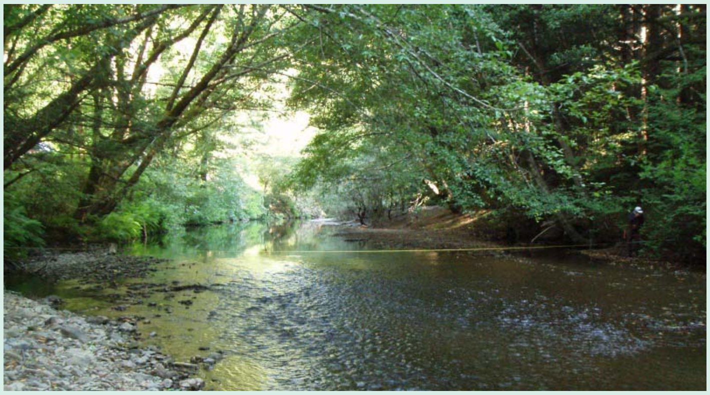
TECHNICAL MEMORANDUM ◦ DECEMBER 2012

North Gualala Water Company Site-Specific Studies Report

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Cover photographs: Cross-section D2, located just downstream of the USGS North Fork Gualala River gage, at 40, 9.4, 8.2, and 3 cfs (clockwise from upper left). Photographs taken by Dennis Halligan, Stillwater Sciences.

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1 INTRODUCTION

1.1 Water Rights Permitting Background

The North Gualala Water Company (NGWC) holds water right Permit 14853, which authorizes the diversion of up to 2.0 cubic feet per second (cfs) of water from the North Fork Gualala River for municipal use. The NGWC makes diversions under Permit 14853 through NGWC's Production Wells (PW) 4 and 5. These wells are located approximately 200 feet from the North Fork Gualala River and pump water from alluvial materials adjacent to the river.

A 1978 State Water Resources Control Board (SWRCB or State Board) order on a NGWC petition for change in the authorized place of use in Permit 14853 established the present bypass flow requirements for the permit. These bypass flow requirements, which specify the minimum flows that must be in the river when any pumping of PW 4 and 5 is occurring, vary over the course of the calendar year, as follows:

- 40 cfs (15 November to 29 February)
- 20 cfs (1 March to 31 May)
- 4 cfs (1 June to 14 November)

The North Fork Gualala River's natural unimpaired (without diversion) flows during the 15 November to 31 May bypass periods frequently are less than these minimum bypass flow requirements. However, the NGWC still must pump these wells to meet the demands of its municipal water customers during such conditions. To help address this issue, the NGWC has filed water right Application 31792 with the SWRCB. This application seeks a permit that will authorize NGWC to pump up to 0.7 cfs (185 acre-feet annual limit) of water from PW 4 and 5 during the 15 November through 31 May period. This permit would authorize the NGWC to divert water during times when diversions are not authorized under Permit 14853 (i.e. when flows are less than the bypass requirements in Permit 14853).

The NGWC has also filed petitions for extension of time for Permit 14853 with the SWRCB. These petitions request extensions of the deadline in Permit 14853 for applying water to full beneficial use. If these petitions are granted, then the NGWC will be authorized to continue to increase its diversions under Permit 14853 (when such diversions are authorized) as necessary to meet the demands of NGWC's customers.

In 2010, the State Board adopted its *Policy for Maintaining Instream Flows in Northern California Coastal Streams* (SWRCB 2010). The primary objective of this Instream Flow Policy is to ensure that the administration of water rights occurs in a manner that maintains instream flows needed for the protection of fishery resources (SWRCB 2010). To achieve this objective, the Policy establishes principles and guidelines for maintaining instream flows for the protection of fishery resources. The Policy allows water rights applicants and petitioners to implement the policy principles through regionally protective criteria (Section 2.2 of SWRCB 2010) or site-specific studies (Appendix C of SWRCB 2010).

For Application 31792 and the petitions for extension of time for Permit 14853, the NGWC has elected to conduct site-specific studies to help determine instream flow criteria that are protective of fishery resources in the North Fork Gualala River.

1.2 Site-specific Study Determination Process

The process to determine which site-specific studies the NGWC was required to conduct is documented in Stillwater Sciences (2011a and 2011b).

As discussed in these reports, the NGWC met with representatives of SWRCB, National Marine Fisheries Service (NMFS), California Department of Fish and Game (CDFG), and consultants on two separate occasions. These meetings included discussions of the community's water use, NGWC's pumping of PW 4 and 5 and water rights history, North Fork Gualala River hydrology, other water sources, anadromous fish use of the river and critical life history periods, California Environmental Quality Act (CEQA) documentation, and project timelines. This multi-faceted discussion provided a holistic view of the project context. During the meetings, it was agreed that upstream adult and juvenile steelhead migration passage, benthic macroinvertebrate production, and summer juvenile steelhead rearing habitat were the critical issues that would require site-specific studies. It also was agreed that background information for all the study elements specified in Appendix C of SWRCB (2010) would be addressed in a "reconnaissance assessment," which was included in Stillwater Sciences (2011a).

This report documents the results of site-specific studies that were performed in compliance with the SWRCB (2010) guidelines and this process.

2 METHODS

2.1 Study Reach

The Study Reach extended from the upstream end of Elk Prairie downstream to the United States Geological Survey (USGS) North Fork Gualala River stream gage (#11467553), a distance of 4,200 ft (Figure 2-1). Two subreaches (upstream and downstream) were established within the study reach, as depicted in Figure 2-2. The upstream and downstream reaches each are approximately 2,100 feet long. The upstream reach was assumed to not be under the potential influence of water pumping activities at PW 4 and 5. This assumption was based on the direction of groundwater flow as reported in Luhdorff and Scalmanini (1998). The downstream reach was assumed to be under the influence of well pumping activities, based on the Luhdorff and Scalmanini (1998) groundwater flow direction.

2.2 Habitat Typing

The habitat inventory followed the Level III methodology presented in the California Salmonid Stream Habitat Restoration Manual, Third Edition (Flosi et al. 1998). The habitat inventory was conducted within downstream and upstream reaches. The downstream habitat typing reach extended from the North Fork Gualala River's confluence with the Little North Fork Gualala River upstream to a point located approximately 130 ft upstream of the point where the river is closest to Production Well #5, a total distance of 1,321 ft. The upstream reach habitat typing extended from that point upstream a distance of 2,104 ft (Figure 2-2).

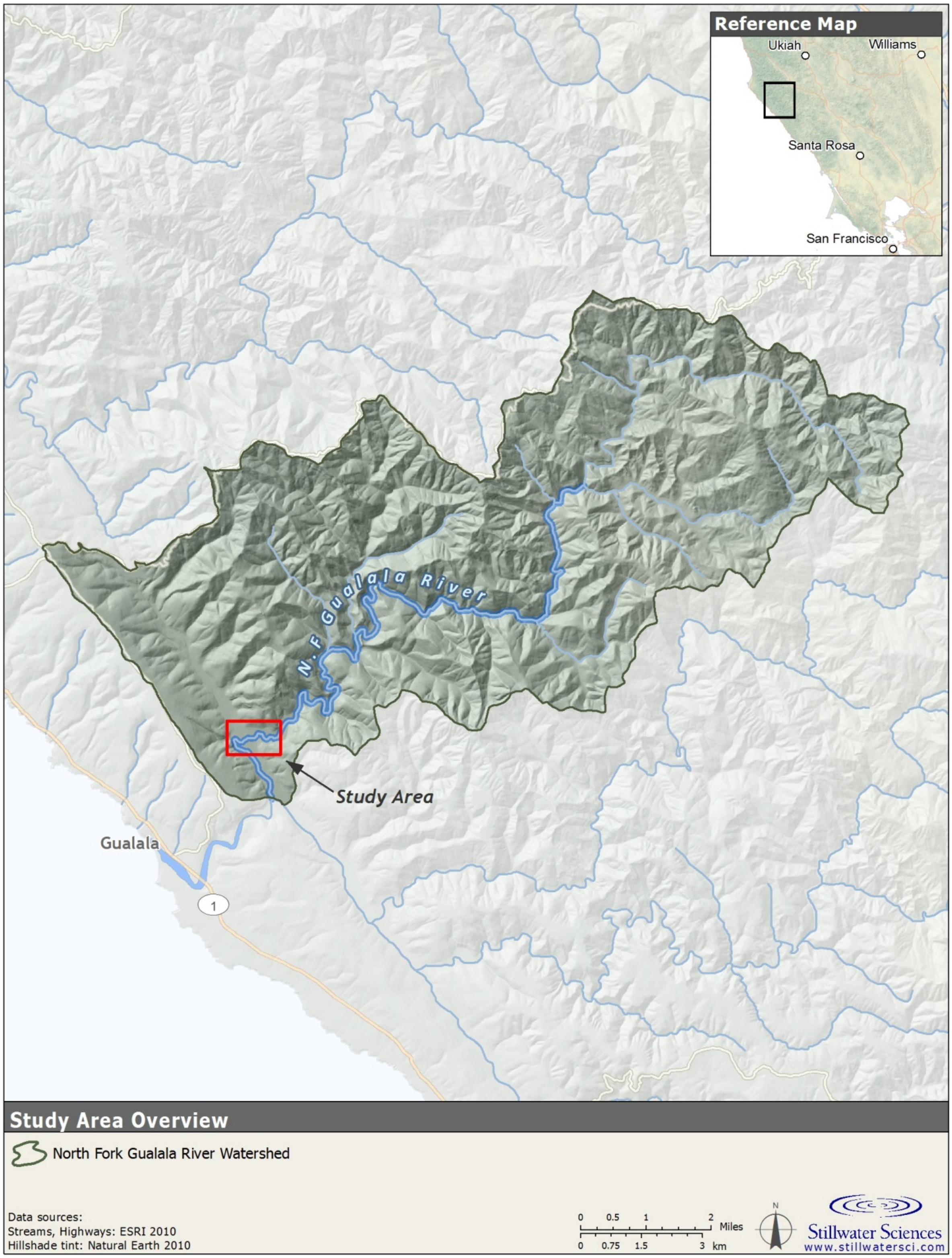

Figure 2-1. Study area location.

The Level III Stream Inventory (Flosi et al. 1998) described six habitat classification types (riffle, cascade, flatwater, main-channel pool, scour pool, and backwater pool), which can be collapsed into three Level II types (riffle, flatwater, and pool). Habitat units were numbered sequentially on the field form as they were encountered and assigned a type identification number of 1 through 6. The mean length and width of each unit were determined using a hip chain. Readings for mean depth, maximum depth, and depth of pool tail crest were taken to the nearest tenth of a foot by use of a graduated stadia rod. Pool tail crest depth at each pool unit was measured in the thalweg. Additional data collected included pool tail embeddedness, percentage and composition of instream cover, dominant and subdominant substrate, percentage canopy cover, bank substrate, and vegetation composition. See Flosi et al. (1998) for additional details on habitat typing methodology.

Field data from the habitat inventory were entered into a Microsoft Access® database program. This program processed and summarized the data and produced tables. Tabular data summaries included:

- Level III habitat type metrics,
- average percent shelter by habitat type,
- dominant substrates by habitat type,
- sub-dominant substrates by habitat type,
- canopy, streambank, and vegetative characteristics by habitat type, and
- summary of measured fish habitat elements.

2.3 Adult Steelhead Passage

The upstream passage study focused on identifying the depth of water required to support upstream migration requirements for adult steelhead during the 15 November to 31 May time period, which is their normal migration period and corresponds with the diversion season for Application 31792.

The Thompson (1972) "critical riffle" methodology was used to help estimate the minimum river flow necessary for upstream adult steelhead migration passage under the Thompson criteria. In order for a riffle to be considered "passable" under the Thompson (1972) method, at least 25% of the total riffle width and a continuous portion of at least 10% of the riffle width need to meet the 0.6 ft depth criterion. Any riffle cross-section not meeting any of the width or depth criteria is considered to be "not passable." The percentage passable for the cross-sections was then averaged to determine the minimum flow necessary for passage under the Thompson (1972) method.

Cross-sections were established at the six shallowest riffles [three in the upstream reach (U1a, U1b, and U2) and three in the downstream reach (D1, D1b, and D2)] that appeared to be the most limiting for upstream adult migration within the Elk Prairie to Little North Fork subreach (Figure 2-2). At each critical riffle, permanent pins were installed on both sides of the creek to establish a repeatable cross-section for measurements. Water depth data were recorded at 2-ft intervals and at the thalwegs across each cross-section at river flows as close as possible to 10, 20, 40, and 60 cfs, as measured at the USGS North Fork Gualala River gage. These relationships were then compared with upstream and downstream passage criteria for steelhead (Table 2-1) to determine what river flows are protective of adult migration under the Thompson criteria. Data collection for the adult passage assessment occurred between 27 April and 4 August 2011.

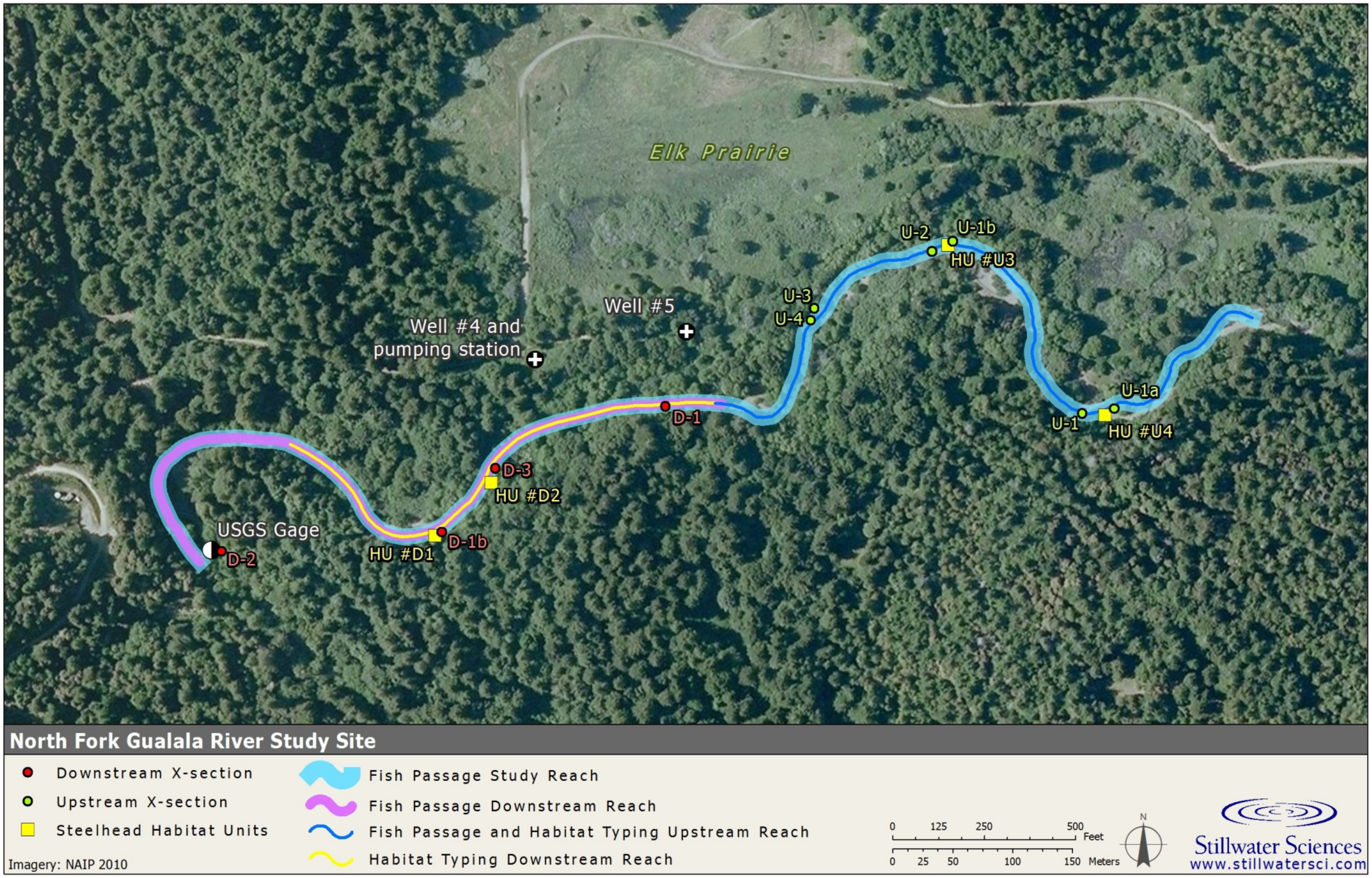

Figure 2-2. Study reach and data collection locations in the North Fork Gualala River.

Table 2-1. Steelhead passage habitat criteria, from Thompson (1972).

Passage requirement	Criteria
Supports upstream migration of adults to spawning habitat (December through April)	≥0.6 ft water depth
Supports downstream migration of adult kelts to ocean (March through mid-June)	≥0.6 ft water depth
Supports upstream and downstream juvenile migration (all year)	≥0.2 ft water depth

2.4 Juvenile Steelhead Passage

The juvenile steelhead passage study focused on identifying the depth of water required to support juvenile fish movement during the summer and fall low-flow period, which corresponds with the 1 June to 14 November diversion period in Permit 14853.

Similar to the adult steelhead passage study, the Thompson (1972) "critical riffle" methodology was used to help estimate the minimum river flow necessary for juvenile steelhead migration passage under the Thompson criteria. Cross-sections were established at the six shallowest riffles [three in the upstream reach (U1, U3, and U4) and three in the downstream reach (D1, D2, and D3)] that appeared to be the most limiting for juvenile passage within the Elk Prairie to Little North Fork subreach (Figure 2-2). At each critical riffle, permanent pins were installed on both sides of the river to establish a repeatable cross-section for measurements. Water depth data were recorded at 2-ft intervals across each cross-section at river flows as close as possible to 10, 8, 5, 4, and 3 cfs, as measured at the USGS North Fork Gualala River gage. Thalweg depth data were also collected at the identified riffles. These relationships were then compared with upstream and downstream passage criteria for juvenile steelhead (Table 2-1) to determine what flows were protective of their migration under the Thompson criteria.

In 2011, cross-section width and water depth data were collected along the same cross-sections that were utilized for the adult passage analysis. Juvenile passage data were collected at river flows of 20, 10, and 6.3 cfs, as measured at the USGS North Fork Gualala River gage. However, early fall rains resulted in the North Fork Gualala River flows never dropping below 6 cfs in 2011, which precluded data collection at the 4 cfs target. Therefore, the juvenile passage site-specific study was halted for 2011 and was scheduled to be repeated during the summer of 2012, with the goal of collecting data at river flows of 4 cfs or lower.

The 2012 winter and spring high flows resulted in changes to the river morphology and two of the 2011 upstream and one downstream study riffles from 2011 became pools or flatwaters. In addition, there were some changes in the remaining 2011 study riffles. As a result, three new riffles were established and the end pins for the remaining sites were reset. The target river flows were also revised downward due to the results of the 2011 effort, which showed ample juvenile passage at the 20 cfs river flow. Therefore, 2012 data were collected at river flows as close as possible to 10, 8, 5, 4, and 3 cfs.

Water velocity data were collected along each riffle cross-section using a flow meter during the 2011 field effort. However, there were errors in the velocity data collected at water depths of less than 0.2 ft, due to bottom turbulence and the sensor making contact with the substrate. A significant number of stations along each cross-section were shallower than 0.2 ft. This resulted in unmeasured areas along the cross-sections and introduced errors into the subsequent river flow calculations. As a result, the river flow calculations showed either more or less river flow at the individual cross-section than at those upstream and downstream as well as the USGS gage. Due to this inherent inaccuracy, the collection of water velocity data at the critical riffles was dropped from the study. Instead, riffle depth/fish passage/river flow relationships were determined using the cross-section and USGS North Fork Gualala River gage discharge data. (Consistent with USGS terminology, this report sometimes refers to river flows as "discharges.")

2.5 Benthic Macroinvertebrates

Changes in the magnitude of river flows, and associated changes in depths and velocities over riffles could affect the amounts of drift insect deliveries to juvenile steelhead feeding locations in pools. This is because the amount of hydraulically diverse riffle area is directly proportional to the amount of benthic macroinvertebrate (BMI) production (i.e., more riffle area equates to more drifting insects). Stillwater Sciences (2011b) developed generic BMI habitat criteria that correspond with suitabilities of 0.5 and above [i.e., considered "good" BMI habitat from analyses conducted by Gore et al. (2001) and Taylor et al. (2009)]. These criteria included water depths of 0.3 to 3.1 ft, velocities of 0.2 to 2.3 ft/s, and gravel and cobble substrates (Stillwater Sciences 2011b).

