Manure applied on frozen soil or snow - what will happen to my nitrogen?

blog-crop-news.extension.umn.edu/2019/01/manure-applied-on-frozen-soil-or-snow.html

By Melissa Wilson, manure management and water quality Extension specialist

It was a tough fall for manure application. In many places of the state it was wet and harvest was delayed. On top of that, winter arrived earlier than it has in the past couple of years. Many people were forced to apply manure on top of frozen soils or even snow. We've gotten a lot of questions about how the nitrogen in the manure will be impacted.

When manure is applied on the surface of frozen soils or on top of snow, we have two concerns. First, it cannot seep into the ground, so if there is any runoff in your fields, it can carry the manure to low spots or away from the field entirely which may cause environmental issues. We have already seen widespread rain in December across southern Minnesota and snow melt in January in many parts of the state. Fields with higher amounts of residue are less likely to have as much runoff as fields with low residue, so this problem may be worse in some fields and not others.

The second problem we have to consider is the ammonia losses. Remember that manure has two main forms of nitrogen: organic-nitrogen and ammonium-nitrogen. When ammonium-nitrogen is on the soil surface instead of being mixed in with the soil, it can volatilize and be lost as ammonia gas. This is mainly driven by chemical and physical factors. While the freezing temperatures slow the reaction down, research suggests it doesn't stop it entirely. Plus, with the freeze thaw cycles we have seen this year, it is difficult to pinpoint how much will be lost as the manure sitting on the surface freezes and thaws, too. This problem is likely to impact all manure types, but especially swine manure since the total nitrogen content is roughly 60 to 80 percent ammonium-nitrogen when applied.

The good news is that with the cooler temperatures, the conversion of ammonium-nitrogen in manure to nitrate-nitrogen form is minimal. We do not expect nitrate leaching or denitrification to be increased because of the conditions in which manure was applied this year. This is because bacteria are responsible for the conversion, and the freezing temperatures minimize their activity in the winter. This could change depending on the kind of spring we have, however.

Unfortunately, we cannot predict exactly how much nitrogen was lost this year if it was applied on frozen soil or snow. Manure nutrient release can vary depending on specific circumstances. Our best guess is to use our guidelines in Table 1. This will help determine the percent of nitrogen available the first year when broadcasting manure with no incorporation (see the second column). The actual amount available may be more or less, however.

My best advice is to keep an eye on your crop this upcoming year and be prepared to sidedress additional nitrogen if the crop is looking deficient. The Minnesota Pollution Control Agency says you can apply an additional 20 percent of total crop N needs above UMN nitrogen guidelines (PDF) if soil conditions or cool weather warrants additional nitrogen application.

Table 1. Nitrogen availability and loss as affected by method of manure application and animal type.

Percent of total nitrogen available for first year crop after application

Animal type	Broadcast incorporated later than 96 hours or not incorporated	Broadcast incorporated in 12-96 hours	Broadcast incorporated in less than 12 hours	Inject - sweep	Inject - knife
Beef	25%	45%	60%	60%	50%
Dairy	20%	40%	55%	55%	50%
Swine	35%	55%	75%	80%	70%
Poultry	45%	55%	70%	--	--

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RESEARCH ARTICLE

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Livestock manure driving stream nitrate

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Abstract Growth and consolidation in the livestock industry in the past 30 years have resulted in more total farm animals being raised on fewer Iowa farms. The effects of this on stream water quality at the landscape scale have largely gone unexplored. The main objective of this work was to quantify the effects on stream nitrate levels of livestock concentration in two western Iowa watersheds relative to seven other nearby watersheds. To achieve this objective, we used data on high-frequency nitrate concentration and stream discharge, commercial nitrogen fertilizer use, and manure-generated nitrogen in each watershed. Our analysis shows much higher stream nitrate in the two watersheds where livestock concentration has been greatest, and little difference in commercial fertilizer inputs with the widespread availability of manure N. Reducing N inputs and better management of manure N, including analysis of crop N availability in soil and manure, can reduce uncertainty regarding fertilization while improving water quality.

Keywords Concentrated livestock · Commercial fertilizer · Flow weighted average · Manure · Nitrate-nitrogen

INTRODUCTION

The state of Iowa, located in the U.S. Midwest, has long been one of the country's leading producers of hogs, cattle, poultry, and eggs. Currently Iowa exceeds all other states in egg and pork production and is fourth in production of feeder cattle (USDA 2018). Iowa has also been a leading producer of both corn (*Zea mays* L.) and soybeans (*Glycine max* [L.] Merr.), frequently topping all other U.S. states in harvested totals of these commodities (Jones et al. 2018a). Co-locating crop production and livestock within the state has created efficiencies of production, transportation, and fertilization.

High yield agriculture, such as that conducted on nearly 70% of Iowa's area (USDA 2018), depends on addition of nitrogen fertilizers. Various forms of fertilizer nitrogen are used throughout the state to enhance crop yields, especially those of corn. Most of this nitrogen is applied as formulations of ammonia/ammonium (NH_3/NH_4^+) and nitrate (NO_3–N) generated from industrial processes, but also animal manures where available. The use of industrially produced nitrogen fertilizers emerged as an important component of U.S. and Iowa agriculture following World War II (Commoner 1977). Before 1945, nearly all nitrogen inputs used to fertilize Iowa corn fields came from legumes such as alfalfa and clovers, and animal waste. However, after this time, the use of inorganic nitrogen fertilizers increased 13-fold from 1945 to 1972 as they quickly became affordable and widely available (Commoner 1977). Livestock, especially cattle, consumed the alfalfa and clover, but commercial fertilizer allowed farmers to forgo hay crops and cattle. This enabled many Iowa farmers to specialize on corn and soybean production (Hendrickson and James 2005). The demand for animal protein, however, continued to increase with world population and increased income levels (Delgado et al. 2001). With fewer farmers wanting or needing livestock, those that continued with livestock production were able to greatly enlarge their operations. This is especially evident in Iowa with hog production. In 1980, 65 000 Iowa farmers raised a total of 13 million hogs; by 2002, the number of hog farmers had dwindled to 10 000, but total hog numbers increased to 14 million (Herriges et al. 2005). This dramatic shift in production resulted in many hogs being concentrated in certain areas of the state and a geographical alignment with buyers, packing houses, feed and equipment suppliers, and haulers (Honeyman and Duffy 2006). Similar scenarios have also played out with cattle and poultry. This agricultural specialization that has occurred in Iowa is consistent with changes that are still occurring worldwide (Liu et al. 2017).

This transition from diverse, multi-species farms to ones specializing in corn and soybean production with a subset of the latter raising concentrated livestock has produced both efficiencies and negative environmental consequences. It has long been known that nitrogen fertilization correlates with stream nitrate in the U.S. Cornbelt (Klepper 1974) with impacts on municipal water supply (Hatfield et al. 2009) and Gulf of Mexico Hypoxia (Rabalais et al. 2002). However, because nitrogen inputs cycle through plant biomass and into and out of soil organic matter (Jackson et al. 2000), and because of the time lag of pollutant transport to streams via groundwater pathways (Van Meter et al. 2017), it is nearly impossible to trace stream nitrate back to commercial fertilizer, animal manure, legumes, or soil organic matter. Hence, many have attempted to gain insights on nitrate sources and pathways using nitrogen budgeting (David et al. 1997; Libra et al. 2004; Jones et al. 2016).

The intensity of crop and livestock production in Iowa has made the state a major contributor to Mississippi River basin nitrate loads (David et al. 2010; Jones et al. 2018a, b). Nitrate loading from Iowa appears to be increasing (Jones et al. 2018a), especially in the Missouri River and its Iowa tributaries (Sprague et al. 2011; Li et al. 2013), and Iowa contributes up to 89% of the annual Missouri River nitrate load even though Iowa areas draining to the Missouri comprise only 3% of the total watershed area (Jones et al. 2018a). Northwest Iowa, which drains to the Missouri River, is an area where livestock production has been concentrated in recent years (Andersen and Pepple 2017). The overall objective of our research was to assess whether the manure generated from high animal densities drives stream nitrate levels in the region. Using high-frequency river monitoring data collected from nine western Iowa watersheds draining to the Missouri River, two of which have a much larger animal density than the others, and comparing the water quality data to crop area, fertilization, and livestock populations, we show that river nitrate levels are linked to agricultural and livestock management.

MATERIALS AND METHODS

Study area

The nine western Iowa watersheds selected for study are shown in Fig. 1 and Table 1. These nine watersheds were selected because they all drain to the Missouri River and were instrumented with real-time, continuous nitrate sensors co-located with a discharge measurement station. Areas upstream of the water quality and discharge monitoring locations constitute 23% of Iowa's area and 74% of the state's area that drains to the Missouri River. Agricultural land use dominates each catchment and large point source discharges are absent, with no cities greater than 10 000 population draining into any of the watersheds.

Agricultural data

County-level data for the latest available (2012) commercial nitrogen fertilizer were obtained from the US Geological Survey National Water Quality Assessment project (Gronberg and Spahr 2012). County-level manure data were obtained from Gronberg and Arnold (2017). There is reason to believe that the 2012 commercial fertilizer data are relevant in the present day because changes in crop areas from 2012 to 2017 were small in the nine watersheds, e.g., − 6.2, + 5.4, and − 1.3% for corn, soybean, and total corn plus soybean, respectively, and statewide commercial fertilization rates have not changed appreciably since 1990 (Hatfield et al. 2009).

Data for animal populations were collected from two sources. Recent (2018) data for animal numbers were obtained from the Iowa Department of Natural Resources (IDNR) Animal Feeding Operations (AFO) database (IDNR 2018a). The IDNR's database is mostly limited to regulated facilities; therefore, numbers obtained from this source are likely to represent less than the actual number of animals raised in these areas. When calculating total animal units (AU) in a watershed, the population of a species is multiplied by the equivalence factor shown in Table 2 (IAC 2018). Historical county-level hog (1980–2012) and cattle (2002–2012) population data were obtained from USDA (2018) and adjusted to each watershed area based on the portion of the county that lies within the individual watershed. Watershed-level hog and cattle populations for 2018 were obtained from IDNR (2018a). The county-level areas planted with corn and soybeans in 2012 and 2017 were obtained from USDA (2018) and adjusted to the county's area portion within each watershed.

For the purposes of constructing a rough agronomic N budget for each watershed, inputs included commercial N (CN), N generated by manure (MN), fixation N (FN) from the previous year's soybean crop while outputs included N harvested in the grain (GN) (Eq. 1).

$$CN + MN + FN - GN = N \text{ surplus or deficit.} \quad (1)$$

Biological N fixation of soybean in 2016 was calculated according to Barry et al. (1993) using county-level crop areas and soybean yields adjusted to the area portion lying

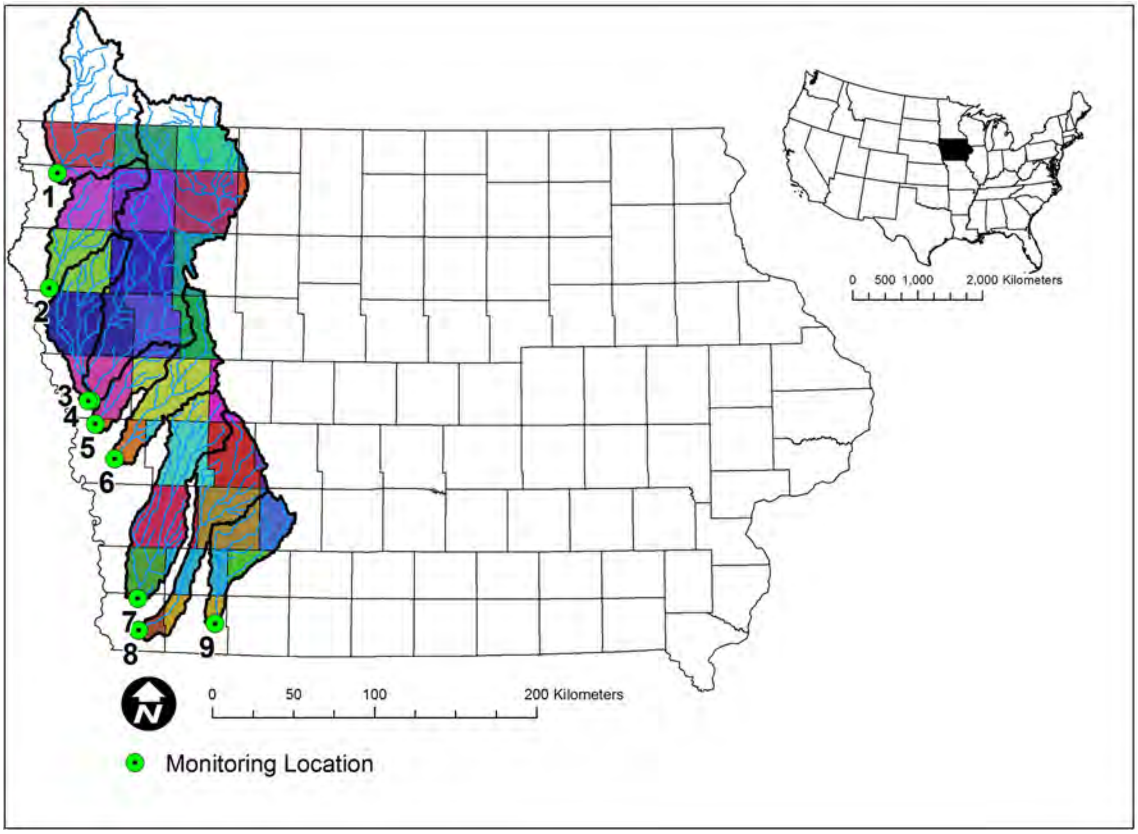

Fig. 1 Nine western Iowa watersheds are evaluated here. The number corresponds to the watershed number shown in Table 1. The green circle designates monitoring location near the outlet

within each watershed. Nitrogen harvested in corn grain was calculated using watershed crop yields and the measured average for Iowa corn reported by Blesh and Drinkwater (2013). Export of N in the harvested soybeans was calculated assuming 6.4% N in soybean seeds according to the USDA protocols using the Crop Nutrient Tool (2009).

Hydrology

Watershed precipitation totals for 2017 were estimated based on data collected at 22 stations within the individual watersheds and averaging data from each watershed location. These data were obtained from the Iowa State University Mesonet network (2017). Discharge data for all the sites were generated by the U.S. Geological Survey (USGS 2018). These 15-min interval data were aggregated into daily averages and the water yield was calculated by dividing total annual discharge by watershed area.

Water quality

High frequency (15 min) 2017 NO_3–N concentration data were obtained from the University of Iowa's Water Quality Information System (Jones et al. 2018b). This network of real-time water quality sensors measures NO_3–N concentrations at about 65 sites throughout Iowa including those shown in Fig. 1. Data quality for the network is governed by a QA/QC plan adopted from USEPA and USGS protocols. Basic QA protocols include systematic monitoring of incoming water quality data, remote monitoring of field sensor/system health (e.g., battery voltage and signal strength), automatic data review through the use of data thresholds and limits, and use of data descriptors for denoting state of data review. Measurements are generated by the Hach Nitratax sc plus (Loveland, CO, US) nitrate sensor and accuracy is verified through regular collection of grab samples that are lab-analyzed. Extensive details about measurement and quality control protocols can be found at Jones et al. (2018b). Data from the IDNR ambient monitoring program were used (IDNR 2018b) for periods when high-frequency data were missing (i.e., equipment malfunction and Dec–Feb). Linear interpolation was used to estimate NO_3–N concentrations on days with no NO_3–N data. Daily average NO_3–N concentrations were multiplied by daily average discharges and then summed to obtain annual NO_3–N loads and yields (load per watershed area). Flow weighted average (FWA) NO_3–N concentrations

Table 1 Watersheds in the study area along with crop area, livestock densities, commercial N fertilizer application rates, and nitrogen generated from animal manure

Figure 1 Map No.	Name	Iowa area (km^2)	Area fractions 2012			Area fractions 2017			Animal Units (AU) ha^{-1} 2017	kg ha^{-1} Corn + soybean area			kg ha^{-1} Corn area only
			Corn	Soybean	Total corn–soybean	Corn	Soybean	Total corn–Soybean		Commercial N application rate (2012)	Manure N generated	Commercial N + generated manure N	Commercial N + generated manure N
1	Rock River	1748	0.50	0.33	0.81	0.44	0.34	0.78	5.00	116	111	227	369
2	Floyd River	2295	0.48	0.34	0.82	0.47	0.35	0.82	3.53	112	117	229	379
3	Monona-Harrison Ditch	2331	0.42	0.31	0.73	0.38	0.33	0.71	1.31	122	37	159	261
4	Little Sioux R.	8350	0.45	0.34	0.79	0.42	0.35	0.77	1.04	119	40	159	262
5	Soldier River	1049	0.46	0.31	0.76	0.42	0.33	0.75	0.76	128	22	150	240
6	Boyer River	2202	0.49	0.31	0.81	0.45	0.34	0.79	1.13	138	38	176	235
7	W. Nishnabotna R.	3434	0.44	0.32	0.76	0.40	0.35	0.75	0.68	121	23	144	241
8	E. Nishnabotna R.	2862	0.39	0.31	0.69	0.36	0.33	0.69	0.53	106	32	138	233
9	W. Nodaway R.	1974	0.33	0.29	0.63	0.32	0.32	0.64	0.45	91	24	115	201

Table 2 Factors used to calculate total animal units (AU). Populations are multiplied by the factors shown to quantify total AU

Animal species	Factor
Horses	2.0
Mature dairy cattle	1.4
Slaughter or feeder cattle	1.0
Immature dairy cattle	1.0
Hogs > 25 kg	0.4
Hogs 7–25 kg	0.1
Turkeys > 3 kg	0.018
Chickens > 1.4 kg	0.01
Turkeys < 3 kg	0.0085
Chickens < 1.4 kg	0.0025
Fish	0.001

were calculated by dividing total load by total discharge. Minnesota areas draining to the Rock and Little Sioux Rivers were used when calculating yields.

RESULTS

Agricultural

Current density of animals ranged from 0.45 (West Nodaway) to 5.00 AU ha^{-1} (Table 1). The Floyd (3.53 AU ha^{-1}) and Rock (5.00 AU ha^{-1}) watersheds had much higher animal densities than the other seven watersheds (average 0.84 AU ha^{-1}). Cattle and hogs are by far the largest contributors to AU units in all watersheds, and historical data for these species are shown in Fig. 2, illustrating how the concentration of hogs has risen since 1980 and cattle since 2002. Hog densities have increased since 1980 in the Rock, Floyd, Monona-Harrison Ditch, and Little Sioux watersheds and declined in the others, with the decline especially pronounced in the West Nodaway (− 80%) and increases largest in the Floyd (+ 126%) and Rock watersheds (+ 269%). Overall, hog populations increased 41% since 1980, but when the Floyd and Rock watersheds are excluded, the increase is only 4.2%. The Floyd and Rock watersheds also have the highest current cattle densities at 1.14 and 1.70 per ha, respectively. Since 2002, the average cattle population grew by 37%, but increased only 0.01% when the Rock and Floyd watersheds are excluded. Large declines in cattle populations occurred in the Soldier (− 46%) and West Nodaway (− 74%) watersheds.

Areas planted with corn and soybean were obtained for 2012 and 2017 (Table 1) for comparison with available fertilization and water quality data. Overall in the nine watersheds, the total corn–soybean area was 1.3% lower in

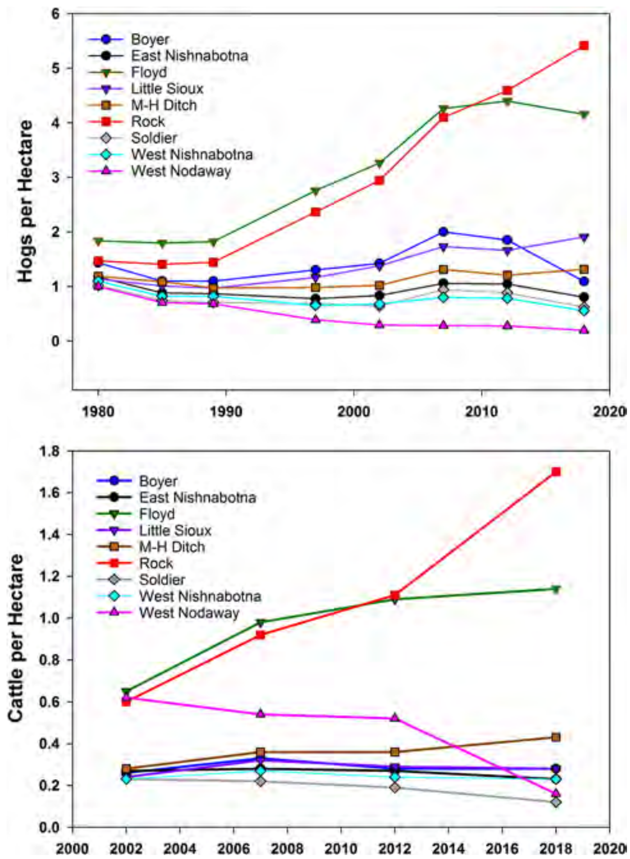

Fig. 2 Hog and cattle densities in the nine studied watersheds

2017 compared to 2012, with 6.2% less corn area and 5.4% more soybean area. Between watersheds, the biggest increase from 2012 to 2017 was in the West Nodaway (+ 1.6%) while the largest decrease was in the Monona-Harrison Ditch watershed (– 2.7%). Total corn–soybean area declined from 2012 to 2017 in all watersheds except the Floyd and West Nodaway. The cropped portion of each watershed ranged from 0.64 (West Nodaway) to 0.82 (Floyd) with an overall average of 0.74 in 2017.

The latest available fertilization data are from 2012 and are listed in Table 1. The commercial rates plus generated manure are based on 2012 crop areas and vary from 115 (West Nodaway) to 229 kg ha^{-1} of combined corn and soybean area. However, soybeans usually do not receive much nitrogen fertilizer in Iowa, with a statewide average of 15.7 kg ha^{-1} (Jones et al. 2016). Considering this, amounts per corn area alone ranged from 201 kg ha^{-1} (West Nodaway) to 379 kg ha^{-1} (Floyd) and averaged 269 kg ha^{-1} across all watersheds. Interestingly, the commercial N rates in the Rock watershed (116 kg ha^{-1} to all corn–soybean area) and the Floyd watershed (112 kg ha^{-1}) were similar to the nine-watershed average (117 kg ha^{-1}), this even with abundance of manure N generated by livestock (111 and 117 kg ha^{-1}, respectively). The commercial N rates in the West Nodaway watershed (91 kg ha^{-1} to all corn–soybean area) were lowest of the nine watersheds, even though the generated manure N was also quite low at 24 kg ha^{-1}, second lowest of the group.

Water quality and hydrology

The annual nitrate (NO_3–N), precipitation, and discharge data for 2017 are shown in Table 3. The precipitation recorded in the Rock (804 mm) and Floyd (759 mm) watersheds was substantially less than the other seven watersheds where the average was 917 mm. Despite lower amounts of rainfall, the Rock and Floyd each had the highest annual NO_3–N yields (24.7 and 30.5 kg ha^{-1}, respectively) and FWA NO_3–N concentration (11.5 and 16.2 mg L^{-1}, respectively) (Fig. 3). The averages for the other seven watersheds were 20.0 kg ha^{-1} (yield) and 7.3 mg L^{-1} (FWA concentration). The Monona-Harrison Ditch watershed had the lowest yield of NO_3-N (11.1 kg ha^{-1}) and the West Nodaway River had the lowest FWA concentration (4.9 mg L^{-1}).

Nitrogen budget

An estimated 2017 nitrogen budget was constructed assuming the fertilization rates from 2012 were relevant to 2017, using commercial N and manure data, crop yield data from 2017, and soybean area and yield from 2016 to calculate contributions from nitrogen fixation. This is shown in Table 4 along with the FWA NO_3–N concentrations for comparison. The surplus nitrogen, i.e., the amount applied as commercial fertilizer plus the amount generated by livestock plus the amount fixed by soybeans the previous year minus the amount harvested in the grain, ranged from 55 kg ha^{-1} (West Nodaway) to 161 kg ha^{-1} (Floyd) and averaged 99 kg ha^{-1} across the nine watersheds. The watersheds with the three largest surplus N values (Floyd, Rock, and Boyer) also had the three highest FWA concentrations while the watersheds with the two smallest surpluses also had the two smallest FWA concentrations. The average surplus for the Rock and Floyd (155 kg ha^{-1}) was nearly double the average of the other seven watersheds (83 kg ha^{-1}).

The FWA concentrations were well correlated with fertilization and crop area (Fig. 4). These concentrations correlated significantly ($p < 0.01$) with surplus nitrogen (fertilizer + manure + fixation-grain N), commercial + manure + fixation N, commercial + manure N, and manure N, and less significantly with area portion in corn and soybean ($p < 0.05$). The FWA concentrations did not correlate with commercial N ($p > 0.10$).

Table 3 2017 hydrology and stream NO_3–N data

Watershed	Annual precipitation (mm)	Discharge[a]	NO_3–N measurement days (N)	NO_3–N yield ($kg\ ha^{-1}$)	NO_3–N yield/precipitation ($g\ ha^{-1}\ mm^{-1}$)	FWA[b] NO_3–N ($mg\ L^{-1}$)
Rock River	804	215	115	24.7	30.7	11.5
Floyd River	759	188	284	30.5	40.2	16.2
Monona-Harrison Ditch	942	172	171	11.1	11.8	7.2
Little Sioux River	816	241	181	17.1	20.9	7.1
Soldier River	846	259	233	21.9	25.9	8.5
Boyer River	1056	312	249	27.1	25.7	8.7
West Nishnabotna River	846	291	293	23.9	28.3	8.2
East Nishnabotna River	974	430	193	23.7	24.3	5.5
West Nodaway River	963	282	288	13.9	14.4	4.9
Average	890	266	223	21.5	24.7	8.6

[a]Discharge calculated by dividing total discharge volume at the outlet by watershed area draining to the site

[b]FWA is Flow Weighted Average concentration, which is obtained by dividing total river NO_3–N load by total discharge

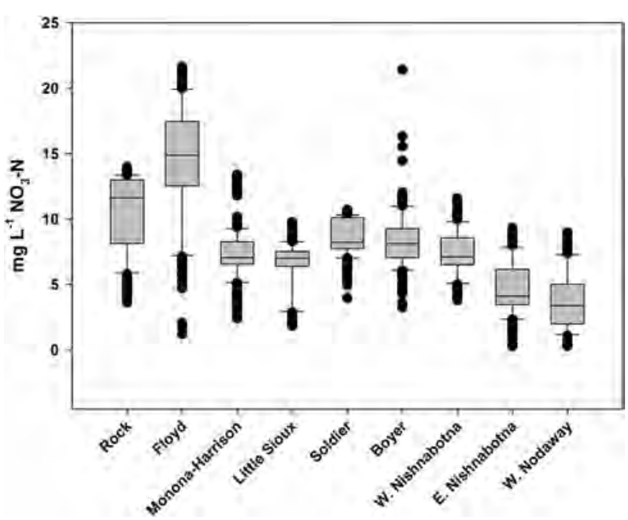

Fig. 3 Box plots of 2017 daily average NO_3–N concentrations. The boxes bracket the 25th–75th percentiles; the line in the box indicates the median; the whiskers the 10th and 90th percentiles, and the dots are data points less than (greater than) the 10th (90th) percentiles

DISCUSSION

Iowa State University (ISU) Extension guidelines for N application rates ($kg\ ha^{-1}$) range from 135 to 165 (average 150) for corn following soybean, and 193–221 (average 206) for corn following corn under the current price structure for commercial nitrogen fertilizer and corn grain (Sawyer 2016). When we adjust for statewide N rates to soybeans (15.7 $kg\ ha^{-1}$, Jones et al. 2016), commercial fertilizer data for 2012 show average annual commercial N rate to corn in these nine watersheds is 189 $kg\ ha^{-1}$, generally in-line-to-slightly-above ISU guidelines. However, these rates do not account for the substantial amounts of manure N generated in the nine watersheds, and especially in the Floyd and Rock watersheds, where the generated manure N is roughly equivalent to commercial N sales. After the generated manure N is added to commercial N, then the amount of N per corn-hectare exceeds ISU guidelines in all watersheds except the West Nodaway, where coincidentally the lowest FWA NO_3-N was recorded in 2017. In the Floyd and Rock watersheds, the commercial N plus N generated from manure sources is ~ 370–380 $kg\ ha^{-1}$ of corn (accounting for average N application to soybean), which is about double ISU recommendations. In these two watersheds, the "surplus" N (i.e., commercial + manure + fixation − grain) actually exceeds the ISU recommendations for corn grown after soybeans. It should be pointed out that this is based on 2012 animal populations and that hog and cattle numbers increased substantially in the Rock watershed since then (Fig. 2). The fate of all manure N applied to agricultural fields is not well understood. Some amount of the N in fresh animal manure is lost to volatilization (Kirchmann and Witter 1989) and never becomes available for crop uptake. There is evidence, however, that much of this volatilized N is deposited within 1 km of the confinement (Loubet et al. 2009) and McGinn et al. (2016) reported a 50% decline in deposition 200 m from a cattle confinement. Thus, much of this volatilized N is not lost from the watershed. Additionally, some portion of manure N is often in organic forms and not immediately available to plants after field application, a condition informed by testing the manure and soil for available N (NO_3–N and NH_4–N) (Paul and Beauchamp 1993). This organic N must eventually become available to crops and/or leach into the stream

Table 4 Estimated 2017 nitrogen budget for using commercial N rates, generated livestock manure, soybean fixation from previous year, N harvested in the grain, and stream NO_3–N for comparison

Watershed	Commercial N + generated manure N (Kg NO_3–N ha^{-1} $year^{-1}$)	Fixation from 2016 soybean crop	Fixation from 2016 soybean crop	Commercial N + manure N + fixation N-grain N	FWA NO_3–N (mg L^{-1})
Rock River	226	100	178	148	11.5
Floyd River	229	107	175	161	16.2
Monona-Harrison Ditch	159	110	169	100	7.2
Little Sioux River	158	111	172	97	7.1
Soldier River	150	96	171	74	8.5
Boyer River	176	98	171	103	8.7
West Nishnabotna River	145	97	159	83	8.2
East Nishnabotna River	138	95	163	70	5.5
West Nodaway River	115	98	159	55	4.9

network, and thus it must be considered in watershed N budgets. Finally, it is likely some of the generated manures are being transported beyond watershed boundaries for application elsewhere. Long-range hauling (more than ~ 8 km), however, becomes economically problematic (Fleming et al. 1998) and there is evidence that farmers tend to apply manure on fields nearby confinements (Innes 2000; Jackson et al. 2000). Thus, the majority of manure generated within watersheds of the size studied here is likely to remain in that watershed. All things considered, the amount of purchased (commercial) N plus the amount of N generated by manure is far beyond crop nutrient requirements in some of these watersheds, and this surplus N will accumulate as decaying plant matter, soil organic matter and organisms, and soil water NO_3–N, creating a growing pool of mobile N (Jackson et al. 2000).

When 2017 water quality data are considered alongside these estimates of fertilization and generated manure, the Floyd and Rock watersheds stand out not only for their level of fertilization, but also for stream NO_3–N concentration levels. Despite the relative dryness in these two watersheds compared to the others, their FWA NO_3–N concentrations are nearly double those of the other seven when considered in aggregate (13.9 vs. 7.3 mg L^{-1}). Likewise, the commercial plus manure N in the West Nodaway and East Nishnabotna watersheds is only 60% of that in the Rock and Floyd, and this is reflected in stream water quality where NO_3–N concentrations are only 37% as high as in the Rock and Floyd watersheds. Howarth et al. (2012) estimated when net anthropogenic N inputs (NANI), similar to the surplus N described here, exceeded 1070 kg N km^{-2} $year^{-1}$, 25% of this amount on average was exported to rivers worldwide. The average surplus N for our nine watersheds was 4489 kg N km^{-2} during 2017, and an all-watershed average of 33% of this amount exited in the stream network. Our simple N budgets, which do not incorporate pathways such as atmospheric deposition of N and N returned to livestock in animal feed, still produce a value not that different from the Howarth et al. (2012) analysis, and our stream export values could be expected to exceed those of Howarth et al. (2012) because our surplus N is 4 times as large as the threshold in that study.

It is notable that the Rock watershed, with higher livestock densities than the Floyd watershed (Fig. 2), actually has lower levels of stream NO_3–N (Fig. 3). It is important to note that 58% of the Rock River watershed lies outside of the state of Iowa in Minnesota. The state of Minnesota Pollution Control Agency (MPCA) conducts NO_3–N water monitoring on the Rock River at a site about 18 stream-km north of the Iowa border (MPCA 2018). In 2017, six samples were collected by MPCA from April 26 to September 27 and averaged 8.48 mg L^{-1} NO_3–N. The concentrations downstream at Rock Valley, Iowa, the site of the monitoring conducted for this study, were 10.04 mg L^{-1} during that period. Thus, we suspect that lower concentrations of NO_3–N in water from Minnesota are diluting higher concentrations of NO_3–N in water contributed by Iowa portions of the Rock watershed.

Recently, the metric NO_3–N yield per unit of precipitation (g NO_3–N ha^{-1} mm P^{-1}) was used to compare NO_3–N delivery in seven Iowa watersheds (Jones et al. 2018c). In the second 15 years of that study (2002–2016), an average of 22 g NO_3–N ha^{-1} was mobilized to streams per mm of precipitation. For the 2017 water quality and hydrology data presented here, the nitrogen yield from the Floyd (40.2 g NO_3–N ha^{-1} mm P^{-1}) and Rock (30.7 g NO_3–N ha^{-1} mm P^{-1}) watersheds were considerably higher than the other seven, where the aggregated average was 22.0. The West Nodaway watershed received 204 mm more precipitation than the Floyd (27% more) but the NO_3–N yields were less than half, a clear indicator that the

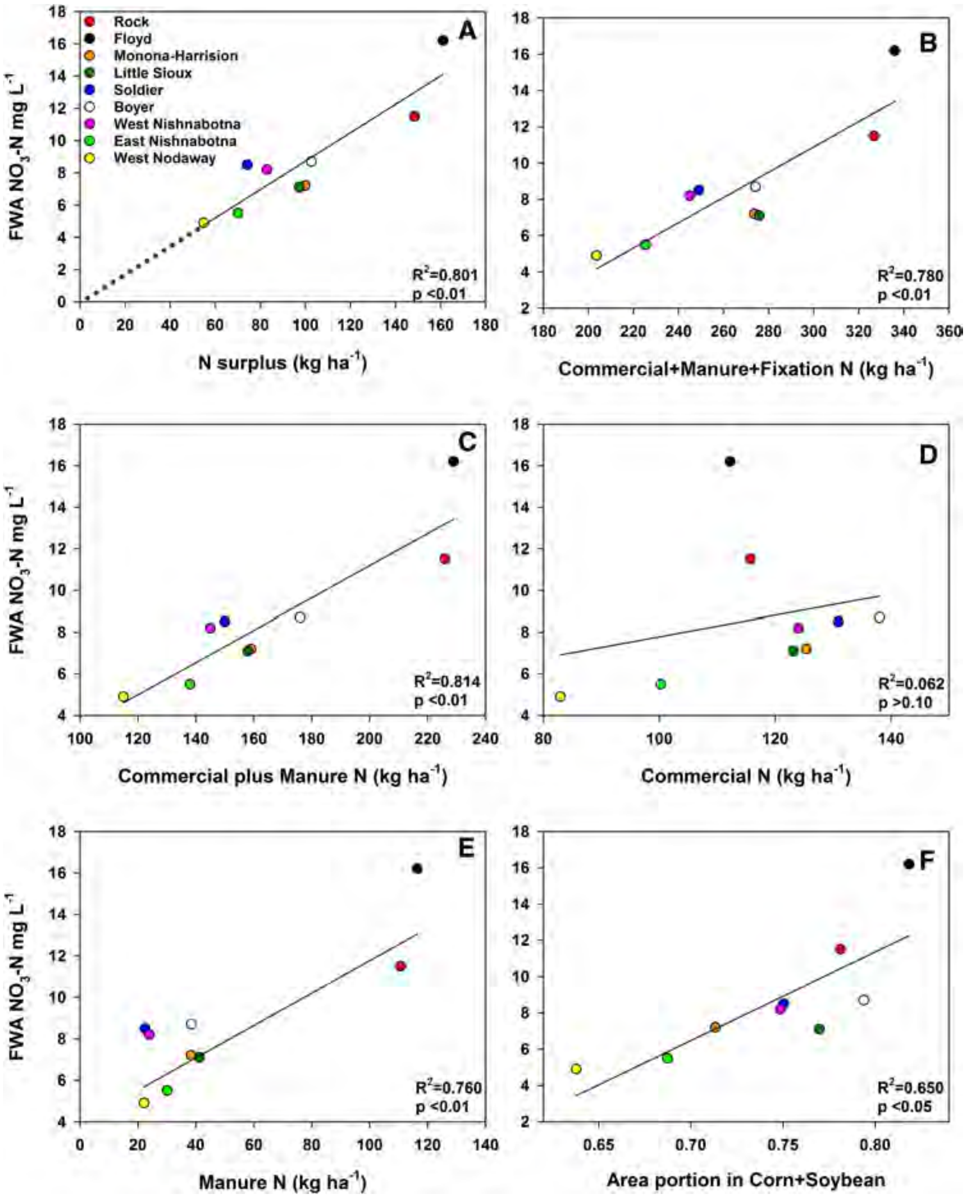

Fig. 4 Correlations of 2017 watershed Flow Weighted Average (FWA) NO_3–N concentrations with N surplus (**a**), sum of commercial, manure and fixation nitrogen (**b**), sum of commercial and manure nitrogen (**c**), commercial nitrogen (**d**), generated manure nitrogen (**e**), and area portion in corn and soybean (**f**). The dotted portion of the regression line in **a** is an extrapolation backward to a zero surplus condition. FWA is defined as total NO_3–N load divided by total discharge for 2017

supply of loss-vulnerable N was far higher in the Floyd watershed compared to the West Nodaway.

