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## Technical Developments in Materials and Techniques for Fish and Debris Passage: The Iron Gate Dam Experience

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# Technical Developments in Materials and Techniques for Fish and Debris Passage

## The Iron Gate Dam Experience



# Barrier Curtains

Controlling Temperature, Algae and Dissolved Oxygen



Acknowledgements:

Watercourse Engineering, Davis California

PacificCorp, Portland Oregon

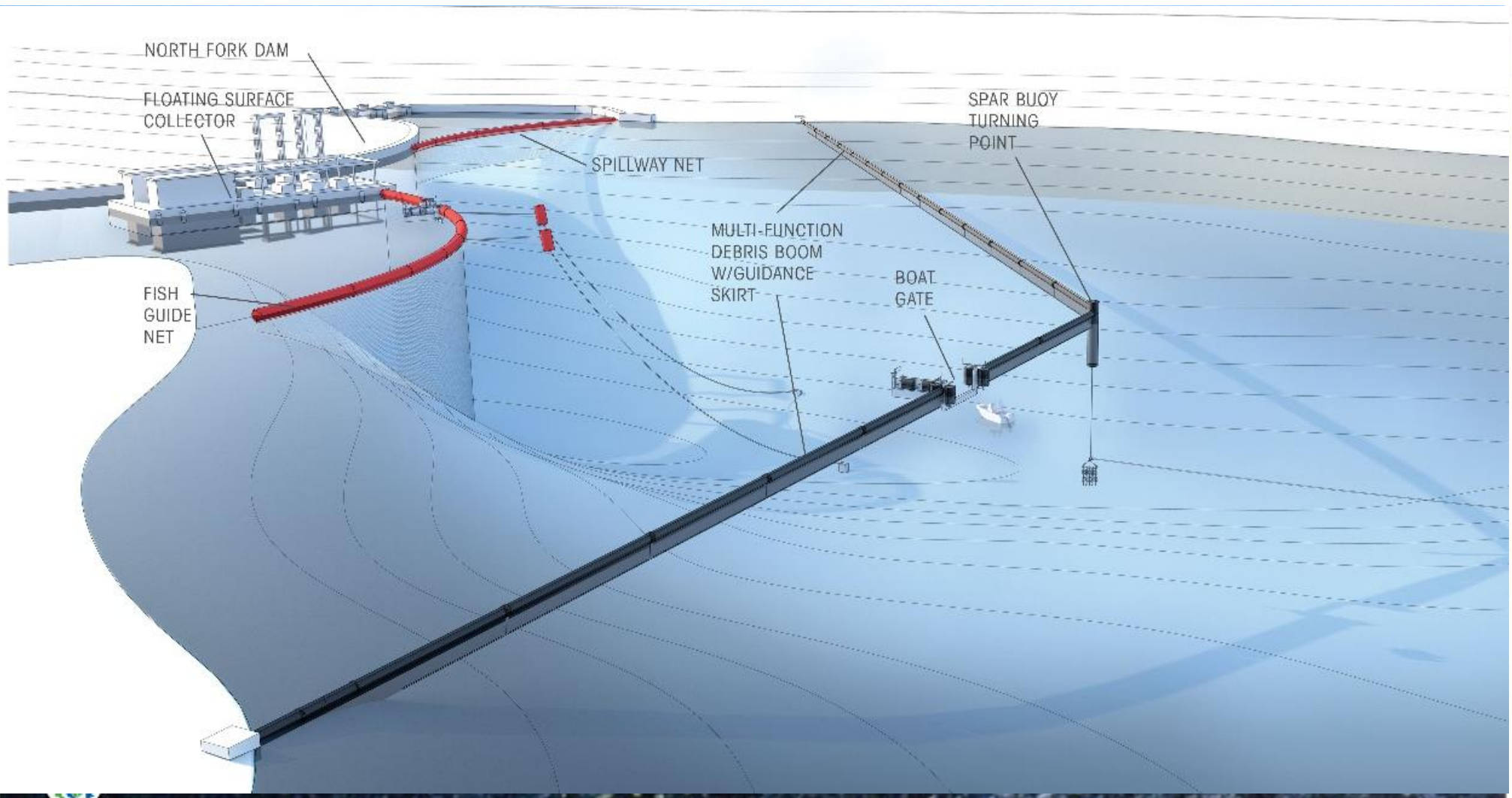
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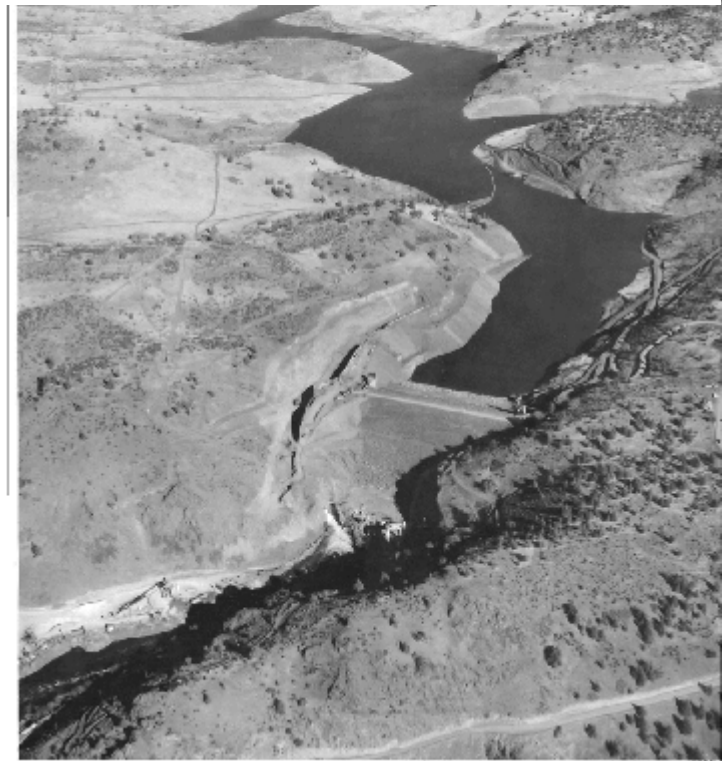
# Iron Gate

- Earth fill hydroelectric dam
- The lowermost of a series of power dams on the Klamath river
- Poses the first barrier to migrating salmon in the Klamath.



