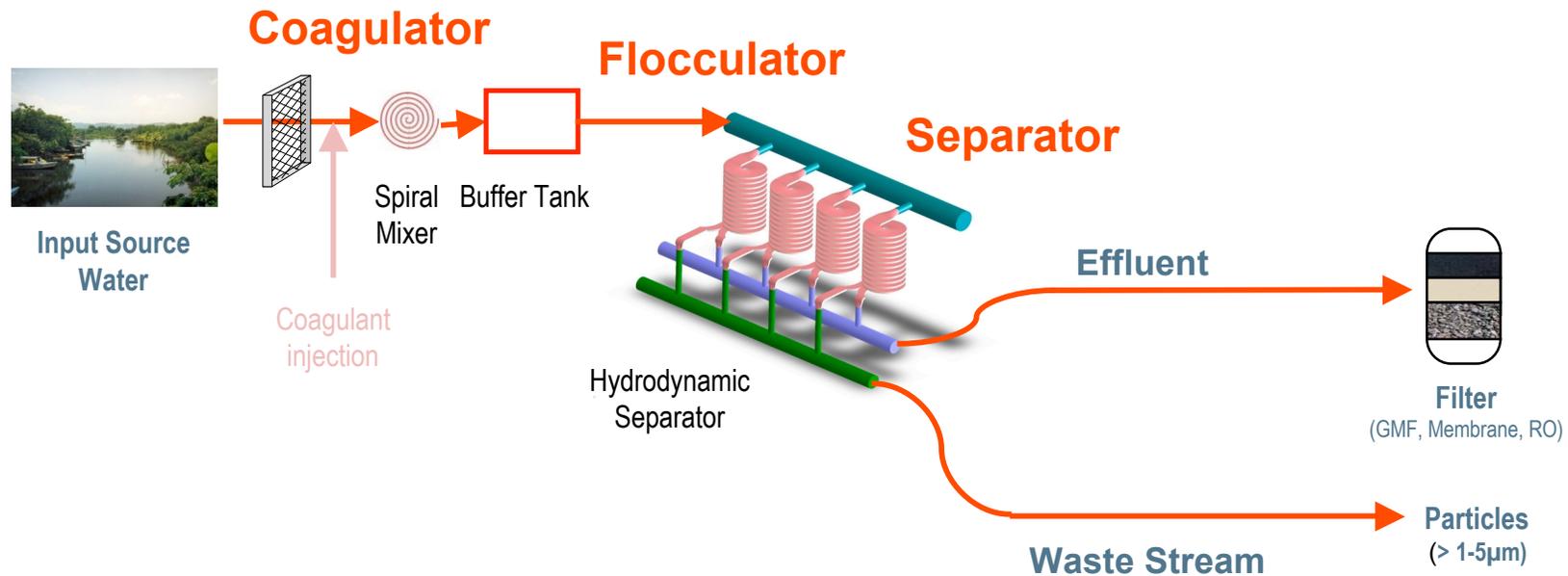


Sedimentation

Flocculation

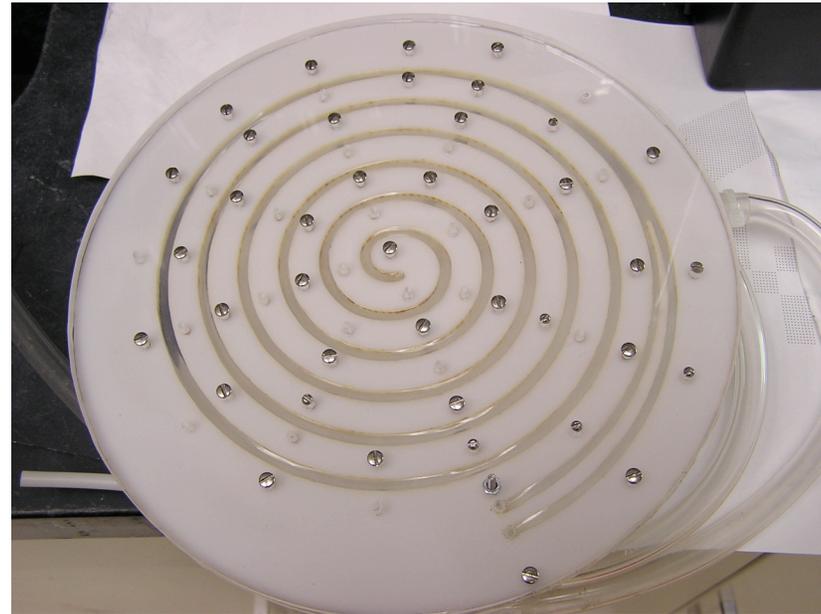
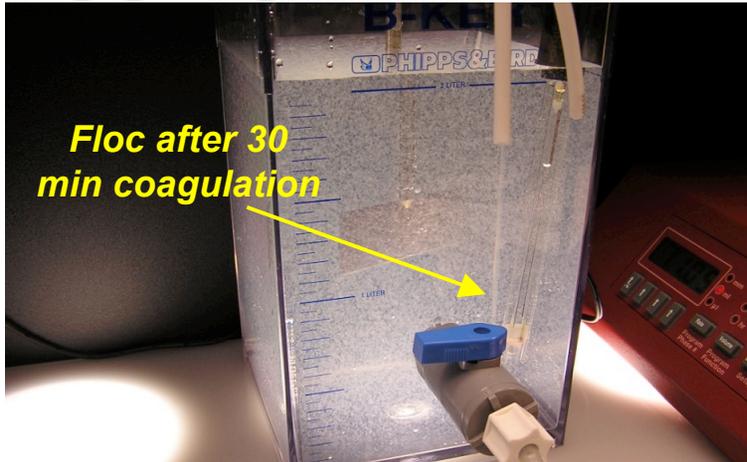
Carbon reactor

# Municipal Water Treatment Application Concept

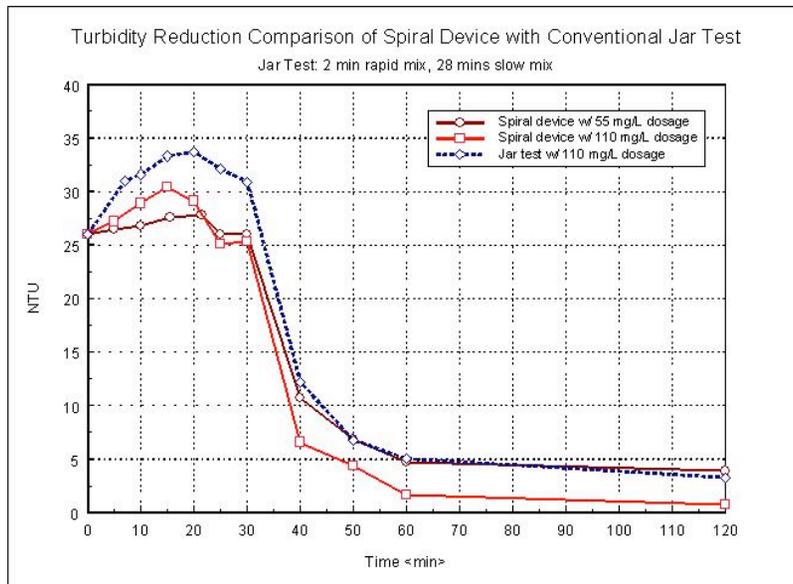


- Replace flocculation and sedimentation steps
  - Decrease flocculation & sedimentation processing time from hours to minutes
  - Reduce flocculation & sedimentation area requirements by up to 70%
- Reduce coagulant dosage by 50%