Li et al. (2013) evaluated NO_3–N concentrations and trends for Iowa streams from 1998 to 2012. Of the 48 Iowa streams in that study that had sufficiently long data records for trend analysis, the Rock and Floyd Rivers had the largest positive trends for NO_3–N concentration (0.33 and 0.29 mg L^{-1} $year^{-1}$, respectively) during a time when hog and cattle populations in the two watersheds were doubling (Fig. 2). The statistical significance of those trends was strong ($p < 0.01$). The other sites in that study that were also evaluated here included the West Nodaway River (increasing trend of 0.17 mg L^{-1} $year^{-1}$), Boyer River (0.16 mg L^{-1} $year^{-1}$), West Nishnabotna River (0.06 mg L^{-1} $year^{-1}$), Soldier River (0.03 mg L^{-1} $year^{-1}$), and Little Sioux River (0.03 mg L^{-1} $year^{-1}$). Without detailed information about manure nitrogen quantities, Li et al. (2013) speculated that manure applications associated with increasing hog populations were a driving factor for the upward NO_3–N trends in western Iowa, and we believe the data presented herein are consistent with that.

There are examples in the literature linking livestock concentration with surplus stream nutrients and degraded water quality in other parts of the world. For example, the northwestern Black Sea was seriously degraded from the 1960s to the 1980s by nutrient runoff from the Danube River, but rapidly improved after 1989 with the closure of many large animal farms as a result of the fall of communist regimes (Mee 2006). Considering that the average animal unit density in our study was 1.60 ha^{-1}, the average magnitude of N surplus we report (99 kg ha^{-1}) is consistent with research from other agricultural regions. For example, Wang et al. (2018) reported average N surpluses of 75-306 kg ha^{-1} when AU density exceeded 1 ha^{-1} for several countries in Europe, Asia, and the Americas. Oenema et al. (2007) reported highest levels of NO_3–N leaching in Europe to be in the northwest where livestock densities were highest. Leaching rates 20 to over 50 kg ha^{-1} were reported in that study, compared to 30.5 and 24.7 kg ha^{-1} for the Floyd and Rock watersheds, the two highest-density livestock watersheds of the nine assessed here. When considering the NO_3–N transported by these streams, and especially the Rock and Floyd Rivers, it is relevant to consider how this pollutant links to various processes that control stream amounts. At the landscape scale in the U.S. cornbelt, the NO_3–N loading is clearly transport-limited (Sprague et al. 2011; Jones et al. 2017). However, there are years within individual watersheds where supply limitations are controlling (Jones et al. 2017). Furthermore, fertilizer nitrogen has been shown to be a strong predictor and regulator of stream NO_3–N concentrations (David et al. 2010; Li et al. 2013). The Floyd and Rock were the two driest watersheds evaluated here, but still had by far the highest NO_3–N delivery of these nine western Iowa basins. The fact that in the Floyd and Rock watersheds, the commercial N inputs combined with generated manure N were nearly double the other watersheds illustrates the importance of N supply management for water quality improvement. There is ample evidence that U.S. Cornbelt farmers over-apply nitrogen, often in manure forms (Yadav et al. 1997; Jackson et al. 2000; Sheriff 2005; Khanal et al. 2014). This is not necessarily wasteful; rather, the economics of nitrogen can make it more profitable for farmers to concentrate manure applications on nearby fields and purchase chemical fertilizer for the rest of the farm (Letson et al. 1998). In fact, Jackson et al. (2000) concluded that in some scenarios it makes clear economic sense for large livestock confinements to maximize N volatilization losses. In these circumstances, manure becomes a waste product and the practice of squandering manure nutrients itself is not necessarily economically wasteful (Fleming et al. 1998; Sheriff 2005), i.e., the farmer may benefit financially by not fully taking advantage of the fertility benefits available in the generated manure. Many farmers may also manage manure application rates based not on N, but rather phosphorus and/or potassium. Farmers also may apply manure in the fall, followed by commercial fertilizer applications the following spring.

Interestingly, the N inputs in the West Nodaway watershed are in line with ISU recommendations for corn cultivation, and the FWA NO_3–N concentration was a relatively modest 4.9 mg L^{-1} and the daily concentration never exceeded the safe drinking water standard of 10 mg L^{-1}. This watershed illustrates the obvious opportunity for farmers and policy makers to make progress towards Iowa's water quality goal of a 45% NO_3–N load reduction (Iowa Nutrient Reduction Strategy 2013). Figure 4a indicates that reducing surplus N by better balancing inputs relative to expected crop needs would reduce stream NO_3–N levels. When considering Fig. 4a, extrapolating the regression backward to a zero surplus N condition results in a FWA NO_3–N concentration of < 1 mg L^{-1}. We acknowledge that legacy N (Van Meter et al. 2017) may elevate stream NO_3–N for prolonged periods after inputs are balanced with crop requirements and that the extrapolation in 4(A) is somewhat speculative. Nonetheless, it is apparent that better management and accounting of manure inputs could generate significant and rapid progress towards Iowa's water quality objective for stream N. The surplus N relates much more strongly to generated manure N ($R^2 = 0.83$) than commercial N inputs ($R^2 = 0.14$) among the nine watersheds and therefore this suggests a starting place when assessing inputs on the watershed scale. These findings are consistent with Khanal et al. (2014), who determined that manure-fertilized rotations had a higher net N (i.e., difference between inflows and outflows) statewide in Iowa. While the amount of N generated in livestock manure is not a precise estimate of what will be available to the receiving crop, methods exist to help reduce this uncertainty (Paul and Beauchamp 1993) and integration of commercial fertilizer and manure recommendation systems that account for soil fertility, crop needs, and availability of manure N is needed (Liu et al. 2017). With commercial fertilizer sales seemingly unrelated to the availability of manure N in these watersheds, refinements in planning and manure management hold great potential for producing water quality improvement in areas where livestock has been concentrated. Several policy recommendations were proposed by Jackson et al. (2000) to address similar issues in Central Iowa. These included alternative livestock housing, increased regulatory scrutiny of manure management plans, modification of land zoning rules, and incentivizing extended crop rotations that include small grains and forage legumes. Although now nearly 20 years old, we wish to emphasize that while these recommendations have mostly gone unheeded, they continue to hold potential for more efficient nitrogen use and water quality improvement.

CONCLUSIONS

While commercial fertilizer nitrogen input rates are similar among these nine western Iowa watersheds, generated manure N is far higher in two, the Floyd and Rock River watersheds, and the FWA NO_3–N concentrations at the outlets of these watersheds are approximately double that of the other seven. The commercial N inputs plus the generated manure N in these two watersheds total 370-380 kg corn ha^{-1}, which is about double the recommended application rates. The FWA NO_3–N concentration was significantly correlated with total N inputs and generated manure but not with commercial N fertilizer amounts. The only watershed where commercial fertilizer N inputs plus generated manure was consistent with the rate recommendations was the West Nodaway watershed, where the FWA NO_3–N concentrations were lowest and never exceeded 10 mg L^{-1}. Overall, the results from this study strongly suggest that better management of manure holds promise for producing significant water quality improvements at a watershed scale.

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Reduce water quality issues from manure

Minnesotans know how precious clean surface and groundwater is to recreation and wildlife habitat in the state. Access to clean water is something that many take for granted, but protecting it from harm needs to be a top priority.

Pollution from towns and farms harm both surface and groundwater. Nitrogen, phosphorus, and pathogens are the most common water pollutants from manure on farms.

Nitrogen

Nitrogen – in the form of nitrate – is of most concern in groundwater since that is where 3 out of 4 Minnesotans get their drinking water.

- The nitrate threshold for safe drinking water is only 10 ppm. Above that level, infants may develop a condition that limits the supply of oxygen to the blood.
- Nitrates that leave Minnesota through the Mississippi River add to the Gulf of Mexico dead zone. Added nitrates cause an excess of ocean plants and algae to grow.
- When the plants and algae die, they are decomposed by bacteria that use up dissolved oxygen. This causes areas of low oxygen to form where ocean plants and animals cannot live.

Phosphorus

Phosphorus is a major concern because it causes excessive plant and algae growth in lakes and rivers. This causes an oxygen-depleting reaction similar to what happens in the Gulf of Mexico dead zone.

Fish kills and loss of habitat are caused by the decreased oxygen content. Certain types of algae growth caused by phosphorus (called harmful algal blooms) can harm the health of humans and animals that come in contact with them.

Pathogens

Pathogens such as harmful bacteria and viruses in manure become an issue when they enter waterways and groundwater.

E. coli, Cryptosporidium, and Giardia are just a few pathogens that can cause serious health problems in people and animals that come in contact with contaminated water.

Tips to reduce water quality impacts of manure:

Though farms are not the only source of water contamination, farmers still have the responsibility to do their part in protecting water quality. These recommendations can help farmers manage manure to reduce the amount of pollutants leaving their farm or field.

1. Manage runoff and leaching from stockpiled manure. Stacking solid manure on a concrete pad will reduce leaching of nutrients through the soil. Also, placing the stockpile in an open-sided shed, on a level surface, and above the seasonal high-water table will reduce runoff risk. A catch basin can also be placed nearby to hold any runoff before it reaches a waterway.
2. Manage runoff and leaching from open lots. Catch basins and grass buffer strips can be used to hold and filter runoff from open lots before it reaches a waterway.
3. Manage leaching from storage pits. Impermeable concrete, synthetic, or clay soil liners should be used in manure pits to keep nutrients from leaching downward. Pits should also be monitored closely and pumped before overflowing.
4. Use clean-water diversion system. Berms, ditches, and gutters can be used to divert upslope and rain water from areas with manure so that it does not carry nutrients and pathogens to waterways.
5. Use correct manure application techniques on fields. Apply nutrients only as needed in accordance with the University of Minnesota and Minnesota Pollution Control Agency's guidelines. Whenever possible, incorporate manure into the soil to reduce risk of surface runoff. Do not apply on saturated or frozen soils as this will increase runoff.

Chryseis Modderman, Extension educator

Reviewed in 2020

Please scan the above QR code to visit the live webpage for links.

https://extension.umn.edu/manure-management/reduce-water-quality-issues

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 5

CHICAGO, IL 60604

May 9, 2024

Lisa M. Scheirer, Supervisor
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Re: U.S. Environmental Protection Agency Review of Pre-Public Notice Draft Feedlot NPDES General Permit (MNG440000)

Dear Ms. Scheirer:

The U.S. Environmental Protection Agency has reviewed the Pre-Public Notice Draft Feedlot NPDES General Permit (Permit), fact sheet, and supporting documents that were submitted to EPA on February 29 and March 1, 2024. Based on our review to date, EPA provides the following comments:[1]

1. EPA has direct implementation for the NPDES program in Indian Country. The Permit should contain language excluding concentrated animal feeding operations (CAFOs) located within Indian Country from coverage under the Permit.

2. The Permit needs to specify the required contents of the notice of intent for coverage under the Permit. 40 C.F.R. § 122.28(b)(2)(ii).

3. The Permit needs to specify the deadlines for submitting notices of intent for coverage under the Permit. 40 C.F.R. § 122.28(b)(2)(iii).

4. Permit Part 1.4 allows for suspension of the Permit in accordance with Minn. R. 7001.0170 through 7001.0190; however, the referenced state rules do not include suspension of permits. Federal regulations do not recognize suspension of permits; federal regulations recognize modification, revocation and reissuance, or termination of permits. The word "suspended" needs to be removed. 40 C.F.R. §§ 122.62 and 124.5.

[1] All cited federal regulations are made applicable to states by 33 U.S.C. §§ 1314(i) and 1342(c)(2) and 40 C.F.R. § 123.25.

5. Permit Part 2.5 contains requirements regarding the change of ownership or control of the facility. Minn. R. 7020.0405 only allows a change of ownership or control of an animal feeding operation or manure storage area through a permit modification. Therefore, Part 2.5 needs to be revised to conform with 40 C.F.R. § 122.63, by requiring that a permit modification request include a written agreement with a specific date for transfer of permit responsibility, coverage, and liability between the current and new permittees.

6. When manure is transferred, Permit Part 9.4 requires that the permittee provide to the manure recipient, at the time of transfer of ownership, a "Manure Transfer Tracking" form that is generated by the Nutrient Management Tool. This form does not include the date of manure transfer but should. 40 C.F.R. § 122.42(e)(3).

7. Permit Part 10.2 requires the CAFO to use Minnesota's Nutrient Management Tool to develop and maintain the Manure Management Plan (MMP). The Minnesota Nutrient Management Tool does not conform with the following requirements of 40 C.F.R. § 122.42(e)(1) nor does the Permit include specific conditions that conform with these federal requirements. Conditions addressing these federal requirements need to be included in the Permit or the Minnesota Nutrient Management Tool could be updated to include these federal requirements.

    a. The Permit does not specifically prohibit the disposal of mortalities in storm water storage systems. 40 C.F.R. § 122.42(e)(1)(ii).
    b. The Permit does not specifically require that clean water be diverted, as appropriate, from the production area., 40 C.F.R. § 122.42(e)(1)(iii).
    c. The Permit does not specifically prohibit the disposal of chemicals and other contaminants handled on-site into storm water storage systems. 40 C.F.R. § 122.42(e)(1)(iv).

8. Permit Part 15.1 contains land application setback requirements. Federal regulations require that manure, litter, and process wastewater not be applied closer than 100-foot to any down-gradient surface waters, open tile intake structures, sinkholes, agricultural well heads, or other conduits to surface waters unless a compliance alternative is exercised. Part 15.1 includes setbacks for several land features; however, Part 15.1 does not include a setback for the broader term "other conduits to surface waters" which would ensure setback requirements apply to all conduits to surface waters rather than just those identified in the Permit. 40 C.F.R. § 412.4(c)(5).

9. Permit Parts 16.2 and 16.3 require "that the production area is designed, constructed, operated, and maintained to contain all manure, manure-contaminated runoff, ***or*** process wastewater, and all direct precipitation" (Emphasis added). To conform with federal regulations, the word "or" needs to be removed from Parts 16.2 and 16.3. Federal regulations require that production areas are designed, constructed, operated and maintained to contain all manure, litter, ***and*** process wastewater (Emphasis added). 40 C.F.R. Part 412.

10. Permit Part 26.5 does not conform to the federal requirements because it does not identify an overflow as a discharge. In order to conform with federal regulations, Part 26.5 needs to be revised to read "... unless the ***discharge is an*** overflow of manure or process wastewater ***that*** is caused by a precipitation event ..." (Emphasis added). 40 C.F.R. Part 412.

11. Federal regulations require that each NPDES permit (1) include monitoring requirements to ensure compliance with permit limitations and (2) specify required monitoring including type, intervals, and frequency sufficient to yield data which are representative of the monitored activity. 40 C.F.R. §§ 122.44(i) and 122.48. Permit Part 27.5 requires the permittee to ensure that all discharges, spills, or overflows associated with the facility do not cause or contribute to non-attainment of water quality standards. The Permit needs to require monitoring of discharges, spills, or overflows to ensure compliance with Part 27.5. In order to assess compliance with the reference to water quality standards in Part 27.5, monitoring of discharges to surface waters from a production area for volume, duration, pH, phosphorus, NH_3-N, BOD, TSS, dissolved oxygen, and *E.coli* should be required.

12. The federal definition of "production area" includes bedding material in the raw materials description, while the definition of "Production Area" in Permit Part 30.47 does not include "bedding materials" in the raw materials description. Part 30.47 definition of "Production Area" needs to be revised to conform with the federal definition. 40 C.F.R. § 122.23(b)(8) and 40 C.F.R. § 412.2(h).

13. The Standard Conditions of 40 C.F.R. § 122.41 are not incorporated by reference into the Permit. The Permit does not contain the following standard conditions or words used to describe particular conditions do not adequately conform with the following federal standard conditions:

    a. Duty to Comply § 122.41(a);
    b. Permit Actions § 122.41(f);
    c. Duty to Provide Information § 122.41(h);
    d. Monitoring and Records § 122.41(j);
    e. Signatory Requirement § 122.41(k);
    f. Reporting Requirement - Permit Transfers § 122.41(l)(3);
    g. Reporting Requirement - Compliance Schedules § 122.41(l)(5);
    h. Reporting Requirement - Twenty-Four Hour Reporting § 122.41(l)(6);
    i. Reporting Requirement - Other Information § 122.41(l)(8);
    j. Reporting Requirement - Identification of the initial recipient for NPDES electronic reporting data § 122.41(l)(9);
    k. Bypass § 122.41(m); and
    l. Upset § 122.41(n).

In addition to the comments listed above, EPA recommends you consider and address the comments identified in Enclosure A in order to improve the overall Permit.

When the proposed permit is prepared, please forward one copy and Minnesota's response to any significant comments received during any public notice period to this office at r5NPDES@epa.gov. Please include the permit name and permit number in the subject line and cc kuss.michael@epa.gov. If you have any technical questions related to EPA's review, please contact Michael Kuss of my staff. He can be reached at 312-886-5482 or kuss.michael@epa.gov.

Thank you for your cooperation during the review process and your thoughtful consideration of our comments.

Sincerely,

STEPHEN JANN

Digitally signed by STEPHEN JANN
Date: 2024.05.09 13:00:18 -05'00'

Stephen M. Jann
Manager, Permits Branch
Water Division

Enclosure

cc: George Schwint, Principal Feedlot Engineer, MPCA

Please consider the following comments and recommendations to clarify and improve the draft permit:

1. It is recommended that the Permit include a requirement to identify, in the MMP, subsurface drain tiles on all fields where manure or process wastewater is land applied, and to require observation of subsurface drain tile outlets prior to, during and following land application of manure or process wastewater for volume/rate of flow and color, turbidity, foam, and odor to identify any discharges that may violate effluent limitations.

2. Permit Part 1.2 authorizes the Permittee to operate the facility in compliance with the requirements of Minn. R. 7020, and Minn R. 7020.2015 prohibits animals from entering waters of the State. The Permit could be improved by including a requirement that specifically prohibits the direct contact of confined animals with waters of the United States. 40 C.F.R. § 122.42(e)(1)(iii).

3. Federal regulations require that manure, litter, and process wastewater not be applied closer than 100-foot to any down-gradient surface waters, open tile intake structures, sinkholes, agricultural well heads, or other conduits to surface waters unless a compliance alternative is exercised. 40 C.F.R. § 412.4(c)(5)(ii) provides that a CAFO may demonstrate that an alternative conservation practice or field-specific conditions will provide pollutant reductions equivalent or better than the reductions achieved by a 100-foot setback. Permit Parts 15.4 through 15.7 include alternative conservation practices. Permit Part 10.2 requires that the manure management plan developed by a Permittee contain requirements of land application of manure sections of the Permit, this would include Parts 15.4 through 15.7. EPA recommends that the State require Permittees selecting to use one of the alternative conservation practices included in Parts 15.4 through 15.7 include a demonstration in the MMP that the alternative conservation practice implemented on a specific land application area will provide pollutant reductions equivalent or better than the reductions achieved by a 100-foot setback.

4. If a production area is designed, constructed, operated and maintained consistent with federal regulations, the need for emergency manure application should be rare, if at all. It seems a need should only arise, if at all, at the end of the design storage period of the collection of storage devices (i.e., just before crop harvest in the fall and just before the lifting of winter land application restrictions). Permit Part 30.20 defines Emergency Manure Application, and Permit Parts 13.2 and 13.6 authorize emergency land application. Weather is inherently variable. EPA recommends that the definition of emergency manure application provide further clarification on what constitutes "unusual weather conditions" and expand the definition to include opportunities to manage manure other than storage, i.e., treatment, before emergency manure application is allowed.

DEPARTMENT OF AGRICULTURE

Examination of Soil Water Nitrate-N Concentrations from Common Land Covers and Cropping Systems in Southeast Minnesota Karst

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Abstract

The purpose of this study was to identify the range of soil water nitrate-nitrogen (nitrate) concentrations measured at a four-foot depth from nine different land covers and cropping systems in southeast Minnesota. Results from the five-year study (2011-2015) found low concentrations of soil water nitrate, generally less than 2 mg/L, from prairie, forest and low maintenance homeowner lawn sites. Cattle pasture sites and a golf course averaged 5.1 and 3.7 mg/L, respectively. A grass field border and grassed waterway had similar concentrations and averaged between 5.9 mg/L (non-fertilized) and 8.9 mg/L (fertilized). Concentrations from the grass strips were higher than expected and likely explained by subsurface mixing of soil water between adjacent land covers. Nitrate concentrations collected from lysimeters in cultivated row crop settings were comparable to tile drained sites in Minnesota, but were highly variable and averaged 22.3 mg/L with a typical range of 8.0 to 28.0 mg/L. Corn fields with alfalfa in the rotation had nitrate concentrations averaging 6.6 mg/L which were 70% lower when compared to sites without perennials. When considered within the context of this study's limitations, data collected from the Southeast Lysimeter Network could serve as a useful educational tool for farmers, crop advisors, rural homeowners and groundwater advisory groups.

Background and Purpose

The geology of southeastern Minnesota's Driftless Area is comprised of carbonate bedrock (limestone and dolostone), sandstone and shale. Over millennia, naturally acidic rain and soil water has interacted with carbonate bedrock to form karst features including dissolutionally-enlarged fractures, subterranean conduits, sinkholes, and springs. Most of the bedrock formations in this area are covered by less than 50 feet of surficial deposits (Mossler, 1995) and in many areas, moderate to well-drained soils are less than ten feet thick (Dogwiler, 2013). This can result in direct hydrologic connections between the land surface and underlying bedrock and can facilitate the rapid movement of water and potential contaminants from the land surface into bedrock aquifers used for drinking water (Green et al, 2014; Runkel et al, 2014), and ultimately groundwater return flow to springs, streams and rivers. One of the most common nutrients found in southeast Minnesota groundwater is nitrate-nitrogen (NO_3^--N, from this point forward referred simply as nitrate). Nitrate is a common form of plant-available nitrogen that is water soluble and can primarily come from nitrogen fertilizer, manure, sewage, or the breakdown of soil organic matter. If not utilized by plants or retained in soil organic material, nitrate can move rapidly by water and leach through the soil and into groundwater.

The loss of nitrogen from agricultural lands has both local and regional impacts. Regionally, excess nitrogen lost from agricultural applications, primarily from the upper Midwest, are one of the main contributors to the hypoxic zone in the Gulf of Mexico (Alexander et al, 2008, Robertson et al, 2019). A 2013 report estimated that about 89% of the nitrogen measured in surface water in southeast Minnesota watersheds was derived from cropland, primarily through groundwater pathways (MPCA, 2013). More locally, results from private drinking water testing in Houston, Fillmore and Winona Counties have shown 15.3% to 19.1% of the sampled wells were at or above the drinking water health standard of 10 mg/L for nitrate (MDA, 2017).

Understanding the source of nitrate and how it moves into groundwater is a key step in helping manage the region's water resources. A common question raised during nitrate reduction planning discussions is how do nitrates compare between different crops or landcovers? The objective of this five-year study was to identify the range of nitrate concentrations present in soil water infiltrating from the unsaturated root zone across common land covers and cropping systems in southeast Minnesota. Land use in this region mainly consists of cultivated row crops so much of this investigation focused on agricultural land covers, but other non-agricultural land covers including prairies, forests, pastures and turf were also studied. Although this investigation does not attempt to fully quantify the magnitude of the nitrate flux or loading to aquifers, our results provide insight to the potential risk of loss to groundwater associated with various land covers. These data will help inform farmers, their advisors and other stakeholders as they work toward reducing nitrate in drinking water and surface water.

Information presented in this report were collected as part of an initiative known as the Southeast Minnesota Lysimeter Network (SLN). This undertaking represented a collaboration among several partners, including the Fillmore Soil and Water Conservation District (SWCD), Winona SWCD, Winona State University-Southeastern Minnesota Water Resources Center (SMWRC), Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Agriculture (MDA). Funding for this work was provided in-part by Minnesota's Clean Water Fund from MPCA and through MDA's Root River Field to Stream Partnership (RRFSP).

Methods

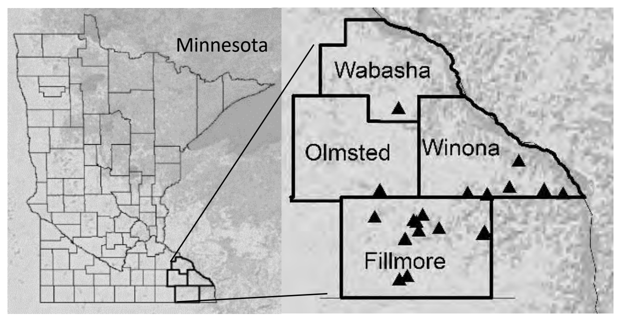

Figure 1. Lysimeter network locations across a four County area in southeast Minnesota.

The study took place across four counties and 23 sites in southeast Minnesota from 2011-2015 (Figure 1). Table 1 summarizes the 2015 land use across the four-county study area. On average, land managed for corn-soybean production, forest, and grass/pasture was over 80% while landcovers in alfalfa, turf and golf courses were less than 10%. Sampling sites were located on private property and cooperators were identified by staff from the Fillmore SWCD, Winona SWCD and MDA. The most common agricultural practices in southeast Minnesota were sampled, as well as several other common non-agricultural land cover types (Table 2). Land covers were grouped into three categories: non-agriculture, ag pasture/grass strips and ag row-crop. Crop and nitrogen management information were collected for each agricultural site and consisted of nitrogen application rates, timing, source and placement (Table 3). Nitrogen application rates included the actual amount of nitrogen from commercially applied fertilizers, first and second year manure credits and credits from alfalfa. Total nitrogen rates also included incidental nitrogen sources from starter, ammonium thiosulfate (AMS), diammonium phosphate (DAP) and monoammonium phosphate (MAP) fertilizers containing nitrogen. Tables 1 and 2 provide additional management details about each site. Soils at the monitoring locations consisted of well drained to moderately well drained silt-loam soil types. The typical range of organic matter in these soils is 2.7% to 3.9% with an average of 3.3%.

Table 1. Land use as a percentage of county area. (Source: 2015 Cropscape Cropland Data Layer-Center for Spatial Information and Science Systems)

County	Corn and Soybeans	Alfalfa	Forest	Grass/Pasture	Turf/Homeowner Lawns[1]	Golf Course[2]
	-----------------------------% of county area------------------------------------					
Fillmore	45%	6%	22%	21%	3%	<0.1%
Olmsted	43%	4%	15%	23%	6%	0.1%
Winona	22%	6%	39%	21%	4%	0.1%
Wabasha	33%	5%	24%	23%	3%	<0.1%
Overall Avg.	36%	5%	25%	22%	4%	<0.1%

[1]Uses the developed open space classification in CropScape and likely overestimates the area managed for turf.
[2] Digitized from the MNGEO 2015 aerial photography.

Equipment

Soil water samples were collected using 50 porous cup tensiometers (Figure 2), more commonly called suction cup lysimeters. Lysimeters consisted of a 24-inch long piece of PVC pipe, sampling and suction lines and porous ceramic tip. The basic construction involved attaching and sealing a ceramic tip to one end of a 1.5 inch diameter PVC pipe with epoxy and attaching a rubber stopper to the other end. The rubber stoppers were secured with electrical tape and special adhesive to ensure complete sealing. Two, 0.25 inch diameter plastic tubes were passed through the rubber stopper to ensure an air tight seal. One tube was used as the sample line. It extended to the bottom of the porous ceramic tip and was used for sampling water from the lysimeter. The other line, the suction line, was used to create a vacuum within the lysimeter.

At cultivated row crop sites, lysimeters were installed to a depth of four feet within the vadose zone and placed a minimum of 40 feet into the field. This distance was used to minimize edge of field variability caused by compaction, non-uniform fertilizer applications, and help avoid other factors that can be common in the headland areas of row-crop fields. At most locations, at least two lysimeters were paired together at each site to better understand variability. Having two lysimeters also provided redundancy in the event one lysimeter failed. Typically, paired lysimeters were installed 20 feet apart. To prevent damage from tillage equipment, a trenching machine was used to create a 2.5 foot deep trench to route the sample and suction lines from lysimeters to the field edge. The sample and suction line tubing was routed through PVC conduit to protect it from being crushed by the soil during reburial and terminated in a single sampling port. At the desired lysimeter location within the field, an additional 1.5 foot deep hole was excavated within the bottom of the trench using a four-inch diameter soil auger. To minimize soil disturbance directly above the lysimeters, the hole was hand augered at an approximate 20-degree angle from the bottom and long axis of the machined trench. This ensured that the sampling tip was beneath undisturbed soil and not directly under the

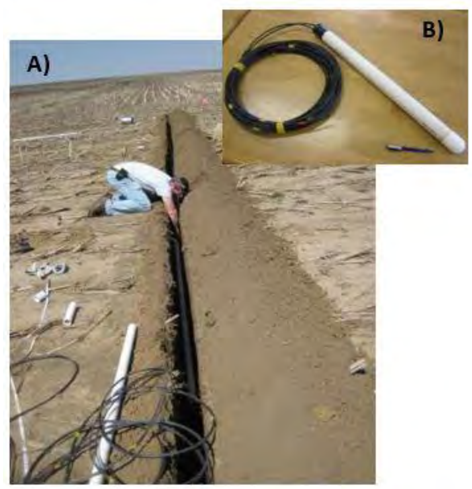

Figure 2. A) Installation of lysimeter sample and vacuum lines in a field managed for continuous corn silage and dairy manure. Sample lines were trenched 2.5 feet below the surface while lysimeters were placed four feet below the soil surface. **B)** Porous tension ceramic cup lysimeter with vacuum and sampling lines. Pen in lower right corner of photograph used for scale and is pointing at the ceramic tip.

excavated trench. A distilled water and silica slurry mixture was placed in the augered hole around the ceramic tip to ensure adequate hydraulic contact and movement of water to the lysimeter. Bentonite clay was packed above the ceramic tip during backfill to prevent drainage along the side of the lysimeter. At the golf course and homeowner lawn sites, lysimeters were installed using a hand auger to a depth of about two feet. At two row-crop sites, the full four-foot depth was not achieved because of refusal due to shallow bedrock. In all cases the lysimeters were installed a minimum of 4 to 6 inches above the bedrock at least two feet below the surface. At all sites the depth of the lysimeter sampling tip was below the rooting depth of the associated land cover vegetation. Lysimeters were permanently installed at each location and not removed during the study period. Lysimeter construction, installation and training was provided by MDA and SMWRC with assistance from Fillmore SWCD and MPCA.

Sampling and Analysis

A 30-40 centibar vacuum was applied to the lysimeters between sampling periods. Sampling intervals were consistent throughout the study period and were collected every two weeks during the frost-free period, typically from April through October (Figure 3). In some years it was possible to start sampling in March and extend sampling through November due to above normal temperatures. Samples were collected using a hand operated vacuum pump and one-liter Erlenmeyer flask. In most cases 300-600 mL of water was available for sampling of which 100 mL was used for nitrate analysis. Samples were placed on ice in a cooler and kept refrigerated until analysis. Water samples were analyzed using a Hach® DR6000 UV spectrophotometer (pour-through method 357-10049, DOC 316.53.01072) located in the MDA Preston field office within a week of sample collection. The detection limit using this method is 0.1 mg/L. Samples were analyzed using standardized quality assurance and control (QA/QC) procedures. As part of the QA/QC, a duplicate of no less than 10% of the water samples were selected randomly and analyzed by the Minnesota Department of Agriculture (MDA Lab) certified laboratory located in St. Paul. It should be noted that the MDA lab method includes both nitrite and nitrate (NO_2-N + NO_3-N) while the DR6000 method does not report nitrite(NO_2-N). Nitrite is seldom present in groundwater and if detected is typically less than 0.3 mg/L, transforms quickly to the more stable nitrate form (USEPA, 1987), and therefore is not considered to be a significant factor when comparing the two methods. Additional details regarding the duplicate sample results are included in Appendix C of this report. Statistical group tests were used to identify significant differences between the various land covers. If *p* values were less than or equal to 0.05 when using non-parametric tests on the nitrate median, the groups were considered statistically different. The Mann-Whitney test was used when comparing individual pairs while the Kruskal-Wallis multiple comparison test was used across all land covers. Statistical analysis was conducted using R and Minitab® statistical software.

Figure 3. *Soil water nitrate collection from a continuous corn grain site (OM70/90). The sampling port was located in a grassed waterway.*

Table 2. Land cover and farming practices evaluated during the five-year soil water nitrate study.

Land Cover	Land Cover Grouping	Lysimeter ID	Location (# of lysimeters)	Description
Prairie	Non-Agriculture	CW/CY QW/QY	Fillmore (2) Winona (2)	CW/CY field had previously been in row crops and was enrolled in the conservation reserve program (CRP) for five years prior to sampling. QW/QY field was managed since the 1980's as a long-term bluff-top prairie with no contributing area from other land covers or uses. Vegetation at both sites consisted of well-established warm season grasses and forbs.
Forest	Non-Agriculture	JW/JY	Winona (2)	Mature deciduous hardwood hillslope with a moderate level of understory vegetation. Site JW was uphill while JY was downhill, about 20 feet apart.
Lawn	Non-Agriculture	LW/LY KW/KY	Winona (4)	LW/LY did not receive fertilizer while KW/KY received a one-time application during the first year. Both residential lawn sites consisted of Kentucky bluegrass.
Golf Course	Non-Agriculture	MW/MY	Wabasha (2)	Samples collected from the fairway (MW-rough) and an adjacent tee box (MY). The fairway site received low maintenance fertilizers while the tee box received an annual rate of 120 lb N/ac divided between three different applications.
Pasture	Pasture and Grass	GW/GY RW/RY PW/PY	Winona (2) Fillmore (4)	Pastures with cow/calf beef herds that consisted of both rotationally grazed and non-rotational management with low to moderate stocking density. Site GW/GY received 50-60 lb N/ac of urea and AMS broadcast applied every spring. RW/RY was a rotationally grazed dairy pasture site. About 15 cows were pastured in a 30'x30' pen and rotated out once a month with 1-2 weeks of recovery between rotations. Heavy grazing resulted in excessive manure coverage. PW/PY received spring broadcast liquid dairy manure which contained about 30 lb N/ac. Due to lysimeter failure, this site was not sampled in 2013 and 2014.
Grass Strip (non-fertilized)	Pasture and Grass	CFE20	Fillmore (1)	This site was managed as a grassed field border. Kentucky blue and brome grasses were mowed periodically. The field border was 60 feet wide and no nitrogen fertilizers were applied. Surrounding fields consisted of corn and soybeans and had slopes between 4-6%. The lysimeter was placed in the middle of the strip near the toe slope.
Grass Strip (Fertilized)	Pasture and Grass	OMAgw OMCgw	Fillmore (2)	This site was a fertilized grassed waterway in a field managed for continuous corn grain. The grassed waterway was about 15 feet wide and was mowed occasionally and consisted of brome and timothy. The grassed waterway received the same amount of commercial nitrogen fertilizer as the corn field. The continuous corn field received 150 to 240 lb N/ac.
Alfalfa with Corn	Row Crops	A70/90, CFE60/80, F70/90, NW/NY	Fillmore (8)	All fields had a minimum of three out of the five years with alfalfa and at least one year of corn. A70/90 was an organic field that received nitrogen from organic fertilizer (fish), manure and alfalfa credits. CFE 60/80 was managed for soybeans in 2011 and corn in 2012 and then rotated to alfalfa from 2013-2015. Field F70/90 was managed for alfalfa from 2011-2014 and then rotated to corn in 2015. About 40 lb N/ac was applied annually to this alfalfa field. During the corn year it received a total of 185 lb N/ac (125 lb N/ac from commercial fertilizer at preplant, sidedress and 60 lb N/ac alfalfa credit). NW/NY was managed for alfalfa the first four years and the last year was corn. The alfalfa received periodic liquid dairy manure applications.
Corn and Soybean Rotations & Continuous Corn	Row Crops	B70/90, E70/90, H70/90,CFW40/60/80, D70/90, I70/90 (OMA7090,OMB7090, OMC7090,OMD7090B)	Fillmore (19) Olmsted (2)	All sites contained a mix of row crop fields managed for corn-soybean rotations or continuous corn. Three sites received manure while other sites received only commercial fertilizer. All sites also applied a wide range of application rates (140 lb/ac to 240 lb/ac). At one continuous corn site (OMABCD), four different rates of manure and commercial fertilizer were applied (140, 160, 190, 220 lb N/ac) during a two-year period to evaluate the relationship between nitrogen credits from dairy beef bedding pack manure and soil water nitrate. Site B70/90 was a no-till site and transitioned from CRP to row cropping in 2009. Typical N rates were 150 lb/ac for C/S and 180 lb/ac for C/C. D70/90 was continuous corn from 2011-2013 with an average 200 lb N/ac from liquid dairy manure. E70/90 was mainly managed for corn silage and soybeans. Fall seeded cover crops were established in the fall to extend cattle grazing in the spring. About 160 lb N/ac was applied for C/S and 190 lb N/ac for C/C. Lysimeters were placed below a terrace and could have been affected by upgradient lateral flow. H70/90 was managed for continuous corn and total nitrogen rates ranged from 180 to 200 lb N/ac with split nitrogen applications.

Table 3. Land cover and nitrogen management details by site and year. Total nitrogen rates in pounds per acre (lb/ac) from manure or commercial fertilizers is displayed in parenthesis. Total nitrogen includes first and second year manure nitrogen credits and credits associated with alfalfa and other incidental nitrogen sources from starter, AMS, DAP and MAP fertilizers.

