

The Use of Angled Bar Racks and Louvers for Protecting Fish at Water Intakes



**A Symposium on Cooling Water Intake Technologies
To Protect Aquatic Organisms**

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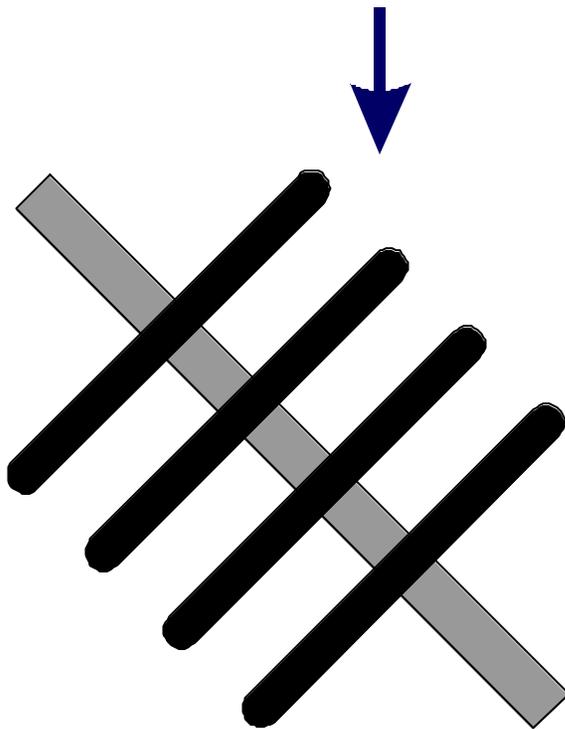
EPRI

Angled Bar Racks and Louvers

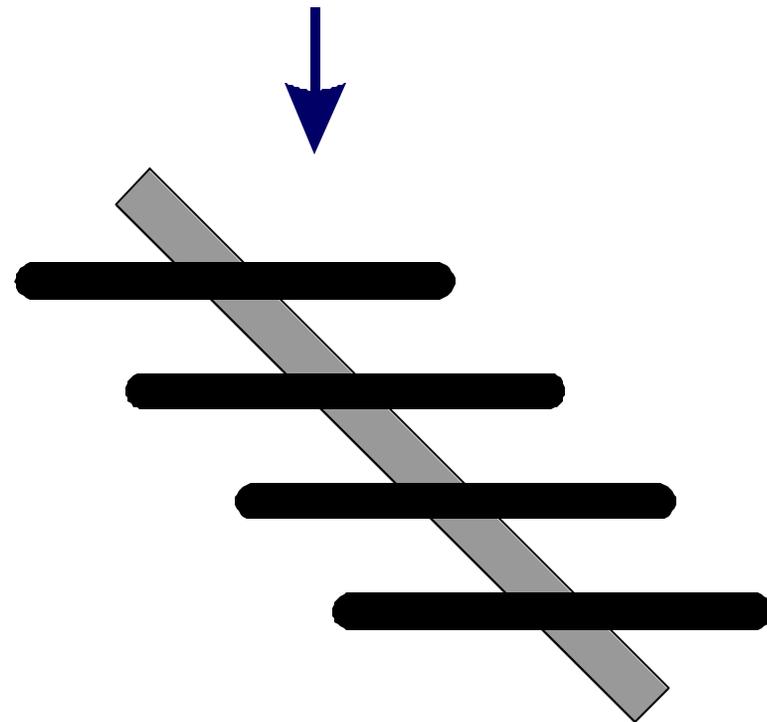
- ◆ **Field Installations and Evaluations**
 - **Hydro**
 - **Water Diversions**
 - **CWIS**
- ◆ **EPRI Bar Rack and Louver Study**
- ◆ **Potential for Angled Bar Racks and Louvers to be Applied at CWIS**

Bar Rack and Louver Design

APPROACH FLOW



Bar Rack



Louver

Angled Bar Racks

Guidance Mechanism and Important Considerations

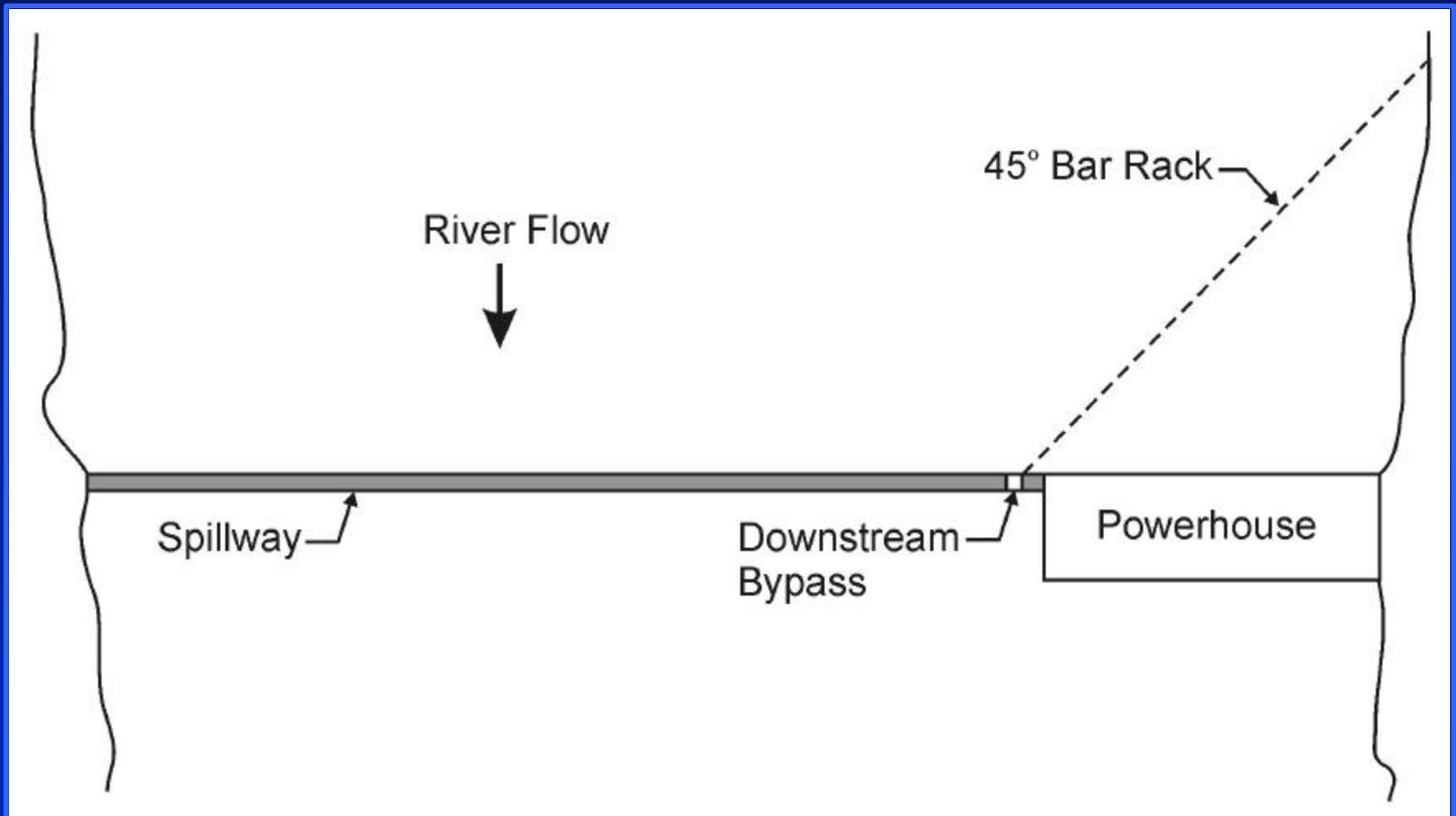
- ◆ Angled bar racks typically are designed to physically exclude fish and guide them to a bypass
- ◆ Most angled bar rack facilities have been installed at 45° to the flow and have bar spacings between 1 and 2 inches
- ◆ Important hydraulic parameters include approach and bypass velocity
- ◆ Important biological considerations include the species and size classes that are targeted for protection

