Central Coast Water Board – Irrigated Lands Program

Technical Report on Total Nitrogen Applied (TNA) and Irrigation and Nutrient Management Plan (INMP) Summary Report Data

April 4, 2025

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1. Background

In 2021, the Central Coast Regional Water Quality Control Board (Central Coast Water Board) adopted Order R3-2021-0040, the Agricultural Order. The Agricultural Order requires growers to report information annually on the amount of nitrogen applied (A) to all crops (synonymous to commodities) on each ranch and the amount of nitrogen removed (R) when the crops are harvested. The data is reported by growers in the Total Nitrogen Applied (TNA) and Irrigation and Nutrient Management (INMP) Summary reports. The TNA report includes nitrogen applied information and the INMP Summary Report includes nitrogen applied, nitrogen removed, and irrigation information. This information is then used to calculate, at the individual ranch-level, a nitrogen applied minus nitrogen removed (A-R) value, which represents the amount of nitrogen remaining on the ranch and potentially subject to discharge. This information is also used to calculate the nitrogen ratio (A/R) value, which represents the nitrogen use efficiency on the ranch.

An expert agricultural panel will be convened to answer questions stemming from the State Water Board Remand of the Agricultural Order, Order WQ 2023-0081. The expert panel task is to "review the nitrogen applied and nitrogen removed data and evaluate the suitability of expanding the use of the multi-year A/R ratio target values and A-R difference values in our irrigated lands regulatory programs." This technical report summarizes nitrogen applied and removed data from reports submitted by growers to the Central Coast Water Board to assist the expert panel. Some information summarized in this report is also available in the Irrigated Lands Program Dashboard for Grower Reporting and Water Quality.

Nitrate Pollution and Primary Drivers

During years 2012 to 2019, 28% of on-farm domestic wells sampled had mean concentrations that exceeded the Maximum Contaminant Level (MCL) for nitrate (10 mg/L nitrate as nitrogen) (see Agricultural Order Attachment A - Findings Section C.1, par. 9). More current data from the year 2024 indicates that 28% of on-farm domestic wells sampled and 29% of irrigation wells sampled had mean concentrations that exceeded the nitrate MCL. This data is available in the "Groundwater Monitoring" section of the dashboard. TNA and INMP reporting requirements in the Agricultural Order address the primary drivers that cause groundwater nitrogen contamination from irrigated agricultural discharges (see Agricultural Order Attachment A - Findings Section C.1, par. 12). The primary drivers include:

a. Over-application of synthetic fertilizer nitrogen – addressed through fertilizer nitrogen application limits.
b. Amount of nitrogen waste in the field after crops are harvested – addressed through nitrogen discharge targets.
c. Under-utilization of nitrate present in the soil – addressed through requirement to monitor soil nitrate.
d. Under-utilization of nitrate present in irrigation water – addressed through requirement to monitor irrigation water nitrate concentration and volume.
e. Inefficient irrigation that results in the over-application of irrigation water to some or all portions of fields, which causes increased nitrate leaching below the crop root zone and drives additional fertilizer applications – addressed through requirements to estimate crop evapotranspiration and monitor irrigation water volume, and through fertilizer nitrogen targets and nitrogen discharge targets.

2. Central Coast Water Board Nitrogen Application and Removal Data

The Central Coast Water Board has been collecting TNA reports since 2014. Requirements to report TNA were phased in, first based crops identified as high risk for nitrate loading to groundwater and later based on groundwater quality and areas with high groundwater recharge rates. Between 2014 to 2016, approximately 700 ranches representing 117,000 acres (28 percent of enrolled acres) submitted TNA reports. In 2017 the reporting requirement was expanded to approximately 1,700 ranches representing 230,000 acres (55 percent of enrolled acres). The reporting requirement was expanded again in 2021, phasing in nitrogen applied reporting such that by 2023, all ranches were required to submit either TNA or INMP Summary Reports (over 3,900 ranches and 400,000 acres).

The requirement to submit nitrogen removed is also phased in over time. The INMP Summary Report includes nitrogen applied, nitrogen removed, measured irrigation water applied, and crop evapotranspiration values. INMP Summary Reports were required for ranches located in Groundwater Phase 1 area (GWPA 1) for the first time in 2024. Ranches in GWPA 2 will begin reporting their INMP by 2026 and ranches in GWPA 3 by 2028 (see the ILP Compliance Calendar, page 4). Ranches in GWPA 1 are required to submit INMP Summary Report sooner than others because the risk of nitrogen movement to groundwater is the highest in these areas due to high groundwater recharge rates, vulnerable soil, and shallow groundwater (Agricultural Order Attachment A - Findings, Section C.1, par. 1).

2.1 Total Nitrogen Applied Data (TNA Reports)

Summary results of nitrogen applied reported in 2023 TNA reports

3,289 ranches submitted TNA reports in year 2023, representing approximately 323,710 ranch acres (physical acres) and 461,310 crop acres.[1] The majority of the crops reported were lettuce (27%), wine grapes (22%), broccoli (13%), strawberry (6%), cauliflower (6%), spinach (4%), and celery (2%). All other crops represent the remaining 21% of crops grown in the Central Coast region. Table 1 shows the median values of nitrogen applied to the ranch in pounds/ranch-acre, broken down by each category expressed in the A-R formula.[2] This data shows that the majority of nitrogen applications are from conventional fertilizer and a small portion is from irrigation water.

Table 1. Median nitrogen applications for each applied category in the A-R formula that are greater than zero in pounds/ranch-acre for 2023 TNA reports.

Category	Median Nitrogen Applied (lbs/ra-ac)
A_{FER}[3]	138
A_{ORG}[4]	85
A_{COMP}[5]	39
A_{IRR}	5

[1] Crop acres are acres that had at least one crop rotation. For example, one physical acre can have two different crops harvested in a year, which would be counted as two crop-acres.
[2] The letter “A” represents the nitrogen applied to the ranch, and the letter “R” represents the nitrogen removed from the ranch.
[3] Median A_{FER} values are for all ranches that applied conventional fertilizer (2,494 or 91% of total ranches)
[4] Median A_{ORG} values are for all ranches that applied organic fertilizer (639 or 19% of total ranches)
[5] Median A_{COMP} values are for all ranches that applied compost (494 or 15% of total ranches)

Figure 1 below shows the distribution of conventional fertilizer nitrogen applications per crop acre and is available on the TNA Summary Statistics page of the ILP dashboard. The majority of crops (75%) received less than 260 pounds of nitrogen per crop acre from conventional fertilizers. Figure 2 shows the distribution of conventional fertilizer nitrogen applications per crop acre for all crops except wine grapes.

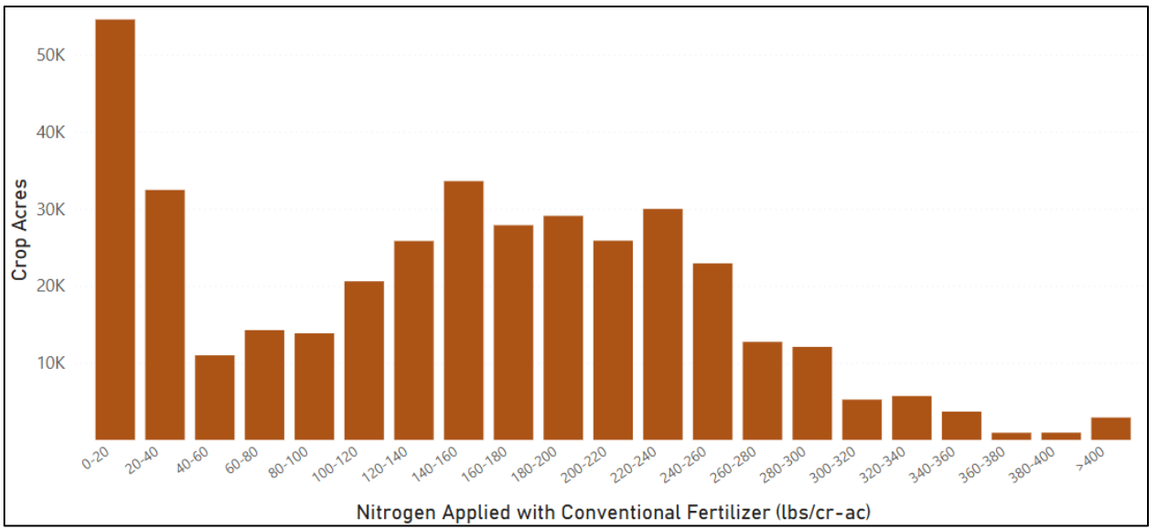

Figure 1. Histogram of nitrogen application rates from 2023 TNA reports. Wine grapes account for the majority of crops that receive between 0-40 pounds of nitrogen per crop acre.