# The Klamath Hydroelectric Project

- Owned and operated by PacifiCorp.
- Developments include:
  - (1) East Side
  - (2) West Side
  - (3) Keno
  - (4) J.C. Boyle
  - (5) Fall Creek Powerhouse (on a tributary)
  - (6) Copco No. 1
  - (7) Copco No. 2
  - (8) Iron Gate





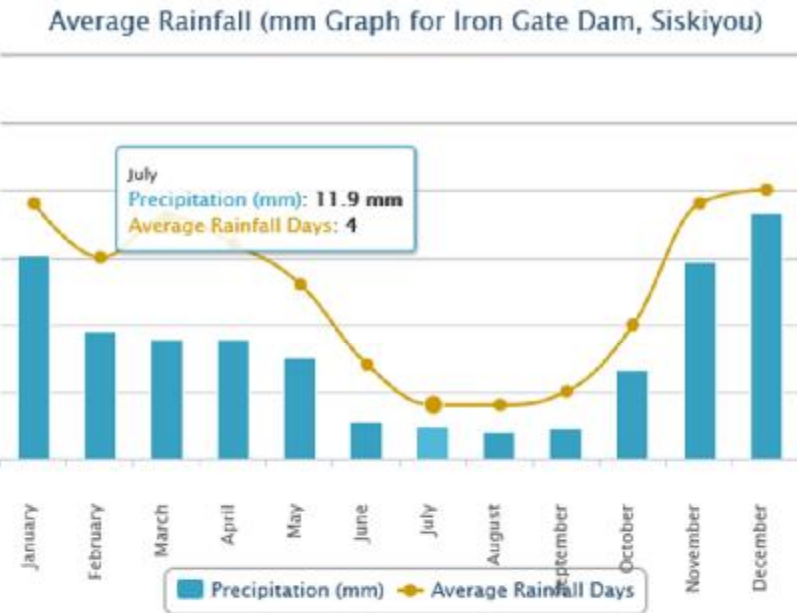
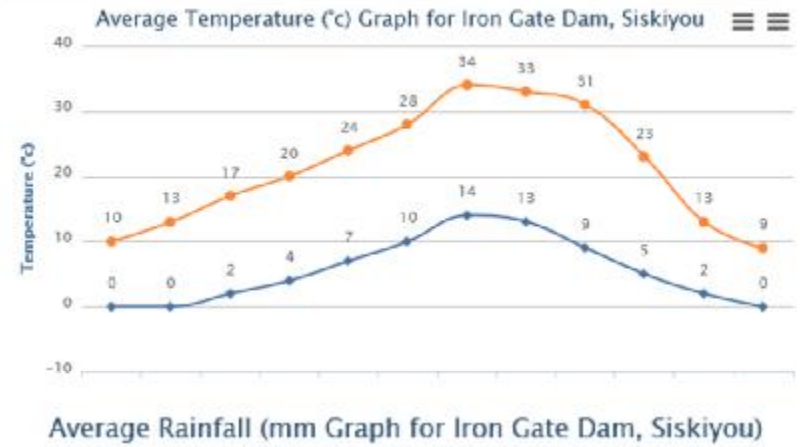
# Water Quality Issues

- Blue-green algal blooms
- *Microcystis aeruginosa* (Microcystis), produces microcystin, a liver toxin...led to annual issuance of state health advisories during the late summer and early fall.
- Anadromous fish in the watershed have declined significantly in recent years which may be related to various factors.





Iron Gate Reservoir Intake Tower, Trash Rack, and A-frame Debris Boom. (Photo Date: September 10, 2008.)





# 2015 Intake Barrier Curtain Installed

- Segregate reservoir surface waters with higher blue-green algae
- Create a preferential flow from below the surface photic zone to the reservoir intake to prevent the surface waters with higher blue-green algae concentrations from being entrained into the intake and released downstream
- Potentially facilitate movement of cool water from the lower depths of the reservoir toward the conduit intake, releasing cooler water downstream.
- Improve water quality conditions downstream





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# Curtain Design

- Strength and flexibility to function over a total reservoir water surface elevation fluctuation of 16 ft. (from 2,330 ft. to 2,314 ft.), reflecting recent reservoir operating levels.
- Curtain depth need to be adjustable during trials.
- The connection between the floats, netting, and fabric panels is as impermeable as practical to improve chance of success.
- Curtain was designed to improve on the a previous trial curtain, 2014.