Angled Bar Racks

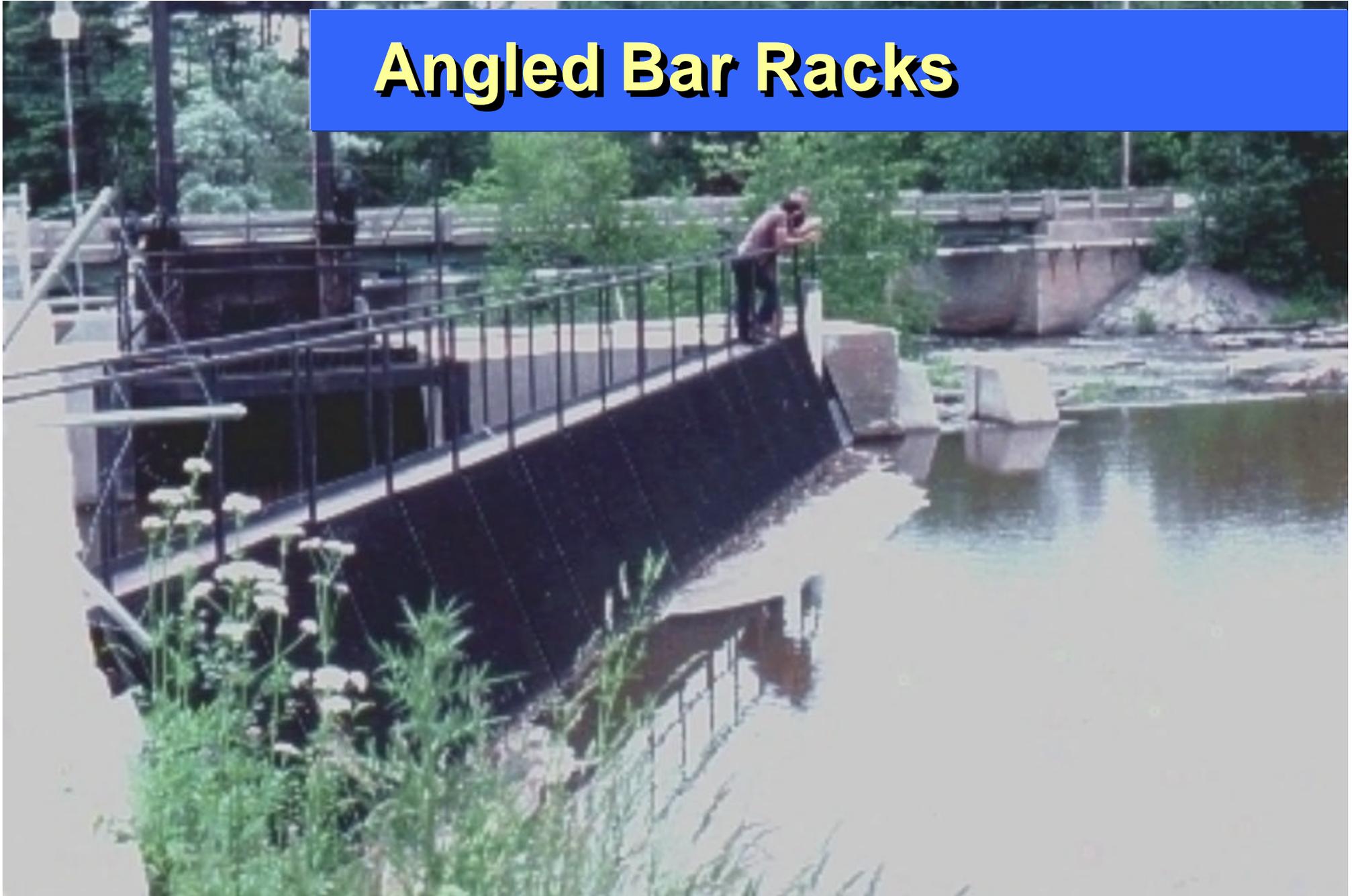
Previous Applications and Existing Data

- ◆ Narrow-spaced, angled bar racks have been prescribed for use at many hydroelectric projects in the Eastern U.S.
- ◆ Most bar rack installations and evaluations have focused on anadromous species (Atlantic salmon, juvenile shad and herring)
- ◆ Results have been mixed; effectiveness is dependent on fish behavior and hydraulics

Angled Bar Racks



Angled Bar Racks



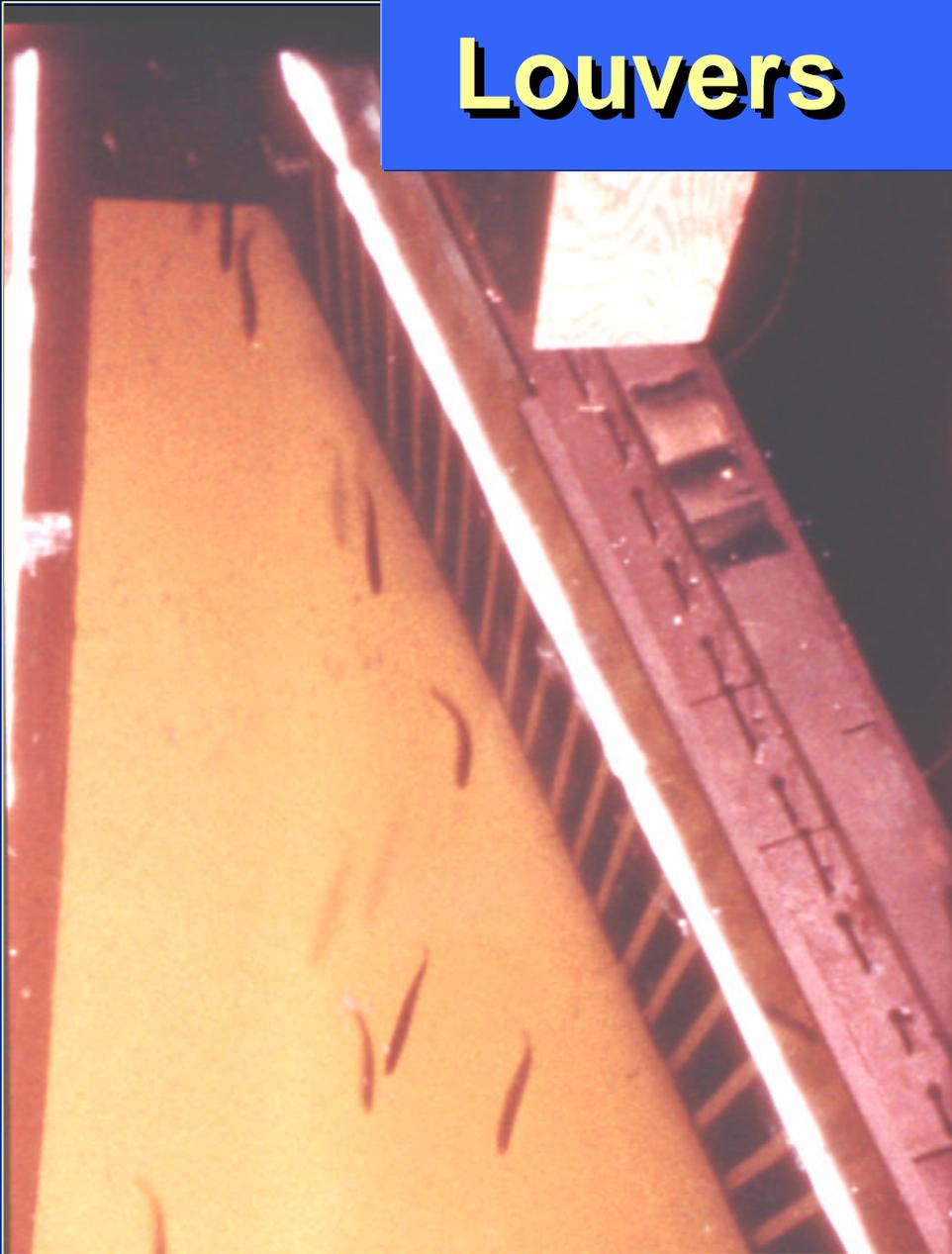
Louvers

Guidance Mechanism and Important Considerations

- ◆ Louvers create hydraulic conditions that elicit behavioral avoidance reactions from approaching fish
- ◆ Important design parameters include structure angle (15-30 degrees), slat spacing (1 to 12 inches), and bypass design
- ◆ Important hydraulic parameters include approach and bypass velocity
- ◆ Important biological considerations include species and size classes that are targeted for protection