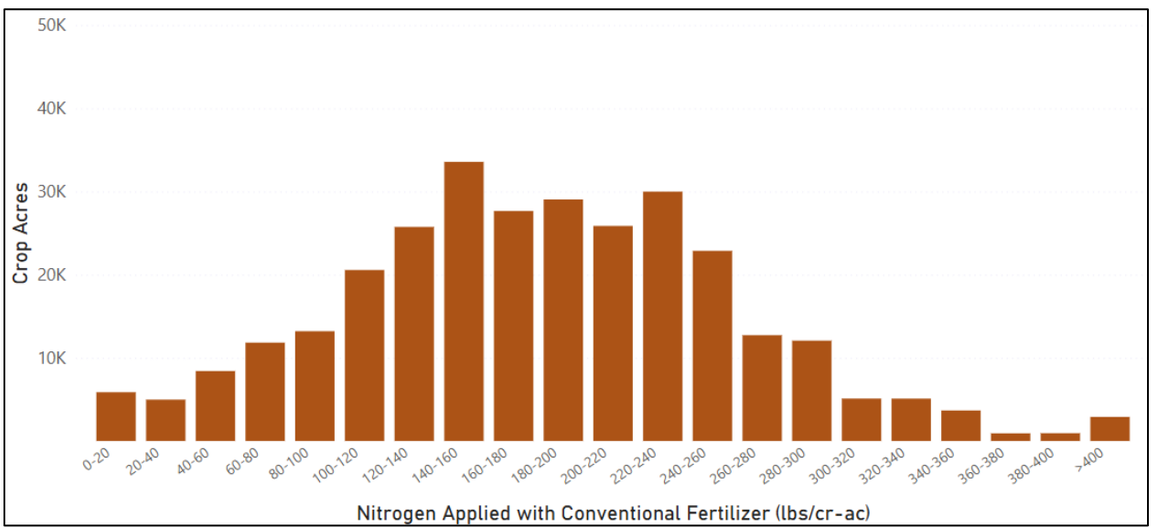

Figure 2. Histogram of nitrogen application rates from 2023 TNA reports, excluding wine grapes.

The Agricultural Order established crop-specific fertilizer nitrogen application targets to address the over-application of synthetic fertilizer.[6] These targets are based on the 90th percentile and 85th percentile of Central Coast region fertilizer nitrogen applications reported between 2014-2019 (Agricultural Order, Table C.1-2) and is used to identify fertilizer nitrogen application outliers (see Agricultural Order, Attachment A - Findings Section C.1, par. 23). In 2023, 92% of crops met the 90th percentile target and 90% of crops met the 85th percentile target.

[6] The California Nitrogen Assessment documented that synthetic nitrogen fertilizer application rates per acre increased an average of 25 percent between 1973 and 2005, along with a shift from field crops to perennials and vegetable crops and the transition to multiple crop plantings within each year. The California Nitrogen Assessment estimated that over half of the nitrogen applied as fertilizer ends up polluting the air and water (Findings, Section C.1, par. 11)… one of the causes of the severe groundwater nitrate contamination observed in groundwater basins in the central coast region is the over-application of synthetic fertilizer nitrogen (Findings, Section C.1, par. 19).

Table 2 below shows the applicable fertilizer nitrogen application targets and the percentage of crops acres meeting each target. For example, 98% of lettuce crop acres met the 90th percentile target (approximately 1160,000 crop acres).

Table 2. Crops meeting fertilizer nitrogen application targets for 2017-2023.

Crop	**90th Percentile Target**	**Percentage Of Crop Acres Meeting 90th Percentile Target**	**85th Percentile Target**	**Percentage Of Crop Acres Meeting 85th Percentile Target**
Broccoli	295	96	280	91
Cauliflower	310	93	285	86
Celery	360	97	330	88
Lettuce	275	98	255	94
Spinach	245	88	230	84
Strawberry	320	94	295	90
All Other Crops	500	99	480	99

A high percentage of all the crops shown in Table 2 are meeting their respective fertilizer nitrogen application targets; Spinach has the lowest compliance rate with 87% of spinach acres meeting the 85th percentile.

Figure 3 below shows the distribution of spinach crop acres compared to the 90th and 85th percentile targets. The red bars (representing 238 ranches and 21,317 crop acres) represent the spinach crop acres that did not meet either of the fertilizer nitrogen application targets and are therefore considered outliers. The yellow bars (representing 86 ranches and 8,103 crop acres) are for spinach ranch acres that met the 90th percentile target but not the 85th percentile target and will be considered outliers after the compliance date of 12/31/2025. The blue bars are spinach ranch acres that meet both fertilizer nitrogen application targets.

In comparison, Figure 4 below shows the distribution of crop acres compared to the California Department of Food and Agriculture (CDFA) fertilizer nitrogen application guidelines for spinach. The red bars represent the spinach crops that received fertilizer nitrogen applications above the recommended range (approximately 8% of spinach crop acres). The yellow bars are crops that received fertilizer nitrogen applications within the recommended range (approximately 66%). The blue bars are crops that received application below the recommended range (approximately 26%).

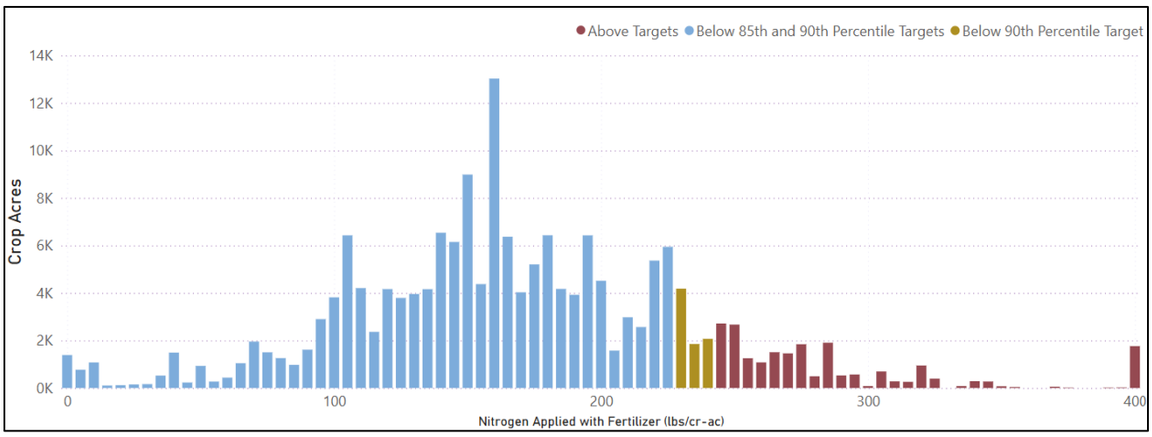

Figure 3. Distribution of crop acres with conventional fertilizer nitrogen application rates for spinach crops in 2023 TNA reports, colored according to compliance with Agricultural Order nitrogen application targets.