As explained in section 2.4, determinations of river flows at individual cross-sections were dropped from the study due to the problems inherent in trying to accurately measure water velocities in shallow locations. However, water velocities were measured at 111 cross-section points where the water depths were equal to or greater than 0.3 ft deep when the USGS North Fork Gualala River gage measured river discharges of 20, 10 and 6.4 cfs. These velocity data were used to assess whether or not points along riffles with water depths equal to or greater than 0.3 ft had the BMI criteria water velocities of 0.2 to 2.3 ft/s. The data show that 97 (87%) of these points had water velocities within the 0.2 to 2.3 ft/s BMI water velocity criterion. In addition, 11 (12%) of these sites had water velocities between 0.3 and 2.7 ft/sec [within the Gore et al. (2001) and Taylor et al. (2009) criteria], and 2 (1%) had velocities below 0.3 ft/sec. Based upon these data, the assumption was made that any riffle depths equal to or exceeding 0.3 ft would have suitable water velocities for BMI production.

2.6 Age 2+ Steelhead Habitat Assessment

The habitat areas for age 2+ steelhead were assessed under a range of river flows. Preferred habitat for age 2+ steelhead was delineated at four locations using preferred habitat criteria developed by Barnhart (1986), Bjornn and Reiser (1991), and Stillwater Sciences (2010). Preferred habitat for age 2+ steelhead include water velocities in the 1 to 3 ft/s range, water that is 1 to 3 ft deep, head of pool locations, and cover elements such as undercut banks, submerged terrestrial vegetation, or woody debris that provide easy access to feeding lanes. The habitat area delineation was conducted at four pool sites within the study reach at river flows of 9.4, 8.2, 5.3, 4.8, and 3.0 cfs. The sites were all located in pools due to the lack of runs or riffles in the study reach that met the depth criteria.

The locations of age 2+ steelhead habitat areas were determined by:

1. Running a 150-ft-long measuring tape down the middle of the habitat unit,
2. Measuring the distance from the centerline to the left and right (looking downstream) banks,
3. Placing a mark for each bank measurement on a piece of the graph paper at the scaled distance from the centerline,
4. Connecting all the dots to delineate the bank lines of the habitat unit,
5. Taking depth, velocity, and cover measurements to determine the margins of preferred habitat,
6. Placing a habitat edge mark at the scaled distance from the centerline onto the graph paper and connecting the dots to delineate the preferred habitat polygon at the site, and
7. Calculating the area of each polygon using a planimeter.

Error associated with the preferred habitat criteria mapping method was estimated by repeating the delineation of one of the polygons three different times. The differences in area calculations between the three delineations formed the basis for estimating the range of error associated with the methodology.

2.7 Steelhead Fry Edgewater Habitat

Edgewater habitat is typically heavily utilized by newly emergent salmonid fry and to a lesser degree by age 0+ fish. Therefore, edgewater habitats are critical for early life history stages of anadromous fish. The distance between the left and right bank water line at each of the fish passage cross-sections for each discharge (60, 40, 20, 10, 9.4, 8.2, 6.8, 5.3, 4.8, and 3.0 cfs) was calculated. This calculated distance was used to assess how decreasing river flows affected edgewater habitat width within the upstream and downstream reaches. In addition, the distance between the left and right bank lines in the individual age 2+ steelhead habitat area sketches (described above) at 9.4, 8.2, 5.3, 4.8, and 3.0 cfs was used to assess edgewater habitat width reductions in response to decreasing flows.

3 RESULTS

3.1 Habitat Typing

Habitat typing was conducted within the upstream and downstream reaches on the North Fork Gualala River on 13 July 2012. The mean daily river flow at the time of this survey, as measured at the USGS North Fork Gualala River gage, was 9.4 cfs during the habitat typing data collection period. Water temperatures ranged from 15 to 16 degrees Celsius during the survey period.

3.1.1 Upstream reach

A total of 26 individual habitat units were identified and measured within the 2,093-ft long upstream reach. Four of the six Level III habitat types were present within the reach; backwater pools and cascades were not present.

The frequency and lengths of Level III habitat types within the downstream reach are summarized in Table 3-1. Maximum pool depths ranged from 2.6 to 7.0 ft and averaged 4.1 ft. Residual pool depths ranged from 2.2 to 7.0 ft and averaged 3.6 ft.

A lower embeddedness score (a value of 1 equates to <25% embedded with fine sediment) provides the highest quality spawning substrates while a value of 5 represents unsuitable substrate such as bedrock, beaver dam, or logs. Of the pool tail-outs measured, 50% had an embeddedness value of 1 (less than 25% embedded), 30% had an embeddedness value of 2 (25–50% embedded), 10% had a value of 3 (51–75% embedded), and the remaining 10% had a value of 4 (>75% embedded); none had a value of 5 (unsuitable). The pool length-weighted embeddedness value for the reach was 2.1. Good quality spawning habitat was available in most locations.

Instream shelter for salmonids is composed of those elements that can either provide protection from predation (cover components such as undercuts, bubble curtains, terrestrial cover, etc.), reduce water velocities so fish can rest and conserve energy (boulders, wood complexity), and/or allow separation of fish to reduce density-related competition. Standard qualitative shelter values of 0 (none), 1 (low), 2 (medium), or 3 (high) were assigned according to the complexity of the cover. A shelter rating is calculated for each habitat unit by multiplying assigned shelter value with the total percent cover (a quantitative estimate of the percentage of the habitat unit covered was made using an overhead view). Thus, shelter ratings can range from 0 to 300, and are expressed as mean values by habitat types within a stream. A shelter rating of 80 or greater is desirable. The scour pools had an average shelter rating of 96, which indicates good quality instream habitat cover (Table 3-2). Small woody debris was the dominant shelter type within the upstream reach, followed by submerged terrestrial vegetation.

Gravel and sand were the primary dominant substrates observed (Table 3-3). The primary sub-dominant substrate was sand, followed by small cobble (Table 3-4).

The amount of canopy cover over the low flow channel averaged 50%, most of which consisted of deciduous trees (Table 3-5). The right and left banks of the low-flow channel had similar vegetation characteristics.

The Level III habitat type attributes are summarized in Table 3-6. Overall, the wetted portion of the downstream reach had an average width of 17 ft. Instream cover and average percent of low-flow canopy components were 27% and 50%, respectively. This reach was dominated by pool and flatwater habitats, with scour pools being the dominant pool type.

Table 3-1. Frequency and lengths of Level III habitat types in the upstream reach.

Level III habitat types	Number of units	% by occurrence	Sum of length (ft)	% by total length
Riffle	10	38	457	22
Flatwater	6	23	714	34
Main channel pool	1	4	29	1
Scour pool	9	35	893	43
Total	**26**	**100**	**2,093**	**100**

Table 3-2. Average shelter values and composition for Level III habitat types in the upstream reach.

Level III habitat type	# of units	Average shelter value	Average shelter rating	Average shelter composition (% area)[1]								
				% undercut	% SWD	% LWD	% rootwad	% terr. veg.	% aquatic veg.	% bubble curtain	% boulder	% bedrock
Riffle	10	.5	28	4	79	0	0	15	0	3	0	0
Flatwater	6	1.2	39	0	44	4	8	43	0	3	0	0
Main channel pool	1	3.0	75	0	20	0	0	40	0	40	0	0
Scour pool	9	3.3	96	6	26	28	20	17	0	2	0	0

[1]The shelter composition for each habitat type may add up to greater than 100% due to rounding.

Table 3-3. Dominant substrates by habitat type in the upstream reach.

Level III habitat type	Substrate	% of substrate within habitat type	% of substrate by total reach length
Riffle	Gravel	100	22
Flatwater	Gravel	100	34
Main channel pool	Sand	100	1
Scour pool	Gravel	38	16
	Sand	51	22
	Small cobble	11	5

Table 3-4. Sub-dominant substrate by habitat type in the upstream reach.

Level III habitat type	Substrate	% of substrate within habitat type	% of substrate by total reach length
Riffle	Sand	3	1
	Small cobble	97	21
Flatwater	Sand	77	26
	Small cobble	23	8
Main channel pool	Gravel	100	1
Scour pool	Gravel	62	26
	Sand	25	11
	Small cobble	13	6

Table 3-5. Canopy cover and bank vegetation coverage by habitat types in the upstream reach.

Habitat type	# of units	Average % canopy cover	Canopy composition		Average % left bank vegetated	Average % right bank vegetated
			% Hardwood	% Conifer		
Riffle	10	41	97	3	25	29
Flatwater	6	47	100	0	30	44
Main channel pool	1	85	100	0	40	60
Scour pool	9	59	87	13	37	38
Overall	**26**	**50**	**74**	**6**	**31**	**37**

Table 3-6. Summary of measured habitat elements in the upstream reach.

Habitat type	# of units	Total habitat length (ft)	% of total length	Average length (ft)	Average width (ft)	Average depth (ft)	Average maximum depth (ft)	Average depth pool crest (ft)	Average residual pool depth (ft)	Average area (ft²)	Average % instream cover	Average % low flow canopy
Riffle	10	457	22	46	14	0.4	0.7	na	na	631	20	41
Flatwater	6	714	34	119	18	0.7	1.6	na	na	2,162	21	47
Main channel pool	1	29	1	29	16	1.5	2.6	0.4	2.2	464	25	85
Scour pool	9	793	38	99	17	1.7	4.0	0.5	3.4	1,722	32	59
SC scour pool	1	100	5	100	35	4.0	7.0	0.01	7.0	3,500	40	55
Overall	**26**	**2,093**	**100**	**84**	**17**	**1.1**	**2.3**	**0.4**	**3.8**	**1,550**	**27**	**50**

na = not applicable
SC = side channel

3.1.2 Downstream reach

The total length of the habitat typing portion of the downstream reach was 1,321 ft. A total of 20 individual habitat units were identified and measured. Three of the six Level III habitat types (riffle, flatwater and scour pool) were present within the reach; the other three habitat types (main channel pools, backwater pools, and cascades) did not occur.

The frequency and lengths of Level III habitat types within the downstream reach are summarized in Table 3-7. Scour pools were the only pool type within the reach. Maximum pool depths ranged from 2.5 to 6.5 ft and averaged 4.5 ft. Residual pool depths ranged from 1.9 to 5.3 ft and averaged 3.8 ft.

The depth of cobble embeddedness was estimated at pool tail-outs. Of the pool tail-outs measured, 40% had an embeddedness value of 2 (25–50% embedded) and 60% had a value of 4 (>75% embedded). The pool length-weighted embeddedness value for the reach was 3.2, which indicated that spawning habitat quality was in relatively poor condition in most of the survey reach.

A shelter rating was calculated for each habitat type using a scale of 0–300. A shelter rating of 80 or greater is desirable. Riffles, flatwaters, and scour pools had shelter ratings of 0, 50, and 97, respectively (Table 3-8). Woody debris was the dominant shelter type within the downstream reach, followed by undercut banks.

Gravel and sand were the primary dominant substrates observed (Table 3-9). The primary sub-dominant substrates were gravel followed by sand (Table 3-10).

The average percent of canopy cover was relatively high at 69%, most of which consisted of deciduous trees (Table 3-11). The right and left banks of the low-flow channel had similar vegetation characteristics.

The Level III habitat type attributes are summarized in Table 3-12. Overall, the wetted portion of the downstream reach had an average width of 22 ft. Instream cover and average percent low-flow canopy components were 27% and 69%, respectively. Flatwaters were the dominant habitat type.

Table 3-7. Frequency and lengths of Level III habitat types in the downstream reach.

Level III habitat types	# of units	% by occurrence	Sum of length (ft)	% by total length
Riffle	**6**	30	194	15
Flatwater	**5**	45	665	50
Scour pool	**9**	25	462	35
Total	**20**	**100**	**1,321**	**100**

Table 3-8. Average shelter values and composition for Level III habitat types in the downstream reach.

Level III habitat type	# of units	Average shelter value	Average shelter rating	Average shelter composition								
				% undercut	% SWD	% LWD	% rootwad	% terr. veg.	% aquatic veg.	% bubble curtain	% boulder	% bedrock
Riffle	6	0	0	0	0	0	0	0	0	0	0	0
Flatwater	9	1.8	50	29	26	3	16	26	0	0	0	0
Scour pool	5	2.8	97	18	24	21	21	16	0	0	0	0

Table 3-9. Dominant substrate by habitat type in the downstream reach.

Level III habitat type	Substrate	% of substrate within habitat type	% of substrate by total reach length
Riffle	Gravel	100	15
Flatwater	Gravel	68	34
	Sand	32	16
Scour pool	Gravel	24	8
	Sand	76	27

Table 3-10. Sub-dominant substrate by habitat type in the downstream reach.

Level III habitat type	Substrate	% of substrate within habitat type	% of substrate by total reach length
Riffle	Small cobble	100	15
Flatwater	Gravel	32	16
	Sand	63	32
	Small cobble	6	3
Scour pool	Gravel	76	27
	Sand	24	8

Table 3-11. Canopy cover and bank vegetation coverage by habitat types in the downstream reach.

Habitat type	# of units	Average % canopy cover	Canopy composition		Average % left bank vegetated	Average % right bank vegetated
			% Hardwood	% Conifer		
Riffle	6	62	98	2	19	31
Flatwater	9	72	87	13	39	23
Scour pool	5	73	81	19	26	21
Overall	**20**	**69**	**89**	**11**	**28**	**25**

Table 3-12. Summary of measured habitat elements in the downstream reach.

Habitat type	# of units	Total habitat length (ft)	% of total length	Average length (ft)	Average width (ft)	Average depth (ft)	Average maximum depth (ft)	Average depth pool crest (ft)	Average residual pool depth (ft)	Average area (ft²)	Average % instream cover	Average % low flow canopy
Riffle	6	194	15	32	18	0.3	0.5	na	na	590	0	62
Flatwater	9	665	50	74	27	0.8	1.8	na	na	1,979	23	72
Scour pool	5	462	35	92	18	2.2	4.5	0.7	3.8	3,593	34	73
Overall	**20**	**1,321**	**100**	**66**	**22**	**1.0**	**2.3**	**0.7**	**3.8**	**1,966**	**27**	**69**

na = not applicable

3.2 Adult Steelhead Passage

Adult steelhead passage conditions were evaluated at four North Fork Gualala River flows. The study cross-sections were located as depicted in Figure 2-2 and pictured in Appendix A. Cross-section data were collected in the upstream and downstream reaches between 27 April and 4 August 2011.

Conditions were suitable for adult steelhead passage at a river flow of 60 cfs at all but one riffle (Table 3-13). The one riffle that did not pass (D2) at 60 cfs did meet the 10% continuous criteria (Table 3-14). At a river flow of 40 cfs, only one riffle (U2) was considered passable under the Thompson (1972) criteria. At 40 cfs, all of the upstream reach cross-sections achieved the 10% continuous width criterion. At 40 cfs, one of the downstream reach cross-sections met the 10% criterion and two riffles did not meet the passage criteria, as defined by Thompson (1972). At river flows of 20 cfs, none of the cross-sections were considered passable as defined by Thompson (1972). Only one upstream reach cross-section had suitable passage conditions at 10 cfs. None of the other upstream or downstream reach riffles met either the 25% total or 10% continuous width criteria at river flows of 10 cfs.

The sand bar separating the mouth of the Gualala River from the ocean was open and allowing access from the ocean by steelhead when North Fork Gualala River flows were 60 and 40 cfs. This sand bar was closed during the 21 June and 4 August 2011 field efforts when the North Fork Gualala River was flowing at 20 and 10 cfs, respectively, and upstream and downstream adult steelhead migration was likely over by then.

The D2 riffle, which was 66 ft wide, was not considered “passable” under the Thompson (1972) criteria at a river flow of 60 cfs even though it had 14 ft of continuous width that achieved the 0.6 ft depth criteria. Similarly, five cross-sections (U1a, U1b, D1, D1b, and D2) were not “passable” under the Thompson (1972) width criteria when the river flow was 40 cfs; however these cross sections did have migration lanes that were equal to or greater 0.6 ft deep (Table 3-14). Adult steelhead are capable of passing through riffles that have narrow slots of adequate depth. Adult salmonids can also pass riffles with water depths shallower than 0.6 ft (Figure 3-1); however, under such conditions, the adult salmonids come into contact with the substrate, which can result in abrasion that may ultimately affect survivability if the fish need to pass many shallow riffles on the way to spawning areas.

Figure 3-1. Adult Chinook salmon crossing a 0.3-ft deep riffle on the Mad River, Humboldt County in October 2012. Photograph taken by Dennis Halligan, Stillwater Sciences.

Table 3-13. Results of adult fish passage evaluation based on adult passage criteria in Thompson (1972).

Cross-section	Adult passage during discharge as measured at USGS gage			
	60 cfs	**40 cfs**	**20 cfs**	**10 cfs**
U1a	Passable	Not passable [1]	Not passable [1]	Passable
U1[2]	Passable	nd	nd	nd
U1b[3]	nd	Not passable [1]	Not passable	Not passable
U2	Passable	Passable	Not passable	Not passable
D1	Passable	Not passable [1]	Not passable	Not passable
D1b[3]	nd	Not passable	Not passable	Not passable
D2	Not passable [1]	Not passable	Not passable	Not passable

[1] Criteria achieved for percentage of continuous width, but not for percentage of total width.
[2] This cross-section was dropped from the analysis due to lack of riffle development at the 40 cfs flow level.
[3] No 60 cfs data since this cross-section was added to the analysis due to formation of a riffle at 40 cfs.
nd = no data

Table 3-14. Percentage of total and continuous cross-section width passable by adult steelhead in the North Fork Gualala River in 2011.

Cross-section	Flow (cfs)							
	60		**40**		**20**		**10**	
	Total width passable (%)	**Continuous width passable (%)**	**Total width passable (%)**	**Continuous width passable (%)**	**Total width passable (%)**	**Continuous width passable (%)**	**Total width passable (%)**	**Continuous width passable (%)**
U1a	52	52	20	10	18	18	33	33
U1b	nd	nd	10	10	0	0	0	0
U2	86	86	34	34	7	7	0	0
D1	29	29	22	13	5	5	0	0
D1b	nd	nd	7	7	0	0	0	0
D2	21	21	3	3	0	0	0	0
Average	47	47	16	13	5	5	6	6

nd = no data

The relationship between flow and the 25% total and 10% continuous width of the riffles passable to adult steelhead using the Thompson (1972) method is shown in Figures 3-2 and 3-3. These figures indicate that the 25% total passable width is met at 40 cfs and the 10% continuous passable width is achieved at 23 cfs.

Riffle thalweg depths were recorded along each of the downstream and upstream cross-sections and plotted against the target flows as recorded at the USGS North Fork Gualala River gage. Riffles U1b and D2 had the shallowest thalweg depths within the upstream and downstream reaches, respectively. The 0.6 ft depth criterion at the U1b riffle was met at a river flow of about 31 cfs (Figure 3-4), and this criterion is met at a river flow approximately 32 cfs at the D2 riffle (Figure 3-5). Therefore, there is little difference between the upstream and downstream reaches regarding the river flows that are necessary to create completely uninhibited passage conditions for adult steelhead through the riffle thalwegs.

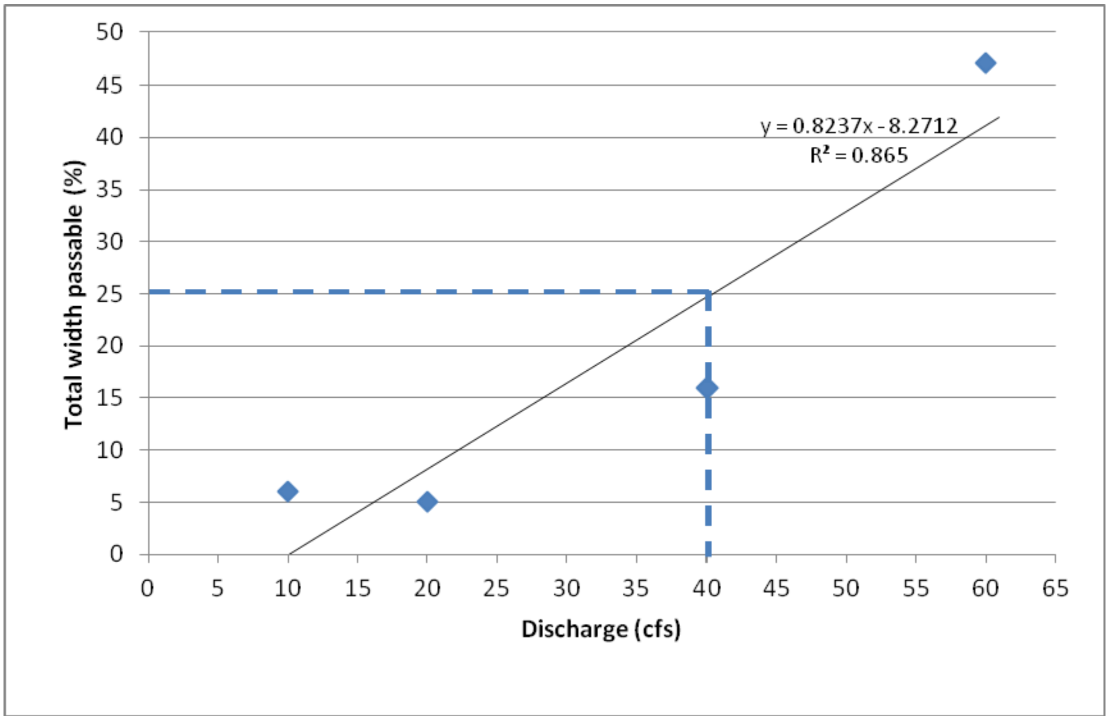

Figure 3-2. Average total usable width (% of total wetted width) for adult steelhead passage as per the Thompson (1972) method.