Louvers

Fish Guiding Along
Louver System



Louvers

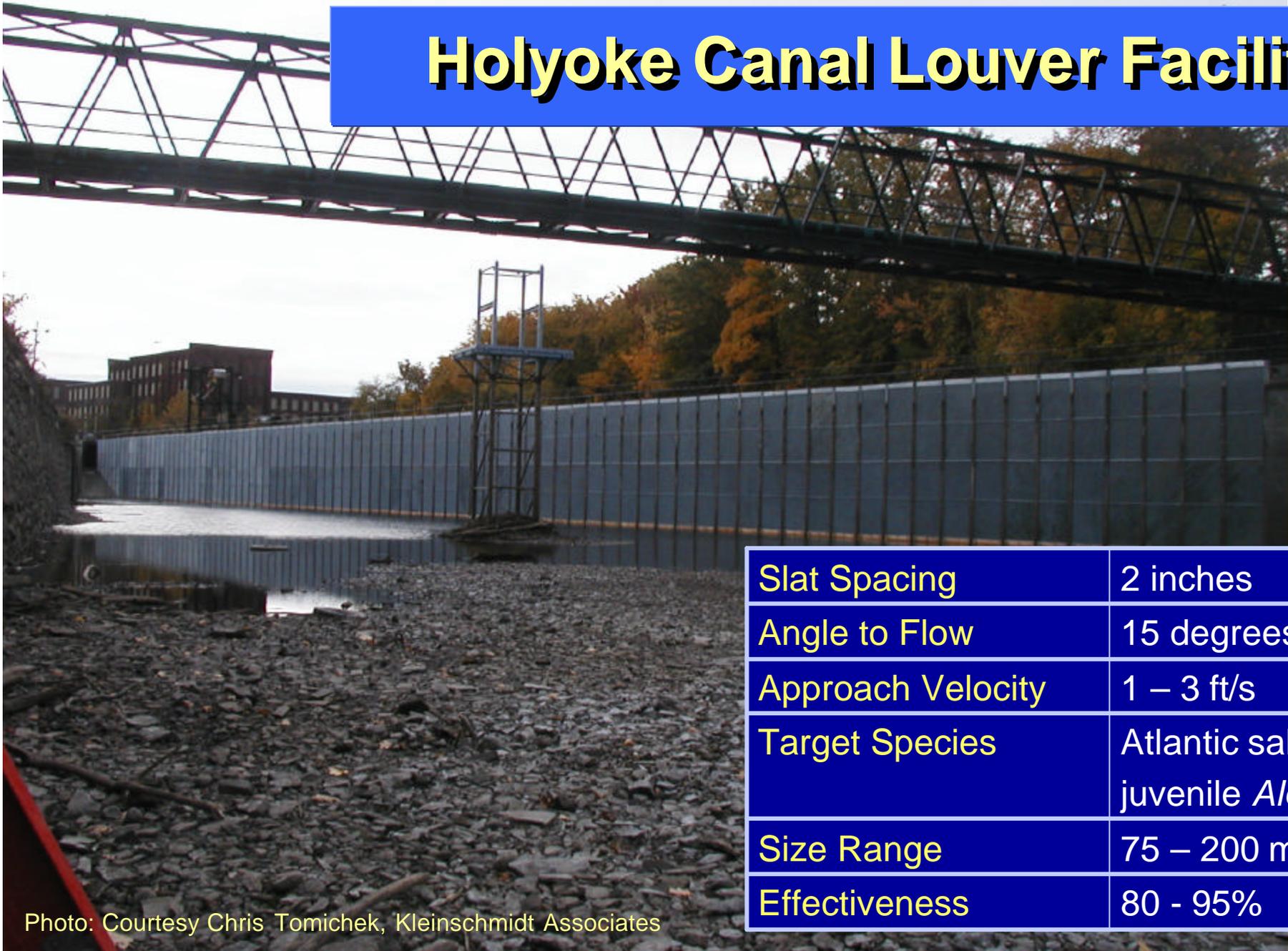
Previous Applications and Existing Data

- ◆ Louvers have been effective at guiding anadromous species at several hydro sites
- ◆ Limited to no information for most freshwater, estuarine, and coastal species
- ◆ Limited use and evaluation at CWIS

Holyoke Canal Louver Facility



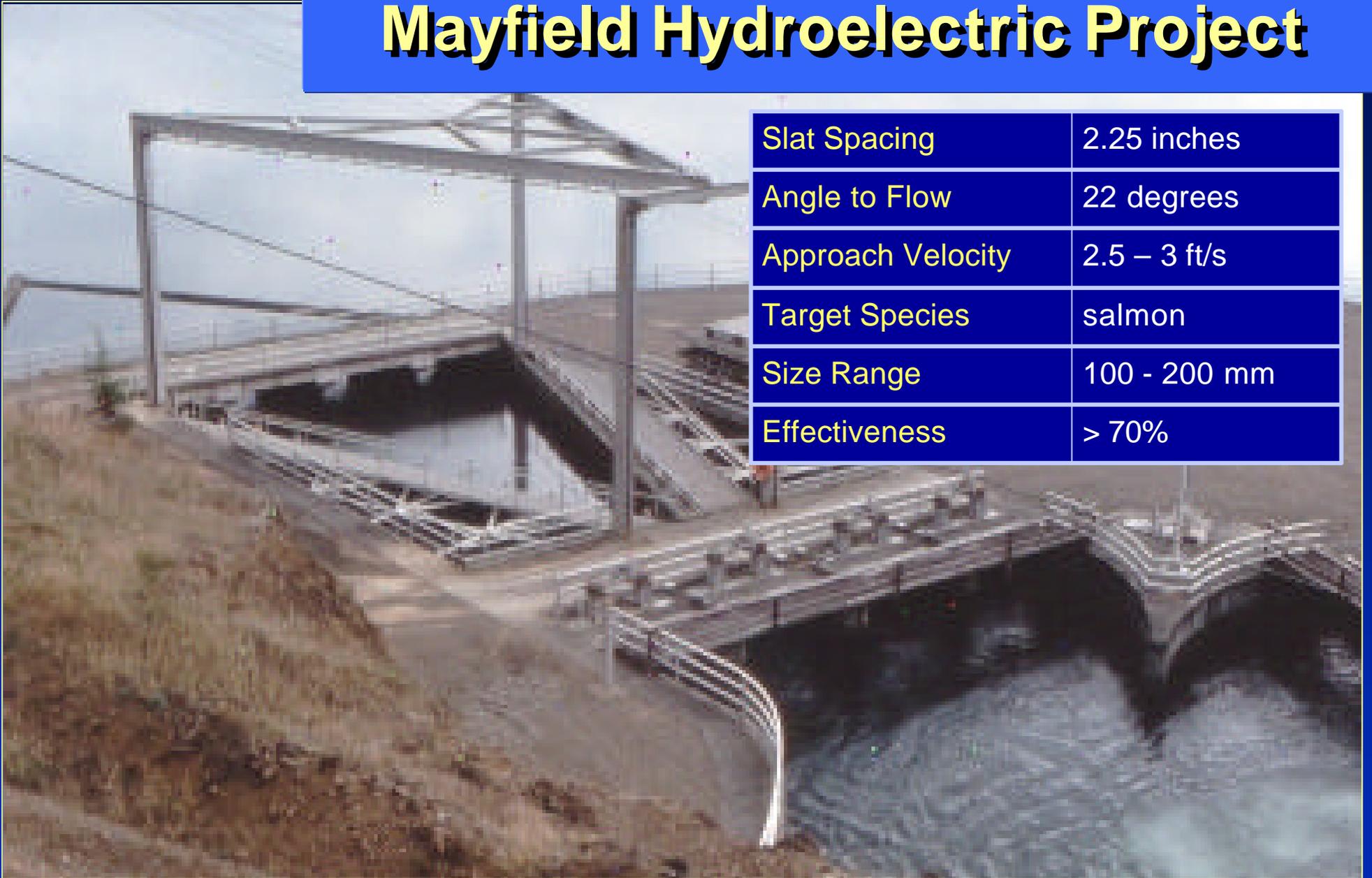
Holyoke Canal Louver Facility



Slat Spacing	2 inches
Angle to Flow	15 degrees
Approach Velocity	1 – 3 ft/s
Target Species	Atlantic salmon juvenile <i>Alosa</i>
Size Range	75 – 200 mm
Effectiveness	80 - 95%

Photo: Courtesy Chris Tomichek, Kleinschmidt Associates

Mayfield Hydroelectric Project



Slat Spacing	2.25 inches
Angle to Flow	22 degrees
Approach Velocity	2.5 – 3 ft/s
Target Species	salmon
Size Range	100 - 200 mm
Effectiveness	> 70%

Skinner Fish Collection Facility

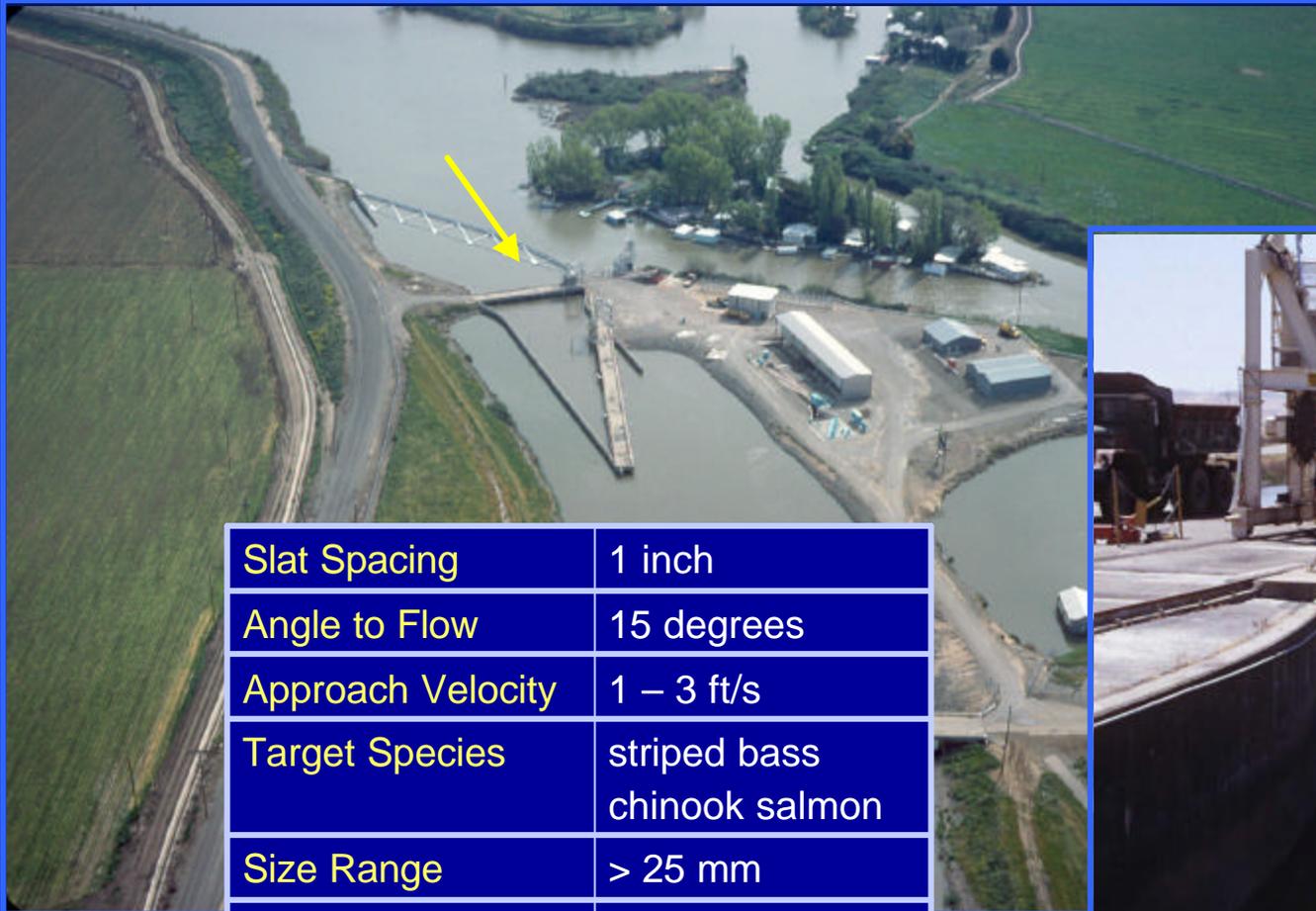


Slat Spacing	1 inch
Angle to Flow	15 degrees
Approach Velocity	1 – 3 ft/s
Target Species	striped bass chinook salmon
Size Range	> 25 mm
Effectiveness	0 – 95%