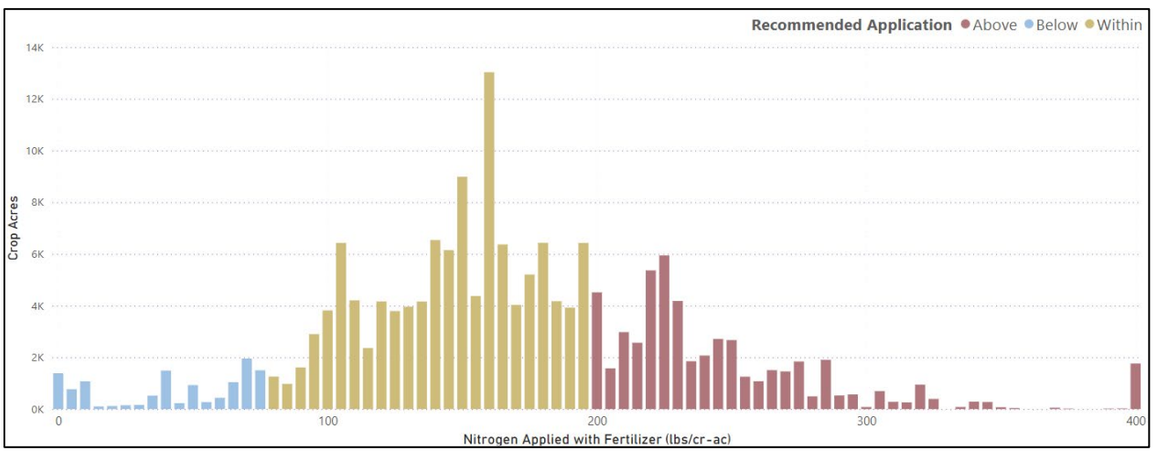

Figure 4. Distribution of crop acres with conventional fertilizer nitrogen application rates for spinach crops in 2023 TNA reports, colored according to compliance with CDFA recommended nitrogen application rates.

These graphics are also available for other crops on the "TNA – Nitrogen Application Targets" page of the dashboard. The figures below show how the fertilizer nitrogen application targets are reasonable compared to the CDFA crop fertilization guidelines. For example, 83.6% of spinach crop acres meet both Agricultural Order fertilizer nitrogen application targets; 6.8% of spinach crop acres meet the fertilizer guidelines.

2.2 Irrigation and Nutrient Management Data (INMP Summary Reports)

The INMP Summary Report dataset is currently smaller compared to the TNA Report dataset because only ranches in GWPA 1 were required to submit an INMP Summary Reports in 2023 for the first time. The ranches in GWPA 1 have a higher median cropping intensity than other ranches in the Central Coast region (1.5 crop acres per ranch acre in GWPA 1 compared to 1.3 crop acre per ranch acre in GWPA 2 and 3). This means that each ranch acre in GWPA 1 reported an average of 1.5 crop rotations in 2023.

Note: the amount of nitrogen discharged from each ranch is calculated for the entire ranch and analyzed in pounds/ranch-acre, consistent with the Nitrogen Discharge Targets (Agricultural Order, Table C.1-3). This is different from how nitrogen application is calculated, which is crop-by-crop and analyzed in pounds/crop-acre.

Summary results from 2023 INMP Summary Reports

340 ranches submitted INMP Summary Reports, representing about 49,000 ranch acres and 80,000 crop acres. The major crops reported include lettuce (31%), wine grapes (13%), broccoli (13%), spinach (10%), strawberry (7%) and cauliflower (5%). All other crops account for the remaining 18%. The median values of nitrogen applied and removed are broken down by category in Table 3 and visualized by crop group in Figure 5.

Table 3. Median nitrogen applications and nitrogen removed from the ranches with values greater than zero in pounds/ranch-acre for 2023 INMP Summary Reports.

Component	Median Nitrogen Value (lbs/ra-ac)
Nitrogen applied (median values)	
A_{FER}[7]	215
A_{ORG}[8]	161
A_{COMP}[9]	35
A_{IRR}	36
Nitrogen removed (median values)	
R_{HARV}	83
R_{SEQ}[10]	10
Nitrogen discharge (median values)	
A-R	202
A/R	3.8

[7] Median A_{FER} values are for all ranches that applied conventional fertilizer (311 or 91% of total ranches)
[8] Median A_{ORG} values are for all ranches that applied organic fertilizer (50 or 15% of total ranches)
[9] Median A_{COMP} values are for all ranches that applied compost (49 or 15% of total ranches)
[10] Median R_{SEQ} values are for all ranches that reported nitrogen sequestration (48 or 14% of total ranches)

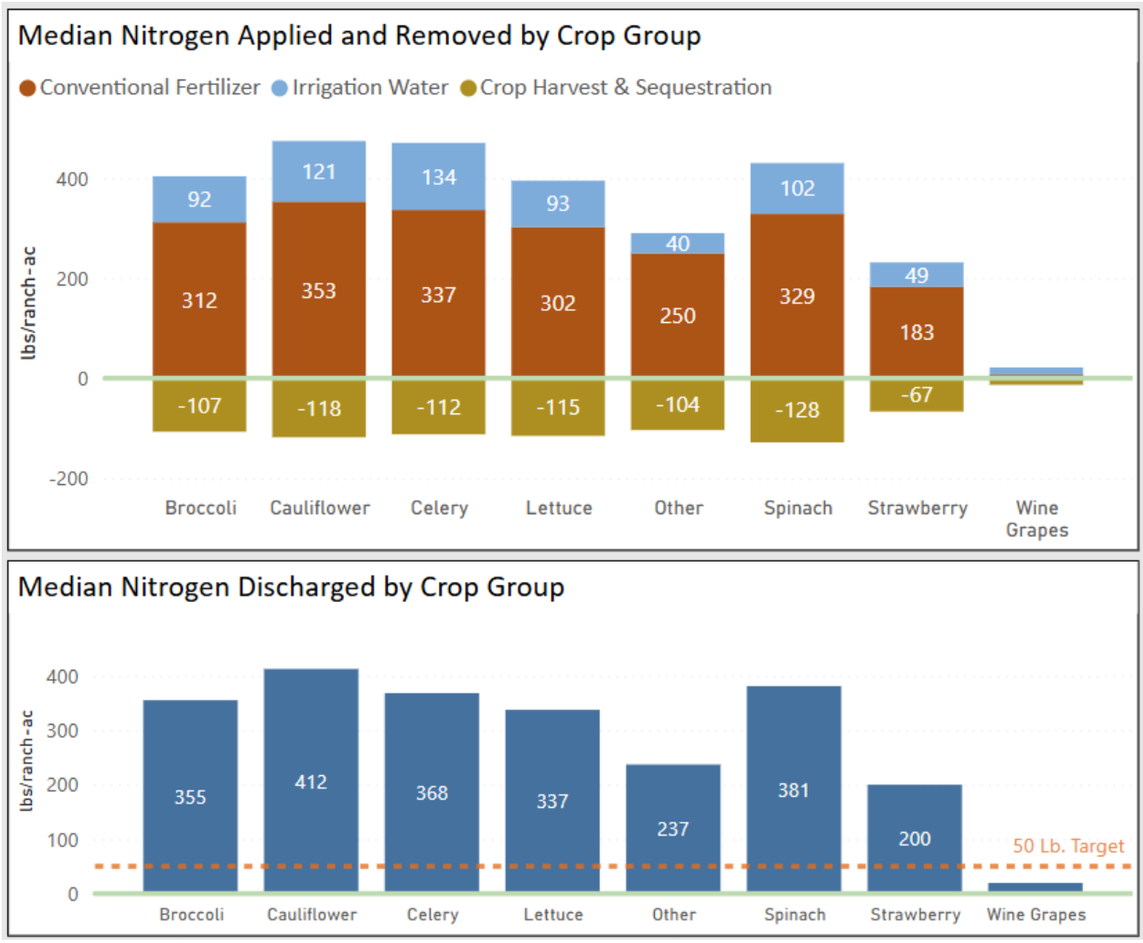

Figure 5. Top Graph: Nitrogen applied (via conventional fertilizer and irrigation water) and nitrogen removed (via crop harvest and sequestration) by crop group in 2023 INMP Summary Reports. Bottom Graph: Nitrogen discharged by crop group. Ranches that grow cauliflower (81 ranches and 4,000 crop acres) have the highest median nitrogen discharged and the highest nitrogen applied with conventional fertilizer.