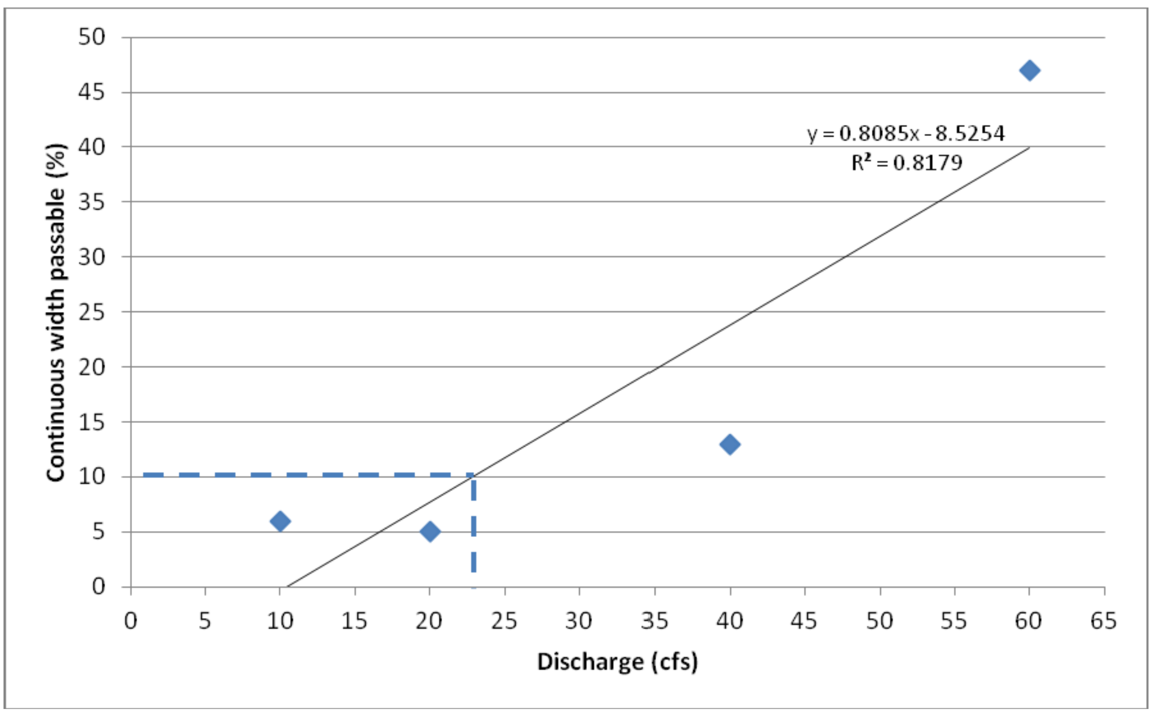

Figure 3-3. Average continuous usable width (% of total wetted width) for adult steelhead passage as per the Thompson (1972) method.

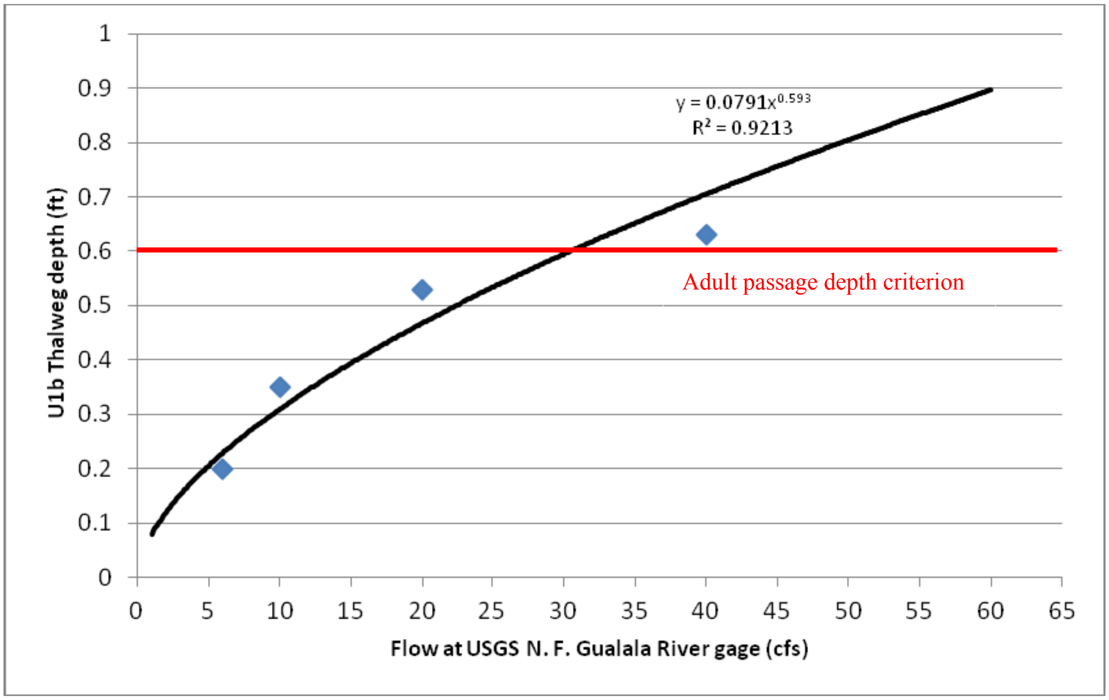

Figure 3-4. Thalweg depth at the upstream reach cross-section Ub1 in the North Fork Gualala River.

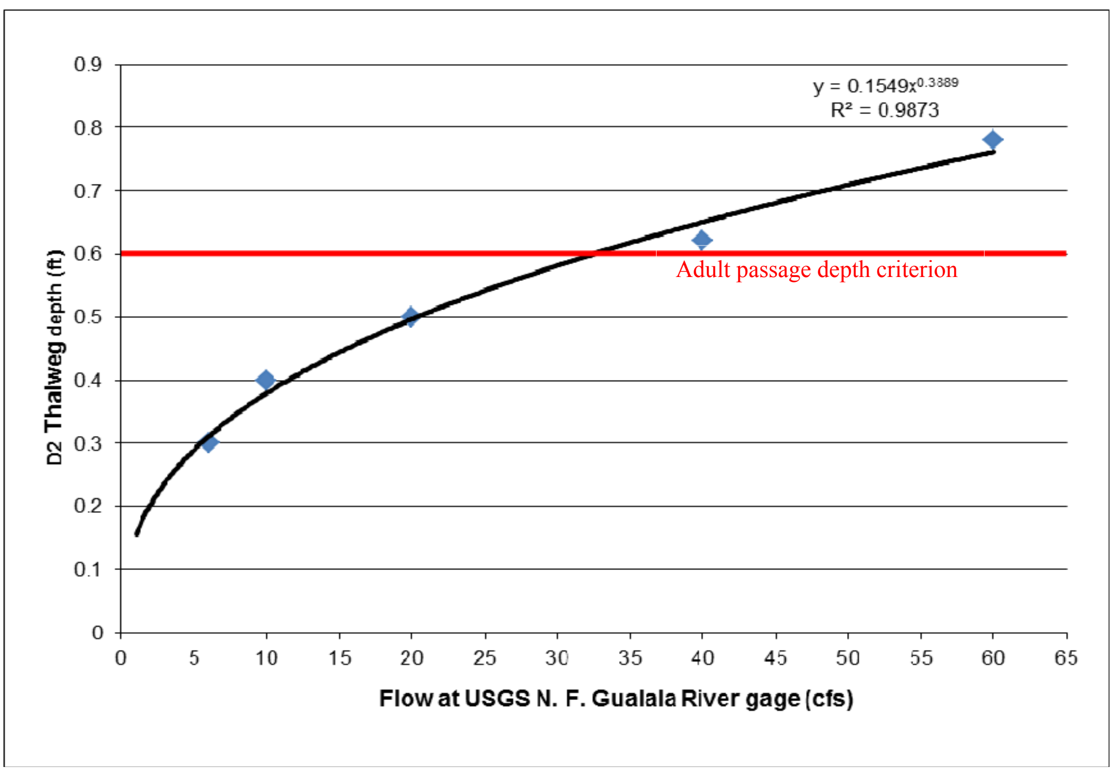

Figure 3-5. Thalweg depth at the downstream reach cross-section D2 in the North Fork Gualala River.

3.3 Juvenile Steelhead Passage

Juvenile steelhead passage conditions in the upstream and downstream reaches were evaluated at five river flows (9.4, 8.2, 5.3, 4.8, and 3.0 cfs), on dates between 12 July and 5 October 2012. The study cross-sections were located as depicted in Figure 2-2 and pictured in Appendix B. Conditions were suitable for juvenile steelhead passage at each of the cross-sections and met at least the 10% continuous width criterion at all of these river flows (Table 3-15).

The relationship between flow and the 25% total and 10% continuous width of the riffles passable to juvenile steelhead using the Thompson (1972) method is shown in Figures 3-6 and 3-7. These figures indicate that the 25% total and 10% passable widths are at approximately 1cfs.

Riffles U1b and D3 had the shallowest depths within the upstream and downstream reaches, respectively (Table 3-16). The riffle thalweg depths at both of these cross-sections were plotted against the river flows measured at the USGS North Fork Gualala River gage. The 0.2 ft depth criterion at the upstream reach U1b riffle would be met at a river flow of about 0.7 cfs (Figure 3-8), and at a river flow of approximately 2.8 cfs at the downstream reach D3 riffle thalweg (Figure 3-9).

Table 3-15. Percentage of total and continuous cross-section width passable by juvenile steelhead in the North Fork Gualala River in 2012.

Cross-section	Flow (cfs)									
	9.4		8.2		5.3		4.8		3.0	
	Total width passable (%)	Continuous width passable (%)	Total width passable (%)	Continuous width passable (%)	Total width passable (%)	Continuous width passable (%)	Total width passable (%)	Continuous width passable (%)	Total width passable (%)	Continuous width passable (%)
U1b	45	45	40	40	36	27	39	29	21	10
U3	77	77	81	81	61	36	51	38	50	25
U4	73	73	89	89	73	73	62	62	47	47
D1	78	78	83	83	72	72	58	58	43	43
D2	46	46	43	43	37	20	32	18	41	27
D3	63	63	56	56	37	37	30	30	36	36
Average	61	61	65	65	53	44	45	39	40	31

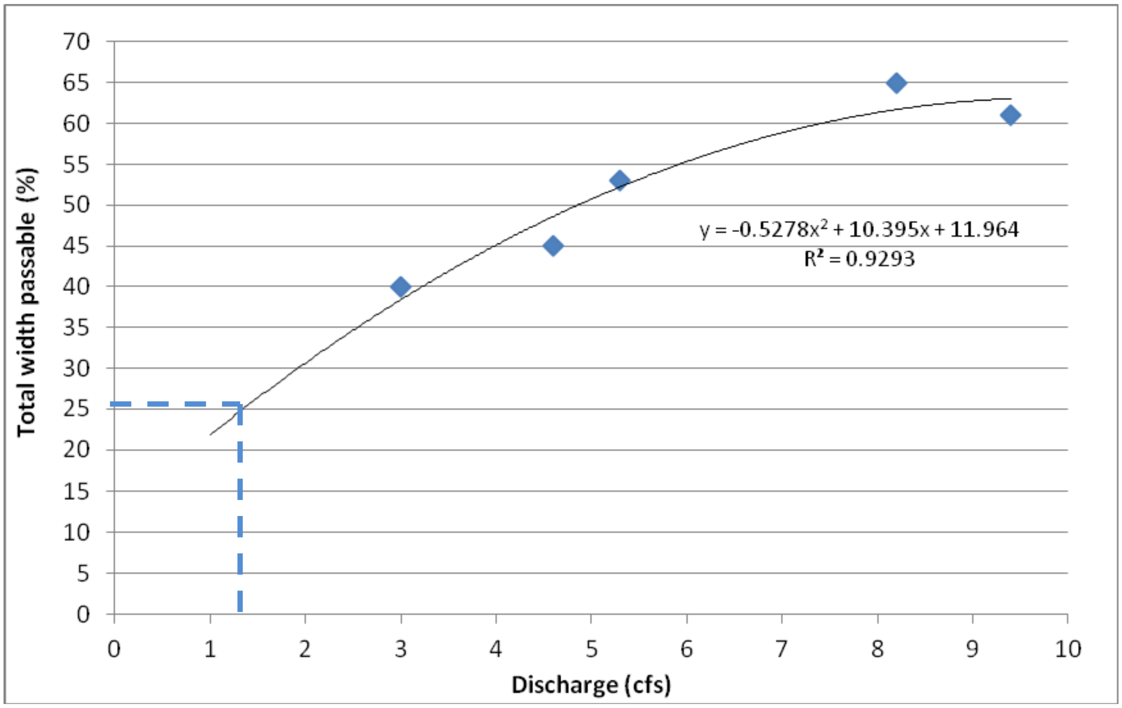

Figure 3-6. Average total usable width (% of total wetted width) for juvenile steelhead passage as per the Thompson (1972) method.

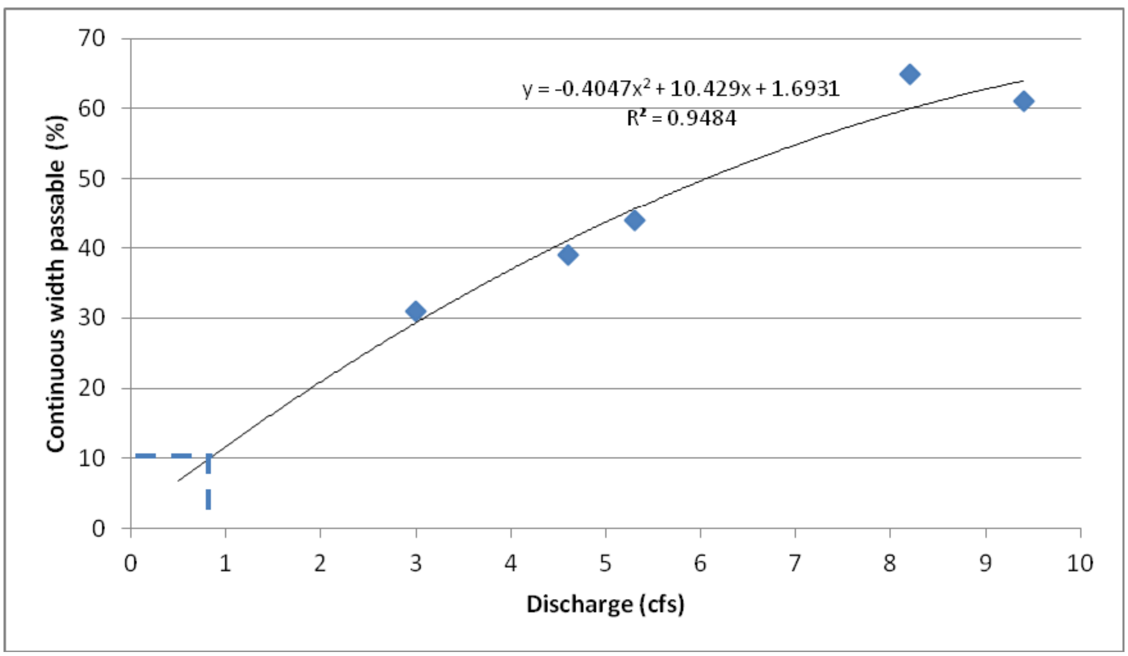

Figure 3-7. Average continuous usable width (% of total wetted width) for juvenile steelhead passage as per the Thompson (1972) method.

Table 3-16. Riffle thalweg depths at the juvenile fish passage cross-sections in the North Fork Gualala River in 2012.

Cross-section	Riffle thalweg depth (ft)				
	9.4 cfs	**8.2 cfs**	**5.3 cfs**	**4.8 cfs**	**3.0 cfs**
U1b	0.45	0.45	0.38	0.38	0.32
U3	0.4	0.35	0.35	0.3	0.24
U4	0.6	0.55	0.38	0.38	0.33
D1	0.55	0.55	0.38	0.38	0.29
D2	0.45	0.44	0.34	0.3	0.31
D3	0.45	0.4	0.24	0.26	0.23

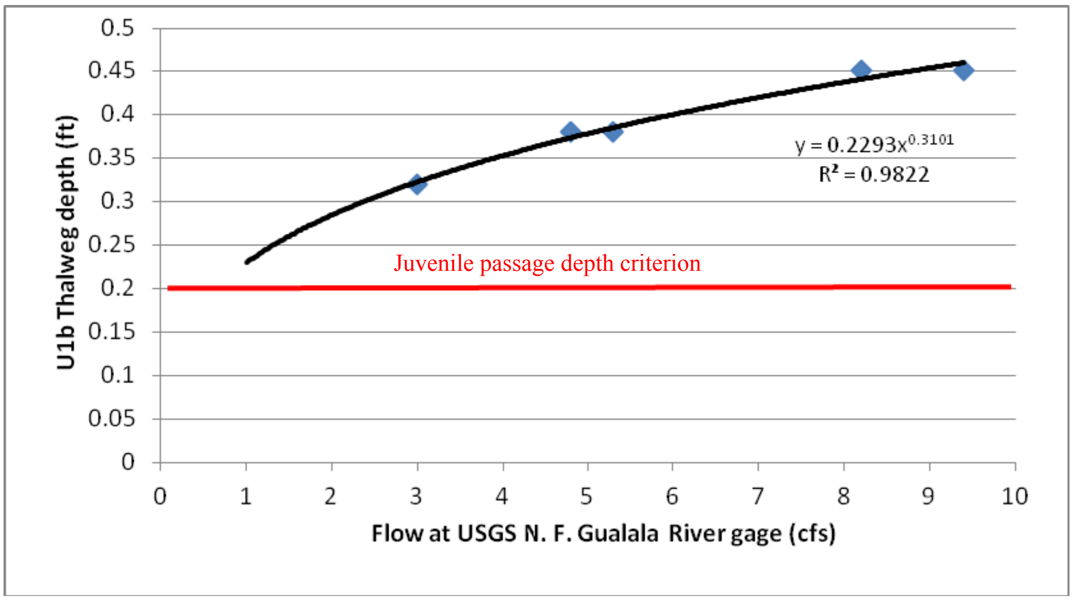

Figure 3-8. Thalweg depth at the upstream reach cross-section U1b in the North Fork Gualala River.

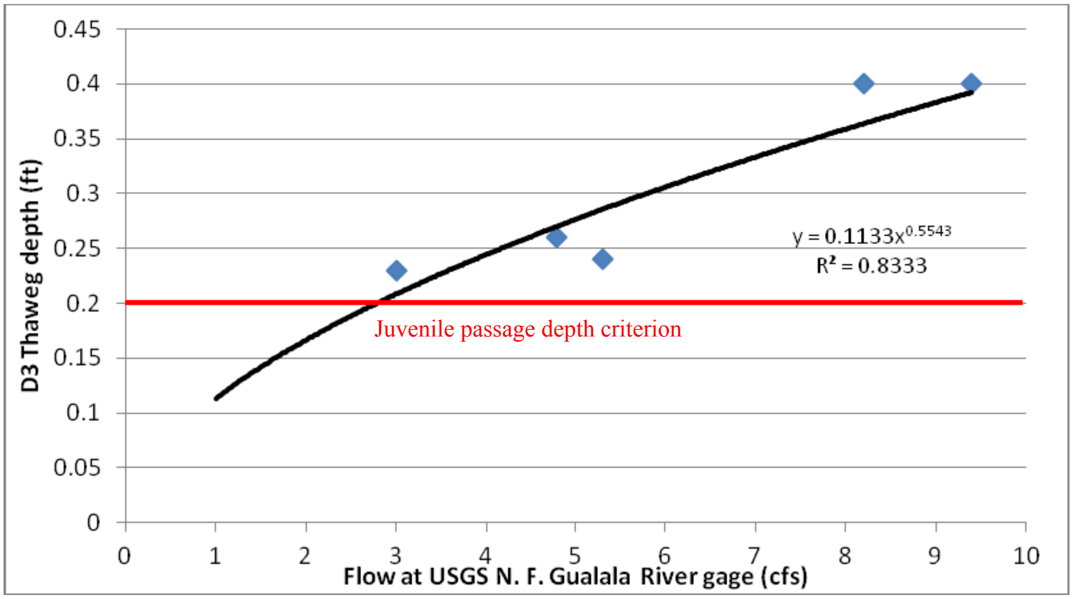

Figure 3-9. Thalweg depth at the downstream reach cross-section D3 in the North Fork Gualala River.