# Spiral Mixer: Rapid Mixing & Accelerated Aggregation Kinetics



*Single inlet, 2 outlet spiral mixer*



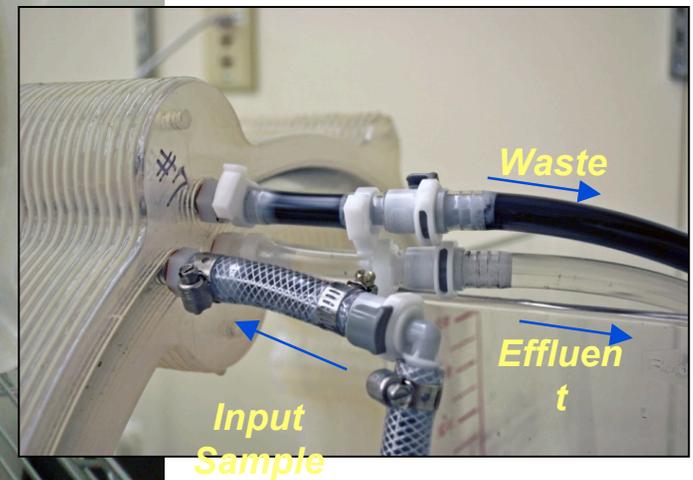
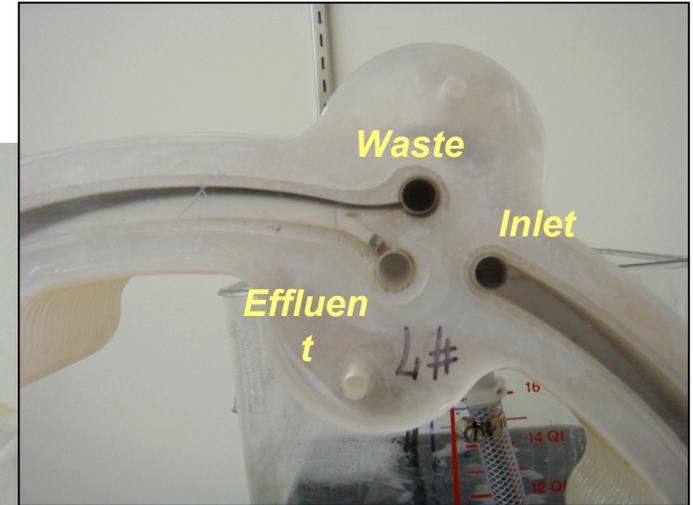
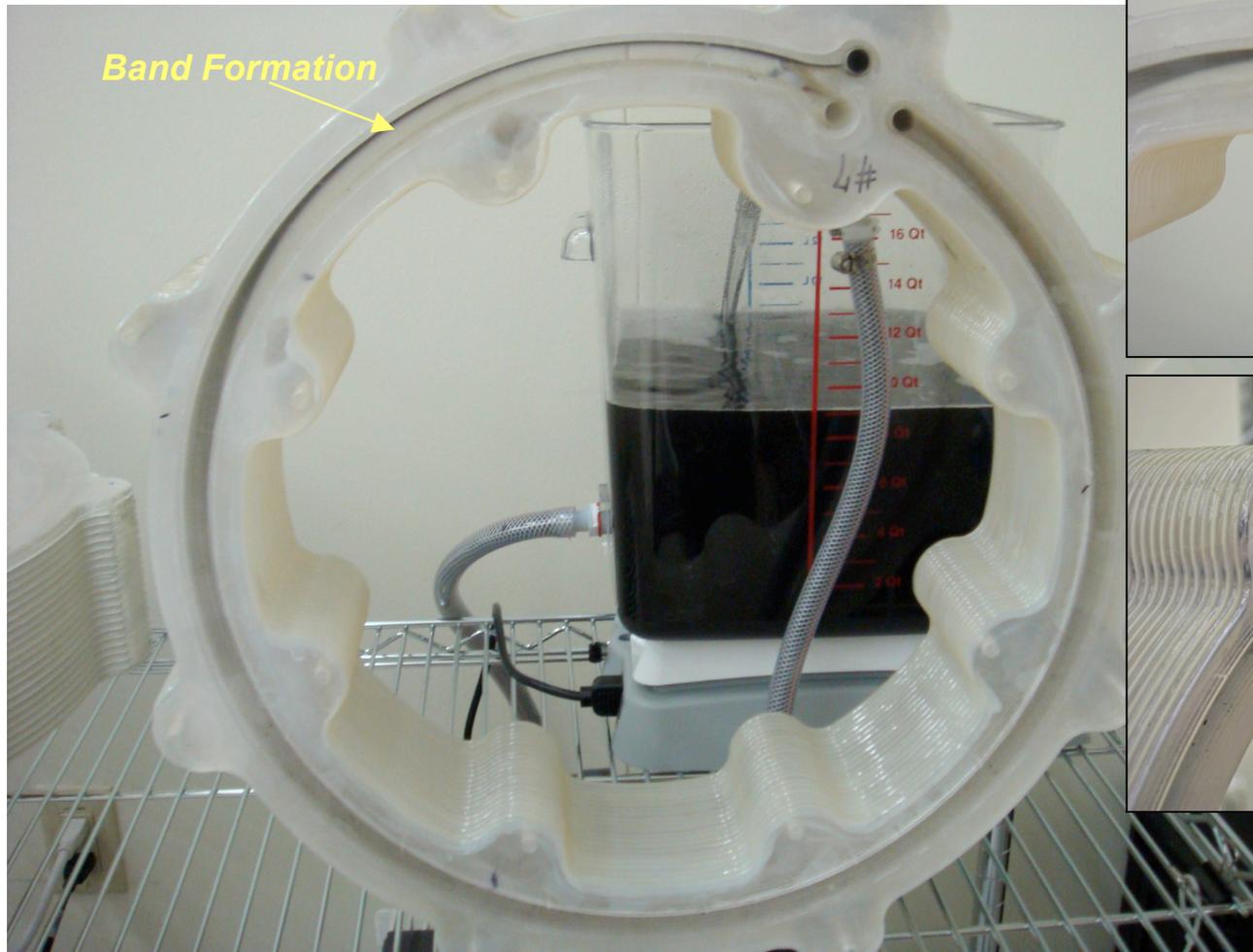
- 1) Faster and more complete coagulation with spiral channel for improved mixing
- 2) Custom shear rate produces dense and uniform-sized floc which are more amenable to rapid aggregation
- 3) Chemical dosage may be reduced by 50% to attain same turbidity (NTU) reading

