BUREAU OF RECLAMATION

Columbia River Diversions and Irrigated Agricultural Acres

Technical Memorandum

Columbia Pacific Northwest Region

U.S. Department of the Interior

June 2019

Mission Statements

The Department of the Interior conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photo: Irrigated agriculture, Columbia River basin, Washington.

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1 Introduction

The Columbia River system is a source of water for irrigation and municipal and industrial (M&I) water. Changes to flow in the river and storage in the reservoirs could affect the ability to deliver water to nearby lands for agricultural uses. In order to assess these effects, it is necessary to understand the linkage between specific river reaches and lands that receive water from those reaches. In the Pacific Northwest, this is a dataset that is not readily available and not trivial to develop.

1.1 Objective and Scope

This document describes the methods used to determine the number of surface water diversions from the Columbia River, groundwater diversions from within one mile of the river, and lands irrigated with this water for agriculture. This document also summarizes recent crop patterns within these acreages.

This analysis was limited to diversions, wells, and lands that receive water from the mainstem of the Columbia, Lower Snake, Clearwater, Kootenay, Pend Oreille, Clark Fork, and Flathead Rivers within the United States. Specifically, this analysis was limited to lands irrigated from the Hydrologic and Hydraulic (H&H) reaches defined by the U.S. Army Corps of Engineers. Irrigated acres were assessed for H&H Reaches 1 through 9 and 14 through 30 (Figure 1).

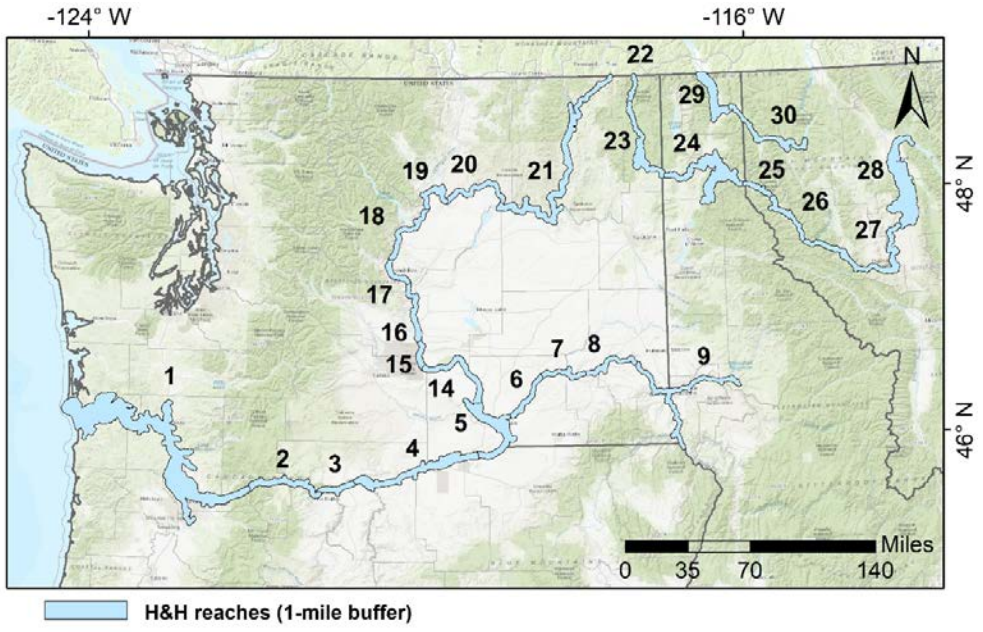

Figure 1. Map of Hydrology and Hydraulics reaches on the Columbia, Snake, Clearwater, Kootenay, Pend Oreille, Clark Fork, and Flathead Rivers

2 Methods

Water rights data for Washington, Oregon, Idaho, and Montana were merged to a common attribute system and analyzed to quantify the number of points-of-diversion (PODs) and irrigated acres (i.e., places-of-use; POUs) that divert water from the H&H reaches (Reclamation 2018). PODs were counted and classified by water sources and diversion types (e.g., surface water/pumps vs. groundwater/wells) and water uses (e.g., agricultural vs. M&I). Within the POUs, acres of specific irrigated crop types were measured by overlaying the POU spatial extents with satellite-based crop classifications for 2013 to 2017 based on information from the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) (USDA 2013 to 2017).

2.1 Processing Summary

The process for assessing the potentially-affected lands can be broken up into the sequence of steps identified below.

1. Water rights data for the four states were reformatted into standardized system, with unique non-conflicting identifying numbers for each state.

2. Water rights were linked to PODs based on water rights numbers.

3. PODs were associated with the closest reach and spatially subsampled to include surface water pumps and wells within one mile of the water edge.

4. PODs were linked, based on water right numbers, to POUs.

5. Water rights information on water uses was used to classify POUs into either agricultural or lumped M&I uses. Water source and diversion type attributes were merged into shared categories (i.e., pumps with surface water; wells with groundwater) because the water rights data for some states only specified one or the other (Section 2.2).

6. POUs are often based on property boundaries and include non-agricultural lands within these areas. To restrict the analysis to agricultural lands, pre-existing satellite-based crop classifications were used to clip the POUs to the areas where crops were identified during at least one of five years from 2013 to 2017.

7. For each reach, total crop-delimited irrigated acres were measured for each of the POU groupings (water use types, diversion types/sources, total).

8. Crop classifications were also used to calculate the total acres of different crop types identified within the agricultural crop-delimited POUs of each reach in each year. This analysis was repeated for five years and averaged.

2.2 Water Rights Data Preprocessing and Reclassification

Water rights (WRs), PODs, and POUs for Washington, Oregon, Idaho, and Montana were obtained, respectively, from the Washington Department of Ecology, Oregon Water Resources Department, Idaho Department of Water Resources, and Montana Department of Natural Resources. To facilitate comparison across jurisdictions, individual features were assigned unique identifiers that were used to link WRs, PODs, and POUs. This was performed by prefixing state-specific identifiers with each state's abbreviation. Additionally, equivalent attributes of interest were remapped into single attributes (e.g., 'PlaceOfUse' values for Idaho, and 'pou_use_id' for Oregon, were remapped to 'POU_ID').

The data vary in content, format, and completeness. The data contain information on water sources, diversion types, and water uses, which were used to classify PODs and POUs. Existing values for irrigated acres were not used because most features were missing this information; many POUs contain non-agricultural lands and the accuracy of irrigated acres was unclear. The data are more complete in Washington, while features in Oregon, Idaho, and Montana may lack certain attributes. The possible values for specific attributes varied both within and across jurisdictions. A classification scheme was developed to reclassify these different data into standardized attributes.

Water source attribute values included a range of different water features; features were reclassified as having a surface water source if the attribute contained any of the following text fragments: 'river','lake', 'trib', 'creek', 'spring', 'fork', 'slough', 'pond', 'stream', 'lagoon', 'riv', 'rvr', 'lk', 'cr', 'sump', 'res', 'columbia r', 'oreille r', 'oleile'. Some of these fragments were added to catch specific features. Groundwater source data were more consistent and were readily identified by either 'well' or 'ground' text values. Diversion types also had consistent attribute values, with 'well' and 'we' used to classify wells and 'pump' used to classify pumps. Water use types were more difficult to classify, with a wide range of possible values. Features were classified as agricultural if their water use value contained the following word fragments: 'irrigat', 'stock', 'agri', 'nursery', 'crops', 'frost'. Features were classified as M&I if their water use value contained any of the following word fragments: 'municipal', 'condit', 'commerc', 'industri', 'fire', 'mitigation', 'recreation', 'heat exch', 'dust', 'geo', 'highway', 'human', 'manufac', 'mining', 'railway', 'school', 'domesti', 'lawn'. All comparisons were done in lowercase to avoid case-sensitivity.

Classifications were recorded by adding feature attributes representing each classification type to the dataset and assigned true or false Boolean values according to their classifications (e.g., Well_bool = 1). Separate attributes were used for each class to retain data in areas where contrasting classes tested true (e.g., both well and surface water pump diversion types). Retaining individual classifications as separate attributes allowed duplicative and overlapping POUs to be merged into single representative POUs. This was necessary to avoid counting the same lands twice when calculating total acres for reaches and groups, while also retaining water rights information. Since POUs may be used for multiple purposes and served by multiple water sources (e.g., surface and groundwater sources), overlaps between POUs with different attributes

were retained when summarizing acres for different groups but merged within individual groups to avoid counting lands twice. For example, the total irrigated acres for a reach are typically lower than the sum of acres irrigated by either surface water or groundwater because the individual groups are allowed to overlap where lands are irrigated by both water sources.

To completely classify the data where water source or diversion type attributes were missing, and because the data are related, well and groundwater attributes were merged by assigning true values if either case were true, as were pump and surface water classes. This allowed most features to be classified into either well/groundwater or pump/surface water categories.