Site ID	Land Cover	Land Cover Grouping	2011	2012	2013	2014	2015
CW/CY	Prairie	Non ag	CRP/Prairie (0)	CRP/Prairie (0)	CRP/Prairie (0)	CRP/Prairie (0)	CRP/Prairie (0)
QW/QY	Prairie	Non ag	Prairie (0)	Prairie (0)	Prairie (0)	Prairie (0)	Prairie (0)
JW/JY	Forest	Non ag	Forest (0)	Forest (0)	Forest (0)	Forest (0)	Forest (0)
LW/LY	Lawn	Non ag	Lawn (0)	Lawn (0)	Lawn (0)	Lawn (0)	Lawn (0)
KW/KY	Lawn	Non ag	Lawn-fertilized (160)	Lawn (0)	Lawn (0)	Lawn (0)	Lawn (0)
MW/MY	Golf Course	Non ag	Golf Course (140)	Golf Course (140)	Golf Course (140)	Golf Course (140)	Golf Course (140)
GW/GY	Pasture	Pasture and grass	Pasture, spring bdcst. No-inc. (50)	Pasture, spring bdcst. No-inc. Urea/AMS (56)	Pasture, spring bdcst. No-inc. Urea/AMS (56)	Pasture, spring bdcst. No-inc. Urea/AMS (56)	Pasture, spring bdcst. No-inc. Urea/AMS (56)
RW/RY[1]	Pasture	Pasture	Pasture (manure N, qty unknown)	Pasture (manure N, qty unknown)	Pasture (manure N, qty unknown)	Pasture (manure N, qty unknown)	Pasture (manure N, qty unknown)
PW/PY	Pasture	Pasture and grass	Pasture[1] (manure N, qty unknown)	Pasture, summer bdcst. No-inc. liquid dairy manure (13)	Pasture, summer bdcst. No-inc. liquid dairy manure (33)	Pasture, summer bdcst. No-inc. liquid dairy manure (33)	Pasture, summer bdcst. No-inc. liquid dairy manure (33)
CFE20	Grass strip NF	Pasture and grass	Grass field border (0)	Grass field border (0)	Grass field border (0)	Grass field border (0)	Grass field border (0)
OMACgw	Grass strip F	Pasture and grass	Grassed waterway (186)	Grassed waterway (180)	Grassed waterway (200)	Grassed waterway (200)	Grassed waterway (240)
A70/90	Alfalfa with corn	Row crop (organic)	Corn, spring knife inj. Swine, bank liq. Fish, legume crdt. (285)	Oats/alfalfa, foliar liq. Fish, 2nd yr manure and legume crdts (101)	Alfalfa, foliar liq fish (20)	Corn, spring bdcst, noinc. Bedding pack beef manure, band liq. Fish, 1st yr legume crdt. (140)	Oats/alfalfa, foliar liq. Fish, 2nd yr manure credit (21)
CFE60/80	Alfalfa with corn	Row crop	Soybean	Corn, fall liquid hog inject (180)	Oats/alfalfa	Alfalfa	Alfalfa
F70/90	Alfalfa with corn	Row crop	alfalfa, summer bdcst, no inc. DAP (9)	alfalfa, summer bdcst, no inc. DAP (36)	Alfalfa, summer bdcst, no inc. DAP (36)	Alfalfa, summer bdcst, no inc. DAP (36)	Corn, fall P&K strip till, side dres incorp. UAN, legume credits (185)
NW/NY[1]	Alfalfa with corn	Row crop	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Corn
B70/90	C-S	Row crop	Corn, spring 4x4 band UAN Rawson cart, no till (179, split)	Soybeans, spring bdcst AMS and 9-23-30, no till (11)	Corn, spring 4x4 band UAN Rawson cart, no-till (150,split)	Soybeans, spring bdcst AMS, 9-23-30 (11), no till	Soybeans, spring bdcst AMS, no-till (2)
BCE40 /60/80	C-C	Row crop	Corn, spring commercial bdcst/incorp. urea (178)	Corn, spring commercial bdcst/incorp. urea (180)	Corn silage, spring urea, bdcst/incorp. (189)	Corn silage, fall, liquid dairy inject (151)	Corn silage, fall liquid inject (168)

Site ID	Land Cover	Land Cover Grouping	2011	2012	2013	2014	2015
CFW40/ 60/80	C-C	Row crop	Corn silage, fall liquid dairy inject (182)	Corn silage, Fall liquid dairy inject (180)	Corn silage with rye cover. Spring Urea, bdcst/incorp (207)	Corn silage, fall liquid dairy inject (199)	Corn silage, Fall liquid dairy inject (190)
D70/90	C-C	Row crop	Corn (prev. CRP), spring liq. dairy bdcst-inc., pp bdcst Urea/AMS, starter (198)	Corn, spring pp, bdcst-inc., Urea/AMS, starter, 2nd yr manure credits (204)	Corn, spring pp, bdcst-inc., Urea/ams, starter (191)	Oats/alfalfa, spring pp bdcst-inc. AMS (21)	Alfalfa (21)
E70/90	C-S w/ Rye	Row crop	Corn silage w/ rye grazed, spring pp bdcst inc. UAN/DAP, starter (188)	Corn silage w/rye grazed, spring pp bdcst, inc. UAN/DAP/starter (188)	Soybeans, spring cattle grazed off cover crop (0)	Corn w/rye grazed off in spring, spring starter, post UAN bdcst, no incorp. (156)	Soybeans, spring cattle grazed off cover crop (0)
H70/90	C-C	Row crop	Corn, fall strip till, DAP/AMS, spring Urea/ESN bdcst, inc., starter, sidedress (UAN) (183)	Corn, fall strip till, DAP/AMS, spring Urea/ESN bdcst, inc., starter, sidedress (UAN) (183)	Corn, fall strip till, DAP/AMS, spring Urea/ESN bdcst, inc., starter, sidedress (UAN) (183)	Corn, fall strip till, DAP/AMS, spring Urea/ESN bdcst, inc., starter, sidedress (UAN) (204)	Corn, fall strip till, DAP/AMS, spring Urea/ESN bdcst, inc., starter, sidedress (UAN) (204)
I70/90[1]	C-C	Row crop	Corn	Corn	Corn	Soybeans	CRP
OM70/90	C-C	Row crop	Corn, bdcst-inc. within 12 hours, fall applied beef bedding pack and UREA. Replicated test strips (175)	Corn, bdcst-inc. within 12 hours, 2nd year beef bedding pack credits and UREA. Replicated test strips (175)	Corn bdcst-inc. Urea/AMS, sidedress UAN w/coulter (240)	Corn bdcst-inc. Urea/AMS, sidedress UAN w/coulter (240)	Corn bdcst-inc. Urea/AMS, sidedress UAN w/coulter (240)

[1] Some or all nitrogen fertilizer records were not available

Abbreviation key: C-C = corn following corn rotation, C-S = Corn following soybean rotation, bdcst-inc. = broadcast-incorporate, DAP = diammonium phosphate, MAP = monoammonium phosphate, AMS = ammonium sulfate, UAN = urea ammonium nitrate, ESN = environmentally stable nitrogen, pp = preplant

Study Considerations and Limitations

Lysimeters are one of the most basic and economical ways to collect soil water samples for nitrate monitoring. See Appendix A for additional discussion: *Considerations when Interpreting Soil Water Nitrate Concentrations from Lysimeters.* This study's interpretations were constrained by several factors. The main objective was to assess the relative range of nitrate concentrations across a wide range of land covers. As such, there was limited ability to replicate some of the land cover categories at multiple sites. About two-thirds of the land cover categories had less than three replications. In the case of the golf course or homeowner lawns, only one or two sites were monitored and there were no turf sites with high nitrogen fertilizer inputs. As a percentage of the county land use, however, turf represents less than 5% of the county area and golf courses less than 0.1% (Table 2). Due to time and labor constraints and the practicality of retrieving samples, usually fewer than three lysimeters were installed within the row crop field sites. Other studies have preferred to use sub-surface pattern tile research plots to better control for other variables. (Randall and Goss, 2008 and Brouder et al, 2005). Monitoring nitrate concentrations and loss from tile drainage systems are preferred since drainage water measured at the tile outlet represents an integrated average across the entire field rather than a few point locations. However, this study was motivated to specifically assess nitrate concentration ranges associated with non-tile drained karst landscapes. The relatively steep topography and moderate to well-drained silt loam soils that are characteristic of the Driftless Area of southeastern Minnesota are generally not suitable for intensive, patterned subsurface tile drainage systems and, as such, the practice is not common within the region.

This experimental design attempted to address the cautions (described in Appendix A) that must be taken when interpreting results collected from lysimeters. Primarily, the inclusion of at least a pair of lysimeters located a minimum of 20 feet apart at each field site provides an opportunity to compare the results for each sampling event and assess if the nitrate concentrations of the paired samples were consistent, and therefore likely representative of the larger site.

Precipitation During the Study Period

Precipitation can influence the range of nitrate concentrations measured in soil water. Small soil water sample volumes collected during dry conditions tend to have higher concentrations while during very wet conditions nitrates can be reduced due to dilution. Additionally, nitrate can be ‘stored’ in the soil profile during unusually dry periods and then be flushed out during subsequent wet periods (Kaushal et al, 2010). This has been well documented in several studies in southeast Minnesota, northeast Iowa and Midwest streams (Schilling et al, 2019, Van Metre et al, 2016, Barry et al, 2020).

Annual precipitation totals were summarized from the National Weather Service station at Preston during the study period (Table 4). The weather station at the City of Preston was selected because it is centrally located within the study area and has a long-term precipitation record. The 30-year (1981-2010) normal or average for Preston was 35.6 inches per year. Annual precipitation totals ranged from a low 28.1 inches in 2012 to a high of 47.6 inches in 2013 with a five-year average of 34.9 inches. When compared to the percent departure from normal, values ranged from 21% below normal to 34% above normal in 2012 and 2013, respectively. When the departure from normal was within 10%, precipitation was considered near normal. If precipitation was below normal by more than 10% it was considered dry and when 10% above normal it was considered wet. Years 2011 and 2012 were both dry while years 2014 and 2015 were near normal. Figure 4 shows that 2013 was very wet with most precipitation occurring from April through June and October.

Table 4. Annual precipitation totals, departure from normal and classification during the study period. The 30-year (1981-2010) normal or average for Preston is 35.6 inches.

Year	2011	2012	2013	2014	2015
Total Annual Precip. (in.)	28.6	28.1	47.6	36.3	34.0
Departure from normal (%)	-20%	-21%	+34%	+2%	-4%
Classification	Dry	Dry	Wet	Near Normal	Near Normal

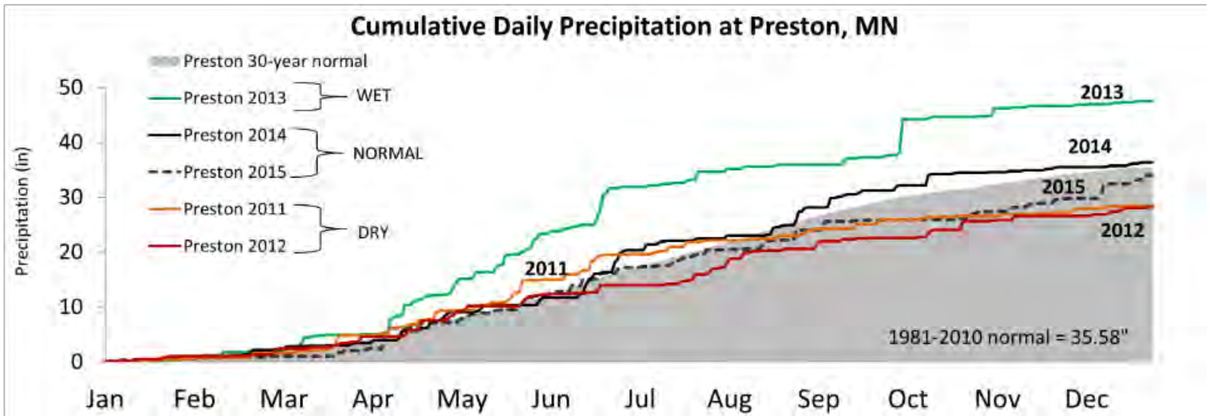

Figure 4. Cumulative daily precipitation at Preston during the study period (2011-2015). The study period contained a mixture of wet, dry and normal conditions.

Interpreting Nitrate Concentrations from Row-Crop Fields

General guidelines for interpreting nitrate concentrations measured in sub-surface tile drainage water were summarized in a 2005 report from Purdue University Extension (Brouder et al, 2005). A modified table from this report is provided as Table 5 and includes data from the Midwest corn-belt. Although soil water samples collected during this study may not be a direct comparison to tile drainage water, Table 5 is a useful reference for helping interpret soil water nitrate concentrations. Brouder et al. (2005) indicates that concentrations between 10 to 20 mg/L would be typical for Midwestern corn belt row crop systems with nitrogen applied at economically optimum nitrogen rates. It should be noted these concentrations can vary considerably by site and weather conditions.

Table 5. General guidelines for interpreting nitrate-N concentrations in tile drainage water. The interpretation is derived from numerous studies conducted throughout the Midwest corn belt and highlights land management strategies commonly found in association with a concentration measured in tile water leaving the field (modified from Brouder et al, 2005).

Tile Drainage Nitrate Concentration (mg/L)	Interpretation
≤ 5	Native grassland, Conservation Reserve Program (CRP) land, alfalfa, managed pastures.
5-10	Row crop production on a mineral soil without N fertilizer. Row crop production with N applied at 45 lb/acre below the economically optimum N rate row crop production with successful winter crop to “trap” N.
10-20	Row crop production with N applied at optimum N rate
≥ 20	Row crop production where: **a)** N applied exceeds crop need **b)** N applied is not synchronized with crop needs **c)** environmental conditions limit crop production and N fertilizer use efficiency **d)** environmental conditions favor greater than normal mineralization of soil organic matter.

Lysimeter Comparison Values

Northcentral Lysimeters

For the past several decades the MDA's Fertilizer Field unit has initiated groundwater protection demonstration projects using lysimeters. These sites have been used to help foster partnerships among farmers, their crop advisors, citizens and local, state and university staff. Some of the longest running demonstration sites are located on coarse textured irrigated soils in northcentral Minnesota (Figure 5).

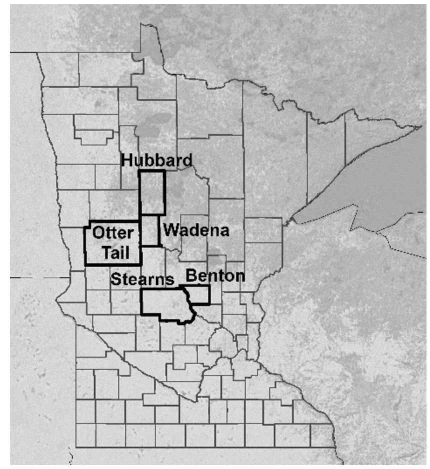

Figure 5. MDA northcentral water quality demonstrations sites. Project counties outlined in black.

Soil water nitrate collected from a wide range of cropping systems and weather conditions provide a useful comparison with the SLN. It should be noted that all the northcentral sites contain coarse textured sandy loam or loamy sand soil textures and many sites were irrigated. Table 6 provides the summary statistics and reflect sampling conducted between years 2000-2019.

Table 6. Soil water nitrate-N summary statistics across various cropping systems in northcentral Minnesota. Data reflect years from 2000-2019.

Crops grown	Number of Samples	Mean	St Dev	Min.	Q1	Median	Q3	Max.
		-------------------------Soil water nitrate-N (mg/L)------------------------------						
corn-soybeans	4,755	30.4	17.9	<0.1	16.3	28.0	41.1	120.0
corn, soybeans, edible beans, potato, alfalfa	5,787	35.1	29.2	<0.1	15.0	29.0	46.0	240.0

Table 7 displays the summary statistics of soil water nitrate measured from turf sites located in Otter Tail and Stearns county. Data collected from the Otter Tail county site reflect years 2000-2004 and the Stearns site reflect years 2014-2019. Lysimeter depth was about 16 to 20 inches at these sites. The Stearns site is a long-term study to evaluate the relationship between soil water nitrate and lawn nitrogen fertilizer application rates. Replicated and randomized treatments included a zero-rate check, a low rate of 3 lb N/1,000 ft^2, a medium rate of 6 lb N/1,000 ft^2 and a high rate of 9 lb N/1,000 ft^2. These data provide a very useful reference for nitrate concentrations measured from fertilized and non-fertilized turf sites in Minnesota.

Table 7. Soil water nitrate-N summary statistics from the two turf sites in northcentral Minnesota. Data reflects years from 2000-2019.

Cover Type	Number of Samples	Mean	St Dev	Min.	Q1	Median	Q3	Max.
		-------------------------Soil water nitrate-N (mg/L)------------------------------						
Turf/Lawn	1,946	2.3	4.1	<0.1	0.7	1.1	2.1	50.0

Lysimeter Comparison Values

MDA and Discovery Farms Minnesota On-Farm Drainage Tile Monitoring

Another source of information that can be used for comparison with the SLN is from a network of on-farm sub-surface tile drainage monitoring sites associated with the MDA and Discovery Farms Minnesota. Table 8 summarizes the annual flow weighted mean concentrations (FWMC) and yield (lb/ac) from 2011-2015. Samples were collected across nine counties (Figure 6) using automated equal flow increment composite sampling methods. Crops grown included corn, soybean and corn with alfalfa rotations. It also included sites that received dairy and hog manure and sites with only commercial fertilizer. The FWMC across all sites was 21.4 mg/L with a typical range (i.e. interquartile range) of 15.6 mg/L to 25.6 mg/L. The average nitrate loss was 17.0 lb/ac with an interquartile range of 5.5 lb/ac to 31.1 lb/ac.

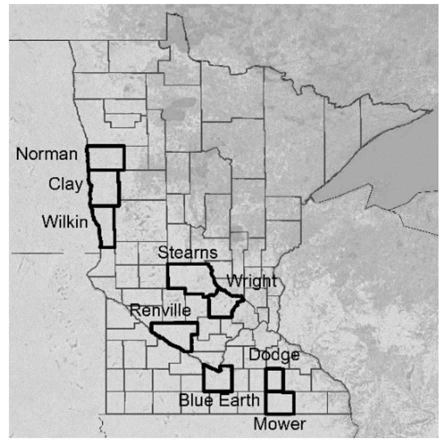

Figure 6. On-farm drainage tile monitoring locations associated with the MDA and Discovery Farms Minnesota. Project counties are outlined in black.

Table 8. Annual FWMC's and loss from sub-surface tile drainage across in nine counties from 2011-2015. Data from Discovery Farms Minnesota and Minnesota Department of Agriculture.

Number of Site Years	Mean	St Dev	Minimum	Q1	Median	Q3	Maximum
	------------------------------------FMWC (mg/L)------------------------------------						
34	21.4	8.9	3.7	15.6	19.8	25.6	50.3
	------------------------------------Loss (lb/ac)------------------------------------						
35	17.0	15.2	0.0	5.5	10.5	31.1	55.1

Results and Discussion

Soil water nitrate concentrations measured across nine different types of land covers in the SLN are summarized in Figure 7 and Table 9. Nearly 3,000 individual nitrate tests were analyzed from 50 different lysimeters across 23 different sites during the five-year study. In Figure 7, land cover types were grouped into three different categories and the averages were sorted from lowest to highest N concentration within each category. The box plot represents the middle 50% of the data or the interquartile range. Although soil water sampled from lysimeters is not used directly for drinking water, the Environmental Protection Agency (EPA) maximum contaminant level of 10 mg/L for drinking water is provided for reference and shown as a dashed horizontal line. The length of each box indicates variability. Figure 7 clearly shows that the non-agriculture sites have much less variability and lower soil water nitrate while the agricultural sites have both higher nitrate and higher variably. Results from the group statistical tests are also provided in Figure 7 and last row of Table 9. Time-series charts showing the average monthly nitrate concentrations by individual site can be found in Appendix B. Table 10 provides the statistical analysis results between the various paired land cover types. When significant, the value in parenthesis below the *p* value represents the median point difference in mg/L between the respective pairs. For instance, when comparing the prairie versus forest land covers there were no significant differences (p value = 0.718). However, when comparing the prairie to the golf course, the golf course had significantly higher concentrations (p <0.01) and this difference was estimated to be 2.4 mg/L.

Non-Agriculture

The lowest nitrate concentrations were found in the 'non-agriculture' group which included grassland prairie (CRP), deciduous forest, low maintenance homeowner lawns and a golf course. Soil water nitrate concentrations within this category averaged between 0.1 mg/L to 3.7 mg/L with a typical range (i.e. interquartile range) of <0.1 to 5.3 mg/L. Standard deviations for the prairie and forest were very small and ranged from 0.3 mg/L to 0.9 mg/L. For comparison, Randall et al, (1997) found flow weighted average nitrate concentrations of 2 mg/L from a drainage tile research plot managed for CRP in southcentral Minnesota. The highest concentration observed at one of the lysimeter network prairie sites was 3.1 mg/L. This high reading is likely related to a millipede infestation within one of the lysimeter sampling ports. This particular species, a yellow-spotted millipede (Apheloria tigana), produces cyanide to fend off potential predators. Under aerobic conditions, the biodegradation of cyanide compounds produces ammonia which is then converted to nitrite and nitrate in the presence of nitrifying bacteria (Richards and Shieh, 1989).

For the lawn and golf course sites the average concentrations ranged from 1.1 to 3.3 mg/L. For comparison, average soil water nitrate concentrations from the northcentral Minnesota turf sites were similar and averaged 2.3 mg/L (Table 7) . A maximum concentration of 26 mg/L was observed at the homeowner lawn site in 2011. This was the result of a one-time over-application of nitrogen to the lawn by the homeowner. The golf course represented samples collected from the fairway and tee box. The fairway received minimal nitrogen fertilizer applications while the tee box received scheduled applications throughout the growing season. Fertilizer application records were not available, but conversations with the course manager indicated that low rates (less than 1.0 lb/1000ft^2 or ~40 lb/ac) were applied typically three times a year on the tee and only one time on the fairway. A 2015 and 2016 study sampled nitrate from shallow monitoring wells across six golf courses in Iowa (Schilling et al, 2018). The average nitrogen rate applied to the tee box, fairway and rough was estimated at less than 40 lb N/ac. Results from that study found that nitrate was not detected above 1.0 mg/L at half of the six courses and the overall mean concentration was 2.2 mg/l. Schilling et al. (2018) also approximated the mass of nitrate recharge to groundwater. This was estimated to be less than 10% of the commercial fertilizer nitrogen that was applied.

Statistically, the prairie and forest sites had the same concentrations. The homeowner lawn sites had higher concentrations when compared to the prairie and forest while the golf course had the highest average concentrations of 3.7 mg/L. When comparing the golf course site to the row crop sites, the row crop sites had significantly higher concentrations (p = <0.01) and this median point difference was estimated to be 14.0 mg/L.

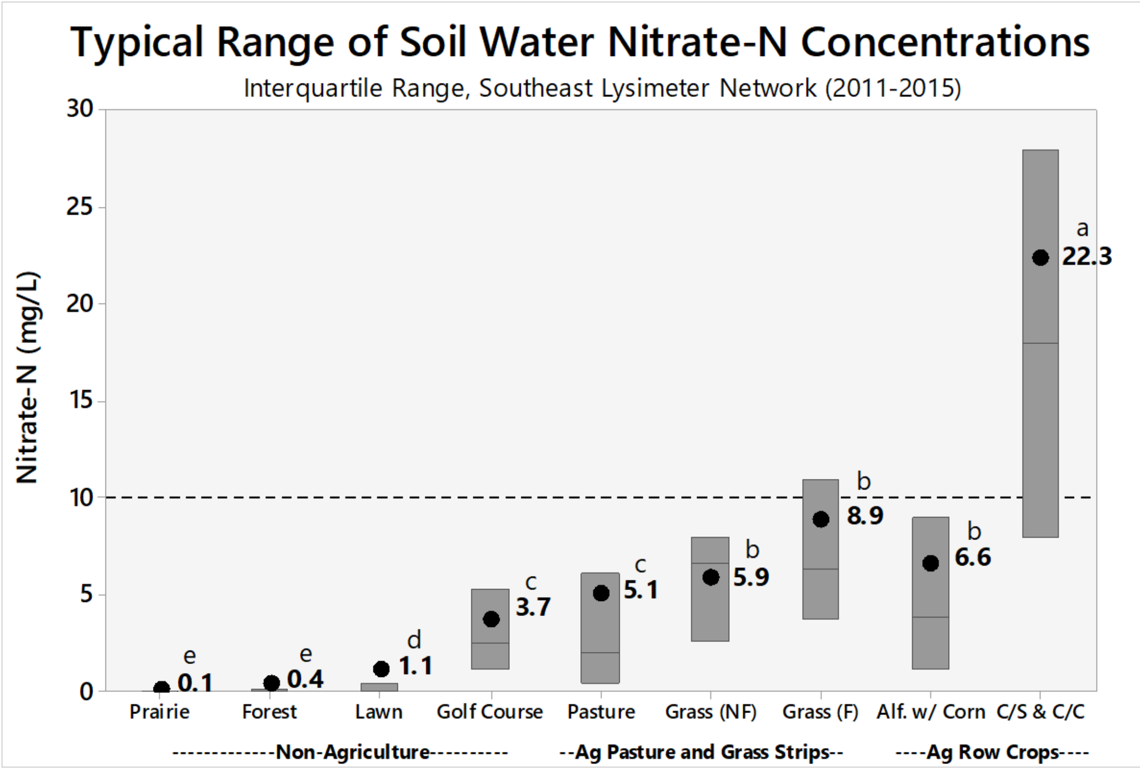

Figure 7. Typical range of soil water nitrate concentrations measured across nine different types of land covers in southeast Minnesota from 2011-2015. This chart represents nearly 3,000 individual samples collected from suction-cup lysimeters, typically from a depth of four feet. The boxes represent the interquartile range or middle 50% of the data. Average values as black dots are displayed next to each box while the median is represented by the horizontal line. Sites that do not share the same letter (displayed above the average value) are significantly different at the 0.05 level when using a Kruskal-Wallis multiple comparison test on the median. Although soil water is not used directly for drinking water, the dashed horizontal line is included as a reference and represents the 10 mg/L drinking water standard. For the grass strip sites, NF is non-fertilized, and F is fertilized. For the Ag row crops, alfalfa with corn had at least three years of alfalfa in the rotation and one year of corn during the sampling period. C/S were fields managed for corn-soybean rotations while C/C were sites managed for corn following corn or continuous corn. These two rotations were grouped together.

Table 9. Soil water nitrate-N summary statistics by land cover type from 2011-2015.

	--------Non-Agriculture-------				-Ag Pasture and Grass Strips -			--Ag Row Crops--	
Variable	Prairie	Forest	Lawn	Golf Course	Pasture	Grass Strip (NF)	Grass Strip (F)	Alf. w/ Corn	C-S and C-C
	-----Nitrate-N mg/L-----								
Mean	0.1	0.4	1.1	3.7	5.1	5.9	8.9	6.6	22.3
Std. dev.	0.3	0.9	3.6	3.2	8.2	3.3	9.6	8.2	21.8
Minimum	<0.1	<0.1	<0.1	0.1	<0.1	1.0	0.1	<0.1	0.1
Q1	0.1	<0.1	0.1	1.2	0.5	2.6	3.8	1.2	8.0
Median	0.1	0.1	0.1	2.6	2.0	6.7	6.3	3.9	18.0
Q3	0.1	0.2	0.5	5.3	6.2	8.0	11.0	9.0	28.0
Maximum	3.1	4.5	26.0	16.0	46.0	13.0	64.0	64.0	170.0
# of sites	2	1	2	1	3	1	1	4	8
# of lys.	4	2	4	2	6	1	2	8	21
# samples	150	96	235	104	198	60	106	546	1,478
Significance*	e	e	e	c	c	b	b	b	a

*(NF) = non-fertilized, (F) = fertilized, C-S = corn following soybeans and C-C = corn following corn *Sites that do not share the same letter were considered significantly different at the 0.05 level when using a Kruskal-Wallis multiple comparison test between medians.*

Table 10. Statistical analysis results between paired land cover types. The top value represents the *p* value. Cells shaded gray were considered statistically different at the 0.05 level when using the Mann-Whitney paired test between medians. Shaded cells with an asterisk are significant at the <0.01 level. When significant, the median point nitrate-nitrogen concentration (mg/L) difference between respective pairs is displayed in parentheses. For instance, when comparing the prairie versus the forest there were no significant differences (*p* value = 0.718). However, when comparing the prairie (column) to the golf course (row), the golf course had significantly higher concentrations (*p* < 0.01) and this difference was estimated to be 2.4 mg/L.

**p value < 0.01*	Prairie	Forest	Lawn	Golf Course	Pasture	Grass Strip non-fertilized	Grass Strip fertilized	Alfalfa w/Corn
Forest	0.718							
Lawn	* (<0.1)	0.033 (<0.1)						
Golf Course	* (2.4)	* (2.2)	* (2.0)					
Pasture	* (1.9)	* (1.7)	* (1.6)	0.123				
Grass Strip- non-fertilized	* (6.5)	* (6.3)	* (6.1)	* (2.4)	* (2.5)			
Grass Strip- fertilized	* (6.2)	* (6.0)	* (5.7)	* (3.3)	* (3.5)	0.187		
Alfalfa w/Corn	* (3.8)	* (3.8)	* (3.4)	* (1.0)	* (1.2)	0.092	* (-2.0)	
C-S and C-C	* (17.9)	* (17.9)	* (17.0)	* (14.0)	* (14.5)	* (12.1)	* (10.1)	* (12.3)

Ag Pasture and Grass Strips

The average soil water nitrate concentrations in the 'ag pasture and grass strip' category averaged between 5.1 to 8.9 mg/L with an interquartile range 0.5 mg/L to 11.0 mg/L. Nitrate concentrations from pasture sites averaged 5.1 mg/L and were significantly lower than the ag grass strips ($p < 0.01$), but were not significantly different from the golf course ($p = 0.123$). Pasture sites were seeded to perennial cool season forage grasses and grazed by cow/calf beef operations. Nitrogen inputs were limited to that supplied by manure and low amounts of commercial fertilizer. Some sites were rotationally grazed with no additional commercial fertilizer applied during the study while other sites received up to 60 lb N/ac/year of nitrogen fertilizer. At some sites, nitrogen inputs from manure were underestimated due to limited grazing records. At pasture site GW/GY it was observed in 2015 that cattle were loafing near the lysimeter sampling port. This presumably resulted in concentrated manure and urine input directly above the lysimeter, resulting in atypical nitrate transport to the lysimeter. Six months of samples ranging in nitrate-N concentrations of 66 to 360 mg/L were considered outliers and not used in the analysis.

In addition to the three pasture sites, two grass strips were monitored. One was managed as a grass field border while the other was a grassed waterway. The field border did not receive nitrogen while the grassed waterway received the same amount of fertilizer as the adjacent corn field. At the field border site, the 50-foot wide strip of grass ran parallel with the field slope and was located between two row-crop fields. This site was managed for cool-season grasses and was mowed occasionally for forage. At a second site, a grass strip was managed as a grassed waterway within a concentrated flow area within a field managed for continuous corn. Typical of most commercial fertilizer applications, the grassed waterway received the same rate of fertilizer as the adjacent corn field. Even though the field border didn't receive fertilizer while the grassed waterway did, statistically both grass strip sites had similar concentrations (p=0.187). It's possible that in some years, some of the nitrogen fertilizer applied to the field could have been broadcast beyond the target application area and incidentally fertilized the field border as well. Another contributing factor could be related to shallow sub-surface soil water flow from an adjacent crop field. Lateral flow and mixing of shallow soil water from adjacent corn fields likely occurred at both the fertilized and non-fertilized grass strip sites. Adjacent fields near the non-fertilized field border site have slopes of 4-6%, therefore, soil water sampled from the lysimeter could have been a mix of water that infiltrated through both the grass strip and an adjacent crop field that received nitrogen fertilizer. Piezometers were not installed to measure groundwater flow direction, but visual evidence during lysimeter installation suggested that subsurface groundwater flow direction was consistent with surface slope of the field. With that said, nitrate concentrations were significantly lower in both the fertilized and non-fertilized grass strips when compared to continuous corn or corn-soybean rotations (p<0.01). When comparing the ag grass strips to average nitrate concentrations found in corn-soybean land covers, the non-fertilized and fertilized grass strips had 60-74% less nitrate in soil water. Grass strips placed at the field edge were likely helping reduce concentrations contained in shallow, lateral flow from adjacent cropland. This reduction could be caused by a variety of factors including lower nutrient inputs within the grass strip, dilution from rainwater infiltrating within the grass strip, nitrogen uptake by the cool-season grass over a longer growing season when compared to the adjacent row crops, landscape position, immobilization and denitrification.

Ag Row Crop

The third category, 'Ag Row Crop', represented row crop fields managed for corn and soybean rotations (C-S) and continuous corn (C-C) and corn rotations with alfalfa. The 'Alfalfa with corn' classification had at least three years of alfalfa in the rotation and one year of corn during the sampling period. Row crop sites without alfalfa received a mix of both manure and commercial fertilizers and one site was organic. Soil water nitrate averaged 6.6 mg/L under row crop sites with alfalfa which equated to 70% less nitrate when compared to row crop fields without alfalfa in the rotation. Randal et al (1997) found that nitrate loss in subsurface drainage water from continuous corn and corn-soybean systems were about 37 and 35 times higher, respectively, than from alfalfa and CRP systems primarily due to greater evapotranspiration. This results in less drainage and greater uptake and/or immobilization of nitrogen by perennial crops.

Sites managed for continuous corn and corn-soybean rotations without perennials had the highest concentrations in the lysimeter network and averaged 22.3 mg/L with an interquartile range between 8 mg/L to 28 mg/L. This range indicates a high degree of variability and likely reflects the wide range of nitrogen management on the selected farms, diverse weather conditions and inherent variability associated with lysimeters. The standard deviation for the corn and soybean row-crop sites was 21.8 mg/L. For comparison, the standard deviations from the non-agriculture sites ranged from just 0.3 to 3.2 mg/L.

Results from a row-crop field in Fillmore County, site B70/90, were interesting. It was expected that this site would have concentrations between a typical range of 10-20 mg/L. However, in four of the five study years, concentrations remained at or below 10 mg/L and during the first two years nitrate concentrations were typically below 2.0 mg/L. This field was previously in CRP for ten years and did not receive nitrogen fertilizer. This resulted in less residual soil nitrate stored within the soil profile and less nitrate available for leaching in subsequent years. A legacy effect caused by the CRP grassland combined with dry conditions in 2011 and 2012 likely explain why concentrations remained very low during the first two years of row crop production. This farmer also applied lower rates of nitrogen because less nitrogen was expected to be lost through volatilization and leaching with a split nitrogen application program. Although the effectiveness of split applications can be mixed and weather dependent, this practice generally results in higher nitrogen use efficiencies and about 7% less nitrate loss when compared to a pre-plant nitrogen fertilizer application program (Iowa State University, 2013).

Nitrate loss calculation estimates

Nitrate loading was approximated from the SLN row crop sites. Nitrate loss expressed in traditional farm scale units (pounds per acre) was estimated by multiplying the volume of recharge passing through the soil by the nitrate concentration when using the following equation:

Nitrate loss (lb/ac) = 27,154 gal/ac. in. *8.34 lb/gal / 1,000,000 * nitrate concentration (mg/L) * drainage (in.) This equation results in a conversion factor of 0.226 and the following simplified equation:

$$0.226 * \text{nitrate (mg/l)} * \text{drainage (in.)} = \text{lb/ac nitrate}$$

For example, assuming a nitrate concentration of 10.0 mg/L and 5-acre inches of drainage water, the amount of nitrate loss equates to 0.226 * 10.0 * 5.0 = 11.3 lb/ac. In this study, drainage volumes were not measured directly from the lysimeters, but were estimated from a nearby long-term tile monitoring site and applied to the row crop sites in the lysimeter network. This comparison assumes that drainage and evapotranspiration rates were similar across the lysimeter network. Where accurate weather data exist, nitrate loading estimates from the lysimeter network could be improved by using a water balance method and applying an evapotranspiration model that is specific to each site. At a tile drainage monitoring site located about 30 miles west of the Lysimeter Network study area (station SRT, MDA-Root River Field to Stream Partnership) in Mower county, Minnesota an average 24% of the annual precipitation or 8.0 inches of drainage per acre was measured from 2011-2015 (Table 8). This equated to a FWMC of 15.7 mg/L or when 25.3 lb/ac nitrate loss. This field was managed for a corn-soybean rotation and the corn crop typically received a total of 170 lb/ac of pre-plant nitrogen.

Table 11. Annual sub-surface drainage, and nitrate FWMC's and loss from a 59-acre field managed for corn and soybeans in Mower County. This long-term monitoring site is located about 30 miles west of the Lysimeter Network and is one of several edge of field demonstration sites associated with the Root River Field to Stream Partnership.

	2011*	2012	2013	2014	2015	Average
Annual precip. (in.)	22.6	23.4	40.0	32.0	34.1	30.4
Drainage (in./ac)	3.0	0.9	11.9	9.8	14.5	8.0
Drainage: Precip (%)	13%	4%	30%	31%	43%	24%
Nitrate-N (FWMC, mg/L)	13.0	23.7	13.5	15.8	12.5	15.7
Nitrate-N (lb/ac)	8.8	5.1	36.6	35.0	40.9	25.3

*Values are underestimated and represent a partial season. Data were not available from January 1, 2011 through May 17, 2011.

With the assumption that 8-acre inches of drainage water also occurred on the lysimeter network fields, the average nitrate loss was estimated to be 40.3 lb/ac with an interquartile range of 14.5 lb/ac to 50.6 lb/ac. For comparison, the average nitrate loss from the Mower site was 25.3 lb/ac. This was about 60% lower than the SLN. These differences can be partly explained by the following factors: (1) Lower permeability of the glacial till soils at the Mower county site could result in higher rates of denitrification under certain years and conditions and therefore less nitrate measured in drainage leachate (Rodvang and Simpkins, 2001) (2) Nitrate losses from 2011 reflect a partial year at the Mower county site and are underestimated due to a partial year of sampling (3) lysimeter loss estimates may not represent the entire field when compared to tile drainage samples, and (4) the SLN contains a greater diversity of nitrogen management practices including rotations with continuous corn and manure that had higher nitrogen fertilizer inputs.

Row-crop Nitrate Comparisons

To aid interpretation, results from the SLN were compared to other lysimeter and tile drainage sites in Minnesota and Midwest corn belt.

Generally, nitrates measured from the corn-soybean and continuous corn sites in the SLN were within the range of concentrations found in sub-surface drainage tile across Minnesota (Table 8). Nitrate concentrations were not significantly different ($p=0.212$) and both data sets averaged between 21.4 to 22.3 mg/L. Although the averages were very similar, the standard deviation from the lysimeter network was 12.9 mg/L higher. The likely reason for this difference is because lysimeters represent small point measurements within the field and therefore subject to more variation. In contrast, pattern tiled drainage sites have less variation since the concentration measured at the tile outlet represents a composite mixture of drainage water that is representative of the entire area of the drained field. When concentrations were compared to tile drainage sites across the Midwest corn belt (Table 5), the SLN concentrations were about 12% higher than the 20 mg/L row crop reference value contained in that report.

When the SLN corn-soybean and continuous corn sites were compared to a irrigated northcentral corn-soybean site (Table 6) during the same monitoring period of 2011-2015, the northcentral site had significantly higher concentrations ($P<0.05$) and the median point difference was estimated to be 6.6 mg/L. Higher nitrate concentrations are to be expected in this region of the state because the sandy soils that are common in this area can result in greater nitrate loss below the crop root zone. Furthermore, row crops grown on coarse textured soils require higher rates of nitrogen fertilizer, therefore, soil pore water can contain higher nitrate in solution.

