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ABSTRACT

Fish impingement on the mid-Columbia River is a concern only from April through June, and is limited to a few species. A comparison of fish impingement was made from May through June 1977 at two water intake facilities located 276 m (900 ft) apart on the Columbia River at River Mile 380. The intakes each have a capacity of over 25 m^3/s (891 cfs), are similarly designed, and have comparable water intake velocities. Collections from traveling screens at 100-N intake yielded 89 dead chinook salmon fry. During the same period 766 chinook salmon fry were collected at the Hanford Generating Project (HGP). These data represent an estimated impingement of 2695 chinook salmon fry, 97% of which survived.

Impingement for other fish species was similar at both intakes, except that HGP impinged twice as many yellow perch fry as 100-N (2642 versus 1296). Several hypotheses are offered to explain the differences in impingement between intakes. These include subtle differences in forebay configuration, curtain wall location, and possible differences in fish behavioral responses to the intake facilities.

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INTRODUCTION

This paper compares fish impingement at two adjacent water intakes on the Columbia River (River Mile 380) in southeastern Washington State on the U.S. Department of Energy's (DOE) Hanford Reservation. The site is between Priest Rapids and McNary Dams and on the last free-flowing stretch of the Columbia River above Bonneville Dam (Figure 1). Most of the Columbia River is now a series of impoundments created by hydroelectric dams. River flows through the Hanford Reach range from 1019.5 to >11,328 m^3/s, and are regulated daily and weekly by Priest Rapid Dam in response to power demands.

The 100-N Reactor, operated by United Nuclear Industries for DOE, is a dual purpose reactor providing plutonium for United States defense purposes, and steam for the adjacent Hanford Generating Project (HGP), operated by Washington Public Power Supply System. The 100-N water intake is about 276 m (905 ft) downstream from HGP (Figure 2).

*Study was conducted for the U.S. Energy Research and Development Administration (now DOE) under Contract EY-76-C-06-1830.

Fish impingement was studied at HGP from March 1973 through April 1976 (Gray et al., 1975; Page et al., 1975, 1976). Impingement at 100-N was studied in 1977 (Page et al., 1977). We simultaneously compared fish impingement at the two intakes during 1977.

INTAKE DESCRIPTIONS

River water is supplied to 100-N by four 6.6 m^3/s (233.9 cfs) pumps. Total pumping capacity is 26.4 m^3/s (935.6 cfs). Only three pumps, 19.8 m^3/s (701.8 cfs), are required for normal operation. There are six pump bays each with a traveling screen. The two center pump bays are for emergency water pumps and the four outer-most for the circulating water pumps (Figure 3). The pump bays are connected by 1.8 by 1.8 m (6 by 6 ft) interflood gates.

River water is supplied to HGP by four 8.9 m^3/s (314.1 cfs) pumps (Figure 3). Total pumping capacity is 35.6 m^3/s (1256.6 cfs). Only three pumps, 26.7 m^3/s (924.3 cfs), are operated when river temperatures are less than 7.2°C (45°F). The HGP intake has two pump bays with three traveling screens each. The pump bays are not interconnected.

The traveling screens are constructed of a vertical row of panels each 3.05 by 0.61 m (10 by 2 ft) with 0.32 cm (1/8 in) square openings (Figure 4). In front of the traveling screens, each intake has a curtain wall extending down to about 116 m (380 ft) above sea level (Figure 5). The lower edges of these curtain walls are 2 m below the water surface at average river flows. At HGP, the curtain wall is behind a trash rack. At 100-N, the trash rack extends down from the curtain wall. Each intake has fish escape ports on the exterior downstream wall.

Trash accumulating on the traveling screens is carried to the top of the intakes and washed into a sluice way that terminates in a sump pit (Figure 3). A 40.6 cm (16 in) diameter pipe returns screen wash water, impinged fish and other material to the river downstream of each intake.

Studies at HGP (Gray et al., 1975) showed larger numbers of fish passed through or around the screens than were impinged. Passage was apparently through openings between the screen panels, along side of the screens and beneath the screens. To reduce screen passage, the major suspected fish entry points were sealed. Similar entry ways at 100-N are not closed and the magnitude of screen passage there is unquantified.

The traveling screens at 100-N are rotated and washed for 10 to 30 min daily with a high pressure, 63,279 kg/m^2 (90 psi), spray wash. During our observations the screens at HGP were rotated and washed continuously. The high pressure spray was preceded by a low pressure, 10,546 kg/m^2 (15 psi), spray. The addition of a low pressure spray and continuous screen washing were made at HGP in 1976 to reduce fish mortality resulting from impingement and/or removal from the screens (Page et al., 1976).

Impingement Velocities

The traveling screens are of similar design at both facilities as is the calculated water velocity through the traveling screens. Calculated impingement velocity (i.e. the velocity through the screen mesh) at HGP is 0.72 m/s (2.36 ft/s), assuming four-pump operation and minimum river elevations. Calculated impinging velocity at the 100-N intake is 0.87 m/s (2.86 ft/s) assuming one traveling screen for each circulating water pump and minimum river elevation. If the incoming circulating water is assumed to enter equally through all six screens, the calculated velocity is 0.58 m/s (1.9 ft/s). Actual velocity through the mesh probably lies between these two values.

PREVIOUS HGP IMPINGEMENT STUDIES

Studies at HGP (Gray et al., 1975; Page et al., 1975, 1976) revealed that over 90% of the fish impinged were zero-age chinook salmon less than 50 mm (1.97 in) fork length. These fish emerge as fry from redds in the river bed between Priest Rapids Dam and the study site (Figure 1) and are present from December through June. Impingement at HGP is generally highest in April and May. About two million swim-up chinook salmon fry emerge each year above the site and are vulnerable to impingement (Page et al., 1976). The fry are the offspring of the last major population of fall chinook salmon spawning in the mainstem Columbia River.

Although other fish species were impinged during HGP studies, their numbers were insignificant compared to those of chinook salmon. Modifications to the HGP intake, similar to those used at the Surry Power Station (White and Brehmer, 1977), have increased survival of impinged fish to more than 93% (Page et al., 1976, 1977).

SAMPLING

A continous sampling device was installed at HGP in 1976 (Figure 6). It consisted of an additional opening in the sump pit and a sample pipe from the sump pit to a net-lined swimming pool. The system diverted about 25% of the HGP screen wash water to the swimming pool where fish and other material were removed daily. The system sampled 31.5 ℓ/s (1.11 cfs) of screen wash water. Tests showed that 3.42 live chinook salmon fry were impinged for each live chinook salmon fry collected in the swimming pool, and 5.01 dead chinook salmon fry were impinged for each dead chinook salmon fry collected (Page et al., 1976, 1977). Fish dead at time of collection may have died as a result of impingement related injuries, or may have died prior to impingement.