# 10 LPM Vertical Orientation Operation



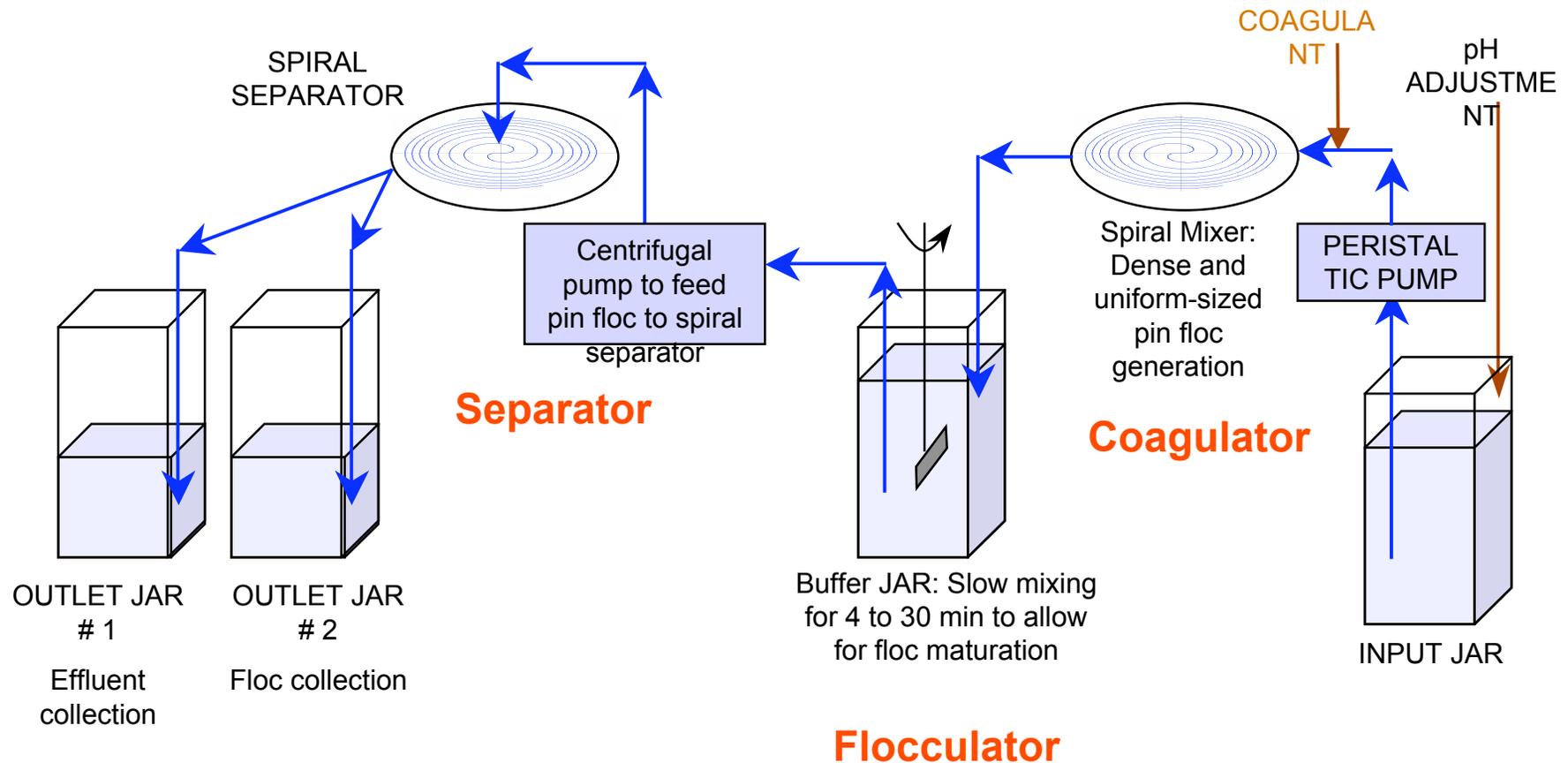
Video

*Inensitive to sedimentation*

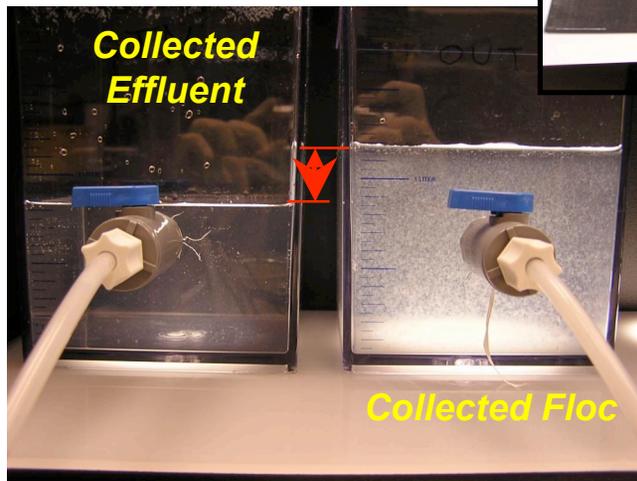