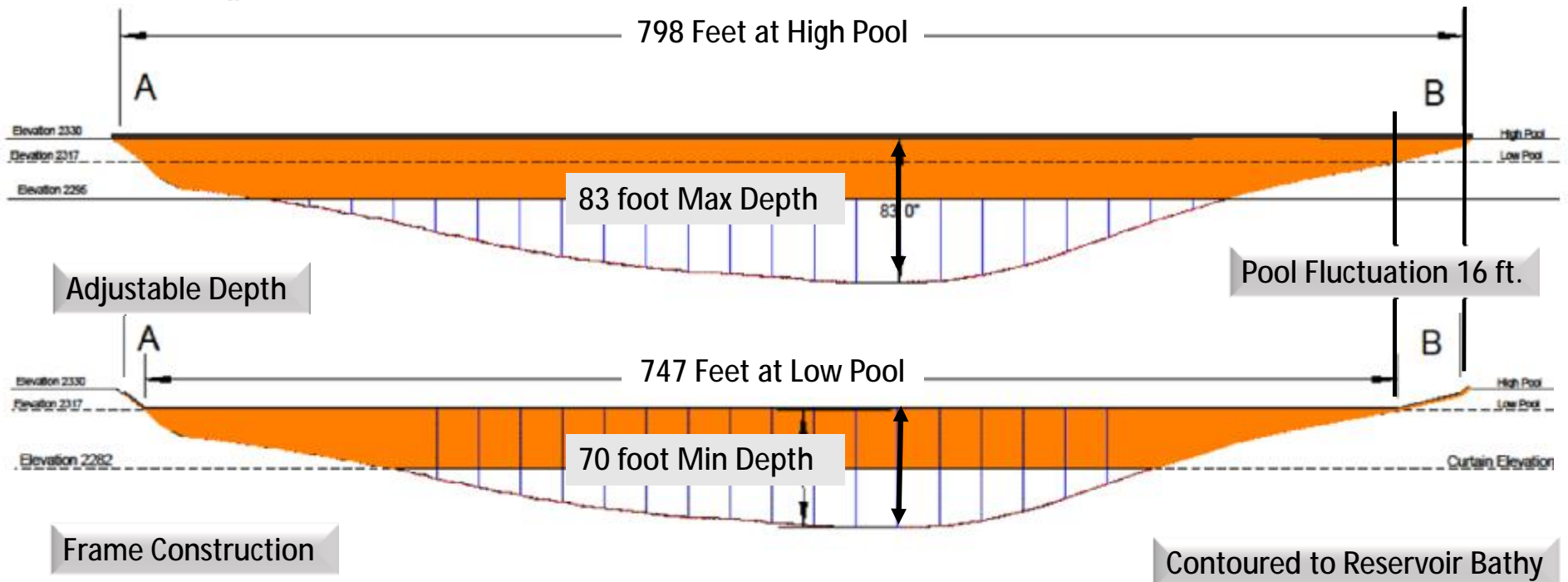


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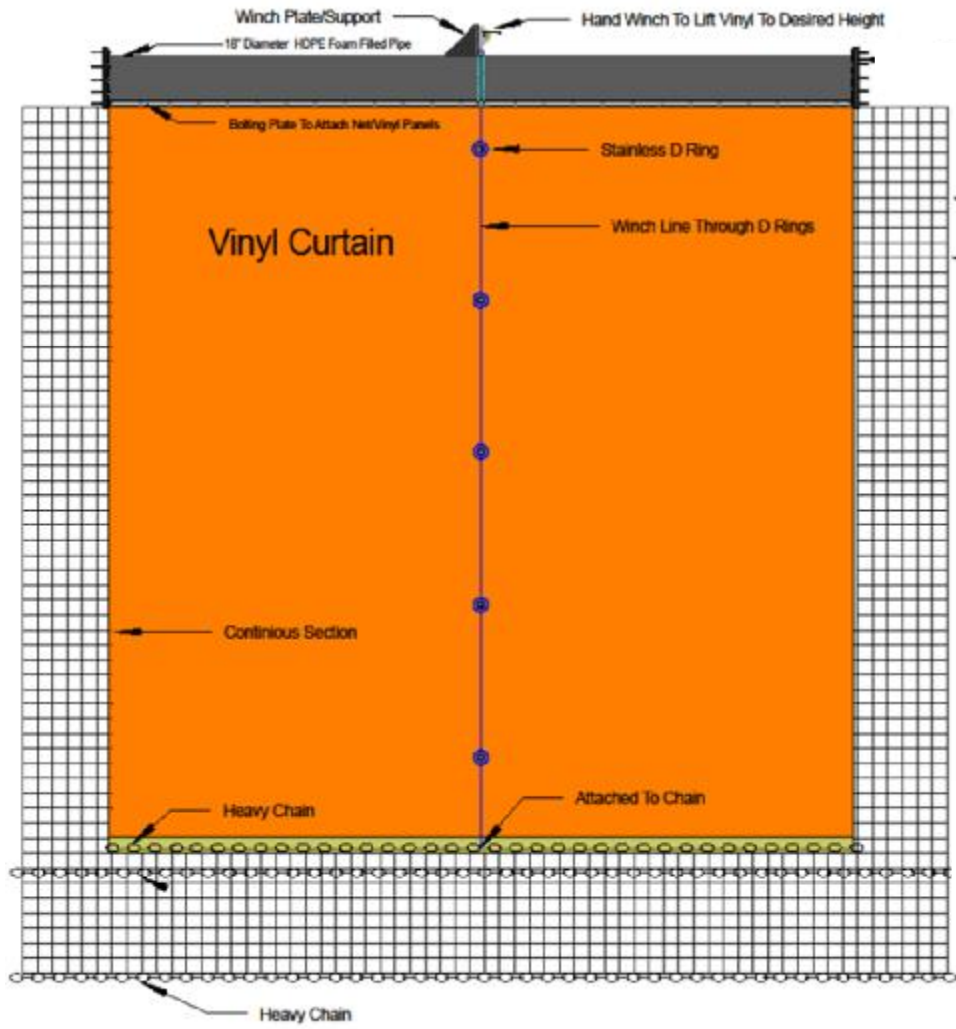
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# Curtain Design







Pacific Netting Products Inc  
 Iron Gate Dam Algae Barrier  
 Typical Barrier layout  
 Date: 1/15/2015    Drawn: PC-IGD-004 Rev: 0    Scale: None    Not For Construction



# Impervious Surface



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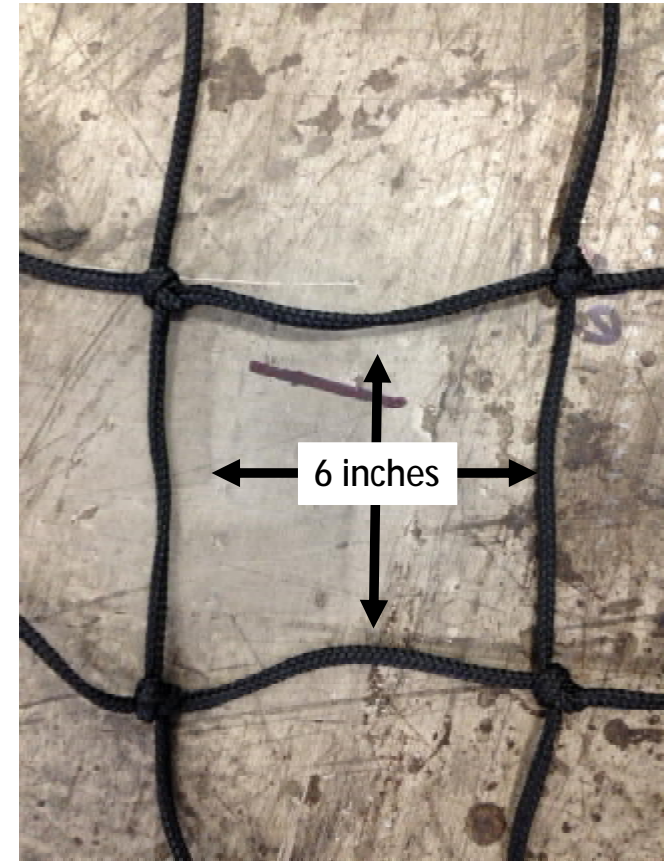


## Seaman Corp. XR-5

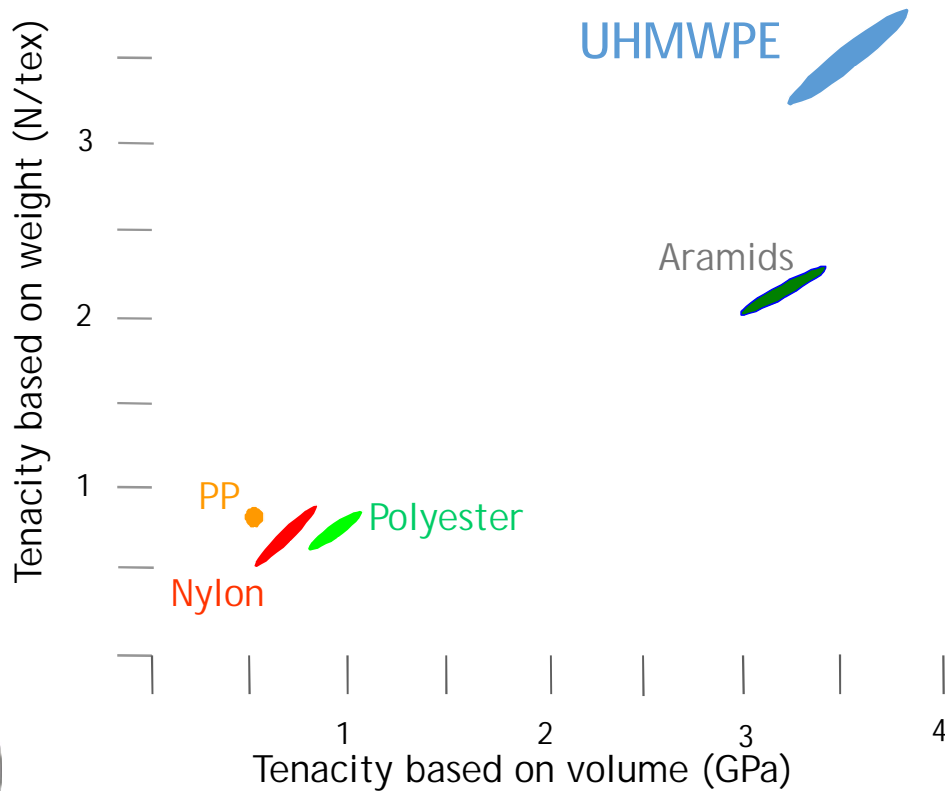
- Synthetic reinforced geomembrane
- High Puncture Resistance: 30 mil thick 868lbs
- Fabric inhibits damage spread if torn or punctured
- Flexible, prefabricated panels (15,000+ square feet) practical.
- Material is not subject to environmental stress cracking