Suggestions for Further Study

Where appropriate weather data are available, nitrate loss estimates could be refined using a water balance method and evapotranspiration model for each site. In future studies, performance monitoring of septic system drain fields in areas with low and high density housing, cover crops and alternative crops such as hemp should be explored. For site B70/B90, concentrations were much lower than expected and additional investigation could be warranted regarding the effect of no-till and split nitrogen applications in a corn-soybean rotation. Additional monitoring of grassed waterways and edge of field grass strips would also be beneficial. Grassed waterways are one of the most widely used conservation practices by farmers in southeast Minnesota and quantifying the effect of these practices would be beneficial as an input for groundwater modeling. For best management practice (BMP) comparison sites, additional statistical analysis should be conducted to estimate how many samples would be needed to detect a given percent change in nitrate concentration at the 0.10 and 0.05 confidence levels. This could help lower labor and analytical costs in future monitoring efforts.

Summary and Conclusions

Low levels of soil water nitrate, generally less than 0.5 mg/L, were consistent across the prairie and forest sites. In these land covers, nitrate concentrations are very low because nitrogen is mineralized from soil organic sources and the nitrogen supplied is in equilibrium with plant nitrogen needs. A fertilized golf course site averaged less than 4 mg/L and had similar concentrations when compared to cattle pasture sites. Fertilized and non-fertilized grass strips (grassed waterway and field border) were higher than expected but averaged less than 9.0 mg/L. Elevated concentrations, especially in the non-fertilized grass field border, are likely explained by subsurface mixing of soil water between adjacent land covers. Nitrate concentrations in row crop settings averaged 22.3 mg/L and were spread across a large range of values as depicted by a standard deviation of 21.8 mg/L. This high degree of variability can be explained by the wide range of cropping systems and management systems sampled, diverse weather conditions and variability that is inherent with lysimeter sampling. Although highly variable, average row crop nitrate levels from the lysimeter network were similar to flow weighted concentrations collected from sub-surface drainage tile sites across Minnesota during the same monitoring period.

Any nitrate not used by row crops is susceptible to leaching from the rooting zone and can increase the risk for transport to groundwater, especially in karst landscapes. The use of BMPs, especially proper rate and timing of nitrogen, are key practices to help reduce nitrate concentrations in groundwater. Though, it's important to recognize that these practices alone may not consistently obtain levels below the drinking water standard of 10 mg/L. Integrating perennials into row crop systems can be a key practice for reducing nitrate in groundwater. The use of perennials is used by many livestock farmers in southeast Minnesota and the performance of this practice was measured. In corn rotations with alfalfa, soil water nitrate averaged 6.6 mg/L which was 70% lower when compared to row crop sites without perennials. This reduction can be explained by lower nitrogen inputs, increased nitrogen uptake and/or immobilization and higher rates of evapotranspiration by perennial covers over a longer growing season when compared to row crops (Randal et al, 2008).

The use of lysimeters proved to be a cost-effective tool to estimate the relative range of concentrations and nitrate risk to groundwater between various types of land covers. When shared within the context of this study's limitations, data collected from the Southeast Lysimeter Network serves as a useful educational tool for farmers, crop advisors, rural homeowners and groundwater advisory groups.

Acknowledgements

This work could not have occurred without the cooperation of the twenty-two landowners and farmers that allowed access to their farms for this study. Special recognition is provided to Winona State University and students Blake Lea and Dane Mckeeth for their dedicated assistance. Appreciation is given to Justin Watkins for his support, to Kimm Crawford for his statistical advising and to Katie Rassmussen, Matt Ribikawskis, Dave Wall and Greg Klinger for their review. Special thanks to current and former employees of Fillmore SWCD including Joe Magee, Jennifer Ronnenberg, Dawn Bernau and Dean Thomas for helping with sample collection, site selection and installation. Funding for this work was provided in-part by the Minnesota Pollution Control Agency and Minnesota's Clean Water Fund through MDA's Root River Field to Stream Partnership.

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APPENDIX A

Considerations when interpreting soil water nitrate-nitrogen concentrations collected from lysimeters

Lysimeters are one of the most basic, versatile and economical ways to collect samples for measuring nitrate-nitrogen (nitrate) concentrations in soil water. Measuring nitrate concentrations in the unsaturated vadose zone and lowermost depth of the crop rooting zone of cultivated crops can provide important insights and feedback regarding nitrogen management practices. However, results can be highly variable. For instance, nitrate results collected two lysimeters separated only a few feet apart can vary considerably. The following is a brief list of factors to consider when interpreting results collected from lysimeters.

Soils are complex systems with various chemical, physical and biological interactions, and measuring the movement of nitrate through soil is controlled by the complex interaction of these properties combined with variations in precipitation. Consider the complex movement of water through the soil. Water moves in an irregular manner through the soil profile along a path of least resistance. During dry conditions, water moves between the small pore spaces between the soil particles very slowly. This slow form of water movement is called matrix flow. During wet conditions, such as during a large rain event when the soil is approaching saturation, flow through larger pores such as worm holes or old root channels occurs. This is a fast form of water movement called preferential flow. Nitrate concentrations vary between matrix flow and preferential flow which helps explain why soil water nitrate concentrations from lysimeters located only a few feet apart can be substantially different. These concepts are best illustrated in Figure 1 (adapted from Haarder et al., 2011) showing the cross section of a soil profile after infiltrating four inches of water-soluble blue dye on a sandy textured soil. The wetting front and irregular preferential flow pattern are clearly shown as the blue dye percolates through the soil. In this case, if a lysimeter had been placed on the left side of the soil profile, nitrate concentrations could have been much different when compared to the right side.

Figure 1. This photograph shows the cross section of a soil profile with blue dye poured at the soil surface. The wetting front and irregular preferential flow pattern are clearly shown as the blue dye percolates through the soil. This can help explain why soil water nitrate concentrations from one lysimeter can have markedly different concentrations when compared to another lysimeter only a few feet away. Figure adapted from Haarder et al, 2011.

Another factor to consider is that nitrate measured by lysimeters within the crop root zone represents the amount of nitrate present at that specific point in the soil profile and may not always correspond to what is observed in deeper groundwater. At common lysimeter install depths, usually about four feet, the fate and movement of nitrate can take several pathways. Some of those include: (i) percolate to deeper bedrock layers where it can mix with older groundwater that has been diluted from non-crop land covers (ii) migrate back to the root zone through capillary rise or (iii) be converted into nitrogen gas

(N_2) by denitrification or other reduction processes deeper in the soil profile or aquifer. Despite these factors, nitrate concentrations measured in coarse-textured/sandy aquifers or shallow, unconfined karst aquifers in southeast Minnesota can have nitrates that are consistent with the range of concentrations measured in soil water beneath row-crop fields.

Due to sample and labor constraints involved with lysimeter sampling, typically only a few lysimeters are installed within a small area of a crop field. Lysimeters in effect become point measurements that may not capture the high level of spatial variability represented within the field. This makes it difficult to discern if nitrate concentrations are an accurate representation of the entire field and management system or just that particular point within the field. That is why sub-surface pattern tile drainage sites or groundwater springs are preferred monitoring locations for nitrate, since concentrations represent a composite mixture that is averaged across the drained field area or springshed contributing area. To reduce uncertainty, pairs or groups of lysimeters are typically installed and a mean concentration is applied to the lysimeter group.

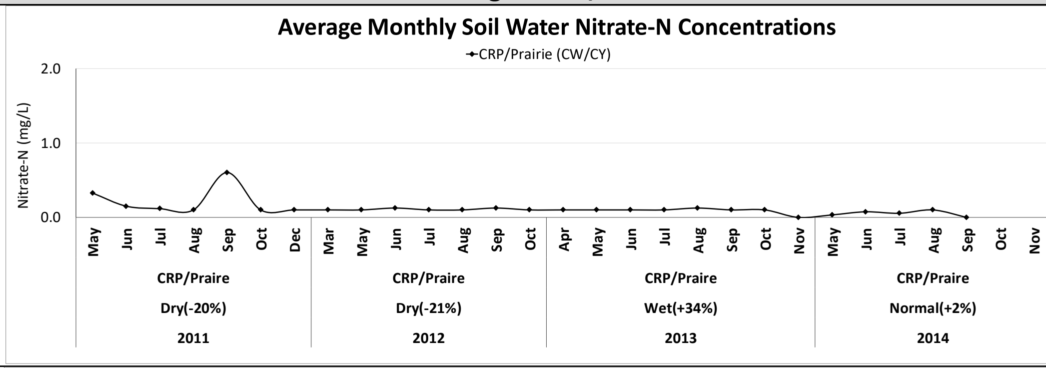
Additional factors to consider:

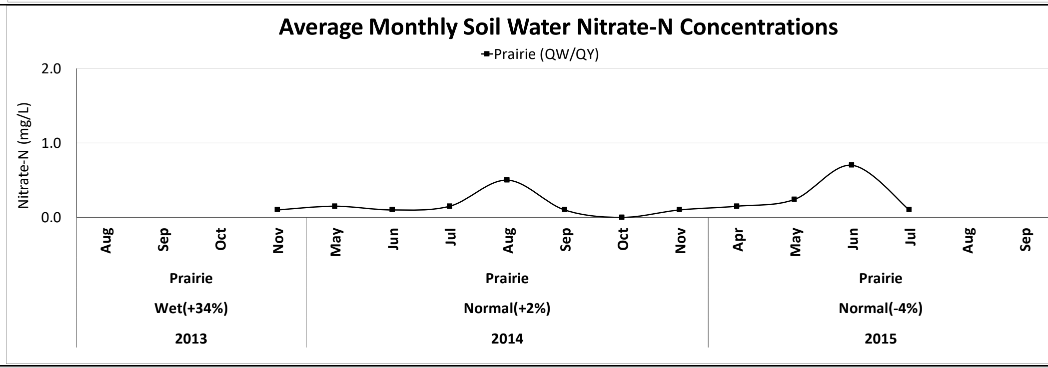
- Typically, a vacuum is paced on the lysimeter to allow collection of a soil water sample. This vacuum could bias preferential flow to the lysimeter within the soil column, causing the sample to not fully represent the water moving through the soil profile.
- Ideally, drainage volume from lysimeters should also be measured to help normalize for differences in sample size between sites and lysimeters by calculating a flow weighted mean concentration (FWMC). A FWMC is defined as the total mass load divided by the total water volume. This normalization process allows comparison among different sites based on the total volume of water rather than the concentration itself. Flow weighted averaging is an appropriate method to represent the average nitrate concentration over multiple sampling events and are much better than simply averaging the individual concentrations since sampling events with low volumes can bias results with sample events that collect small volumes with very high concentrations. Accurately measuring drainage volume from lysimeters is challenging so FWMCs are typically not calculated.
- The soil immediately surrounding lysimeters is disturbed during installation. It may take at least a year for the soil to fully settle around the lysimeters resulting in higher uncertainty in the measurements during that period.
- Samples can be influenced by adjacent, upgradient land use due to lateral movement of shallow groundwater flow paths. This can be a factor for some locations with steeper field slopes.

With these considerations in mind, the use of lysimeters can be a cost-effective tool for evaluating nitrate concentrations and can serve as an important educational tool for farmers, crop advisors, rural homeowners and groundwater advisory groups.

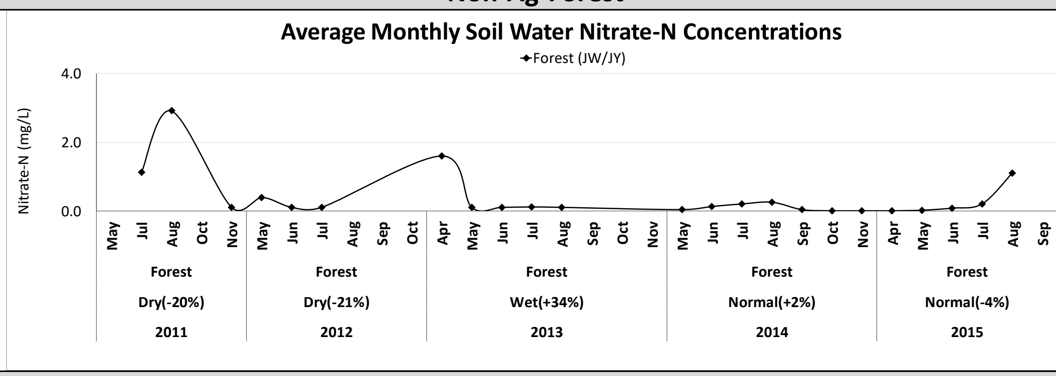
APPENDIX B- Average monthly nitrate by lysimeter site

Non-Ag Prairie/CRP

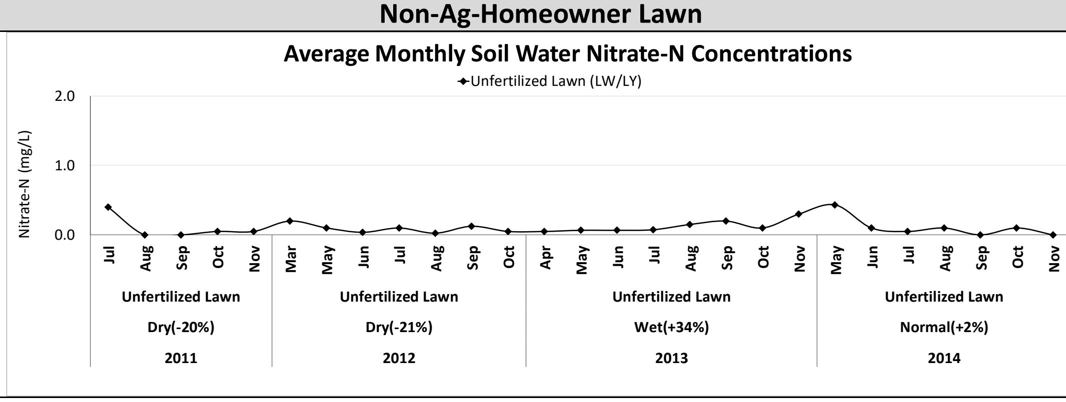




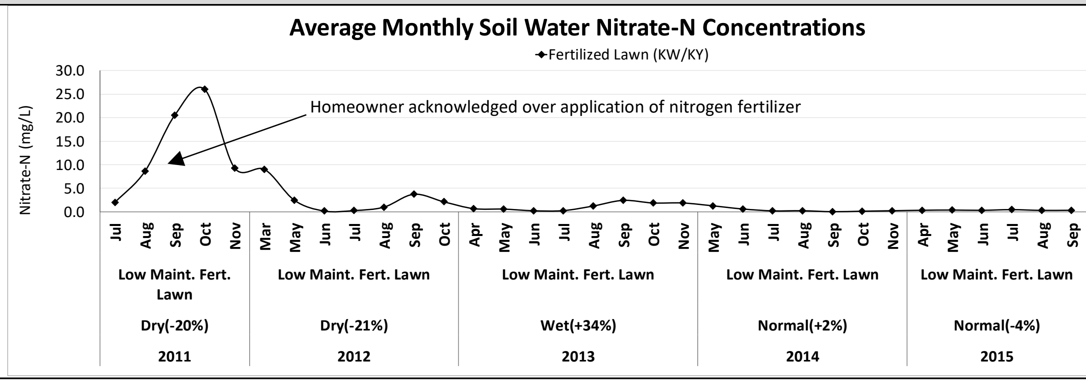
Non-Ag-Forest



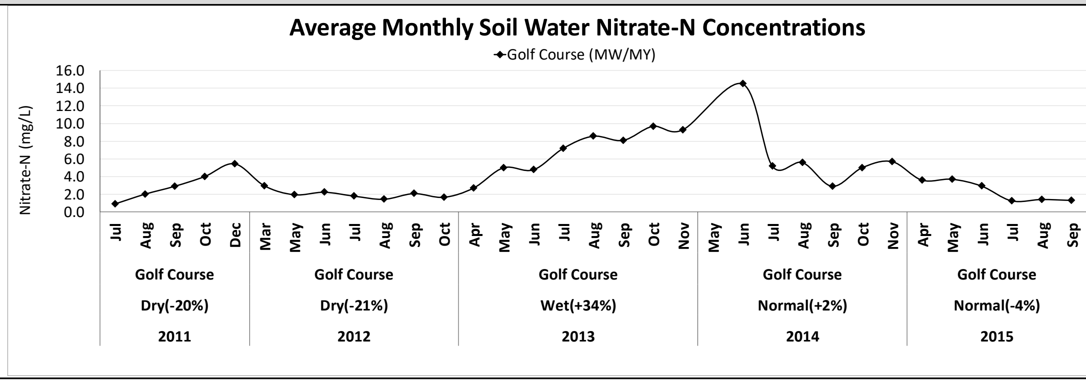
Non-Ag-Homeowner Lawn



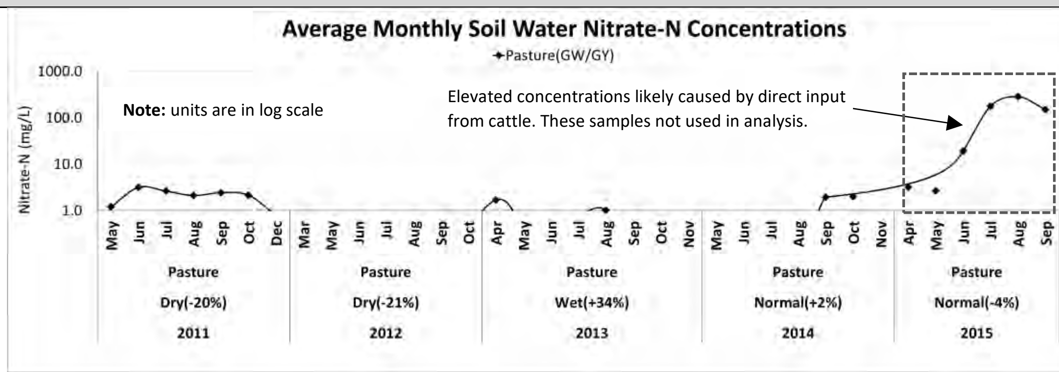
Homeowner Lawn

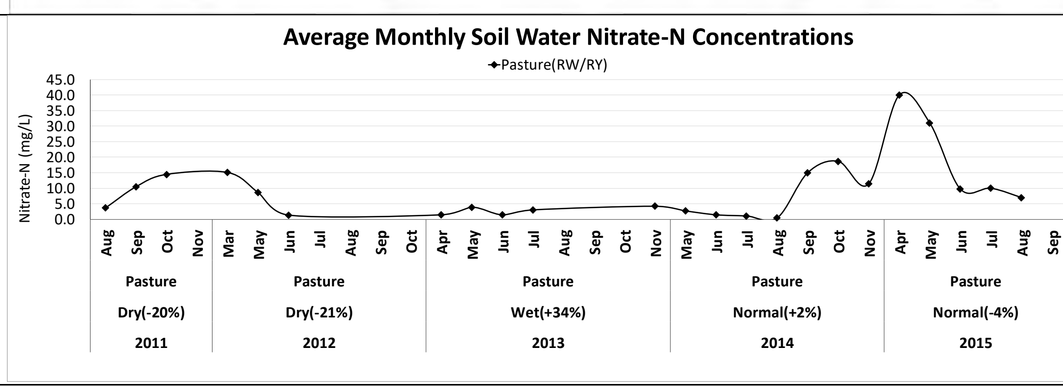


Golf Course

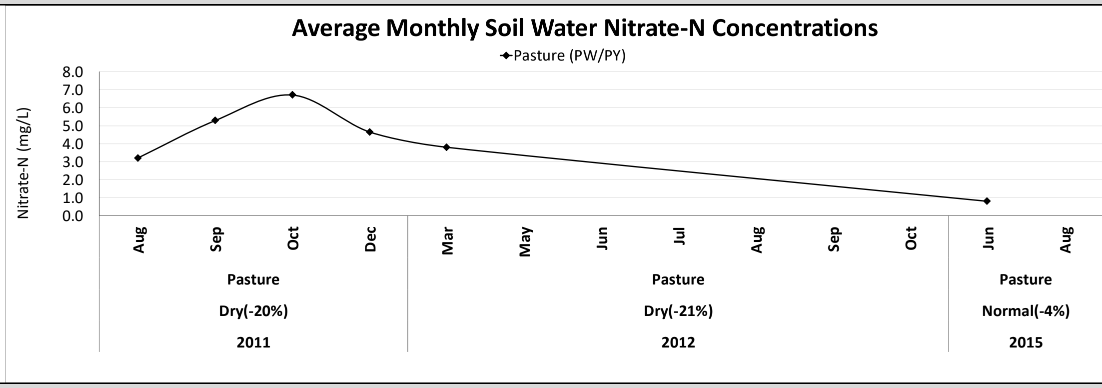


Pasture

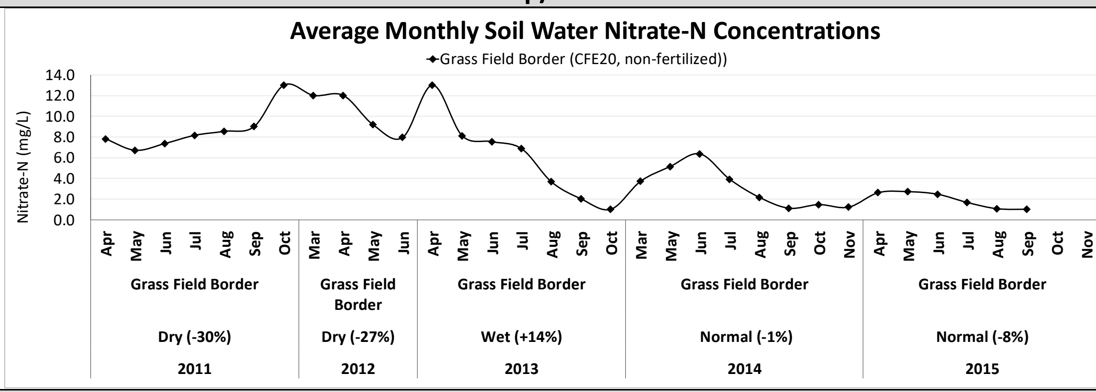




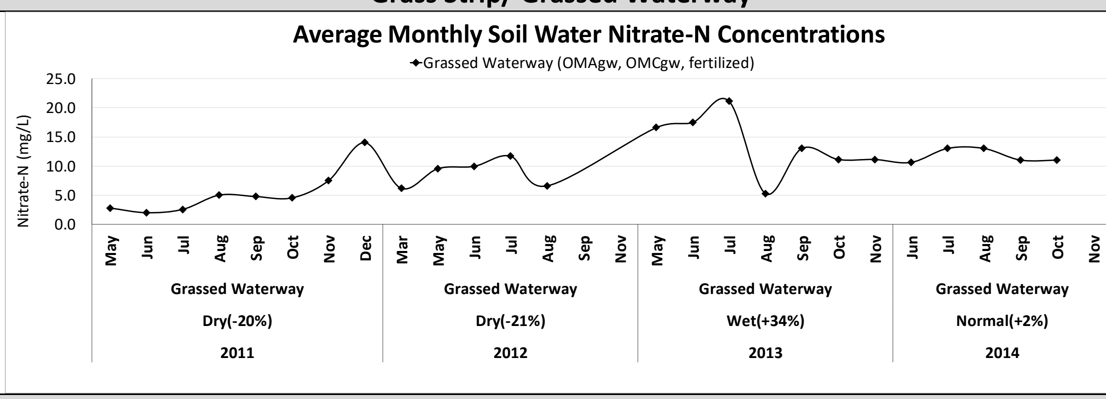
Pasture



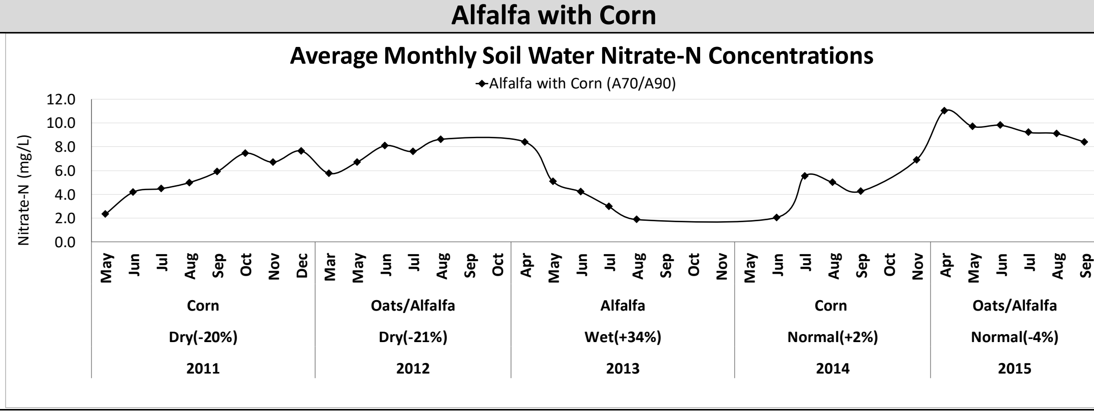
Grass Strip/Field Border



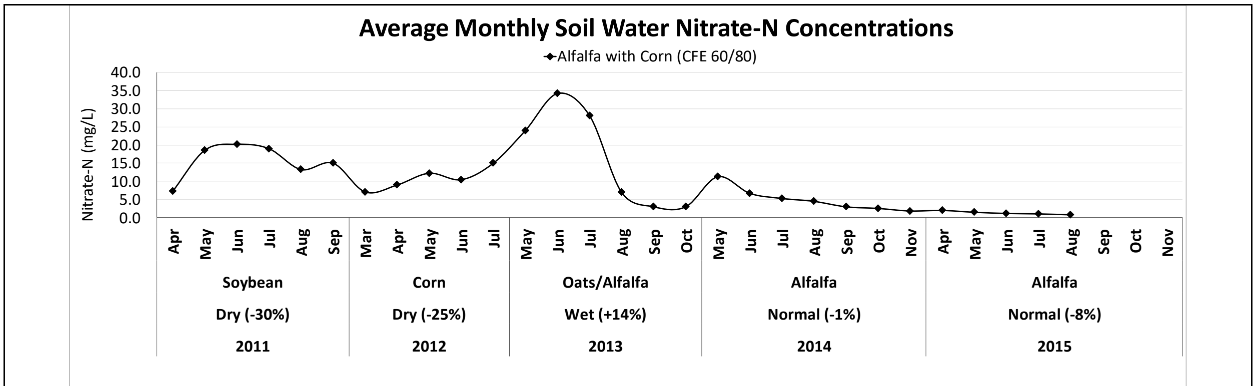
Grass Strip/ Grassed Waterway

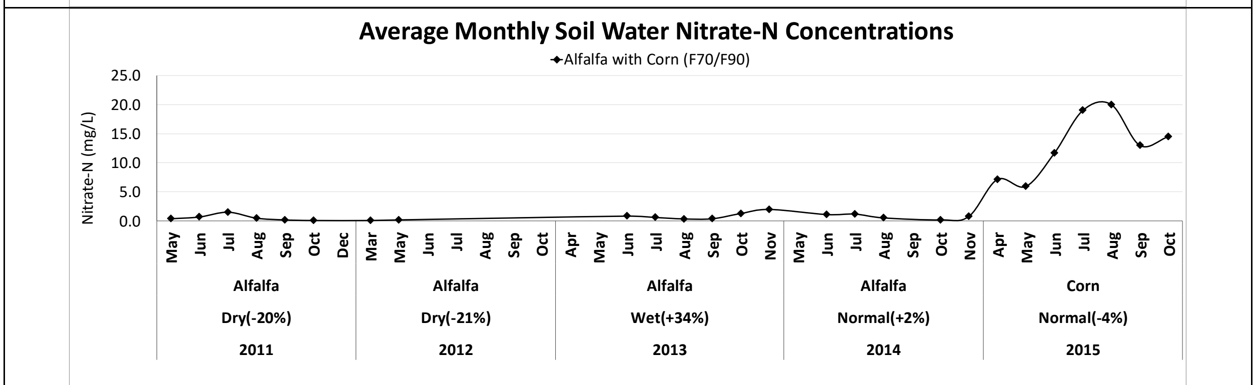


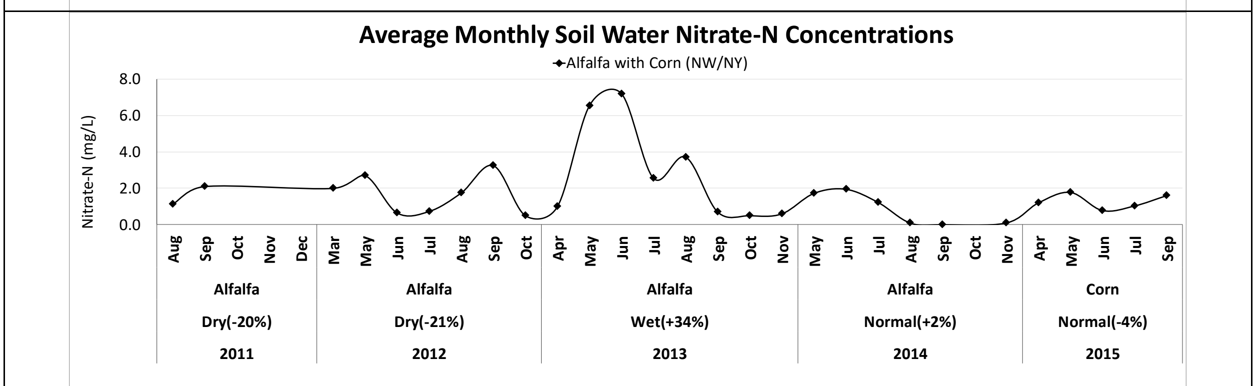
Alfalfa with Corn



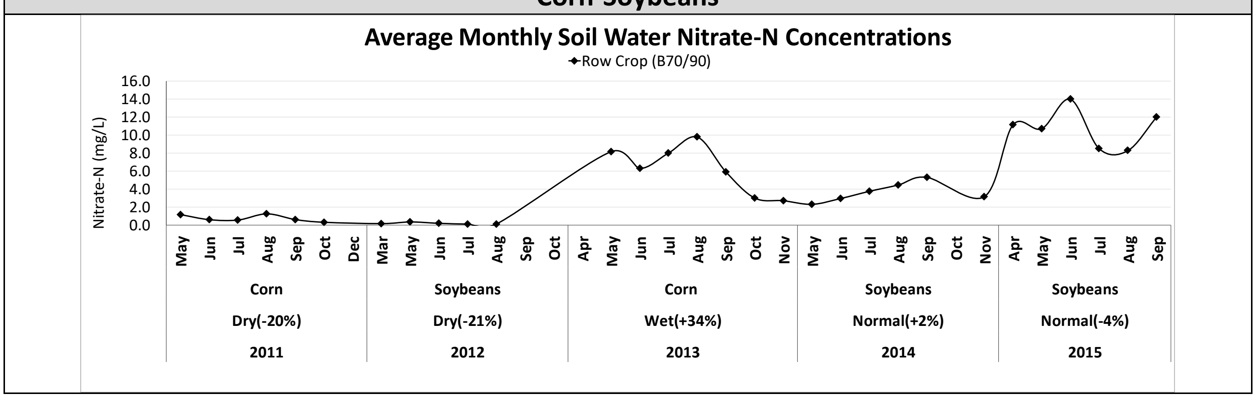
Alfalfa with Corn

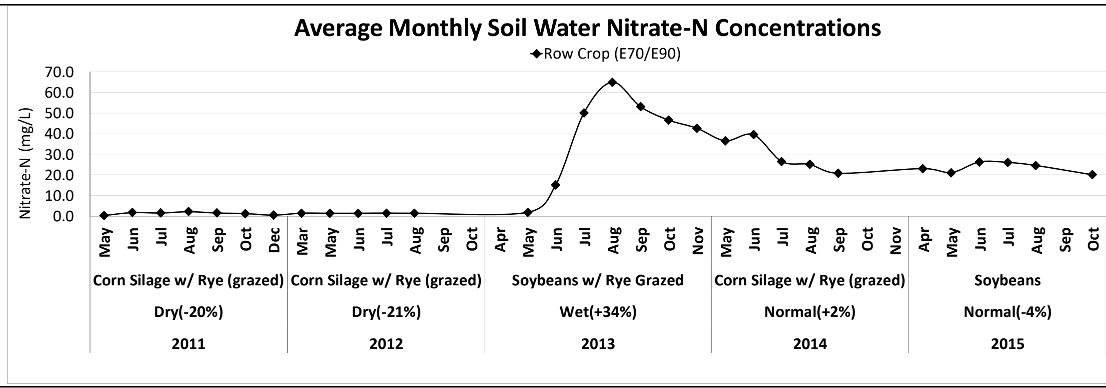




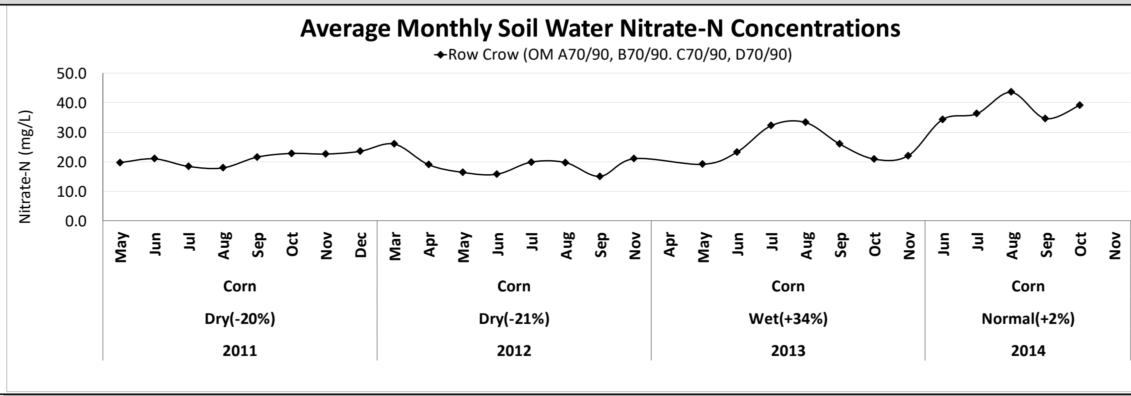


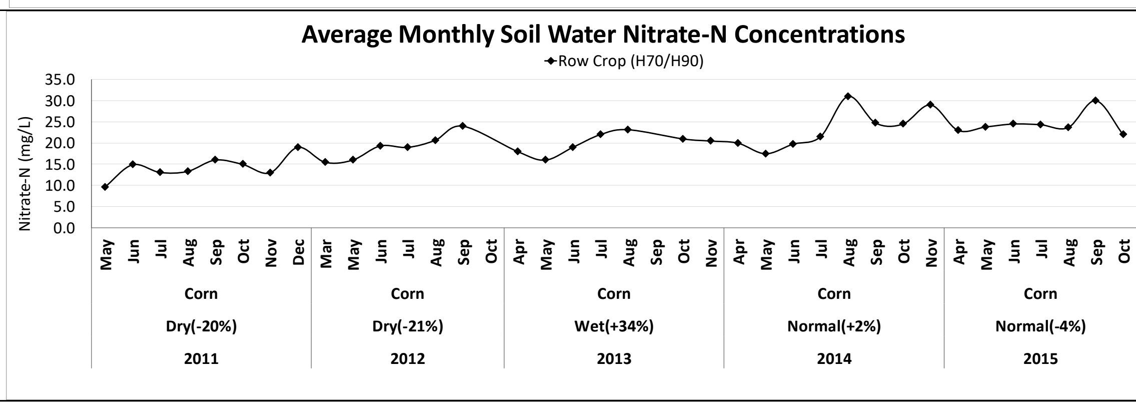
Corn-Soybeans

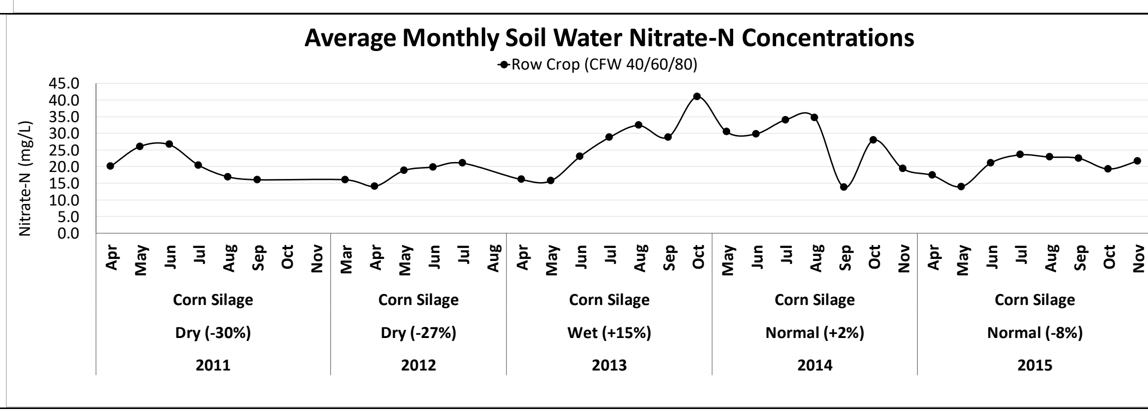


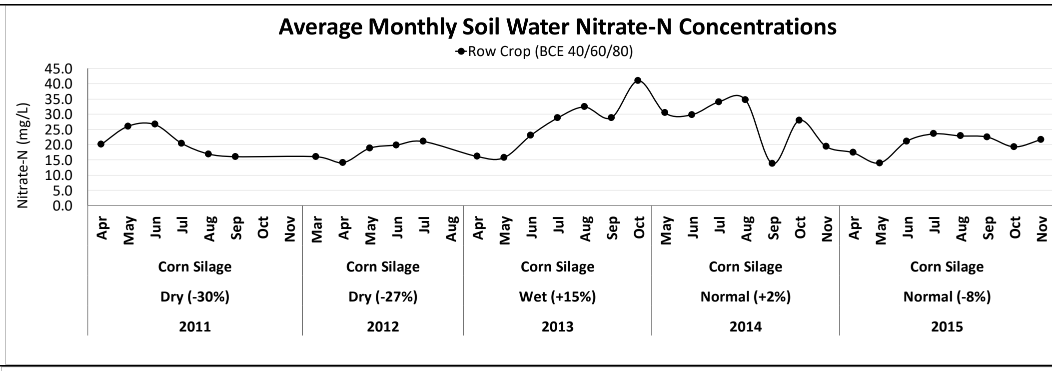


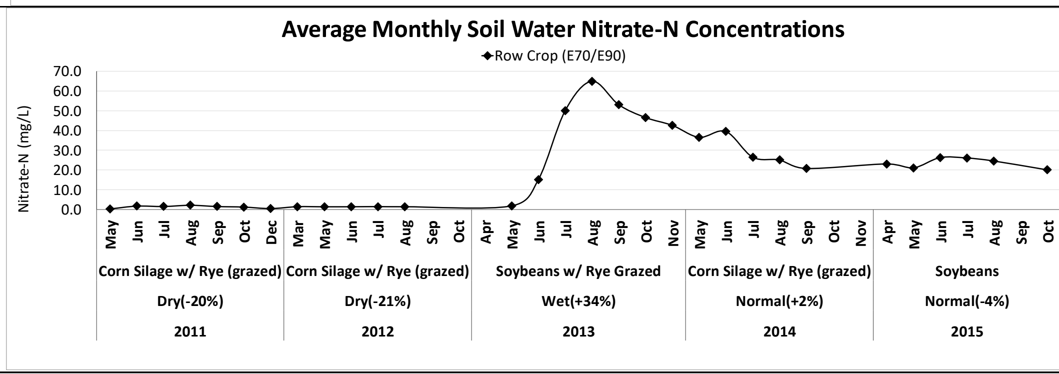
Continuous Corn

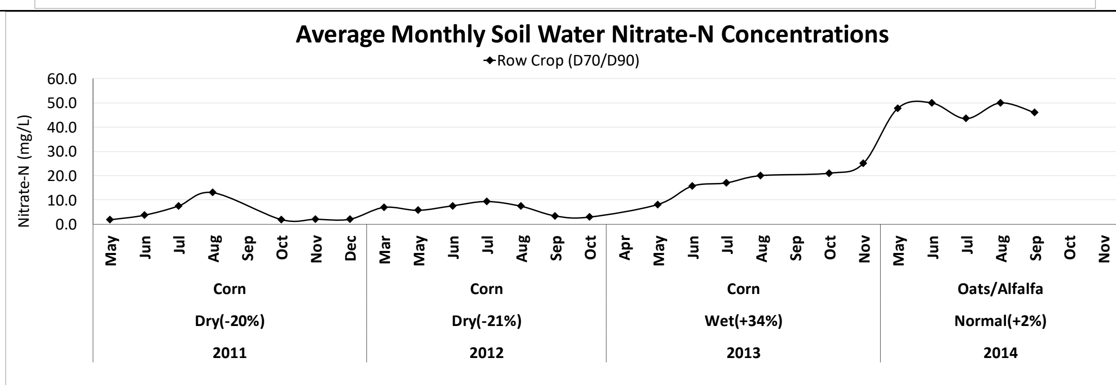


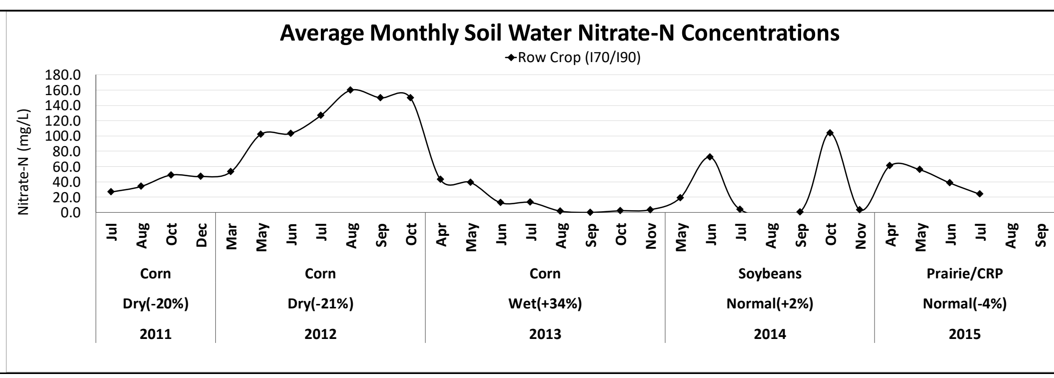





Average Monthly Soil Water Nitrate-N Concentrations
Row Crop (BCE 40/60/80)
Nitrate-N (mg/L)
45.0 40.0 35.0 30.0 25.0 20.0 15.0 10.0 5.0 0.0
Apr May Jun Jul Aug Sep Oct Nov Mar Apr May Jun Jul Aug Apr May Jun Jul Aug Sep Oct May Jun Jul Aug Sep Oct Nov Apr May Jun Jul Aug Sep Oct Nov
Corn Silage Dry (-30%) 2011
Corn Silage Dry (-27%) 2012
Corn Silage Wet (+15%) 2013
Corn Silage Normal (+2%) 2014
Corn Silage Normal (-8%) 2015