2.3 Crop Data Reclassification and Summary

Crop type estimates from the 2013-2017 Crop Data Layers (USDA 2013 to 2017) were used to assess the acres of individual crop classes within the POU sub-group classified as having agricultural water use. These data are spatially-continuous 30-meter resolution gridded estimates of crop and land cover types based on intra-annual variations in the satellite-measured reflectance of light (visible light plus infrared) from the land surface. Land surface light signatures vary with plant types and can be used to predict dominant crop cover within each 30 by 30 square meter grid cell. Summarizing these data within the POUs yields estimates of the total irrigated acres of different crop types.

The Crop Data Layers (CDLs) contain many crop and non-crop land cover types, with over 100 unique classes (Figure 2, Figure 3, and Figure 4). The CDL crop types were reclassified into 18 more generalized groups of crops. Acres of individual crop types were totaled within the agricultural POUs of each reach for each of the five years and used to calculate five-year average crop acreages. Developed (i.e., M&I) and non-agricultural acres were summarized but excluded from agricultural totals.

The number of acres of lands supporting crops vary from year to year, especially where fields are fallowed as part of crop rotation. To get a more complete estimate of the total agricultural acres served by irrigation, the POUs were delimited to areas that supported crops during the 2013 to 2017 period for which quality CDLs were available. If crops were grown within a given 30 by 30 square meter grid cell during any of the five years, and if the area was within an agricultural POU, the area was classified as irrigated agricultural land. The resulting five-year irrigated acres are greater than the cropped acres for individual years, due to land cover changes (e.g., fallowing). The five-year crop extents were summarized within the agricultural POUs, grouped by the combined water-source and diversions types, and summarized by reach. This yielded the total agricultural acres irrigated by wells/groundwater and pumps/surface water within each reach during the five-year period.

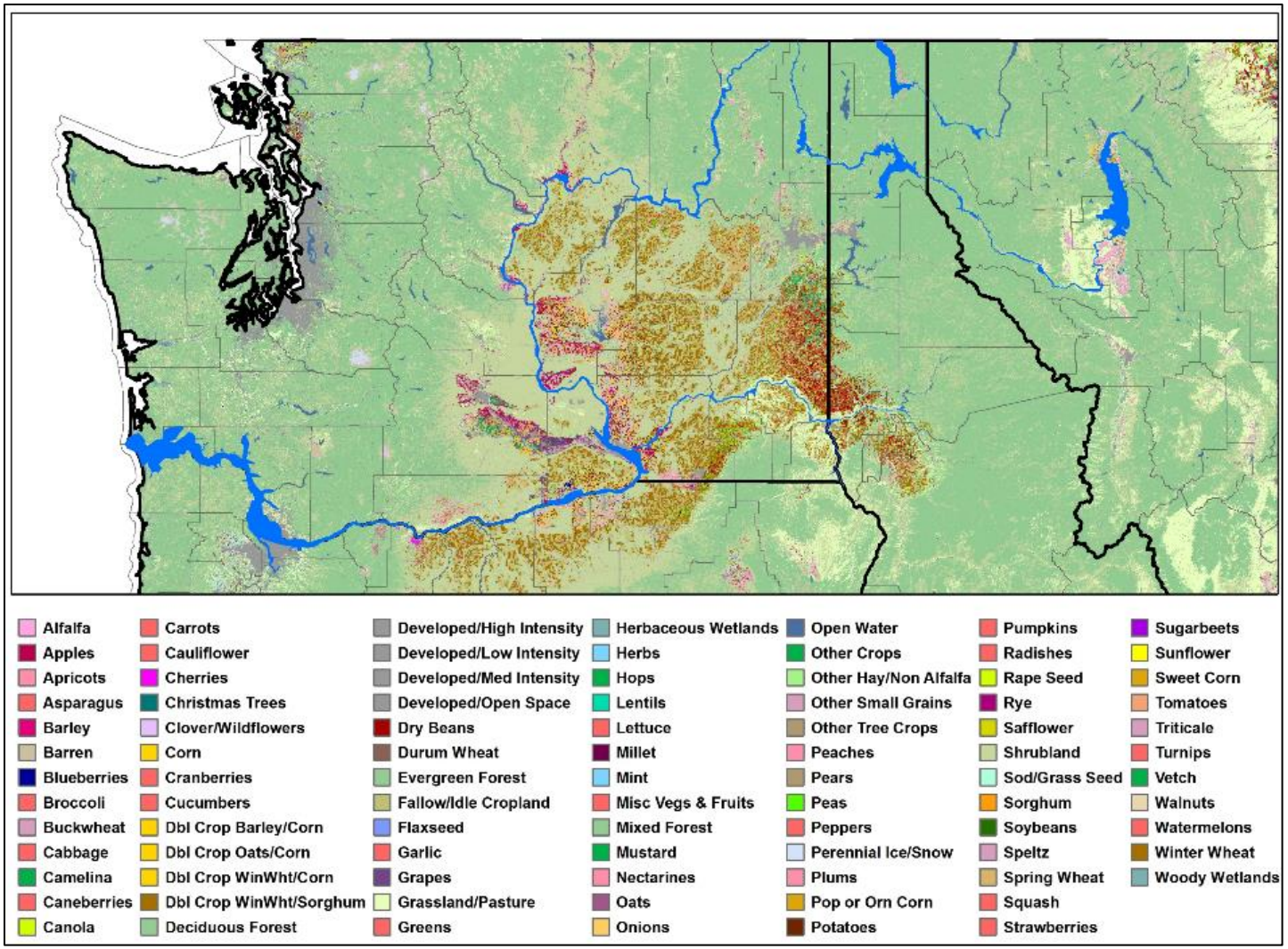

Figure 2. Larger-scale example of Crop Data Layer before reclassification, with H&H reaches overlain in blue

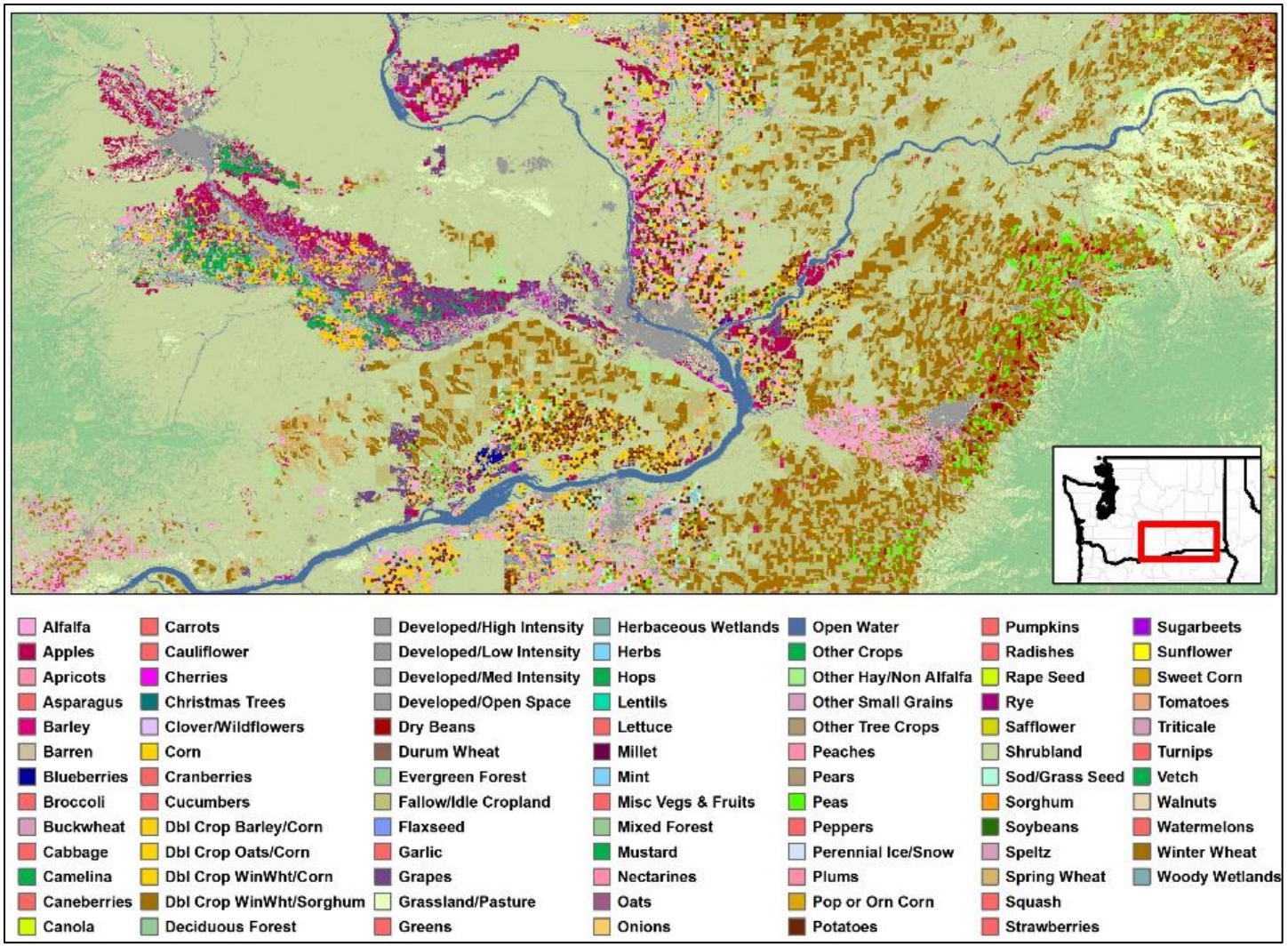

Figure 3. Medium-scale example of Crop Data Layer for the confluence of the Snake and Columbia Rivers, before reclassification