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# Strength and Shape: Polyester Net, 6 Inch mesh



# Comparison of Polyester Properties

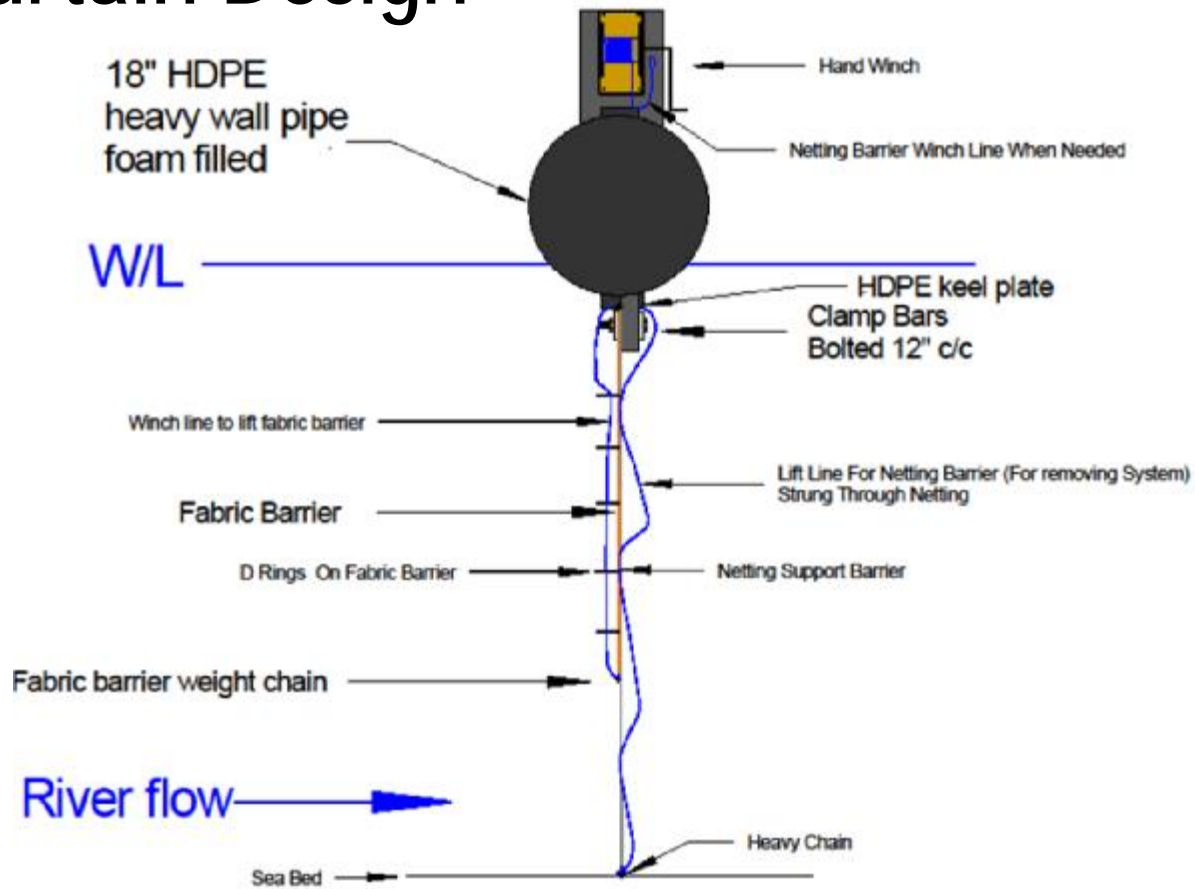


- Slightly stronger than Nylon
- Unlike nylon
  - Does not lose strength when wet
  - Is not stretchy.
- Combines good strength and durability, relatively low stretch and reasonable prices.
- Specific gravity of 1.38
- Low creep under load.
- Excellent abrasion resistance





# Barrier Curtain Design





# Anchor Design

- Anchors located along the length of the curtain and have sufficient capacity to hold the curtain and net system in place.
- Danforth-type anchors are used to provide the curtain with lateral stability to maintain its position and resist wind-driven loading and reservoir currents.
- Steel crown floats are located approximately 50 ft. from the curtain to separate vertical anchor load forces from the curtain system.
- Shoreline anchors are located at the upstream dam face and at the northeast shoreline.