Average Monthly Soil Water Nitrate-N Concentrations
Row Crop (E70/E90)
Nitrate-N (mg/L)
70.0 60.0 50.0 40.0 30.0 20.0 10.0 0.0
May Jun Jul Aug Sep Oct Dec Mar May Jun Jul Aug Sep Oct Apr May Jun Jul Aug Sep Oct Nov May Jun Jul Aug Sep Oct Nov Apr May Jun Jul Aug Sep Oct
Corn Silage w/ Rye (grazed) Dry(-20%) 2011
Corn Silage w/ Rye (grazed) Dry(-21%) 2012
Soybeans w/ Rye Grazed Wet(+34%) 2013
Corn Silage w/ Rye (grazed) Normal(+2%) 2014
Soybeans Normal(-4%) 2015


Average Monthly Soil Water Nitrate-N Concentrations
Row Crop (D70/D90)
Nitrate-N (mg/L)
60.0 50.0 40.0 30.0 20.0 10.0 0.0
May Jun Jul Aug Sep Oct Nov Dec Mar May Jun Jul Aug Sep Oct Apr May Jun Jul Aug Sep Oct Nov May Jun Jul Aug Sep Oct Nov
Corn Dry(-20%) 2011
Corn Dry(-21%) 2012
Corn Wet(+34%) 2013
Oats/Alfalfa Normal(+2%) 2014


Average Monthly Soil Water Nitrate-N Concentrations
Row Crop (I70/I90)
Nitrate-N (mg/L)
180.0 160.0 140.0 120.0 100.0 80.0 60.0 40.0 20.0 0.0
Jul Aug Oct Dec Mar May Jun Jul Aug Sep Oct Apr May Jun Jul Aug Sep Oct Nov May Jun Jul Aug Sep Oct Nov Apr May Jun Jul Aug Sep
Corn Dry(-20%) 2011
Corn Dry(-21%) 2012
Corn Wet(+34%) 2013
Soybeans Normal(+2%) 2014
Prairie/CRP Normal(-4%) 2015

APPENDIX C
Quality assurance report: duplicate RPD results

Water samples were analyzed using a Hach® DR6000 UV spectrophotometer (pour-through method 357-10049, DOC 316.53.01072) located in the MDA Preston field office within a week of sample collection. Samples were analyzed using standardized quality assurance and control (QA/QC) procedures. To evaluate the performance of the machine during this study, a minimum of 10% of the nitrate samples were split in the field and sent to the Minnesota Department of Agriculture certified laboratory (MDA Lab) located in St. Paul. Field duplicate samples were used as a part of the quality assurance plan to evaluate the performance and precision of the DR6000 and determine the extent of any analytical problems. Due to budget constraints, duplicate samples were sent in two out of the five years during the study. The MDA lab method (SM 4500-No3 F) using flow injection includes both nitrite and nitrate ($NO_2 + NO_3$-N) while the DR6000 method does not report nitrite. Nitrite (NO_2-N) is seldom elevated in groundwater because it is typically transformed quickly to nitrate, therefore, it is not considered to be a significant factor when comparing the two methods.

The Relative Percent Difference (RPD) calculation method was used to evaluate the precision of duplicate samples when comparing the DR6000 to the MDH certified lab for years 2014 and 2015. The RPD is the difference between the MDH certified lab and samples analyzed by the DR6000 machine divided by their average and expressed as a percent. The RPD calculation is:

$$RPD = \frac{|X1 - X2|}{(X1 + X2)/2} * 100$$

X1 = sample concentration determined by Hach DR6000 X2= sample concentration determined by MDA certified lab

A goal of this testing program was to have 90% of the duplicate samples within 10% of the RPD. Table 1 and Figure 1 summarize the RPD results. For 2014, 61 field duplicate pairs were analyzed representing 17% of the total samples analyzed on the DR6000. Of the 61 pairs, 87% of the DR6000 duplicate samples were within the 10% RPD goal and 95% were within 20% RPD. In 2015, 114 sample pairs were analyzed representing 31% of the total samples. Of the 114 sample pairs, 89% of the DR6000 samples were within 10% of the RPD and 95% of the duplicate samples were within the 20% RPD. Across both years, 88% of the samples were within 10% of the RPD. Across both years, 90% of the samples were within a RPD of 11%. The overall difference between the DR6000 samples and those analyzed by the MDH lab ranged from -0.3 mg/L to 0.6 mg/L (IQR). The median difference between the DR6000 method and the MDH certified lab was 0.3 mg/L. The method report limit is 0.1 mg/L for the DR6000.

Table 1. Relative Percent Difference (RPD) results between Hach DR6000 and MDA certified lab.

Year	Duplicates	<10% RPD	<15% RPD	<20% RPD
		-----% of duplicate samples-----		
2014	61	87%	93%	95%
2015	114	89%	96%	96%
All Years	175	88%	95%	96%

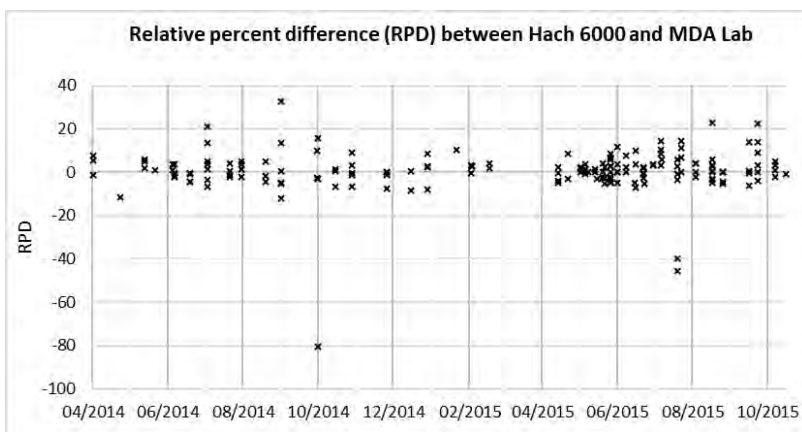


Figure 1. Time series chart of RPD results

United States Environmental Protection Agency
Region 10
1200 Sixth Avenue, Suite 155
Seattle, Washington 98101-3188

Authorization to Discharge under the
National Pollutant Discharge Elimination System

In compliance with the provisions of the Clean Water Act (CWA), 33 U.S.C. § 1251 *et seq*., as amended by the Water Quality Act of 1987, P.L. 100-4, the "Act",

Concentrated Animal Feeding Operations (CAFOs) in Idaho
as defined in Section I of this permit

are authorized to discharge in accordance with discharge point(s), effluent limitations, monitoring requirements, and other conditions set forth herein.

This permit shall become effective: June 15, 2020

This permit and the authorization to discharge shall expire at midnight: June 14, 2025

The permittee shall reapply for a permit reissuance on or before Date, 180 days before the expiration of this permit if the permittee intends to continue operations and discharges at the facility beyond the term of this permit.

/s/

Daniel D. Opalski, Director
Water Division

This permit was modified: ______________________________

Mathew J. Martinson
CAPT, USPHS
Branch Chief
Permitting, Drinking Water and Infrastructure

Table of Contents

I. PERMIT AREA AND COVERAGE

A. Permit Area and Eligibility

This permit offers National Pollutant Discharge Elimination System (NPDES) permit coverage for discharges from facilities that meet the definition of a concentrated animal feeding operation (CAFO), as defined by 40 CFR § 122.23(b)(2), in the State of Idaho. Any facility that meets the definition of a large, medium or small CAFO, as defined in 40 CFR § 122.23(b)(4), (6), and (9), and that is not specifically excluded per one of the conditions in Section I.F.1, is eligible for coverage under this permit.

CAFO owners/operators ineligible for coverage under this permit (Section I.F.1) or who believe the terms and conditions of this permit are not appropriate for their CAFO facility, must apply for an individual permit in accordance with Section I.F.3.

B. Application for Coverage

1. Owners/operators of CAFOs seeking to be covered by this permit must submit an NOI (Appendix A) and a Nutrient Management Plan (NMP) that meets the requirements of Section III.A of this permit.
2. Signature Requirements: The NOI must be signed by the owner/operator or other authorized person in accordance with Section V.C.5 of this permit.
3. Where to Submit: A signed copy of the NOI must be sent to:

    United States Environmental Protection Agency,
    Region 10 Manager, NPDES Permits Section
    1200 Sixth Avenue, Suite 155, WD 19-C04
    Seattle, WA 98101-3188

    Copies of the NOI shall also be sent to the Idaho State Department of Agriculture (ISDA), the Idaho Department of Environmental Quality (IDEQ) state office, and the appropriate IDEQ regional offices listed below.

    Beginning December 21, 2020, all NOIs must be submitted electronically.

Idaho State Department of Agriculture 2270 Old Penitentiary Road P.O. Box 790

Idaho Department of Environmental Quality Water Quality Division IDEQ State Office 1410 N. Hilton Boise, ID 83706 (208) 373-0570 tambra.phares@deq.idaho.gov			
IDEQ Boise Regional Office 1445 N. Orchard Boise, ID 83706 (208) 373-0490 chase.cusack@deq.idaho.gov	Counties:	Ada Adams Boise Canyon Elmore	Gem Owyhee Payette Valley Washington
IDEQ Coeur d'Alene Regional Office 2110 Ironwood Parkway Coeur d'Alene, ID 83814 (208) 666-4605 chantilly.higbee@deq.idaho.gov	Counties:	Benewah Bonner Boundary	Kootenai Shoshone
IDEQ Idaho Falls Regional Office 900 N. Skyline, Suite B Idaho Falls, ID 83402 (208) 528-2679 alex.bell@deq.idaho.gov	Counties:	Bonneville Butte Clark Custer Fremont	Jefferson Lemhi Madison Teton
IDEQ Lewiston Regional Office 1118 "F" St. Lewiston, ID 83501 (208) 799-4874 sujata.connell@deq.idaho.gov	Counties:	Clearwater Idaho Latah	Lewis Nez Perce
IDEQ Pocatello Regional Office 444 Hospital Way #300 Pocatello, ID 83201 (208) 239-5007 matthew.schenk@deq.idaho.gov	Counties:	Bannock Bear Lake Bingham Caribou	Franklin Oneida Power
IDEQ Twin Falls Regional Office 650 Addison Ave. W., Suite 110, Twin Falls, ID 83301 (208) 737-3877 sean.woodhead@deq.idaho.gov	Counties:	Blaine Camas Cassia Gooding	Jerome Lincoln Minidoka Twin Falls

4. Upon receipt, EPA will review the NOI and NMP for completeness. EPA may request additional information from the CAFO owner or operator if additional information is necessary to complete the NOI and NMP or to clarify, modify, or supplement previously submitted material. If EPA makes a preliminary determination that the NOI is complete, the NOI, NMP, and draft terms of the NMP to be incorporated into the permit will be made available for a thirty (30) day public review and comment period (http://yosemite.epa.gov/r10/HOMEPAGE.NSF/Information/R10PN). The process for submitting public comments and requests for hearing will follow the procedures applicable to draft permits as specified by 40 CFR §§ 124.11 through 124.13. EPA will respond to comments received during the comment period as specified in 40 CFR § 124.17 and, if necessary, require the CAFO owner or operator to revise the NMP in order to obtain permit coverage. If determined appropriate by EPA, CAFOs will be granted coverage under this general permit upon written notification by EPA. EPA will identify the terms of the NMP to be incorporated into the permit in the written notification. Each permittee must comply with the site-specific permit terms established by EPA based on the CAFO's site specific NMP.

5. For new sources, the National Environmental Policy Act (NEPA) requires EPA to conduct an environmental review pursuant to 40 CFR Part 6. NEPA requirements must be complied with prior to authorizing permit coverage to new sources (i.e., Large CAFOs whose construction began after April 14, 2003). New sources seeking permit coverage must submit an Environmental Information Document (EID) or Draft Environmental Assessment (EA) along with their NOI and NMP (40 CFR § 6.200(g)(2) and 40 CFR § 6, Subpart C). Information concerning preparation of an EID or EA can be obtained by contacting the NEPA compliance officer in the EPA, Region 10, NPDES Permits Section.

   These NEPA and NOI requirements also apply to expansions of existing CAFOs that meet the definition of a new source at 40 CFR § 122.2 and the new source criteria at 40 CFR § 122.29(a) and (b). In order to determine if an expansion is a new source, the applicant must submit to EPA information describing the expansion and a map showing the location of the expansion. If EPA determines the expansion meets the new source definition, the owner/operator must prepare and submit an EID or draft EA as described above. The information must be submitted to:

   United States Environmental Protection Agency,
   Region 10 Manager, NPDES Permits Section
   1200 Sixth Avenue, Suite 155, 19-C04
   Seattle, WA 98101-3188

C. Permit Expiration

This permit will expire five (5) years from the effective date. If this permit is not reissued or replaced prior to the expiration date, the permit will be administratively continued and remain in force and effect until it is replaced by a new/reissued permit. Any permittee who has submitted a NOI and been granted coverage will automatically remain covered by the administratively continued permit. Coverage under an administratively continued permit cannot be granted following the expiration date.

D. Change in Ownership

If a change in the ownership of a facility whose discharge is authorized under this permit occurs, coverage under the permit will automatically transfer if (1) the current permittee notifies EPA at least 30 days prior to the proposed transfer date; (2) the notice includes a written agreement between the existing and new permittees containing a specific transfer date for permit responsibility, coverage, and liability between them; and (3) EPA does not notify the existing permittee and the proposed permittee that the operation is no longer eligible for coverage under the General Permit. If the new CAFO owner or operator modifies any part of the NMP, the NMP shall be submitted to EPA in accordance with Section III.A.5 of the permit. EPA will determine if the scope of changes warrants public notice and comment per the requirements of Section I.B.4.

E. Termination of Permit Coverage

1. A permittee may request to terminate coverage under this permit if the permittee makes such a request in writing and one of the following conditions is met:
   a) The facility has ceased all operations and all wastewater or manure storage structures have been properly closed in accordance with the Idaho Natural Resources Conservation Service (NRCS) Conservation Practice Standard No. 360, Closure of Waste Impoundments (Appendix B) contained in the Natural Resources Conservation Service Field Office Technical Guide and all other remaining stockpiles of manure, litter, or process wastewater not contained in a wastewater or manure storage structure are properly disposed in accordance with Section III.C; or
   b) The facility is no longer a CAFO that discharges manure, litter, or process wastewater to waters of the United States; or
   c) The entire discharge is permanently terminated by elimination of the flow or by connection to a publicly owned treatment works (POTW).
2. Requests to terminate coverage under this permit must be made in writing and submitted to EPA at the following address:

   United States Environmental Protection Agency,
   Region 10 Manager, NPDES Permits Section
   1200 Sixth Avenue, Suite 155, 19-C04
   Seattle, WA 98101-3188

Beginning December 21, 2020, all requests to terminate coverage must be submitted electronically.

3. Termination of coverage will become effective 30 days after the EPA sends written notice to the permittee unless the permittee objects within that time.

F. Individual Permit Coverage

1. The following CAFOs are not eligible for coverage under this permit, and must apply for an individual permit:
   a) CAFOs that have been notified by EPA that they are ineligible for coverage under this general permit due to a history of non-compliance.
   b) CAFOs that are seeking coverage that will adversely affect species that are federally listed as endangered or threatened ("listed") under the Endangered Species Act (ESA) or adversely modify critical habitat of those species.
   c) CAFOs that are seeking coverage that will have the potential to affect historic properties. CAFO owners/operators must determine whether their permit-related activities have the potential to affect a property that is listed or eligible for listing on the National Register of Historic Places.
   d) CAFOs with discharges to a designated Outstanding Resource Water. As of the effective date of this permit there are no Outstanding Resource Waters approved by the Idaho Legislature.
   e) CAFOs located in Indian Country.
2. EPA may require any facility authorized by this permit to apply for, and obtain, an individual NPDES permit. EPA will notify the operator, in writing, that an application for an individual permit is required and will set a time for submission of the application. Coverage of the facility under this general NPDES permit is automatically terminated when: (1) the operator fails to submit the required individual NPDES permit application within the defined time frame; or (2) the individual NPDES permit is issued by EPA.
3. Any owner/operator who believes that the terms and conditions of this general permit are not appropriate for his/her CAFO facility, either prior to or after obtaining coverage under this permit, may request to be covered under an individual permit pursuant to 40 CFR § 122.28(b)(3)(iii). The owner/operator shall submit an application for an individual permit (Form 1 and Form 2B) with the reasons supporting the application to EPA. If a final, individual NPDES permit is issued to an owner/operator otherwise subject to this general permit, the applicability of this NPDES CAFO general permit to the facility is automatically terminated on the effective date of the individual NPDES permit. Otherwise, the applicability of this general permit to the facility remains in full force and effect.

II. Effluent Limitations and Standards

A. Effluent Limitations and Standards Applicable to the Production Area

Except as provided in Section II.A.3, there must be no discharge of manure, litter, or process wastewater into waters of the United States from the production area except as provided below.

1. Whenever precipitation causes an overflow of manure, litter, or process wastewater, pollutants in the overflow may be discharged into waters of the United States provided:

   a) The production area is designed, constructed, operated, and maintained to contain all manure, litter, process wastewater, and the runoff and direct precipitation from the 25-year, 24-hour storm event for the location of the CAFO.

   b) The design storage volume is adequate to contain all manure, litter, and process wastewater accumulated during the storage period including, at a minimum, the following:

      (i) The normal precipitation less evaporation during the storage period;

      (ii) The normal runoff during the storage period;

      (iii) The direct precipitation from a 25-year, 24-hour storm event;

      (iv) The runoff from the 25-year, 24-hour storm event from the production area;

      (v) The residual solids after liquid has been removed;

      (vi) The necessary freeboard to maintain structural integrity; and

      (vii) In the case of treatment lagoons, the necessary minimum treatment volume.

2. The production area must be operated in accordance with the additional measures and records specified below:

   a) Visual Inspections. There must be routine visual inspections of the CAFO production area. At a minimum, the following must be visually inspected:

      (i) Weekly visual inspections of all storm water diversion devices, runoff diversion structures, and devices channeling contaminated storm water to the wastewater or manure storage structures;

      (ii) Daily visual inspections of all water lines, including drinking water and cooling water lines;

      (iii) Weekly inspections of the manure, litter, and process wastewater impoundments, storage and containment structures. The inspection will note the level in liquid impoundments as indicated by the depth marker in Section II.A.2.b) in this section;

   b) Depth Marker. All open surface liquid impoundments must have a depth marker that clearly indicates the minimum capacity necessary to contain the runoff and direct precipitation of the 25-year, 24-hour rain fall event. Install a depth marker in all open wastewater or manure storage structures. The depth marker must clearly indicate the minimum capacity necessary to contain the runoff and direct precipitation of the 25-year, 24-hour rainfall event.

c) Corrective Actions. Any deficiencies found as a result of the daily and weekly inspections must be corrected as soon as possible.

d) Mortality Handling. Mortalities shall not be disposed of in any liquid manure or process wastewater system and must be handled in such a way as to prevent the discharge of pollutants to surface waters of the United States.

e) Record keeping requirements for the production area. The maintenance of complete on-site records documenting the implementation of all required additional measures and corrective actions listed above must be maintained for a period of five years.

3. For all swine, poultry, and veal facilities for which construction of the facility began after April 14, 2003 (New Sources), there shall not be a discharge of manure, litter or process wastewater pollutants into waters of the United States from the production area.

B. Effluent Limitations and Standards Applicable to the Land Application Area

For CAFOs where manure, litter, or process wastewater is applied to land under the control of the CAFO owner/operator, the NMP required by Section III of this permit must include the following requirements:

1. Nutrient transport potential. The NMP must incorporate elements in Section III.A.2.f) based on a field-specific assessment of the potential for nitrogen and phosphorus transport from the field.
2. Form, source, amount, timing, and method of application. The NMP must address the form, source, amount, timing, and method of application of nutrients on each field to achieve realistic production goals, while minimizing nitrogen and phosphorus movement to surface waters.
3. Determination of application rates. Application rates for manure, litter, or process wastewater must minimize phosphorus and nitrogen transport from the field to surface waters in accordance with the Section III.A.2.h).
4. Site-specific conservation practices. Identify appropriate site-specific conservation practices to be implemented, including as appropriate buffers or equivalent practices, to control runoff of pollutants to waters of the United States in accordance with Section III.A.2.f).
5. Protocols to land apply manure, litter or process wastewater. Establish protocols to land apply manure, litter or process wastewater in accordance with site specific nutrient management practices that ensure appropriate agricultural utilization of the

nutrients in the manure, litter or process wastewater in accordance with Section III.A.2.h).

6. Manure and soil sampling. Manure must be analyzed at least once annually for nitrogen and phosphorus content in accordance with Section III.A.2.g)(i). Soil must be analyzed annually for nitrogen and phosphorus content in accordance with Section III.A.2.g)(ii). The results of these analyses must be used in determining application rates for manure, litter, and process wastewater;

7. Inspection of land application equipment for leaks. Equipment used for land application of manure, litter, or process wastewater must be inspected periodically for leaks;

8. Land application setback requirements. Unless the permittee exercises one of the compliance alternatives of this section as provided below in (a) or (b), manure, litter, and process wastewater may not be applied closer than 100 feet to any down-gradient surface waters, open tile line intake structures, sinkholes, agricultural well heads, or other conduits to surface waters.

   a) Vegetated buffer compliance alternative. As a compliance alternative, the CAFO may substitute the 100-foot setback with a 35-foot wide vegetated buffer where applications of manure, litter, or process wastewater are prohibited.

   b) Alternative practices compliance alternative. As a compliance alternative, the CAFO may demonstrate that a setback or buffer is not necessary because implementation of alternative conservation practices or field-specific conditions will provide pollutant reductions equivalent or better than the reductions that would be achieved by the 100-foot setback. Alternative conservation practices can include practices that are designed in consultation with a Professional Engineer licensed in the state of Idaho. Alternatively, an adequate demonstration may include the use of site-specific data using a tool such as the Idaho NRCS Water Quality Technical Note #6, Idaho Nutrient Transport Risk Assessment (INTRA) (Appendix E) or the Idaho Phosphorus Site Index (Appendix I) and associated implementation of alternative conservation practices recommended as a result of these tools.

9. No Dry Weather Discharge. There shall be no dry weather discharge of manure, litter, or process wastewater to a water of the United States from a CAFO as a result of the application of manure, litter or process wastewater to land areas under the control of the CAFO. This prohibition includes discharges to waters of the United States through tile drains, ditches or other conveyances, and irrigation return.

   a) During any land application of manure, litter, or process wastewater to a land application area, a visual inspection of the downgradient edge of the field and any other potential discharge locations (e.g., tile drains, ditches, or other conveyances) must be conducted during the land application event and after the land application event to check for field runoff and discharges. This also applies where a land application setback or compliance alternative is required pursuant to Section II.B.8 of this permit, to confirm that the land application setback or compliance alternative is being maintained and functioning as intended, and to determine if there are any discharges. In the event of a discharge, the monitoring requirements of Section IV.E.1 must be implemented.

10. Prohibition on Land Application to Frozen, Snow-Covered and Saturated Soils. The land application of manure, litter, or process wastewater must not occur when the land application area is:

    a) Frozen and/or snow-covered soils, or

    b) When the top two inches of soil are saturated from rainfall, snow melt, irrigation, or when current or predicted weather is capable of producing such conditions.

III. Special Conditions

A. Nutrient Management Plan

The permittee shall develop, submit, and implement a site-specific Nutrient Management Plan (NMP). The NMP shall identify and describe practices that will be implemented to ensure compliance with the effluent limitations and special conditions of this permit (Sections II and III). Unless otherwise stated in this permit, the NMP must be developed in accordance with Section III.A.2 below.

1. Schedule. The completed NMP must be submitted to EPA with a NOI for CAFOs seeking coverage under this permit. The permittee shall implement its NMP upon authorization under this permit.

2. NMP Content. The NMP must include site-specific practices and procedures necessary to implement the applicable effluent limitations and standards. In addition, the NMP must:

    a) Ensure adequate storage of manure, litter, and process wastewater including procedures to ensure proper operation and maintenance of the wastewater and manure storage structures. All wastewater and manure storage structures shall be designed, constructed, operated, and maintained in accordance with the requirements specified in Section II.A.1 of this permit.

        (i) The permittee must determine if existing or planned wastewater and manure storage structures are adequately sized in accordance with Section II.A.1 by evaluating each wastewater or manure storage structure. The permittee may use the Idaho Animal Waste Management (IDAWM) Software, Version 4, December 2000 (Appendix C) and accompanying spreadsheet, the NRCS

Animal Waste Management Software, or demonstrate that the facility is designed with adequate storage capacity as determined by runoff and design calculations followed by an as-built survey conducted by a Professional Engineer licensed in the state of Idaho. If the evaluation determines that the existing wastewater or manure storage structures have a storage capacity less than the minimum capacity requirements specified in Section II.A.1, the NMP must include measures the permittee will take to ensure that the storage capacity specified in Section II.A.1 is met. The NMP must include in the evaluation the results of the wastewater and manure storage structure evaluations, including any corrective and interim measures, and a schedule for implementation.

(ii) The permittee must ensure the proper operation and maintenance of each wastewater and manure storage structure by evaluating compliance with NRCS Appendix 10D and IDAPA 02.04.14.030.01. If the evaluation of the wastewater or manure storage structures identifies deficiencies in the operation or maintenance of the structures, the permittee must identify measures to address those deficiencies in its NMP. This evaluation must be completed in one of the following ways:

(a) By a Professional Engineer, geologist, hydrogeologist, or another qualified individual, in which case the NMP must include the results of the evaluation; or

(b) By completing the Washington NRCS Engineering Technical Note #23, January 2013 (Appendix D), in which case the NMP must include the results of the evaluation.

(iii) The permittee must include a subsurface discharge monitoring plan to identify and monitor any subsurface discharges from each wastewater or manure storage structure in accordance with the specifications in Section IV.D.6. The NMP must include the subsurface discharge monitoring plan and the results of all subsurface monitoring from each wastewater and manure storage structure. The permittee must develop a subsurface discharge monitoring plan as part of the NMP unless the exceptions in (a) or (b) below are met:

(a) Each wastewater or manure storage structure must be evaluated by a Professional Engineer, geologist, hydrogeologist or another qualified individual documenting that each wastewater or manure storage structure does not have a subsurface discharge to Waters of the United States.

(b) Confirm, and maintain documentation in NMP, that each wastewater and manure storage structure is constructed of concrete or steel, or with a double-layer synthetic liner with leak detection, and is properly operated and maintained in accordance with III.A.2.a.ii.

b) Ensure proper management of mortalities (i.e., dead animals) to ensure that they are not disposed of in a liquid manure, storm water, or process wastewater storage or treatment system that is not specifically designed to treat animal mortalities. Mortality handling practices must be in accordance with all applicable Federal, State, and local regulatory requirements.

The permittee must include information in its NMP that addresses both typical and catastrophic mortalities. At a minimum, the NMP must identify the following:

(i) Schedules for collecting, storing, and disposing of carcasses;

(ii) Description of on-site storage before disposal;

(iii) Description of final disposal method;

(iv) Additional management practices to protect waters of the United States for on-site disposal including composting or burial; and

(v) Contingency plans for mass mortalities.

c) Ensure that clean water is diverted, as appropriate, from the production area. Any clean water that is not diverted and comes into contact with raw materials, products, or byproducts including manure, litter, process wastewater, feed, milk, eggs, or bedding is subject to the effluent limitations specified in Section II.A of this permit. Where clean water is not diverted from the production area, the wastewater or manure storage structure shall include adequate storage capacity for the additional clean water. Clean water includes, but is not limited to, snow melt and/or rain falling on the roofs of facilities and runoff from adjacent land. The NMP must identify the BMPs or engineering controls, existing or needed, to exclude clean water from the production area. The NMP must include operation and maintenance procedures required to maintain the existing BMPs or engineering controls or the timing for the construction of needed BMPs or engineering controls.

d) Prevent the direct contact of animals confined or stabled at the facility with waters of the United States. Animals confined at the CAFO must not come into direct contact with waters of the United States. At a minimum, the NMP must describe the BMPs or engineering controls the CAFO will use to prevent animals in the production area from coming into contact with waters of the United States.

e) Ensure that chemicals and other contaminants handled on-site are not disposed of in any manure, litter, process wastewater, or storm water storage or treatment system unless specifically designed to treat such chemicals or contaminants. All wastes from dipping vats, pest and parasite control units, and other facilities utilized for the management of potentially hazardous or toxic chemicals shall be handled and disposed of in a manner sufficient to prevent pollutants from entering the manure, litter, or process wastewater storage structure or waters of the United States. The NMP must include references to any applicable chemical storage and handling protocols and incorporate specific BMPs and actions that will be taken to prevent the improper disposal of chemicals and other contaminants into any manure, litter, process wastewater, or storm water storage or treatment system. The NMP should also consider chemical handling plans for the protection of wells, water supplies, and any drainage ways that are close to chemical storage and handling areas.

f) Identify appropriate site-specific conservation practices to be implemented on the land application areas, including as appropriate buffers or equivalent practices as stipulated in Section II.B.8, to control runoff of pollutants to waters of the United States. The NMP must include appropriate conservation practices identified by evaluating each land application area using the Idaho NRCS Water Quality Technical Note #6, Idaho Nutrient Transport Risk Assessment (INTRA) (Appendix E). CAFOs may opt to utilize the Idaho Phosphorus Site Index (P Index) (Appendix I). The NMP must include the results of the INTRA or P Index evaluations. All CAFOs must follow guidance provided by INTRA and the P Index. If the site-specific conservation practices are NRCS conservation practice standards, the NMP must include provisions to operate and maintain those site-specific conservation practices according to the specific NRCS conservation practices standard. If the owner/operator proposes alternative practice or performance standards, the NMP must describe and cite those standards so that EPA can perform an adequate review. In addition, the NMP must include a schedule for implementation of site-specific conservation practices and proper operation and maintenance procedures.

g) Protocols for appropriate testing of manure, litter, process wastewater, and soil.

(i) Manure must be analyzed at least once annually for nitrogen and phosphorus content in accordance with the University of Idaho Manure and Wastewater Sampling CIS 1139 (Appendix F). The results of these analyses must be included in the NMP and be used in determining application rates for manure, litter, and process wastewater as described in Section III.A.2.h).

(ii) Soil samples must be taken from every field to which manure, litter and process wastewater will be applied. Soil must be analyzed annually in accordance with University of Idaho Bulletin 704 (Appendix G). At a minimum, soil samples must be analyzed for the following constituents: pH, soil organic matter (SOM), Nitrate- Nitrogen (NO_3-N), Ammonium-Nitrate (NH_4-N), and phosphorus (P). The results of these analyses must be included in the NMP and used in determining application rates for manure, litter, and process wastewater as described in Section III.A.2.h).

(iii) Soil samples must be analyzed by a laboratory certified by the North American Proficiency Testing Program (NAPT). Manure samples must be analyzed by a certified Manure Analysis Proficiency Laboratory.

h) Establish protocols to land apply manure, litter, or process wastewater in accordance with site specific nutrient management practices that ensure appropriate agricultural utilization of the nutrients in the manure, litter, or process wastewater.

Annual nutrient budgets must be generated to determine land application rates for each field where manure, litter, or process wastewater is applied. The annual budget must be included in the NMP and be developed in accordance with the University of Idaho Fertilizer Guides or related University of Idaho Crop Production Guide. In the absence of an appropriate University of Idaho Fertilizer or Crop Production Guide, a fertilizer or production guide from a Pacific Northwest Land Grant University may be used (i.e., Oregon State University or Washington State University). In the absence of specific Land Grant University fertilizer or production guides, the NMP must identify and include the best available data used to determine specific land application rates for the crop. The NMP must express land application rates of nutrients in pounds per acre, and volume of manure, litter, and process wastewater in tons, gallons or cubic feet. Ensuring accurate application rates reduces probability of off-site transport. The NMP developed to meet the requirements of this permit, and submitted to the permitting authority for review, must include all necessary calculations. Thereafter, for the remainder of the permit term, application rates may be calculated annually, or immediately prior to land application, if all data and calculations are appropriately documented in the NMP.

i) Identify and maintain site specific records to document the implementation and management of the minimum elements described in Sections **Error! Reference source not found.**-h and in compliance with the permit.

3. Signatory. The NMP shall be signed by the owner/operator or other signatory authority in accordance with Section V.C.5 (Signatory Requirements) of this permit.

4. NMP Availability**.** A current copy of the NMP shall be kept on site at the permitted facility in accordance with Section IV.A of this permit and provided to the permitting authority upon request.

5. Changes to the NMP

a) When a permittee makes changes to the CAFO's NMP previously submitted to EPA, the CAFO owner or operator must provide EPA with the most current version of the CAFO's NMP and identify changes from the previous version.

b) When changes to a NMP are submitted to EPA, EPA will review the revised NMP to ensure that it meets the requirements of Section II and Section III.A.2. If EPA determines that the changes to the NMP necessitate revision to the terms of the NMP incorporated into the permit issued to the CAFO, EPA will determine whether such changes are substantial as defined by 40 CFR 122.42(e)(6).

Substantial changes to the terms of a NMP incorporated as terms and conditions of a permit include, but are not limited to:

(i) Addition of new land application areas not previously included in the CAFO's NMP;

(ii) Changes to the maximum amounts of nitrogen and phosphorus derived from all sources for each crop;

(iii) Addition of any crop or other uses not included in the terms of the CAFO's NMP; and

(iv) Changes to site specific components of the CAFO's NMP, where such changes are likely to increase the risk of nitrogen and phosphorus transport to waters of the United States.

c) If EPA determines that the changes to the terms of the NMP are not substantial, EPA will make the revised NMP publicly available and include it in the permit file, revise the terms of the NMP incorporated into the permit, and notify the permittee and the public of any changes to the terms of the NMP that are incorporated into the permit.

d) If EPA determines that the changes to the terms of the NMP are substantial, EPA will provide the public with the opportunity to comment upon the changes to the NMP and the information submitted by the CAFO owner or operator as set forth in Section III.A.2. of this permit. EPA will respond to all significant comments received during the comment period. The process for public comments, hearing requests and the hearing process, if a hearing is held, will follow the procedures set forth in 40 CFR 124.11 through 124.13.

EPA may require the permittee to further revise the NMP, if necessary. Once EPA incorporates the revised terms of the NMP into the permit, EPA will notify the permittee of the revised terms and conditions of the permit.