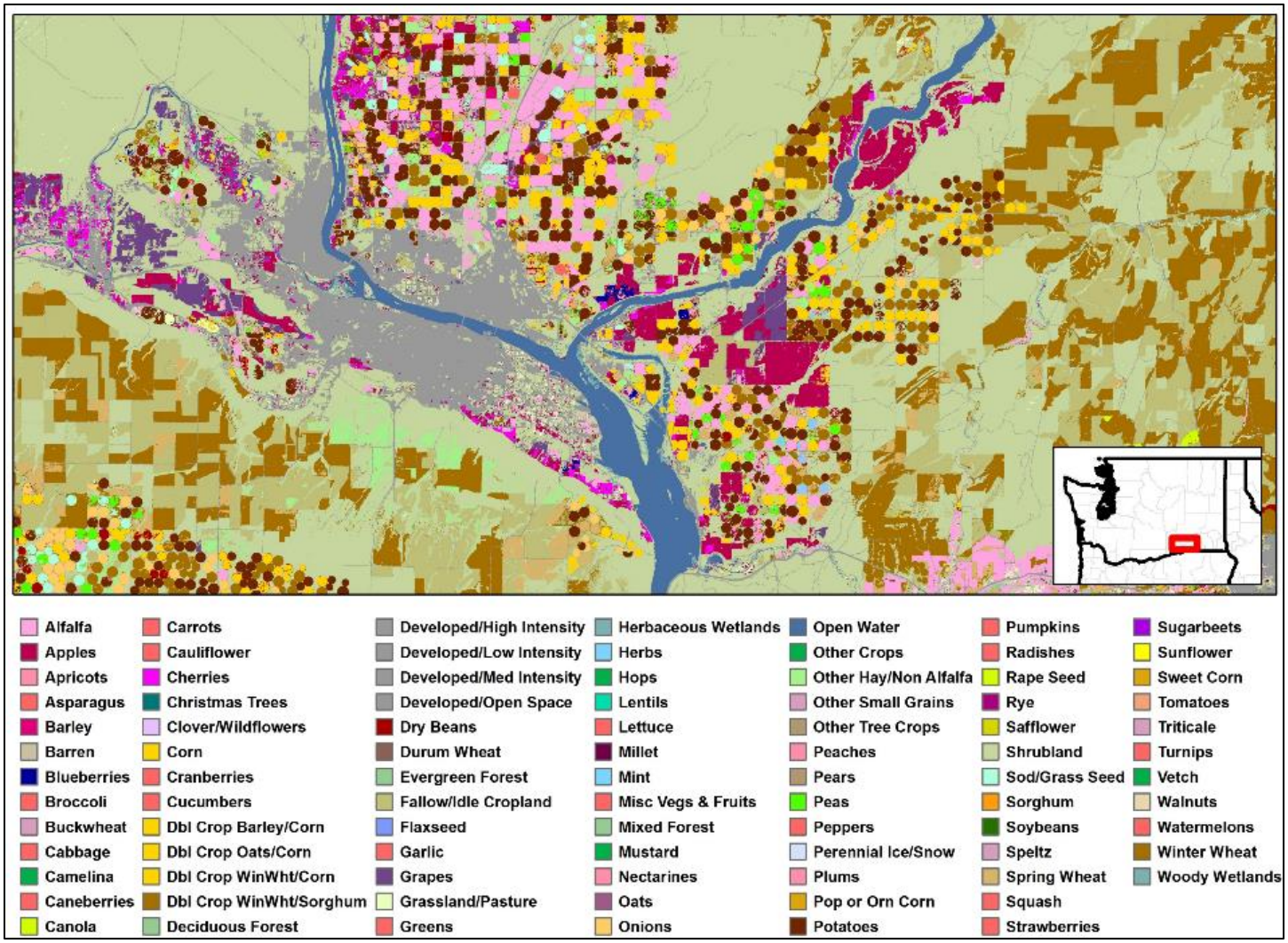

Figure 4. Smaller-scale example Crop Data Layer for the confluence of the Columbia (left) and Snake (right) Rivers, before reclassification

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2.4 Exclusions and Exceptions

The POU dataset was manually edited and cleaned to correct data problems. A minor number of individual water rights included lands far from the associated reach, in addition to lands near the reach. The POUs were grouped by reach and visually assessed to identify and remove outliers far outside the area possibly irrigated from the reach. These areas were usually small and overlapped by other POUs which were associated with the correct reach, so these lands were still included as necessary.

Some areas were excluded from the analysis because they either receive water from other water sources or use alternative water delivery mechanisms (e.g., water exchanges). These areas include lands irrigated from the lower Yakima River, the Umatilla River, and the Columbia Basin Project. Specific details regarding each exclusion are provided below. PODs associated with the omitted POUs were also removed from the POD dataset.

For Reach 5, some lands southwest of Richland and Kennewick listed the water source as the Columbia River, although they are irrigated from the Kennewick Main Canal which is diverted from the lower Yakima River. These Yakima-sourced POUs were omitted (Figure 5). POUs in Richland and Kennewick irrigated by water pumped directly from the Columbia River were not removed.

Additionally, on the south side of the downstream portion of Reach 5, irrigated lands near the Umatilla River in Oregon were also excluded. Although their current water source is the McNary pool on the Columbia River, they pump this water as part of an exchange for leaving their water in the Umatilla River (Figure 5). This includes the area around Cold Springs Reservoir. Note that this exclusion applies only to POUs diverting water from Reach 5; POUs near the Umatilla River that divert water from Reach 4 were not excluded.