At 100-N, all impinged material was collected by installing a basket, lined with 0.32 cm (1/8 in) Vexar®, in the sump pit (Figure 7). Screens were usually washed once per day and tests showed collection of 100% of impinged fish.

IMPINGEMENT

Seven fish species were collected from the traveling screens at 100-N (Table 1). Yellow perch fry and chinook salmon fry were most frequently collected (Table 2). Fourteen times more yellow perch fry were collected than chinook salmon fry. All fish collected at 100-N were dead. Evidence indicates most fish died as a result of impingement.

Ten fish species were collected at HGP (Table 1). In addition to the seven species encountered at 100-N, the list included sucker, longnose dace and threespine stickleback. Chinook salmon fry (766 live and 15 dead) were the most common fish impinged (Table 3). Based on sample efficiency, it was estimated that 2620 (766 x 3.42) live and 75 (15 x 5.01) dead chinook salmon fry (2695 total) were impinged at HGP. If yellow perch fry are sampled with the same efficiency as chinook salmon fry, then 2432 live and 210 dead yellow perch fry (2642 total) were impinged at HGP. Note, however, that 97% of the

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2695 chinook salmon fry and 92% of the 2642 yellow perch fry survived impingement at HGP. Survival of other species was similar. Virtually equal numbers of chinook salmon fry and yellow perch fry were impinged at HGP.

Twice as many yellow perch fry were impinged at HGP as at 100-N, and 30 times as many chinook salmon fry (Figure 8). More chinook salmon fry were impinged in May than June. Impingement of yellow perch peaked in June.

POSSIBLE EXPLANATIONS

Several hypotheses may help explain differences in impingement noted in our studies. First, the HGP intake (located upstream from 100-N) removes vulnerable fish from the river, thereby reducing the number of fish exposed at 100-N. Since HGP immediately returns most impinged fish to the river alive, upstream of 100-N, this does not account for the observed differences.

Fish may not be as likely to encounter the 100-N intake because it sits further from the river, in a more pronounced forebay (Figure 2). However, the removal of berms, which previously created a similar forebay at HGP, had no discernable effect on impingement (Gray et al., 1975).

Fish in front of the intakes may be less likely to enter 100-N, perhaps as a result of differences in the location of the curtain wall. Experimental releases of rainbow trout fry, similar in size to the impinged wild chinook, in the forebay of both intakes showed HGP impinged three times more fish than 100-N.

Additional releases of live and dead rainbow trout fry immediately (<1 m) in front of the traveling screens at both intakes showed that HGP impinges six times more live fish than 100-N, even when they were presented directly to the screens (Table 4). However, the 100-N intake impinged about

1.3 times more dead fish than HGP. The impingement of more dead fish and fewer live fish at 100-N suggests that though velocities at the screen may be higher, environmental stimuli at 100-N may induce fish to avoid the screens.

Fish may pass through or around the traveling screens at 100-N instead of becoming impinged. Prior to modification to eliminate screen passage at HGP, more fish passed the screens than were impinged (Gray et al., 1975). Although this hypothesis cannot be dismissed entirely, SCUBA diver observations of the intakes and sampling of the pump wells behind the traveling screens suggest screen passage may be less of a problem at 100-N than it once was at HGP. Impingement of yellow perch fry at 100-N, which were smaller than the chinook salmon fry, also suggests screen passage may not explain observed differences in impingement.

Subtle differences in water velocity, circulation patterns, and design and operation of the intakes may provide behavior stimuli and induce avoidance of the screens by fish at 100-N. More detailed examinations of the complex interactions between fish and water intake facilities are needed to understand which intake design features and operational procedures protect fish.

ACKNOWLEDGMENTS

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TABLE 1

Common and Scientific Names of Fish Collected from Hanford Generating Project and 100-N Traveling Screens and by Beach Seining, May through July 1977

Common Name	Scientific Name	Collection Site*
chinook salmon	*Oncorhynchus tshawytscha*	H,N,B
Pacific lamprey	*Entosphenus tridentatus*	H,N
threespine stickleback	*Gasterosteus aculeatus*	H,B
redside shiner	*Richardsonius balteatus*	H,N,B
whitefish	*Prosopium williamsoni*	H,N
squawfish	*Ptychocheilus oregonensis*	H,N,B
sculpin	*Cottus* spp.	H,N,B
yellow perch	*Perca flavescens*	H,N,B
longnose dace	*Rhinichthys cataractae*	H,B
sucker	*Catostomus* spp.	H,B

*H = Hanford Generating Project, N = 100-N, B = Beach Seine

TABLE 2

Numbers and Species of Fish Collected from 100-N

Screen Washings from 6 May through 28 June 1977

Date	chinook fry	Pacific lamprey	redside shiner	squawfish	whitefish	sculpin	yellow perch
6 May 77	34			3			
11 May 77	40						
12 May 77							
18 May 77	2						
20 May 77	4		1	1			
24 May 77	1					1	
26 May 77							
1 June 77	1						
2 June 77					1		
7 June 77	3						
9 June 77	4			1			5
14 June 77							143
16 June 77							262
21 June 77		2		1			747
23 June 77							138
28 June 77	—	—	—	—	—	—	1
TOTAL	89	2	1	6	1	1	1296

TABLE 3

Numbers and Species of Fish Collected from HGP

Screen Washings from 6 May through 6 July 1977

Date	chinook A	chinook D*	Pacific lamprey A	Pacific lamprey D	stickleback A	stickleback D	dace A	dace D	redside shiner A	redside shiner D	squawfish A	squawfish D	whitefish A	whitefish D	sculpin A	sculpin D	sucker A	sucker D	yellow perch A	yellow perch D
6 May 77	48	1							1											
11 May 77	223	5	1		1				19		6				1		1			
12 May 77	178	2			5				3		23				4					
18 May 77	134	3	1		4		1		3		19	1			5		1			
20 May 77	60	2			2				2		7				12					
24 May 77	41	1			3		2				9		1		10	1				
26 May 77	29				2				1		17		1		13					
1 June 77	12										3		1		9					
2 June 77	19								3		8				8					
7 June 77	12														3					
9 June 77	5	1									3								3	
14 June 77	2																		134	6
16 June 77	2										1						1		139	
21 June 77					1						1		1						16	23
23 June 77											1		1						408	9
28 June 77	1																		11	4
TOTALS	766	15	2	0	18	0	3	0	32	0	98	1	5	0	65	1	3	0	711	42