B. Lagoon Liner Requirements

Liner Requirements: CAFOs constructing new wastewater or manure storage structures or modifying existing wastewater or manure storage structures shall have a liner that is constructed and maintained in accordance with Idaho NRCS practice standards. Any damage to the liner must be evaluated by a Professional Engineer and corrected within thirty (30) days of the damage, unless the Permitting Authority approves an alternative schedule. The permittee must submit the request within thirty (30) days of the damage, and it must include the Professional Engineer's evaluation of the risks of pollutant releases if the liner is not repaired immediately. All documentation of liner maintenance shall be kept with the NMP.

C. Facility Closure

The following conditions shall apply to the closure of lagoons and other earthen or synthetic lined basins and other manure, litter, or process wastewater storage and handling structures:

1. Closure of Lagoons and Other Surface Impoundments

   a) No lagoon or other earthen or synthetic lined basin shall be permanently abandoned.

   b) Lagoons and other earthen or synthetic lined basins shall be maintained at all times until closed in compliance with this section.

   c) All lagoons and other earthen or synthetic lined basins that are no longer needed as a part of a waste management system and are to be permanently decommissioned or converted for another use must be properly closed consistent with the Idaho NRCS Practice Standard Code 360 contained in Natural Resources Conservation Service Field Office Technical Guide (Appendix B). Consistent with this standard the permittee shall remove all waste materials to the maximum extent practicable and dispose of them in accordance with the permittee's NMP, unless otherwise authorized by EPA.

   d) For any lagoon or other earthen or synthetic lined basin that is not in use for a period of twelve (12) consecutive months but will not be permanently decommissioned or converted to another use, the permittee shall:

      (i) Maintain the structure as though it were actively in use in order to prevent compromise of structural integrity.

      (ii) The permittee shall notify EPA, in writing, of the action taken, and shall conduct routine inspections, maintenance, and record keeping as though the structure were in use. Prior to restoration of use of the structure, the permittee shall notify EPA, in writing, and provide the opportunity for inspection. The permittee shall properly handle and dispose of the water used to preserve the integrity synthetic or earthen liner during periods of non-use in accordance with the NMP.

   e) Unless otherwise authorized by EPA, completion of closure for lagoons and other earthen or synthetic lined basins shall occur as promptly as practicable after the permittee ceases to operate or, if the permittee has not ceased operations, twelve (12) months from the date on which the use of the structure ceased, unless the lagoons or basins are being maintained for possible future use in accordance with the requirements above.

2. Closure Procedures for Other Manure, Litter, or Process Wastewater Storage and Handling Structure

   No other manure, litter, or process wastewater storage and handling structure shall be abandoned. Closure of all such structures shall occur as promptly as practicable within twelve (12) months after the date on which the use of the structure ceased, unless the lagoons or basins are being maintained for possible future use in accordance with the requirements above. To close a manure, litter, or process wastewater storage and handling structure, the permittee shall remove all manure, litter, or process wastewater and dispose of it in accordance with the permittee's NMP, or document its transfer from the permitted facility in accordance with off-site transfer requirements specified in this permit Section III.D, unless otherwise authorized by EPA.

D. Requirements for the Transfer of Manure, Litter, and Process Wastewater

1. In cases where CAFO-generated manure, litter, or process wastewater is sold or given away, the permittee must comply with the following conditions:

   a) Maintain records showing the date and amount of manure, litter, and/or process wastewater that leaves the permitted facility;

   b) Record the name and address of the recipient;

   c) Provide the recipient(s) with representative information on the nutrient content of the manure, litter, and/or process wastewater analyzed in accordance with Section III.A.2.g)(i); and

   d) Retain the records on-site, for a period of five years, and submit the records to EPA, upon request.

IV. RECORDS, REPORTING, MONITORING, AND NOTIFICATION

A. Records Management

1. Record Keeping Requirements for the Production Area

   The permittee must maintain on-site for a period of five (5) years from the date they are created a complete copy of the NOI, the NMP, records to document the implementation and management of Section II.A and Section **Error! Reference source not found.**-(e), Section IV.D and Section IV.A.1.a)-i below. The permittee must make these records available to EPA upon request.

   a) Records documenting the inspections of all storage, containment and treatment structures as required under Section II.A.2.a) and Section **Error! Reference source not found.**;

   b) Weekly records of the depth of the manure and process wastewater in storage, containment and/or treatment structure(s), as applicable, as indicated by the depth marker under Section II.A.2.b);

   c) Documentation of whether or not the wastewater level in all liquid waste storage structures is below the level required to maintain capacity to store the runoff and precipitation from a 25-year, 24-hour storm under Section II.A.2.b);

d) Records documenting the inspections of all stormwater diversion and channel structures under Section III.A.2.c);

e) Records documenting the inspections of all water line inspections, including drinking and cooling water lines and whether or not leaks were discovered;

f) For all structures in Section II.A.2.a)(i)-iii, records documenting any actions taken to correct deficiencies required under Section II.A.2.c). Deficiencies not corrected with thirty (30) days must be accompanied by an explanation of the factors preventing immediate correction;

g) Records of mortalities management and practices used by the permittee to meet the requirements of Section II.A.2.d) and Section III.A.2.b);

h) Records documenting the current design of any wastewater or manure storage structure to meet the requirements of Section II.A.1.b). including volume for solids accumulation, design treatment volume, total design volume, and approximate number of days of storage capacity; and

i) Records of the date, time, and estimated volume of any overflow and additional requirements of Section IV.D.

2. Record Keeping Requirements for the Land Application Area

Each permittee must maintain on-site for a period of five (5) years from the date they are created, a complete copy of the information required by Section II.B and Section III.A.2.f)-i, and the records specified in Section IV.A.2.a)-g below. The permittee must make these records available to EPA upon request. For every field, provide the following information associated with the same unique field identification used in the NMP:

a) The date(s) manure, litter, or process waste water application was begun for each field, for each land application event and all methods associated with the application of the manure, litter or process wastewater, including application method, incorporation method, soil surface conditions, weather conditions, number of acres utilized, amounts of manure, litter and process wastewater, and total amounts of nitrogen and phosphorus applied under Sections II.B.2, 3 and 5 and Section III.A.2.h);

b) Documentation of all manure, litter or process wastewater sample collection and analysis protocols under Section II.B.6 and Section III.A.2.g)(i);

c) Documentation of all soil sample collection and analysis protocols under Section II.B.6 and Section III.A.2.g)(ii);

d) Documentation that all required setbacks, buffers or approved alternatives and conservation practices identified in the NMP were observed and/or implemented, and an explanation for any deviation from these practices under Section II.B.4 and Section II.B.8;

e) The date that the equipment used for the land application event was last inspected under Section II.B.7; and

f) Documentation for all requirements for manure, litter and process wastewater transfers under Section III.D.

g) Documentation of visual inspections of potential land application area discharge locations and land application setback(s) or compliance alternative(s) specified in Sections II.B.9.a)

B. Annual Reporting Requirements

1. The permittee shall submit an annual report by March 1st of each year. Prior to December 20, 2020, reports must be submitted electronically or in hard copy to EPA, the appropriate IDEQ district office and Idaho State Department of Agriculture. Hard copies may be submitted to the addresses below.

    U.S. EPA Region 10
    Attn: ICIS Data Entry Team
    1200 6th Avenue, Suite 155 ECAD-101
    Seattle, Washington 98101-3188

    Idaho State Department of Agriculture
    Division of Animal Industries
    P.O. Box 790
    Boise, Idaho 83701

    After December 20, 2020, annual reports must be submitted *electronically only* to IDEQ. Annual Reports must continue also be submitted to the Idaho State Department of Agriculture.

2. The permittee may seek an electronic reporting waiver by submitting a request. Prior to July 1, 2020, this request must be submitted to EPA. Beginning July 1, 2020, this request must be submitted to IDEQ. This waiver request should contain the following details: facility name; NPDES permit number; facility address; name, address and contact information for the owner, operator, or duly authorized facility representative; and a brief written statement regarding the basis for claiming such a temporary waiver. The request will be either approved or denied within 120 days. The duration of the temporary waiver will not exceed 5 years.

3. The annual report must include all of the information detailed in the Annual Report Template in Appendix H. The permittee may use the fillable pdf template provided or may compile all of the required information in a separate document. Completion and electronic submittal of the Annual Report template shall fulfill the electronic reporting requirements.

C. Notification of Unauthorized Discharges Resulting from Manure, Litter, and Process Wastewater Storage, Handling, On-site Transport and Application

1. If, for any reason, there is an unauthorized discharge of pollutants to a water of the United States, the permittee is required to make immediate oral notification within 24-hours to the EPA Region 10, NPDES Compliance Section, Enforcement and Compliance Assurance Division, Seattle, WA at 206-553-1846 and notify ISDA, the appropriate IDEQ regional office, and the appropriate county authorities in writing, within five (5) working days of the discharge of pollutants to a water of the United States from the facility. In addition, the permittee shall keep a copy of the notification submitted to EPA and ISDA together with the other records required by this permit. The discharge notification shall include the following information:
   a) A description of the discharge and its cause, including a description of the flow path to the receiving water body and an estimate of the flow and volume discharged; and
   b) The period of non-compliance, including exact dates and times, the anticipated time it is expected to continue, and steps taken or planned to reduce, eliminate and prevent recurrence of the discharge.

D. Monitoring Requirements for All Discharges from Wastewater or Manure Storage Structures

1. In the event of any overflow or other discharge, including any subsurface discharges, of pollutants to waters of the United States from a manure or wastewater storage structure, whether or not authorized by this permit the following actions shall be taken:
   a) All discharges from wastewater or manure storage structures to waters of the United States shall be sampled and analyzed. Samples must, at a minimum, be analyzed for the following parameters: total nitrogen, nitrate nitrogen, ammonia nitrogen, total phosphorus, *E. coli*, five-day biochemical oxygen demand (BOD5), total suspended solids, pH, and temperature. The discharge must be analyzed in accordance with approved EPA methods for water analysis listed in 40 CFR Part 136;
   b) For any overflow or other discharge, including any subsurface discharge, subject to monitoring under paragraph 1, if the duration of the discharge event exceeds 24 hours, the discharge shall be monitored daily until the discharge ceases.
2. Record an estimate of the volume of the release and the date and time;
3. Samples shall consist of grab samples collected from the point of overflow or discharge from the waste impoundment or production area. Subsurface discharges shall be sampled at the point of discharge to the receiving water. If the point of discharge to the receiving water is inaccessible, samples of subsurface discharges shall be collected at a point that provides a sample that is representative of the discharge to the receiving water. A minimum of one sample shall be collected within 30 minutes of the detection of the overflow or discharge and the sample(s) of the overflow or discharge must be collected and analyzed in accordance with EPA

approved methods for water analysis listed in 40 CFR Part 136. The sample(s) collected from the overflow or discharge must be representative of the overflow or discharge;

4. If conditions are not safe for sampling, the permittee must provide documentation of why samples could not be collected and analyzed. For example, the permittee may be unable to collect samples during dangerous weather conditions (such as local flooding, high winds, hurricane, tornadoes, electrical storms, etc.). However, once dangerous conditions have passed, the permittee shall collect a sample from the wastewater or manure storage structure from which the discharge occurred;

5. The analytical results of the representative sample(s) taken from the overflow or discharge must be submitted to EPA Region 10, Enforcement and Compliance Assurance Division, within thirty (30) days of the overflow or discharge. Copies of the analytical results shall also be submitted to ISDA and the IDEQ state and appropriate regional office at the addresses listed in Section I.B.3 of this permit; and

6. Subsurface Discharge Monitoring Plan. For those CAFOs required to include a subsurface discharge monitoring plan in the NMP, pursuant to Section **Error! Reference source not found.** of this permit, the plan that is included in the CAFO's NMP must include site-specific information and procedures that will be implemented to address the following:

   a) Identification of the structures and/or locations to be monitored;

   b) Routine periodic monitoring adequate to identify leaks, damage, and other issues that could cause a subsurface discharge, including the frequency of monitoring and the specific technology or protocols that will be used;

   c) Criteria or protocols that will be used to determine whether a subsurface discharge has occurred; and

   d) Site specific protocols for monitoring subsurface discharges in accordance with the requirements in Section IV.D.

E. Monitoring Requirements for Discharges from Land Application Areas

1. In the event of any runoff or discharge from a CAFO's land application area to a water of the United States, the actions specified below must be taken. Discharges subject to monitoring requirements include, but are not limited to, (1) dry weather discharges resulting from land application of manure, litter, or process wastewater, including discharges through tile drains, ditches, or other conveyances, and irrigation return, and (2) stormwater or snowmelt runoff or discharges of manure, litter, or process wastewater that has not been applied in accordance with site specific nutrient management practices that ensure appropriate agricultural utilization of the nutrients

in the manure, litter or process wastewater as provided in 33 U.S.C. § 1362(14) and 40 CFR § 122.23(e).

a) All discharges that meet either of the two criteria specified in Section E.1 above from land application areas to waters of the United States shall be sampled and analyzed as follows.

   (i) Grab samples of the discharge must be collected at a location prior to mixing with the receiving waters, that will provide for a representative sample of the discharge. The specific sampling location(s) must be documented.

   (ii) Samples shall be collected in accordance with the protocols described in Section 3 of EPA's Industrial Stormwater Monitoring and Sampling Guide (EPA 832-B-09-003, April 2021). For sheet flow discharges that are too shallow to collect with a sample bottle, the protocols in the Industrial Stormwater Monitoring and Sampling Guide may be supplemented with procedures for installing a temporary barrier device or similar structure to intercept runoff flow.

   (iii) Samples must, at a minimum, be analyzed for the following parameters: total Kjeldahl nitrogen (TKN), nitrate nitrogen, nitrite nitrogen, total phosphorus, E. coli, fecal coliform, and five-day biochemical oxygen demand (BOD_5).

   (iv) The discharge samples must be analyzed in accordance with approved EPA methods for water analysis listed in 40 CFR Part 136.

b) Samples of the receiving water shall be collected upstream and downstream of the point of discharge to the receiving stream as follows.

   (i) Upstream samples must be collected at a location that provides a representative sample of the water quality immediately upstream of the discharge, prior to mixing with the discharge. Downstream samples must be collected at a location that provides a representative sample of the water quality after mixing with the discharge and prior to the introduction of other pollutant sources. The specific sampling locations must be documented.

   (ii) Samples shall be collected in accordance with EPA Region 4's Surface Water Sampling procedures (LSASDPROC-201-R5, December 2021).

   (iii) Grab samples of ambient receiving waters must, at a minimum, be analyzed for the following parameters: total Kjeldahl nitrogen (TKN), nitrate nitrogen, nitrite nitrogen, total phosphorus, E. coli, fecal coliform, and five-day biochemical oxygen demand (BOD_5).

   (iv) The receiving water samples must be analyzed in accordance with approved EPA methods for water analysis listed in 40 CFR Part 136.

c) A log shall be kept of the receiving water conditions throughout the reach bounded by the upstream and downstream sampling locations during the discharge event. The log must document any discoloration; bottom deposits; condition of any aquatic life observed; presence of visible films, sheens or coatings; fungi, slimes or objectionable growths; and potential nuisance conditions.

d) For any discharge subject to monitoring under Section E.1, if the duration of the discharge event exceeds 24 hours, the discharge and receiving water shall be monitored daily until the discharge ceases.

e) An estimate of the volume of the discharge and the date and time must be recorded;

f) If conditions are not safe for sampling, the permittee must provide documentation of why samples could not be collected and analyzed. For example, the permittee may be unable to collect samples during dangerous weather conditions (such as local flooding, high winds, hurricane, tornadoes, electrical storms, etc.). However, once dangerous conditions have passed, the permittee shall collect a sample of the discharge. If the discharge stops before dangerous conditions have passed, and therefore cannot be sampled, the permittee shall record the estimated time, duration, and volume of the discharge, and the reason the sample could not be collected, and include this information in the Notification of Unauthorized Discharge submitted in accordance with Section IV.C of this permit.

g) The analytical results of the representative sample(s) taken from the discharge and receiving water must be submitted to EPA Region 10, Enforcement and Compliance Assurance Division, within thirty (30) days of the discharge. Copies of the analytical results shall also be submitted to ISDA and the IDEQ state and appropriate regional office at the addresses listed in Section I.B.3 of this permit.

F. Spills / Releases in Excess of Reportable Quantities

1. This permit does not relieve the permittee of the federal reporting requirements of 40 CFR §§ 110, 117 and 302 relating to spills or other releases of oils or hazardous substances.

Where a release containing a hazardous substance or oil in an amount equal to or in excess of a reportable quantity established under either 40 CFR § 110, 40 CFR § 117 or 40 CFR § 302, occurs during a 24-hour period:

a) The permittee must provide notice to the National Response Center (NRC) (800–424–8802; in the Washington, DC, metropolitan area, call 202–267– 2675) in accordance with the requirements of 40 CFR §§ 110, 117 and 302 as soon as site staff have knowledge of the discharge; and

b) The permittee must, within 7 calendar days of knowledge of the release, provide a description of the release, the circumstances leading to the release, and the date of the release. The permittee must also implement measures to prevent the reoccurrence of such releases and to respond to such releases.

2. Any spill of hazardous material must be immediately reported to the appropriate IDEQ regional office (see table below). Spills of petroleum products that exceed 25 gallons or that cause a visible sheen on nearby surface waters should be reported to IDEQ within 24-hours. Petroleum product spills of less than 25 gallons that do not cause a sheen on nearby surface waters shall only be reported to IDEQ if clean-up cannot be accomplished within 24-hours.

IDEQ Regional Office contact information for reporting spills

Regional Office	Phone #	Regional Office	Phone #
Boise	(208) 373-0550	Lewiston	(208) 799-4370
Coeur d'Alene	(208) 769-1422	Pocatello	(208) 236-6160
Idaho Falls	(208) 528-2650	Twin Falls	(208) 736-2190

Outside of regular business hours, qualified spills should be reported to the IDEQ 24-hour reporting hotline at 1-833-IPDES24.

V. STANDARD PERMIT CONDITIONS

A. General Monitoring, Recording, and Reporting Requirements

1. Representative Sampling

Samples and measurements must be representative of the volume and nature of the monitored discharge.

2. Reporting of Monitoring Results

If applicable, the permittee must submit the legible originals of the monitoring results to the Director of the Enforcement and Compliance Assurance Division with copies to ISDA at the following addresses:

US EPA Region 10
Attn: ICIS Data Entry Team
1200 Sixth Avenue, Suite 155 ECAD 20-C04
Seattle, Washington 98101-3140
Idaho State Department of Agriculture
Division of Animal Industries
P.O. Box 790
Boise, ID 83701

3. Monitoring Procedures

Monitoring must be conducted according to test procedures approved under 40 CFR § 136, unless other test procedures have been specified in this permit or approved by EPA as an alternate test procedure under 40 CFR § 136.5.

4. Additional Monitoring by Permittee

   If the permittee monitors any pollutant more frequently than required by this permit, using test procedures approved under 40 CFR § 136 or as specified in this permit, the permittee must include the results of this monitoring in the calculation and reporting of the data submitted to EPA.

   Upon request by EPA, the permittee must submit results of any other sampling, regardless of the test method used.

5. Records Contents.

   Records of monitoring information must include:

   a) The date, exact place, and time of sampling or measurements;
   b) The name(s) of the individual(s) who performed the sampling or measurements;
   c) The date(s) analyses were performed;
   d) The names of the individual(s) who performed the analyses;
   e) The analytical techniques or methods used; and
   f) The results of such analyses.

6. Retention of Records

   The permittee must retain records of all monitoring information, including, all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by this permit, a copy of the NPDES permit, and records of all data used to complete the application for this permit, for a period of at least five years from the date of the sample, measurement, report or application. This period may be extended by request of EPA or State/Tribal agency at any time.

7. Other Noncompliance Reporting

   The permittee must report all instances of noncompliance, not required to be reported within 24 hours, at the time that monitoring reports for Section V.A.2 (Reporting of Monitoring Results) are submitted. The reports must contain the information listed in Section IV.B of this permit ("Notification of Discharges Resulting from Manure, Litter, and Process Wastewater Storage, Handling, On- site Transport and Application").

8. Changes in Discharge of Toxic Pollutant

   The permittee must notify the Director of the Water Division and IDEQ as soon as it knows, or has reason to believe:

   a) That any activity has occurred or will occur that would result in the discharge, on a routine or frequent basis, of any toxic pollutant that is not limited in the permit, if that discharge may reasonably be expected to exceed the highest of the following "notification levels":

(i) One hundred micrograms per liter (100 ug/l);

(ii) Two hundred micrograms per liter (200 ug/l) for acrolein and acrylonitrile; five hundred micrograms per liter (500 ug/l) for 2,4- dinitrophenol and for 2-methyl-4, 6-dinitrophenol; and one milligram per liter (1 mg/l) for antimony;

(iii) Five (5) times the maximum concentration value reported for that pollutant in the permit application in accordance with 40 CFR § 122.21(g)(7); or

(iv) The level established by EPA in accordance with 40 CFR § 122.44(f).

b) That any activity has occurred or will occur that would result in any discharge, on a non-routine or infrequent basis, of any toxic pollutant that is not limited in the permit, if that discharge may reasonably be expected to exceed the highest of the following "notification levels":

(i) Five hundred micrograms per liter (500 ug/l);

(ii) One milligram per liter (1 mg/l) for antimony;

(iii) Ten (10) times the maximum concentration value reported for that pollutant in the permit application in accordance with 40 CFR § 122.21(g)(7); or

(iv) The level established by EPA in accordance with 40 CFR § 122.44(f).

c) The permittee must submit the notification to the Water Division at the following address:

US EPA Region 10
Attn: NPDES Permits Section Manager
1200 Sixth Avenue, Suite 155, 19-C04
Seattle, Washington 98101-3188

B. Compliance Responsibilities

1. Duty to Comply

The permittee must comply with all conditions of this permit. Any permit noncompliance constitutes a violation of the Act and is grounds for enforcement action, for permit termination, revocation and reissuance, or modification, or for denial of a permit renewal application.

2. Penalties for Violations of Permit Conditions

a) Civil and Administrative Penalties. Pursuant to 40 CFR § 19 and the Act, any person who violates section 301, 302, 306, 307, 308, 318 or 405 of the Act, or any permit condition or limitation implementing any such sections in a permit issued under section 402, or any requirement imposed in a pretreatment program approved under sections 402(a)(3) or 402(b)(8) of the Act, is subject to a civil penalty not to exceed the maximum amounts authorized by Section 309(d) of the Act and the Federal Civil Penalties Inflation Adjustment Act (28 U.S.C. § 2461 note) as amended by the Debt Collection Improvement Act (31 U.S.C. § 3701 note) (currently $66,712 per day for each violation).

b) Administrative Penalties. Any person may be assessed an administrative penalty by the Administrator for violating section 301, 302, 306, 307, 308, 318 or 405 of this Act, or any permit condition or limitation implementing any of such sections in a permit issued under section 402 of this Act. Pursuant to 40 CFR 19 and the Act, administrative penalties for Class I violations are not to exceed the maximum amounts authorized by Section 309(g)(2)(A) of the Act and the Federal Civil Penalties Inflation Adjustment Act (28 U.S.C. § 2461 note) as amended by the Debt Collection Improvement Act (31 U.S.C. § 3701 note) (currently $26,685 per violation, with the maximum amount of any Class I penalty assessed not to exceed $66,712). Pursuant to 40 CFR 19 and the Act, penalties for Class II violations are not to exceed the maximum amounts authorized by Section 309(g)(2)(B) of the Act and the Federal Civil Penalties Inflation Adjustment Act (28 U.S.C. § 2461 note) as amended by the Debt Collection Improvement Act (31 U.S.C. § 3701 note) (currently $26,685 per day for each day during which the violation continues, with the maximum amount of any Class II penalty not to exceed $333,552).

c) Criminal Penalties:

(i) Negligent Violations. The Act provides that any person who negligently violates sections 301, 302, 306, 307, 308, 318, or 405 of the Act, or any condition or limitation implementing any of such sections in a permit issued under section 402 of the Act, or any requirement imposed in a pretreatment program approved under section 402(a)(3) or 402(b)(8) of the Act, is subject to criminal penalties of $2,500 to $25,000 per day of violation, or imprisonment of not more than 1 year, or both. In the case of a second or subsequent conviction for a negligent violation, a person shall be subject to criminal penalties of not more than $50,000 per day of violation, or by imprisonment of not more than 2 years, or both.

(ii) Knowing Violations. Any person who knowingly violates such sections, or such conditions or limitations is subject to criminal penalties of $5,000 to $50,000 per day of violation, or imprisonment for not more than 3 years, or both. In the case of a second or subsequent conviction for a knowing violation, a person shall be subject to criminal penalties of not more than $100,000 per day of violation, or imprisonment of not more than 6 years, or both.

(iii) Knowing Endangerment. Any person who knowingly violates section 301, 302, 303, 306, 307, 308, 318 or 405 of the Act, or any permit condition or limitation implementing any of such sections in a permit issued under section 402 of the Act, and who knows at that time that he thereby places another person in imminent danger of death or serious bodily injury, shall, upon conviction, be subject to a fine of not more than $250,000 or imprisonment of not more than 15 years, or both. In the case of a second or subsequent conviction for a knowing endangerment violation, a person shall be subject to a fine of not more than $500,000 or by imprisonment of not more than 30 years, or both. An organization, as defined in section 309(c)(3)(B)(iii) of the Act, shall, upon conviction of violating the imminent danger provision, be subject to a fine of not more than $1,000,000 and can be fined up to $2,000,000 for second or subsequent convictions.

(iv) False Statements. The Act provides that any person who falsifies, tampers with, or knowingly renders inaccurate any monitoring device or method required to be maintained under this permit shall, upon conviction, be punished by a fine of not more than $10,000, or by imprisonment for not more than 2 years, or both. If a conviction of a person is for a violation committed after a first conviction of such person under this paragraph, punishment is a fine of not more than $20,000 per day of violation, or by imprisonment of not more than 4 years, or both. The Act further provides that any person who knowingly makes any false statement, representation, or certification in any record or other document submitted or required to be maintained under this permit, including monitoring reports or reports of compliance or non-compliance shall, upon conviction, be punished by a fine of not more than $10,000 per violation, or by imprisonment for not more than 6 months per violation, or by both.

3. Need to Halt or Reduce Activity not a Defense

It shall not be a defense for the permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with this permit.

4. Duty to Mitigate

The permittee must take all reasonable steps to minimize or prevent any discharge in violation of this permit that has a reasonable likelihood of adversely affecting human health or the environment.

5. Proper Operation and Maintenance

The permittee must at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with the conditions of this permit. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures. This provision requires the operation of back-up or auxiliary facilities or similar systems which are installed by the permittee only when the operation is necessary to achieve compliance with the conditions of the permit.

6. Bypass of Treatment Facilities

   a) Bypass not exceeding limitations. The permittee may allow any bypass to occur that does not cause effluent limitations to be exceeded, but only if it also is for essential maintenance to assure efficient operation. These bypasses are not subject to the provisions of paragraphs b and c of this Part.

   b) Notice.

      (i) Anticipated bypass. If the permittee knows in advance of the need for a bypass, it must submit prior written notice, if possible at least 10 days before the date of the bypass.

      (ii) Unanticipated bypass. The permittee must submit notice of an unanticipated bypass as required under Section IV.C. ("Notification of Discharges Resulting from Manure, Litter, and Process Wastewater Storage, Handling, On-site Transport and Application").

   c) Prohibition of bypass.

      (i) Bypass is prohibited, and the Director of the Enforcement and Compliance Assurance Division may take enforcement action against the permittee for a bypass, unless:

         (a) The bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;

         (b) There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass that occurred during normal periods of equipment downtime or preventive maintenance; and

         (c) The permittee submitted notices as required under paragraph b of this Section.

      (ii) The Director of the Enforcement and Compliance Assurance Division may approve an anticipated bypass, after considering its adverse effects, if the Director determines that it will meet the three conditions listed above in paragraph c.i. of this Part.

7. Upset Conditions

   a) Effect of an upset. An upset constitutes an affirmative defense to an action brought for noncompliance with such technology-based permit effluent limitations if the permittee meets the requirements of paragraph b of this Section. No determination made during administrative review of claims that noncompliance was caused by upset, and before an action for noncompliance, is final administrative action subject to judicial review.

b) Conditions necessary for a demonstration of upset. To establish the affirmative defense of upset, the permittee must demonstrate, through properly signed, contemporaneous operating logs, or other relevant evidence that:

(i) An upset occurred and that the permittee can identify the cause(s) of the upset;

(ii) The permitted facility was at the time being properly operated;

(iii) The permittee submitted notice of the upset as required under Section IV.C, "Notification of Discharges Resulting from Manure, Litter, and Process Wastewater Storage, Handling, On- site Transport and Application;" and

(iv) The permittee complied with any remedial measures required under Section V.B.4, "Duty to Mitigate."

c) Burden of proof. In any enforcement proceeding, the permittee seeking to establish the occurrence of an upset has the burden of proof.

8. Toxic Pollutants

The permittee must comply with effluent standards or prohibitions established under Section 307(a) of the Act for toxic pollutants within the time provided in the regulations that establish those standards or prohibitions, even if the permit has not yet been modified to incorporate the requirement.

9. Planned Changes

The permittee must give written notice to the Director of the Water Division as specified in Section III.A.5.b). as soon as possible of any planned physical alterations or additions to the permitted facility whenever:

a) The alteration or addition to a permitted facility may meet one of the criteria for determining whether a facility is a new source as determined in 40 CFR § 122.29(b); or

b) The alteration or addition could significantly change the nature or increase the quantity of pollutants discharged. This notification applies to pollutants that are subject neither to effluent limitations in the permit, nor to notification requirements under Section V.A.8. ("Changes in Discharge of Toxic Substances").

10. Anticipated Noncompliance

The permittee must give written advance notice to the Director of the Enforcement and Compliance Assurance Division any planned changes in the permitted facility or activity that may result in noncompliance with this permit.

C. General Provisions

1. Permit Actions

This permit may be modified, revoked and reissued, or terminated for cause as specified in 40 CFR §§ 122.62, 122.64, or 124.5. The filing of a request by the permittee for a permit modification, revocation and reissuance, termination, or a notification of planned changes or anticipated noncompliance does not stay any permit condition.

2. Duty to Reapply

If the permittee intends to continue an activity regulated by this permit after the expiration date of this permit, the permittee must apply for and obtain a new permit. In accordance with 40 CFR § 122.21(d), and unless permission for the application to be submitted at a later date has been granted by the Regional Administrator, the permittee must submit a new application at least 180 days before the expiration date of this permit.

3. Duty to Provide Information

The permittee must furnish to EPA, within the time specified in the request, any information that EPA may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with this permit. The permittee must also furnish to EPA, upon request, copies of records required to be kept by this permit.

4. Other Information

When the permittee becomes aware that it failed to submit any relevant facts in a permit application, or that it submitted incorrect information in a permit application or any report to EPA, it must promptly submit the omitted facts or corrected information in writing.

5. Signatory Requirements

All applications, reports or information submitted to EPA must be signed and certified as follows.

a) All permit applications must be signed as follows:

(i) For a corporation: by a responsible corporate officer.

(ii) For a partnership or sole proprietorship: by a general partner or the proprietor, respectively.

(iii) For a municipality, state, federal, Indian tribe, or other public agency: by either a principal executive officer or ranking elected official.

b) All reports required by the permit and other information requested by EPA must be signed by a person described above or by a duly authorized representative of that person. A person is a duly authorized representative only if:

(i) The authorization is made in writing by a person described above;

(ii) The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated facility or activity, such as the position of plant manager, operator of a well or a well field, superintendent, position of equivalent responsibility, or an individual or position having overall responsibility for environmental matters for the company; and

(iii) The written authorization is submitted to the Director of the Enforcement and Compliance Assurance Division.

c) Changes to authorization. If an authorization under Section V.C.5.b) is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of Section V.C.5.b) must be submitted to the Director of the Enforcement and Compliance Assurance Division and the Idaho State Department of Agriculture prior to or together with any reports, information, or applications to be signed by an authorized representative.

d) Certification. Any person signing a document under this Section must make the following certification:

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

6. Availability of Reports

In accordance with 40 CFR § 2, information submitted to EPA pursuant to this permit may be claimed as confidential by the permittee. In accordance with the Act, permit applications, permits and effluent data are not considered confidential. Any confidentiality claim must be asserted at the time of submission by stamping the words "confidential business information" on each page containing such information. If no claim is made at the time of submission, EPA may make the information available to the public without further notice to the permittee. If a claim is asserted, the information will be treated in accordance with the procedures in 40 CFR § 2, Subpart B (Public Information) and 41 Fed. Reg. 36902 through 36924 (September 1, 1976), as amended.

7. Inspection and Entry

   The permittee must allow the Director of the Enforcement and Compliance Assurance Division, EPA Region 10; State/Tribal agency; or an authorized representative (including an authorized contractor acting as a representative of the Administrator), upon the presentation of credentials and other documents as may be required by law, to:

   a) Enter upon the permittee's premises where a regulated facility or activity is located or conducted, or where records must be kept under the conditions of this permit;
   b) Have access to and copy, at reasonable times, any records that must be kept under the conditions of this permit;
   c) Inspect at reasonable times any facilities, equipment (including monitoring and control equipment), practices, or operations regulated or required under this permit; and
   d) Sample or monitor at reasonable times, for the purpose of assuring permit compliance or as otherwise authorized by the Act, any substances or parameters at any location.

8. Property Rights

   The issuance of this permit does not convey any property rights of any sort, or any exclusive privileges, nor does it authorize any injury to persons or property or invasion of other private rights, nor any infringement of federal, tribal, state or local laws or regulations.

9. Transfers

   This permit is not transferable to any person except after written notice to the Director of the Water Division as specified in Part I.D. The Director may require modification or revocation and reissuance of the permit to change the name of the permittee and incorporate such other requirements as may be necessary under the Act. (See 40 CFR § 122.61; in some cases, modification or revocation and reissuance is mandatory).

10. State Laws

    Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable state law or regulation under authority preserved by Section 510 of the Act.

VI. DEFINITIONS

1. **Animal feeding operation (AFO)** means a lot or facility (other than an aquatic animal production facility) where the following conditions are met: (i) animals (other than aquatic animals) have been, are, or will be stabled or confined and fed or maintained for a total of forty-five (45) days or more in any twelve (12) month period, and (ii) crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility.
2. **Application** means the EPA standard national forms for seeking coverage under for an NPDES permit, including any additions, revisions or modifications to the forms; or forms approved by EPA for use in "approved States," including any approved modifications or revisions [e.g. for NPDES general permits, a written "notice of intent" pursuant to 40 CFR § 122.28; for NPDES individual permits, Form 1 and 2B pursuant to 40 CFR § 122.1(d)].
3. **Concentrated animal feeding operation (CAFO)** means an AFO which is defined as a Large CAFO or Medium CAFO by 40 CFR § 122.23 (b)(4) and (b)(6), or that is designated as a CAFO per 40 CFR § 122.23(b)(9)(c).
4. **Grab sample** means a sample which is taken from a waste stream on a one-time basis without consideration of the flow rate of the waste stream and without consideration of time.
5. **Land application** means the application of manure, litter, or process wastewater onto or incorporated into the soil.
6. **Land application area** means land under the control of a CAFO owner or operator, whether it is owned, rented, or leased, to which manure, litter, or process wastewater from the production area is or may be applied.
7. **Large CAFO** means an AFO that stables or confines as many as or more than the numbers of animals specified in any of the following categories: (i) 700 mature dairy cattle, whether milked or dry; (ii)1,000 veal calves; (iii)1,000 cattle other than mature dairy cows or veal calves. Cattle includes but is not limited to heifers, steers, bulls and cow/calf pairs; (iv) 2,500 swine each weighing 55 pounds or more; (v)10,000 swine each weighing less than 55 pounds; (vi) 500 horses; (vii) 10,000 sheep or lambs; (viii) 55,000 turkeys; (ix) 30,000 laying hens or broilers, if the AFO uses a liquid manure handling system; (x)125,000 chickens (other than laying hens), if the AFO uses other than a liquid manure handling system; (xi) 82,000 laying hens, if the AFO uses other than a liquid manure handling system; (xii) 30,000 ducks (if the AFO uses other than a liquid manure handling system); or (xiii) 5,000 ducks (if the AFO uses a liquid manure handling system).

8. **Liquid manure handling system** means a system that collects and transports or moves waste material with the use of water, such as in washing of pens and flushing of confinement facilities. This would include the use of water impoundments for manure and/or wastewater treatment.

9. **Manure** is defined to include manure, litter, bedding, compost and raw materials or other materials commingled with manure or set aside for land application or other use.

10. **Medium CAFO** means any AFO that stables or confines as many or more than the numbers of animals specified in any of the following categories: (i) 200 to 699 mature dairy cattle, whether milked or dry cows; (ii) 300 to 999 veal calves; (iii) 300 to 999 cattle other than mature dairy cows or veal calves. Cattle includes but is not limited to heifers, steers, bulls and cow/calf pairs; (iv) 750 to 2,499 swine each weighing 55 pounds or more; (v) 3,000 to 9,999 swine each weighing less than 55 pounds; (vi)150 to 499 horses, (vii) 3,000 to 9,999 sheep or lambs, (viii) 16,500 to 54,999 turkeys, (ix) 9,000 to 29,999 laying hens or broilers, if the AFO uses a liquid manure handling system; (x) 37,500 to 124,999 chickens (other than laying hens), if the AFO uses other than a liquid manure handling system; (xi) 25,000 to 81,999 laying hens, if the AFO uses other than a liquid manure handling system; (xii) 10,000 to 29,999 ducks (if the AFO uses other than a liquid manure handling system); or (xiii) 1,500 to 4,999 ducks (if the AFO uses a liquid manure handling system) **and** either one of the following conditions are met (a) pollutants are discharged into waters of the United States through a man-made ditch, flushing system, or other similar man-made device; or (b) pollutants are discharged directly into waters of the United States which originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the animals confined in the operation.

11. **Notice of Intent (NOI)** is a form submitted by the owner/operator applying for coverage under a general permit. It requires the applicant to submit the information necessary for adequate program implementation, including, at a minimum, the legal name and address of the owner or operator, the facility name and address, type of facility or discharges, and the receiving stream(s). [40 CFR § 122.28(b)(2)(ii)].