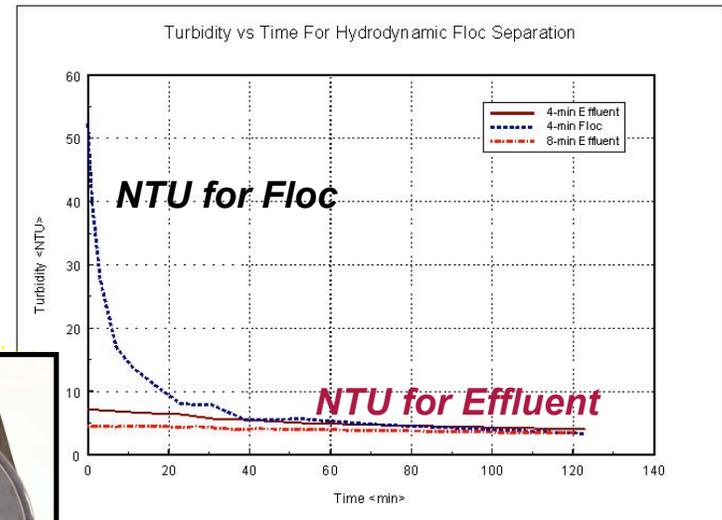
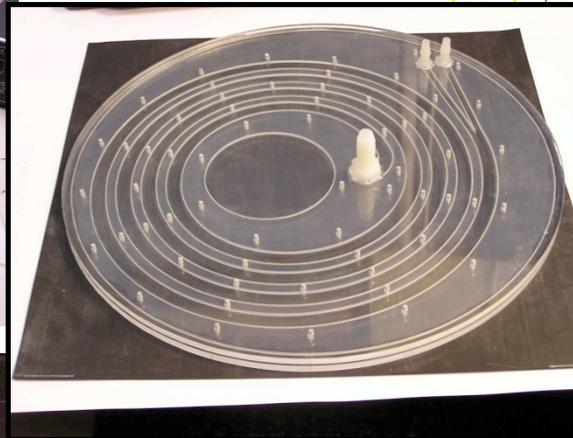
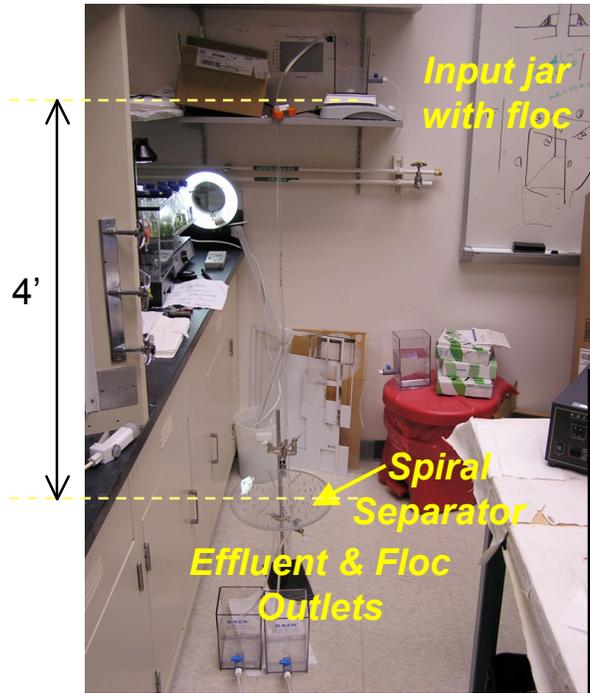