*A = Alive; D = Dead

TABLE 4

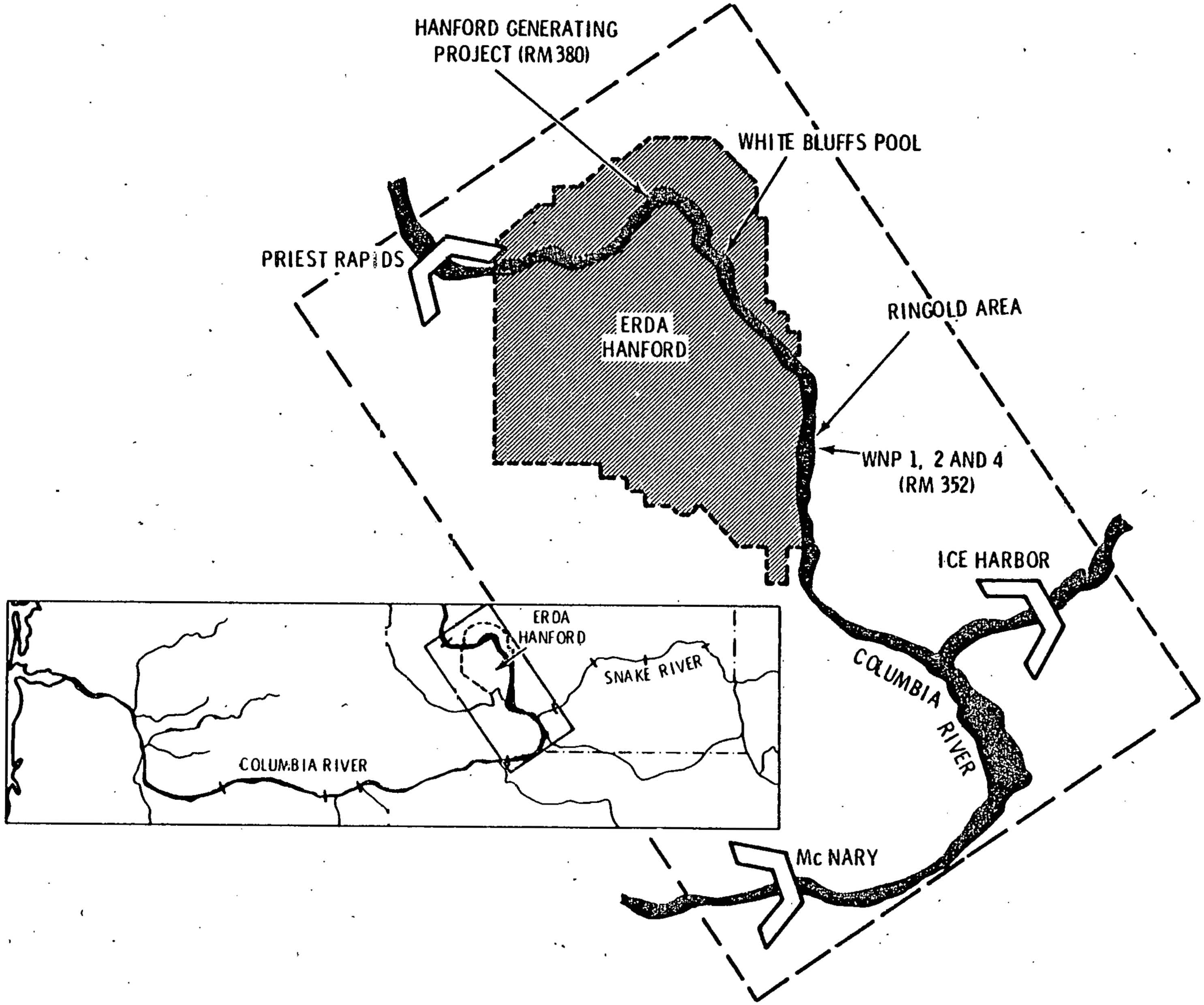
Number of Experimental Rainbow Trout Collected after Release*

Behind the Trash Racks on June 1977 at HGP and 100-N

	Number Fish Recovered in Screen Wash	
Elapsed Time	HGP	100-N
20 hr	42 live 63 dead	21 live 428 dead
44 hr	0 0	1 5
68 hr	1 0	0 0
92 hr	0 0	0 0
164 hr	0	0
188 hr	2 0	0 0
Total	45 live 63 dead	22 live 433 dead
Adjusted for sample efficiency†	154 live 316 dead	
Percent recovered	26% 53%	4% 72%