3.4 Benthic Macroinvertebrates

BMI assessment data were collected during the juvenile passage field effort. The data showed that riffle area and preferred BMI habitat availability decreased as flows declined during the summer and fall months. In some cases, the percentage of a cross-section that met the BMI criteria dropped to 0 at a river flow of 3 cfs (Table 3-17). Riffle area in the upstream and downstream reaches decreased by an average of 41 and 27 percent, respectively, as the river flow decreased from 9.4 to 3.0 cfs. However, even though the 0.3 ft depth criterion was not met at the lower river flows, BMI production did not actually stop. Mayfly larvae were observed under cobbles in shallow edgewaters. In addition, juvenile steelhead were consistently observed actively feeding at 3 cfs in the pools downstream of the upstream and downstream cross-sections.

Table 3-17. Riffle area and percentage of upstream and downstream cross-sections meeting the BMI criteria in the North fork Gualala River study reach.

Cross-section	Flow (cfs)									
	9.4		8.2		5.3		4.8		3.0	
	Riffle area (ft²)	% meeting BMI depth criteria	Riffle area (ft²)	% meeting BMI depth criteria	Riffle area (ft²)	% meeting BMI depth criteria	Riffle area (ft²)	% meeting BMI depth criteria	Riffle area (ft²)	% meeting BMI depth criteria
U1b	345	28	340	9	249	9	165	5	133	10
U3	203	66	187	58	212	24	193	13	173	0
U4	344	45	341	36	202	27	286	35	188	17
D1	247	75	255	66	224	16	218	17	214	0
D2	1,620	12	1,587	6	1,564	3	1,083	3	1,046	3
D3	393	47	368	40	327	0	325	0	259	0

3.5 Age 2+ Steelhead Habitat

Age 2+ steelhead habitat was delineated at four locations during the 2012 juvenile fish passage flow evaluations (Figure 2-1, Appendices B and C). All of the habitat units (HU) were located in pools immediately downstream of riffles.

A three-pass calibration of the delineation protocol was conducted on 4 August 2011 at the 10 cfs river flow, as measured at the USGS North Fork Gualala River gage. The purpose of the calibration was to determine the potential range of error in the steelhead habitat polygon delineation. The calibration was conducted in the pool that was downstream of cross-section U1a. The three polygons of the same habitat unit measured 90, 91, and 96 ft^2. The error range for the calibration was about ±3 percent.

Age 2+ steelhead habitat areas were delineated in two upstream (HU #U3 and HU#U4) and two downstream (HU# D1 and HU#D2) locations. The reduction in river flow from 9.4 to 3.0 cfs during the study period represented a 68% decrease in flow. In general, both the upstream and downstream units showed decreases in habitat area as the river flows dropped (Table 3-18). HU# D2 experienced the most dramatic decrease in habitat area; however, this unit was almost devoid of instream cover elements and the delineation was based on depth and velocity criteria alone. The presence of cover elements (undercut bank, submerged terrestrial vegetation, and rootmass) minimized the loss of suitable habitat area in HU# D1, U3, and U4, even though flows continued to decrease.

Table 3-18. Age 2+ steelhead habitat area at four locations within the North Fork Gualala River in 2012.

Habitat unit	Age 2+ habitat area (ft²)					Percentage decrease from 9.4 to 3.0 cfs
	9.4 cfs	8.2 cfs	5.3 cfs	4.8 cfs	3.0 cfs	
U3	103	116	82	96	94	9
U4	148	124	128	90	114	23
D1	376	392	298	267	247	34
D2	61	50	24	21	23	62

3.6 Steelhead Fry Edgewater Habitat

Differences in edgewater habitat availability for steelhead fry at various river flows were assessed by calculating the changes in the wetted channel width at the adult and juvenile fish passage cross-sections and age 2+ steelhead habitat locations.

In general, riffle cross-section wetted widths decreased as river flows dropped from 60 to 6.4 cfs in 2011, and from 9.4 to 3 cfs in 2012 (Tables 3-19 and 3-20). In 2011, the upstream reach cross-sections averaged a 56% decrease in wetted channel width as flows dropped while the cross-sections in the downstream reach narrowed by an average of 24%. As river flows dropped in 2012, the wetted channel width at the cross-sections decreased by an average of 26% and 28% within the upstream and downstream reaches, respectively.

Table 3-19. Riffle cross-section widths within the North Fork Gualala River study reach in 2011.

Cross-section	Riffle cross-section wetted width (ft)				
	60 cfs	40 cfs	20 cfs	10 cfs	6.4 cfs
U1a	88.2	80	66	24.3	10.5
U1b	nd	39.7	38	36.8	19.3
U2	30.1	29.3	27.5	26.5	21.7
D1	47.8	46.1	42	41.4	40.6
D1b	nd	59	44	42.7	41.3
D2	66.4	66	52	52.6	49.3

Table 3-20. Riffle cross-section widths within the North Fork Gualala River study reach in 2012.

Cross-section	Riffle cross-section wetted width (ft)				
	9.4 cfs	8.2 cfs	5.3 cfs	4.8 cfs	3.0 cfs
U1b	35	39	23	21	19
U3	18	17	17	16	16
U4	16	14	14	13	13
D1	16	15	13	12	12
D2	58	58	60	56	44
D3	25	25	22	20	17

The wetted channel widths at the age 2+ steelhead habitat locations showed relatively small, but consistent, narrowing as river flows decreased (Table 3-21). The two upstream reach units lost an average of 11% of their wetted width while the downstream reach habitat units narrowed by an average of 13%. River flows decreased by 68% during this period.

Table 3-21. Changes in wetted widths at age 2+ habitat locations at decreasing flows.

Habitat unit	Age 2+ steelhead habitat wetted width (ft)				
	9.4 cfs	8.2 cfs	5.3 cfs	4.8 cfs	3.0 cfs
U3	19	18	17	16	16
U4	17	17	17	16	16
D1	16	16	15	15	15
D2	25	24	23	22	20

4 DISCUSSION

4.1 Habitat Typing

The pool:riffle:flatwater percentages by channel length in the upstream and downstream reaches were 44:22:34 and 35:15:50, respectively, at a river flow of 9.4 cfs. The channel in the upstream reach is more confined and narrower than the channel in the downstream reach, which may have played a role in the difference in pool habitat. Channel-forming processes occur during high flow periods and would not be affected by the NGWC's pumping of Production Wells 4 and 5.

Average wetted width of riffles in the upstream reach was about 4 ft narrower than the average for the downstream reach. Therefore, one would expect that the same river flow would result in deeper riffles in the upstream reach than in the downstream reach, which is what was observed. The average depths in the upstream and downstream reach riffles were 0.4 and 0.3 ft, respectively, while the average maximum depths were 0.7 and 0.5 ft.

4.2 Adult and Juvenile Steelhead Passage

4.2.1 Thompson method

The Thompson (1972) protocol provides an assessment technique and specific criteria that must be met in order for the protocol to reach the conclusion that riffles are passable for migrating salmonids. However, the criteria in this protocol are very conservative in relation to fish size criteria, do not realistically reflect steelhead migration abilities, and do not consider channel morphology. Because of these deficiencies, the Thompson protocol often leads to inconsistent determinations of which riffles are passable and which riffles are not passable.

The Thompson depth criterion [0.6 ft (7.2 inches)] is based on providing uninhibited passage for the largest steelhead. Based on steelhead fork-length-to-body-depth data collected at Warm Springs Hatchery on the Russian River during late 2010 to early 2011 (F. Bajjaliya and R. Titus, CDFG, unpublished data), a fish with a body depth of 7 inches would be about 34 inches long. Out of the 241 fish recorded at the Warm Springs Hatchery, only one fish had a body depth greater than 7 inches. Similarly, DeHaven (2010, 2009, 2008) collected length data for over 2,290 adult steelhead in the Wheatfield Fork Gualala River. Of these, only five fish were greater than 34 inches in length.

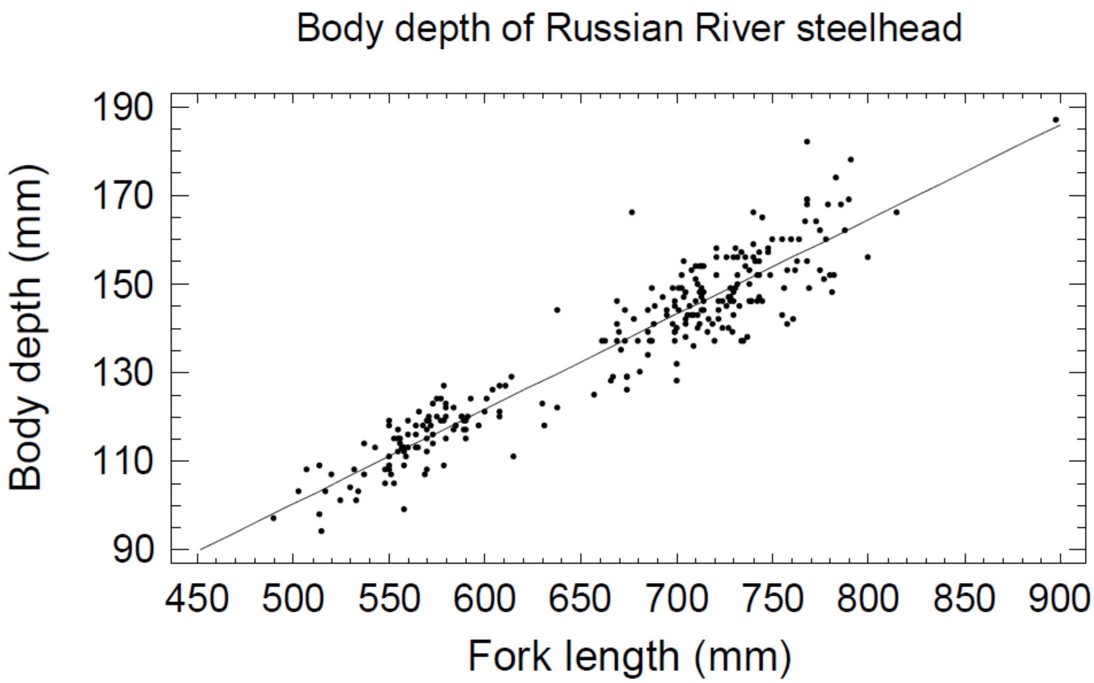

Figure 4-1. Body depth as a function of fork length from Russian River steelhead sampled at Warm Springs Hatchery during late 2010 and early 2011 (F. Bajjaliya and R. Titus, CDFG, unpubl. data).

Anadromous fish have an inherent ability to identify the upstream migration path through a riffle that has the greatest depth and velocity during low-flow periods. Hundreds of field observations made over 20 years have shown that adult salmonids are capable of finding and migrating upstream through relatively narrow thalwegs (D. Halligan, Senior Fisheries Biologist, Stillwater Sciences, field observations, 1992–2012). An adult salmonid that has a body width of 0.5 ft migrating through a 30-ft wide riffle with suitable depth does not require the 10% continuous (3 ft) or 25% total (7.5 ft) width in order to pass. If an adult salmonid was not able to pass through the <10% continuous (<3 ft) or <25% total (<7.5 ft) width of a 30-ft wide riffle, then it would not be able to enter or spawn in a tributary stream that is 10 ft wide where the 10% continuous riffle migration path having suitable depth is only 1ft wide. However, steelhead do in fact heavily utilize small tributary streams that have wetted widths of 10 ft or less.

The Thompson (1972) 10/25% width criteria do not take riffle morphology into account when assigning a "passable/not passable" determination. For example, a 40-foot-wide riffle would be considered not passable if it has less than 4 ft of continuous width and less than 10 ft of its total width at least 0.6 ft deep. However, a 20-foot-wide riffle would be considered passable if it has at least 2 ft continuous width and 5 ft total width at least 0.6 ft deep. These criteria therefore indicate that a fish would not be able to pass the 40-foot-wide riffle, but would be able to pass through the 20-foot-wide riffle, even though the 20-foot riffle's migration lane is half the width of the migration lane in the 40-foot wide riffle. The present study's results demonstrate this basic problem. Specifically, both cross-sections U1b and D1b had 4-foot-wide migration avenues at 40 cfs, but D1b was not considered passable under the Thompson criteria.

The decrease in the percentage of the riffle that is determined to be "passable" or "not passable" by the Thompson (1972) method does not necessarily follow proportionally with increasing or decreasing river flows. For example, cross-section U1a (adult passage) showed an increase in the percentage of the riffle width that was passable as river flows decreased (Table 3-14). This was due to the shallow margins going dry as flows decreased, which reduced the wetted width of the riffle yet retained the deepest portions, and thus increased the proportion of the remaining wetted width that passed. This type of result occurred for five of the six juvenile passage cross-sections (Table 3-15).

4.2.2 Adult steelhead migration behavior

Thompson (1972) stated that the purpose of the adult passage methodology was to make flow recommendations that provide adequate water for physical movement through most critical reaches and on upstream to spawning areas, but "not provide flows generally believed necessary to induce migration." As any steelhead angler along the North Coast knows, the best fishing in small coastal rivers occurs during and following flow runoff conditions that exceed winter baseflow levels, if turbidity conditions are suitable. These elevated flow periods are when fish enter the river systems from the ocean and when they are actively moving upstream and distributing themselves within the watershed. During low-flow periods, fish that are currently in the river typically hold in suitable pools (with cover) and do not migrate, even if the riffle immediately upstream of the holding pool has adequate water depth.

Richard DeHaven, a retired U.S. Fish and Wildlife Service biologist, observed steelhead migration timing patterns in the Wheatfield Fork Gualala River for 10 years while conducting spawning surveys. He found that steelhead tend to "go with the flow" and their migration movements corresponded to the rising and descending limbs of high runoff hydrographs. DeHaven (2007) estimated that adult steelhead in the Wheatfield Fork migrate through the spawning survey index reach (upstream and downstream) at an average rate of 6.2 miles per day. DeHaven (2008) reported that upstream migration ceased when river flows exceeded 3,000 cfs. DeHaven (2008) also observed that adult steelhead begin to stack up in holding pools when the Wheatfield Fork Gualala River flows dropped to about 150 cfs, and that upstream migration ceased at river flows of 75 cfs. Adult steelhead began moving again in response to the next upturn in the hydrograph.

The North Fork Gualala River watershed encompasses approximately 30,560 acres and is about 43% the size of the Wheatfield Fork watershed. Although the Wheatfield Fork migration and holding flow triggers are likely different than those experienced in the North Fork, the behavioral responses of adult steelhead to hydrological conditions are likely similar; that is, in both rivers, steelhead hold during high-flow and low-flow conditions.

The sandbar at the Gualala River mouth opens and closes depending on tidal and wave action and river flow. During the course of the adult passage data collection effort, the mouth of the river was open to the ocean when North Fork Gualala River flows were 60 and 40 cfs, and the mouth closed when these river flows were 20 and 10 cfs. It is assumed that adult steelhead are able to enter the Gualala River during the periods when the river mouth was open, and presumably they move fairly rapidly upstream, unless they hold as suggested by DeHaven (2008). The upstream point of the North Fork Gualala River downstream reach is located approximately 4.6 miles upstream of the sand bar at the mouth of the Gualala River. Given that 3 miles of this distance is in the mainstem Gualala River, which has very good conditions for upstream migration (deep pools), it is reasonable to assume that an adult steelhead would be able to travel those 4.6 miles in a single day.

The adult steelhead migration season may be more appropriately viewed as a series of migration opportunities based on storm hydrographs and not so much as a several months long continuum. Therefore, bypass flow requirements may be able to be tailored to individual runoff hydrographs that facilitate adult steelhead movement, rather than a single minimum bypass flow requirement for the entire season, which has little relationship to migration behavior.

4.2.3 USGS gage as fish passage monitoring point

The riffle thalweg depth-to-flow relationships in the upstream and downstream riffles mirrored the river stage-to-discharge relationship at the USGS North Fork Gualala River gage. As river flows dropped from 60 cfs to 40 cfs, the river stage at the USGS gage dropped 0.12 ft, while the D2 cross-section stage dropped 0.16 ft (Table 4-1). In addition, the values for stages at the USGS gage were similar (differences of ≤ 0.05 ft) to the thalweg depths at cross-sections D2 and U1b, which suggests that monitoring the USGS stage data may be useful for assessing fish passage conditions. For example, if a minimum stage of 0.6 ft. at the USGS gage were set as an adult passage target, then a river flow of 31 cfs at the gage would be very close to river flow needed to meet the adult passage depth criteria at the upstream cross-sections (Figure 4-2).

Table 4-1. Comparison of stage at the USGS North Fork Gualala River gage with selected study cross-section thalweg depths during June through August 2011.

USGS gage flow (cfs)	USGS gage stage (ft)	Cross-section U1b thalweg depth (ft)	Cross-section D2 thalweg depth (ft)
60	0.78	Nd	0.78
40	0.66	0.63	0.62
20	0.51	0.53	0.50
10	0.40	0.35	0.40

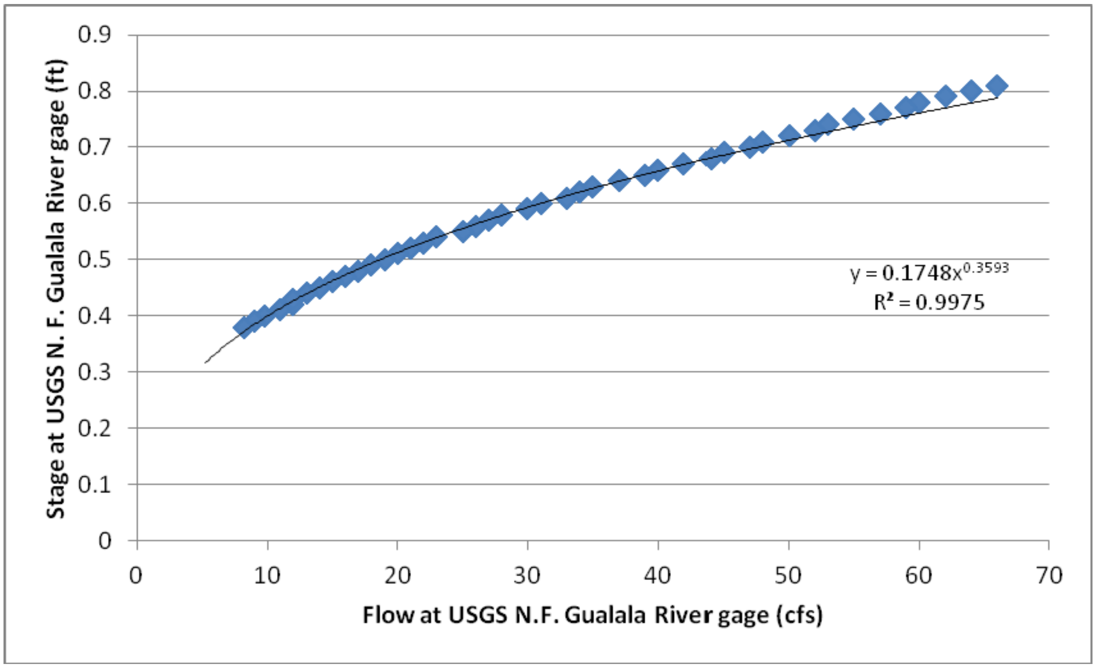

Figure 4-2. USGS North Fork Gualala River gage stage/discharge data for 3 June to 8 August 2011.

The gage stages and riffle thalweg depths for juvenile passage at the U1b and D2 cross-sections also track reasonably well (Table 4-2). However, this relationship did not hold up as well for two other cross-sections, where thalweg depths were 0.12 ft shallower than depths at the gage at a river flow of 3 cfs (Table 3-16). If the USGS gage stage is to be used for monitoring juvenile passage potential, then it is recommended that the target stage be set at 0.3 ft, which will allow for difference between the observed gage stage and thalweg depths. That would allow for a conservative juvenile steelhead-based bypass flow of about 2 cfs at the gage.

Table 4-2. Comparison of stage at the USGS North Fork Gualala River gage with selected study cross-section thalweg depths during June through August 2011.