12. **Process wastewater** means water directly or indirectly used in the operation of the CAFO for any or all of the following: spillage or overflow from animal or poultry watering systems; washing, cleaning, or flushing pens, barns, manure pits, or other AFO facilities; direct contact swimming, washing, or spray cooling of animals; or dust control. Process wastewater also includes any water which comes into contact with or is a constituent of raw materials, products, or byproducts including manure, litter, feed, milk, eggs, or bedding.

13. **Production area** means that part of an AFO that includes the animal confinement area, the manure storage area, the raw materials storage area, and the waste containment areas. The animal containment area includes but is not limited to open

lots, housed lots, feedlots, confinement houses, stall barns, free stall barns, milkrooms, milking centers, cowyards, barnyards, medication pens, walkers, animal walkways, and stables. The manure storage area includes but is not limited to lagoons, runoff ponds, storage sheds, stockpiles, under house or pit storages, liquid impoundments, static piles, and composting piles. The raw materials storage area includes but is not limited to feed silos, silage bunkers, and bedding materials. The waste containment area includes but is not limited to settling basins, and areas within berms and diversions which separate uncontaminated storm water. Also included in the definition of production area is any egg washing or egg processing facility, and any area used in the storage, handling, treatment, or disposal of mortalities.

14. **Small CAFO** means an AFO that is designated as a CAFO and is not a Medium CAFO.
15. **Setback** means a specified distance from waters of the United States or potential conduits to waters of the United States where manure, litter, and process wastewater may not be land applied. Examples of conduits to surface waters include but are not limited to: Open tile line intake structures, sinkholes, and agricultural well heads.
16. **The Act** means Federal Water Pollution Control Act as amended, also known as the Clean Water Act as amended, found at 33 USC 1251 et seq.
17. **Vegetated buffer** means a narrow, permanent strip of dense perennial vegetation established parallel to the contours of and perpendicular to the dominant slope of the field for the purposes of slowing water runoff, enhancing water infiltration, and minimizing the risk of any potential nutrients or pollutants from leaving the field and reaching waters of the United States.
18. **Waters of the United States** means waters as defined in 40 CFR Part 122.2.

APPENDIX A - NOTICE OF INTENT - EPA FORM 2B

United States Environmental Protection Agency	Office of Water Washington, D.C.	EPA Form 3510-2B Revised March 2019

Water Permits Division

Application Form 2B

Concentrated Animal Feeding Operations and Concentrated Aquatic Animal Production Facilities

NPDES Permitting Program

Note: Complete this form ***and*** Form 1 if your facility is a new or existing concentrated animal feeding operation or concentrated aquatic animal production facility.

Paperwork Reduction Act Notice

The U.S. Environmental Protection Agency (EPA) estimates the average burden for concentrated animal feeding operation respondents to collect information and complete Form 2B to be 9.2 hours (8.7 hours to complete and submit the application and 0.5 hours to complete and submit a nutrient management plan). EPA estimates the average burden for concentrated aquatic animal production respondents to collect information and complete Form 2B to be 5.5 hours. These estimates include time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing and reviewing the collection of information. Send comments about the burden estimates or any other aspect of this collection of information to the Chief, Information Policy Branch (PM-223), U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue, NW, Washington, DC 20460, and to the Office of Information and Regulatory Affairs, Office of Management and Budget, 725 17th Street, NW, Washington, DC 20503, marked “Attention: Desk Officer for EPA.”

FORM 2B—INSTRUCTIONS

General Instructions

Who Must Complete Form 2B?

You must complete Form 2B if you answered "Yes" to Item 1.2.1 on Form 1—that is, if you are a concentrated animal feeding operation (CAFO) or a concentrated aquatic animal production (CAAP) facility.

Where to File Your Completed Form

Submit your completed application package (Forms 1 and 2B) to your National Pollutant Discharge Elimination System (NPDES) permitting authority. Consult Exhibit 1–1 of Form 1's "General Instructions" to identify your NPDES permitting authority.

Public Availability of Submitted Information

The U.S. Environmental Protection Agency (EPA) will make information from NPDES permit application forms available to the public for inspection and copying upon request. You may not claim any information on Form 2B (or related attachments) as confidential.

You may make a claim of confidentiality for any information that you submit to EPA that goes beyond the information required by Form 2B. Note that NPDES authorities will deny claims for treating any effluent data as confidential. If you do not assert a claim of confidentiality at the time you submit your information to the NPDES permitting authority, EPA may make the information available to the public without further notice to you. EPA will handle claims of confidentiality in accordance with the Agency's business confidentiality regulations at Part 2 of Title 40 of the *Code of Federal Regulations* (CFR).

Completion of Forms

Print or type in the specified areas only. If you do not have enough space on the form to answer a question, you may continue on additional sheets, as necessary, using a format consistent with the form.

Provide your EPA Identification Number from the Facility Registry Service, NPDES permit number, and facility name at the top of each page of Form 2B and any attachments. If your facility is new (i.e., not yet constructed), write or type "New Facility" in the space provided for the EPA Identification Number and NPDES permit number. If you do not know your EPA Identification Number, contact your NPDES permitting authority. See Exhibit 1–1 of the "General Instructions" of Form 1 for contact information.

Do not leave any response areas blank unless the form directs you to skip them. If the form directs you to respond to an item that does not apply to your facility or activity, enter "NA" for "not applicable" to show that you considered the item and determined a response was not necessary for your facility.

The NPDES permitting authority will consider your application complete when it and any supplementary material are received and completed according to the authority's satisfaction. The NPDES permitting authority will judge the completeness of any application independently of the status of any other permit application or permit for the same facility or activity.

Definitions

The legal definitions of all key terms used in these instructions and Form 2B are in the "Glossary" at the end of the "General Instructions" in Form 1.

Line-by-Line Instructions

Section 1. General Information

Item 1.1. Mark whether your facility/business type is a CAFO or a CAAP.

- For a CAFO, you must complete Sections 1 through 6 and Section 8.
- For a CAAP, you must complete Sections 1, 7, and 8.

Item 1.2. Indicate whether your facility is an existing or proposed facility. Mark "Proposed Facility" if your facility is presently not in operation or is expanding to meet the definition of a CAFO in accordance with the regulations at 40 CFR 122.23.

Section 2. CAFO Owner/Operator Contact Information

Item 2.1. Provide the name, title, telephone number, and email address of the owner/operator of the facility/business.

Item 2.2. Provide the complete mailing address of the owner/operator of the facility/business.

Section 3. CAFO Location and Contact Information

Item 3.1. Provide the legal name and location (complete mailing address) of the facility. Also indicate whom the NPDES permitting authority should contact about the application, including a telephone number and email address.

Item 3.2. Provide the latitude and longitude of the entrance to the production area (i.e., the part of the operation that includes the animal confinement area, the manure storage area, the raw materials storage area, and the waste containment areas). Latitude and longitude coordinates may be obtained in a variety of ways, including use of hand held devices (e.g., a GPS enabled smartphone), internet mapping tools (e.g., https://mynasadata.larc.nasa.gov/latitudelongitude-finder/), geographic information systems (e.g., ArcView), or paper maps from trusted sources (e.g., U.S. Geological Survey or USGS). For further guidance, refer to http://www.epa.gov/geospatial/latitudelongitude-data-standard.

Item 3.3. If the facility uses a contract grower, provide the name and complete mailing address of the integrator.

Section 4. CAFO Topographic Map

Item 4.1. Provide a topographic map of the geographic area in which the facility is located, showing the specific location of the production area(s). You are not required to provide the topographic map required by Section 7 of Form 1.

On each map, include the map scale, a meridian arrow showing north, and latitude and longitude to the nearest second. Latitude and longitude coordinates may be obtained in a variety of ways, including use of hand held devices (e.g., a GPS enabled smartphone), internet mapping tools (e.g., https://mynasadata.larc.nasa.gov/latitudelongitude-finder/), geographic information systems (e.g., ArcView), or paper maps from trusted sources (e.g., USGS).

On all maps of rivers, show the direction of the current. In tidal waters, show the directions of ebb and flow tides.

You may develop your map by going to the United States USGS's National Map website at http://nationalmap.gov/. (For a map from this site, use the traditional 7.5-minute quadrangle format. If none is available, use a USGS 15-minute series map.) You may also use a plat or other appropriate map. Briefly describe land uses in the map area (e.g., residential, commercial.). Note that you have completed your topographic map and attached it to the application.

Section 5. CAFO Characteristics

Supply all information in Section 5 if you checked "Existing facility" in response to Item 1.2.

Item 5.1. Provide the maximum number of each type of animal in open confinement or housed under roof (either partially or totally) that are held at your facility for a total of 45 days or more in any 12-month period. Provide the total number of animals confined at the facility.

Item 5.2. Identify the applicable types of containment and storage for manure, litter, and process wastewater at the facility and indicate the capacity of storage in days and gallons or tons.

Item 5.3. Indicate the total number of acres that are drained and collected in the containment and storage structure(s).

Item 5.4. Specify the tons of manure or litter and the gallons of process wastewater generated at the facility on an annual basis.

Item 5.5. Indicate whether the manure, litter, and/or process wastewater is land applied. If yes, continue to Item 5.6. If no, skip to Item 5.8.

Item 5.6. Indicate the number of acres of land under the control of the applicant that are available for land application of the manure, litter, or process wastewater.

Item 5.7. Check any of the identified best management practices that are being implemented at the facility to control runoff and protect water quality.

Item 5.8. Indicate if the manure, litter, and/or process wastewater is transferred to any other persons. If yes, continue to Item 5.9. If no, skip to Item 5.10.

Item 5.9. Specify the tons of manure or litter or the gallons of process wastewater transferred annually to other people.

Item 5.10. Describe any alternative uses of manure, litter, or process wastewater, if any (e.g., composting, pelletizing, energy generation).

Section 6. CAFO Nutrient Management Plans

Item 6.1. Indicate if you have submitted a nutrient management plan that satisfies the requirements at 40 CFR 122.42(e) and, if applicable, the requirements at 40 CFR 412.4(c).

Item 6.2. If you have not yet submitted a nutrient management plan, explain why not.

Item 6.3. Indicate if a nutrient management plan is being implemented at the CAFO. If not land applying, describe the alternative uses of the manure, litter, and wastewater (e.g., composting, pelletizing, energy generation).

Item 6.4. Indicate the date of the last review or revision of the nutrient management plan.

Note: A permit application is not complete until a nutrient management plan is submitted to the NPDES permitting authority.

Section 7. CAAP Facility Characteristics

Item 7.1. Indicate if the CAAP facility is located on land. If the facility is located in water (e.g., a net pen or submerged cage system), check "No" and skip to Item 7.3. If yes, continue to Item 7.2.

Item 7.2. Provide the maximum daily and maximum average monthly discharge at the CAAP facility by outfall number. Outfall numbers should correspond with the outfall numbers provided on the map submitted in Section 7 of Form 1. Values given for flow should be representative of your normal operation. The maximum daily flow is the maximum measured flow occurring over a calendar day. The maximum average monthly flow is the average of measured daily flow over the calendar month of highest flow.

Item 7.3. Indicate the number of ponds, raceways, net pens, submerged cages, or similar structures at your facility that result in discharges to waters of the United States. Describe each type and provide the name of the associated receiving water and intake water source.

Item 7.4. List the species of fish or aquatic animals held and fed at your facility. Distinguish between cold-water and warm-water species. The names of fish species should be proper, common, or scientific names as given in Special Publication 34 of the American Fisheries Society, *Common and Scientific Names of Fishes from the United States, Canada, and Mexico*.

For each species, provide the total harvestable weight in pounds (lbs.) for a typical calendar year. Also indicate the maximum weight present at any one time at your facility.

Item 7.5. Indicate the maximum monthly pounds of food given at your facility. Also indicate the month given. The amounts should be representative of your normal operations.

Section 8. Checklist and Certification Statement

Item 8.1. Review the checklist provided. In Column 1, mark the sections of Form 2B that you have completed and are submitting with your application. For each section in Column 2, indicate whether you are submitting attachments.

Item 8.2. The Clean Water Act provides for severe penalties for submitting false information on this application form. CWA Section 309(c)(2) provides that, "Any person who knowingly makes any false statement, representation, or certification in any application, …shall upon conviction, be punished by a fine of no more than $10,000 or by imprisonment for not more than six months, or both."

FORM 2B—INSTRUCTIONS CONTINUED

FEDERAL REGULATIONS AT 40 CFR 122.22 REQUIRE THIS APPLICATION TO BE SIGNED AS FOLLOWS:

A. For a corporation, by a responsible corporate officer. For the purpose of this section, a responsible corporate officer means: (1) a president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy- or decision-making functions for the corporation, or (2) the manager of one or more manufacturing, production, or operating facilities, provided the manager is authorized to make management decisions which govern the operation of the regulated facility including having the explicit or implicit duty of making major capital investment recommendations, and initiating and directing other comprehensive measures to assure long term environmental compliance with environmental laws and regulations; the manager can ensure that the necessary systems are established or actions taken to gather complete and accurate information for permit application requirements; and where authority to sign documents has been assigned or delegated to the manager in accordance with corporate procedures.

B. For a partnership or sole proprietorship, by a general partner or the proprietor, respectively.

C. For a municipality, state, federal, or other public facility, by either a principal executive officer or ranking elected official. For purposes of this section, a principal executive officer of a federal agency includes: (1) The chief executive officer of the agency, or (2) a senior executive officer having responsibility for the overall operations of a principal geographic unit of the agency (e.g., Regional Administrators of EPA).

END

Submit your completed Form 1, Form 2B, and all associated attachments (and any other required NPDES application forms) to your NPDES permitting authority.

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EPA Identification Number	NPDES Permit Number	Facility Name	Form Approved 03/05/19 OMB No. 2040-0004

Form 2B NPDES | EPA

U.S. Environmental Protection Agency
Application for NPDES Permit to Discharge Wastewater

CONCENTRATED ANIMAL FEEDING OPERATIONS and CONCENTRATED AQUATIC ANIMAL PRODUCTION FACILITIES

SECTION 1. GENERAL INFORMATION (40 CFR 122.21(l)(1))

General Information

1.1	Indicate the facility/business type. (Check only one response.) ☐ CAFO ➔ Complete Sections 1 through 6 and Section 8. ☐ CAAP ➔ Complete Sections 1, 7, and 8.
1.2	Indicate the operational status of the facility. (Check one.) ☐ Existing facility ☐ Proposed facility

SECTION 2. CAFO OWNER/OPERATOR CONTACT INFORMATION (40 CFR 122.21(f)(2) and (4) and 122.21(i)(1)(i))

CAFO Owner/Operator Contact Information

2.1	**Owner/Operator Contact**		
	Name (first and last)	Title	
	Phone number	Email address	
2.2	**Owner/Operator Mailing Address**		
	Street or P.O. box		
	City or town	State	Zip code

SECTION 3. CAFO LOCATION AND CONTACT INFORMATION (40 CFR 122.21(i)(1)(ii and iii))

CAFO Location and Contact Information

3.1	**CAFO Location and Contact**		
	Name		
	Address (street, route number, or other specific identifier)	County	
	City or town	State	Zip code
	Facility contact name	Phone number	Email address
3.2	**Latitude/Longitude of Entrance to Production Area** (see instructions)		
	Latitude	**Longitude**	
	° ′ ″	° ′ ″	

EPA Identification Number	NPDES Permit Number	Facility Name	Form Approved 03/05/19 OMB No. 2040-0004

CAFO Location and Contact Information Continued

3.3	**Integrator Name and Address**		
	Name		
	Street address		
	City or town	State	Zip code

SECTION 4. CAFO TOPOGRAPHIC MAP (40 CFR 122.21(i)(1)(iv))

CAFO Topographic Map

4.1 Have you attached a topographic map containing all required information to this application? (See instructions for specific requirements.)

☐ Yes ➔ SKIP to Section 5. ☐ No

SECTION 5. CAFO CHARACTERISTICS (40 CFR 122.21(i)(1)(v ix))

CAFO Characteristics

5.1 Provide information on the type and number of animals in the table below.

Animal Type	Number in Open Confinement	Number Housed Under Roof	Animal Type	Number in Open Confinement	Number Housed Under Roof
☐ Mature dairy cows			☐ Sheep or lambs		
☐ Dairy heifers			☐ Chickens (broilers)		
☐ Veal calves			☐ Chickens (layers)		
☐ Cattle (not dairy or veal calves)			☐ Ducks		
☐ Swine (55 lbs. or more)			☐ Other (specify)		
☐ Swine (under 55 lbs.)			☐ Other (specify)		
☐ Horses			☐ Other (specify)		
☐ Turkeys			**Total Animals**		

5.2 Indicate the type of containment and storage, total number of days, and total capacity for manure, litter, and process wastewater storage in the table below.

Type of Containment and Storage	Total Number of Days	Total Capacity (specify gallons or tons)	Type of Containment and Storage	Total Number of Days	Total Capacity (specify gallons or tons)
☐ Anaerobic lagoon			☐ Belowground storage tanks		
☐ Evaporation			☐ Roofed storage shed		
☐ Aboveground storage tanks			☐ Concrete pad		
☐ Storage pond			☐ Impervious soil pad		
☐ Underfloor pit			☐ Other (specify)		

5.3 Indicate the total number of acres drained and collected in the containment and storage structure(s) reported under Item 5.2.

____________ acres

EPA Identification Number	NPDES Permit Number	Facility Name	Form Approved 03/05/19 OMB No. 2040-0004

CAFO Characteristics Continued

Manure, Litter, and/or Process Wastewater Production and Use

5.4	How many tons of manure or litter and gallons of process wastewater are generated annually at the CAFO?	
	Manure	tons
	Litter	tons
	Process wastewater	gallons
5.5	Is manure, litter, and/or process wastewater generated at the CAFO land applied? ☐ Yes ☐ No ➔ SKIP to Item 5.8.	
5.6	How many acres of land under the control of the applicant are available for applying the CAFO's manure, litter, or process wastewater? ______________ acres	
5.7	Check all land application best management practices that are being implemented. ☐ Buffers ☐ Infiltration field ☐ Setbacks ☐ Grass filter ☐ Conservation tillage ☐ Terrace ☐ Constructed wetlands ☐ Other (specify)	
5.8	Is manure, litter, and/or process wastewater transferred to any other persons? ☐ Yes ☐ No ➔ SKIP to Item 5.10.	
5.9	How many tons of manure or litter and gallons of process wastewater, produced by the CAFO, are transferred annually to other people?	
	Manure	tons
	Litter	tons
	Process wastewater	gallons
5.10	Describe alternative use(s) of manure, litter, or process wastewater, if any.	

SECTION 6. CAFO NUTRIENT MANAGEMENT PLANS (40 CFR 122.21(i)(1)(x))

CAFO Nutrient Management Plans

6.1	Has the applicant attached a nutrient management plan that satisfies the requirements at 40 CFR 122.42(e) and, if applicable, the requirements at 40 CFR 412.4(c)? **Note:** A permit application is not complete until a nutrient management plan is submitted to the NPDES permitting authority. ☐ Yes ➔ SKIP to Item 6.3. ☐ No
6.2	Explain why a nutrient management plan is not attached to the application.
6.3	Is a nutrient management plan being implemented at the CAFO? ☐ Yes ☐ No
6.4	What was the date of the last review or revision of the nutrient management plan? Date ______________________________

EPA Identification Number	NPDES Permit Number	Facility Name	Form Approved 03/05/19 OMB No. 2040-0004

SECTION 7. CAAP FACILITY CHARACTERISTICS (40 CFR 122.21(i)(2))

CAAP Facility Characteristics

7.1 Is the CAAP facility located on land?

☐ Yes ☐ No → SKIP to Item 7.3.

7.2 Provide the maximum daily and maximum average monthly discharge at CAAP by outfall.

Outfall Number	Discharge	
	Maximum Daily Discharge	Maximum Average Monthly Discharge
	gpd	gpd
	gpd	gpd
	gpd	gpd

7.3 Indicate the type and number of discharge structures at the CAAP. Provide a brief description of each structure. Also note the name of the receiving water and the source of the intake water for each structure.

Structure Type	Number of Each	Description	Receiving Water Name	Source of Intake Water
Ponds				
Raceways				
Net pens				Not applicable
Submerged cages				Not applicable
Similar structures (specify) ________				

7.4 List the cold-water and/or warm-water aquatic species raised/produced in the table below. For each species listed, indicate the total yearly and maximum harvestable weight (in pounds).

Cold Water Species			Warm Water Species		
Species	Harvestable Weight		Species	Harvestable Weight	
	Total Yearly	Maximum		Total Yearly	Maximum
	lbs.	lbs.		lbs.	lbs.
	lbs.	lbs.		lbs.	lbs.
	lbs.	lbs.		lbs.	lbs.
	lbs.	lbs.		lbs.	lbs.

7.5 Indicate the calendar month of maximum feeding and the total mass of food fed (in pounds) during that month.

Month of Maximum Feeding	Total Mass of Food Fed
	lbs.

EPA Identification Number	NPDES Permit Number	Facility Name	Form Approved 03/05/19 OMB No. 2040-0004

SECTION 8. CHECKLIST AND CERTIFICATION STATEMENT (40 CFR 122.22(a) and (d))

Checklist and Certification Statement

8.1 In Column 1, below, mark the sections of Form 2B that you have completed and are submitting with your application. For each section, specify in Column 2 any attachments that you are enclosing to alert the permitting authority. Note that not all applicants are required to provide attachments.

Column 1	Column 2
☐ Section 1: General Information	☐ w/ attachments
☐ Section 2: CAFO Owner/Operator Contact Information	☐ w/ attachments
☐ Section 3: CAFO Location and Contact Information	☐ w/ attachments
☐ Section 4: CAFO Topographic Map	☐ w/ topographic map ☐ w/ additional attachments
☐ Section 5: CAFO Characteristics	☐ w/ attachments
☐ Section 6: CAFO Nutrient Management Plans	☐ w/ nutrient management plan ☐ w/ attachments
☐ Section 7: CAAP Facility Characteristics	☐ w/ attachments
☐ Section 8: Checklist and Certification Statement	☐ w/ attachments

8.2 **Certification Statement**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Name (print or type first and last name)	Official title
Signature	**Date signed**

APPENDIX B - ID NRCS CONSERVATION PRACTICE STANDARD CODE 360

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

CLOSURE OF WASTE IMPOUNDMENTS

(No.)

CODE 360

DEFINITION

The closure of waste impoundments (treatment lagoons and liquid storage facilities), that are no longer used for their intended purpose, in an environmentally safe manner.

PURPOSE

- Protect the quality of surface water and groundwater resources
- Eliminate a safety hazard for humans and livestock
- Safeguard the public health

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to agricultural waste impoundments that are no longer needed as a part of a waste management system and are to be permanently closed or converted.

The structure must be constructed to meet NRCS standards or show structural integrity if these impoundments are to be converted to fresh water storage ponds. Investigations for structural integrity must be conducted as specified in the National Engineering Manual (NEM) 501.23.

CRITERIA

General Criteria Applicable to All Purposes

The closure shall comply with all federal, state and local laws, rules and regulations including pollutant discharge elimination system requirements.

All structures used to convey waste to waste impoundments or to provide drainage from the impoundment area shall be removed and replaced with compacted earth material or otherwise rendered unable to convey waste.

Liquid and slurry wastes shall be agitated and pumped to the extent conventional pumping will allow. Clean water shall be added as necessary to facilitate the agitation and pumping. The wastewater shall be utilized in accordance with Waste Utilization (633), as well as Nutrient Management (590). The sludge remaining on the bottom and sides of the waste treatment lagoon or waste storage facility may remain in place if it will not pose a threat to the environment. If leaving the sludge in place would pose a threat, it shall be removed to the fullest extent practical and utilized in accordance with Waste Utilization (633), as well as Nutrient Management (590).

Land Reclamation. Impoundments with embankments may be breached so that they will no longer impound water, and excavated impoundments may be backfilled so that these areas may be reclaimed for other uses. Waste impoundments that have water impounded against the embankment are considered embankment structures if the depth of water is three feet or more above natural ground.

(1) Embankment Impoundments. Waste shall be removed from the site before the embankment is breached. The slopes and bottom of the breach shall be stable for the soil material involved; however, the side slopes shall be no steeper than three horizontal to one vertical (3:1).

(2) Excavated Impoundments. The backfill height shall exceed the design finished grade by 5 percent to allow for settlement. The top one foot of the backfill shall be constructed of soil with greater than 20% clay content and mounded to shed rainfall

runoff. Incorporate available topsoil where feasible to aid establishment of vegetation.

Closed waste storage structures shall be demolished or disassembled or otherwise altered to such an extent that no water can be impounded. Disassembled materials such as pieces of metal shall be temporarily stored until their final disposition in such a manner that they do not pose a hazard to animals or humans.

Demolished materials shall be buried on-site, as allowed by local regulation of landfills or moved off-site to locations designated by state or local officials. If buried on-site, the materials are to be covered with soil to a settled depth of one foot, and the backfill be sufficiently mounded such that runoff will be diverted from the site after the backfill settles.

Conversion to Fresh Water Storage. The converted impoundment shall meet the requirements as set forth in the appropriate NRCS practice standard for the intended purpose.

Safety. When sludge is not removed from a waste impoundment that is being converted to fresh water storage, the impoundment shall not be used for fish production, swimming or livestock watering until water quality is adequate for these purposes. Precautions such as fencing and warning signs shall be used to ensure that the facility is not used for purposes incompatible with the current quality of water.

Personnel shall not enter an enclosed waste impoundment without breathing apparatus or taking other appropriate measures.

Protection. All disturbed areas shall be re-vegetated or other suitable measures used to control erosion and restore the esthetic value of the site. Sites not suitable for re-vegetation through normal cropping practices shall be vegetated using Critical Area Planting (342).

Measures shall be taken during construction to minimize site erosion and pollution of downstream water resources. This may include such items as silt fences, hay bale barriers, temporary vegetation and mulching.

CONSIDERATIONS

Reduce pumping effort to empty waste impoundments where the surface is covered by a dense mat of floating vegetation by first applying herbicide to the vegetation and then burning the residue. Appropriate permits must be obtained before burning.

Minimize the impact of odors associated with emptying and land applying wastewater and sludge from a waste impoundment by using an incorporation application method at a time when the humidity is low, winds are calm and wind direction is away from populated areas.

Soil to fill excavated ponds should not come from important farmlands (prime, statewide, local and/or unique).

Breeched embankments may detract from the overall esthetics of the operation. Embankments should be removed and the site returned to its original grade.

Keep sludge left in place covered with water to prevent its aerobic decomposition with the potential release of nutrients to surface and ground water.

Disassembled structural facilities may be suitable for assembly at another site. Care should be taken during closure to minimize damage to the pieces of the facility, particularly coatings that prevent corrosion of metal pieces.

PLANS AND SPECIFICATIONS

Plans and specifications for closure of abandoned waste treatment lagoons and waste storage facilities shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose. The plans and specifications shall also be consistent with the requirements of that standard.

OPERATION AND MAINTENANCE

The proper closure of a waste treatment lagoon or waste storage facility should require little or no operation and maintenance; however, if it is converted to another use, such as a fresh water facility, operation and maintenance shall be in accordance with the needs as set forth in the appropriate NRCS conservation practice standard for the intended purpose.

APPENDIX C - ID NRCS IDAW

United States Department of Agriculture
Natural Resource Conservation Service

IDAWM
Computer Program

Version 4.00 DECEMBER 2000

Computer Program for Animal Waste Computations
Title: IDAWM Version: 4.00
Date: May 1991 Last Revision: December 2000

Programmed by: Bruce D. Wilson
NRCS Assistant State Conservation Engineer
Portland, Oregon

Modified for Idaho by: Clare J. Prestwich, NRCS
Idaho State Irrigation Engineer

References:

- Oregon Department of Agriculture, Natural Resources Division, Oregon Animal Waste Installation Guidebook, Salem, Oregon, March, 1991
- USDA NRCS, Agricultural Waste Management Field Handbook, US Government Printing Office, Washington, D.C., 1991.
- Economic Worksheet for Animal Waste Utilization, Hal Gordon, NRCS State Economist, Portland, OR, 1992
- Idaho Department of Health and Welfare, Division of Environmental Quality, Idaho Waste Management Guidelines for Confined Feeding Operations, 1993.
- USDA, NRCS, Idaho FOTG Practice Standards 313, 359 and 590.

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Idawm

A. PROGRAM DESCRIPTION
This program can be used as a tool for computing animal waste volumes, nutrient amounts, sizing storage facilities, and/or determining nutrient application area requirements based upon plant uptake. The program uses data and procedural guidelines from the Idaho Waste Management Guidelines for Confined Feeding Operations (IDWMG) and the NRCS Agricultural Waste Management Field Handbook. The data input screens will display reference page numbers in the IDWMG where a description of data and procedures used can be found.

The program was created using version 4.5 of the Microsoft QuickBASIC interpreter. The program consists of 13 executable modules. Each module represents an input screen of the program. Since the program consists of executable modules, the program requires the BRUN45.EXE program file be in the same directory as the program modules in order to run properly.

Four data files are also needed to run the program. The data files consist of animal, crop, climatic and default information. The information in the data files from the OAWG (Oregon Animal Waste Guidebook) was modified for Idaho and can be updated as needed. The default data file has been created but can be altered to save the following information:

--landowner/operator
--climatic station
--type of operation
--animal descriptions
--animal weights
--months of animal confinement
--days animals are confined
--days animals are grazed
--liquid storage period
--solid storage period
--crops selected for nutrient uptake
--nutrient on which to base acreage calculations
--dollar value of nutrients
--selected printer for printing data
--data path and disk drive and path where data is to be stored.

The economics of determining the break even cost and nutrient balance of waste application was develop by Hal Gordon, NRCS Oregon State Economists, and adapted to this program.

B. EQUIPMENT
This program is designed to run on the AT&T PC 6300 series computer or compatible with 640K or RAM memory and running MS-DOS version 2.11 or higher. A single disk drive is required to run the program and a printer is required to print a paper copy of the program output. The program can be provided on 360K, 1.2 MB 5 1/4 inch diskettes or 720K/1.44MB 3 ½ inch diskettes.

C. INSTRUCTIONS TO LOAD AND RUN PROGRAM
If your computer is equipped with a hard disk, you can load the program onto the hard disk by creating a subdirectory and copying all the files from the diskette or diskettes into the subdirectory created on the hard disk or by downloading the program from the NRCS Idaho web page <http://id.nrcs.usda.gov> and clicking on "TECHNICAL RESOURCES", "ENGINEERING TECHNICAL RESOURCE DOWNLOAD PAGE", "COMPUTER PROGRAMS", then "idawm". To run the program from the subdirectory, simply use the change directory command (CD) to change to the subdirectory and type Idawm followed by the enter key. To avoid problems loading or saving data files add the following to the auotexec.bat file in the c:\ directory " path=c:\subdirectory where you loaded the program". If the path statement already exists just add it on to the end of the line. This can be done using any text editor.

If you wish to run the program using the floppy drive, insert diskette number one into the A: or B: disk drive, type

A: or **B:** for the drive the diskette is located in and press the enter key. Type Idawm followed by the enter key to run the program. If you are prompted to "Input run-time module path:", type **A:** or **B** for the disk drive containing the program diskette and press the enter key.

Important-- The first time you run the program;

1. Press the [F3] key to save the default settings.
2. Follow the instructions on page 13 to customize the data for the default screens paying special attention to the printer type and data storage disk drive and data path. Save the defaults by pressing the [PgDn] key at the last input screen so the next time you run the program the defaults will be set up the way you want them for your computer.

The program is initially set up to use the Genicom Dot Matrix printer for printouts and the A: disk drive for data storage.

If you have trouble running the program on your computer, call your IRM staff to insure you have the proper equipment and MSDOS version described in section B.

D. USER INSTRUCTIONS

The Idawm program is "user friendly" to the extent that all the input data needed is asked for in a logical manner. The data field that is activated for the user to enter new or to change default data is identified by that data field being shaded. The entire data field is shaded when the data field is empty and the length of the shaded area is reduced as each character is entered. If the data field is full, the program will provide one extra shaded space to indicate the current location for data input.

The following is a description of editing keys that can help enter and manipulate data in the program:

[ESC]	Pressing the escape key in any input field in the program will allow the user to save data entered and exit the program returning to the DOS operating system. See page 13 for instructions on saving data.
[DEL]	Pressing the delete key will clear all of the data from the data field in which the cursor is located .
[<---]	Pressing the backspace key will delete on character to the left of the shaded area.
[Tab]	Pressing the tab key will move the cursor from current data field to the next.
Shift [Tab]	Pressing the shift key along with the tab key will move the cursor from the current data field to the previous data field.
[PgDn]	Pressing the page down key will move the cursor to the next data entry screen in the program.
[PgUp]	Pressing the page up key will move the cursor to the previous data entry screen in the program.
[->]	Pressing the right cursor key will move the cursor to the next data field to the right.
[<-]	Pressing the left cursor key will move the cursor to the next data field to the left.
[UP]	Pressing the up cursor key will move the cursor to the next data field above the current data field.
[DOWN]	Pressing the down cursor key will move the cursor to the next data field below the current data field location.
[Enter]	Pressing the enter key or carriage return key (<CR>) will move to the next data field.
[Ctrl] [L]	Pressing the [Ctrl] and [L] keys together where indicated will provide a list of items from which to select.
[F1]	Pressing the [F1] function key will allow the user to load a previously saved data file. See page 13 for instructions on how to load a data file.
[F2]	Pressing the [F2] function key will allow the user to save entered data to a data file. See page 13 for instructions on how to save data to a file.
[F3]	Pressing the [F3] function key will allow the user to save data to a default data file that is used each time the program is run. See pages 13-15 for instructions on how to enter and save default data.
[F4]	Pressing the [F4] function key in the solids storage facility or liquid storage facility input screen allows the user to print the graphic display to a dot matrix printer. The user must have loaded the graphics print routine by typing **GRAPHICS** before running the program and selecting this option. If you are running the program through SIMULTASK on a UNIX operating system, this option may not give the desired results. This option is not available if you have specified a laser printer for the printer type in the default settings.

D. User Instructions Continued
The following provides a description of each data entry screen in the program:

SCREEN 1, PROGRAM DEVELOPMENT INFORMATION
The program will display information about the version of the program and a telephone number for help. No data entry is required on SCREEN 1. Press any key to proceed to SCREEN 2. The program will indicate that it is loading data from the default data file. The program will automatically proceed to SCREEN 2 once all of the necessary data is loaded. If the required data files are missing the program will not run.

SCREEN 2, ANIMAL WASTE MANAGEMENT PLANNING WORKSHEET
OPERATOR/LANDOWNER
Enter the name of the operator or landowner. As a default the file will be saved under this input. This data field will accept 1-40 characters. If manure for different animal groups is handled differently in storage or utilization you should make a separate idawm computer evaluation for the different groups. Example – milking cows manure stored and land applied, heifers and calves manure stored in corral in manure pack for several years; evaluate with separate analysis. Multiple computer runs can be used to evaluate alternatives for handling and/or utilizing the manure. Options for runs i.e. John Smith storage milkers, John Smith all animals.
LOCATION
Enter the location of the confined animal feeding operation (CAFO). This data field will accept 1-40 characters.
ASSISTED BY
Enter the name of the person providing assistance to the landowner. This data field will accept 1-40 characters.
CLIMATIC STATION
Enter the climatic station that best represents the location of the CAFO operation. Pressing [Ctrl] [L] will display an alphabetical list of 79 climatic stations to choose from (2 pages). Use the up and down cursor keys to choose the climatic station you want and press [Enter]. A correct entry in this data field is required to move to the next data entry screen. This data field will accept 1-20 characters. Other climatic station can be added by editing the file rf.awm with any text editor. The format is given at the top of the file. Data must be entered in this format. The 1 in 5 monthly precipitation is used for determining runoff from corrals/barns during the December through March period and the average monthly precipitation for the April through November period.
TYPE OF OPERATION
Enter the type of CAFO. Pressing [Ctrl] [L] will display a list of CAFO's to choose from. Use the up and down cursor keys to select the type of CAFO desired and press [Enter]. A correct entry is required in this data field to move to the next data field. This data field will accept 1-9 characters.
DATE
If the date displayed is not correct it may be edited to enter the correct month, day, and year. This data field will accept 1-2 characters.
DESCRIPTION
The animal descriptions displayed may be edited to reflect a more accurate description of the breed and other characteristics of the animals. Care must be taken to maintain similar descriptions or the related volume and nutrient production factors will not be correct. Press [Ctrl] [C] to copy the line of the current data field to the next line. Press [Ctrl] [D] to delete a line that has been copied. The default data lines may not be deleted. These data fields will accept 1-24 characters.
NUMBER
Enter the number of animals associated with each animal description. An entry into at least one of the data fields is required in order to move to the next data entry screen of the program. These data fields will accept 1-6 characters.
WEIGHT LBS
Enter the average weight of each animal described. An entry into at least one of the data fields is required in order to move to the next data entry page of the program. These data fields will accept 1-4 characters.
CONFINEMENT-START
Select the first month of confinement by pressing the [Shift] and the [<] or [>] keys together. If the animals are not confined, use the [Shift] and the [<] keys to select NONE. This data field will not allow data to be entered directly. . To copy the entry to the data field directly below, press [Ctrl] [C].
CONFINEMENT-END
Select the last month of confinement by pressing the [Shift] and the [<] or [>] keys. If the animals are not confined, use the [Shift] and the [<] keys to select none. This data field will not allow data to be entered directly. To copy the entry to the data field directly below, press [Ctrl] [C].

CONFINEMENT-DAYS
This is an automatic calculation by the program. For a JAN starting month and a DEC ending month of a confinement period of 365 days is used. If NONE is entered for both the starting and ending confinement period, 0 days are used for the confinement. Partial month confinement can be reflected by entering two lines for the animal group and adjusting the number of animals per line to reflect partial month conditions. As an example a Oct 15 to April 30 confinement period can be reflected by showing one-half of the animals being confined Oct-Apr and one-half confined Nov-Apr.
DAYS GRAZED
This is an automatic program calculation = 365 days – confinement days.
DAYS LIQUID STORAGE
Enter the planned liquid storage period in days not to exceed 365. To copy the current entry to the data field directly below, press [Ctrl] [C]. This data field will accept 1-3 characters.
DAYS SOLID STORAGE
Enter the planned solid storage period in days not to exceed 365. If all of the waste is handled as a liquid, enter 0. To copy the current entry to the data field directly below, press [Ctrl] [C]. This data field will accept 1-3 characters.