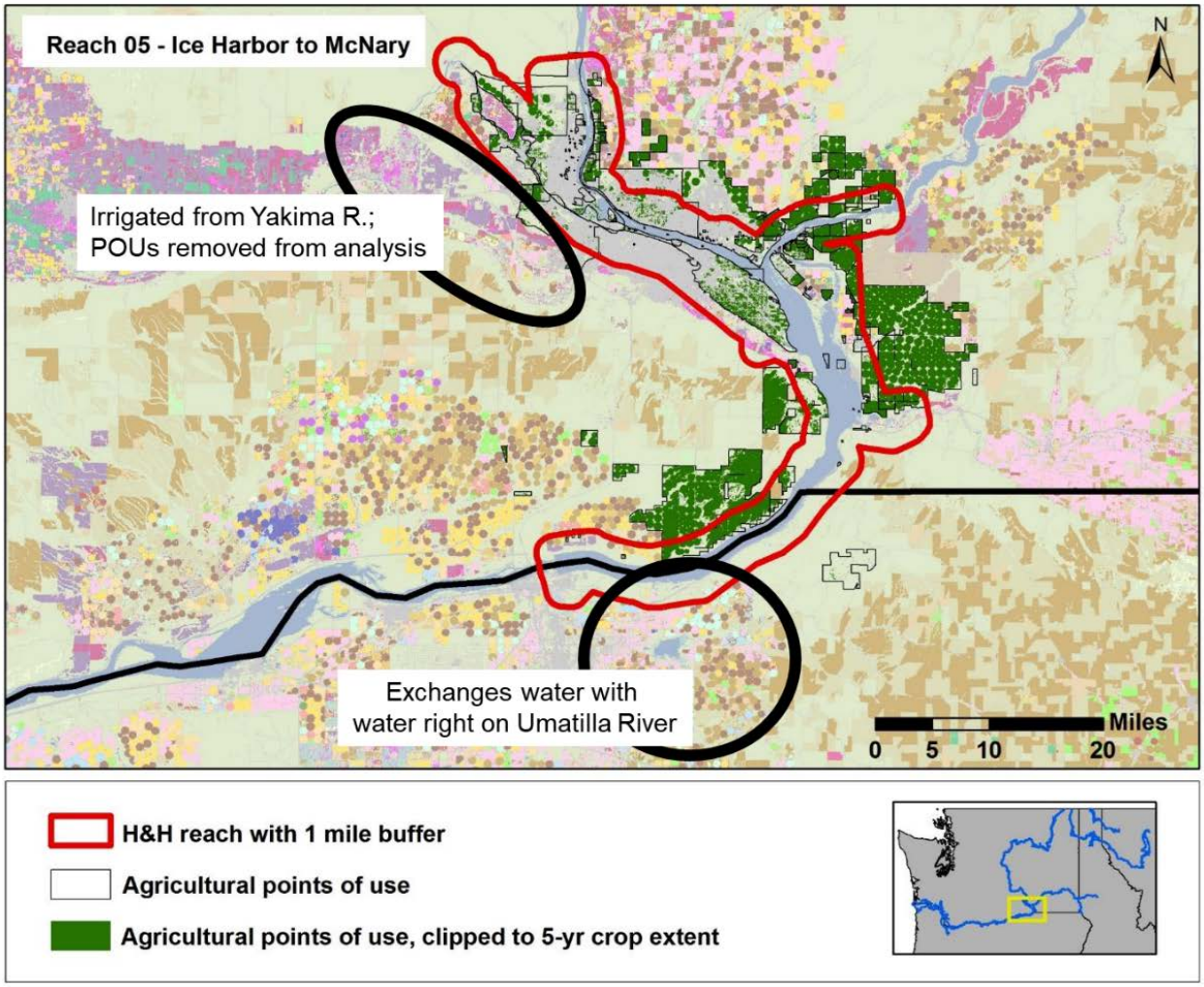

Figure 5. Map of Reach 5 showing points of use before and after clipping, plus excluded areas

H&H Reach 9 includes diversions along the lower Snake and Clearwater rivers that are upstream of the maximum extent of the Lower Granite reservoir and were considered out-of-scope. The extent of this reach was adjusted to more specifically quantify diversions and acres served by water use from the Lower Granite reservoir. PODs upstream of the maximum pool extent were removed from the dataset, as were associated POUs (Figure 6).

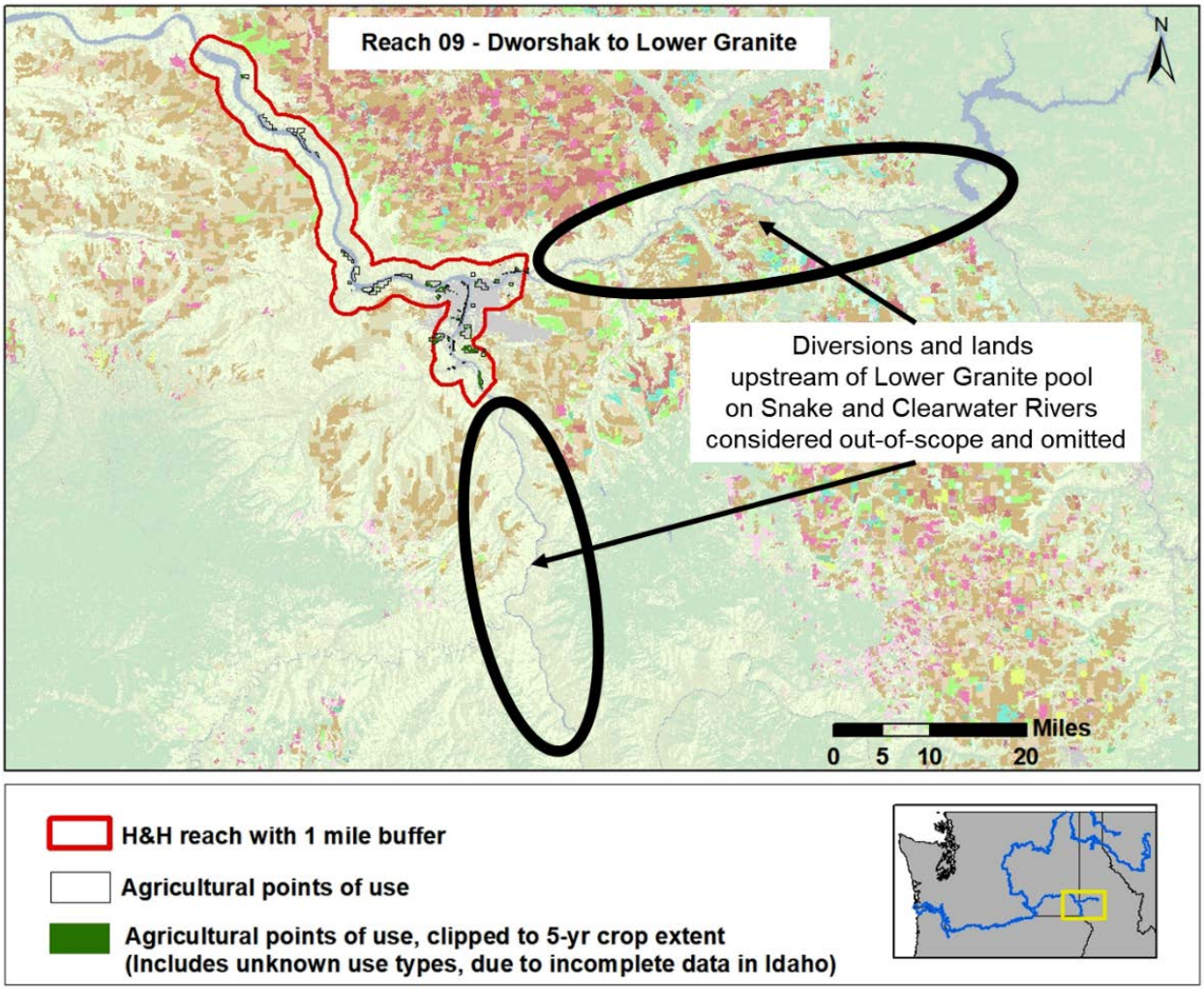

Figure 6. Map of Reach 9 showing points of use along the Lower Granite pool, plus excluded areas

For Reach 21, lands irrigated by the Columbia Basin Project were excluded from the analysis (Figure 7) because water is not directly used from the River. Rather, water is pumped to Banks Lake from Lake Roosevelt and then released to the Columbia Basin Project. While changes to the River might affect Banks Lake pumping, it is not clear whether the lands irrigated from Banks Lake might be affected.