# Anchor Design



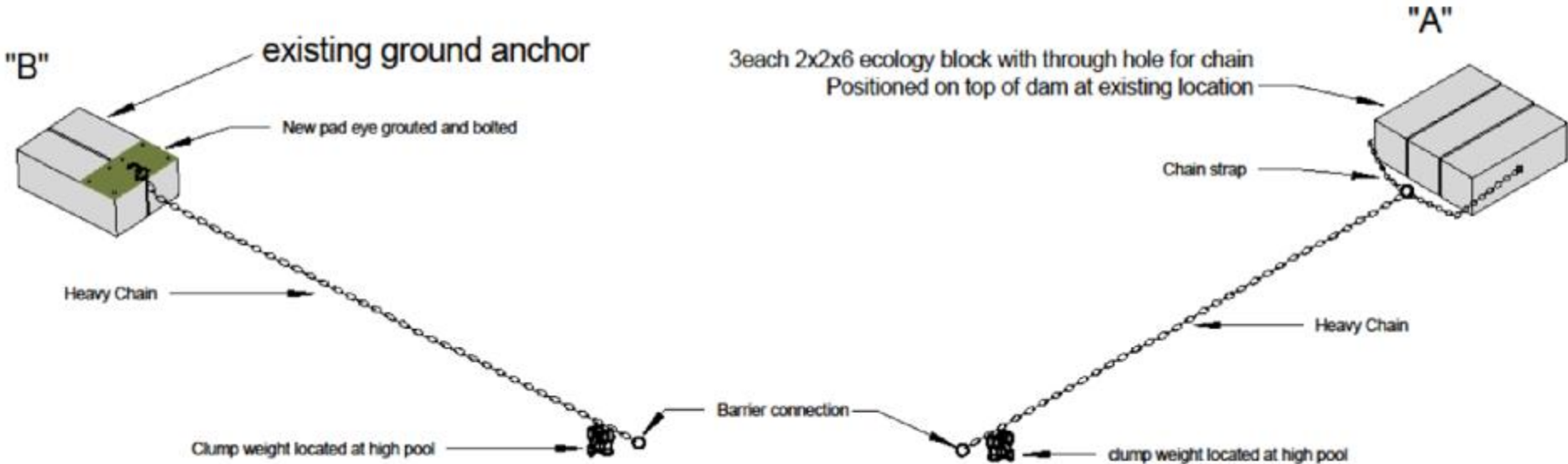
# Anchor Design



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# Shore Anchors



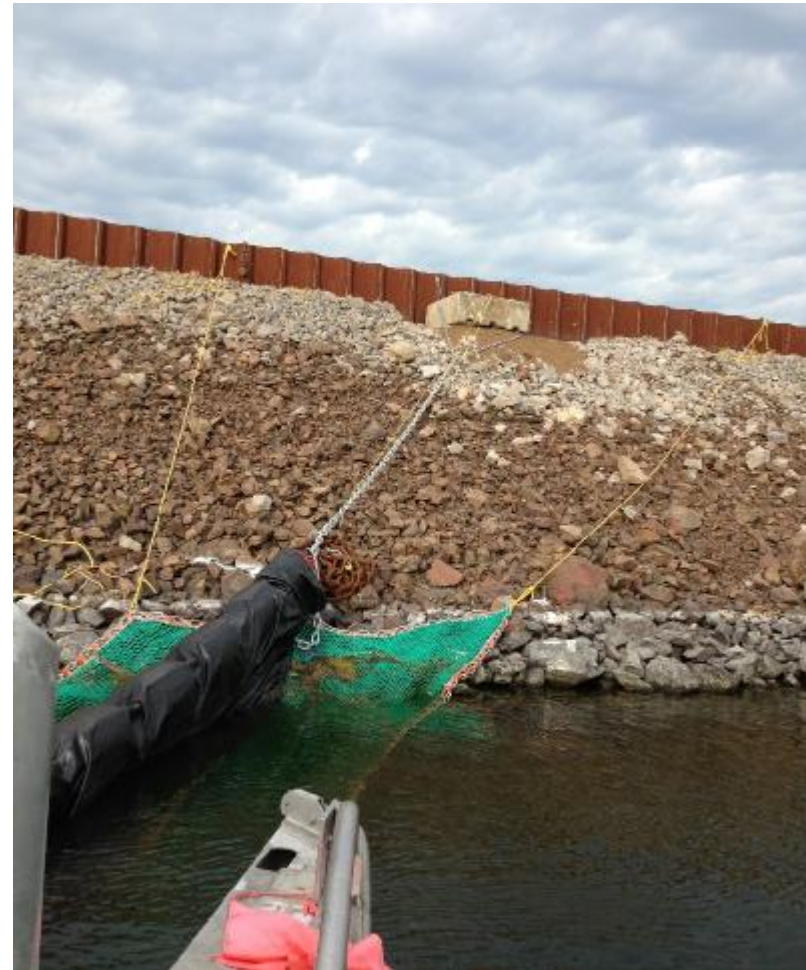


# Shore Anchors





# Shore Anchors



# Flotation

- Rigid float system.
- 18-in.-diameter and 25-ft-long, high-density polyethylene (HDPE), foam-filled MultiFunction Booms
- Each section flange bolted to the next to form a continuous boom
- Provide sufficient buoyancy to maintain the top of the float at a minimum of 12 in. above the water surface at all times.
- Hand winches fitted above boom sections with through-hull fittings below them to allow operators to adjust the temperature curtain to proper depth.



# Flotation





# Flotation



# Flotation



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# Study

Watercourse Engineering, Inc., Davis, California

Monitored the effectiveness of the curtain system at reducing algal biomass entrainment and subsequent release to the Klamath River.



# Study Activities

- Data sondes
  - Continuously-recording collected data on water temperature, dissolved oxygen, pH, conductivity, and phycocyanin on the upstream and downstream sides of the curtain and in the Klamath River below Iron Gate dam.
- Bimonthly grab sampling
  - Twice-monthly vertical grab samples were collected from the water column upstream and downstream of the curtain.
- Short-term, multiday sampling
  - Deployed auto samplers in Iron Gate reservoir upstream of the curtain and in the river downstream of Iron Gate dam.
  - Used an Acoustic Doppler Current Profiler (ADCP) to monitor water column velocities along both sides of the curtain



# Summary of 2015 Results

- Compared surface samples collected 0.5 meter depth upstream of the barrier curtain with downstream samples and indicated downstream reductions in
  - Microcystin (70 percent)
  - *Microcystis aeruginosa* (82 percent)
  - *Aphanizomenon flos-aquae* (97 percent)
  - Chlorophyll-*a* (61 percent)
- Downstream water temperatures and dissolved oxygen levels were similar to *deeper waters* upstream of the curtain



# Studies showed

- The shallow, near-surface water upstream of the curtain essentially stopped moving toward the powerhouse intake.
- The water velocities approaching the curtain were highest near the bottom of the curtain and a flow envelope formed below the photic zone upstream of the curtain.
- This resulted in the withdrawal of deeper waters from Iron Gate reservoir.





