Fish Raceway or Tank (Feet and Cu. Ft.) 398

DEFINITION

A channel or tank with a continuous flow of water constructed or used for high-density fish production.

PURPOSES

To provide a facility containing flowing water of a suitable temperature and quality for dependable production of fish; to manipulate the chemical, physical, and biological factors to enhance fish production; and to maintain water quality.

CONDITIONS WHERE PRACTICE APPLIES

Where water and land resources are suitable for constructing a raceway or tank that can be used to produce a commercial fish crop.

This standard applies to raceways or tanks that conduct flowing water to produce fish. It applies to earthen channels as well as those channels and tanks constructed of concrete, concrete block, timber, rock, fiberglass, or other materials. It does not apply to hatchery operations that utilize troughs or barrels and are primarily indoors.

CRITERIA

General Criteria Applicable to All Purposes

All measures under this practice shall be planned, designed, and installed to meet all federal, state, local, and tribal laws and regulations.

Federal and state threatened, endangered, candidate, rare, and other sensitive species shall be carefully considered in aquatic habitat improvement and included in the management plan. No plan shall have long-term adverse effects on threatened or endangered species or species of concern.

All practices implemented under this practice shall meet or exceed the requirements of the appropriate standard; i.e., a constructed pond will meet or exceed the requirements in the Pond Standard (378).

The facility must be designed to provide protection from flooding, sedimentation, and contamination by pollutants from outside sources.

Fish raceways are generally constructed as: 1) linear channels where water flows in at one end and exits at the other end; or 2) as circular, rectangular, or oval tanks where water enters through nozzles or jets in a manner that creates a rotary circulation within the tank and discharge typically is through the tank center by means of a standpipe or bottom drain. The raceway dimensions shall be designed based upon the available water and planned production level.

Water Requirements

A. Quantity. A water supply of sufficient volume must be available for the species being produced either by gravity or by pumping. About 200 gpm (gallons per minute) is the minimum supply needed. For linear raceways, there shall be a continuous incoming water supply to provide a minimum velocity of 0.05 ft/s (0.015m/s) flowing at a minimum average depth of 2 feet (0.6m). This is approximately two complete water exchanges per hour for a raceway length of 80 to 100 ft (25 to 30 m).

B. Quality. Water must be free of harmful gases, minerals, silt, pesticides, and other pollutants. A water analysis shall be made before design and construction unless previous use or experience indicates the quality is satisfactory. Water quality requirements for trout or catfish are shown in Table 1.

C. Water Reuse. In most cases, water can be reused for up to three raceways provided that the water falls at least 12 inches into the next raceway for aeration. Otherwise, supplemental aeration may be required. ,Ammonia levels in the water are usually the limiting factor for water reuse.

Predators

Fences, screens, nets, wires, or other materials shall be provided as needed to prevent the loss of fish to predators. Traps or other devices that are potentially

harmful for humans, livestock, or pets shall be placed only in secure locations.

TABLE 1
Water Quality Requirements

Quality Parameter		Catfish	Trout
Dissolved Oxygen	Desirable	5 ppm	8 ppm
	Minimum	> 3 ppm	> 5 ppm
Temperature	Desirable	55-64°F (13-18°C)	55-64°F (13-18°C)
	Min.-Max.	45/70°F (7/21°C)	45/70°F (7-21°C)
pH	Desirable	6.5-9.0	6.5-9.0
	Min.-Max.	6.0/9.5	6.0/9.5
Carbon Dioxide	Desirable	< 5ppm	< 3 ppm
	Min.* -Max.	0/15 ppm	0/10 ppm

* Toxicity of Carbon Dioxide varies with dissolved oxygen concentration and temperature.

Waste Treatment

Plans for treatment or use of waste that are generated or caused by the operation of fish raceways or tanks shall be developed and made a part of the design and installation of the practice. The treatments will include the construction of waste storage ponds, storage structures, treatment lagoons, settling basins, or other facilities. Waste utilization by spreading of waste on land will be permissible if a waste utilization plan is developed. Discharges into streams must meet state standards for the stream and comply with all regulations including National Pollutant Discharge Elimination System (NPDES) regulations.

Protection

A protective cover of vegetation shall be established on all exposed surfaces that have been disturbed. If soil or climatic conditions preclude the use of vegetation, other methods may be used for protection. Adequate provisions must be made to protect earth surfaces from wave erosion. Fences shall be installed as needed. Road surfaces along raceways and the outer perimeter of tanks shall be treated as needed to provide access and reduce erosion. Dikes and levees should be crowned to provide drainage.