USGS gage flow (cfs)	USGS gage stage (ft)	Cross-section U1b thalweg depth (ft)	Cross-section D2 thalweg depth (ft)
9.4	0.46	0.45	0.45
8.2	0.44	0.45	0.44
5.3	0.40	0.38	0.34
4.8	0.39	0.38	0.30
3.0	0.35	0.32	0.31

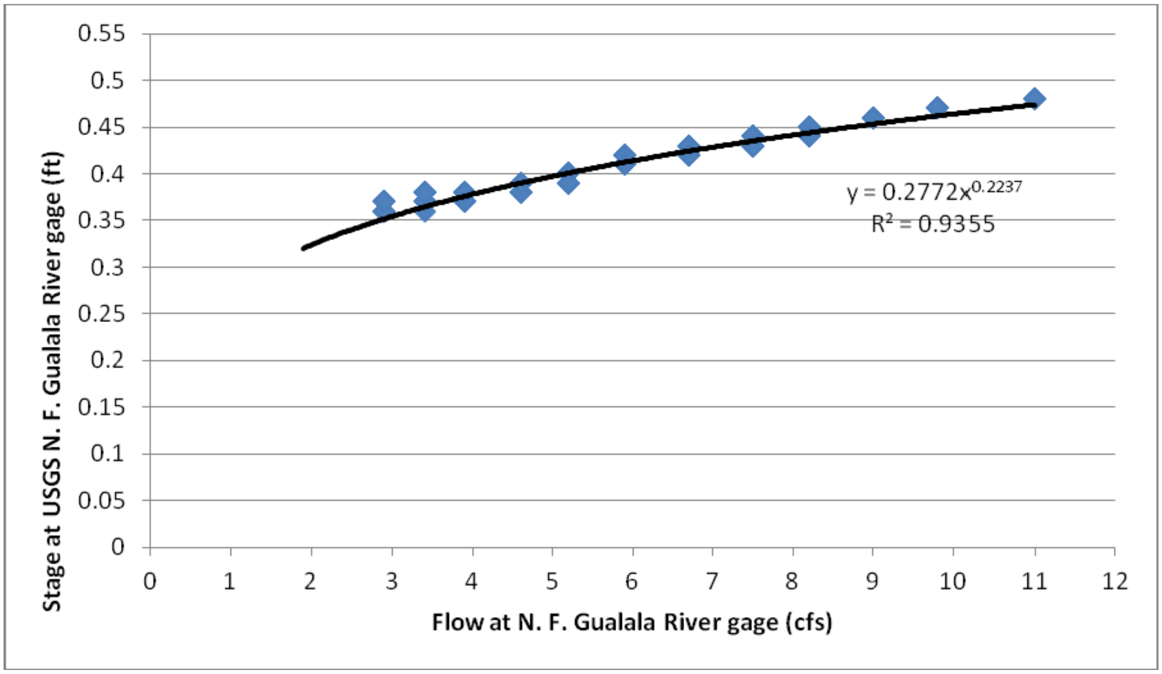

Figure 4-3. USGS North Fork Gualala River gage stage/discharge data for 20 July to 7 October 2012.

4.3 Benthic Macroinvertebrates

The data show that riffle area and preferred BMI habitat availability decrease as river flows decline during the summer and fall months. However, preferred BMI criteria do not include other important habitat features that contribute to salmonid food resource production. For example, submerged aquatic and terrestrial vegetation are BMI production sites and provide food resources for juvenile salmonids. Insect drop from riparian vegetation is also an important food resource. In addition, BMI drift continues even though the preferred depth and velocity criteria might not be met.

Stillwater Sciences (2009) measured BMI drift rates during 8–11 October 2008 in the upstream and downstream reaches of the North Fork Gualala River. River flows during the time of the field work for the Stillwater Sciences (2009) study were measured between 1.4 and 3.9 cfs (Table 4-3). Reported BMI drift rates ranged from 21 to 93 mg/hr with a density of between 0.234 and 0.741 mg/m^3 (Table 4-4).

Table 4-3. Discharge measured in upstream and downstream reaches, fall 2008 (Stillwater Sciences 2009).

Pumping (No/Yes)	Date	Upstream reach discharge (cfs)	Downstream reach discharge (cfs)
No	8 October	2.9	3.9
Yes	9 October	1.4	3.0
No	10 October	2.5	3.5
Yes	11 October	2.3	3.3

Table 4-4. Abundance, biomass, and density of invertebrate drift, fall 2008 (Stillwater Sciences 2009).

Pumping (No/Yes)	Date	Upstream		Downstream	
		Rate (mg/hr)	Density (mg/m^3)	Rate (mg/hr)	Density (mg/m^3)
No	8 October	93	0.739	43	0.425
Yes	9 October	32	0.346	60	0.741
No	10 October	58	0.597	21	0.234
Yes	11 October	33	0.409	34	0.396

4.4 Age 2+ Steelhead Habitat

The most dramatic reduction in Age 2+ steelhead habitat area occurred at the HU#D2 location, which was relatively devoid of instream cover. The 62% loss in habitat area at this site mirrored the 68% reduction in river flow during the study period. The presence of cover elements (undercut bank, submerged terrestrial vegetation, and rootmass) in units HU#D1, HU#U3, and HU#U4 minimized the loss of suitable habitat area even though river flows continued to decrease. This highlights the importance of instream cover for rearing salmonids during the summer and fall low-flow period.

4.5 Steelhead Fry Edgewater Habitat

It can be expected that locations experiencing greater degrees of narrowing in wetted widths as river flows decrease are likely to be those that provide a larger amount of potential edgewater habitat than locations experiencing less narrowing. This is because areas experiencing larger losses in wetted widths as river flows decrease are the areas with low bank slopes. The low bank slopes allow very shallow water to cover greater surface area for a given flow or stage. As flows decrease, the area of very shallow water coverage decreases at a greater rate than in areas with steeper bank slopes.

Riffles tend to provide greater quantity and better quality edgewater habitat than pools. This is because riffles are typically located at depositional meander cross-over areas while pools are subject to scour. Thus, riffles tend to have relatively gentle bank slopes while pool slopes are steeper. In addition, the substrate in riffles and adjacent banks is composed of gravel and small cobble, which can provide the interstitial cover and velocity breaks needed by fry. In contrast, substrate along pool margins tends to be composed of gravel and sand, which do not have interstitial cover or water velocity breaks.

Riffles lost an average of 27% of their wetted width as river flows dropped during the summer and fall of 2012, while the age 2+ steelhead habitat pools lost an average of 12% during this same period. Data at the adult fish passage cross-sections were collected between 27 April and 21 June 2011, while river flows ranged from 60 to 20 cfs. During the spring of 2011, the upstream and downstream cross-sections lost an average of 13% and 20% of their width, respectively, as river flows declined.

It can be argued that the greatest potential for impacts to steelhead fry associated with the loss of edgewater habitat would occur during the spring and early summer. This is because the spring and early summer are when fry emergence occurs, they are actively utilizing the edgewater areas, and flows are relatively high. The loss of edgewater habitat during the late summer and fall has a lesser impact because by that time the fish have grown larger and mostly inhabit deeper and faster water.

5 SUMMARY

The purpose of this study was to help inform the State Board's decision-making process for NGWC's Application 31792 and the petitions for extension of time for Permit 14853. The data collected and information developed during the course of this study will assist in the development of bypass flow criteria that are protective of fishery resources in the North Fork Gualala River.

The principal findings of this study are as follows:

- The compositions and frequencies of habitat types in the upstream and downstream reaches were similar. Approximately 39% of the mainstem channel length in the upstream reach was made up of pools while 35% of the downstream reach was made up of pools.
- Average wetted widths of riffles were about 4 ft narrower in the upstream reach than in the downstream reach, and this difference likely contributed to upstream reach riffles being deeper than downstream reach riffles.
- The Thompson (1972) 10% continuous and 25% total riffle width criteria for adult steelhead passage are met at river flows of about 23 and 40 cfs, respectively.
- The Thompson (1972) 10% continuous and 25% total riffle width criteria for juvenile steelhead passage are met at river flows of about 1 cfs.
- The limitations of the Thompson (1972) method should be taken into consideration when establishing bypass flow criteria.
- Bypass flow requirements may be able to be tailored to individual runoff hydrographs that facilitate adult steelhead movement, rather than having a single static bypass flow requirement that has little relationship to migration behavior.
- The USGS North Fork Gualala River gage data appear to be suitable for monitoring riffle depths and fish passage potential at upstream riffles.
- Preferred BMI habitat availability decreases as flows decline during the summer and fall months, but juvenile steelhead food production and drift continue to occur.
- Age 2+ steelhead rearing habitat abundance decreases as flows drop during the summer and fall, but the effect is minimized by the presence of instream cover.
- Edgewater habitat area decreases as flows drop through the spring and fall months. However, edgewater habitat is more important during the spring and early summer when fry emergence occurs, fry are actively utilizing the edgewater areas, and flows are relatively high.

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Appendices

Appendix A

2011 Adult Steelhead Passage Cross-sections at 20 cfs

Cross-section D2, located downstream of the U.S.G.S. North Fork Gualala River gage, at 20 cfs. Photograph taken on 21 June 2011.

Cross-section D1b at 20 cfs. Photograph taken on 21 June 2011.

Cross-section D1 at 20 cfs. Photograph taken on 21 June 2011.

Cross-section U1 at 20 cfs. Photograph taken on 12 June 2011.

Cross-section U1b at 20 cfs. Photograph taken on 21 June 2011.

Cross-section U1a at 20 cfs. Photograph taken on 21 June 2011.

Appendix B

2012 Juvenile Steelhead Passage Cross-sections and Age 2+ Steelhead Habitat Units at 3 cfs

Cross-section D2 at 3 cfs downstream of the U.S.G.S. North Fork Gualala River gage. Photograph taken on 5 October 2012.

Cross-section D1 and age 2+ steelhead habitat unit #D1 at 3 cfs. The rootmass along the left bank was undercut up to 4 feet deep. Photograph taken on 5 October 2012.

Cross-section D3 at 3 cfs. Photograph taken on 5 October 2012.

Cross-section U3 at 3 cfs. Photograph taken on 5 October 2012.

Cross-section U4 at 3 cfs. Photograph taken on 5 October 2012.

Cross-section U1b and age 2+ steelhead habitat unit #U4 at 3 cfs. Rootmass and overhanging vegetation provided cover elements. Photograph taken on 5 October 2012.

Age 2+ steelhead habitat unit #D2 at 3 cfs. The rootmass along the left bank was not undercut. Photograph taken on 5 October 2012.

Age 2+ steelhead habitat unit #U4 at 3 cfs. Cover provided by bubble curtain, bedrock shelves, and small woody debris. Photograph taken on 5 October 2012.