Photos: Courtesy Darryl Hayes, CH2M Hill

Tracy Fish Collection Facility



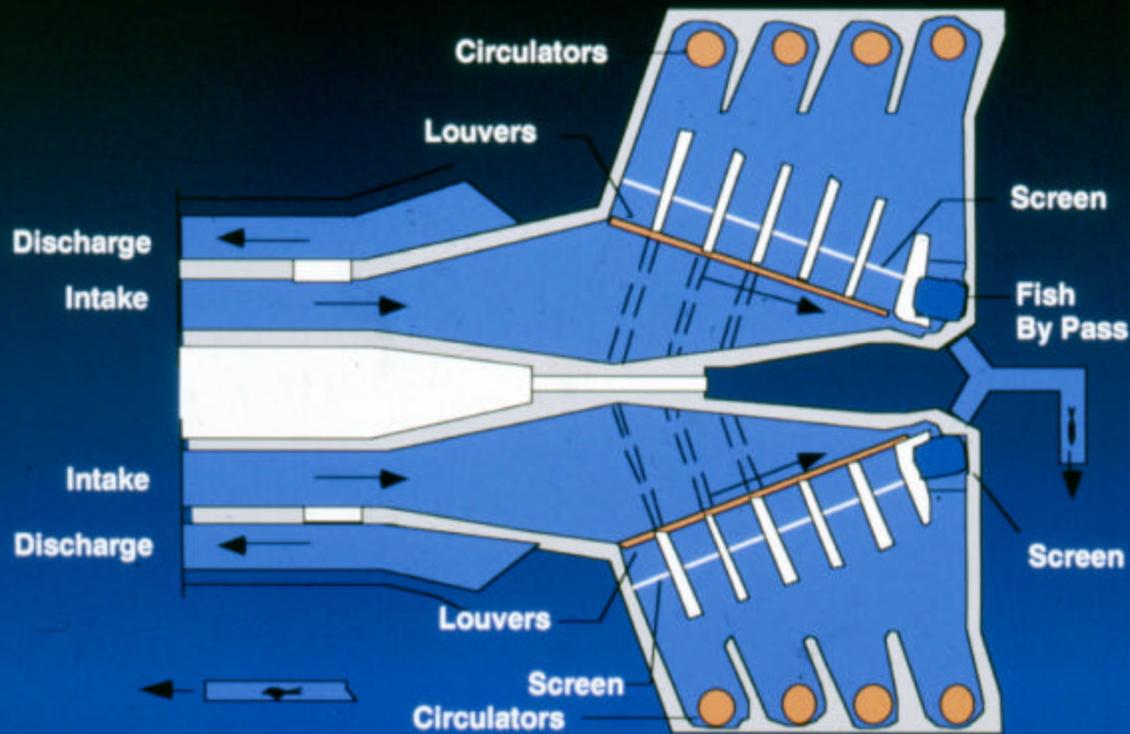
Slat Spacing	1 inch
Angle to Flow	15 degrees
Approach Velocity	1 – 3 ft/s
Target Species	striped bass chinook salmon
Size Range	> 25 mm
Effectiveness	
primary	60 – 90%
secondary	0 - 96%



Photos: Courtesy Darryl Hayes, CH2M Hill

San Onofre NGS

San Onofre Screen Well Concept



Year	Unit 2 Percent Returned	Unit 3 Percent Returned
1984	96.5	95.4
1985	88.3	60.1
1986	75.0	69.9
1987	65.0	67.8
1988	80.0	68.5
1989	41.6	58.4
1990	51.5	36.6
1991	75.4	66.3
1992	74.4	59.3
1993	83.0	78.0
1994	87.7	78.4
1999	72.4	68.2
Mean	74.2	67.2

Courtesy Kevin Herbinson, Southern California Edison Company

EPRI Bar Rack/Louver Study

- ➔ **Quantitatively evaluate the ability of selected fish species to guide along various configurations of bar racks and louvers**
- ➔ **Qualitatively evaluate fish behavior in the vicinity of the bar racks and louvers**

METHODS

Test Parameters

45° Arrays

15° Arrays

Parameter

Bar Rack

Louver

Bar Rack

Louver

Spacing (mm)

25, 50

50

50

50

Velocity (ft/s)