Fish Populations

Fish stocking or loading rates can be estimated by using the following formula:

Load factor (from Table 2) x length of fish in inches x water inflow in gallons/min = pounds of fish supported.

Note: Where water reuse is planned, decrease fish loading rates of consecutive raceways to 75% of the previous raceway.

Note: Add 15% to stocking numbers for mortality.

TABLE 2
Fish Load Factors

Water temp. °F	Load Factor	Water temp. °F	Load Factor
48	1.91	56	1.40
49	1.83	57	1.36
50	1.74	58	1.32
51	1.67	59	1.28
52	1.61	60	1.24
53	1.55	61	1.21
54	1.50	62	1.18
55	1.45	63	1.14

Example: An operator has 3 consecutive raceways. Water reuse is planned with 2 turnovers per hour. Water temperature is 51°F. Water inflow is 400 gal/min., raceway lengths are 90 feet, and 2-3 inch fingerlings will be stocked. How many pounds and what number of fish can be stocked? Table 3 shows the relationship between size of fish and number of fish per pound.

Raceway 1: 1.67 x 2.5 x 400 = 1,670 lbs. of fish

1,670 pounds x 196.2 fish per pound (Table 3) = 327,654 fish. Add mortality of 15% or 327,654 x 1.15 = 376,800 fish to stock in Raceway 1.

Raceway 2: Use 75% of Raceway 1 since water is reused. 0.75 x 376,800 fish = 282,600 fish (1,252 lbs.) to stock in Raceway 2.

Raceway 3: Use 75% of Raceway 2 since water is reused. 0.75 x 282,600 = 211,950 fish (939 lbs.) to stock in Raceway 3.

Note: As these fish grow, new population estimates should be calculated and fish numbers thinned accordingly by selling fish or adding to other raceways.

TABLE 3
Relationship Between Fish Size and Numbers per Pound of Fish

Size in Inches	Number per pound	Size in Inches	Number per pound
1-2	1,423.0	7-8	6.1
2-3	196.2	8-9	4.2
3-4	63.1	9-10	3.0
4-5	28.7	10-11	2.0
5-6	15.6	11-12	1.5
6-7	9.5		

Fish Feeding

Fish feeding is an important aspect of raceway management. The type, size, and amount of feed should be in accordance with manufacturer's specifications.

The recommended feeding levels (pounds of feed per pound of fish) for rainbow trout in 50°-59°F water is identified in Table 4. To calculate the daily amount of feed, multiply the weight of fish in the raceway or tank by the appropriate temperature-length correlated feed factor.

Example: An operator plans on feeding a population weighing 8,000 pounds consisting of 5-inch fish. The water temperature is 54°F. 8,000 x 0.0297 = 237.6 pounds of feed per day needed.

TABLE 4
Daily Suggested Feeding Levels (pounds of feed per pound of fish) for Rainbow Trout

Length (inches)	Water Temperature (°F)									
	50	51	52	53	54	55	56	57	58	59
2.0	.0429	.0468	.0507	.0545	.0585	.0624	.0663	.0702	.0741	.0780
2.5	.0351	.0383	.0415	.0447	.0479	.0510	.0542	.0574	.0606	.0638
3.0	,0330	.0360	.0390	.0420	.0450	.0480	.0510	.0540	.0570	.0600
3.5	,0286	.0312	.0338	.0364	.0390	.0416	.0442	.0468	.0494	.0520
4.0	.0260	.0294	.0318	.0343	.0367	.0392	.0416	.0440	.0465	.0489
4.5	.0241	.0263	.0285	.0307	.0328	.0350	.0372	.0394	.0416	.0438
5.0	.0218	.0238	.0258	.0277	.0297	.0317	.0337	.0357	.0376	.0396
5.5	.0199	.0217	.0235	.0253	.0271	.0289	.0307	.0326	.0344	.0362
6.0	.0182	.0198	.0215	.0231	.0248	.0264	.0281	.0297	.0314	.0330
6.5	.0168	.0183	.0199	.0215	.0229	.0244	.0260	.0275	.0290	.0306
7.0	.0155	.0169	.0183	.0197	.0211	.0225	.0239	.0253	.0267	.0281
7.5	.0145	.0158	.0171	.0184	.0197	.0211	.0224	.0237	.0250	.0263
8.0	.0136	.0148	.0161	.0173	.0185	.0198	.0210	.0223	.0235	.0247
8.5	.0128	.0140	.0152	.0163	.0175	.0187	.0198	.0210	.0221	.0233
9.0	.0114	.0125	.0135	.0146	.0156	.0166	.0177	.0187	.0198	.0208
9.5	.0109	.0118	.0128	.0138	.0148	.0158	.0168	.0178	.0188	.0197
10.0	.0101	.0111	.0120	.0129	.0138	.0148	.0157	.0166	.0175	.0184
10.5	.0097	.0105	.0114	.0123	.0132	.0141	.0149	.0158	.0167	.0176
11.0	.0088	.0096	.0104	.0112	.0120	.0128	.0136	.0144	.0152	.0160
11.5	.0084	.0092	.0100	.0107	.0115	.0123	.0130	.0138	.0146	.0153
12.0	.0081	.088	.0096	.0103	.0110	.0118	.0125	.0132	.0140	.0147
12.5	.0078	.0085	.0092	.0099	.0106	.0113	.0120	.0127	.0134	.0141
13.0	.0075	.0082	.0088	.0095	.0102	.0109	.0115	.0122	.0129	.0136

