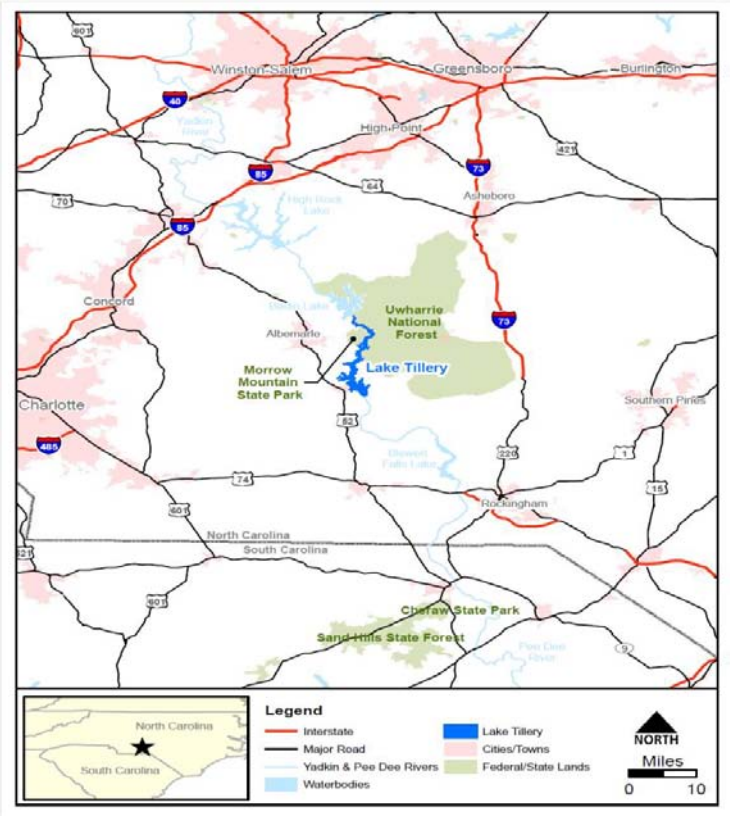
Application of a Reservoir Oxygen Diffuser System to Meet Dissolved Oxygen Requirements at the Tillery Hydroelectric Plant, North Carolina

Tillery Hydroelectric Plant

- Part of the Yadkin-Pee Dee Hydroelectric Project No. 2206
- Began operation in 1928
  - 84 MW peaking and load-following capacity.
- Four generating units
  - 3 Frances units; 1 fixed blade unit
    - Units 1 and 3 – 22 MW (4,456 cfs)
    - Unit 2 – 18 MW (3,627 cfs)
    - Unit 4 – 22 MW (5,145 cfs)

Lake Tillery Characteristics

- Located on the Yadkin-Pee Dee River at RM 218
  - 5,697 acres with 118 miles of shoreline and 15 miles in length
  - Normal lake elevation of 278.2 ft NGVD
  - Hydraulic retention of 8.3 days
  - Warm water, moderately productive reservoir
  - DO hypolimnetic deficit typically occurs from mid May to early October



Relicensing and Regulatory Background

- License application for Project filed with FERC in April 2006.
- FERC issued final EIS for the Project in 2008.
  - Currently operating under existing 1958 license with same terms and conditions.
- Currently awaiting new license issuance by FERC.
- 401 Water Quality Certificate was issued in September 2008.
  - Required to meet DO water quality standards by end of 2011.
  - Instantaneous DO of 4 mg/l and daily average of 5 mg/l.