1, 2, 3

1, 2, 2.5

1, 2, 3

1, 2, 3

Bypass depth

Full

Full

Full

Full

Fish release

Surface

Surface

Bottom

Bottom

Bottom overlay

No

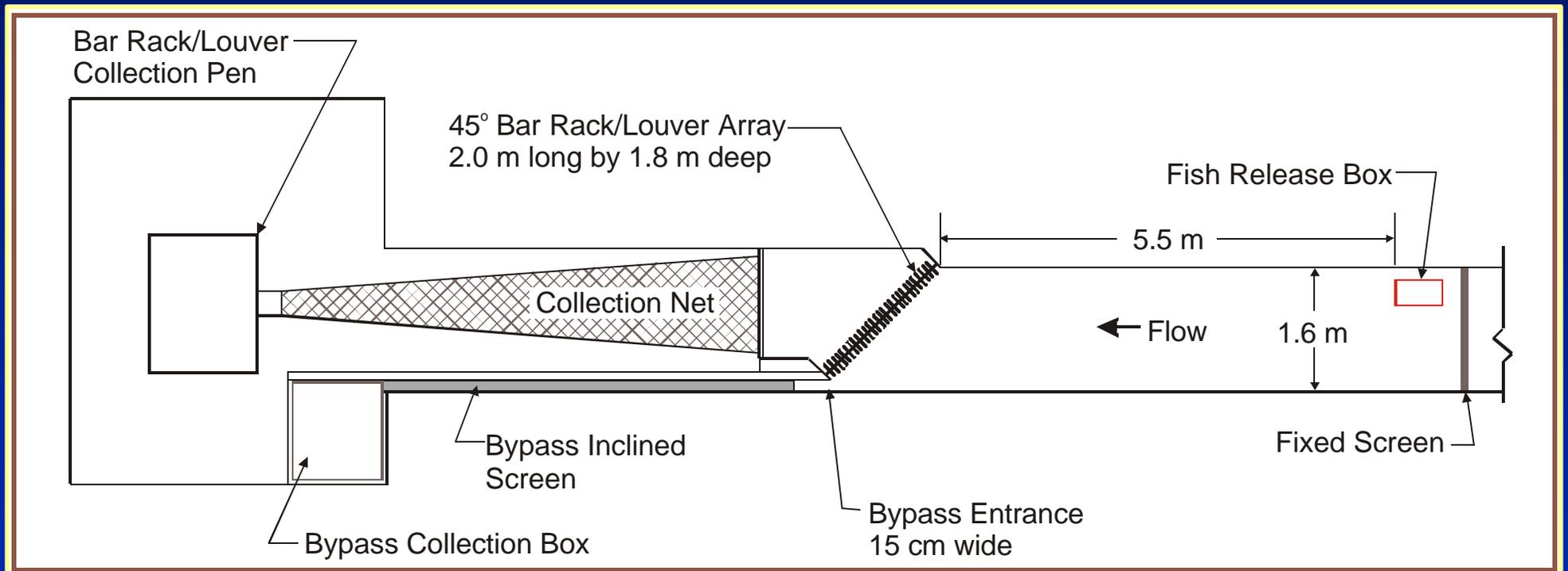
No

Yes/No

Yes/No

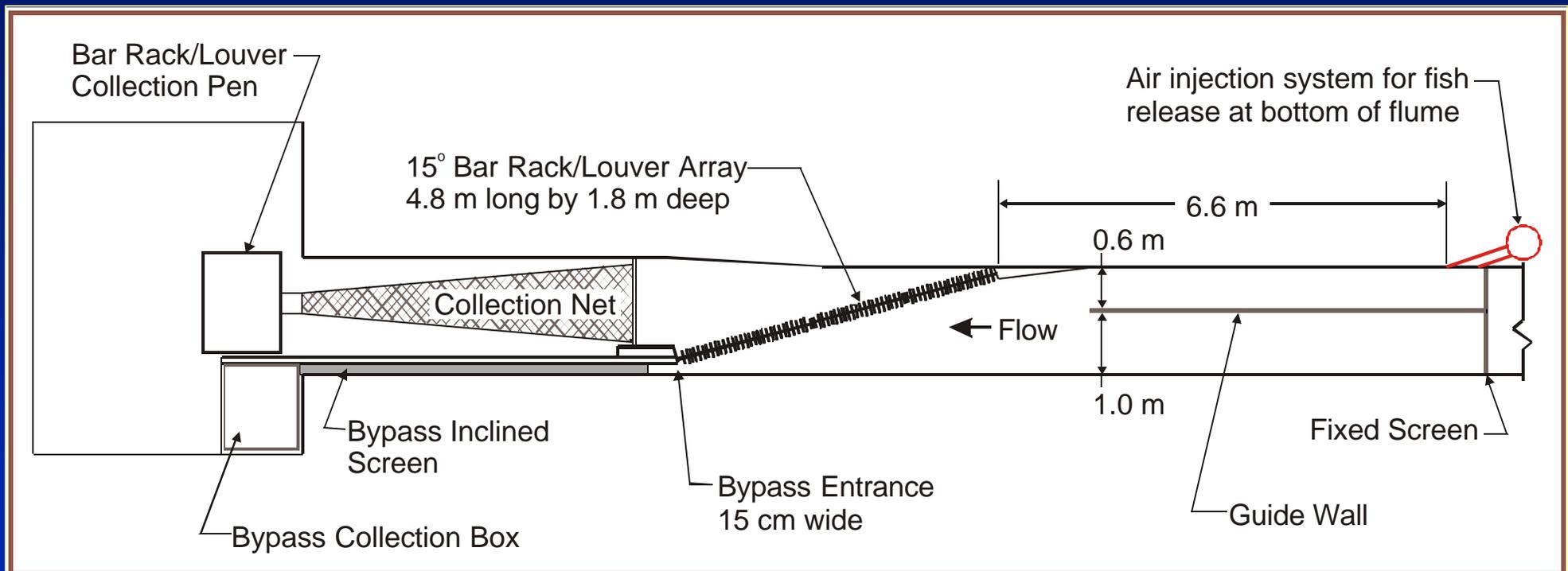
METHODS *Fish Testing Facility*

45° Test Facility

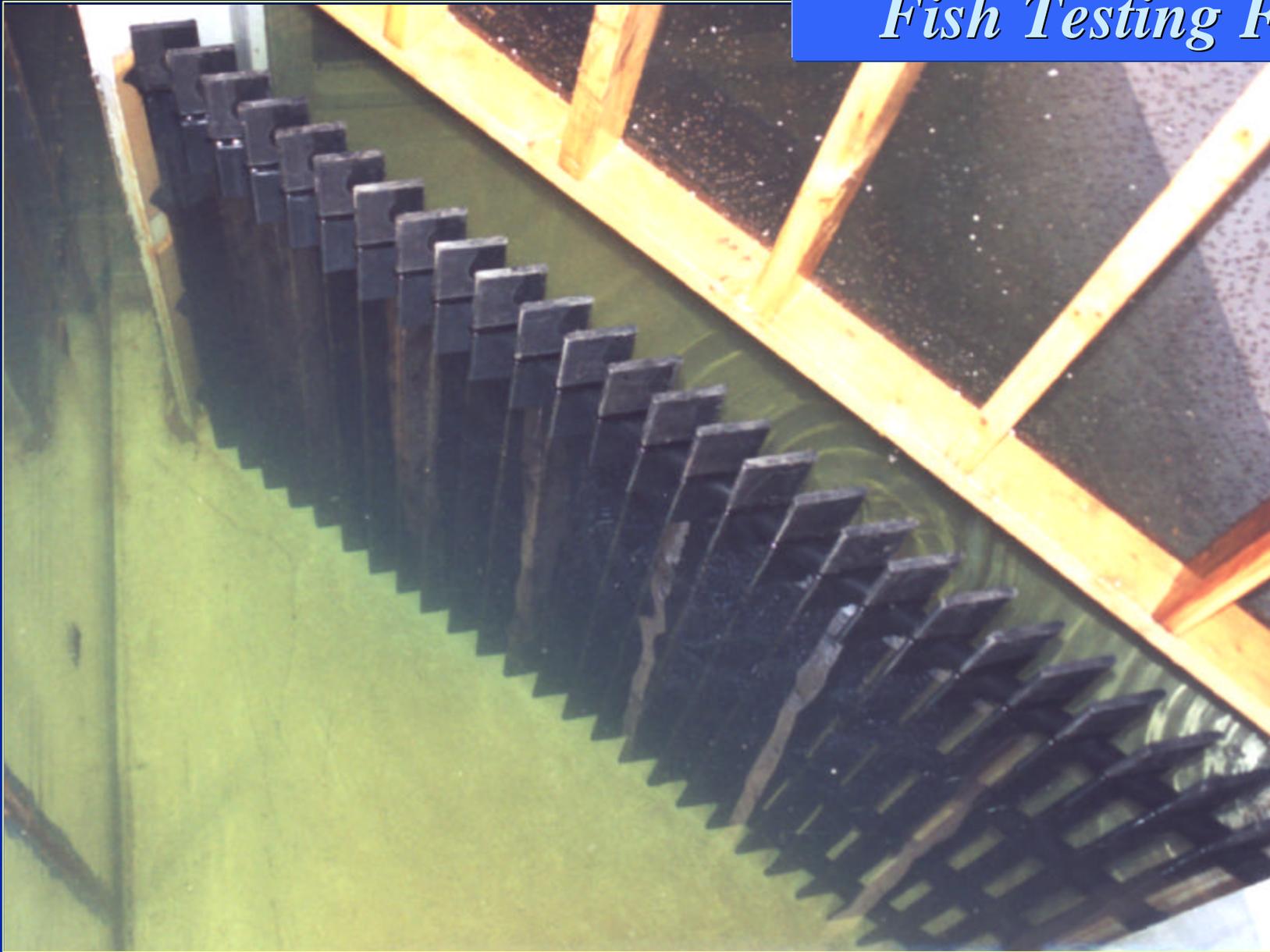


METHODS *Fish Testing Facility*

15° Test Facility



Fish Testing Facility



45°
Louver

Fish Testing Facility

15° Bar Rack without
Bottom Overlay



Fish Testing Facility

90° Bar Rack with
Bottom Overlay



METHODS

Fish Species



golden shiner
79 mm



American eel
560 mm



smallmouth bass
59 – 117 mm



lake sturgeon
153, 332 mm



channel catfish
113 mm



shortnose sturgeon
319 mm

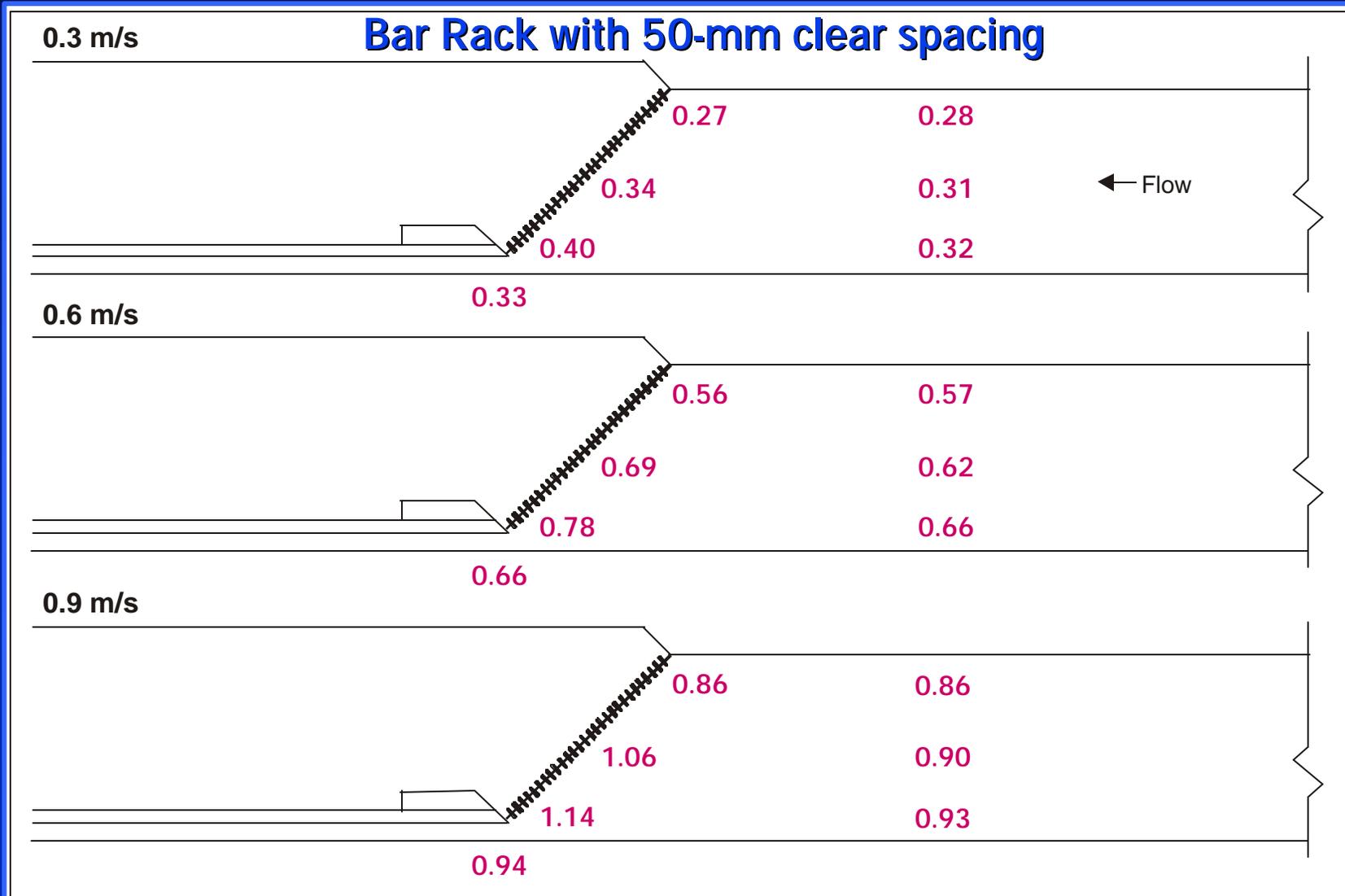


largemouth bass
73 mm



walleye
75 mm

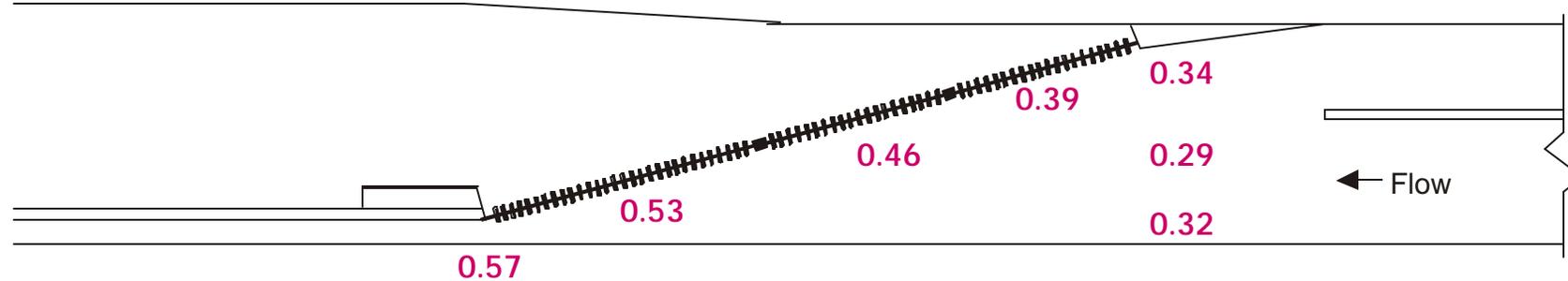
METHODS *Velocity Measurements*