Criteria for Linear Channel Raceways

Channel raceways are generally of two types: a) concrete or concrete block construction; and b) earthen channel constructed with a trapezoidal or parabolic cross section.

A. Concrete or concrete block raceways shall be designed and constructed according to established principles and techniques outlined in the National Engineering Manual (NEM), ACI Code, Masonry Handbook, or other approved guides as appropriate. Where concrete or concrete block raceways are installed, the bulkheads or checkdams must be of the same construction.

B. Earthen channel raceways shall be constructed with a trapezoidal or parabolic cross section. Bottom widths depend on the volume of water available but shall be no less than 4 feet (1.2M). Side slopes shall be 1:1 or flatter depending on a saturated soil slope stability analysis. Side slopes and bottoms of raceways must be smooth and uniform to minimize dead water areas.

Grade. Wherever possible, raceways shall be constructed with a minimum bottom grade of 0.5 ft. per 100 ft. (0.15 m per 30 m). The raceway outlet will control the water surface grade.

Length. The maximum length of each raceway section is determined by site topography and need for re-aeration of the water but should not exceed 100 feet (30 m). Depending on water volume and quality, raceway sections may be constructed in series by installing a bulkhead or checkdam at the lower end of each section.

Freeboard. The minimum difference in elevation between the water surface in the raceway and the top of the bulkhead, dike, or levee alongside the raceway is 0.5 feet (0.15 m).

Dikes and Levees. The minimum top width of an earthen dike or levee shall be 6 feet (1.8 m). Side slopes of earthen dikes or levees above the designed water surface shall be 2:1 or flatter. When the top of the dike or levee is to be used for a road, the minimum top width shall be 14 feet (4.3 m).

Bulkheads. Structural or earthen barriers called bulkheads are to be placed across raceway channels to create shorter sections, to establish and maintain the desired water levels, and to provide aeration of the water. In addition to serving as a barrier, they shall have an opening or throat section that allows complete drainage to the bottom of the raceway channel unless other drainage facilities are provided. Bulkheads may be constructed of earth, concrete, concrete block, rock masonry, steel, or other durable metal, treated lumber, or combination of these. Earthen bulkheads are to have a minimum top width of 4 feet (1.2 m) and side slopes of 2:1 or flatter. Structural bulkheads used in earthen raceways must extend at least 24 inches (61 cm) into the sides and bottom of the channel. Concrete bulkheads shall have a minimum top width of 6 inches (15 cm) and a bottom width of 8 inches (20 cm). Openings and cores in concrete block shall be filled with either concrete or mortar mix. The opening or throat section of bulkheads may be constructed of concrete, concrete block, wood, or metal. It shall have slots or grooves along the vertical face that allow flashboards and screens to be installed.

Drains. A pipe drain with a minimum diameter of 6 inches (15 cm) shall be provided at the bottom of the bulkhead unless flashboards used to establish the desired water level can be removed to provide complete drainage. Where possible, each unit in a series should be constructed so that it can drain independently of the other units.

Screens. Screens shall be provided at the inlet of the system if necessary to exclude wild fish. Screens shall also be placed at each bulkhead between sections and at the exit end to prevent loss of fish. They shall be placed at least 6 to 8 inches (15-20 cm) upstream from the flashboards and extend at least 6 to 8 inches (15-20 cm) above the expected water level to prevent fish from escaping by jumping. Openings for screens shall be designed for the size range of fish to be separated. The water velocity through screens shall be slow enough to prevent trapping fish against the screen.