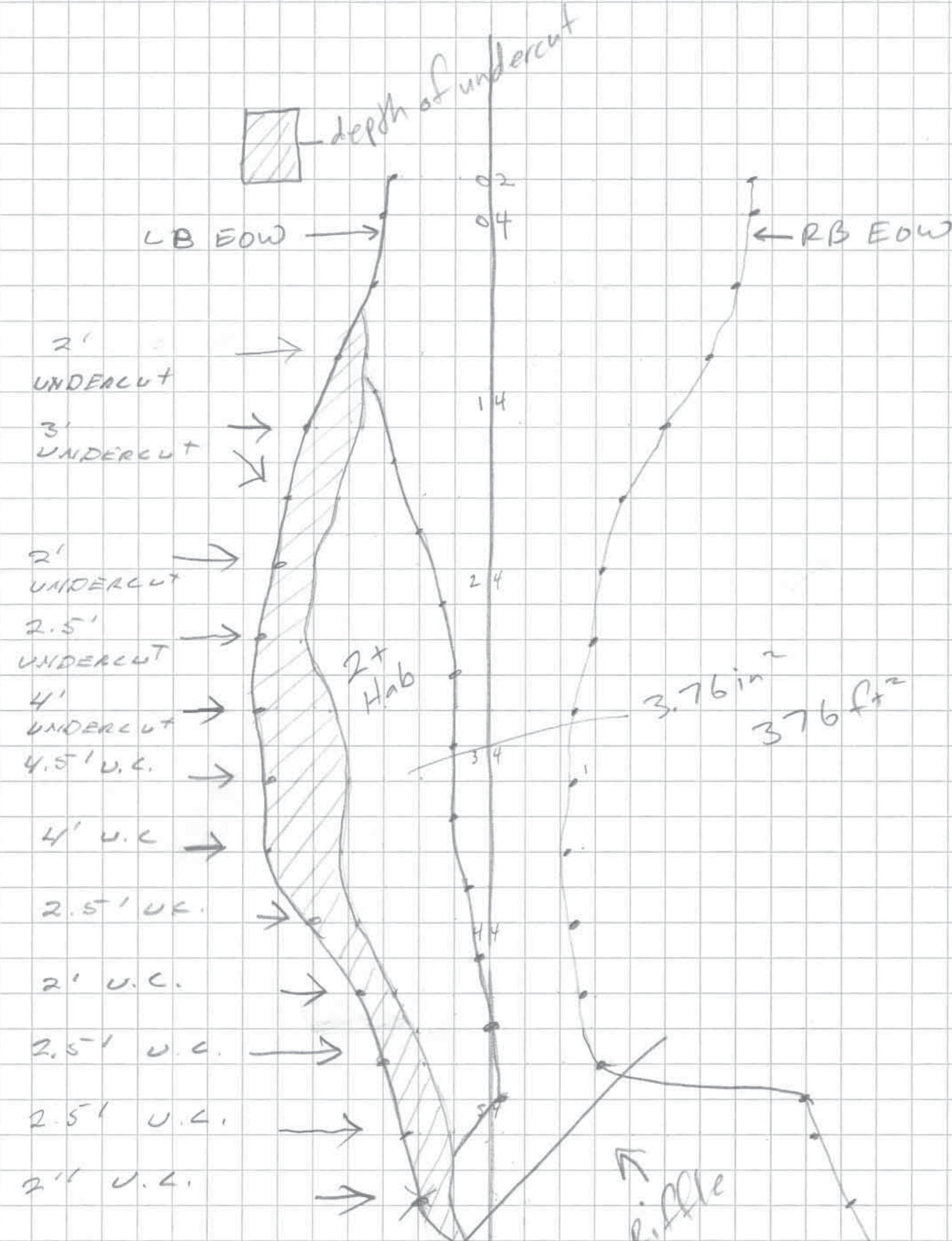
Appendix C

Age 2+ Steelhead Habitat Delineation Sheets

7-12-12 NGWC N.F. Gualala
2+ Steelhead habitat
scale 1 sq = 2 ft. 9.4 cfs

downstream pool from D-1

Habitat unit # D1

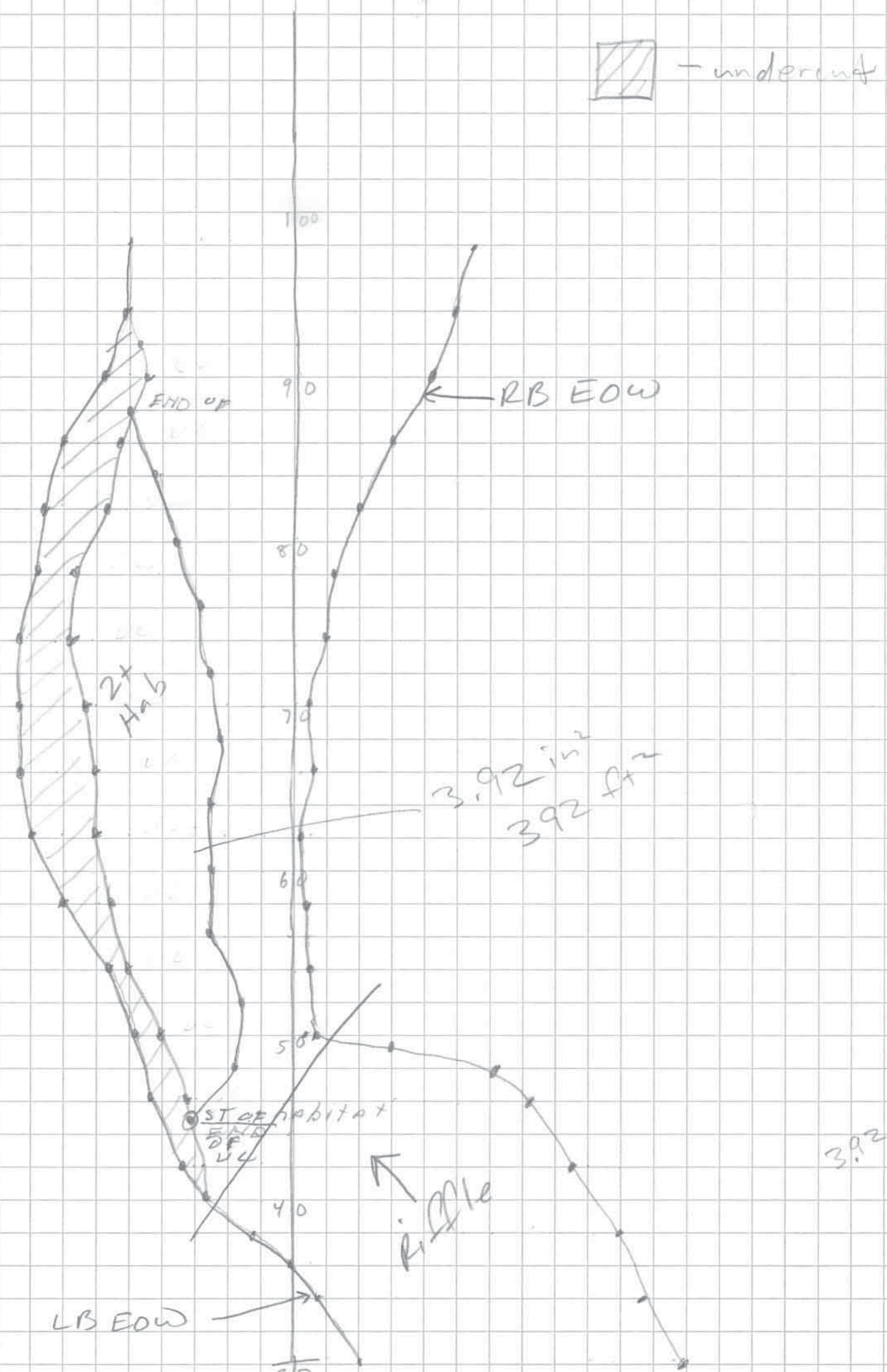


7-25-12 NGWC
NGWC Fish Habitat 2+ 5th
downstream D-1
1 sq. = 2 ft

Habitat Unit #D1

8.2 cfs

FLOW ↑

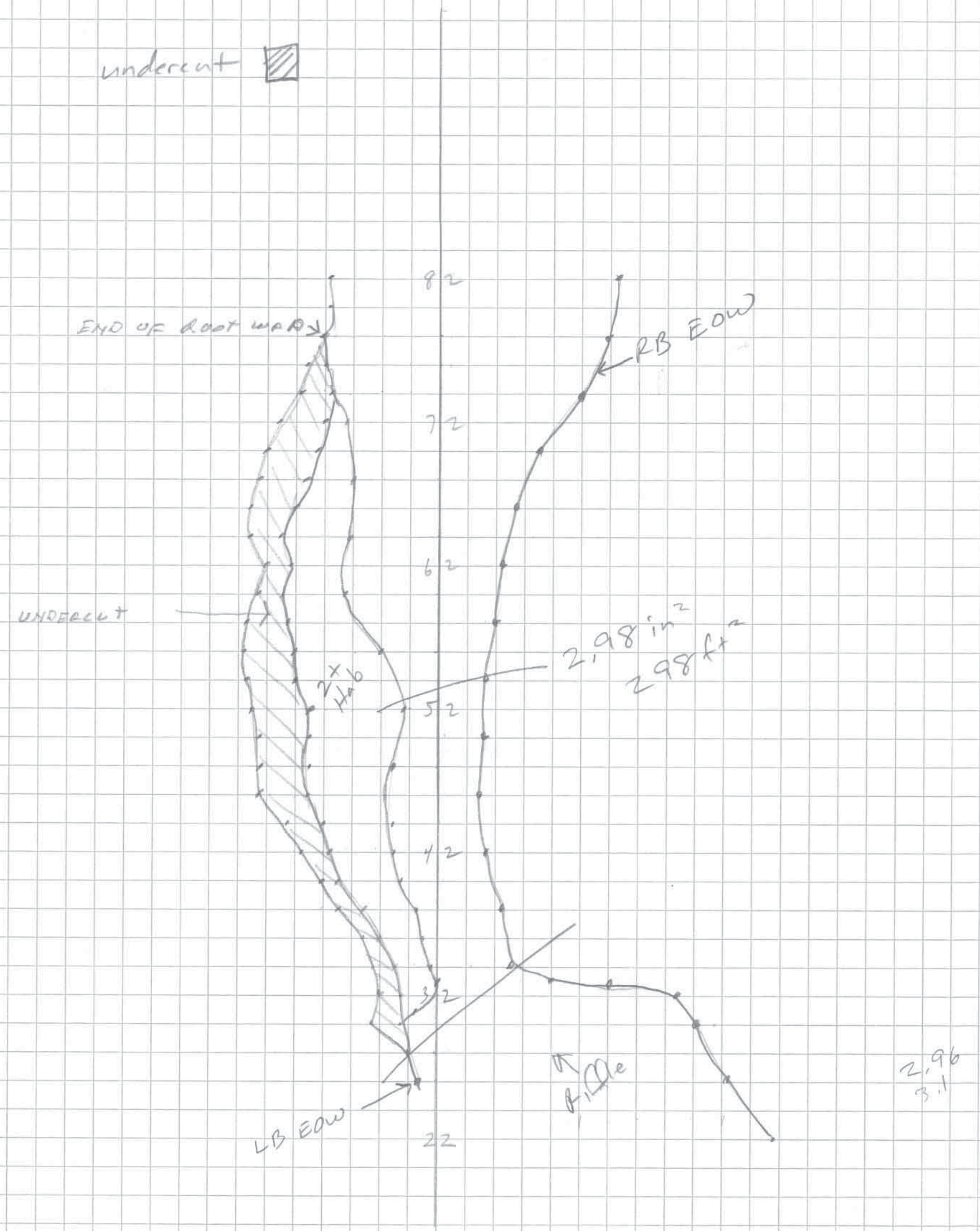


8-15-12

NGWC 2+ 5th habitat Unit #D1 ~~3.9~~ 5.3 cfs @ USGS NFG gauge

N.F. Gualala ~~Treatment~~ downstream

Flow ↑

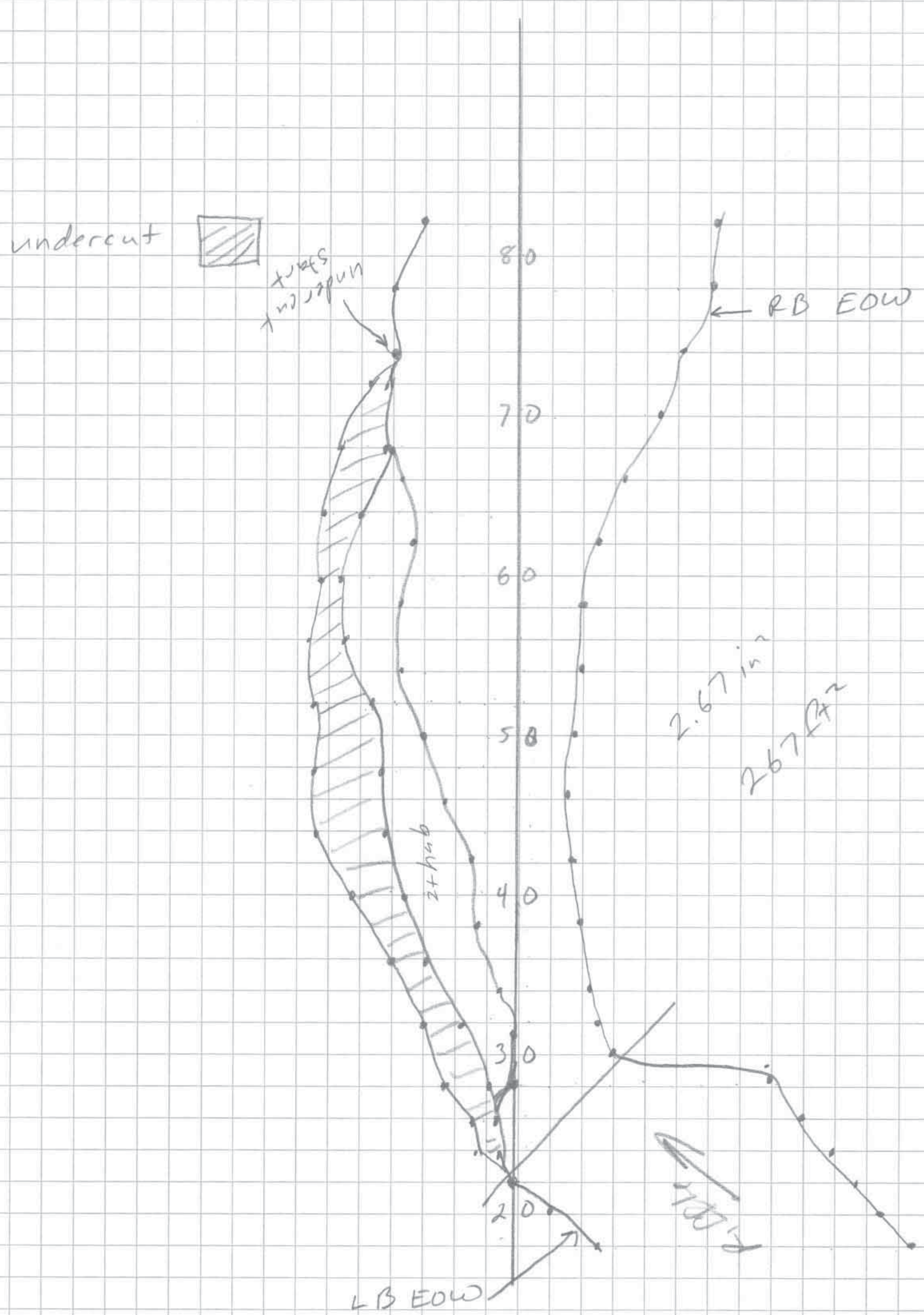


NGWC

8-30-12 2+sth hab unit # D1

Flow = 4.8cfs 1sq = 2ft

Flow ↑

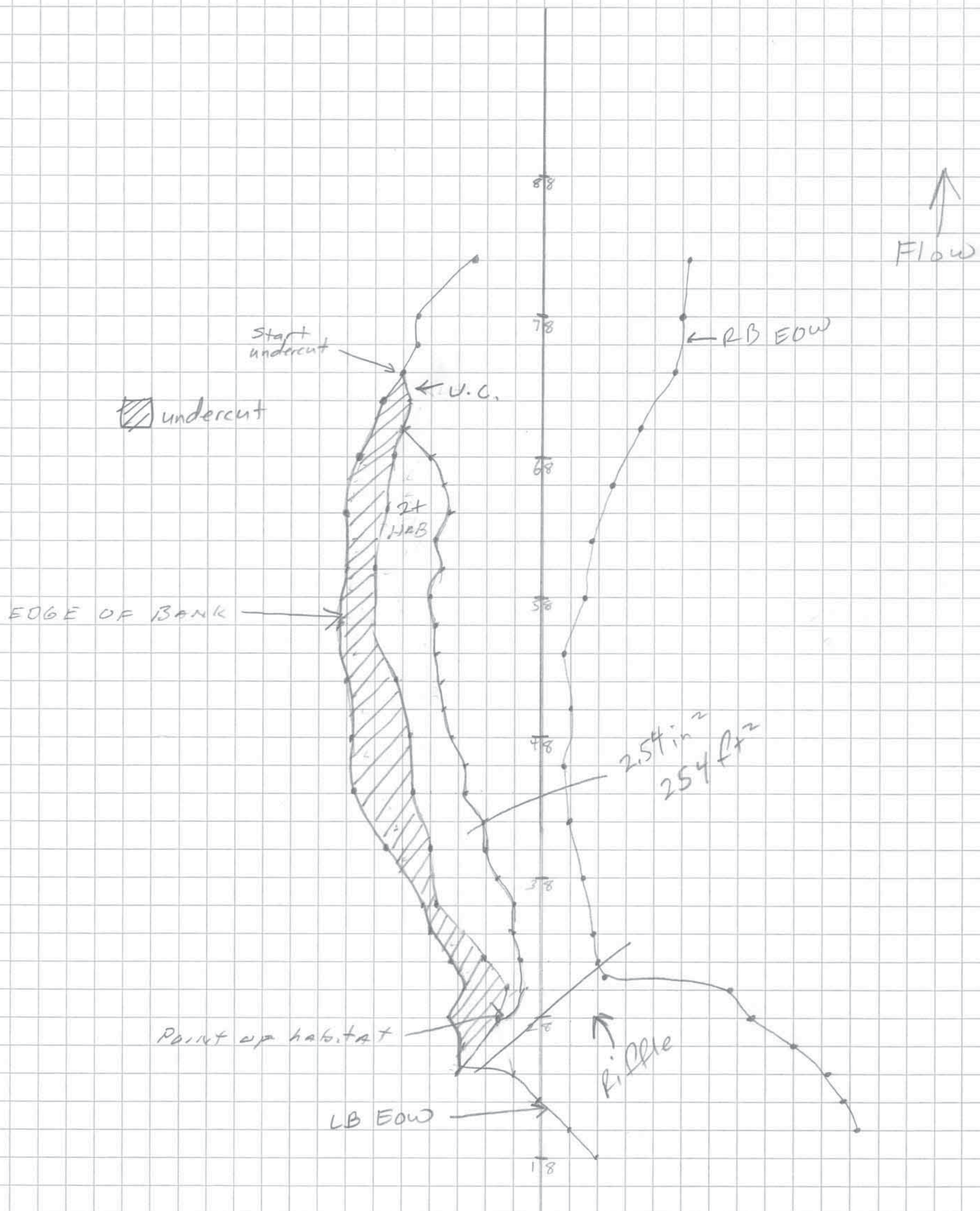


NGWC NFG Fish Passage

10-5-12 2+ sth hab Unit #D1

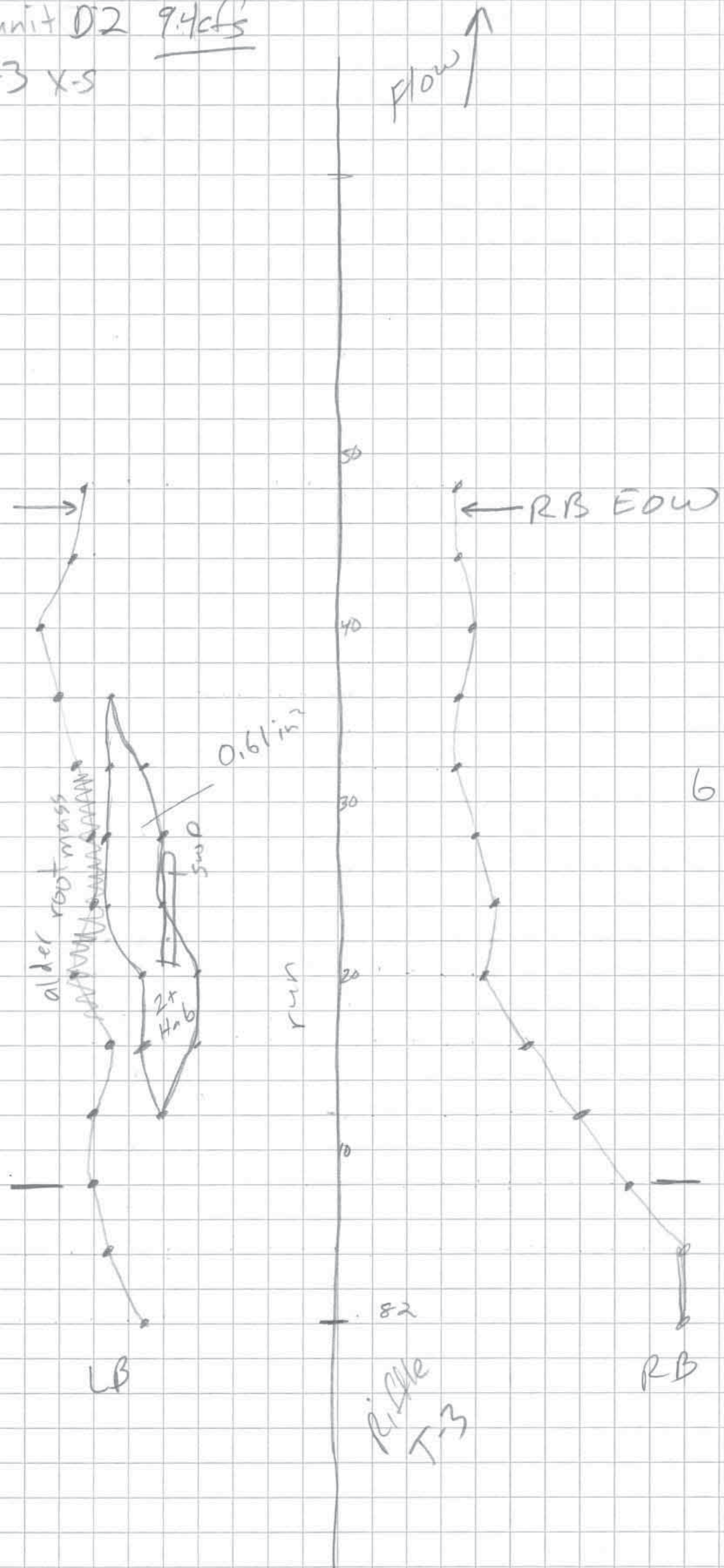
3.0 cfs

1 square = 2'



7-12-12 N.F. Gualala NGWC
2+ steelhead habitat delineation
Prefered criteria: depth 1-3 ft., velocity 1-3 fps, co/bo substrate in runs, head of pools
Scale: 1 square = 2 ft

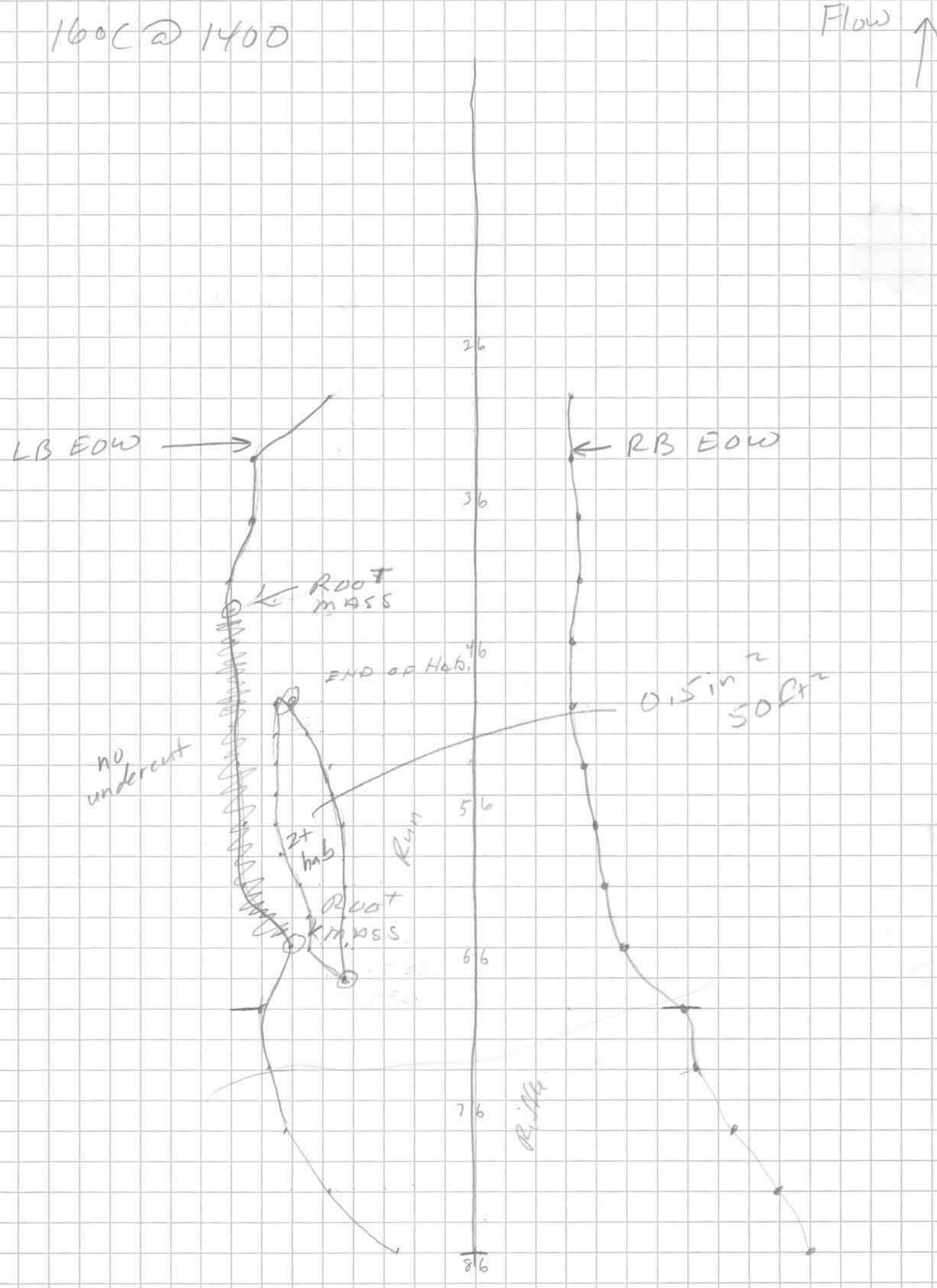
2+ Habitat unit D2 9.4cfs
below D-3 X-S



7-25-12 2+ Sth Habitat NGWC
1 sq = 2' Hab. Unit #D2

8.2 cfs

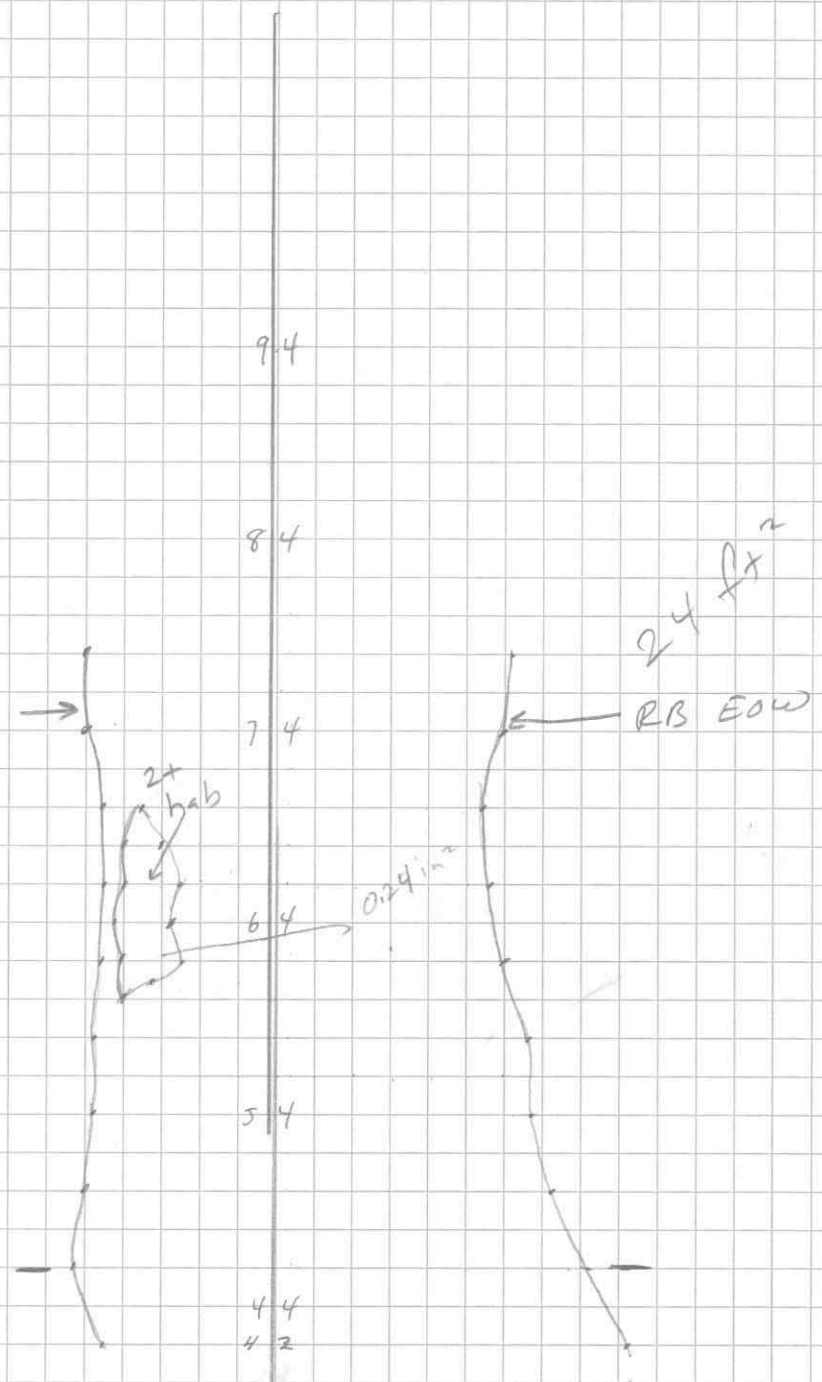
16.0C @ 1400



8-15-12
NGWC
N.F. Gualala 2+ Sth habitat 5.3 cfs 1 square = 2 ft
Unit #D2 (treatment)