Compliance with nitrogen discharge targets

In 2023, ranches in GWPA 1 were subject to a nitrogen discharge target of 500 pounds/ranch-acre; approximately 14% (49 ranches) did not meet this target. Table 4 below includes data for reported A and R values compared to the Agricultural Order A-R nitrogen discharge targets (the 2023 target is 500 pounds/ranch-acre, and the targets are lower for subsequent years with the final target of 50 pounds/ranch-acre in 2051). For example, Table 4 shows that based on the grower reported data from 2023, only 21% of the ranches exceed the 400 pounds/ranch-acre target with a compliance date 12/31/2025.

Table 4. Exceedance of Agricultural Order Nitrogen Discharge (A-R) Targets.

A-R Discharge Target	Ranch Acres Exceeding Target	Percentage of Ranch Acres Exceeding Target	Number of Ranches Exceeding Target	Percentage of Ranches Exceeding Target
500	9,598	3.2%	49	13.6%
400	14,414	11.2%	77	21.4%
300	21,582	23.2%	116	32.3%
200	30,569	43.8%	171	47.6%
150	35,105	59.1%	205	57.1%
100	38,262	70.0%	237	66.0%
50	40,696	80.0%	271	75.5%

Figure 6 below shows the distribution of ranch acres compared to the nitrogen discharge targets. Red bars are those acres that did not meet the 2023 nitrogen discharge target, yellow bars are ranch acres that met the 2023 target but are above the final 50 pounds/ranch-acre target, and blue bars show ranch acres meeting the final nitrogen discharge target. Note that wine grapes account for 91% of ranch acres that already meet the final 50 pounds/ranch-acre nitrogen discharge target (shown in blue bars below).

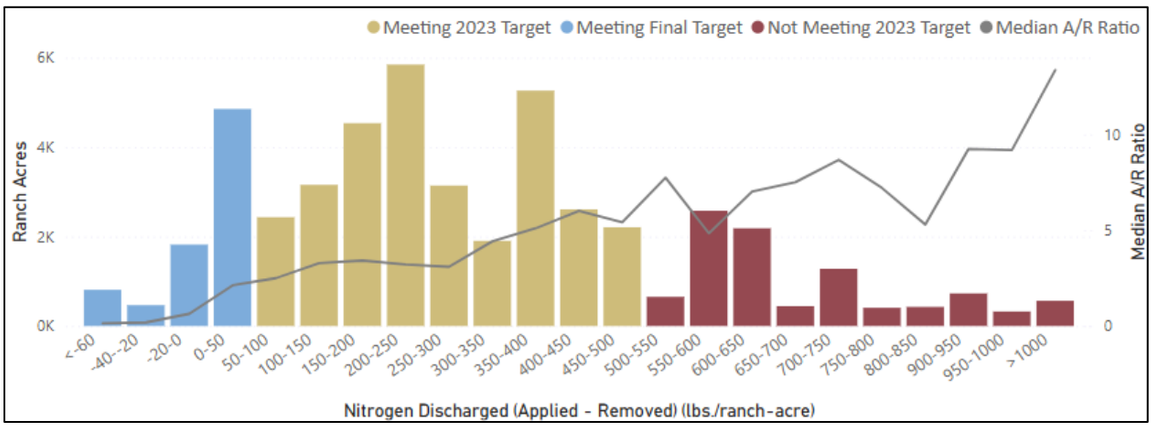

Figure 6. Histogram of ranch acres by range of nitrogen discharged (colored bars and left y-axis) and the median A/R ratio for each nitrogen discharge group (line and right y-axis).

The median A/R value for all ranches reporting the INMP Summary Report in 2023 is 3.8. The median A/R value for ranches exceeding the 500 pounds/ranch-acre nitrogen discharge target is 7.7. The median A/R value for ranches that meet the final 50 pounds/ranch-acre nitrogen discharge target is 1.2. The correlation between calculated A-R and A/R values is generally positive; typically, as a ranch's A-R increases, so does the A/R value. This relationship is demonstrated by the line and right y-axis in figure 6 above.

3. Outliers

3.1 State Water Board Analysis

The State Water Board produced an analysis of available ILRP nitrogen data in November 2024. This report analyzed nitrogen applied and nitrogen removed from ranches with values reported to the Central Valley Water Board between 2020 to 2022 and uses an interquartile range (IQR) approach to identify A/R outliers. Further discussion of the IQR approach is in Section 4 of this technical report.

3.2 Interquartile Range Analysis of Central Coast Water Board INMP Data

For this section of the technical report and to provide an analysis comparable to the State Water Board's November 2024 report, the interquartile range analysis was used to determine outliers for each crop A-R and A/R values using Central Coast Water Board data. The State Water Board's analysis identifies "outliers" based on the number of ranches, rather than the number of acres. Because the Central Coast Water Board requires ranch level reporting, the Central Coast data can also be used to determine the amount of nitrogen discharged by crop acres, and therefore, the potential magnitude of the impact to water quality at the ranch scale. Nitrogen discharge is typically calculated in pounds/ranch-acre, at the crop level, but is calculated for this section of the report in pounds/crop-acre for consistency with the State Water Board report. See more on this distinction in the Discussion section of this technical report (Section 4).

The analysis below identifies outliers by crop acreage as well as the number of ranches. Figures 7, 8, 9, and 10 below display the number of crop acres and the percentage of crop acres considered to be "outliers" for each main crop group, based on the calculated A/R and A-R values (using the IQR approach). Each graph also includes the number of ranches considered to be "outliers" displayed above each bar.

Based on the IQR outlier analysis, 72 ranches were outliers for A/R and 36 for A-R. The total amount of nitrogen discharged by the A-R outliers is 41,940 pounds of nitrogen over 5,090 crop acres.

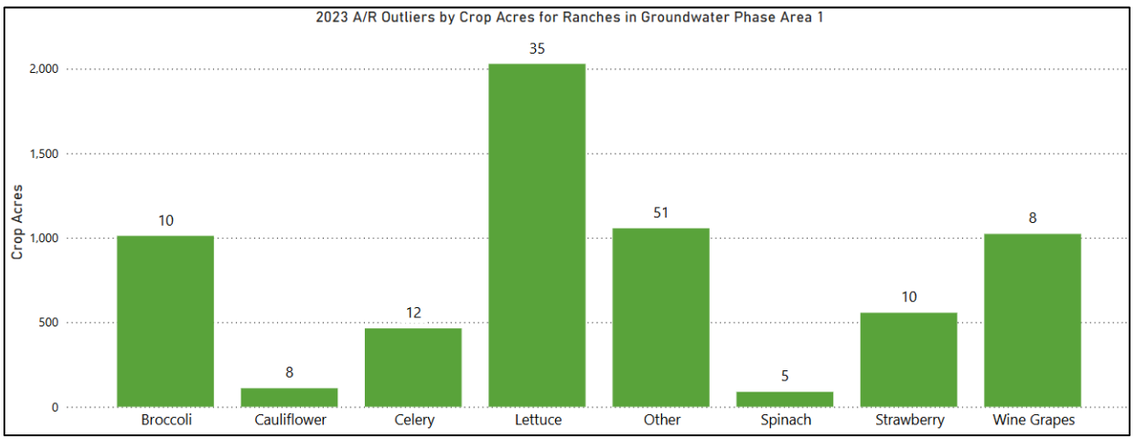

Figure 7. Number of crop acres that are A/R outliers based on the interquartile range outlier method. The number of ranches is included above each bar.