*600 live and 600 dead released at each intake

†Page et al., 1976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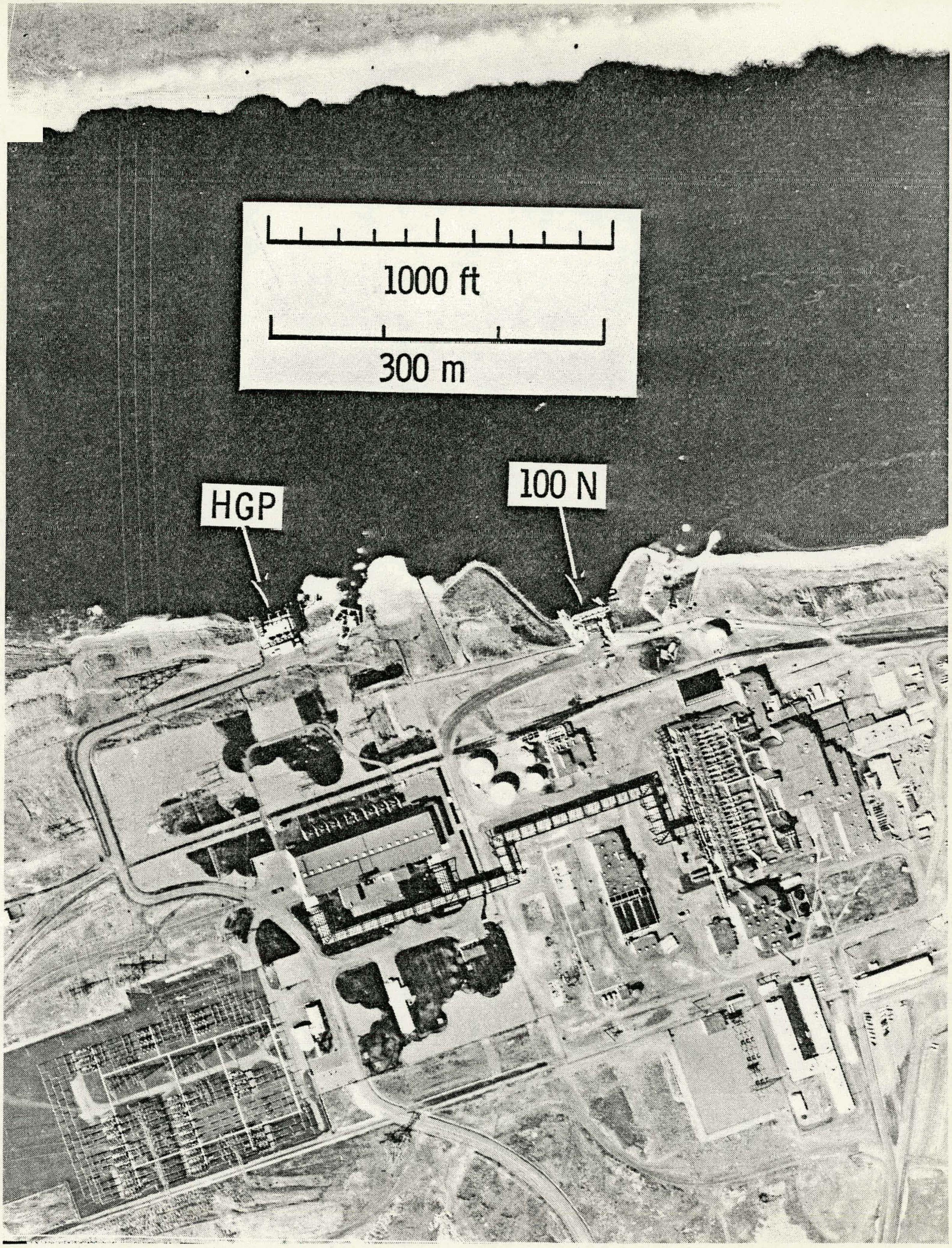
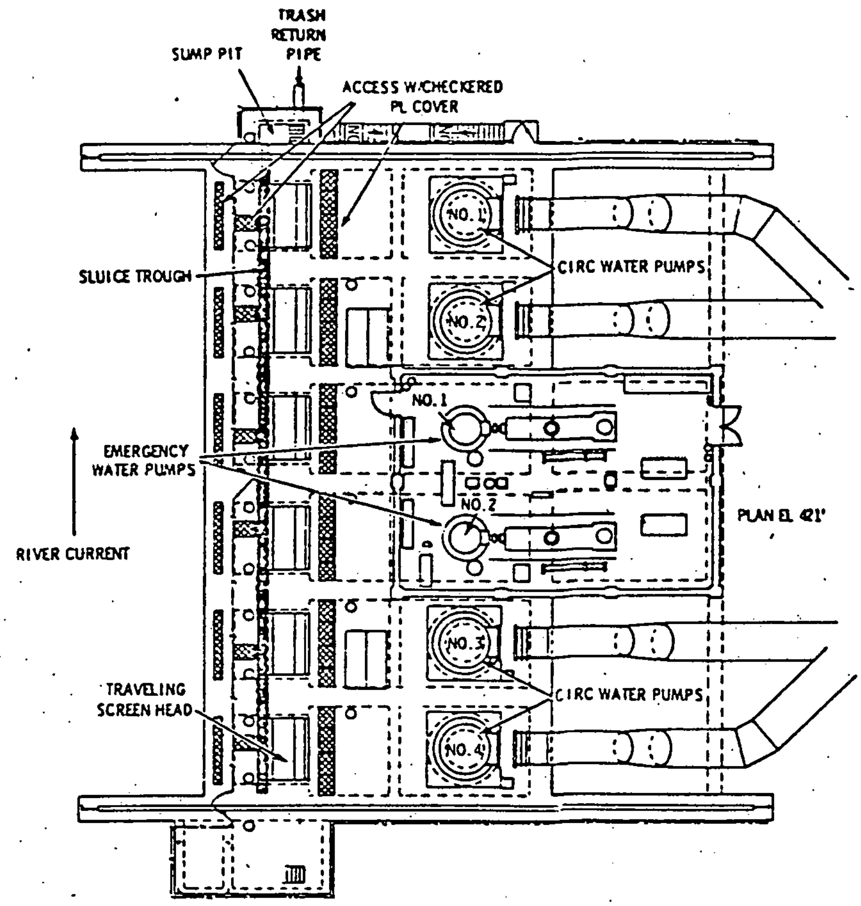
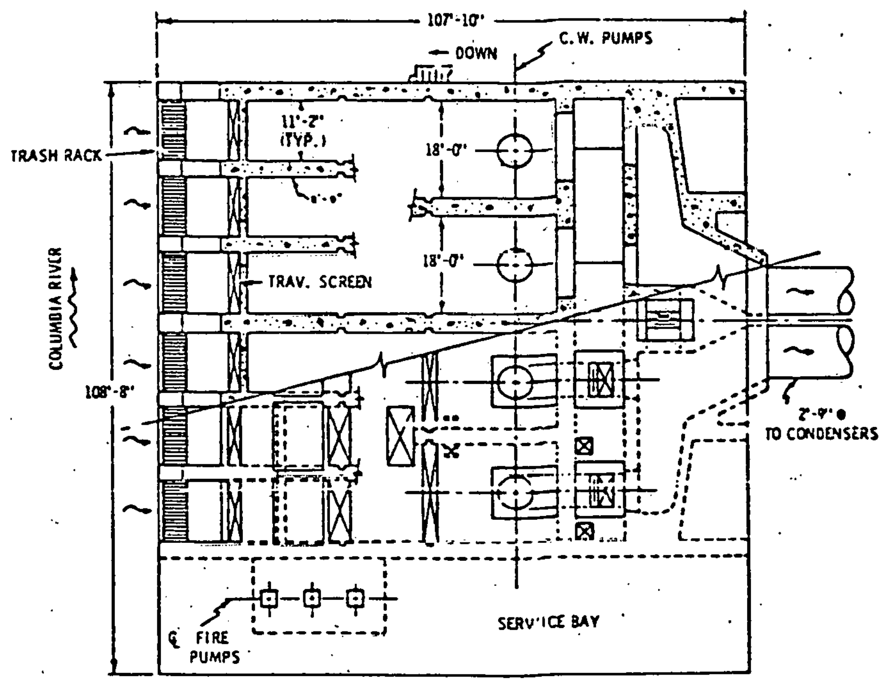
PROJECT (RM 380)
WHITE BLUFFS POOL
PRIEST RAPIDS
ERDA
HANFORD
RINGOLD AREA
WNP 1, 2 AND 4
(RM 352)
ICE HARBOR
COLUMBIA
RIVER
Mc NARY
ERDA
HANFORD
SNAKE RIVER
COLUMBIA RIVER