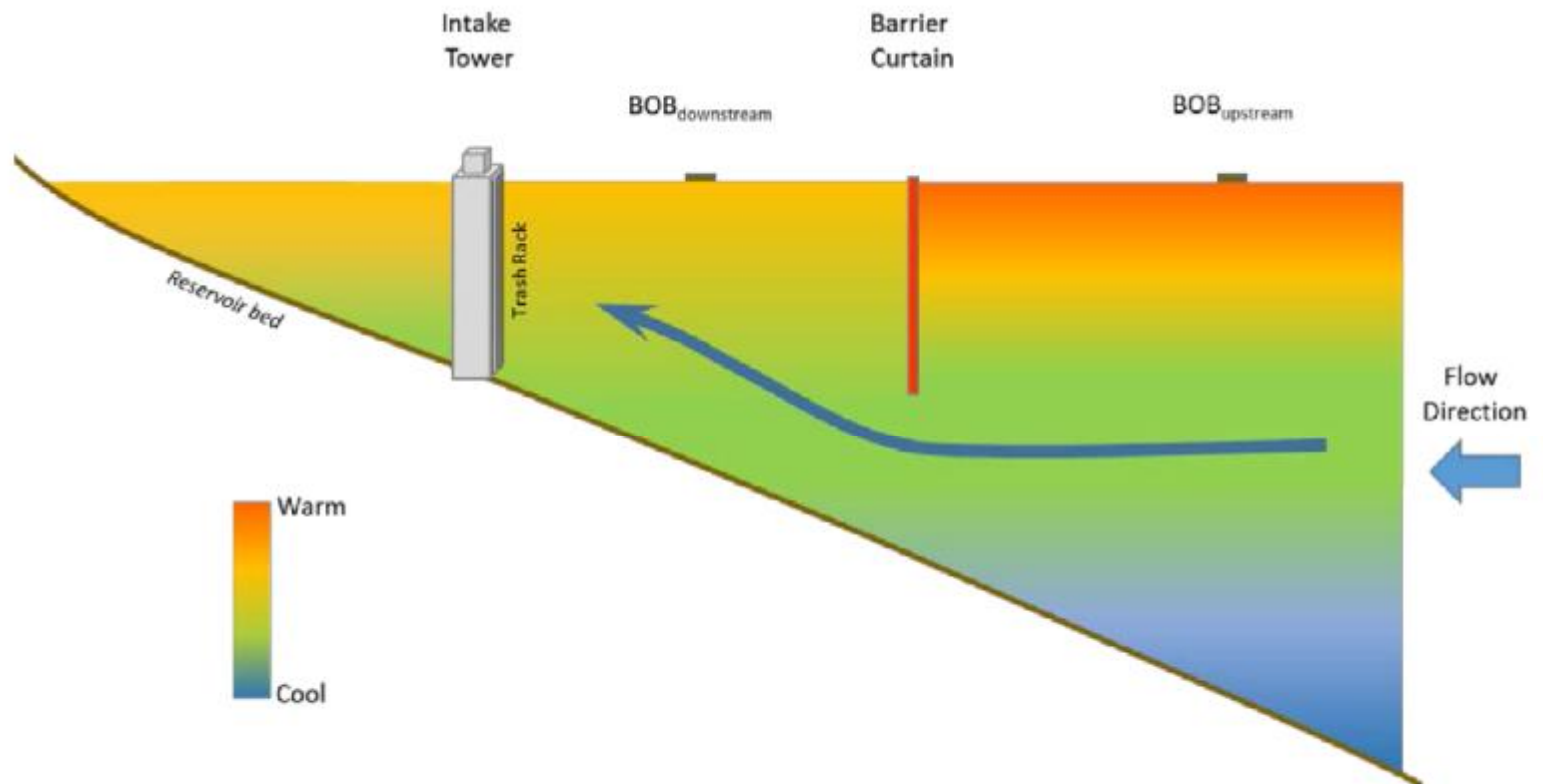
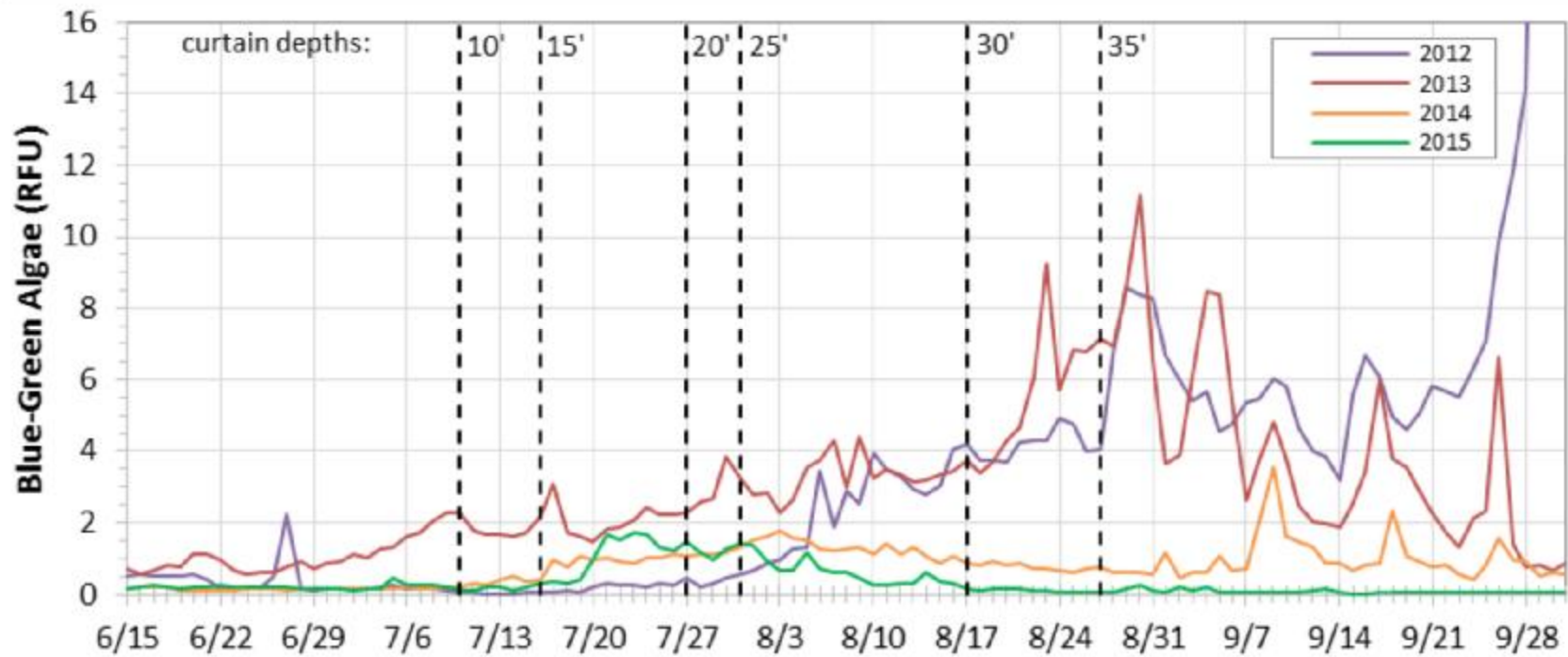


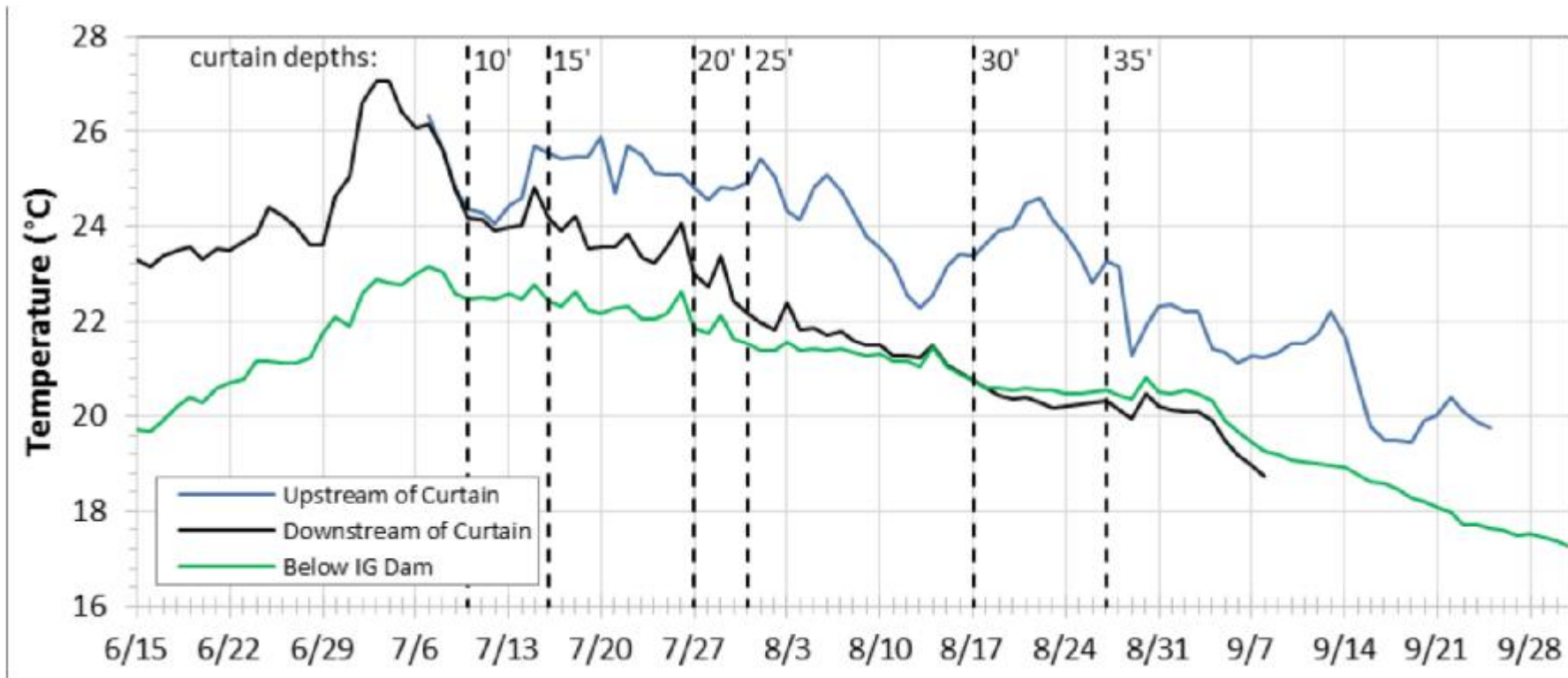
Figure 60. Conceptual Profile View of Thermal Conditions in Iron Gate Reservoir Showing the Location of the BOBs, Curtain, and Intake Tower.