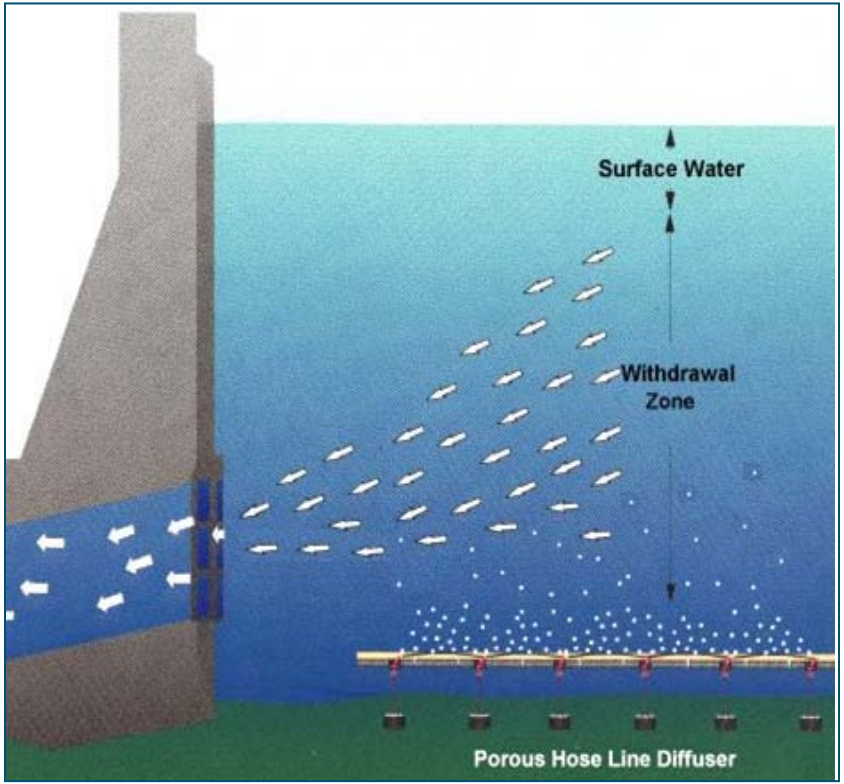
DO Enhancement Technology Evaluation

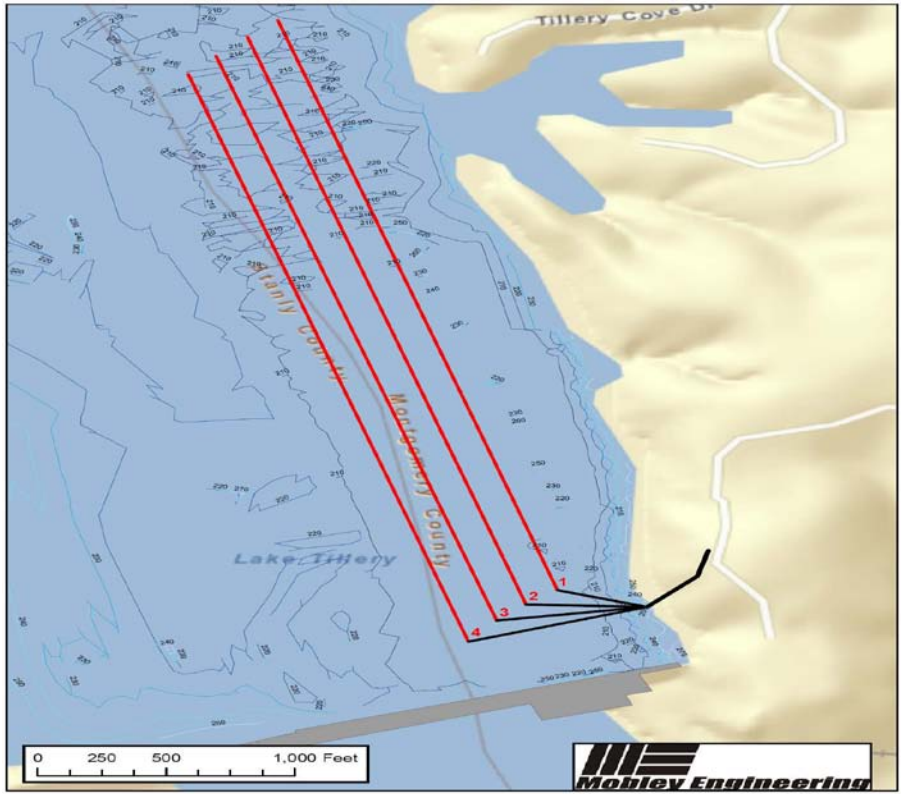
- Conducted from 2006 to 2010 to select most technologically feasible and cost-effective engineering solution.
- Oxygen deficit ranged from 2.0 to 3.0 mg/l based on environmental studies.
- Systematic testing approach of 8 different technologies.
  - Turbine aeration with draft tube passive air admission
  - Turbine aeration with draft tube forced compressed air injection
  - Selective surface withdrawal
  - Surface water mixing with motor-driven impellers
  - Compressed air bubble diffusers
  - Surface water mixers in combination with draft tube venting
  - Compressed air bubble diffusers in combination with draft tube venting
  - Reservoir oxygen diffuser system