1000 ft
300 m
HGP
100 N



PLAN VIEW OF 100N WATER INTAKE STRUCTURE



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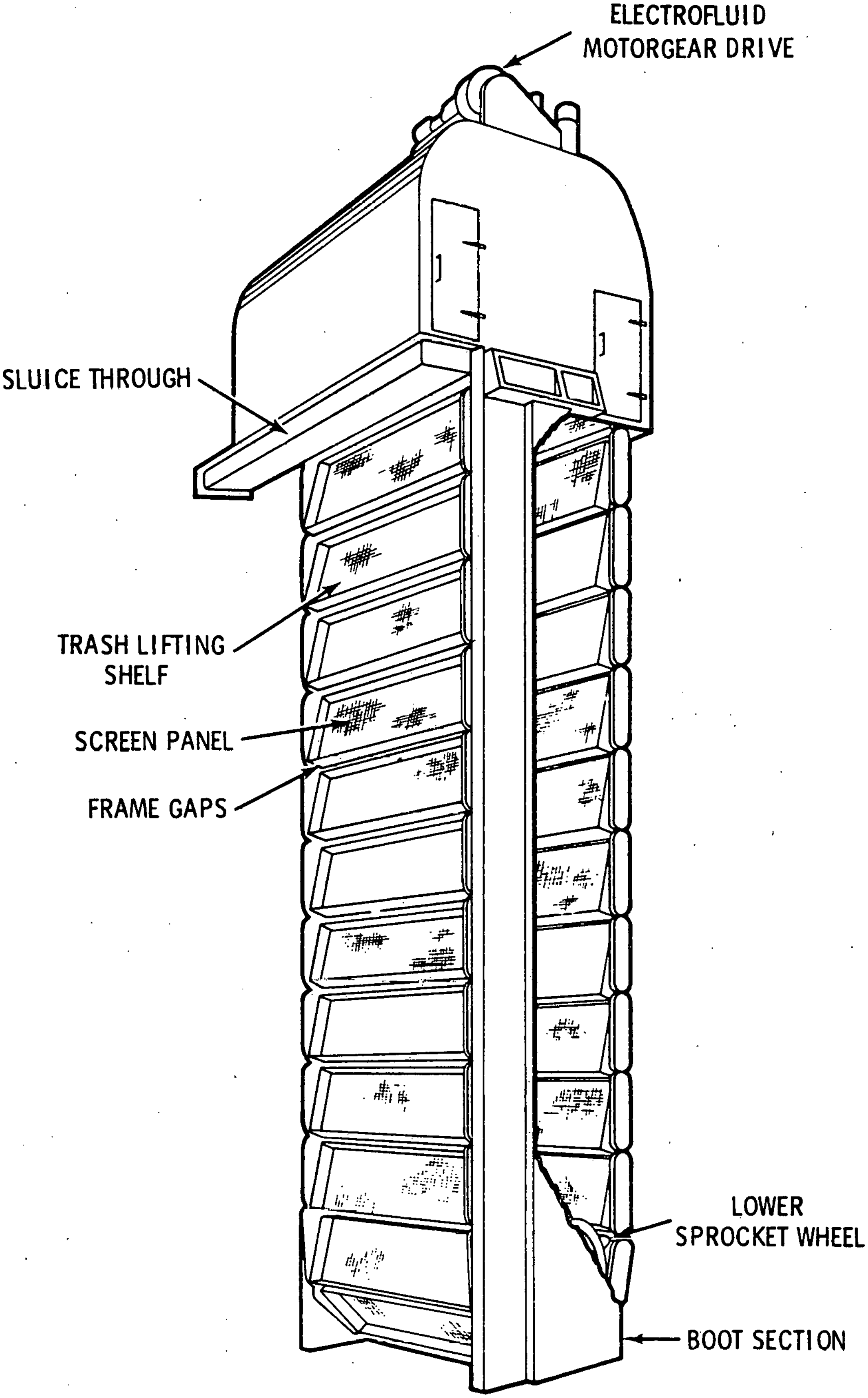
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FRAME GAPS
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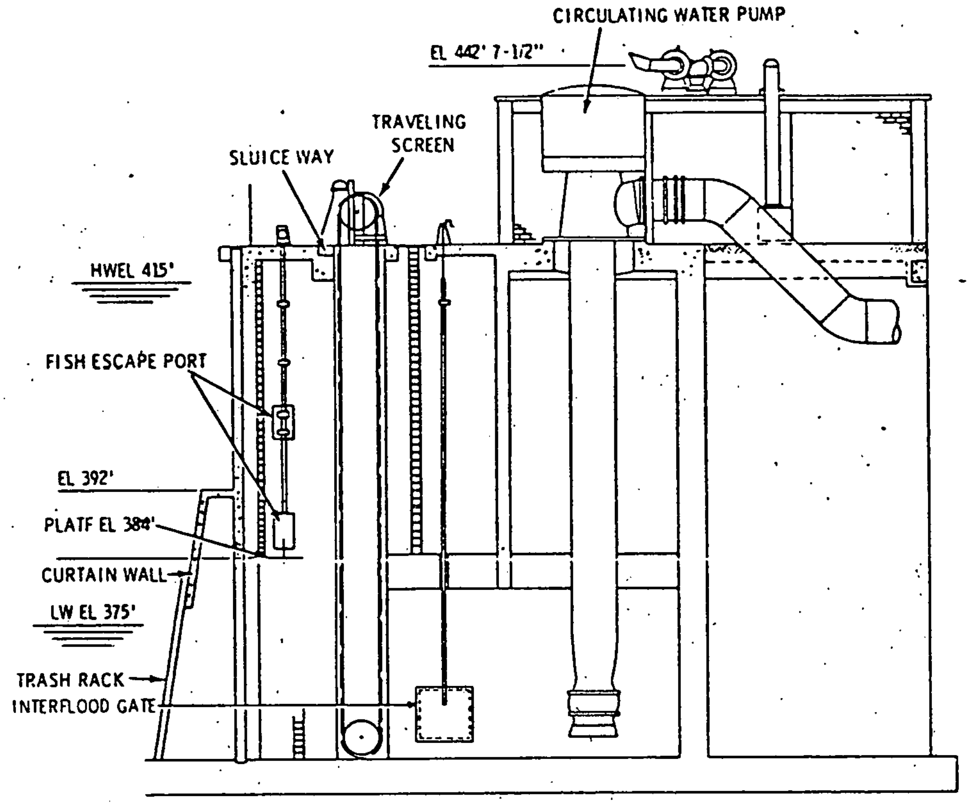
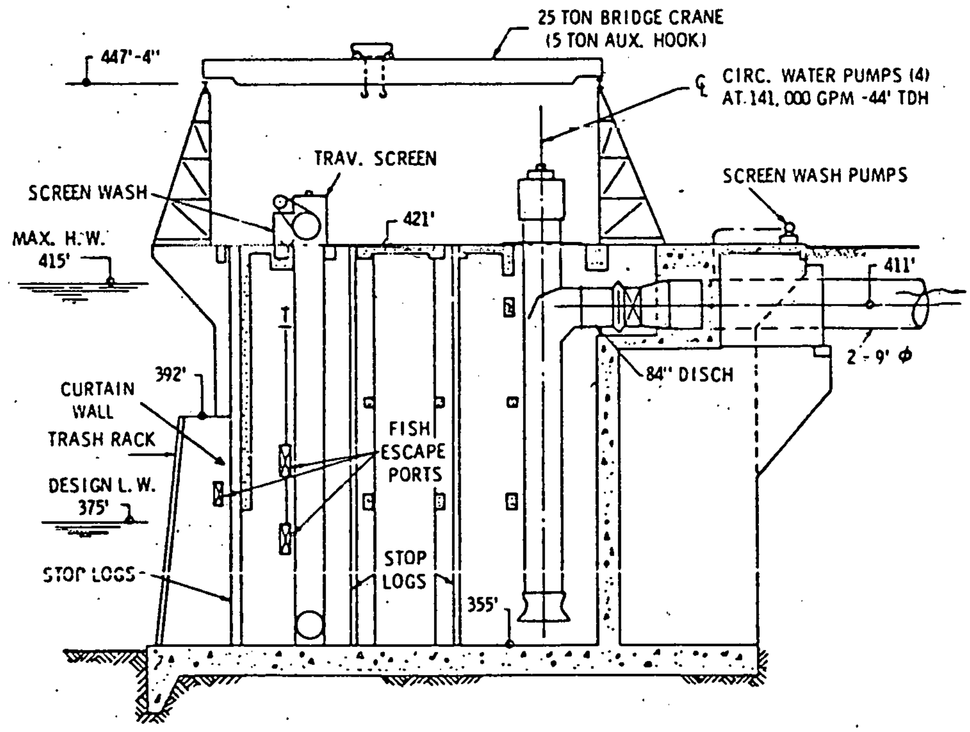
SPROCKET WHEEL
BOOT SECTION