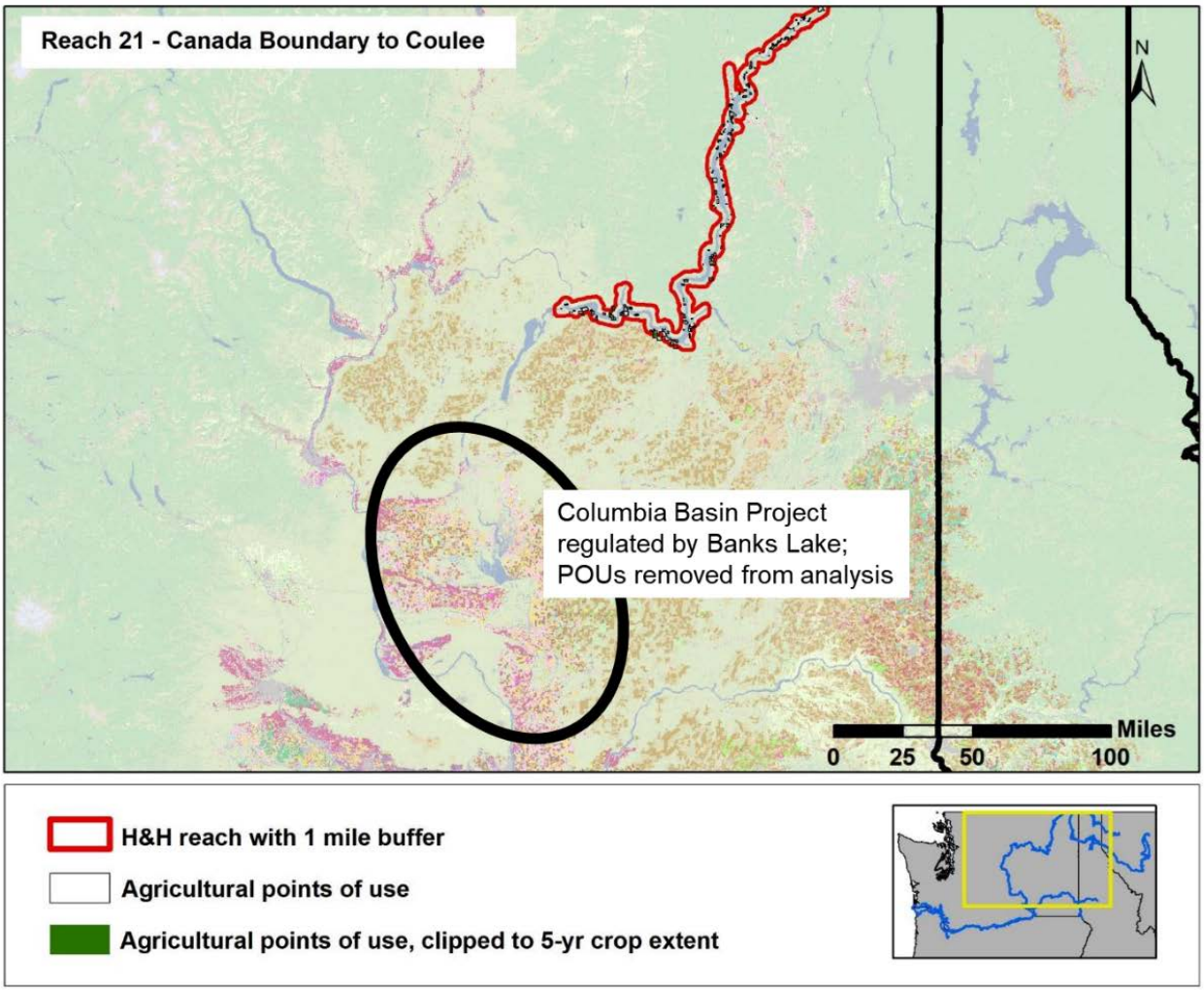

Figure 7. Map of Reach 21 showing POUs and omitted area of the Columbia Basin Project

Missing water rights information prevented many POUs in Montana along the Flathead River from being included in the analysis. The areas were included by adding a single large POU encompassing the missing POUs (POU_ID: MT_3807) to the agricultural group (Figure 8). Because the POU was later clipped to the crop data layer, it is still generally restricted to agricultural lands.

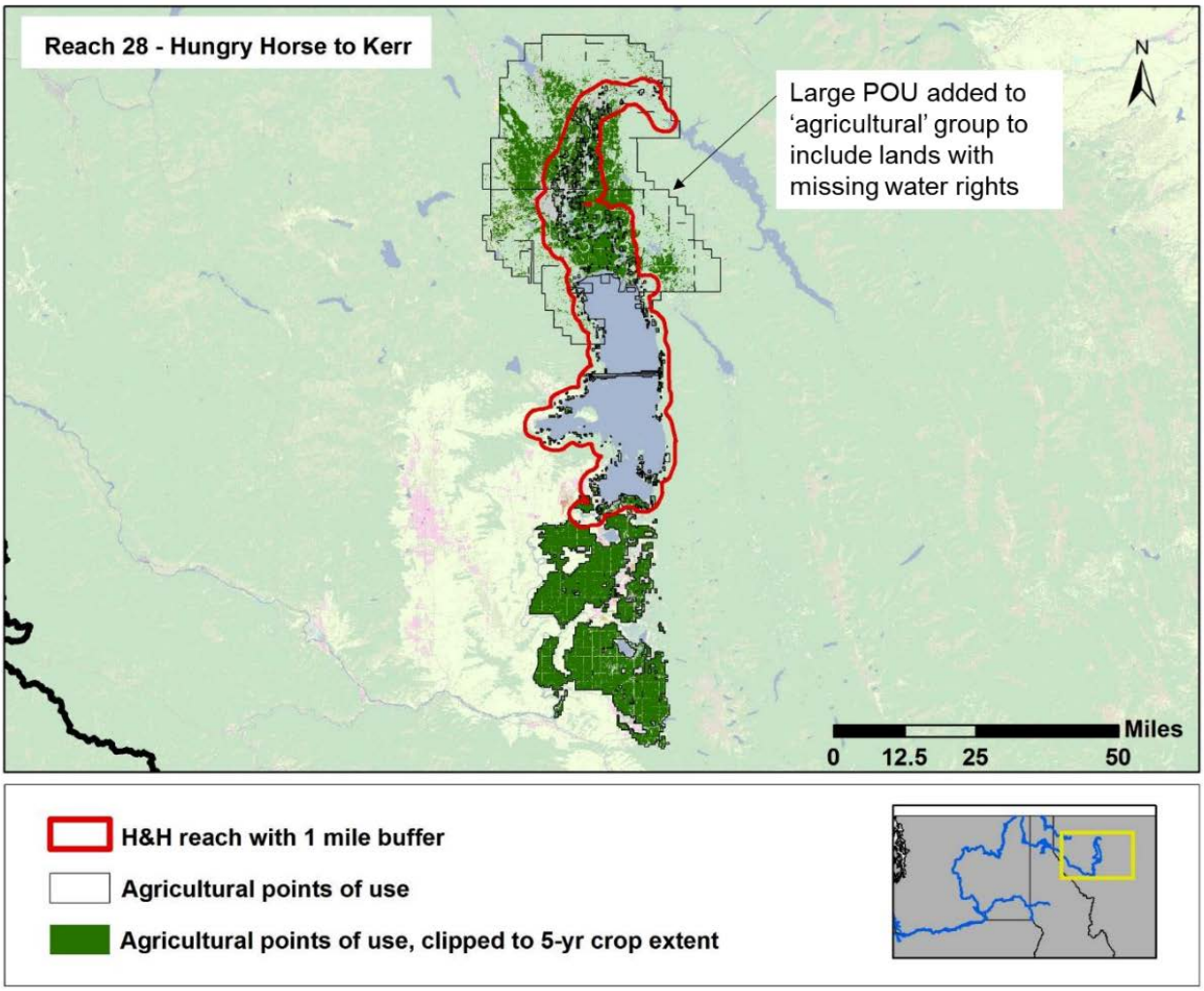

Figure 8. Map of Reach 28 showing points of use (POUs) before (thin black line) and after (green) clipping to the Crop Data Layer

2.5 Other Data Issues and Caveats

Although the best available data were used, missing data introduce a degree of uncertainty that is difficult to quantify. For example, while some areas could not be classified, and were excluded and unaccounted for in the totals, some are overlapped by POUs that do contain the necessary information and are effectively still included. As such, the results should be interpreted with discretion, and the total numbers of PODs and irrigated acres should be treated as estimates, especially in Idaho and Montana.

2.5.1 Points of Diversion (PODs)

For the PODs, water rights data were completely missing for 638 of 22,457 PODs (1, 56, 39, and 542 PODs in Washington, Oregon, Idaho, and Montana, respectively). These diversions could

not be classified by water source or diversion type and could not be linked to POUs and were excluded from analysis. Of the remaining 21,819 PODs, 2,259 were missing H&H river reach data (263 in Oregon; 565 in Idaho; 1,431 in Montana). These PODs are considered out-of-scope because most are located outside of the H&H reach extents, which is probably why they were not assigned to a reach.

Many water rights share diversions but have individual PODs in the water rights data. To more accurately quantify the number of distinct locations where water is diverted, after grouping the data into classes (e.g., agricultural vs. M&I; groundwater and/or wells vs. surface water and/or pumps) PODs for each group within 10 m of each other were merged to single points.

2.5.2 Places of Use (POUs)

For the POUs, 1,563 of the 17,372 POUs were missing water rights data (1,562 throughout Idaho reaches, 1 in Oregon) and could not be included in the analysis. In Idaho, the 1,562 POUs that are missing water rights data make up roughly half of the 3,124 total parcels. These POUs are distributed along the rivers of interest and are not isolated in specific areas.

'Water source' data were blank for 50 of the remaining 15,809 POUs, all located in Montana. These POUs were excluded from groundwater and surface water groupings, but 11 were able to be re-included when water source classifications were merged with 'diversion types' (e.g., merged well and groundwater attributes). All 50 POUs were still able to be used for calculating the irrigated acres of specific crop types.

'Diversion type' data were blank for 1,609 POUs (1,566 in Idaho; 43 in Montana), but 1,523 still had 'water source' data, allowing them to be included in the merged water source and diversion type groupings (e.g., merged well and groundwater attributes). The remaining 43 parcels, all in Montana, that were missing both source and diversion data also happened to be missing reach data and so were not included in any reach summaries.

'Water use' values were present for all of the 15,809 POUs with water rights data, although some values (e.g., 'UNKNOWN') could not be grouped into agricultural or M&I classes.

'Reach' data were blank for 1,725 POUs, preventing them from being linked to H&H river reaches (90 in Oregon; 1,041 in Montana; 594 in Idaho), which often was because the points of diversion were outside the 1-mile buffered H&H reach extents and lacked the water rights information to link them to a reach. These areas are not included in the totals and are considered out-of-scope. Many of the missing Montana lands north of Flathead Lake were added back into the crop acreage analysis by the classification of a large 'industrial' POU also as 'agricultural' (Figure 8).