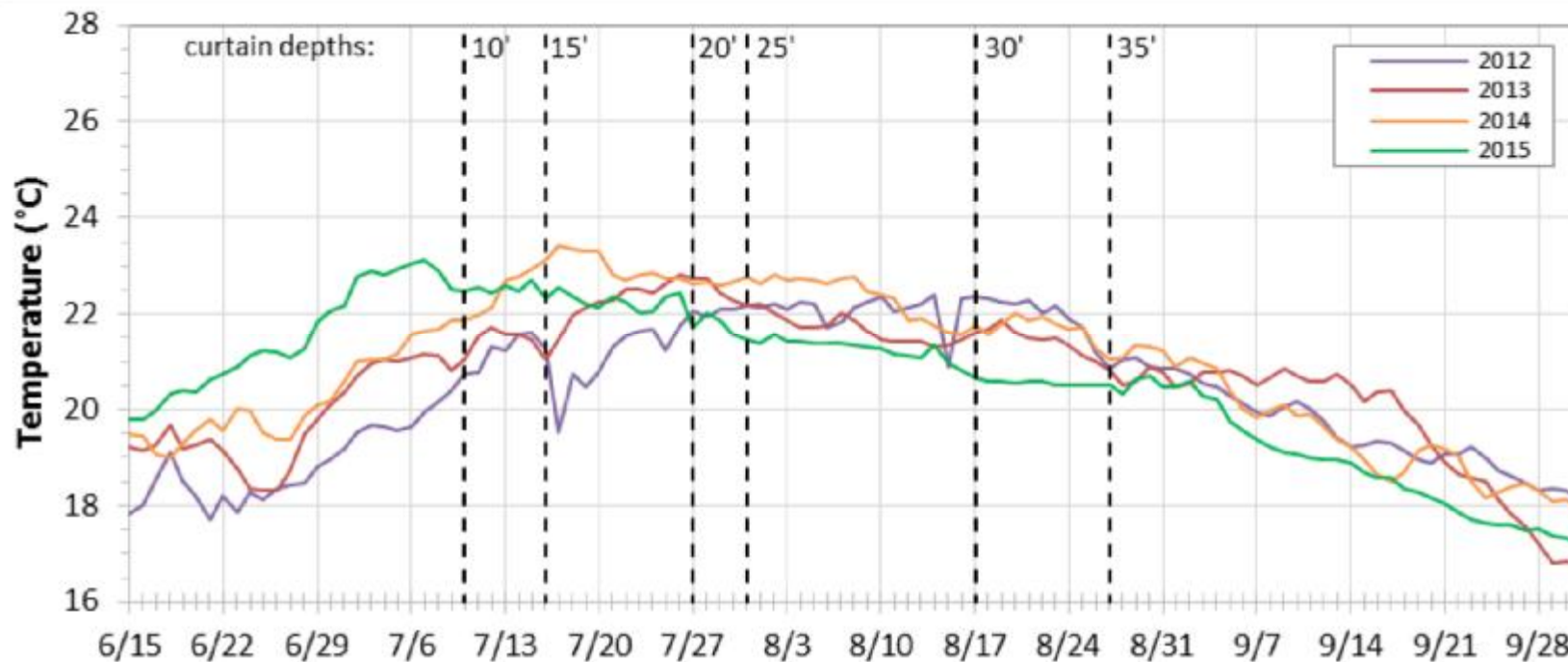
Daily Average BGA Concentration (RFU) as Measured by PacifiCorp Data Sonde in the Klamath River Below Iron Gate Dam (near the Hatchery Bridge) from June 15 to September 15 During Years 2012, 2013, 2014, and 2015.





Daily Average of Near-surface (0.1 to 1.3 m) Water Temperatures Measured by Data Sondes Upstream and Downstream of the Curtain in Iron Gate Reservoir, and in the Klamath River Below Iron Gate Dam (near the Hatchery Bridge) from June 15 to September 30, 2015. Vertical hatched lines indicate dates during 2015 when the curtain was lowered to specified depths.





Daily Average Water Temperature as Measured by PacifiCorp Data Sonde in the Klamath River Below Iron Gate Dam (near the Hatchery Bridge) from June 15 to September 15 During Years 2012, 2013, 2014, and 2015.

Note: Vertical hatched lines indicate dates during 2015 when the curtain was lowered to specified depths. Vertical hatched lines are not shown for the curtain deployment in 2014 (which was initiated on August 12, 2014, unfurled to a maximum depth of 35 ft. on August 28, 2014, and subsequently removed on September 8, 2014).