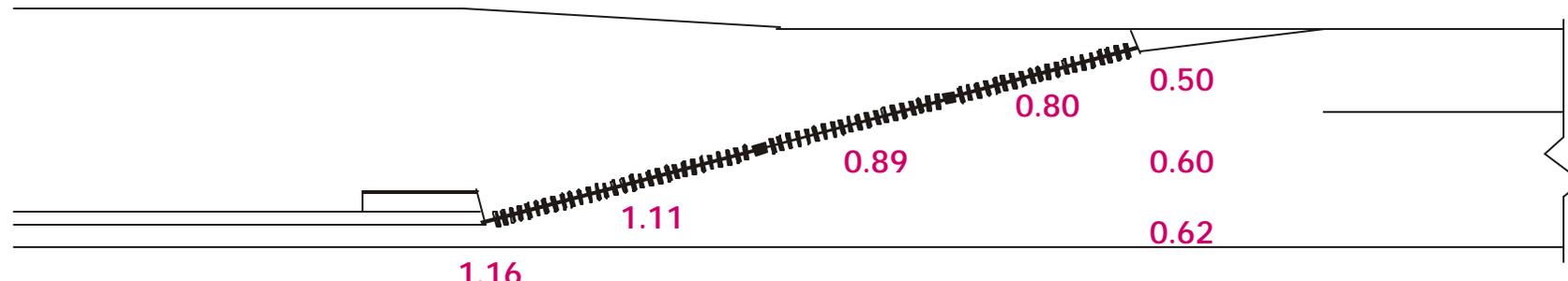
METHODS *Velocity Measurements*

Bar Rack with 50-mm clear spacing

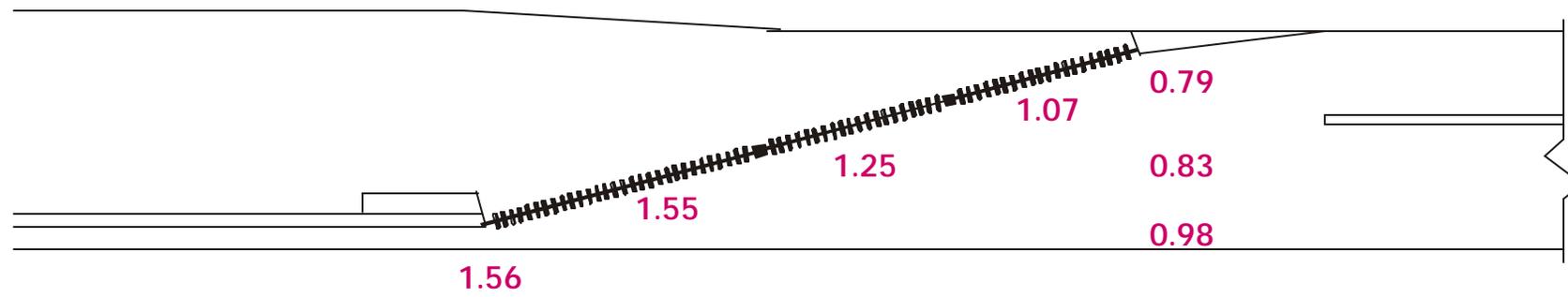
0.3 m/s



0.6 m/s



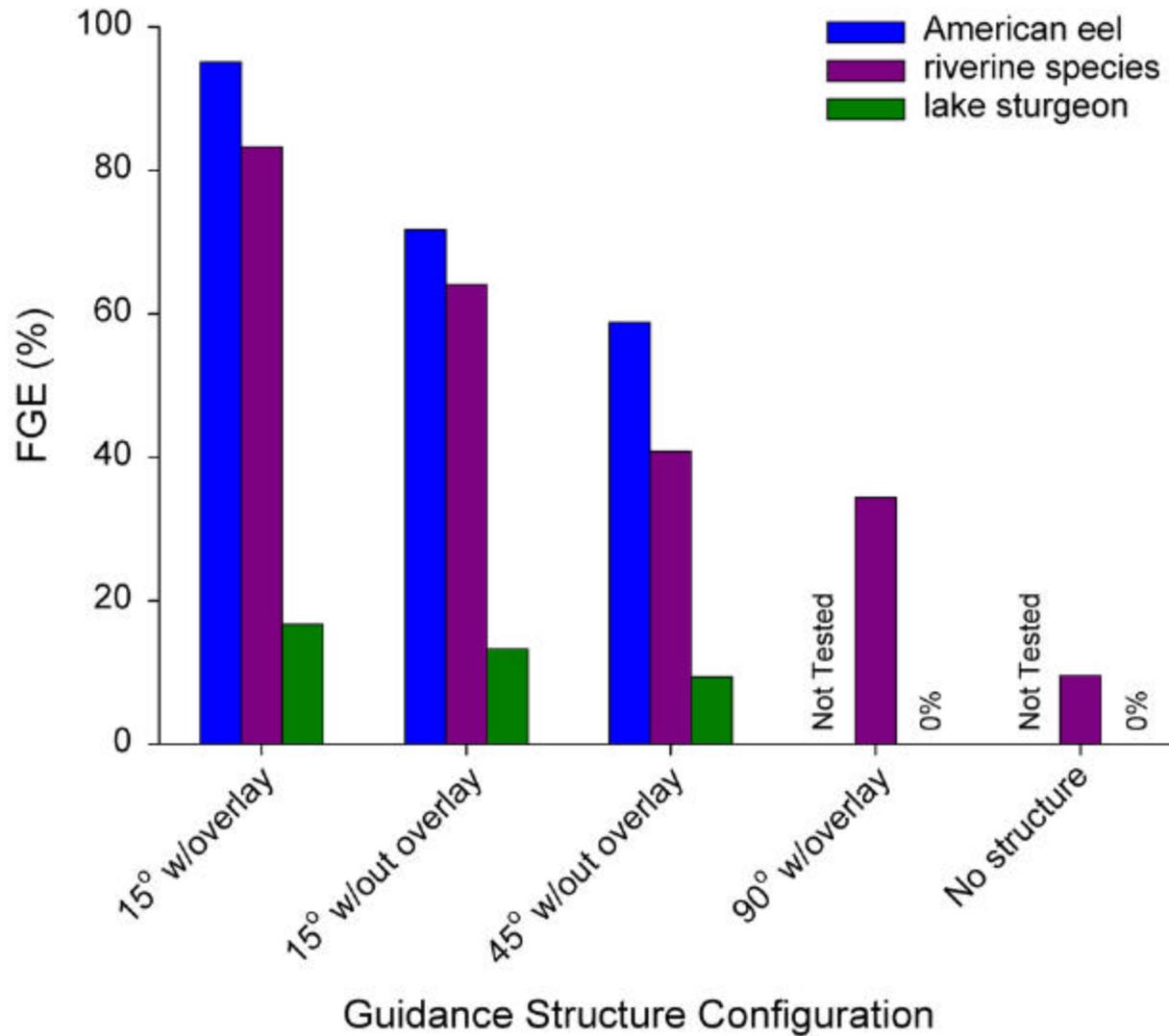
0.9 m/s



Guidance Structure	Bottom Overlay	Vel (m/s)	Fish Guidance Efficiency (%)								
			SMB	WAL	LMB	CHA	GSH	LAS1	LAS2	SNS	EEL
45° bar rack (25 mm)	No	0.3	31.2	--	--	--	56.1	27.3	--	--	65.1
		0.6	51.4	--	--	--	52.6	18.3	--	--	56.8
		0.9	49.3	--	--	--	37.1	0.0	--	--	65.9
45° bar rack (50 mm)	No	0.3	49.6	--	--	--	51.3	20.4	--	--	72.7
		0.6	30.8	--	--	--	27.9	10.0	--	--	57.8
		0.9	20.3	--	--	--	13.1	0.0	--	--	54.5
15° bar rack (50 mm)	no	0.3	--	--	67.8	94.2	--	--	--	--	--
		0.6	69.7	57.1	58.3	75.6	--	10.4	--	--	83.3
		0.9	--	--	58.3	73.5	--	--	--	--	--
15° bar rack (50 mm)	yes	0.3	71.6	79.2	--	--	--	27.5	100.0	100.0	95.1