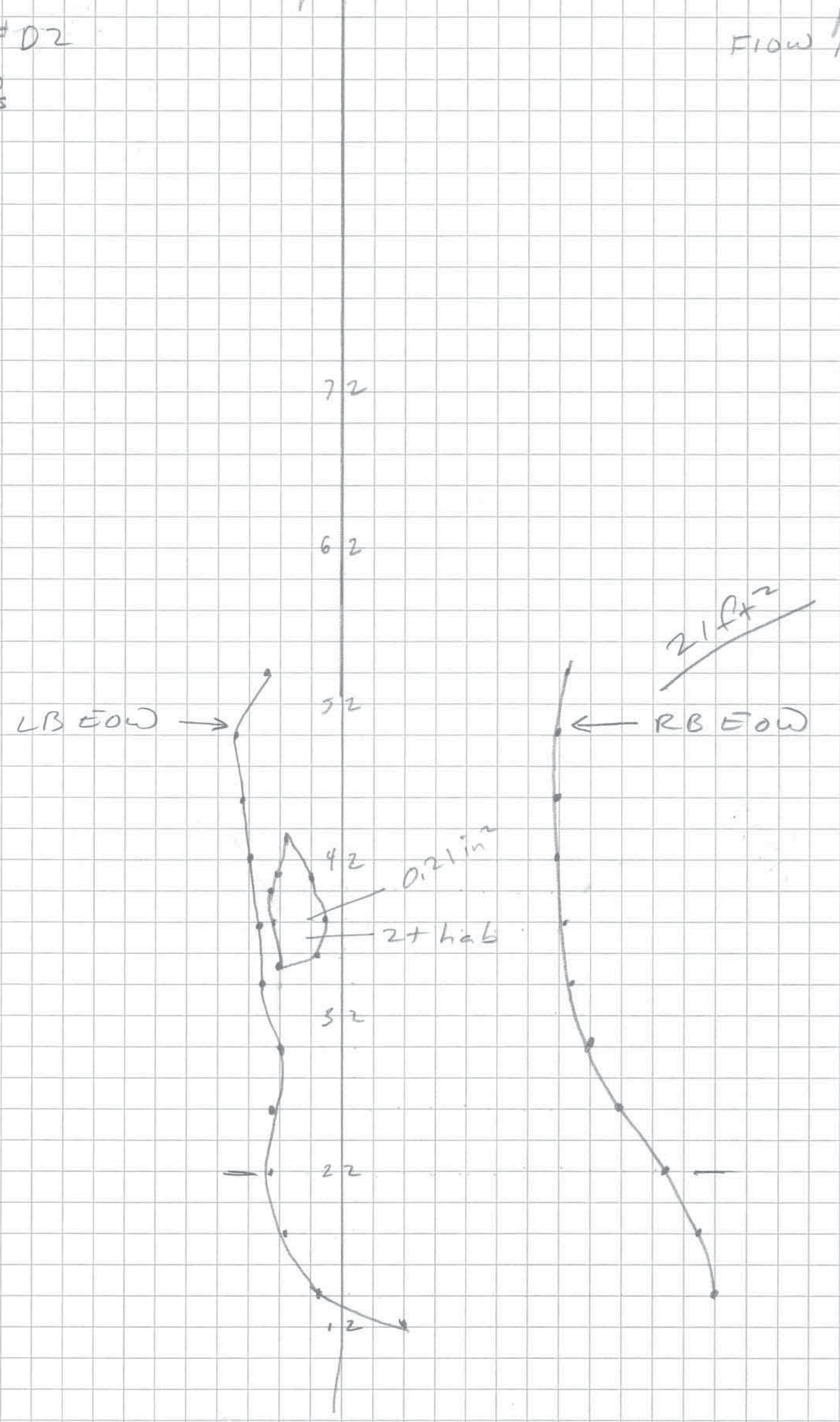
below D-3 X-5

Flow



NBWC NF Gualala
8-30-12
2+ 5th hab unit # D2
4.8 cfs

1 sq = 2 ft

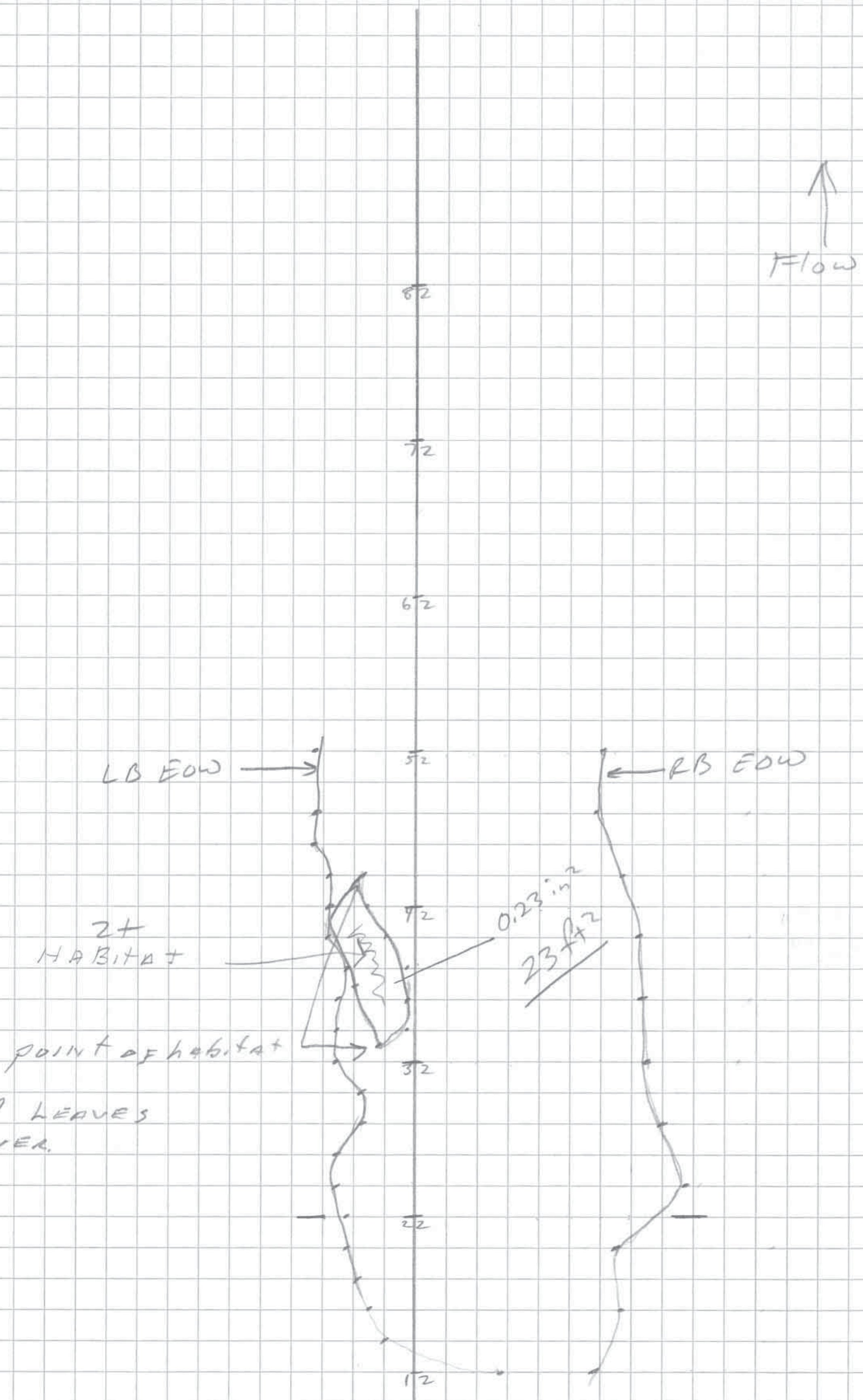


N6WC NF Bualala Fish Habitat 10-5-12

2+ Stlh
Unit # D2

1 sq = 2 ft

3.0 cfs



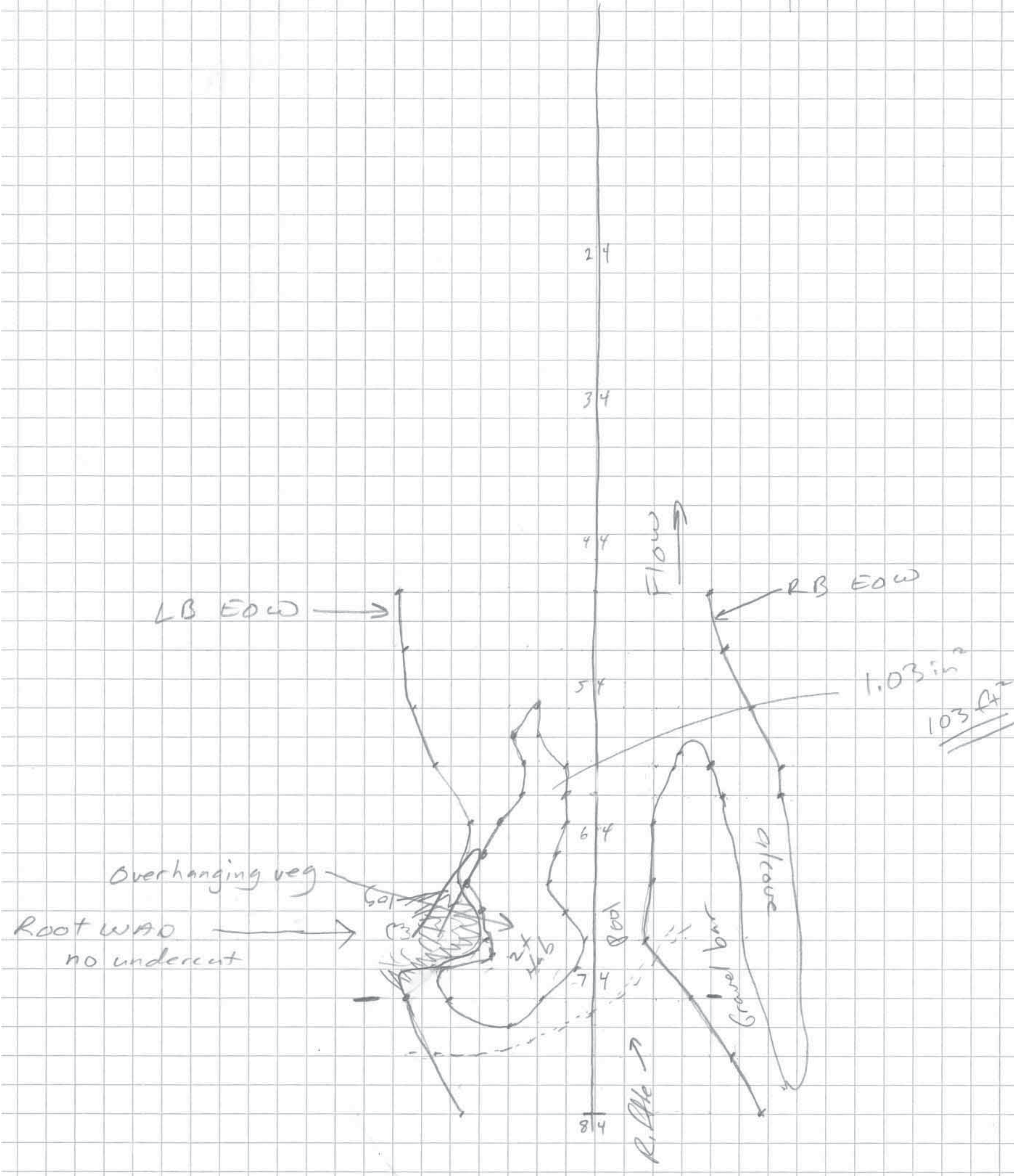
ALLUMULATED LEAVES
CREATING COVER.

NGWC NF Gualala 7-12-12
9.4 cfs 2+steelhead habitat

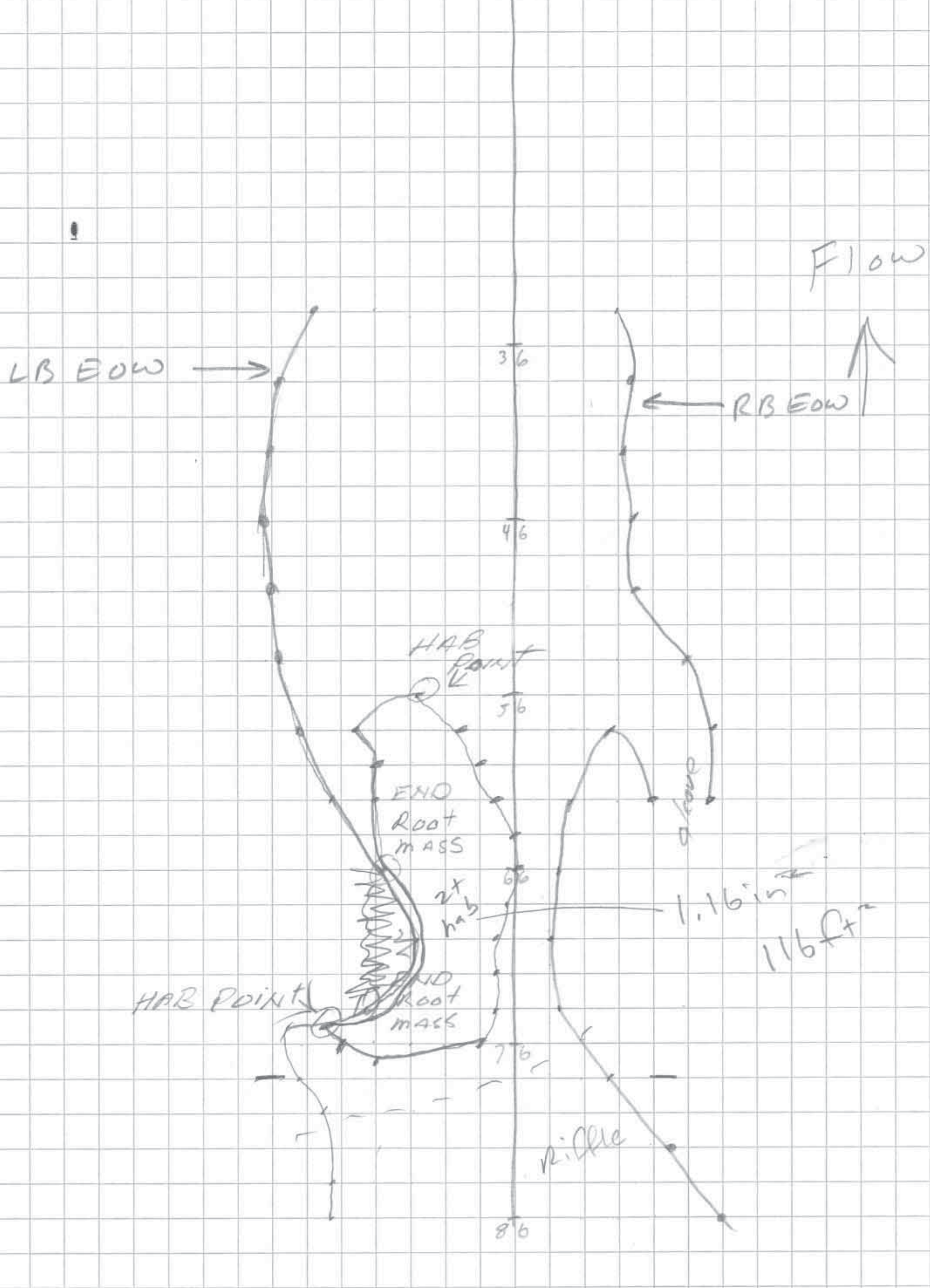
Hab unit #U3 - downstream of U-1b X-S

FLOW ↑

9.4 cfs
18°C @ 1440

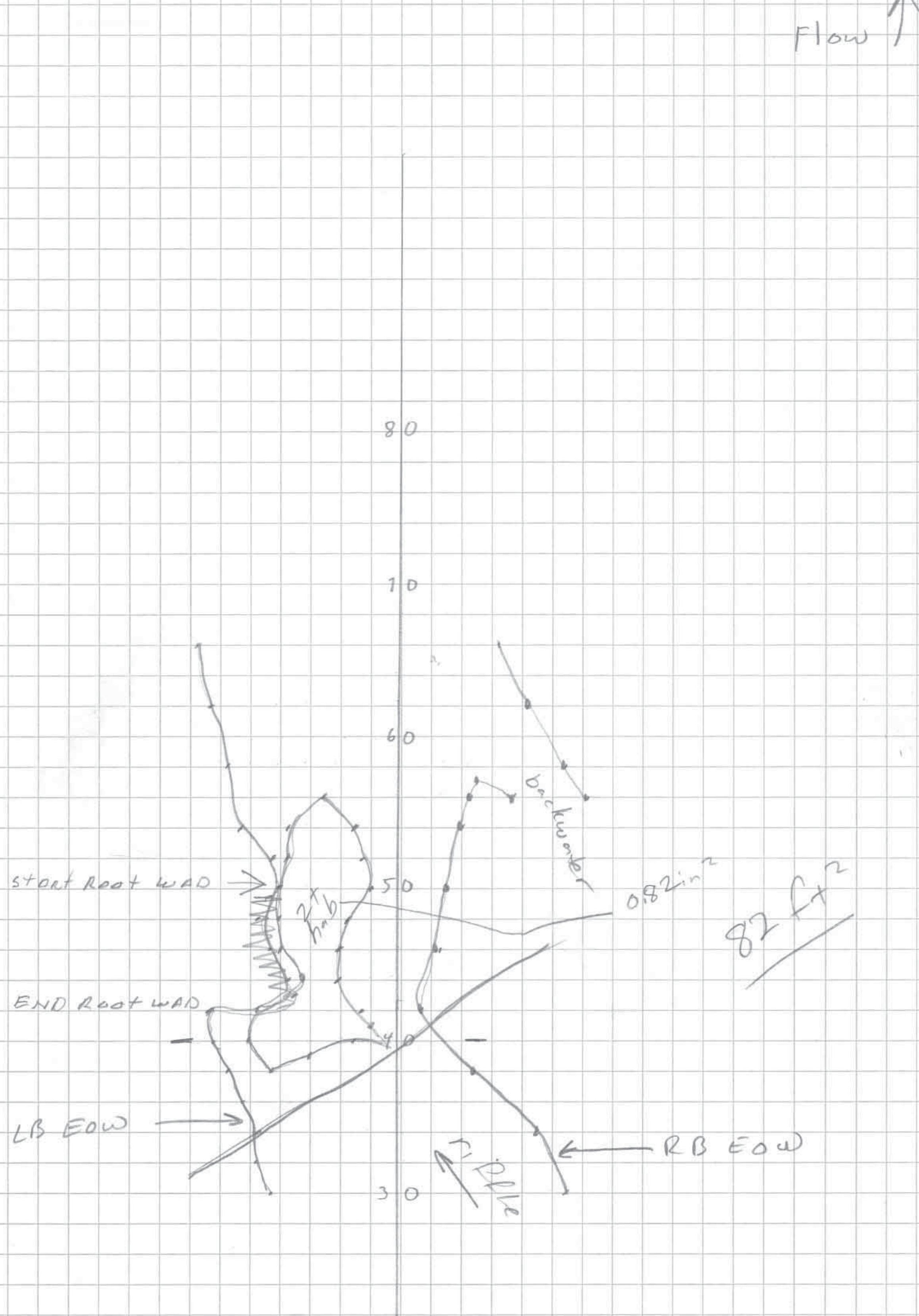


7-25-12 NGWC 2+ Sth Habitat NF Gualala
Habitat Unit # U3 8.2 cfs
downstream of U-1b x-sec.