3 Results

3.1 Diversion Summaries

The Columbia River provides water for diversion to ~10,900 M&I diversions and ~6,100 agricultural diversions (Table 1), with a combined total of ~13,318 points of diversion, which is lower than the sum of agriculture and M&I because ~3,700 diversion locations are used for both. Of the ~13,318 total diversions, ~10,700 are supplied from groundwater and/or wells within 1 mile of the reaches, and ~2,700 are supplied from surface water diversions and/or pumps.

Table 1. Reclassified PODs for each Columbia River reach

H&H Reach	Downstream Boundary	Municipal and Industrial		Agricultural		Total (M&I and Agricultural)	
		Groundwater and/or Wells	Surface Water and/or Pumps	Groundwater and/or Wells	Surface Water and/or Pumps	Groundwater and/or Wells	Surface Water and/or Pumps
30	Bonners Ferry	699	35	104	37	718	68
29	Canada Border	5	2	18	16	21	18
28	Kerr	3,076	767	824	328	3,186	953
27	Thompson Falls	651	49	280	113	726	147
26	Noxon	500	27	132	32	510	53
25	Cabinet Gorge	166	26	42	22	168	41
24	Albeni Falls	174	69	83	93	233	145
23	Box Canyon	279	179	121	98	290	219
22	Boundary	23	4	9	3	24	4
21	Coulee	270	84	165	114	300	150
20	Chief Joseph	49	10	55	48	65	50
19	Wells	252	13	241	112	321	115
18	Rocky Reach	234	38	230	121	322	130
17	Rock Island	275	42	241	89	351	102
16	Wanapum	98	10	79	11	126	18
15	Priest	72	10	76	4	113	14
14	Confluence	21	8	18	22	30	28
9	Lower Granite	71	11	55	30	96	38
8	Little Goose	18	0	15	3	26	3
7	L. Monumental	17	2	17	9	23	9
6	Ice Harbor	28	3	45	25	59	27
5	McNary	1,081	70	936	83	1,346	131
4	John Day	96	14	118	55	170	61

H&H Reach	Downstream Boundary	Municipal and Industrial		Agricultural		Total (M&I and Agricultural)	
		Groundwater and/or Wells	Surface Water and/or Pumps	Groundwater and/or Wells	Surface Water and/or Pumps	Groundwater and/or Wells	Surface Water and/or Pumps
3	The Dalles	47	1	42	4	71	5
2	Bonneville	207	20	122	28	261	38
1	Mouth	981	32	487	59	1,106	89
Total	-	**9,390**	**1,526**	**4,555**	**1,559**	**10,662**	**2,656**

3.2 Irrigated Agricultural Areas

The Columbia River provides irrigation to approximately 673,200 acres of agricultural land (Figure 9; Table 2) within the scope identified (see Section 2.4). Of this area, approximately 561,400 acres are served by only surface water diversions and/or pumps, approximately 47,400 acres are served only by diversions from wells and/or groundwater, and approximately 64,400 acres are served by both.

Table 2. Irrigated acres for each Columbia River reach, defined as lands within POUs that supported crops during at least one year from 2013 to 2017

Reach	2013-2017 Irrigated Acres by Diversion Type and/or Water Source			
	Pump and/or Surface Water	Well and/or Groundwater	Both	Total
30	5	4	0	9
29	4,172	555	111	4,839
28	186,055	536	7,801	194,391
27	1,214	2,956	625	4,795
26	9	4	2	15
25	13	1	0	14
24	105	75	1	182
23	331	211	64	607
22	0	4	0	4
21	1,232	1,571	278	3,081
20	3,123	1,322	1,127	5,572
19	8,500	3,011	5,476	16,987
18	1,727	6,126	1,430	9,283
17	7,227	1,529	2,657	11,412
16	120	6,207	1,220	7,547
15	2,110	3,082	82	5,273

Reach	2013-2017 Irrigated Acres by Diversion Type and/or Water Source			
	Pump and/or Surface Water	Well and/or Groundwater	Both	Total
14	1,213	427	232	1,873
9	27	53	10	90
8	37	125	0	162
7	704	749	1	1,454
6	43,075	3,393	4,869	51,337
5	57,942	6,808	14,724	79,475
4	241,806	6,117	18,840	266,763
3	82	808	45	935
2	380	732	47	1,160
1	4,831	2,084	700	7,615
All*	561,390	47,391	64,437	673,219

*Reaches add up to more than "All" values because they overlap, while "All" merges these areas and only counts them once.

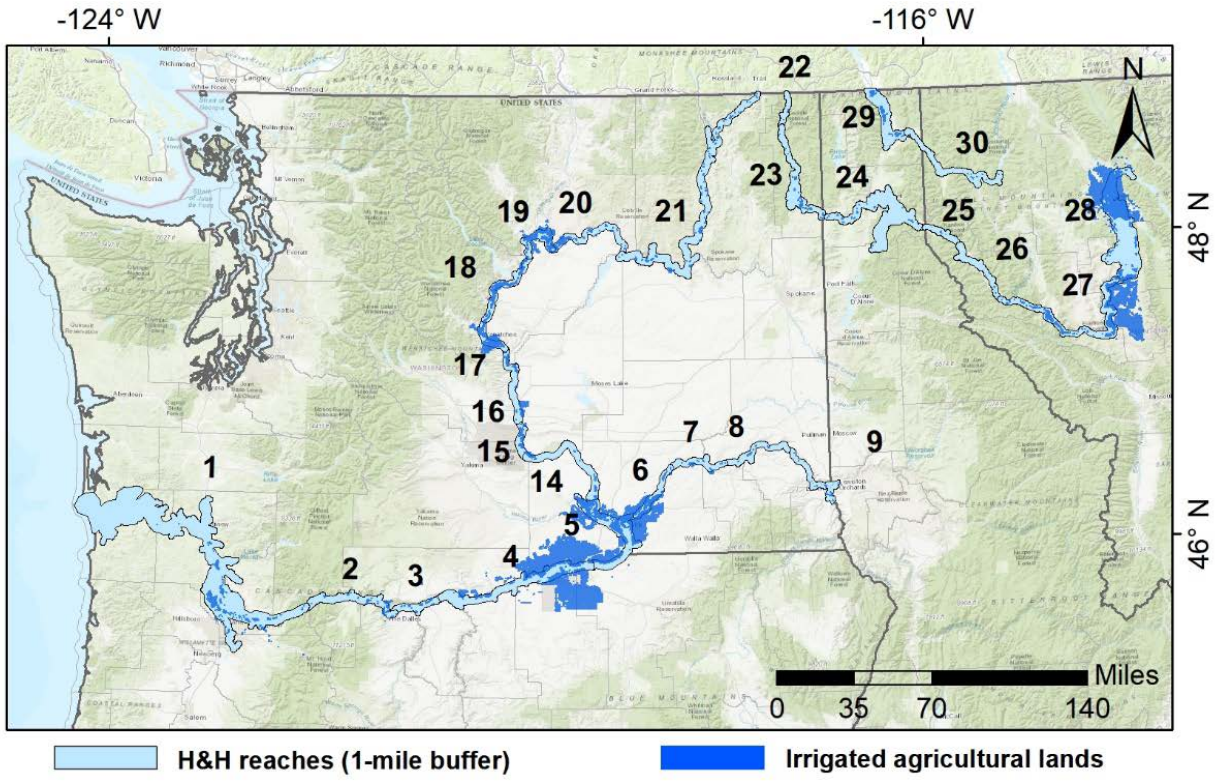

Figure 9. Agricultural lands irrigated from the Columbia River H&H reaches between 2013 and 2017

3.3 Crop Summaries

The acres of different crop types were summarized within the places of use for each reach for the years 2013 to 2017 and on average (Table 3 through Table 8). Of the approximately 673,200 irrigated agricultural acres (Table 2), approximately 541,200 acres exhibited agricultural land cover types in a given year (Table 3) while the remaining acres were classified as non-agricultural despite supporting crops in other years. In individual years, cropped acres range from approximately 495,300 acres (2013; Table 4) to 569,700 acres (2014; Table 5).