		0.6	80.4	78.2	--	--	--	17.4	95.2	100.0	95.0
		0.9	76.3	63.2	--	--	--	2.9	93.4	92.9	88.9
45° louver (50 mm)	no	0.3	43.0	--	--	--	29.5	28.0	--	--	34.9
		0.6	47.3	--	--	--	34.6	0.0	--	--	61.9
		0.9	13.7	--	--	--	22.1	1.7	--	--	45.1
15° louver (50 mm)	no	0.3	--	--	73.3	82.5	--	--	--	--	--
		0.6	55.7	51.3	71.6	73.4	--	16.2	--	--	60.0
		0.9	--	--	60.4	69.9	--	--	--	--	--
15° louver (50 mm)	yes	0.3	88.0	90.6	--	--	--	36.8	100.0	100.0	88.6
		0.6	84.9	75.4	87.3	93.8	--	15.9	94.8	96.0	95.1
		0.9	88.8	62.6	--	--	--	7.4	84.8	93.3	90.2
90° bar rack	yes	0.6	53.3	8.4	--	--	--	0.0	--	--	--
no structure	--	0.6		29.1	0.0	--	--	--	--	--	--

RESULTS

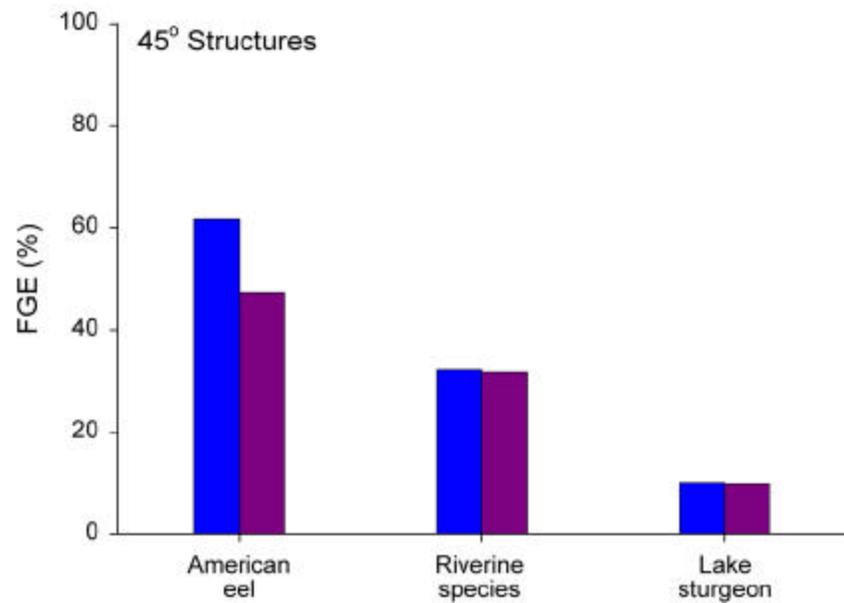
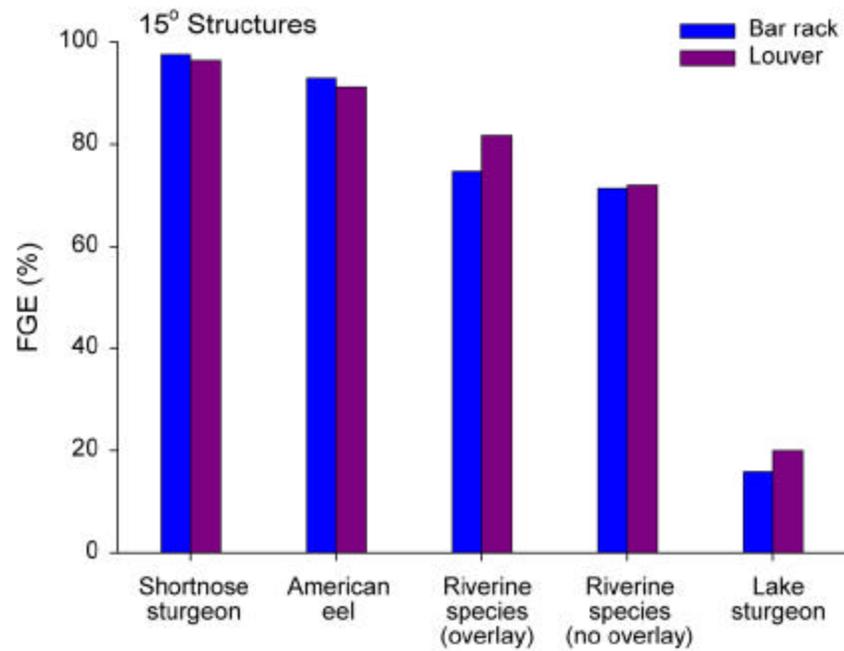
Fish Guidance Efficiency



**FGE by
Guidance Array
(0.6 m/s only)**

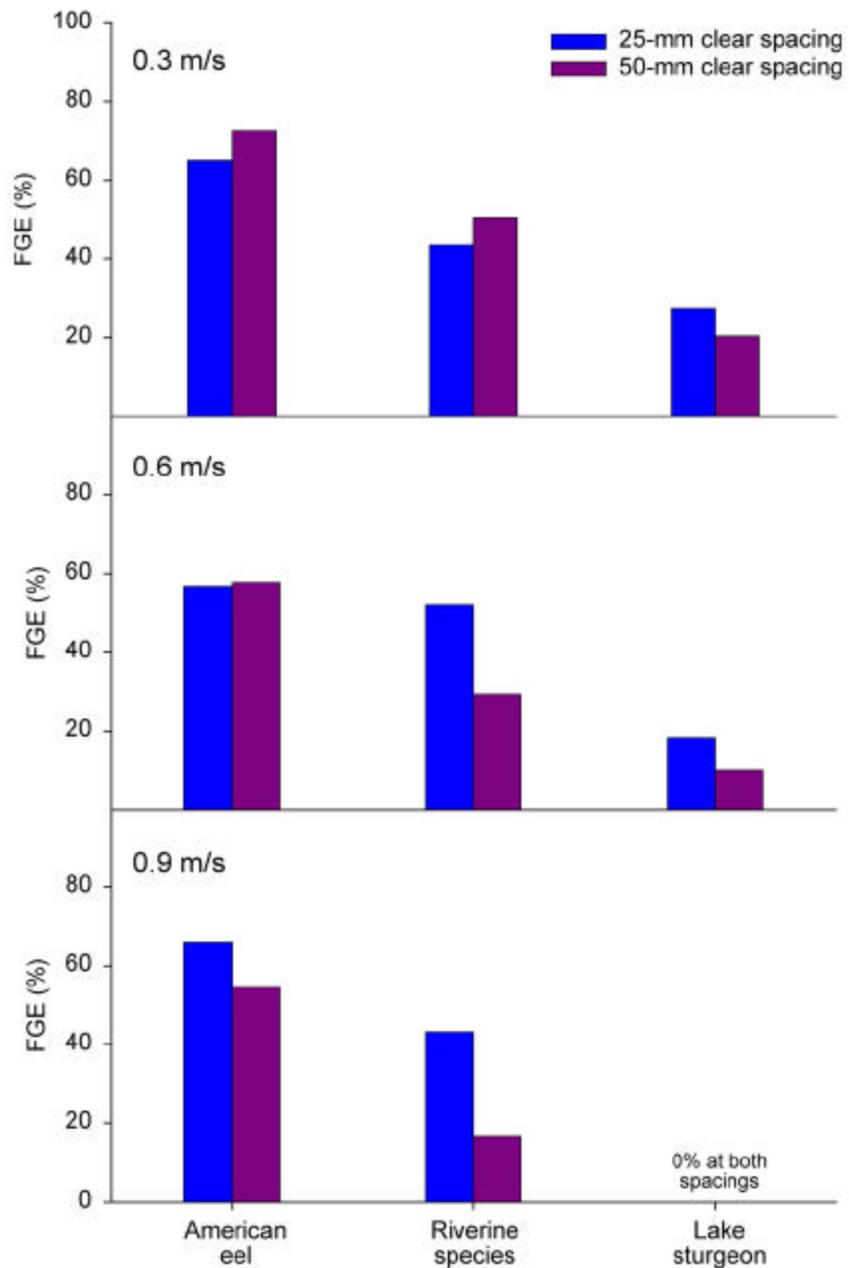
RESULTS *Fish Guidance Efficiency*

FGE by Slat Angle (0.6 m/s only)