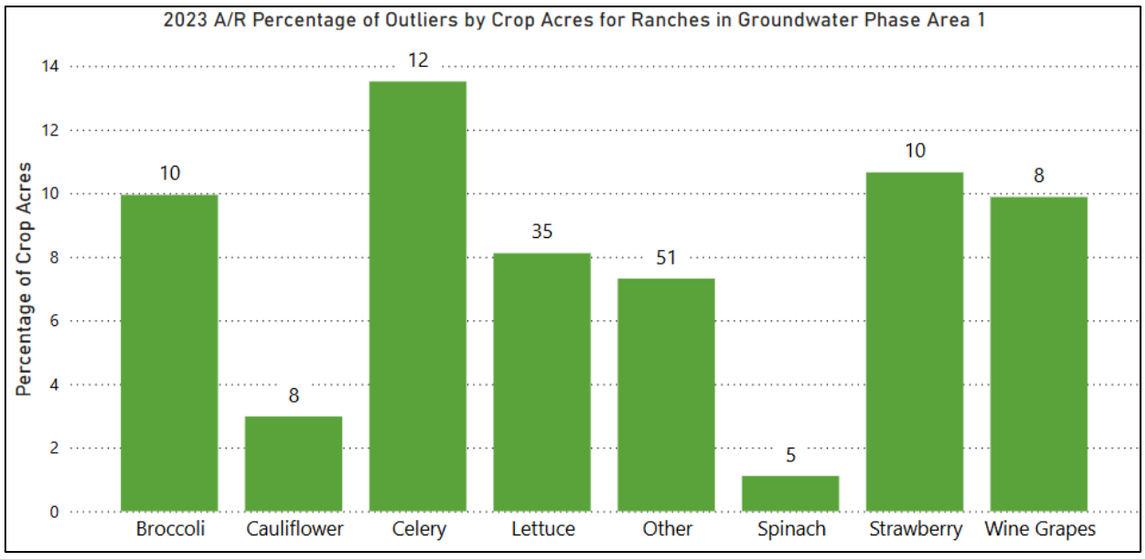

Figure 8. Percentage of crop acres that are A/R outliers based on the interquartile range outlier method. The number of ranches is included above each bar.

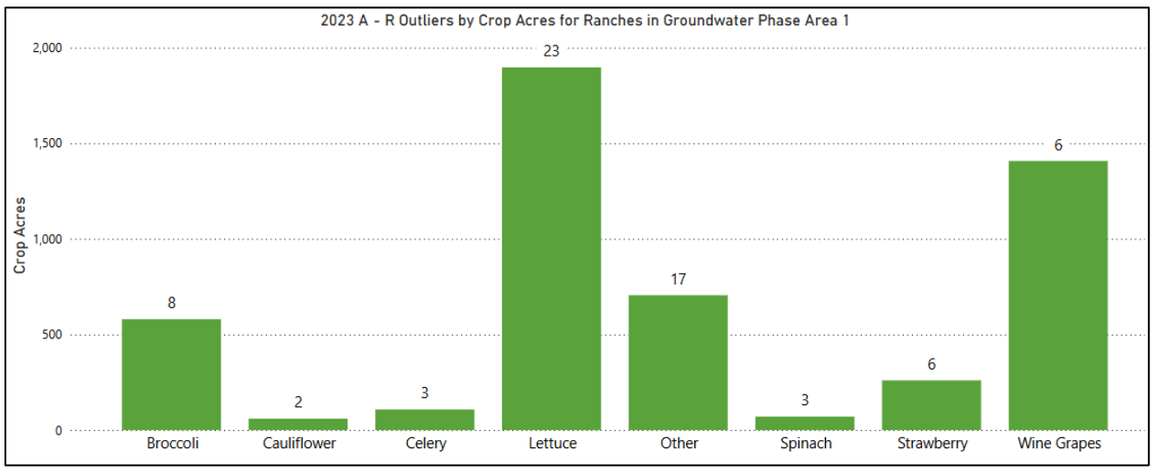

Figure 9. Number of crop acres that are A - R outliers based on the interquartile range outlier method. The number of ranches is included above each bar.

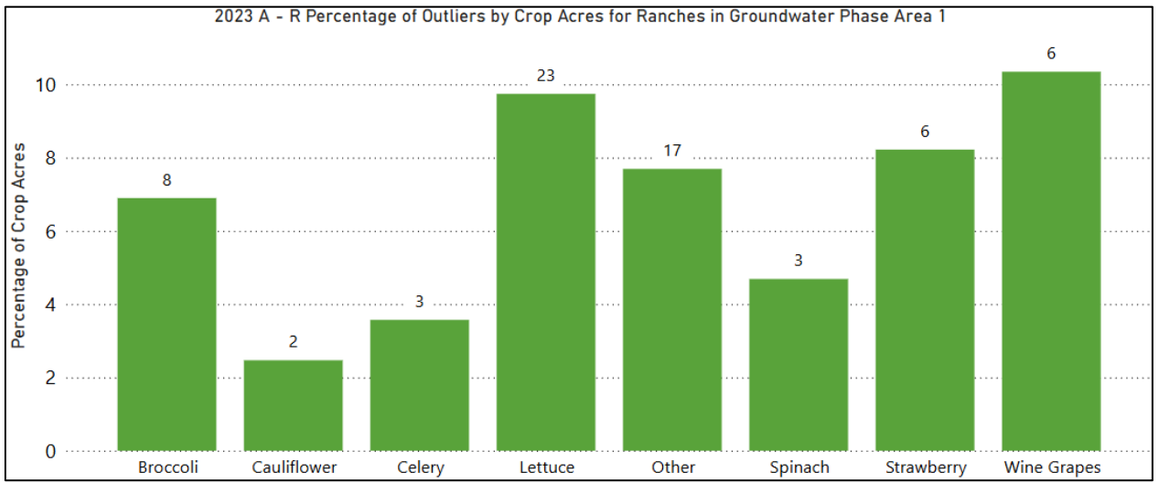

Figure 10. Percentage of crop acres that are A - R outliers based on the interquartile range outlier method. The number of ranches is included above each bar.

3.3. Central Coast Water Board A-R and A/R Data

The Central Valley coalitions released a report for public comment on Crop-Specific Multi-Year Acceptable Ranges of Applied Nitrogen Relative to Nitrogen Removed in October 2024. The purpose of the report is to determine crop-specific acceptable ranges for A/R. The lower end of the range is "informed by scientific literature and recommendations from the University of California Extension specialists and researchers, as well as INMP data

in the case of some annual crops". The average lower end of the range is 1.43 for all crops and the average upper end for all crops is 3.4.

Appendix A Table A.1 provides similar data for Central Coast region crops. A-R and A/R values are calculated for each crop using 2017-2023 TNA data with literature harvest values (representing R3's "lower end") and 2023 INMP data with reported harvest values (representing R3's "upper end"). Literature harvest values and sources are listed in Appendix A Table A.2. The average A/R value for TNA reports with literature harvest values is 1.6 and the average A/R ratio for INMP Summary Reports is 3.5.

4. Discussion

Comparison Limitations

A major data limitation for both the TNA and INMP Summary Reports is grower reporting errors. This is especially important to note for 2023 because over 1,500 ranches submitted reports for the first time. The Central Coast Water Board and third-party program conducted outreach to growers with values significantly outside the predicted ranges and nitrogen discharge targets. However, there are some values that remain unverified and require additional follow-up. Therefore, the analyses in this report and statistics in the dashboard rely on using the median for most values, as it is less skewed by extreme outliers than the average.

Comparing data collected by the Central Coast Water Board to the Central Valley Water Board is challenging because the Central Coast Water Board uses individual ranch reported data to analyze nitrogen discharged from each ranch on an annual basis, while the Central Valley Water Board uses their coalition reported data to analyze nitrogen discharge by crop.[11] This creates differences in how data is analyzed and relies on different assumptions. As mentioned earlier, calculation at a crop level assumes equal distribution of compost and irrigation water to all crops. Calculation at a ranch level rather than crop by crop results in nitrogen discharge values that are comparable between ranches with different management practices and crops. For example, if a ranch has two or three rotations of a crop during the reporting year, their ranch-level discharge will account for how the higher-intensity farming impacts water quality when compared to a ranch with perennials, single-crop rotation ranches, and ranches that grow cover crops between cycles.