Reservoir Oxygen Diffuser System

- Permitted and constructed in an eight month period at $2.5M.
- Two 15,000 gallon horizontal storage tanks capable of delivering 150 tons/O_2 per day.
- Four 26 ft vertical tower vaporizers.
- Oxygen flow control skid with 125 psi operating pressure.
- Programmable Logic Control software to operate system.
- Four 3,500 ft diffuser lines at two operating depths (54 and 66 ft depths).

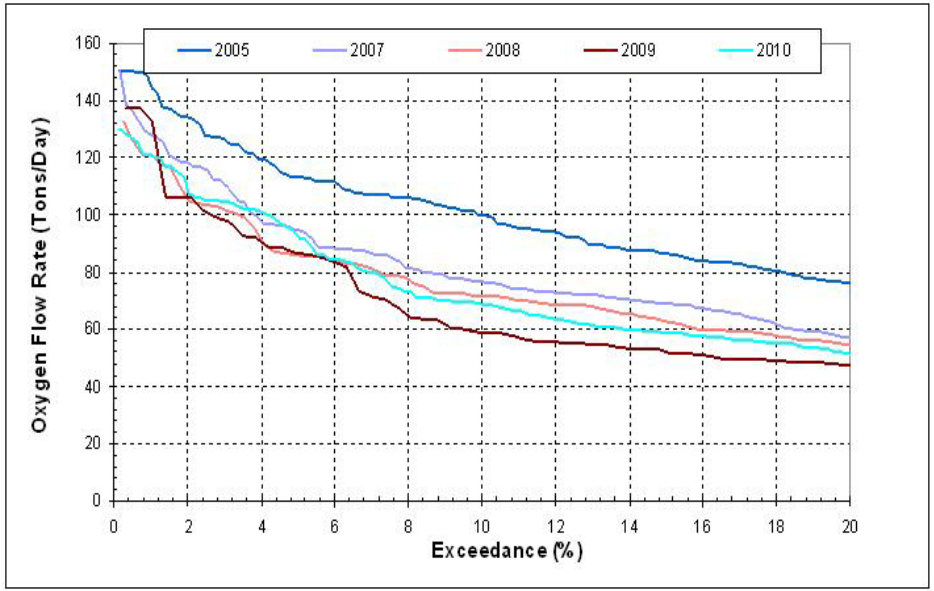
Reservoir Oxygen Diffuser System Operation





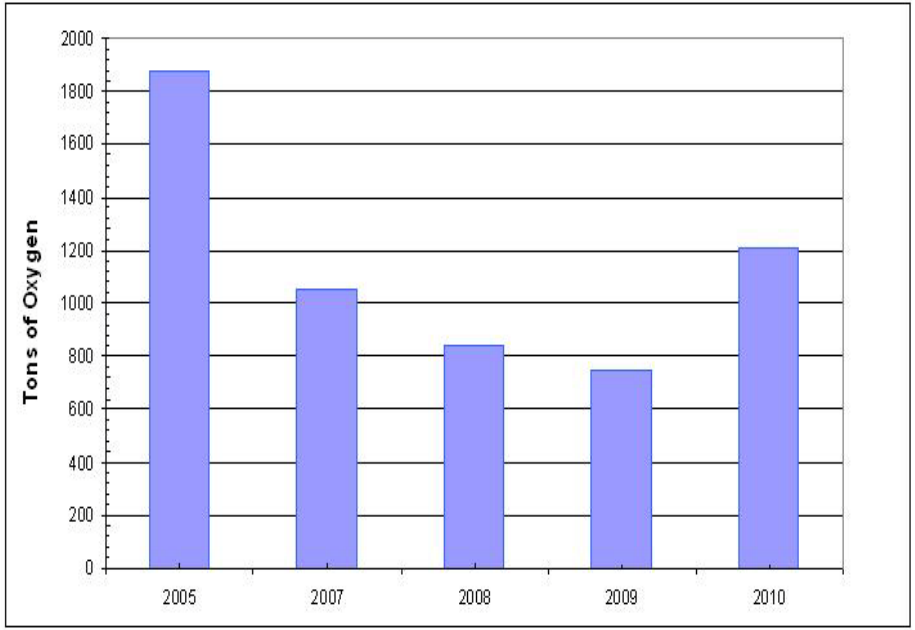
Modeling Oxygen Diffuser System Requirements