Table 3. Five-year average (2013-2017) acres of different crop types within the POUs for each reach

Reach	Irrigated Crop Acres within Agricultural Points of Use (annual average, 2013-2017)																
	Alfalfa, Hay	Apples	Barley	Corn	Fruit	Herbs	Legumes	Nuts	Oil Seed	Onions	Other	Potatoes	Sugar Beets	Trees	Vegetables	Wheat	Total
30	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
29	1,188	0	148	1	0	3	75	0	550	3	175	8	0	0	98	1,762	4,010
28	106,479	7	5,492	1,275	114	203	146	0	5,699	0	703	1,027	0	0	2,055	31,038	154,238
27	2,442	0	37	104	1	218	1	0	5	0	23	5	0	0	4	322	3,159
26	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
25	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
24	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	57
23	203	0	2	0	0	0	0	0	1	0	6	0	0	0	2	7	222
22	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
21	688	3	49	3	1	0	2	0	12	0	17	1	0	3	1	867	1,648
20	237	2,783	1	139	595	2	4	0	50	3	27	2	1	135	3	425	4,405
19	488	10,410	1	129	974	2	7	0	344	1	10	4	0	178	2	742	13,292
18	127	5,247	0	4	834	1	0	0	0	1	3	1	0	10	4	23	6,253
17	94	3,581	0	4	3,730	1	0	0	0	0	4	0	0	92	0	63	7,571
16	580	1,123	2	114	590	23	600	0	3	255	71	17	0	16	11	2,256	5,661
15	350	3,334	0	6	1,195	2	1	0	0	1	1	6	0	160	1	7	5,063
14	68	670	0	14	797	0	11	0	0	1	5	2	0	130	5	11	1,716
9	20	0	1	0	0	0	2	0	0	0	1	0	0	0	0	5	29
8	30	0	4	0	0	0	3	0	1	1	4	0	0	0	1	18	62
7	116	2	4	140	3	0	1	0	6	1	42	0	0	0	21	343	678
6	2,018	11,452	26	5,659	3,622	70	136	0	102	1,135	147	8,239	1	3,734	625	10,196	47,162
5	9,719	9,570	68	11,071	8,344	875	506	0	65	3,533	534	12,641	11	915	1,472	9,057	68,380
4	28,494	4,552	321	37,744	18,497	2,576	2,383	0	457	13,989	12,002	33,121	720	4,291	7,845	45,277	212,268
3	200	30	77	0	171	41	0	0	0	0	16	1	0	8	0	101	646
2	106	9	2	1	595	0	0	0	0	0	1	0	0	39	4	13	769
1	361	3	28	1,264	531	8	169	15	0	6	1,712	230	11	108	365	493	5,306
All	153,455	52,199	6,258	57,595	40,545	4,014	4,049	16	7,294	18,929	15,500	55,302	744	9,811	12,519	102,928	541,158

Table 4. 2013 acres of different crop types within the POUs for each reach

Reach	Irrigated Crop Acres within Agricultural Points of Use – 2013																
	Alfalfa, Hay	Apples	Barley	Corn	Fruit	Herbs	Legumes	Nuts	Oil Seed	Onions	Other	Potatoes	Sugar Beets	Trees	Vegetables	Wheat	Total
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	691	0	327	0	0	0	2	0	817	0	258	0	0	0	8	1,808	3,911
28	82,515	0	7,245	1,080	23	324	28	0	7,140	0	663	1,039	0	0	1,839	31,370	133,265
27	1,713	0	3	109	0	111	0	0	7	0	20	0	0	0	2	229	2,194
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	28	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	33
23	169	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	172
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	623	6	67	1	3	0	1	1	3	0	26	1	0	8	1	1,195	1,936
20	108	2,426	1	217	121	0	2	0	76	13	4	1	0	673	1	739	4,383
19	248	9,324	2	19	275	7	4	0	292	2	3	6	0	859	2	931	11,974
18	137	792	0	6	217	3	0	0	0	3	1	0	0	51	1	5	1,216
17	98	835	0	4	625	3	0	0	0	1	5	1	0	461	0	25	2,058
16	624	1,085	1	160	303	27	196	0	7	45	13	70	0	78	24	2,005	4,637
15	314	3,239	0	3	618	1	0	0	0	0	1	0	0	800	0	1	4,977
14	81	612	0	16	321	0	0	0	0	2	8	4	0	635	6	19	1,704
9	12	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3	18
8	25	0	15	0	0	0	0	0	0	0	2	0	0	0	1	12	57
7	93	2	4	63	0	1	1	0	0	0	20	0	0	0	95	114	394
6	2,714	12,700	11	5,548	5,112	256	178	0	57	1,011	80	7,624	0	414	241	9,595	45,542
5	9,269	8,961	66	9,116	5,800	2,388	248	0	14	3,550	474	12,442	3	2,319	1,040	9,509	65,200
4	23,419	3,345	520	32,456	14,248	2,291	2,436	0	818	13,979	9,389	31,784	18	19,247	3,185	49,098	206,233
3	206	2	106	0	199	3	0	0	0	0	12	0	0	41	0	163	733
2	83	20	1	1	364	0	0	0	0	0	2	0	0	195	7	5	677
1	175	0	9	1,146	707	0	320	21	0	0	1,378	313	4	46	388	584	5,092
All	122,844	43,007	8,379	49,859	28,929	5,415	3,416	23	9,232	18,606	12,342	53,285	26	25,765	6,843	107,296	495,267

Table 5. 2014 acres of different crop types within the POUs for each reach

Reach	Irrigated Crop Acres within Agricultural Points of Use – 2014																
	Alfalfa, Hay	Apples	Barley	Corn	Fruit	Herbs	Legumes	Nuts	Oil Seed	Onions	Other	Potatoes	Sugar Beets	Trees	Vegetables	Wheat	Total
30	8	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	9
29	971	0	224	0	0	10	89	0	580	0	96	0	0	0	12	2,225	4,207
28	129,747	0	6,104	854	513	211	244	0	5,820	0	942	1,150	0	0	2,140	38,588	186,312
27	3,066	0	105	82	2	177	0	0	1	0	49	2	0	0	0	364	3,847
26	11	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	15
25	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
24	54	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	59
23	108	0	0	0	0	0	0	0	1	0	4	0	0	0	0	1	115
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	353	1	25	10	0	0	4	0	46	0	4	0	0	0	1	689	1,134
20	189	2,371	2	224	657	0	0	0	11	1	0	0	1	0	2	39	3,499
19	684	8,735	1	129	1,060	1	1	0	500	1	1	8	0	29	2	515	11,668
18	193	3,882	0	7	681	0	1	0	0	0	1	5	0	0	0	3	4,773
17	86	3,056	0	1	3,350	0	0	0	0	0	1	2	0	0	0	2	6,498
16	760	843	5	176	519	47	766	0	7	210	22	9	0	0	24	2,347	5,736
15	348	3,338	0	1	1,271	0	0	0	0	0	0	25	0	0	1	1	4,986
14	76	581	1	30	968	0	0	0	0	0	0	4	0	1	1	4	1,666
9	14	0	0	0	0	0	1	0	0	0	1	0	0	0	0	3	20
8	14	1	0	0	0	0	0	0	0	0	4	0	0	0	0	19	38
7	40	1	11	83	4	0	0	0	0	1	8	0	0	0	7	267	423
6	1,249	9,424	1	6,604	930	15	26	0	4	311	158	7,264	2	9,356	62	11,320	46,728
5	9,367	8,304	4	13,141	8,039	520	210	0	168	3,323	429	12,960	8	1,935	1,413	7,065	66,887
4	25,984	5,092	101	57,312	16,335	3,319	1,781	0	670	14,556	9,133	35,230	1,480	1,177	9,546	34,514	216,232
3	168	1	143	0	144	2	0	0	0	0	1	0	0	0	1	91	549
2	95	4	2	0	693	0	0	0	0	0	0	0	0	0	12	11	818
1	235	0	64	1,087	685	0	112	31	0	0	1,528	441	4	52	233	461	4,933
All	173,112	45,095	6,790	79,664	35,805	4,304	3,237	31	7,810	18,404	12,395	57,101	1,495	12,553	13,457	98,421	569,673