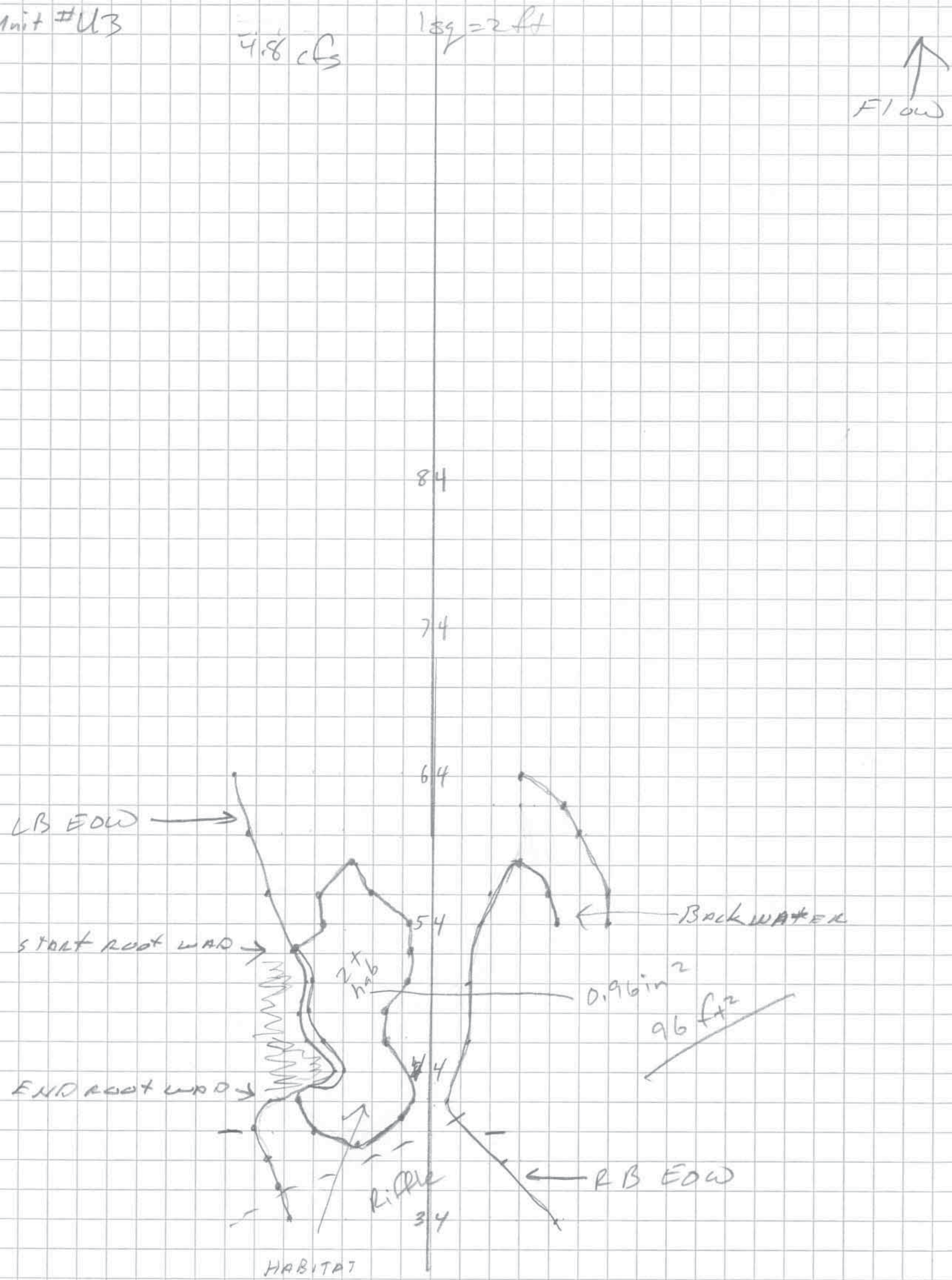


8-15-12 NGWC
NF Gualala 2+ 5th habitat
Habitat Unit #U3

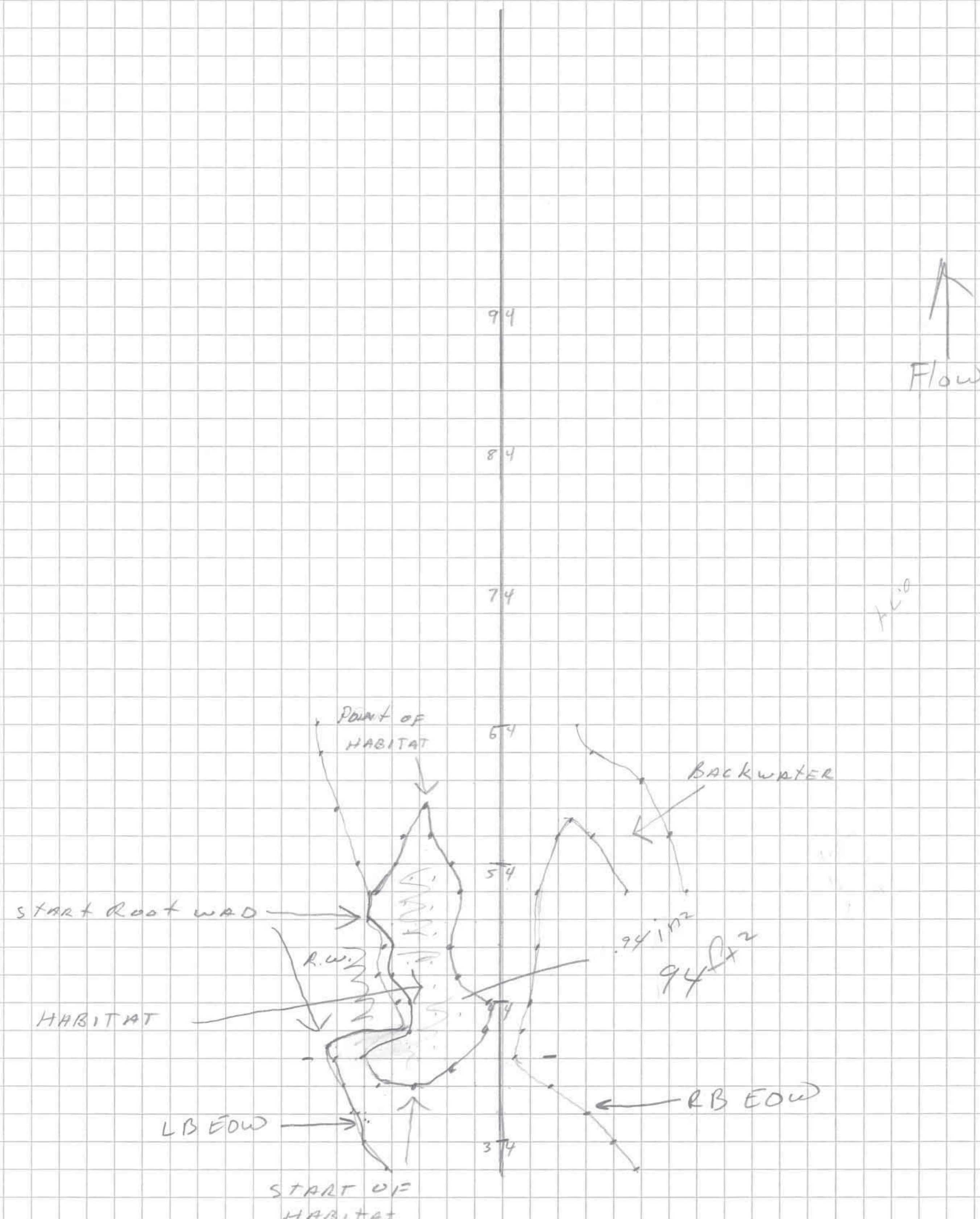
5.3 cfs @ USGS NFG gauge
1 square = 2 ft



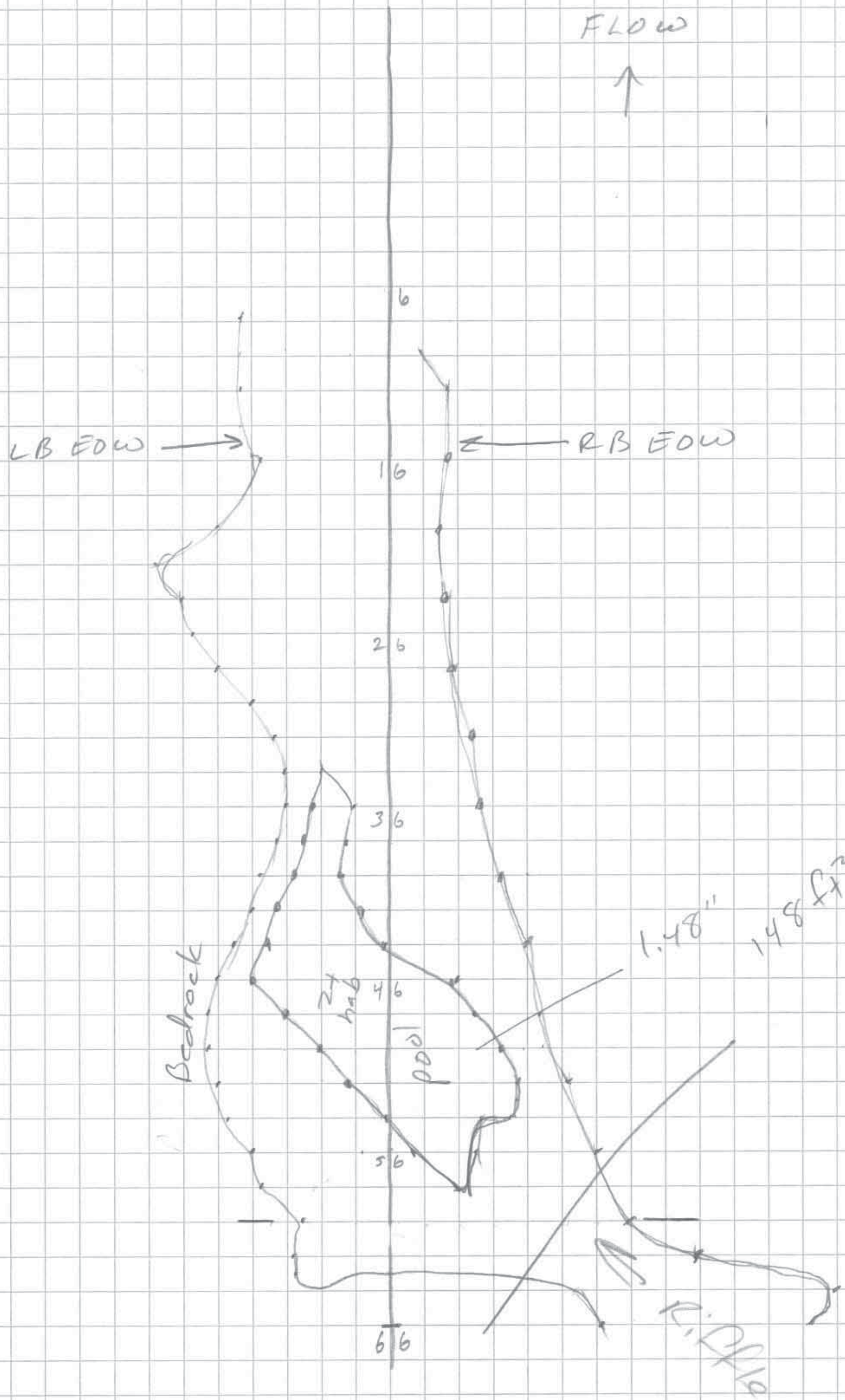
16 Temp °C @ 2:30pm   8-30-12
NGWC
2nd Hab Unit #U3
4.8 cfs



NGWC 10-5-12
NF Gualala
2+ sth habitat 1sq = 2'
Habitat Unit # U3 3.0cfs



7-12-12 NGWC N.F. Gualala
2+ steelhead habitat
1 square = 2 ft 9.4 cfs
Hab. Unit #U4 – 2011 habitat unit #1 but with changed hydraulics



7-25-12 NGWC NF Gualala

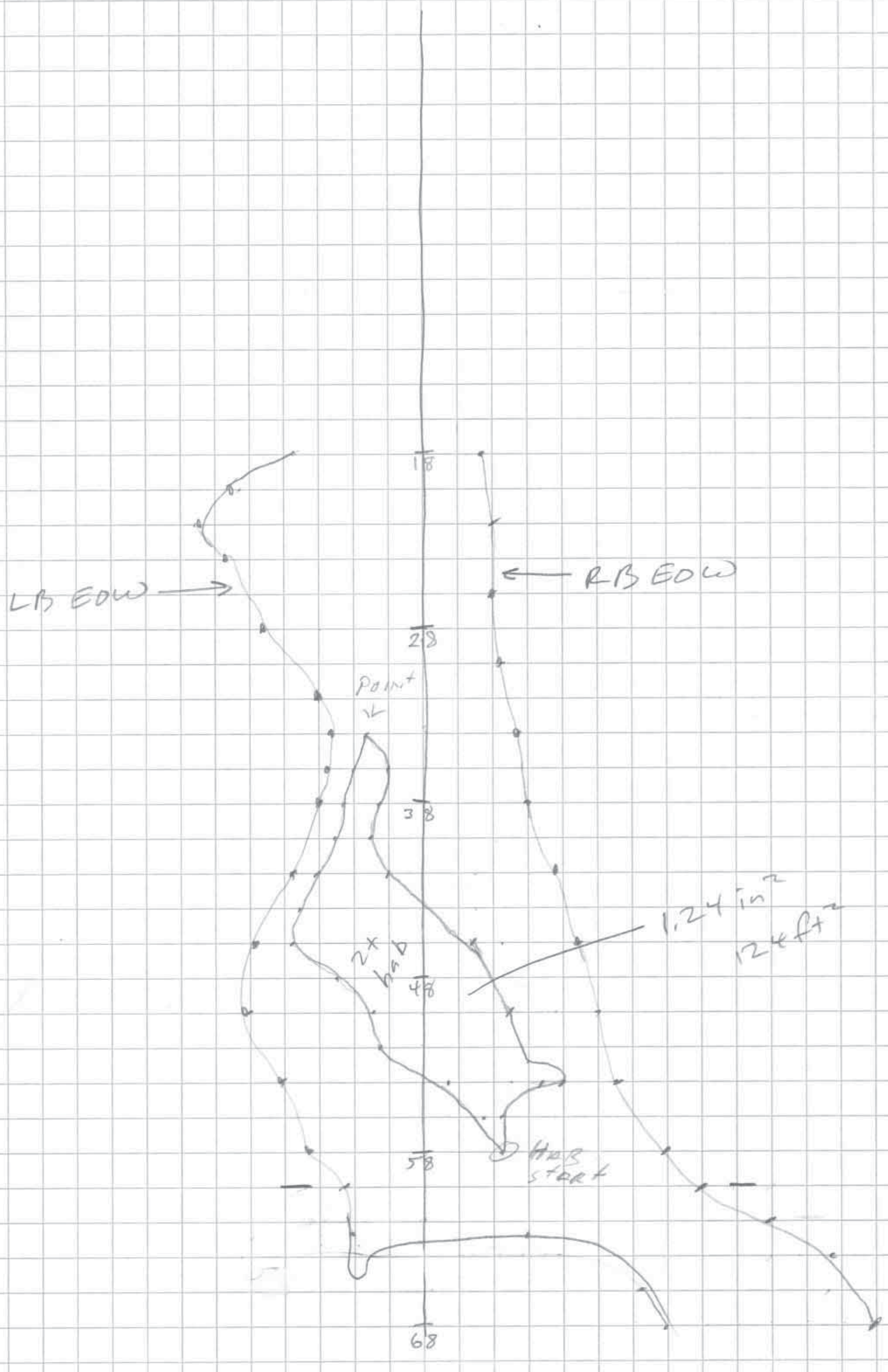
2+ 5th habitat mapping

Habitat Unit #U4

8.2 cfs

Flow ↑

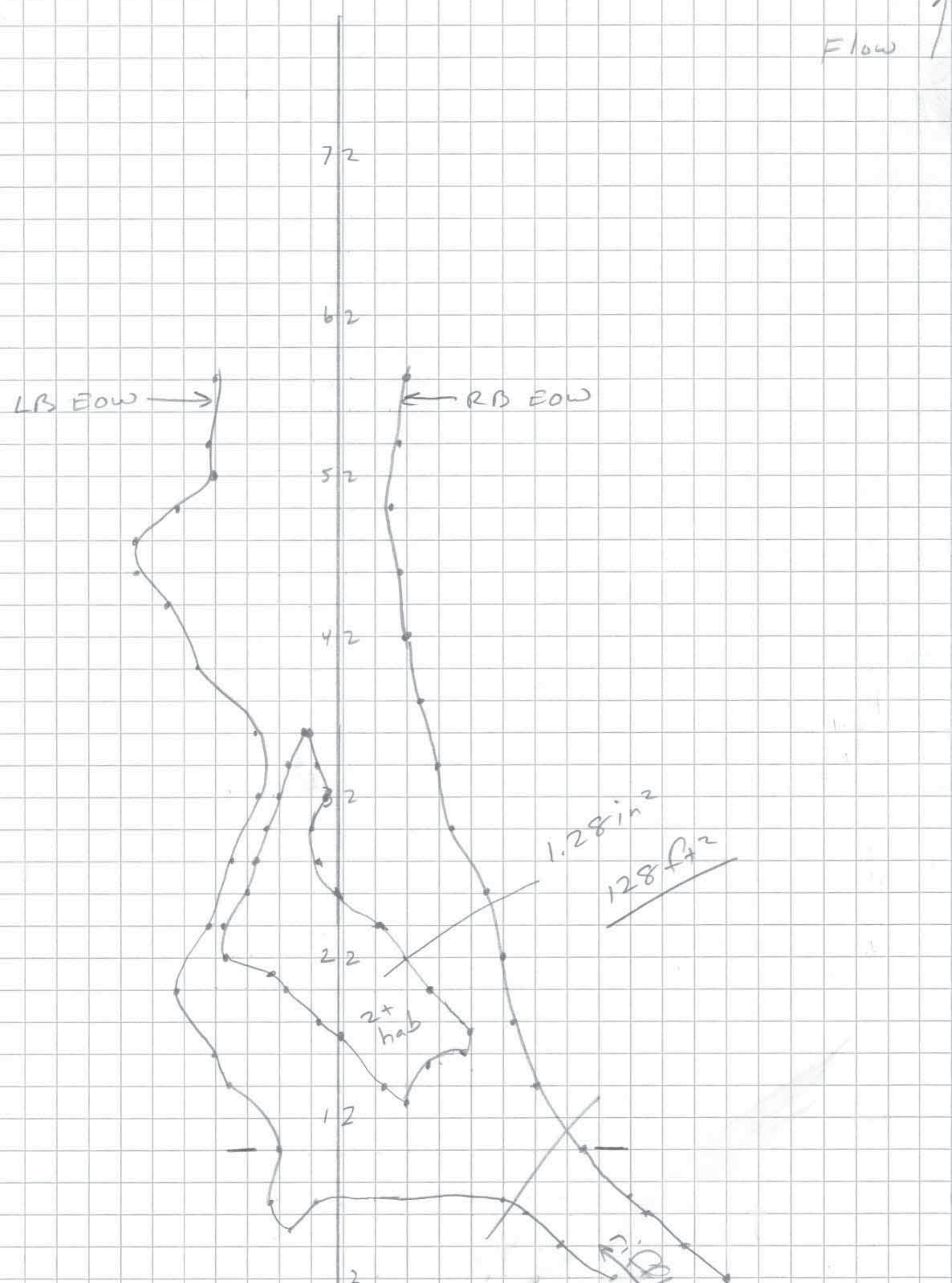
16°C @ 1515



1.19
1.28
1.24

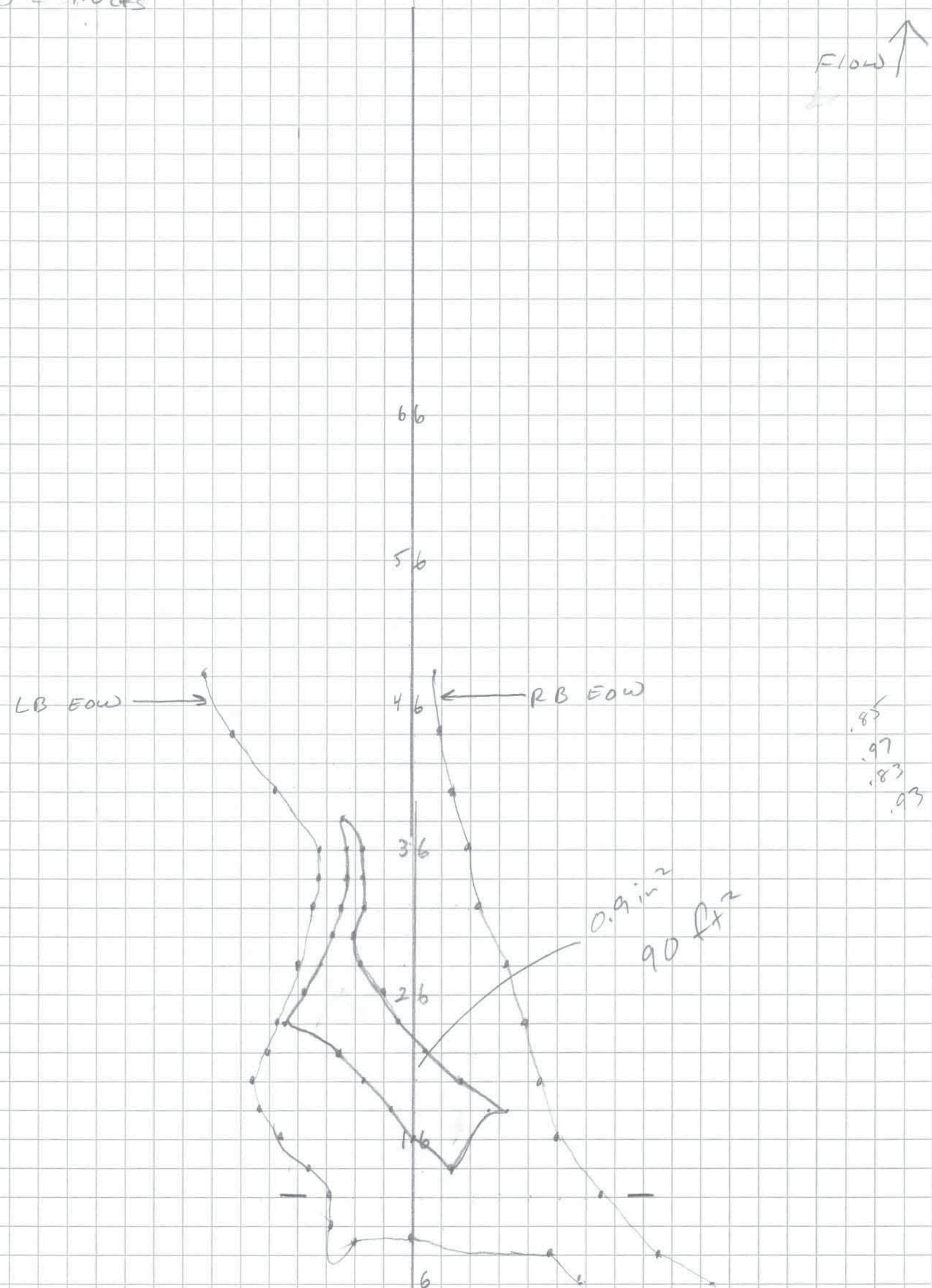
8-15-12
NGWC
2+ Sth habitat mapping
Habitat Unit U-4

53 cfs @ USGS NF Gualala gauge
Scale 1 square = 2 ft
15.5°C @ 1130



8-30-12
NGWC 2+ sth habitat DPH
Hab Unit #U4
flow = 4.8 cfs

1 sq = 2 ft



NGWC
NF Gualala
2+ 5th habitat
Hab Unit # U4

10-5-12
3.0 cfs

1 sq = 2 ft