Aeration. Each bulkhead shall be fitted with a weir overfall. Flashboards in the opening or throat section of the bulkhead may be used for this purpose. The width of the weir or weirs should be equal to the bottom width of the raceway but shall not be less that 4 feet (1.2 m) where flashboards are used to establish

the desired water level. Two or more weirs separated by the rigid center sections shall be installed when the width of the raceway exceeds 8 feet (2.4 m). To increase aeration, a splashboard or series of boards arranged to create successive splashes shall be considered in the design. The minimum distance from the weir crest to the water level below shall be no less than 1 foot (0.31 m).

Sizing Raceways. Raceways must be sized to provide the planned turnover rate. The following information is based on a rate of 2 turnovers per hour.

TABLE 5 *

Water flow (gal/min)	Cu. Ft. of Raceway Needed	Suggested rectangular dimensions length x width x depth
200	800	40 x 8 x 2.5
300	1200	60 x 8 x 2.5
400	1600	64 x 10 x 2.5
500	2000	80 x 10 x 2.5
600	2400	80 x 12 x 2.5
700	2800	78 x 12 x 3
800	3200	89 x 12 x 3
900	3600	86 x 12 x 3.5
1000	4000	96 x 12 x 3.5

* Based on formula G/(C x E) = V

G = Incoming water in gallons/minute
C = 0.1246 gal/min (each cu. ft. of rearing volume requires 0.1246 gal/min for each hourly exchange rate)
E = Planned no. of water exchanges per hour
V = Cu ft of raceway needed

Criteria for Tank Raceways

Tank raceways are circular, rectangular, or oval and are constructed of concrete, metal, fiberglass, or other suitable material. Fiberglass and a variety of similar materials commonly referred to as “plastic” tanks are generally suitable if construction and support are sufficient to provide strength and durability. Noncircular tanks must have a dividing wall to obtain proper circulation. Tank raceways shall be constructed at locations accessible to water supplies, management personnel, and feed and harvest equipment.

Water supply. Water inlets to the tank may be through jets or nozzles or similar devices that provide a tangential force to the water in the tank. These nozzles should be located above the water surface to provide aeration. The nozzles shall be positioned so that flow in the tank is counterclockwise to take advantage of the natural tendency for water in North America to rotate in this direction.

Waste removal. Provisions for waste removal shall be incorporated in the design. Bottom troughs, screens, or center-positioned drain pipe shall be provided as part of the tank construction.

PLANNING CONSIDERATIONS

The cooperator’s objective as well as the limitations and potentials or available resources will dictate the level of development and management to be planned. An assessment must be made to determine the feasibility of the raceway or tank culture system. Planning is complete when all practice components essential to reaching the cooperator's management objectives and maintaining the water resource have been identified.

All state and local laws and regulations concerning the development of ponds and diversions of water shall be adhered to. Only preliminary technical assistance of a nature to assist in obtaining a permit or determining that none is needed shall be provided until a permit or letter stating that none is required has been obtained by the cooperator. Potential permits from the Michigan Department of Environmental Quality include wetland and floodplain concerns and from the Michigan Department of Agriculture including fish breeders, soil erosion, and hatchery concerns.

Consider the type of wastes that may be discharged from the raceway or tank including bacteria and parasites; drugs and chemicals used in disease treatment; and metabolic wastes such as phosphorus, ammonia, feces, and uneaten feed.

Consider the effects on the water budget, and on downstream flows and aquifers that could affect other uses. Consider the effects on wetlands, riparian areas, and water-related wildlife habitats.

Consider the potential effects of installation and operation of this practice on the cultural, archeological, historic, and economic resources.

PLANS AND SPECIFICATIONS

Specifications for this practice shall be prepared for each site. Specifications shall be recorded using approved specification sheets, job sheets, narrative statements in the conservation plan, or other acceptable documentation.

Support date documentation requirements are as follows:

- Inventory and evaluation records
  - Assistance notes or special reports
- Survey notes, where applicable
  - Design survey
  - Construction layout survey
  - Construction check survey
- Design records
  - Physical date, functional requirements, results of chemical parameter check of the water supply, temperature and volume, and source of water supply and sited constraints, where applicable
  - Document the planned fish species
  - Soils/subsurface investigation report, where applicable
- Design and quantity calculations
- Construction drawings/specifications with
  - Location map
  - "Designed by" and "Checked by" names or initials
  - Approval signature
  - Job Class designation
  - Initials from preconstruction conference
  - As-built notes
- Construction inspection records
  - Assistance notes or separate inspection records
  - Construction approval signature
- Record of any variances approved, where applicable

OPERATION AND MAINTENANCE

A plan shall be prepared that provides for inspection, operation, and maintenance of vegetation, pipes, valves, raceways, tanks, dikes, levees, bulkheads, and other parts of the system.