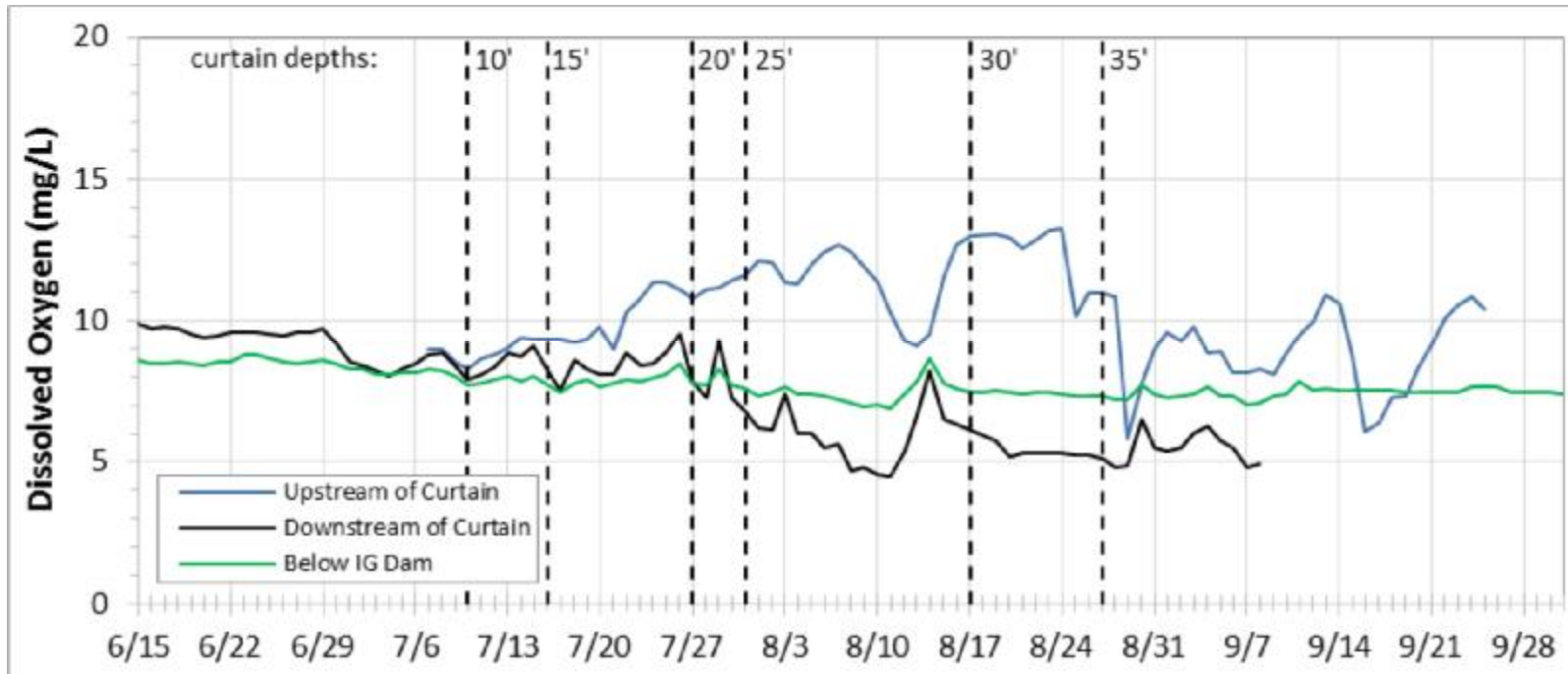




# Dissolved Oxygen

- Dissolved oxygen concentrations upstream and downstream of the curtain diverged under curtain deployment
- Upstream of the curtain, there was higher dissolved oxygen as a result of primary production in near-surface waters.
- Downstream of the curtain, waters from depth had lower dissolved oxygen concentrations.
- Dissolved oxygen concentrations were higher in the Klamath River below Iron Gate dam because of reaeration through the powerhouse.
- A comparison of 2012-2015 dissolved oxygen concentrations below Iron Gate dam suggests that dissolved oxygen levels following curtain deployment were comparable to prior years.





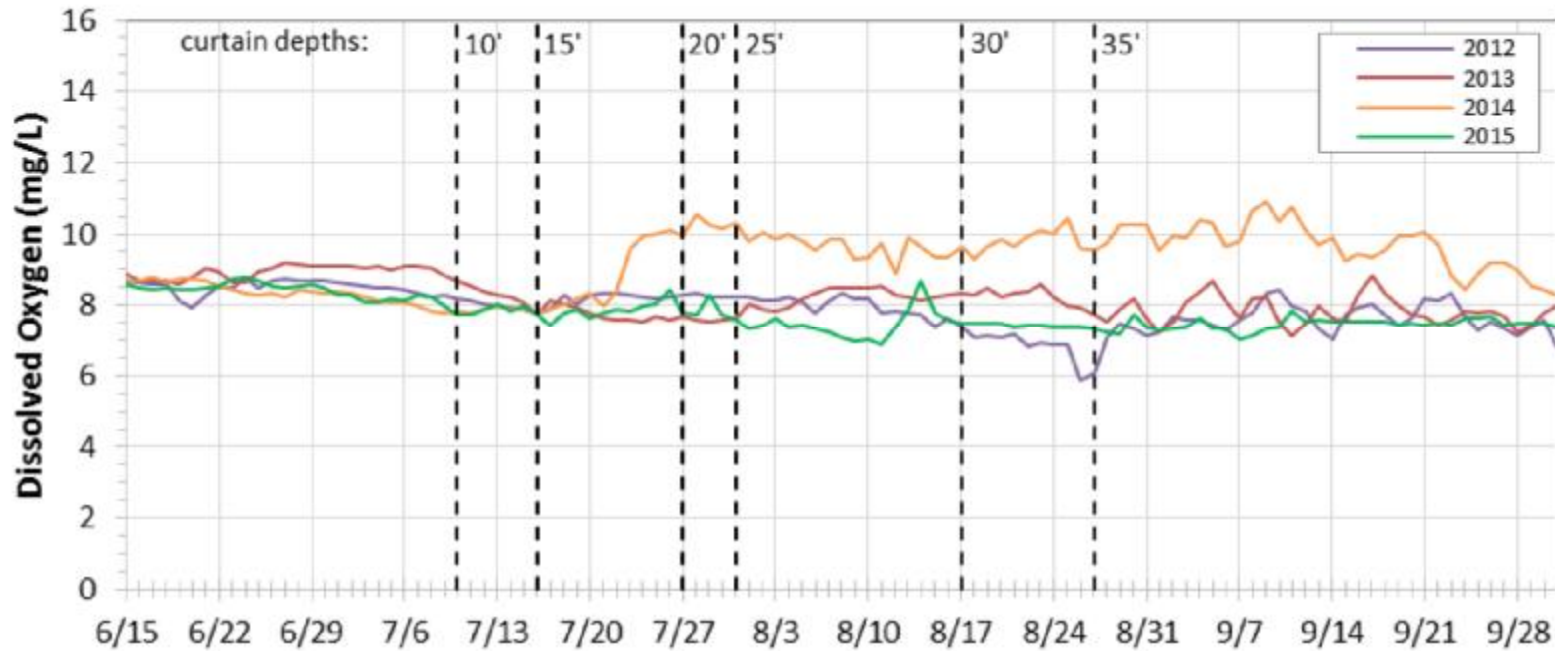


Figure 11. Daily Average Dissolved Oxygen as Measured by PacifiCorp Data Sonde in the Klamath River Below Iron Gate Dam (near the Hatchery Bridge) from June 15 to September 15 During Years 2012, 2013, 2014, and 2015. Note: Vertical hatched lines indicate dates during 2015 when the curtain was lowered to specified depths. Vertical hatched lines are not shown for the curtain deployment in 2014 (which was initiated on August 12, 2014, unfurled to a maximum depth of 35 feet on August 28, 2014, and subsequently removed on September 8, 2014).



# Summary

- Curtain resulted in the withdrawal of deeper waters from Iron Gate reservoir.
- BGA concentrations (as RFU) were reduced downstream of the curtain and in the Klamath River downstream of the dam, water temperatures followed a similar trend, and dissolved oxygen also reflected a deeper withdrawal of water with lower dissolved oxygen.
- Although effects of the curtain were evident at relatively shallow depths (3 to 4.5 m [10 to 15 ft.]), curtain performance at full depth (9 to 10.7 m [30 to 35 ft.]) provided the greatest effect.





# Conclusion

Advances in materials and technology should allow systems the

- strength to provide safe deployment
- effectiveness to address certain water management concerns
- flexibility to be designed in a cost effective, site specific method



# Questions?



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