Table 6. 2015 acres of different crop types within the POUs for each reach

Reach	Irrigated Crop Acres within Agricultural Points of Use – 2015																
	Alfalfa, Hay	Apples	Barley	Corn	Fruit	Herbs	Legumes	Nuts	Oil Seed	Onions	Other	Potatoes	Sugar Beets	Trees	Vegetables	Wheat	Total
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	1,265	0	52	0	0	1	19	0	730	0	18	38	0	0	403	1,609	4,134
28	102,595	16	5,776	1,044	21	129	0	0	4,580	0	350	1,492	0	0	2,129	33,592	151,725
27	2,805	0	34	55	0	157	0	0	11	0	14	14	0	0	10	328	3,427
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	46
23	277	0	4	2	0	0	0	0	0	0	4	0	0	1	4	3	293
22	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
21	600	0	103	1	0	0	2	0	3	0	15	0	0	0	3	805	1,532
20	262	2,959	0	165	639	1	17	0	2	1	72	1	0	0	0	702	4,822
19	540	10,838	0	94	920	0	23	0	683	2	4	2	0	0	1	380	13,488
18	137	6,838	0	2	947	0	0	0	0	0	9	0	0	0	17	26	7,977
17	139	4,912	0	4	3,916	1	0	0	0	0	6	0	0	0	0	45	9,022
16	641	1,149	0	13	587	33	324	0	1	453	295	1	0	0	1	2,053	5,551
15	352	3,486	1	5	1,259	0	0	0	0	0	1	0	0	0	1	25	5,131
14	75	720	0	3	893	0	13	0	0	2	1	2	0	13	15	5	1,743
9	19	0	2	0	0	0	1	0	0	0	0	0	0	0	0	8	30
8	8	0	0	0	0	0	0	0	0	3	0	0	0	0	1	18	31
7	30	3	0	189	0	0	1	0	0	0	168	0	0	0	1	197	591
6	2,155	13,370	81	5,258	5,428	8	109	0	94	1,381	328	9,450	0	0	322	10,001	47,983
5	9,930	9,728	190	11,655	8,019	460	1,019	0	49	4,116	725	13,257	2	12	1,703	8,272	69,136
4	29,994	5,840	228	30,501	19,177	3,564	3,262	0	54	12,305	15,279	34,013	32	2	9,694	50,623	214,568
3	270	38	89	0	171	43	0	0	0	0	1	0	0	0	0	83	696
2	136	5	0	0	652	0	0	0	0	0	0	0	0	2	0	9	804
1	479	0	43	840	168	13	161	11	0	0	1,466	394	4	94	388	1,124	5,184
All	152,102	59,238	6,593	49,790	42,759	4,412	4,951	11	6,204	18,263	18,748	58,652	38	128	14,687	109,821	546,396

Table 7. 2016 acres of different crop types within the POUs for each reach

Reach	Irrigated Crop Acres within Agricultural Points of Use – 2016																
	Alfalfa, Hay	Apples	Barley	Corn	Fruit	Herbs	Legumes	Nuts	Oil Seed	Onions	Other	Potatoes	Sugar Beets	Trees	Vegetables	Wheat	Total
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	1,527	0	34	0	0	4	116	0	425	15	277	0	0	0	66	1,676	4,142
28	109,744	17	6,162	566	8	128	135	0	3,805	0	830	1,226	0	0	2,311	25,807	150,739
27	2,442	0	28	67	0	556	0	0	0	0	4	7	0	0	1	153	3,257
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	94	0	0	0	0	0	2	0	0	0	0	0	0	0	0	15	111
23	312	0	3	0	0	0	1	0	1	0	19	0	0	0	6	25	367
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
21	894	5	45	4	3	1	2	0	2	0	12	1	0	1	0	762	1,732
20	333	3,185	0	30	708	8	0	0	33	0	35	9	4	0	11	97	4,454
19	532	11,488	0	139	1,305	0	6	0	243	0	6	4	0	0	3	924	14,652
18	81	7,385	1	2	1,281	0	0	0	0	0	1	0	0	0	0	12	8,763
17	86	4,784	0	0	5,582	0	0	0	0	0	2	0	0	0	0	195	10,650
16	438	1,314	1	139	812	6	949	0	0	189	21	5	0	0	3	2,718	6,596
15	338	3,238	0	23	1,552	6	3	0	0	4	2	3	0	0	2	3	5,175
14	44	692	0	21	940	0	37	0	0	2	1	0	0	0	0	2	1,739
9	17	0	0	0	0	0	1	0	0	0	1	0	0	0	0	3	22
8	35	0	3	1	0	0	0	0	1	0	12	1	0	0	0	21	74
7	208	2	1	235	9	0	1	0	0	1	12	0	0	0	0	269	739
6	1,699	7,904	20	4,523	3,116	3	206	0	24	1,510	86	8,933	2	8,900	1,191	10,867	48,983
5	10,298	10,912	41	11,245	9,846	506	530	1	18	3,558	514	12,266	34	309	1,510	9,294	70,882
4	29,895	4,111	234	34,958	20,877	1,802	1,288	0	3	14,389	13,753	33,903	2,063	1,022	8,971	45,510	212,778
3	144	64	46	1	145	107	1	0	0	0	37	0	0	0	1	75	621
2	154	15	4	2	647	0	0	0	0	0	0	0	0	0	0	3	827
1	242	11	2	1,464	518	13	54	11	1	23	2,222	0	42	187	611	275	5,676
All	158,903	54,457	6,618	53,357	47,291	3,092	3,333	13	4,554	19,691	17,857	56,358	2,144	10,421	14,691	98,663	551,443

Table 8. 2017 acres of different crop types within the POUs for each reach

Reach	Irrigated Crop Acres within Agricultural Points of Use – 2017																
	Alfalfa, Hay	Apples	Barley	Corn	Fruit	Herbs	Legumes	Nuts	Oil Seed	Onions	Other	Potatoes	Sugar Beets	Trees	Vegetables	Wheat	Total
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	1,485	0	102	6	0	0	150	0	199	0	226	0	0	0	0	1,489	3,658
28	107,794	0	2,171	2,831	5	221	322	0	7,152	0	730	229	0	0	1,856	25,835	149,147
27	2,183	0	15	207	0	87	4	0	7	0	26	0	0	0	6	537	3,072
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	37
23	150	0	2	0	0	0	1	0	3	0	4	0	0	1	0	5	165
22	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
21	971	1	6	1	0	0	1	0	5	0	30	1	0	7	0	883	1,908
20	294	2,972	0	58	847	0	1	0	129	0	22	0	0	0	0	546	4,869
19	434	11,664	2	267	1,310	0	2	0	2	1	39	0	0	0	1	958	14,679
18	85	7,338	0	3	1,042	0	0	0	0	0	1	0	0	0	0	67	8,536
17	62	4,320	0	11	5,176	0	0	1	0	0	6	0	0	0	1	49	9,625
16	435	1,224	3	83	729	2	767	0	0	377	4	0	0	1	3	2,159	5,788
15	397	3,369	0	0	1,274	0	0	0	0	0	1	0	0	0	0	3	5,045
14	65	747	0	3	865	0	2	0	0	1	17	1	0	0	1	27	1,729
9	36	0	1	0	0	0	9	0	0	0	1	0	0	0	0	6	55
8	66	0	1	1	0	0	16	0	3	0	1	0	0	0	2	21	111
7	208	1	2	131	2	0	2	0	28	1	0	0	0	0	0	869	1,243
6	2,274	13,861	18	6,361	3,526	70	163	1	328	1,460	80	7,921	0	0	1,311	9,199	46,574
5	9,730	9,947	37	10,199	10,014	499	523	0	75	3,121	526	12,278	8	0	1,696	11,144	69,795
4	33,176	4,370	524	33,495	21,850	1,901	3,147	0	739	14,715	12,456	30,677	7	7	7,830	46,638	211,531
3	211	45	2	0	194	50	0	0	0	0	28	7	0	0	0	93	629
2	60	2	2	0	619	0	0	0	0	0	1	0	0	0	0	35	720
1	675	1	23	1,785	578	14	197	3	0	7	1,966	1	3	164	208	20	5,645
All	160,313	59,196	2,908	55,304	47,942	2,845	5,306	5	8,671	19,684	16,159	51,115	18	189	12,917	100,438	543,009

4 Conclusions

Water rights data can be combined with satellite-based crop classifications to provide estimates of the acres of land and crops irrigated from different river reaches. PODs are easily associated with specific reaches of the Columbia River because surface water PODs are located along water bodies and groundwater PODs within a mile of the water's edge are typically hydraulically connected to the water body. POUs can be harder to associate with specific river reaches. State water rights data are useful for linking PODs to POUs, allowing them to more easily be associated with specific river reaches, and effectively identifying potential lands irrigated from specific reaches. However, POUs often encompass a larger area (e.g., property and parcel boundaries) than the actual area where water is applied for irrigation. The USDA-NASS CDLs are useful for clipping agricultural POUs to areas that visibly supported crops in recent years. The combined methods use the best available data to determine how specific reaches of a river provide water for diversions, irrigated agricultural lands, and crop production.

The reaches of the Columbia River system encompassed in this analysis (Figure 1) provide water to approximately 10,900 municipal and industrial diversions, approximately 6,100 agricultural diversions, and approximately 13,300 total diversions (about3,700 dual-use diversions). Of the total diversions, approximately 10,700 are supplied from groundwater and/or wells within 1 mile of the reaches and approximately 2,700 are supplied from surface water diversions and/or pumps. Agricultural diversions provided irrigation to approximately 673,200 acres of land that visibly supported crops during at least one year from 2013 to 2017. On average annually, about 541,200 acres were classified as supporting crops, while the remaining approximately 132,000 acres were classified as non-agricultural landcover types (although they supported crops in at least one year, e.g., lands fallowed during crop rotation). Importantly, estimates of diversions, irrigated acres, and crop types are inherently underestimated where incomplete water rights data prevented the association of these data with specific reaches. Water rights data completeness should be considered when interpreting results for specific reaches, e.g., Idaho and Montana.

5 Literature Cited

Parenthetical Reference	Bibliographic Citation
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