- Time-invariant modeling approach.
- 5 years of hourly operational and environmental data, 2005-2010.
- Flow record encompassed range of precipitation and inflows.
- Oxygen transfer efficiency of 85% and BOD/IOD set at 0.5 mg/l.
- System size requirement of 150 tons/day with < 1% of time that the system will not meet DO compliance target of 5 mg/l.

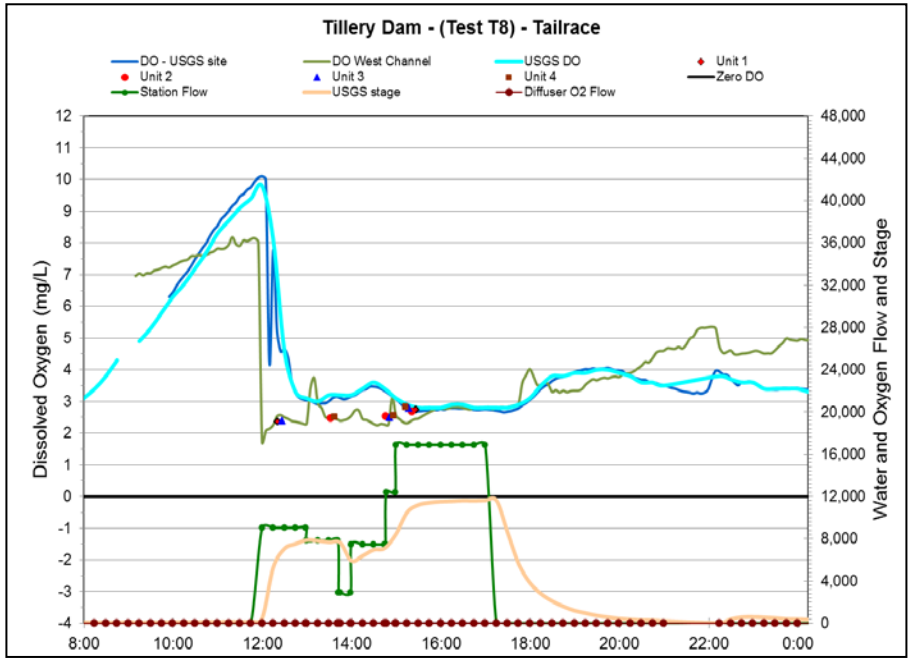


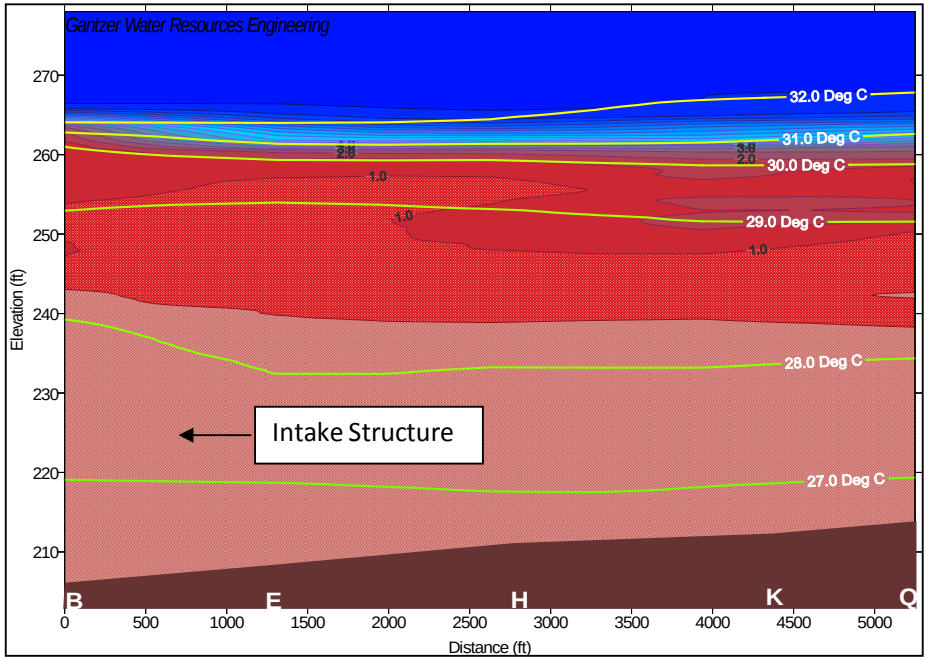
Reservoir Oxygen Diffuser System Predictions

- Oxygen usage was predicted to range from 750 to 1,880 tons annually.
- Estimated annual operating costs ranging from $77,250 to $193,640 with median cost of $106,000.
- System met DO requirements at downstream compliance point 99% of modeled period.
- Peak oxygen demand is 8 week period from July through August.