SCHEMATIC OF 100N WATER INTAKE STRUCTURE



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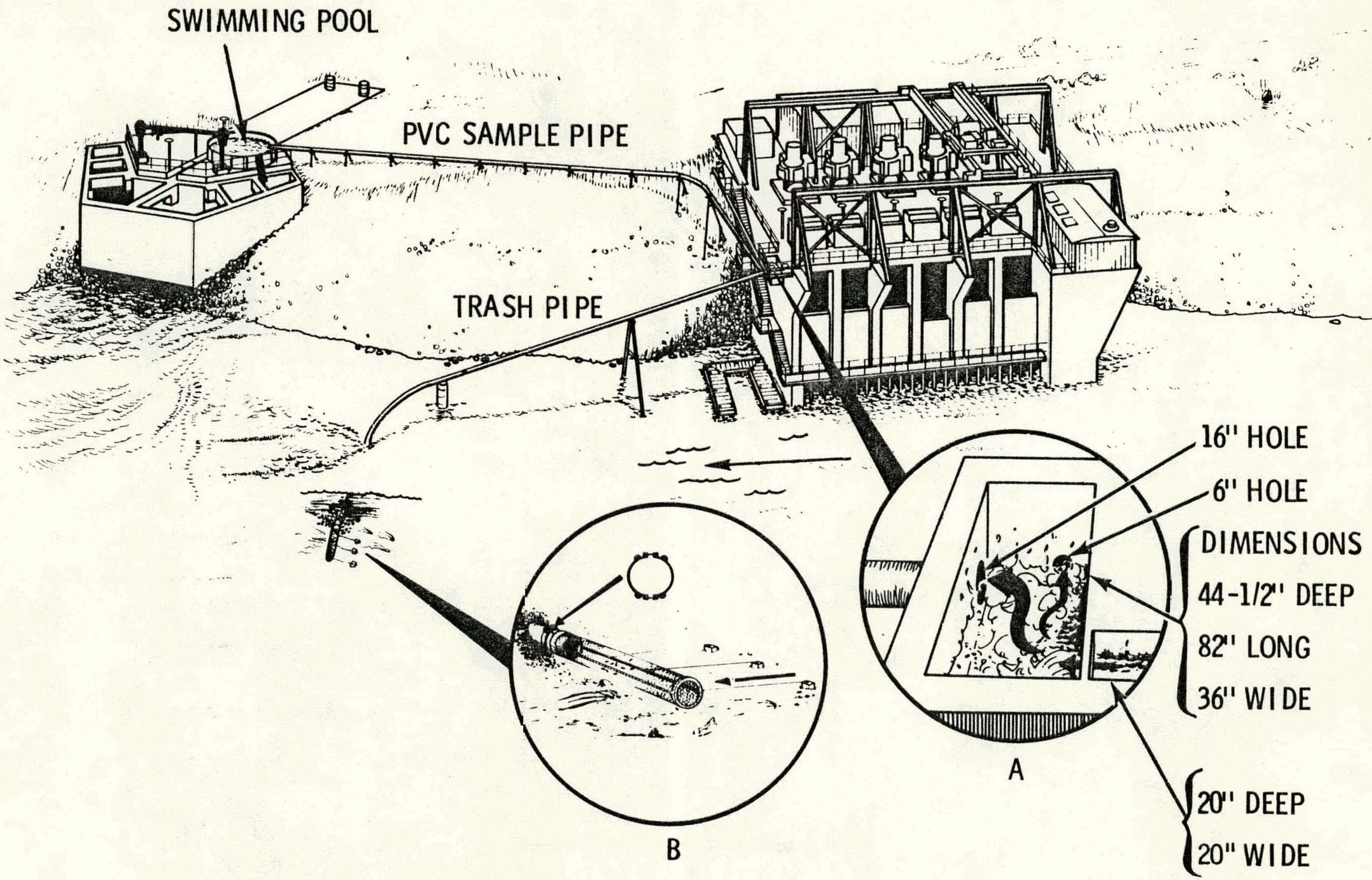
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PVC SAMPLE PIPE