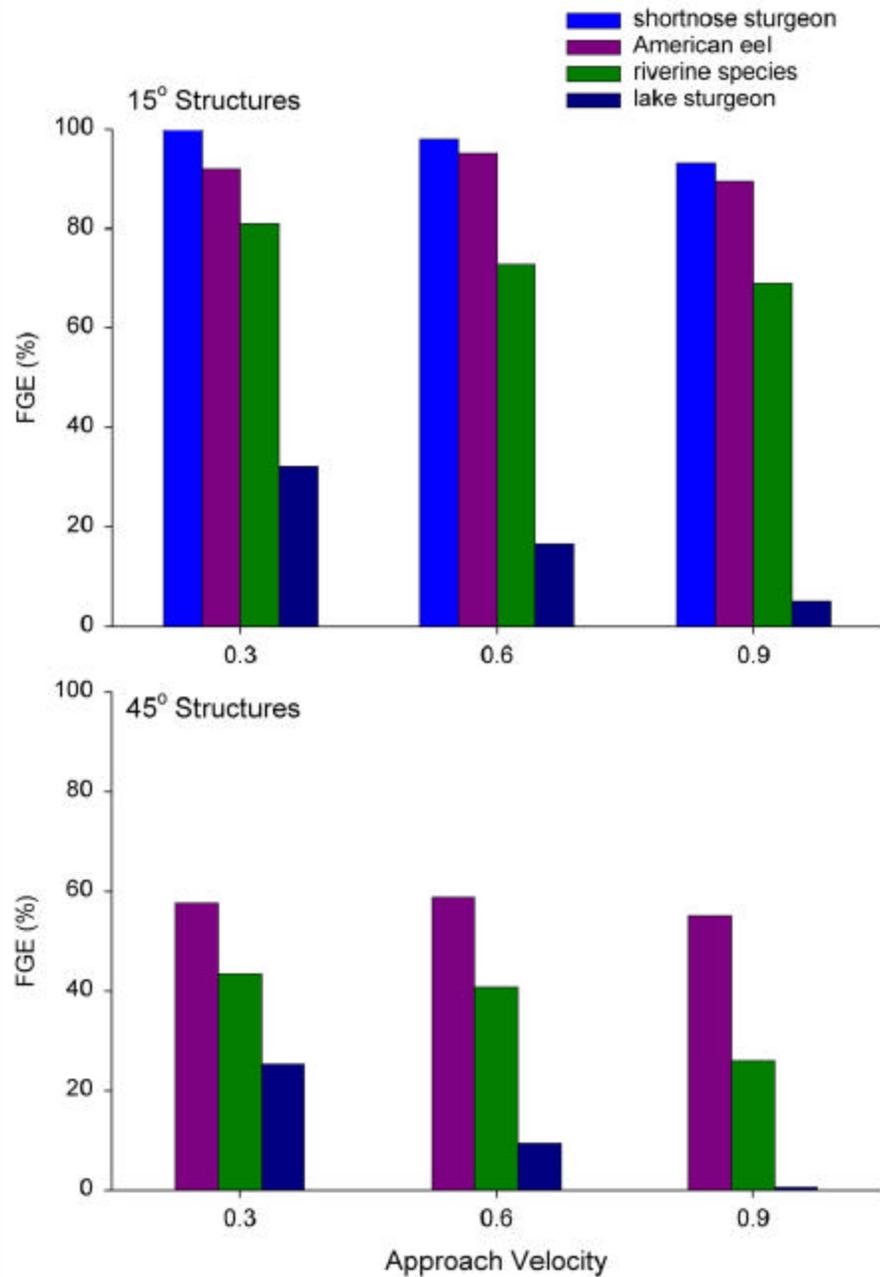


RESULTS *Fish Guidance Efficiency*

FGE by Slat Spacing and Approach Velocity



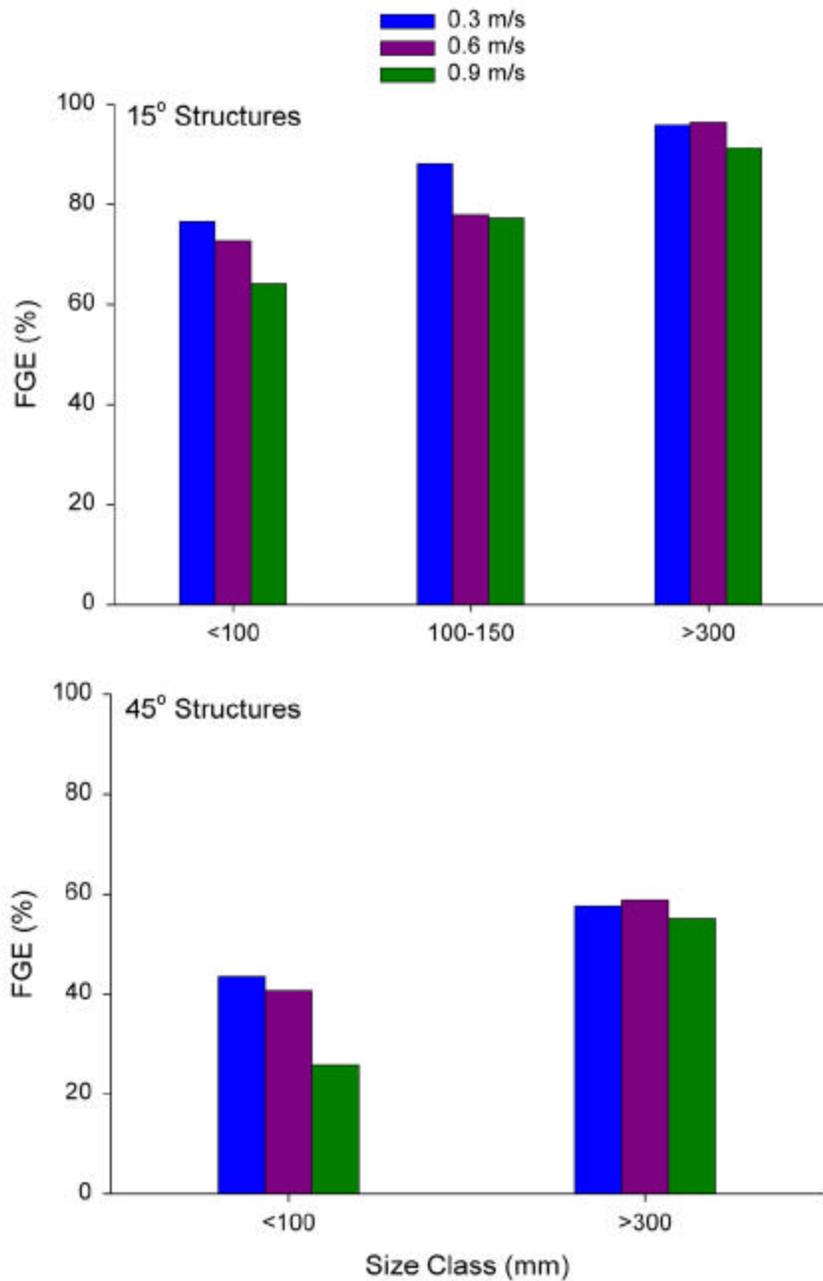
RESULTS *Fish Guidance Efficiency*



FGE by Approach Velocity

RESULTS *Fish Guidance Efficiency*

FGE by Fish Length



EPRI Study Conclusions

- ➔ FGE for the 45° bar rack with 25-mm spacing generally was higher than for the 45° bar rack with 50-mm spacing
- ➔ There was no distinct difference in FGE between the bar rack and louver arrays
- ➔ FGE at the 15° angle was higher than it was at the 45° angle, especially when the bottom overlay was used on the 15° arrays
- ➔ FGE decreased with increasing velocity for most species and structure configurations evaluated
- ➔ With the exception of lake sturgeon, FGE's for larger, bottom-oriented species were higher than for smaller fish that typically swam higher in the water column

EPRI Study Conclusions

- ➔ Tests with the 90° bar rack and with no structure in place demonstrated that fish were actively guiding along the angled bar racks and louvers to the bypass
- ➔ 45° bar racks and louvers do not appear to have considerable potential as a means for guiding riverine species away from water intakes
- ➔ 15° guidance structures do appear to have considerable potential for guiding riverine fishes and silver American eels away from water intakes
- ➔ Design parameters (slat angle and spacing, approach velocity) that are important for successful guidance will depend on target species and size classes

Conclusions

Application of Bar Racks and Louvers at CWIS

- ➔ 45° angled bar racks have limited potential for application at CWIS based on the results from hydro and laboratory evaluations
- ➔ Depending on site design (e.g., canal intake), louvers have potential to effectively reduce impingement of fish at CWIS
- ➔ Targeted species and size classes will influence facility design and operation (e.g., slat spacing, angle to flow, approach velocities)
- ➔ Intake design, location, and hydraulic conditions also will influence guidance facility design and operation, as well as biological effectiveness

Conclusions

Application of Bar Racks and Louvers at CWIS

Species/Size	FGE
Anadromous species 75 – 200 mm	> 80%
Riverine Species 25 – 100 mm	60 - 90%
100 – 200 mm	70 – 95%
> 200 mm	80 – 100%
Estuarine/Coastal > 25 mm	> 60%

Conclusions

Application of Bar Racks and Louvers at CWIS

Optimum Louver Design Criteria

Slat Spacing	≤ 2 inches
Angle to Flow	≤ 30 degrees
Approach Velocity	≤ 3 ft/s
Bypass Velocity Ratio	≥ 1.5