Agricultural Order Outlier Approach

The Agricultural Order employs two methods to target outliers: fertilizer nitrogen application targets for growers not yet submitting INMP Summary Reports and nitrogen discharge targets.

Fertilizer nitrogen application targets are like the State Water Board and Central Valley Water Board approach which uses an interquartile range analysis. The Central Coast Water Board fertilizer nitrogen application targets identify which growers are applying more nitrogen to their crops than 85 and 90 percent of other growers. These fertilizer nitrogen application targets are agronomically feasible and are used to address the over-application of synthetic fertilizer.[12]

Nitrogen discharge targets provide an alternative approach that ultimately will achieve water quality objectives. The final nitrogen discharge target (50 pounds/acre/year) is the minimum amount of nitrogen that can be discharged to groundwater that has potential to cause exceedances of the nitrate MCL (see Agricultural Order Attachment A – Findings section C.1, par. 30). By setting the final target at 50 pounds/acre/year, outliers will be identified based on their individual impact on water quality rather than their discharge relative to other growers.

The Central Valley Water Board also uses a 3-year average to identify outliers to account for seasonal variability and changing weather conditions. The Central Coast Water Board uses an annual approach for two reasons. First, because the Central Coast region has many parcels that rotate between operators yearly. This would mean averaging A/R values for operators growing different crops in the same 3 year-cycle. Second, the Central Coast region has many ranches with multiple crop cycles in the same reporting year. For example, broccoli is a crop with multiple crop cycles and accounted for 68,250 crop acres in 2023 (12% of all crop acres). If a broccoli grower is evaluated based on a 3-year average, that could include up to 9 crop cycles. Using a three-year average would result

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[11] In the Central Coast region, many ranches grow multiple crops on the same ranch with multiple crop rotations during the reporting year. In the Central Valley Region, there are minimal crop rotations and an increase of permanent crops.

[12] Agricultural Order Attachment A – Findings, Section C.1, par. 23: "In establishing the nitrogen application targets and limits, the approach presented in the ESJ Order was considered. The ESJ Order approach involves making comparisons among the population of Dischargers to determine "outliers." The cropspecific application limits established in this Order follow that approach – the 90th percentile of fertilizer nitrogen application for each crop is used to establish the application targets and limits for the top six crops reported in the region."

in wide differences in how water quality impact is evaluated depending on how intensively a ranch is farmed.

To account for the unpredictable nature of farming, the Central Coast Water Board TNA and INMP Summary Reports allow growers to select if their crops produced low or no yield. There is also an optional “explanation” section for nitrogen application and removal decisions. So, information about seasonal variability, weather events and special circumstances that affect a farming operation is provided to the Central Coast Water Board and third-party program staff for review.

5. Resources

This report will be posted to the Irrigated Lands Program website: Irrigated Lands Program (ILP) | Central Coast Regional Water Quality Control Board.

Data from TNA and INMP Summary Reports are summarized in the Central Coast Water Board ILP Dashboard for Grower Reporting and Water Quality (see dashboard pages for TNA and INMP Summary Reporting). Several graphics in this report are available to view and filter on the ILP dashboard.

2024 TNA and INMP Summary Reports are being submitted to the Central Coast Water Board over the next several months and may be incorporated into a future version of this technical report. The data becomes available on the ILP dashboard within several weeks of reports being submitted to the Central Coast Water BOard. The ILP Website Dashboard features data from 2017- present TNA Reports (pages 7-9) and 2023 – present INMP Summary Reports (pages 10-11): Dashboard for Grower Reporting and Water Quality | Central Coast Regional Water Quality Control Board. Additional information in the dashboard includes ILP "Enrollment" which is updated annually in May and "Groundwater Quality" (data on nitrate monitoring for on-farm wells) which is updated annually in the Fall.

Agricultural Order Findings

This report highlights findings from the Agricultural Order Attachment A which can be useful to the expert panel:

- Findings on A/R ratios: Section A, par. 260d (page 80)
- Primary drivers of nitrogen pollution: Section C.1., Section, Par. 12 (page 141)
- Fertilizer nitrogen application targets: Section C.1., Par. 17 – 24 (page 143)
- Basis for final nitrogen discharge limit: Section C.1., Par. 29 – 33 (page 149)
- Compost and organic fertilizer discount factors: Section C.1., Par. 39 – 44 (page 151)
- Nitrogen scavenging credits: Section C.1., Par. 45 - 50 (page153)

Online Guides

The ILP webpage on TNA and INMP reporting hosts guides, instructions and tools in multiple languages to assist growers and consultants with reporting. This includes:

- INMP reporting instructions
- Crop nitrogen removal conversion coefficient standard protocols
- INMP exemptions technical report approval process

Additional online guides:

- California Crop Fertilization Guidelines
- Agricultural Order research and publications by Eric Brennan (Agricultural Research Service)

Appendix A

Table A.1. Crop specific A-R and A/R

This table calculates A-R and A/R values using 2017-2023 TNA reports and 2023 INMP Summary Reports. Each crop type reported on TNA and INMP Summary Reports is included unless the crop is reported on 3 or fewer total reports or less than 10 acres total. These crops are grouped together as “Other”. Crops that are not represented in the 2023 INMP dataset will have blank values for the INMP report columns. Literature removal value sources are detailed in Table A.2.

Crop	Median Estimated A-R Discharge from Literature Values (lbs/ra-ac)	Median A-R Discharge from INMP Reports (lbs/ra-ac)	Median Estimated A/R Ratio from Literature Values (lbs/ra-ac)	Median A/R Ratio from INMP Reports (lbs/ra-ac)	Total TNA Report Acres	Total INMP Summary Report Acres
Alfalfa	75	170	1.5	2.4	2129	38
Amaranth	-4	102	1.0	1.7	90	1
Anise	189	306	2.3	4.6	917	20
Apples	-54		0.3		3074	
Apricots	-81	-43	0.2	0.0	526	101
Artichoke, Annual	191		2.3		21371	
Artichoke, Perennial	127		1.8		4944	
Artichoke, Seed	118		1.7		637	
Arugula	177	138	2.1	3.0	13413	487
Arugula, Baby	213		2.3		4271	
Arugula, Wild	227	226	2.6	2.8	10242	1100
Asparagus	142	242	2.1	3.4	2719	25
Avocados	-41	1	0.5	0.4	16797	46
Basil	61		1.5		79	
Beans	63	203	1.5	4.2	9784	219
Beans, dry	-3	67	1.0	1.2	3338	82
Beans, Lima	88	147	1.6	2.2	1195	79
Beans, Seed	94	179	1.7	2.3	2274	127
Beet	79	237	1.6	4.0	5523	308
Blackberry	53	160	1.5	4.1	7285	268
Blueberry	14	11	1.2	10.9	1341	8
Bok Choy	131	175	1.7	2.7	4778	199

Crop	Median Estimated A-R Discharge from Literature Values (lbs/ra-ac)	Median A-R Discharge from INMP Reports (lbs/ra-ac)	Median Estimated A/R Ratio from Literature Values (lbs/ra-ac)	Median A/R Ratio from INMP Reports (lbs/ra-ac)	Total TNA Report Acres	Total INMP Summary Report Acres
Bok Choy, Baby	141	275	1.7	3.1	1799	108
Boysenberry	-55		0.4		44	
Broccolette	245	325	2.5	4.8	14110	544
Broccoli	182	235	2.1	3.5	443454	10005
Broccoli (Fall/Winter)	116	231	1.7	2.4	2437	21
Broccoli (Spring/Summer)	104	264	1.7	3.6	4540	128
Broccoli Rabe	191	676	2.1	5.7	20827	271
Broccoli, Seed	90	-6	1.7	1.0	1003	42
Broccolini	189	325	2.1	5.6	19219	170
Brussels Sprouts	151	240	1.9	3.4	46781	446
Cabbage	147	256	1.8	3.3	31425	721
Cabbage Green	207	175	2.2	2.1	17428	1051
Cabbage Red	182	170	2.0	2.0	2948	132
Cabbage, Chinese	107	160	1.6	2.4	2001	38
Cabbage, Napa	140	119	1.7	2.0	10090	99
Cabbage, Savoy	261	323	2.4	2.8	1762	11
Carrots	-26	139	0.8	2.6	116	50
Carrots, Baby	163	289	2.1	3.1	690	218
Carrots, Full-Sized	114	233	1.9	3.2	41474	609
Cauliflower	191	253	2.1	3.5	214894	3614
Cauliflower (Fall/Winter)	91	192	1.5	2.2	2571	64
Cauliflower (Spring/Summer)	94	297	1.6	4.8	1971	23
Cauliflower, Seed	163		2.0		746	
Celeriac	13		1.0		125	
Celery	170	241	1.9	3.3	103735	3434
Chard, Green	100	118	1.7	3.0	2758	10
Chard, Red	90	118	1.8	3.0	1752	6
Chard, Swiss	153	176	2.1	2.0	3542	63
Cherimoya	-20		0.8		172	