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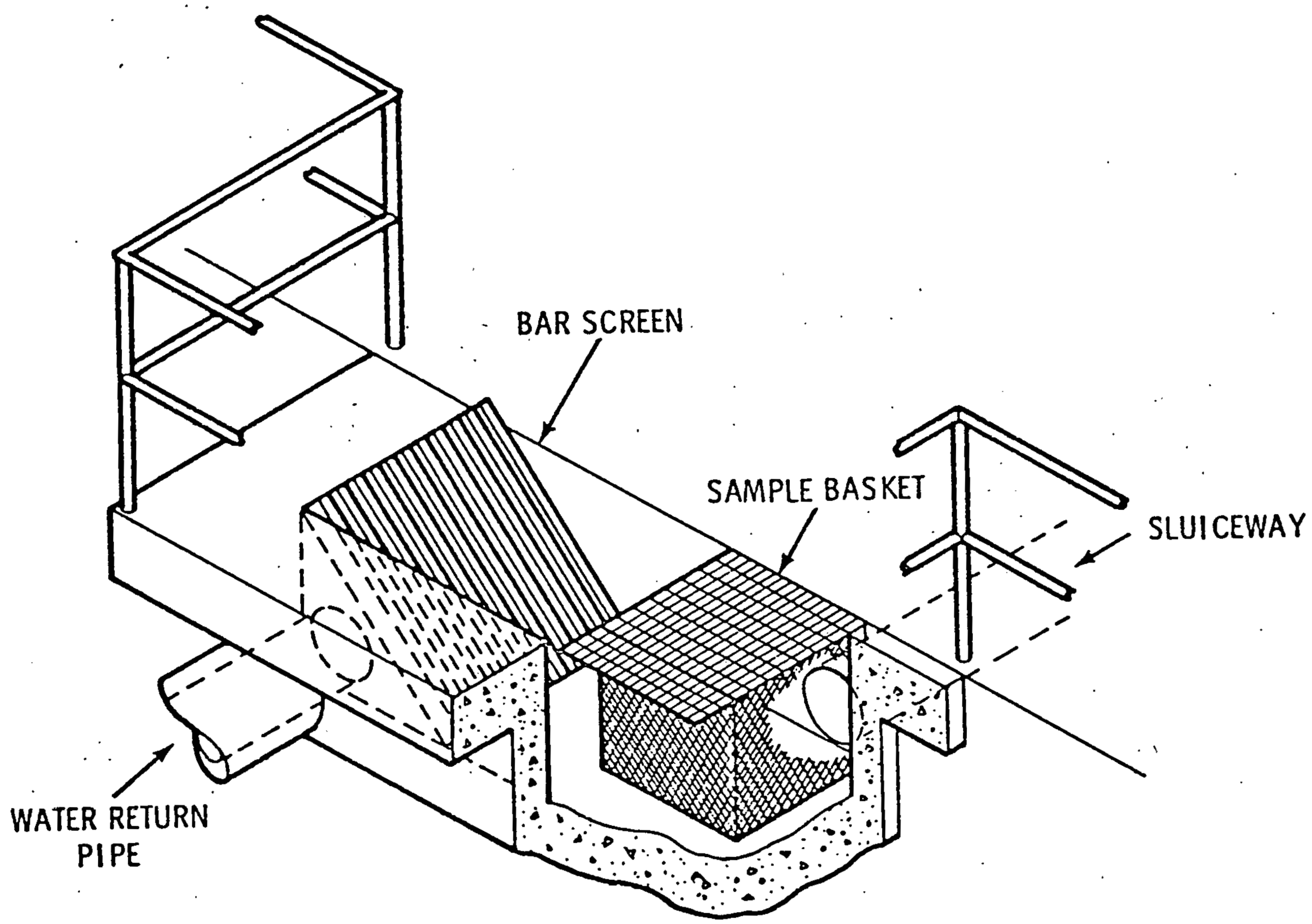
82" LONG
36" WIDE
A
20" DEEP
20" WIDE
B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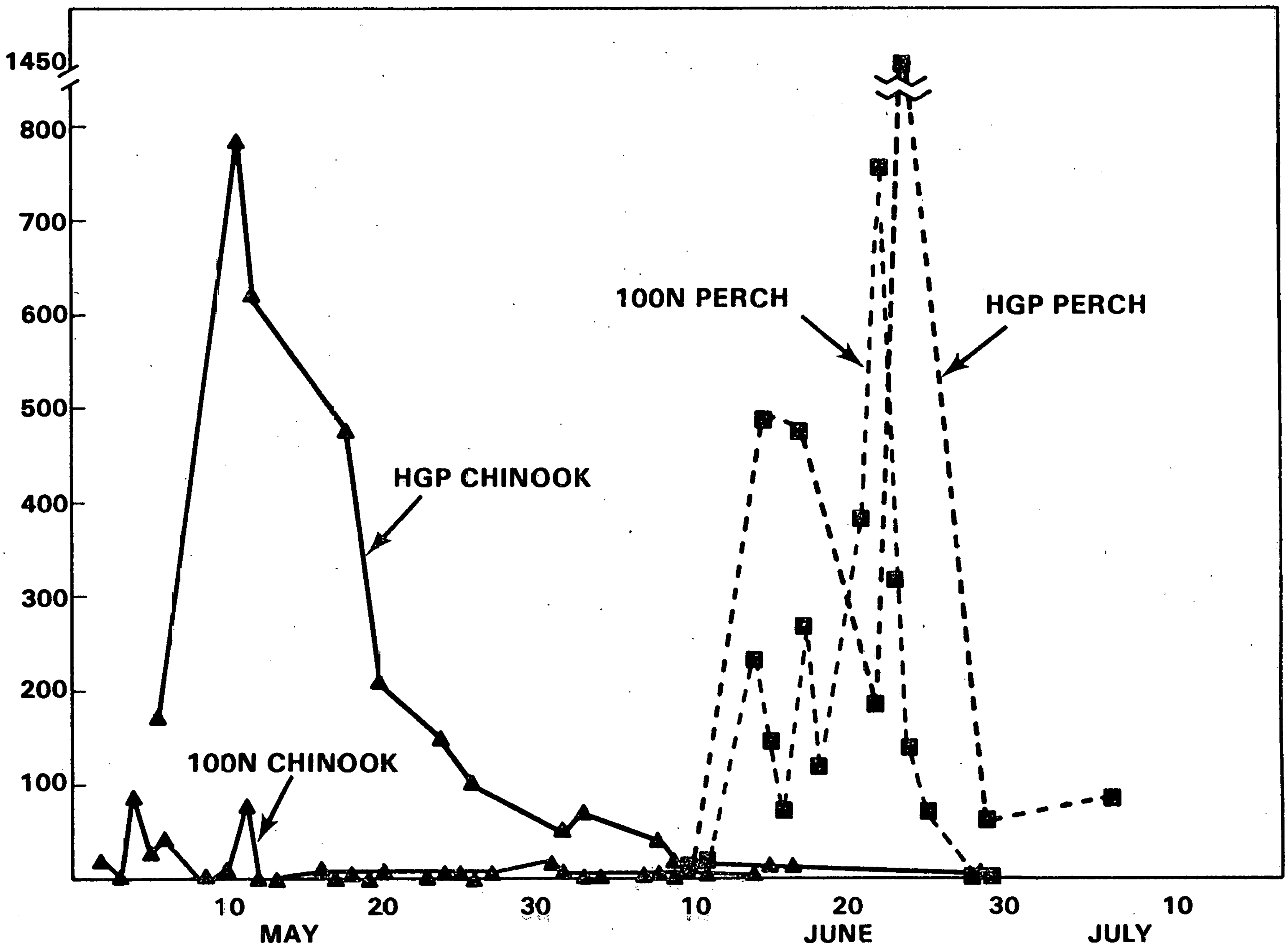
WATER RETURN PIPE