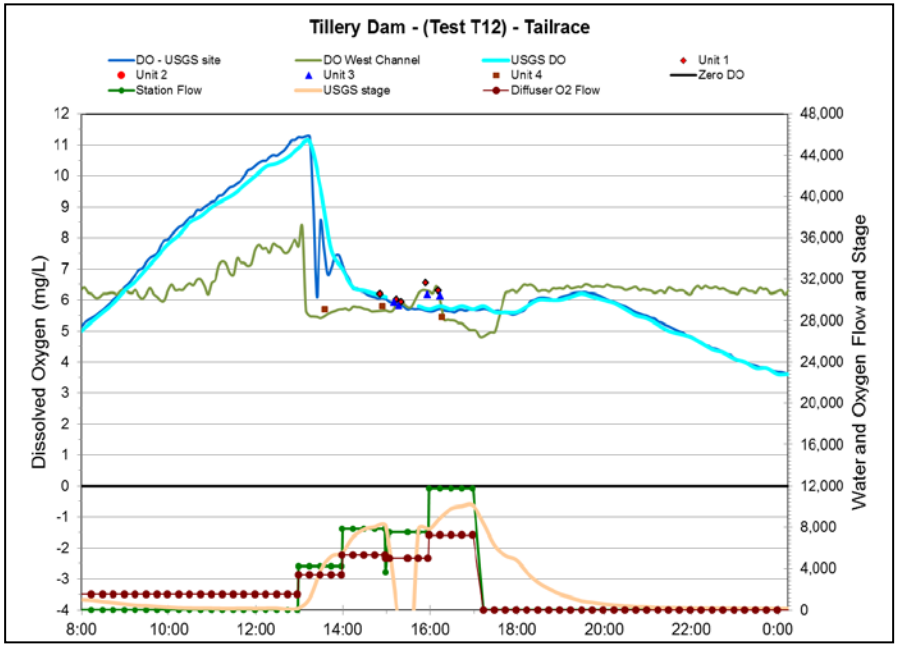


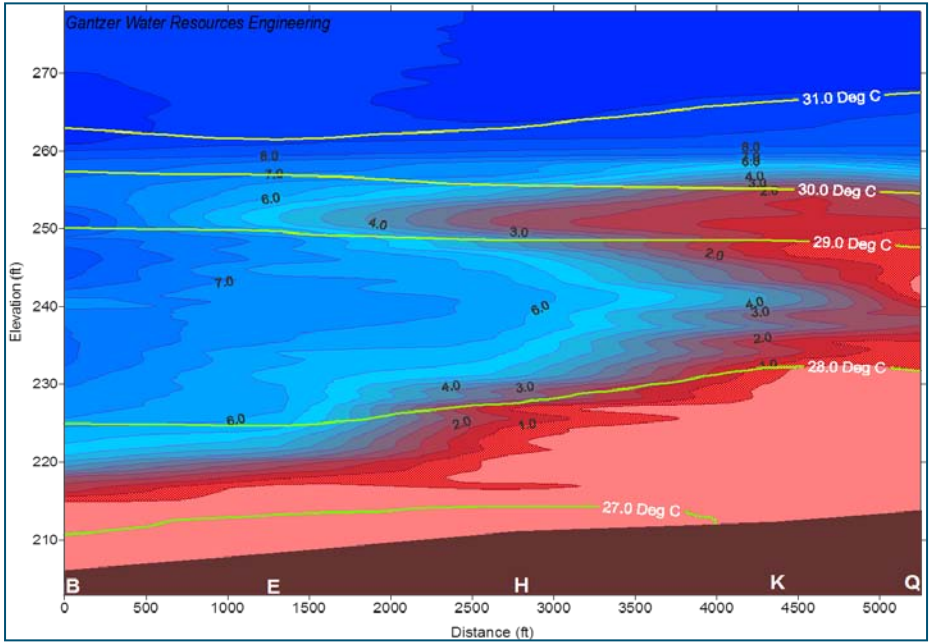
Reservoir Oxygen Diffuser System Testing Results, August 8, 2011