MH Lean, January 2009

# In-Line Coagulation, Flocculation, and Separation



# Spiral Separation of 4 min Floc

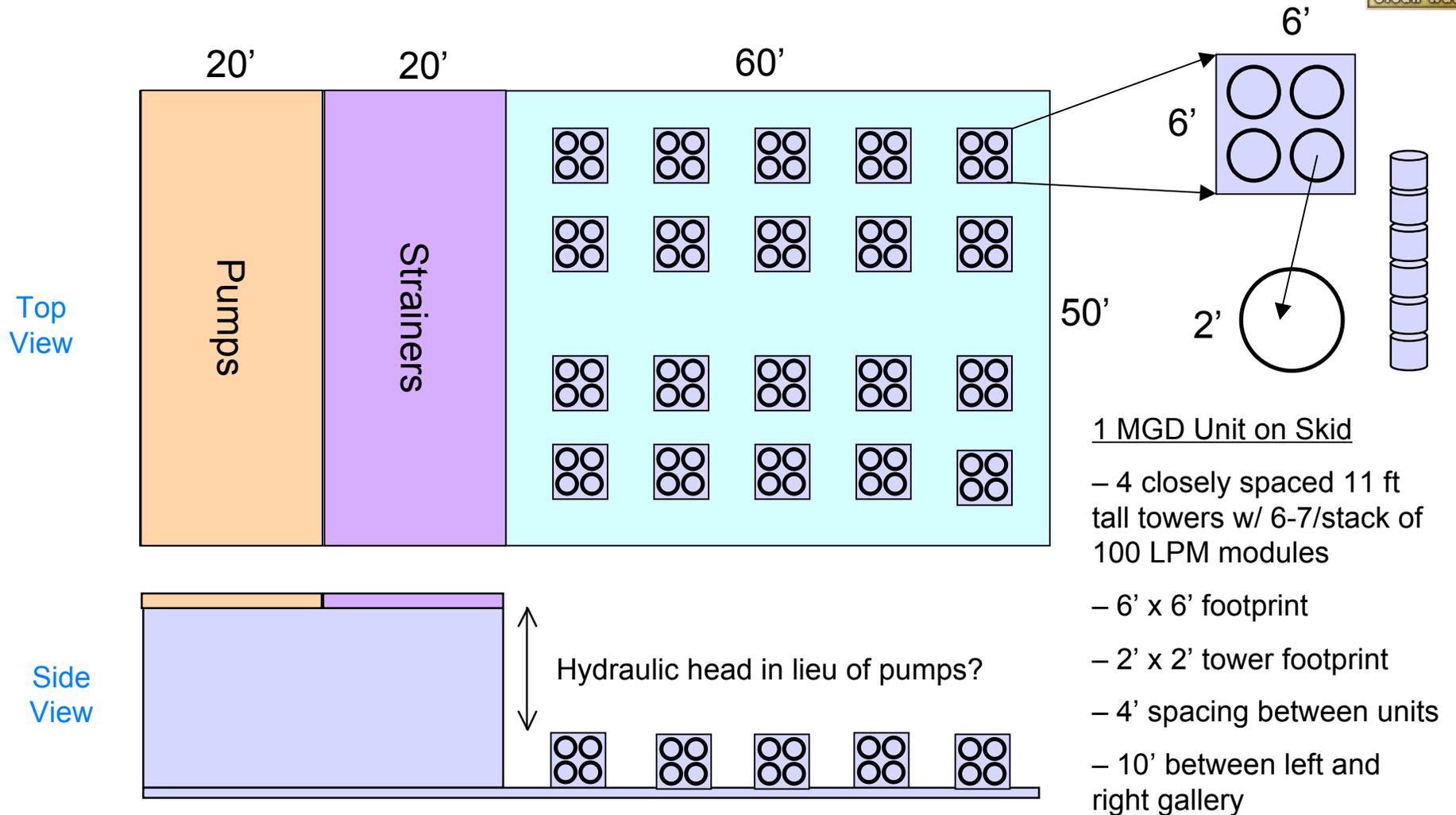


Step	Conv. Process Time (min)	Spiral Process Time (min)
Flash Mix	0.5	0.083
Flocculation (slow mix)	30.0	4.0
Sedimentation /Separation	600.0	10.0

**Gravity fed separation to achieve designed flow rate and pressure of 2psi ~4 ft elevation**



# Concept for PARC 20 MGD Layout

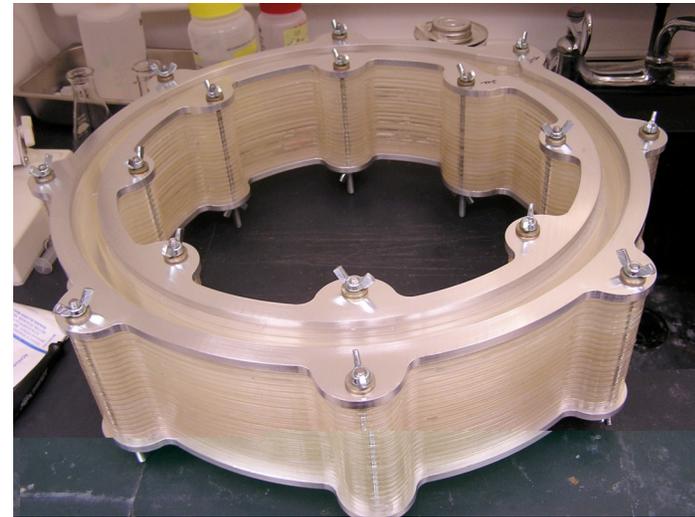


# Performance & Cost

- **Specs**

- Low power, low pressure

**$\Delta P = 2 \text{ psi}$**   
**Power = 150W**  
**Q = 1000 L/min**  
**Energy cost = \$200/yr**



- **Cost comparison**

- w/ conventional and membrane pre-treatments

<b>34%</b>	<b>capital cost saving</b>	<b>Up to 74%</b>
<b>30%</b>	<b>maintenance cost savings</b>	<b>&gt;40%</b>
<b>58%</b>	<b>space savings</b>	<b>67-77%</b>

Based on cost estimates from Marin Municipal Water District, Seawater Desalination Pilot Program - Engineering Report  
 Kennedy/Jenks Consultants, CH2MHill, January 26, 2007. Land cost not included.

Water company consultant



# Summary

- **Described merits of novel Hydrodynamic Separation method**
  - Customizable size cut-off separation of neutrally buoyant particles down to 1-3  $\mu\text{m}$  and to desired efficiency
- **Described merits of Spiral Mixer**
  - Custom shear rate  $\rightarrow$  dense, uniform-sized floc
- **Demonstrated gravity-fed In-line Coagulation, Flocculation, & Separation**
  - Rapid process  $\rightarrow$  reduction from hours to mins
- **Lab R&D prototypes in operation**
  - From mL/min to 100 L/min