1450
800
700
600
500
400
300
200
100
HGP CHINOOK
100N CHINOOK
100N PERCH
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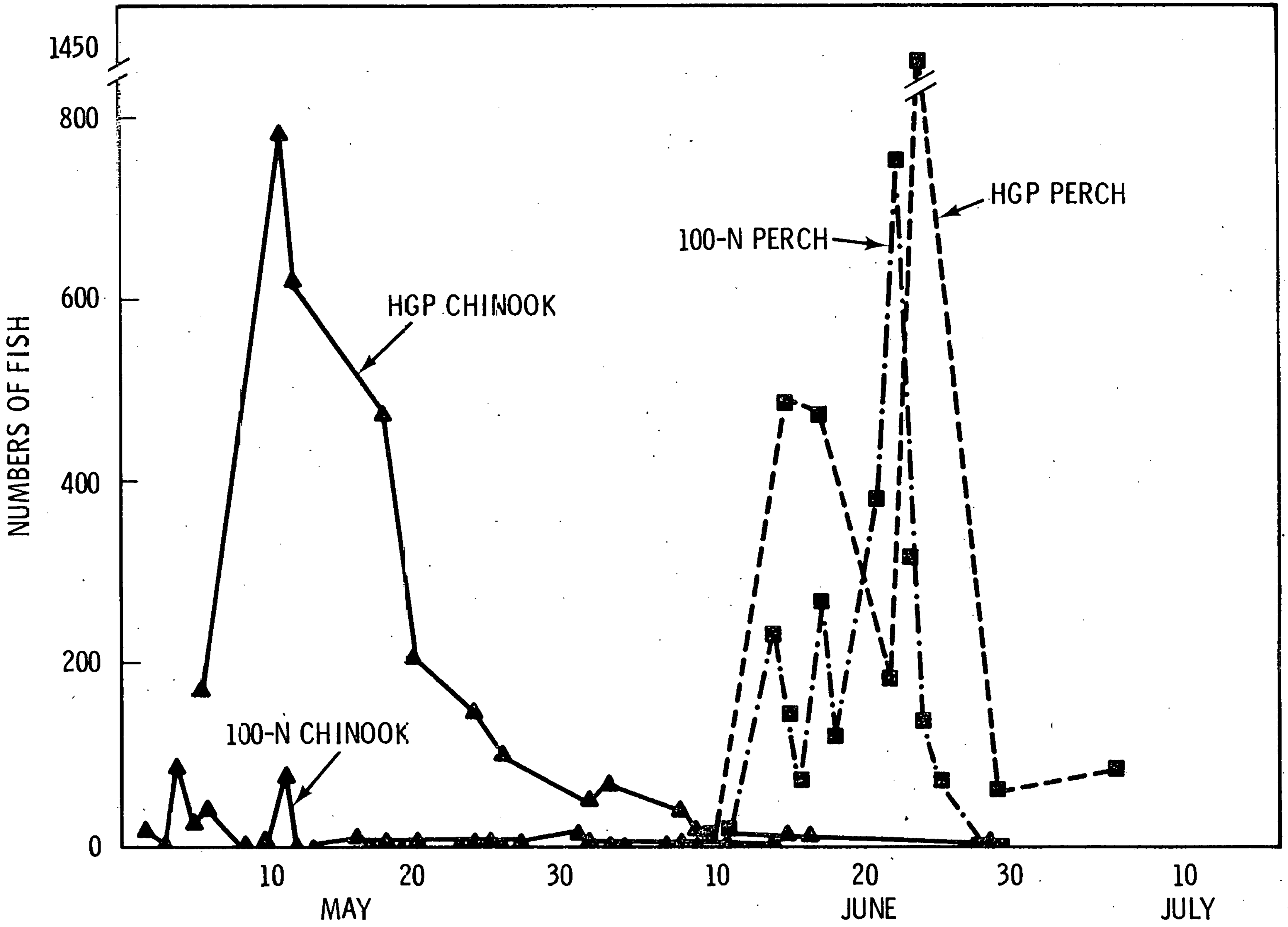
20
30
10
20
30
10
MAY
JUNE
JULY


1450
800
600
400
200
0
NUMBERS OF FISH
HGP CHINOOK
100-N CHINOOK
100-N PERCH
HGP PERCH
10
20
30
10
20
30
10
MAY
JUNE
JULY