Crop	Median Estimated A-R Discharge from Literature Values (lbs/ra-ac)	Median A-R Discharge from INMP Reports (lbs/ra-ac)	Median Estimated A/R Ratio from Literature Values (lbs/ra-ac)	Median A/R Ratio from INMP Reports (lbs/ra-ac)	Total TNA Report Acres	Total INMP Summary Report Acres
Cherry	-17	-62	0.8	0.6	2009	53
Chicory	189		1.9		1132	
Chile	104		1.6		199	
Chinese Greens (A Choy)	-47	458	0.6		50	1
Chinese Greens (Bok Choy)	-39	194	0.7	3.1	275	9
Chinese Greens (Bok Choy, Baby)	-53	173	0.6	8.3	170	8
Chinese Greens (Gai Choy)	-43	173	0.6	2.8	472	10
Chinese Greens (Gai Lan)	-90	60	0.1	2.5	381	1
Chinese Greens (On Choy)	-34	280	0.8	1.7	123	3
Chinese Greens (Shanghai Bok Choy)	-28	458	0.7		666	1
Chinese Greens (Snow Pea Tips)	-115	33	0.3	8.3	338	0
Chinese Greens (Tong Ho)	-40	194	0.6	8.3	162	10
Chinese Greens (Yam Leaves)	-37	38	0.8	0.1	144	3
Chinese Greens (Yu Choy)	-53	215	0.5	3.1	207	4
Chives	-33		0.8		58	
Cilantro	164	234	2.0	3.5	36922	1611
Cilantro, Bunch	128	184	1.7	2.3	3317	255
Collard Greens	72	242	1.6	3.4	704	35
Corn	90		1.9		2808	
Corn - Sweet	65	11	1.5	1.2	2998	31
Cover Crop, Legume (Irrigated)	51	130	1.4	2.9	5820	13
Cover Crop, Legume (Non-Irrigated)	77		1.4		4258	
Cover Crop, Non-Legume (Irrigated)	151	424	1.9	6.4	11275	31
Cover Crop, Non-Legume (Non-Irrigated)	149	648	1.9	5.5	11871	116
Cover Crop, RSCAVENGE (Non-Irrigated)	123		1.7		69	
Cress	108	197	1.7	2.7	388	4
Cucumbers	-22	51	0.8	2.0	1004	46

Crop	Median Estimated A-R Discharge from Literature Values (lbs/ra-ac)	Median A-R Discharge from INMP Reports (lbs/ra-ac)	Median Estimated A/R Ratio from Literature Values (lbs/ra-ac)	Median A/R Ratio from INMP Reports (lbs/ra-ac)	Total TNA Report Acres	Total INMP Summary Report Acres
Daikon	90		1.8		71	
Dandelion Greens	55		1.4		251	
Dill	155	173	2.1	4.1	277	2
Eggplant	-45		0.8		35	
Endive	110	119	1.6	2.0	1752	176
Escarole	78	113	1.4	1.9	588	27
Fennel	165	339	1.9	4.6	6263	62
Flowers	252	133	2.7	4.1	5942	22
Frisee	176	383	2.2	5.3	1577	96
Garlic	123	190	1.9	2.5	10643	676
Grapes - Table	-78		0.1		318	
Grapes - Wine	-80	0	0.1	0.6	160362	11085
Greenhouse Flowers	-88		0.5		133	
Hemp	7		1.1		370	
Herb Savory	-1	345	1.0	4.4	37	6
Jalapeno	7		1.0		720	
Kale	120	200	1.8	2.6	11170	171
Kale (multiple cuttings)	125	133	1.8	1.8	1738	85
Kale, Baby	220	653	2.5	7.1	10610	102
Kale, Baby (multiple cuttings)	160	179	2.0	2.0	545	143
Kohlrabi	188	289	2.0	3.1	1177	119
Leek	90	140	1.6	3.8	4001	152
Lemons	-29		0.6		9225	
Lettuce, Baby	217	239	2.5	3.1	31960	872
Lettuce, Baby (Fall/Winter)	28		1.3		278	
Lettuce, Baby (Spring/Summer)	92		2.0		932	
Lettuce, Head	190	261	2.1	3.4	267001	4342
Lettuce, Head (Fall/Winter)	102	297	1.3	4.8	651	84
Lettuce, Head (Spring/Summer)	113		1.8		3949	

Crop	Median Estimated A-R Discharge from Literature Values (lbs/ra-ac)	Median A-R Discharge from INMP Reports (lbs/ra-ac)	Median Estimated A/R Ratio from Literature Values (lbs/ra-ac)	Median A/R Ratio from INMP Reports (lbs/ra-ac)	Total TNA Report Acres	Total INMP Summary Report Acres
Lettuce, Iceberg	187	233	2.2	3.5	85899	3253
Lettuce, Iceberg (Fall/Winter)	136		1.7		782	
Lettuce, Iceberg (Spring/Summer)	152	262	2.0	2.7	6101	307
Lettuce, Leaf	188	217	2.1	2.7	108131	2665
Lettuce, Leaf (Fall/Winter)	128		1.5		534	
Lettuce, Leaf (Spring/Summer)	174	424	1.9	6.4	2200	13
Lettuce, Romaine	186	229	2.1	3.2	321379	7302
Lettuce, Romaine (Fall/Winter)	74	297	1.5	4.8	3080	28
Lettuce, Romaine (Spring/Summer)	140	231	1.9	2.7	11083	399
Lettuce, Romaine Hearts	226	246	2.3	3.5	91217	2704
Lettuce, Romaine Hearts (Fall/Winter)	54		1.3		446	
Lettuce, Romaine Hearts (Spring/Summer)	156		1.8		777	
Lime	1		1.0		218	
Mache	190		2.4		151	
Melon	-55		0.8		542	
Melon, Cantaloupe	-6		0.6		30	
Melon, Watermelon	-4		0.8		245	
Mint	-85	-122	0.4	19.8	11	7
Mixed Greens	222		2.4		7455	
Mixed Greens, Baby	263	357	2.4	3.4	5098	35
Mizuna	219	383	2.4	3.5	1488	90
Monstera	122		1.8		12	
Mustard	69	242	1.7	3.4	1173	10
Mustard, Baby	228	429	2.5	4.3	6788	375
Nursery Perennials	201		3.0		80	
Nursery Shrubs	128		2.4		154	
Nursery Trees	100	3	2.1		59	9
Oat Hay	103		1.6		1839	