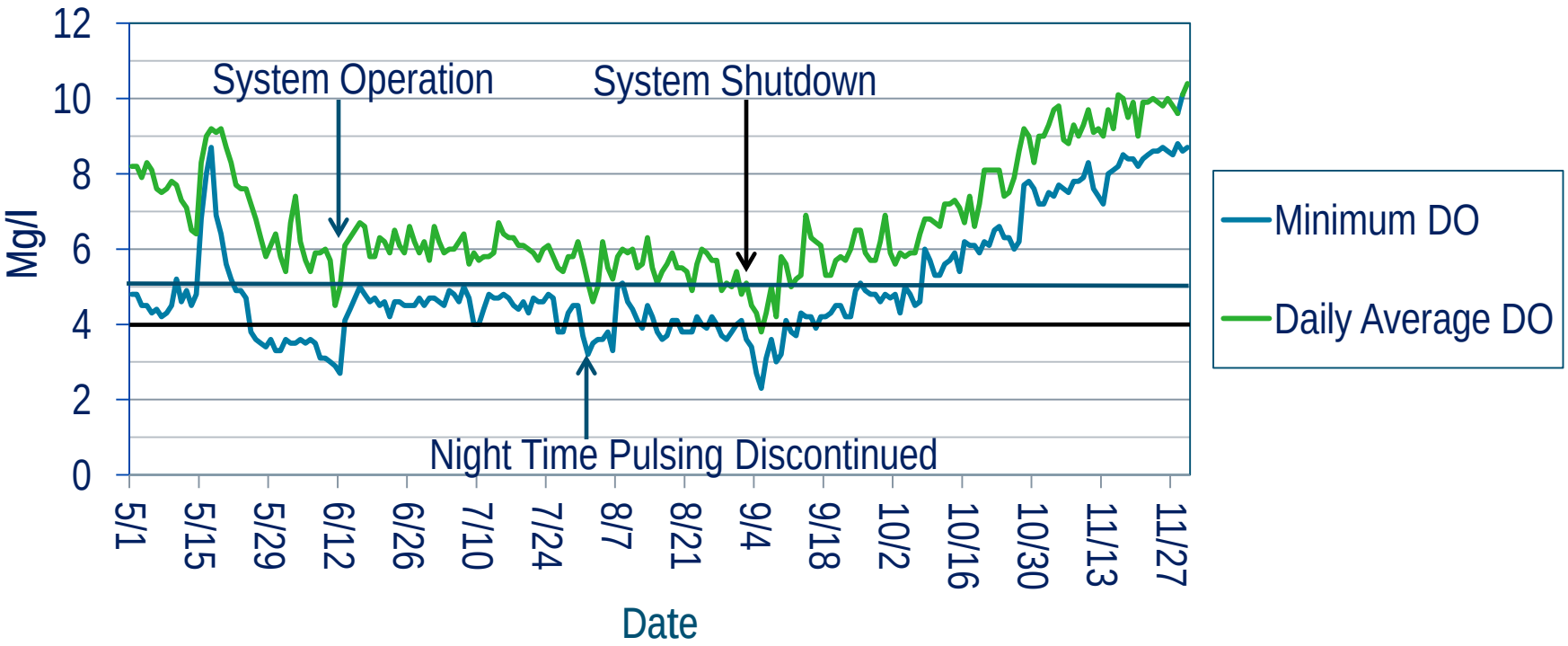


Reservoir Oxygen Diffuser System Testing Results, August 12, 2011





Minimum and Daily Average Dissolved Oxygen Concentrations May-November 2012



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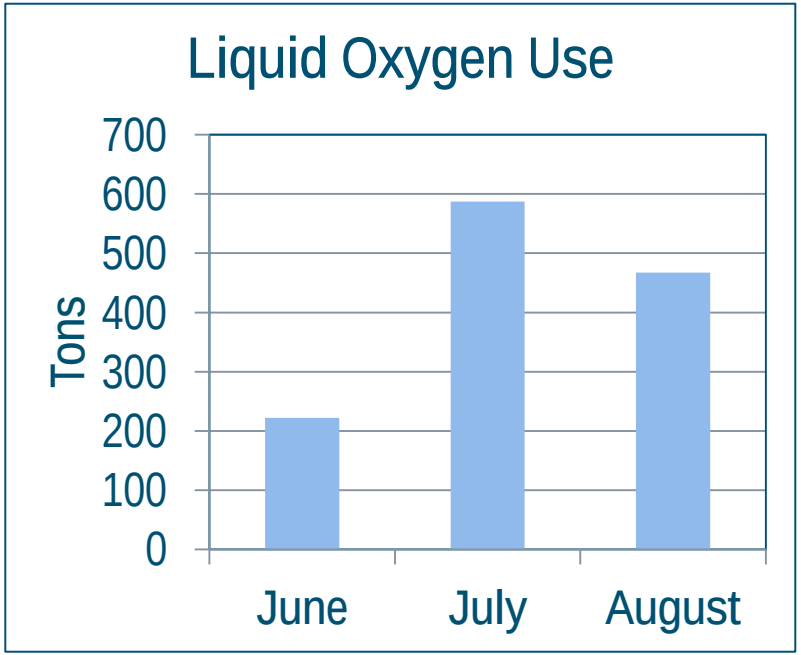
Reservoir Oxygen Diffuser System Testing Performance During 2012

- Oxygen usage ranged from 222 tons in June to 587 tons in July with total use of 1,274 tons.
- Operating liquid oxygen cost for June through August testing period was $169,883.
- DO compliance with system operation was 95% for the daily average DO of 5 mg/l and 96% for the minimum instantaneous DO of 4 mg/l.



Conclusions

- Eight different technologies were evaluated at the Tillery Development over a 5 year period with the reservoir dissolved oxygen diffuser system as the primary means of DO compliance.
- System construction took 8 months to complete at capital cost of $2.5M.
- As part of decision-making process, modeling was performed with real-time plant operational and environmental data to evaluate diffuser size and operating cost requirements.
- Modeling results predicted annual liquid oxygen use ranging from 750 to 1,880 tons annually. Actual use during the 2012 testing period was 1,274 tons.

Conclusions (continued)

- O&M predicted costs of liquid oxygen ranged from $77,250 to $193,640 with median cost of $106,000 (assumption of $103/ton). Actual cost during 2012 testing period was $169,883.
- Dissolved oxygen compliance during the 2012 testing period was 95% for daily average DO of 5.0 mg/l and 96% for instantaneous minimum DO of 4.0 mg/l.
- Night time pulsing of units was an effective means to meet DO water quality standards in the power plant tailrace.
- Managing the O&M costs will be a challenge of operating the system as liquid oxygen costs will vary annually with precipitation, river inflow, and generation levels.
- Operating the system efficiently requires weekly monitoring of lake stratification DO patterns.

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