This practice will be inspected periodically and restored as needed, to maintain the stated purpose. Additional operation and maintenance requirements will be developed on a site-specific basis to assure performance of the practice as intended.

FISH RACEWAY OR TANK SPECIFICATIONS

Engineering Specifications

Clearing. All trees, brush, logs, stumps, roots, loose boulders, or other debris shall be cleared from the raceway or tank construction area and from the area where fill is to be placed for dikes or levees. If needed to establish vegetation, the topsoil and sod shall be stockpiled and later spread on the completed surface.

Excavation. All excavation necessary for the construction of raceways, bulkheads, or tank foundations and footings shall be performed on a workmanlike manner to the lines and grades shown on the drawings or as staked in the field.

Fill placement. The material placed in the dikes or levees shall be free of sod, roots, frozen soil, boulders larger than 6 inches (15 cm) in diameter, and other objectionable material. The placing and spreading of the fill material shall be started at the lowest point of the foundation, and the fill shall be brought up in approximately horizontal layers of such thickness that the required compaction can be obtained with the equipment used.

Compaction. The moisture content of the fill material shall be adequate for obtaining the required compaction. Construction equipment shall be operated over each layer of fill to ensure that the required compaction is achieved. Earth fill placed in close proximity to structures and pipelines shall be compacted using hand tampers or manually operated power tampers or vibrators.

Concrete. Concrete shall receive the detail in mix design and testing consistent with the size and requirements of the job. Mix requirements of necessary strength should be specified. Type of cement, air entrainment, slump, aggregate, or other properties are to be specified where necessary.

All concrete is to be placed, finished, and cured in an acceptable manner. Reinforcing steel is to be placed as indicated on the plans and held securely in place during concrete placement. Subgrades and forms are to be installed to line and grade as shown in the drawings and the forms are to be mortar tight as the concrete is placed.

Concrete tanks shall have a minimum thickness of 6 inches (15 cm) and shall be steel reinforced. They shall have concrete bottoms. All interior surfaces shall be smooth and treated with epoxy sealer or other suitable material to permit sterilization. Washing new concrete tanks with acetic acid is recommended.

Wood construction and metal fabrication. All untreated wood construction, metal fabrication and other miscellaneous materials such as screens, flashboards, and inlet structures that are used in small quantities and are readily replaceable shall be of durable quality. All fabrication of materials will have a good workmanlike appearance.

Metal tanks will be assembled or installed according to manufacture's recommendations. The interior surface will be painted or treated with an epoxy coating or other suitable material that will preserve the metal and be compatible with fish culture. Where the tank's interior surface is rough or contains fiberglass matting, it must be covered or sealed with an approved resin or sealer.

Overall quality and workmanship. Construction operations shall be carried out in such a manner and sequence that erosion and air and water pollution are minimized and held within legal limits. All work will be conducted in a skillful and workmanlike manner.

The completed job shall present a workmanlike appearance. Fencing and vegetative cover to control erosion and pollution shall be established as needed. Appropriate safety measures such as warning signs, rescue facilities, guardrails, and fencing shall be provided as specified.

Biology Specification

Rainbow trout are the primary species dealt with in Michigan. The biological requirements of rainbow trout (water quality, quantity, loading rates, feeding, etc.) are contained in this standard and shall be adhered to. Biological requirements of other species shall be provided by the NRCS biologist. All raceway designs shall be reviewed by the biologist.

REFERENCES

- Wisconsin Fish Raceway or Tank Standard, Wisconsin Field Office Technical Guide.
- Managing Michigan Ponds for Sport Fishing, Extension Bulletin E-1554.
- Scheffer, P.M. and L.D. Marriage 1969. Trout Farming, USDA Leaflet 552.
- Lichtoppler, F. 1993. "Factors to Consider in Establishing a Successful Aquaculture Business in the North Central Region," NCRAC Technical Bulletin 106.
- Darling, D. and Cain, K. 1993. "Trout Culture in the North Central Region," NCRAC Fact Sheet 108.