Crop	Median Estimated A-R Discharge from Literature Values (lbs/ra-ac)	Median A-R Discharge from INMP Reports (lbs/ra-ac)	Median Estimated A/R Ratio from Literature Values (lbs/ra-ac)	Median A/R Ratio from INMP Reports (lbs/ra-ac)	Total TNA Report Acres	Total INMP Summary Report Acres
Olives	-93	11	0.0		4268	4
Onions, dry	118	111	1.8	1.8	10507	877
Onions, Green	62	4	1.4	1.2	3474	1
Oranges	-8		0.9		135	
Orchids	37		1.4		449	
Other	384	139	5.1	2.2	4730	241
Parsley	141	179	1.9	2.5	4750	197
Parsnip	-84		0.3		99	
Peaches	-61		0.3		32	
Pears	-93		0.2		19	
Peas, Seed	140	123	1.8	1.8	5381	59
Peas, Snap or Sugar	165	155	2.0	2.4	26622	615
Peppers, Bell	2	78	1.0	4.2	2223	49
Peppers, Bell, Multiple Harvest Variety	105		2.0		12077	
Peppers, Bell, Single Harvest Variety	117	357	1.9	3.4	2968	130
Peppers, Chili	54	190	1.5	2.2	4863	137
Pimiento	138	357	2.0	3.4	726	5
Pistachios	24		1.6		1672	
Plums	-77		0.3		13	
Poinsettia	-74		0.5		25	
Potatoes	-28		0.7		564	
Pumpkin	86	202	1.7	4.4	1289	66
Radicchio	64	397	1.4	7.8	2887	17
Radish	89	249	1.8	3.1	4160	136
Rapini	138		1.9		1854	
Raspberry	49	247	1.5	6.0	9574	53
Rosemary	151		2.7		96	
Roses	-53		0.4		53	
Ryegrass, Winter	125	173	1.7	4.1	499	35

Crop	Median Estimated A-R Discharge from Literature Values (lbs/ra-ac)	Median A-R Discharge from INMP Reports (lbs/ra-ac)	Median Estimated A/R Ratio from Literature Values (lbs/ra-ac)	Median A/R Ratio from INMP Reports (lbs/ra-ac)	Total TNA Report Acres	Total INMP Summary Report Acres
Seed Crops	107	70	1.9	17.9	4129	19
Shallots	46		1.3		619	
Sorrel	354		5.1		32	
Spinach, Baby	200	325	2.3	4.5	108402	3758
Spinach, Baby (multiple cuttings)	203	191	2.4	2.2	566	1081
Spinach, Baby (multiple cutttings)	181		2.2		11224	
Spinach, Bunch	176	293	2.0	3.5	33978	947
Spinach, Bunch (multiple cuttings)	250		2.6		2782	
Spinach, Clip	230	138	2.4	1.9	42398	2070
Spinach, Clip (multiple cuttings)	212	149	2.3	1.8	17013	136
Spring Mix	175	253	2.2	3.5	52948	2001
Spring Mix (multiple cuttings)	200	191	2.5	2.2	9899	675
Spring Mix, Baby	176	357	2.0	3.4	16879	650
Spring Mix, Baby (multiple cuttings)	109	135	2.0	1.7	2407	101
Sprouts	131		1.7		115	
Squash, Summer	-2	115	0.9	2.4	4871	11
Squash, Winter	-17	40	0.8	1.5	2286	34
Strawberry	53	134	1.4	2.8	59758	3596
Strawberry, 2nd year	67		1.6		3694	
Strawberry, 2-step program, 1st step	160		2.4		3920	
Strawberry, 2-step program, 2nd step	39		1.5		1256	
Strawberry, Greater than 12-months variety	81	78	1.8	3.7	22112	435
Strawberry, Up to 12-months variety	95	168	1.8	3.5	111290	1401
Tangerines	-7		0.3		108	
Thyme	198		2.7		125	
Tomatillo	-42		0.8		780	
Tomato	93	86	1.9	2.2	16007	367
Turf (sod/grass)	27	136	1.3	2.3	55	229

Crop	Median Estimated A-R Discharge from Literature Values (lbs/ra-ac)	Median A-R Discharge from INMP Reports (lbs/ra-ac)	Median Estimated A/R Ratio from Literature Values (lbs/ra-ac)	Median A/R Ratio from INMP Reports (lbs/ra-ac)	Total TNA Report Acres	Total INMP Summary Report Acres
Turnip	66	275	1.4	3.1	625	70
Walnuts	-93	-62	0.1	0.6	2423	50
Wheat	13		1.1		930	
Zucchini	-42		0.5		2089	

Table A.2. Literature harvest removal values by crop

Crop	Harvest Removal (pounds/crop-acre)[13]
Leaf Lettuce[14]	80
Broccoli[15]	99
Head Lettuce[16]	80
Cauliflower[17]	70
Baby Spinach[18]	55
Spinach[19]	85
Celery[20]	160
Strawberry[21]	100
Baby Lettuce[22]	46
Cabbage[23]	180
Mizuna/Spring Mix[24]	58
Cilantro[25]	57
Bell Pepper[26]	110

[13] The values included in this table represent the high end of the literature range and were those used in the calculations performed for this report. More recent research may indicate higher or lower values which staff may use in future calculations.
[14] Leaf lettuce. Smith and Cahn, 2011. Improving Nitrogen Use Efficiency in Lettuce Production. Proceedings American Society of Agronomy and California Plant Health Association, 2011 Conference, page 42.
[15] Broccoli. Smith and Cahn, 2016. Nitrogen Dynamics of Cole Crop Production: Implications for Fertility Management and Environmental Protection. HORTSCIENCE 51(12):1586–1591. 2016.
[16] Head lettuce. Smith and Cahn, 2011. Improving Nitrogen Use Efficiency in Lettuce Production. Proceedings American Society of Agronomy and California Plant Health Association, 2011 Conference, page 42.
[17] Cauliflower. Smith and Cahn, 2016. Nitrogen Dynamics of Cole Crop Production: Implications for Fertility Management and Environmental Protection. HORTSCIENCE 51(12):1586–1591. 2016.
[18] Baby spinach. Heinrich, A. et al. 2013. Nutrient and Water Use of Fresh Market Spinach. HortTechnology, June 2013 23(3).
[19] Spinach. Smith, R, et al. 2014. Evaluation of N Uptake and Water Use of Leafy Greens Grown in High-Density 80-inch Bed Plantings and Demonstration of Best Management Practices. Final report. FREP Final Report. Contract 12-0362-SA.
[20] Celery. Tim Hartz, Extension Specialist/Agronomist, Department of Plant Sciences. University of California Davis, verbal recommended value research results were pending.
[21] Strawberry. California Strawberry Commission presentation to Central Coast Water Board in 2011, https://www.waterboards.ca.gov/centralcoast/board_info/agendas/2011/march/Item_14/stakeholder_2_ca_strawberry_commission.pdf
[22] Baby lettuce. Smith, R, et al. 2014. Evaluation of N Uptake and Water Use of Leafy Greens Grown in High-Density 80-inch Bed Plantings and Demonstration of Best Management Practices. Final report. FREP Final Report. Contract 12-0362-SA.
[23] Cabbage. Smith and Cahn, 2016. Nitrogen Dynamics of Cole Crop Production: Implications for Fertility Management and Environmental Protection. HORTSCIENCE 51(12):1586–1591. 2016.
[24] Mizuna. Smith, R, et al. 2014. Evaluation of N Uptake and Water Use of Leafy Greens Grown in High-Density 80-inch Bed Plantings and Demonstration of Best Management Practices. Final report. FREP Final Report. Contract 12-0362-SA.
[25] Cilantro. Smith, R, et al. 2014. Evaluation of N Uptake and Water Use of Leafy Greens Grown in High-Density 80-inch Bed Plantings and Demonstration of Best Management Practices. Final report. FREP Final Report. Contract 12-0362-SA
[26] Bell peppers. Tim Hartz, Extension Specialist/Agronomist, Department of Plant Sciences. University of California Davis, presentation http://cemonterey.ucanr.edu/files/85599.pdf

Crop	Harvest Removal (pounds/crop-acre)[13]
Tomato[27]	70
Brussels Sprouts[28]	154
Crops Without Assessed Values (Average)	93

[27] Tomato. Tim Hartz, Extension Specialist/Agronomist, Department of Plant Sciences. University of California Davis, verbal recommendation, research results were pending: Fresh tomatoes value is half the amount removed in processing tomatoes, which is 160 lbs/acre.
[28] Brussels sprouts. Smith. 2015. Salinas Valley Agriculture Highlighting agricultural developments, problems, research, & issues for Central Coast CA. http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=16850 .