<u>SCREEN 3, DAILY BEDDING FACTOR</u>
This table shows typical daily bedding factors (first value) and calculates daily volume of bedding for the confined animal units (second value). When actual bedding use is known equate use to a daily animal unit rate. Bedding increases the size of the storage required for holding solid waste.
TYPE
Enter the type of bedding material used (informational description only). This description is printed on the output. This data field will accept 1-30 characters.
SELECTED FACTOR
Enter the appropriate bedding factor using the displayed list as a guide or enter an appropriate bedding factor for the type and volume of bedding used. Leave blank if a separator factor is to be entered which accounts for all solids and bedding separated. If bedding is planned to be used that will not be processed over the separator, enter the appropriate value. This data field will accept 1-5 characters.
SOLID SEPARATION FACTORS
SELECTED SEPARATOR FACTOR OR PERCENT OF TOTAL MANURE TREATED AS A SOLID
One of the first three lines is applicable if a separator structure is used. Enter the appropriate separator factor using the displayed list as a guide **<u>or</u>** manufacture ratings for separator type. Where manure is handle by scraping of waste to a stockpiled or allowed to accumulate in a corral move to the next data field and enter the total percentage of manure treated or handled as a solid. These data fields will accept 1-5 or 3 characters respectively. **The program will not allow entries into both data fields.** Refer to IWMG, Table 2 for general information on where manure is deposited.
Does Feed Seepage Enter Liquid Storage Facility (Y/N)-? YES If feed seepage enters the liquid storage facility, enter Y for yes. If feed seepage does not enter the liquid storage facility, enter "N" for no. Feed seepage is estimated by assuming 30 cubic feet of seepage per 1000-pound animal unit per year. This data field will accept 1-3 characters.

<u>SCREEN 3A, SOLID OPTIONS</u>
If the type of operation is a dairy, then another screen is shown to allow the user to designate how the manure is handled individually for milkers, dry cows, heifers and calves.

<u>SCREEN 4, VOLUME WASH WATER</u>
Note: If the type of operation is not a dairy, not all of the data entry fields described below will be displayed. For operations other than dairies simply refer to the data fields below displayed on the data entry screen. Refer to the IDWMG or the AWMFH for more information on volumes of wash water.
Cow Preparation Manual
If manual wash cow preparation is used, enter the daily wash volume per cow in gallons or cubic feet per day. These data fields will accept 1-6 characters.

Automatic Stall Wash
If automatic stall wash cow preparation is done, enter the daily wash volume per cow in gallons or cubic feet per day. These data fields will accept 1-6 characters.

Sprinkler
If automatic sprinkler wash cow preparation is done, enter the daily wash volume per cow in gallons or cubic feet per day. These data field will accept 1-6 characters.
Total Daily Volume= (number) **Cows X Total Selected Amount=**
The default number of cows for the daily volume of wash water is based on the animal numbers from screen 3, inventory data. If you wish to change the number of cows the daily volume of wash water is based on, simply press the left cursor key while in the sprinkler wash field and enter the desired number. Editing this field will not affect the numbers shown on data entry screen 3, inventory data. This data field will accept 1-6 characters. The program computes the total amount of wash water based on the number of cows washed per day and displays the amount.
Bulk Tank-Automatic
If a automatic bulk tank wash is used, enter the gallons or cubic feet used per wash. These data fields will accept 1-6 characters.
Manual
If a manual bulk tank wash is used, enter the gallons or cubic feet used per wash. These data fields will accept 1-6 characters.
Miscellaneous Equipment
Enter the daily amount of wash water used for miscellaneous equipment in gallons or cubic feet per wash. These data fields will accept 1-6 characters.
Pipelines
Enter the daily amount of wash water used for flushing pipelines in gallons or cubic feet per wash. These data fields will accept 1-6 characters.
Milkhouse And Parlor
Enter the daily amount of wash water used for the milkhouse and parlor in gallons or cubic feet per wash. These data fields will accept 1-6 characters.
Holding Area
Enter the daily amount of wash water used for washing the holding area in gallons or cubic feet per wash. These data fields will accept 1-6 characters.
Total Daily Volumes = {number} **Washes X Total Selected Amount** = If the number of washes shown is not correct, simply press the left cursor key while in the holding area data field and enter the correct number of washes used per day. This data field will accept 1-2 characters. The program will compute the total amount of wash water based on the number of washes per day and display the amount. When categories have different numbers of wash cycles per day, adjust the wash water per category to total water per day and change the number of washes to 1 per day.
LOT RUNOFF AREA
Roof
Enter the roof area, in square feet, that drains into the liquid storage facility. This data field will accept 1-7 characters.
Concrete Slab, Scraped Daily (Y/N) ? YES
Enter the unroofed concrete slab area, in square feet, that drains into the liquid storage facility. This data field will accept 1-7 characters. The default response for the unroofed concrete slab area being scrapped daily is yes. If the unroofed concrete slab area is not scraped daily, simply press the left cursor key while in the concrete slab area data field and press 'N" for no. If the concrete slab is scraped daily, the program will assume 100% of the monthly rainfall as runoff from the slab. If the concrete slab is not scraped daily, the program will apply concrete slab runoff factors to compute the runoff from the slab. This data field will accept 1-3 characters. Concrete and roof runoff have been disabled to match values given in IDWMG.
Unsurfaced Lot
Enter the unroofed unsurfaced lot area, in square feet, that drains into the liquid storage facility. This data field will accept 107 characters.
Total
The program will compute the total amount of surface area contributing to the liquid storage facility and display the amount. For the months of December through March the 1 in 5 year precipitation values are used to calculate runoff. Average Precipitation is used for April through November. Refer to pages 65-67 of the IDWMG.

<u>SCREEN 5, RUNOFF OPTIONS</u>
This screen allows the user to select whether to use the maximum or just the winter precipitation for the design storage period. Use the right or left arrow keys to toggle back and forth and make a selection. Winter precipitation is the default value.

SCREEN 6, IDAHO ANIMAL WASTE OPTION PAGE

At this page the user can (1) recycle through inventory input (2) proceed to storage facility sizing screens (3) proceed to the nutrient evaluation screens. Arrow down to desired option and [Enter] or [PgDn].

SCREEN 7, SOLIDS STORAGE AREA

Width, W= FT

Enter the width of the solid storage facility desired in feet. **For in corral storage, W=0**. This data field will accept 1-3 characters.

Height, H= FT

Enter the total height of the solid storage stack in feet. **For in corral storage, H=0**. This data field will accept 1-4 characters.

Wall Height, h= FT

Enter the wall height of the solid storage facility desired in feet. This data field will accept 1-4 characters.

Stack Slope, z= 2;1

The default stack slope ratio is 2. If a different stack slope ratio is desired, delete the default value and enter the desired stack slope ratio. This data field will accept 1-3 characters.

Covered, (Y/N) ? NO

The default response to the question of whether the tank is covered or not is NO. If the solids storage facility is covered, enter “Y” for yes. If the response is NO, the program will add the surface area of the solids storage facility to the lot runoff area when computing the total runoff entering the liquid storage facility. This data field will accept 1-3 characters.

Note: Press [Ctrl] [X] keys at the same time to compute the length of the solids storage facility “L” in feet and required storage capacity in cubic feet. The program will add 1 gallon per day of seepage per 100-pound animal unit from the solids storage facility to the total seepage entering the liquid storage facility. Refer to page 35 of the IDWMG for more information on seepage from solid storage facilities.

SCREEN 8, SELECT LIQUID STORAGE FACILITY

1- ANAEROBIC LAGOON
2- WASTE HOLDING POND
3- TWO CELL WASTE HOLDING POND
4- CIRCULAR HOLDING TANK
5- EVAPORATION POND

Press the number associated with the type of liquid storage facility desired. If there is not enough annual evaporation to size an evaporation pond, the program will display NOT ENOUGH EVAPORATION TO DESIGN POND and return to this data input screen.

CHOICE->

OK-? (Y/N)

If you have previously made a liquid storage facility selection, the program will show the choice you have made. If you wish to select another type of liquid storage facility, press “N” and then the number of the storage facility desired. If the highlighted type of liquid storage facility is okay, press “Y”, [PgUp] or [PgDn] to continue.

SCREEN 9A, ANAEROBIC LAGOON or WASTE HOLDING POND or EVAPORATION POND

SCREENS 9B and 9C, TWO CELL WASTE HOLDING POND

Side Slope, Z=3:1

The default side slope ratio is 3. If a different side slope ratio is desired, delete the default value and enter the side slope ratio desired. This data field will accept 1-3 characters.

Bottom Width, BW = ft

Enter the bottom width planned or estimated for the holding pond. This data field will accept 1-3 characters.

Bottom Length = ft

Enter the bottom length planned or estimated for the holding pond. This data field will accept 1-4 characters.

Sludge Duration = 10 Yrs

The default duration for sludge accumulation is 10 years. If a different duration is desired, delete the default value and enter the desired duration for sludge accumulation in years. Sludge accumulation is based on a percentage of total solids produced annually per 1000-pound animal unit. This data field will accept 1-2 characters.

Existing Storage = O AF

The default value for the amount of existing storage available is 0 acre-feet. If there is existing storage available, delete the default value and enter the amount in acre feet of existing storage. This data field will accept 1-5 characters.

Surface Area = O SF
The default value for the surface area of the existing storage is 0 square feet. If there is an existing storage facility that is not covered, delete the default value and enter the surface area in square feet of the existing storage facility. This data field will accept 1-7 characters.
Note: Press the [Ctrl] [X] keys to compute the capacity in acre feet, depth of pond needed, "d" in feet, the top width "TW" in feet, and the top length in feet.

SCREEN 9D, CIRCULAR HOLDING TANK
Diameter, DIA= FT
Enter the desired inside diameter of the circular holding tank in feet. This data field will accept 1-4 characters.
Tank Covered (Y/N) ? YES
The default value for the tank being covered is yes. If the tank is not covered, enter "N" for no. If the tank is not covered, the amount of rainfall storage needed in inches and feet will be displayed. This data field will accept 3 characters.
Existing Storage = O CF
The default value for the amount of existing storage available is 0 cubic feet. If existing storage exists, enter the amount in cubic feet. This data field will accept 1-7 characters.
Surface Area = O SF
The default value for the surface area of the existing storage is 0 square feet. If there is an existing storage facility that is not covered, delete the default value and enter the surface area in square feet of the existing storage facility. This data field will accept 1-7 characters.
NOTE: press the [Ctrl] [X] keys to compute the depth of the circular holding tank "d" in feet and the volume of the tank in cubic feet. If the tank depth is greater than 20 feet, the program will indicate that the tank depth computed is unrealistic.

SCREEN 10, IDAHO ANIMAL WASTE OPTION PAGE
This is a repeat of SCREEN 7. At this page the user can (1) recycle through inventory input (2) proceed to storage facility sizing screens (3) proceed to the nutrient evaluation screens. Arrow down to desired option and [Enter] or [PgDn].

SCREEN 11, NUTRIENT LOSSES DURING STORAGE FOR XXXXX
SELECTED VALUES
***LIQUIDS>>>**
SOLIDS>>>
GRAZING>>>
Use the up and down cursor keys to select the storage method category for the type of waste indicated by the asterisk (*LIQUIDS>>>). Pressing the key that represents the first letter of the type of waste stored displays the storage loss category for that type of waste (e.g. [L] for liquids, [S] for solids). There are no storage losses for grazing. Pressing the [Enter] key while selecting a storage method category will allow the user to edit the percent retained values for nitrogen, phosphorous and potassium. These data fields will allow up to 3 characters. The program will not allow the data fields for grazing to be edited. To return to the loss category selection process, use the up cursor key.

SCREEN 12, NUTRIENT LOSSES DURING APPLICATION
SELECTED VALUES;
***LIQUIDS>>>**
SOLIDS>>>
GRAZING>>>

Use the up and down cursor keys to select the application category for the application method for the type of waste indicated by an asterisk (*LIQUIDS>>>). Pressing the key that represents the first letter of the type of waste stored displays the storage loss category for that type of waste (e.g. [L] for liquids, [S] for solids). The application category for grazing cannot be edited. Pressing the [Enter] key while selecting a application method category will allow you to edit the percent retained values for nitrogen, phosphorous and potassium. These data fields will allow up to 3 characters. To return to the loss category selection process, use the up cursor key.

SCREEN 13, DENITRIFICATION LOSSES FOR XXXXX
SELECTED VALUES;
***LIQUIDS>>>**

SOLIDS>>>
GRAZING>>>
In the Soil Drainage Class**,** section use the up and down cursor keys to select the soil drainage class for the type of waste indicated by a asterisk (*LIQUIDS>>>). Pressing the key that represents the first letter of the type of waste stored displays the storage loss category for that type of waste (e.g. [L] for liquids, [S] for solids, [G] for grazing). Pressing the [Enter] key while selecting a soil drainage class will allow you to edit the percent retained values for nitrogen. These data fields will allow up to 3 characters. To return to the drainage class selection process, use the up cursor key.

SCREEN 14, CROP INVENTORY AND TARGET YIELDS FOR XXXXX

Crop
If the crops grown are not displayed, press the [Ctrl] [L] keys to display the crop selection list. The hay/pasture crops include options for evaluating the nutrients based upon stage of growth at harvest. Use the up and down cursor keys to move through the list to find the crops desired. The [PgDn] and [PgUp] keys can be used to go from page to page of the crop list. A crop can be selected by pressing the [Enter] key. A selected crop is indicated by it being highlighted and can be unselected by pressing the [Ctrl] [D] keys. The last page of the crop selection list allows you to enter additional crops that are not listed in the *Idawm*. Be careful to enter nutrient uptake values in their elemental form for any additional crops added. Refer to NRCS Agricultural Waste Management Field Handbook, Chapter Six for information on the crops listed. To return to the data input screen once all of the desired crop shave been selected, press the [Ctrl] [X] key. For some crops several values are shown. Use the values which represent the planned harvest time in relation to stage of growth/maturity of crop. Only include grain straw as a crop when the straw is exported from the farm (not reused in the corrals and recycled back to the fields). The crops applicable to the utilization of the nutrients from the liquids, solids and grazing are entered separately for each of these categories.

Target Yield
Move to the data field adjacent to the crop desired and enter the yield in the units for the crop selected. This data field will accept 1-5 characters.

Years In Rotation
The program defaults to a rotation of 1 year for each crop listed. Edit year of respective crops to reflect the actual crop rotation. The nutrient utilization is based upon the crop, yield and years in the rotation.

SCREEN 15, CONTROLLING NUTRIENTS AND ECONOMICS

Nutrient-
Use the left and right arrow keys to select the nutrient on which the nutrient balance will be computed and press enter. Phosphorous is the default nutrient for the nutrient budget. The nutrient selected is used to compute application management data and acres needed for the crops previously selected for nutrient utilization. For information on nutrient uptake data, refer the NRCS Agricultural Waste Management Field Handbook, Chapter Six.

Value in Dollars-
If the default dollar values for nitrogen, phosphorous and/or potassium are incorrect, use the left and right arrow keys to move to the proper input field and enter the correct dollar value. The data field will accept 1-5 characters.

Fertilizer Application Cost-
If the default value for fertilizer application cost is incorrect, enter the correct dollar value. This data filed will accept 1-5 characters.

Manure Application Cost-
If the default value for manure application cost is incorrect, enter the correct dollar value. This data field will accept 1-5 characters.

System Life-
If the default value for the overall waste management system life is incorrect, enter the correct value for the expected life of the waste management system. This data field will accept 1-5 characters.

Annual Percentage Rate-
If the default value for the annual percentage rate at which money can be borrowed is incorrect, enter the correct annual percentage rate. This data field will accept 1-5 characters.

SCREEN 16, ACRES NEEDED FOR UTILIZATION BASED UPON XXXXX

The program calculates the required acres for the crop rotation specified to utilize the nutrients in the liquid and solid wastes and waste deposited from grazing animals. This computation is based on the utilization of the nutrient indicated. The default analysis proportions the nutrients by the number of years that each crop is in the rotation. **The manure distribution can be altered or adjusted for numerous management/cropping alternatives.**

The break even cost value for dollars invested into a waste management system and nutrient balance will be computed and displayed. The break even cost value is based on nutrient dollar values as they relate to commercial fertilizer costs needed to produce the target yields for the crop grown and take into account differences in application costs for commercial fertilizer and manure.

A nutrient balance will be computed for the nutrient selected and the total acres needed, nutrients utilized, nutrients in excess or still needed will be displayed along with cost data. Negative values indicate excess nutrients are available and positive values indicate additional nutrients may be needed to meet target yields.

SCREEN 17, WHICH TYPE OF IRRIGATION SYSTEM DO YOU USE
Use the arrow key to select the appropriate type of sprinkler, center pivot, Big Gun, wheel line, hand line. This screen appears when sprinkler application of liquid waste is selected in SCREEN 12, if broadcast application is selected SCREEN 19B will appear.

SCREEN 18A, XXXXXX
Enter requested data for the type of sprinkler system being used and/or planned.

SCREEN 19A, MANAGEMENT CRITERIA FOR SPRINKLING APPLICATION OF LIQUIDS
XXXXX Concentration in Storage = XXX PPM or X.XX LBS/ 1000 GAL
The program will compute and display the nutrient concentration in parts per million and pounds per thousand gallons in storage for the nutrient specified for uptake calculations. If the nutrient concentration in storage is known in either parts per million or pounds per 1000 gallons, move to the appropriate data field, delete the displayed value and enter the known value. These data fields will accept 1-5 characters.
Application
(LBS)
XXX
The maximum pounds to be applied of the nutrient specified for uptake calculations will be displayed along with other application data. If the pounds applied per application is incorrect, delete the amount displayed and enter the correct amount in pounds. This data field will accept 1-4 characters.

SCREEN 19B, MANAGEMENT CRITERIA FOR Broadcast APPLICATION OF LIQUIDS
Tank Wagon Capacity = 4000 Gallons
The default value for the tank wagon capacity is 4000 gallons. If the default value is incorrect for the equipment used, delete the default value and enter the correct capacity in gallons. This data field will accept 1-5 characters.
Spread Width = 15 Feet

The default value for the spread width of a tank wagon is 15 feet. If the default value is incorrect for the equipment being used delete the default value and enter the correct spread width in feet. This data field will accept 1-3 characters.

XXXXX Concentration in Storage = XXX PPM or X.XX LBS/1000 Gal
The program will compute and display the nutrient concentration in parts per million and pounds per thousand gallons in storage for the nutrient specified for uptake calculations. If the nutrient concentration in storage is known in either parts per million or pounds per 1000 gallons, move to the appropriate data field, delete the displayed value and enter the known value. These data fields will accept 1-5 characters.
Application
(LBS)
XXX
The maximum pounds to be applied of the nutrient specified for uptake calculations will be displayed along with other application data. If the pounds applied per application is incorrect, delete the amount displayed and enter the correct amount in pounds. This data field will accept 1-4 characters.

SCREEN 20, MANAGEMENT CRITERIA FOR XXXXXXXX APPLICATION OF SOLIDS
Management data will be presented for the application method chosen for solids.
For Tractor Spreader Application of Solids

Tractor Spreader Capacity = 160 Bushels or 199 Cubic Feet
The default value for the tractor spreader capacity is 160 bushels or 200 cubic feet. If the default values are incorrect for the equipment used, move to the appropriate data field, delete the default value and enter the correct capacity in bushels or cubic feet. These data fields will accept 1-4 characters.
Spread Width = 15 Feet
The default value for the spread width of the tractor spreader is 15 feet. If the default value is incorrect for the equipment being used, delete the default value and enter the correct spread width in feet. This data field will accept 1-3 characters.
XXXXX Concentration in Storage = XXX PPM or X.XX LBS/1000 Gal
The program will compute and display the nutrient concentration in parts per million and pounds per thousand gallons in storage for the nutrient specified for uptake calculations. If the nutrient concentration for uptake calculations. If the nutrient concentration in storage is known in either parts per million or pounds per 1000 gallons, move to the appropriate data field, delete the displayed value and enter the known value. These data fields will accept 1-5 characters.
Application
(LBS)
XXX
The maximum pounds to be applied of the nutrient specified for uptake calculations will be displayed along with other application data. If the pounds applied per application is incorrect, delete the amount displayed and enter the correct amount in pounds. This data field will accept 1-4 characters.

SCREEN 21, IDAHO ANIMAL WASTE OPTION PAGE
This is a repeat of SCREEN 7. At this page the user can (1) recycle through inventory input (2) proceed to storage facility sizing screens (3) proceed to the nutrient evaluation screens. Arrow down to desired option and [Enter] or [PgDn].

SCREEN 22, PRINT OUT OPTIONS
Press [I] To print only the Inventory
Press [S] To print Inventory plus Sizing
Press [N] To print Inventory plus Nutrient Use
Press[A] To print All

SCREEN 23, Printed Output-
Press [S] To Send Output to Screen
Press [P] to Send Output to Printer
Press [F] to Send Output to a File

To send the output to the screen, press the [S] key. Use the [PgUp] and the [PgDn] keys to move between output screens.

To send the output to an attached printer, press the [P] key. The type of printers the program supports will be display with the default printer highlighted. If you wish to print to a printer other than the default printer highlighted, use the up and down cursor keys to select the printer desired and press the [Enter] key.
To send the output to a file, press the [F] key. Indicate the data path the program will use to store the output file to. The output file will have a .OUT extension and will be formatted as an ASCII file.

[F1] DATA FILE RETRIEVAL-
Note: The program may automatically go to the save input data screen on page 13 if the input data had not been previously saved before selecting to retrieve data.
SCREEN #1, ENTER DISK DRIVE AND PATH TO RETRIEVE DATA FROM:
DATA FILE PATH . . .
The default disk drive and data path where data files are stored is displayed. If the data files are not stored in the default data path, enter the disk drive and data path where data files are to be retrieved from. Press the [Enter] key to retrieve the data files.
SCREEN #2, FILE NAME
Use the [PgDn] and [PgUp] keys to search for the data file to retrieve input data from and use the [Up] and [Down] cursor keys to move between data files. Press the [Enter] key to select the highlighted data file for data retrieval.

The program will indicate that it is loading data and return to input data screen 3.

[F2] SAVE INPUT DATA-
SCREEN#1, ENTER DATA PATH AND FILE NAME TO STORE DATA TO:
DATA FILE PATH . . .
The default data path is displayed. To save the input data to a data path other than the default data path, delete the default data path and enter the disk drive and path desired. Press the [Esc] key to exit this data entry screen without making changes or saving data.
DISK FILENAME . . .
To change the displayed disk filename, press the [,--] key to remove the unwanted characters or the [Del] key to clear the entire data entry field. This data field will accept 8 characters. Press the [Esc] key to exit this data entry screen without making changes or saving data.
LANDOWNER/OPERATOR . . .
To accept the landowner/operator name displayed and save data, press the [PgDn] key. To change the landowner/operator name displayed, press the [Backspace] key to remove unwanted characters or the [Del] key to clear the entire data entry field and enter the landowner/operator name desired. This data field will accept 40 characters. Press [Esc] to exit this data entry screen without making changes or saving data. Press the [PgDn] key to save the input data to a data file.
Saving Data . . .
The program will indicate it is saving the data and return to the input data screen from which the [F2] key was pressed or continue to the operation selected if the input data had not previously been saved.

[F3] DEFAULT DATA ENTRY-
Note: Press the [PgDn] and [PgUp] keys to move between default data entry screens. The program may automatically go to the save input data screen if the input data had not been previously saved before pressing [F3] to save defaults.
SCREEN #1, ENTER AND/OR SELECT DEFAULTS
ASSISTED BY:
Enter the name of the person who will be using the program the most. This data field will accept 1-40 characters.
CLIMATIC STATION:
Enter the climatic station that best represents the location of the CAFO operation to be assisted as shown on page 150 of the IDAWM. Pressing [Ctrl] [L] will display a list of climatic stations to choose from. Use the up and down cursor keys to choose the climatic station you want and press [Enter]. A correct entry in this data field is required to move to the next data entry screen. This data field will accept 1-20 characters.
TYPE OF OPERATION:
Enter the type of CAFO as describe on pages 71 of the IDWMG that best represents the majority of CAFO's to the assisted. Pressing [Ctrl] [L] will display a list of CAFO's to choose from. Use the up and down cursor keys to choose the type of CAFO you want and press [Enter]. A correct entry is required in this data field to move to the next data entry screen. This data field will accept 1-9 characters.
DESCRIPTION
The animal descriptions displayed may be edited to reflect a more accurate description of the breed and other characteristics of the CAFO. Care must be taken to maintain similar descriptions as described on page 71 in the IDWMG or the related volume and nutrient production factors will not be correct. Press [Ctrl] [C] to copy the line of the current data field and insert it directly below the current line. Press [Ctrl] [D] to delete a line that has been copied. The default data lines may not be deleted. These data fields will accept 1-24 characters.
WEIGHT LBS
Enter the average weights desired for the defaults of each animal described. These data fields will accept 1-4 characters.
CONFINEMENT-START
Select the first month of confinement by pressing the [Shirt] and the [<] or [>] keys. If the animals are not confined, select NONE. This field will not allow data to be entered directly.
CONFINEMENT-END
Select the last month of confinement by pressing the [Shift] and the [<] or [>] keys. If the animals are not confined, select NONE. This field will not allow data to be entered directly.
DAYS LIQUID STORAGE
Enter the planned liquid storage period in days not to exceed 365. To copy the current entry to the data field directly below, press [Ctrl] [C]. This data field will accept 1-3 characters.
DAYS SOLID STORAGE

Enter the planned solid storage period in days not to exceed 365. If all of the waste is handled as a liquid, enter 0. To copy the current entry to the data field directly below, press [Ctrl] [C]. This data field will accept 1-3 characters

SCREENS #2, 3, 4,5, SELECT CROPS FOR NUTRIENT DISPOSAL

Use the up and down cursor keys to move through the crop list to find the crops to be used as the defaults. The [PgDn] and {PgUp] keys can be used to go from page to page of the crop list. A crop can be selected by pressing the [Enter] key. A selected crop is indicated by it being highlighted and can be unselected by pressing the [Ctrl] [D] keys together. The last page of the crop selection list allows you to enter additional crops that are not listed in the IDWMG. Be careful to enter nutrient uptake values in their elemental form for any additional crops added. Refer to NRCS Agricultural Waste Management Field Handbook, Chapter Six for information on the Crop Uptake Nutrient.

CROP

Enter the crop names for the crops planned as defaults that are not listed on the previous screens. This data field will accept 1-25 characters.

CONDITION

Enter the condition of the crops planned to be used as defaults. This data field will accept 1-15 characters.

YIELD UNITS

Enter the yield units (ton, bu) for each crop entered as a default. This data field will accept 1-3 characters.

N

Enter the elemental nitrogen uptake value in pounds per yield unit previously entered for each default crop. This data field will accept 1-5 characters.

P

Enter the elemental phosphorous uptake value in pounds per yield unit previously entered for each default crop. Make sure the value entered is in the elemental form as the value entered will be converted to P_2O_5 by the program. This data field will accept 1-5 characters.

K

Enter the elemental potassium uptake value in pounds per yield unit previously entered for each default crop. Make sure the value entered is in the elemental for as the value entered will be converted to K_20 by the program. This data field will accept 1-5 characters.

SCREEN 6, ENTER CROP DATA FOR NUTRIENT DISPOSAL NOT ON LIST

Input items listed above for screens 2-5 for crop, condition, yield units, N, P and K.

SCREEN #7, ENTER DEFAULT NUTRIENT FOR THE NUTRIENT BALANCE AND COST FACTORS

Nutrient

Use the left and right arrow keys to select the nutrient on which the nutrient balance and management data will be computed and press enter. Phosphorous is the typical default nutrient.

Value in Dollars

Use the left and right arrow keys to move to the proper input field and enter the default dollar value to be used for the corresponding nutrient. The data fields will accept 1-5 characters.

Fertilizer Application Cost

Enter the default dollar value to be used for fertilizer application cost. This data field will accept 1-5 characters.

Manure Application Cost

Enter the default dollar value to be used for manure application cost. This data field will accept 1-5 characters.

System Life

Enter the default value to be used for the overall waste management system life. This data field will accept 1-5 characters.

Annual Percentage Rate

Enter the default value to be used for the annual percentage rate at which money can be borrowed. This data field will accept 1-5 characters.

SCREEN #8, CHOOSE PRINTER

Select Printer

Use the up and down cursor keys to move through the list to find the printer that best represents the printer to be used to get printouts from the program. Press the [Enter] key to select the highlighted printer as the default.

Data File Path . . .

Enter the default disk drive and data path where data files are to be saved. Press the [PgDn] key to save the default data as entered.

Saving Data . . .

The program will indicate it is saving the default data and return to the screen where the [F3] key was selected.

E. PROGRAM LIMITS

SCREEN 2 -

A valid climatic station, a valid type of operation and at least one animal number data field must have data in order to proceed to the next data entry screen.

Only a total of 10 different animal descriptions may be entered.

The program uses the either the maximum or winter rainfall period based on the liquid storage days entered to compute storage requirements. The program also computes the seepage storage requirements based on the maximum liquid storage days entered. Per State of Idaho requirements a 1 in 5 year winter precipitation is used instead of the average precipitation for the months of Dec through March.

SCREEN 3 -
If a separator factor is entered, the program assumes that the factor includes manure and bedding separated. If a bedding factor is also included, the program will add the bedding volume to the separated volume for the solids produced during the storage period selected on screen 3.

SCREEN 7
A reduction of approximately 30 percent in total sludge volumes is made when a separator factor is used. For anaerobic lagoons, no consideration for a reduction in total solids is made when a solid separator factor is used. If the tank depth computed exceeds 20 feet a warning statement will be displayed indicating that the depth is not practical.

SCREEN 14
Only 10 crops may be selected for nutrient utilization.

F. Example #1

Animal Waste Management System Inventory Worksheet for Dairies

Name of Landowner/Operator Don Green

Street Address P.O. Box 5000

City Meridian, or Zip Code 00000

Phone Number 208 555-1212

Assisted by Ed Helpful Date Sometime very soon

General Description of Operation

Current Mr. Green is currently milking 200 Holstein cows and has 40 dry cows, 40 heifers and 50 calves. Concrete slabs are scraped daily. He has 400 acres available for waste application which is in corn for silage and irrigated grass legume pasture and hayland. Alfalfa hay typically cut early bloom.

Planned Mr. Green would like to expand his herd size to 300 Holstein milking cows and improve on his waste management system. He would like a waste holding pond for storing liquid wastes and a solid stack area for solids.

Problems Roofs are not guttered, roofs and open lot areas contribute runoff to liquid storage facility.

Livestock Data Current-

Description	Number	Average Weight Pounds	Days Confined	Days Grazed	Days Storage Liquids	Days Storage Solids
Milkers	200	1400	365	0	10	10
Dry	40	1200	365	0	10	10
Heifers	40	850	212	153	10	10
Calves	50	250	365	0	10	10

Livestock Data Planned-

Description	Number	Average Weight Pounds	Days Confined	Days Grazed	Days Storage Liquids	Days Storage Solids
Milkers	300	1400	365	0	180	120
Dry	40	1200	365	0	180	120
Heifers	50	850	212	153	180	120
Calves	60	250	365	0	180	120

Storage Component Volumes

Cow Prep (Auto Single Cow: 5-15 gal/milker/day)
(Auto Multiple Cow: 25-40 gal/milker/day)
(Manual: 3-7 gal/milker/day) Manual - 4

Bulk Tank (Manual: 30-50 gal/wash)
(Auto: 60-110 gal/wash) Manual - 50 No. Washes 2
Pipeline (75-150 gal/wash) 150 No. Washes 2
Miscellaneous (25-35 gal/wash 30 No. Washes 2
Milkhouse (300-700 gal/wash) 300 No. Washes 2
Holding Area (500-1200 gal/wash) ________________ No. Washes 2
Contributing Drainage Area, Acres
Contributing Roof Runoff Area, Sq. Ft. O, All building will be guttered
Contributing Lot Runoff Area, Sq. Ft Surfaced 2,000 roof, 1000 concrete (scraped daily)
Unsurfaced 15000
Type of Bedding Sawdust
Volume, CY/Day Current-150 CF/day Planned-160 CF/day

From milking and dry cows 95 % of waste to be handled as a solid from heifers and calves 100% of waste handled as a solid.

General Notes

Soils in the utilization area consist of moderately well drained silt loam soils.

Mr. Green uses a traveling “Big Gun” to apply liquids to the fields for utilization. The “Big “Gun operates at 300 GPM with a wetted diameter of 250 feet.

Mr. Green uses a 160 Bushel tractor spreader to spread solids in 15 foot wide strips to field for utilization.

Mr. Green stated he may apply for EQIP.

Assumptions for nutrient evaluations: for liquids a storage pond > than 50% dilution, for solids unroofed storage area, sprinkler application of liquids, spreader application of solids with incorporation within 3 days.

Animal Waste Management

Planning Worksheet

G. Example #2

Animal Waste Management System Inventory Worksheet for Beef

Name of Landowner/Operator Mr. White

Street Address P.O. Box 6000

City Council, Idaho, or Zip Code 83-----

Phone Number 208 555-1212

Assisted by Ed Helpful Date Sometime very soon

General Description of Operation

Current Mr. White has a beef operation in which he feeds approximately 100 – 850 pound ave wt steers. He has 500 acres of alfalfa hay and wheat for disposal of wastes. During summer months animals are grazed or not on property. Alfalfa hay cut when mature.

Planned Mr. White is not planning to expand his herd, but would like to improve on his waste management system. He would like to add some type of waste storage facility to stop storm runoff onto neighbor. Solid wastes will be manure pack in corral. Wants to use a big gun sprinkler for applying liquids. Concrete pad is not scraped on a daily basis. Does not plan on using any wash water.

Problems The existing waste management system does not have any storage. Storm water in winter spring flows into nearby stream.

Livestock Data Current-

Description	Number	Average Weight Pounds	Days Confined	Days Grazed	Days Storage Liquids	Days Storage Solids
Feeders-forage	100	850	243	122	0	0
Feeders					0	0
Cows					0	0
Calves					0	0

Livestock Data Planned-

Average Days

Description	Number	Weight Pounds	Days Confined	Days Grazed	Storage Liquids	Storage Solids
Feeders-forage	100	850	243	122	180	243
Feeders					0	0
Cows					0	0
Calves					0	0

Storage Component Volumes

Holding Area (500-1200 gal/wash) ________________ No. Washes

Contributing Drainage Area, Acres None

Contributing Roof Runoff Area, Sq. Ft. None

Contributing Lot Runoff Area, Sq. Ft Surfaced 1500 SF roofs, 1000 SF concrete slab

Unsurfaced 18000

Type of Bedding Wheat Straw

Volume, CY/Day 142 CF/day Currently and Planned

Utilization Area

Field Number	Crop	Acres	Yield Units/Acre Present	Yield Units/Acre Target	(Good, Fair, Poor) Crop Condition	(Good, Fair, Poor) Management Level
1 & 2	Grass/Legume Past	50	4 ton	4 ton	Good	Good
4 &6	Alfalfa, Hay	60	4 ton	5 ton	Good	Good
3	Wheat	50	75 bu	75 bu	Good	Good

General Notes

Soils in the utilization area consist of moderately well drained silt to silty loam soils. Depth to water table is greater than 4 feet.

No seepage entering liquid storage facility from feed storage area.

Mr. White has a "Big Gun" sprinkler that can be used to apply liquid waste to the utilization area. The "Big Gun" sprinkler has a flow rate of 165 gallons per minute and a wetted diameter of 200 feet. Mr. White also uses a 160 bushel spreader that spreads the solid waste in 20 foot wide strips to the utilization area.

APPENDIX D - WA NRCS ENGINEERING TECHNICAL NOTE #23

TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE
ENGINEERING #23 **SPOKANE, WASHINGTON**
January, 2013

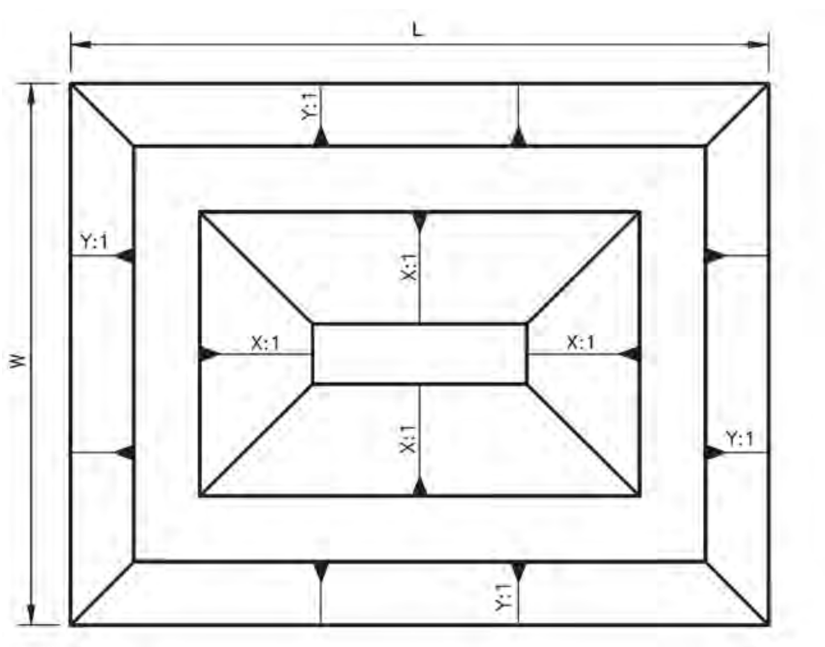
NRCS ASSESSMENT PROCEDURE

FOR

EXISTING WASTE STORAGE PONDS (WSP)

This Technical Note prescribes a consistent review and assessment process for assigning one of four rating categories and subcategories to a waste storage pond (WSP) according to observed factors that may contribute to the risk of contamination of water resources.

The NRCS assessment should not be construed to provide **ANY** regulatory certainty from State regulatory agencies. State of Washington laws and rules prohibit pollution of waters of the state, including ground water. The state requires a permit for discharge of wastewater to waters of the state. This document does not supersede these requirements.



PLAN VIEW

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EXISTING WASTE STORAGE POND (WSP) ASSESSMENT PROCEDURE

INTRODUCTION

NRCS works with Dairy operators across Washington State to provide technical and financial assistance to further their effort in the implementation of practices that serve to protect water resources. Waste storage ponds (WSPs) encountered by NRCS staff, while providing assistance, may have been constructed to an outdated standard or constructed to no standard.

This technical note contains a site inventory and assessment procedure for evaluating existing WSPs. This procedure requires collecting existing WSP site information and conducting an assessment of the WSP and Site, to establish an overall assessment of a WSP according to observed factors that may contribute to the risk of water resources. The assessments in this technical note are qualitative in nature and are not intended to quantify seepage amounts occurring from existing WSP's.

BACKGROUND

Waste storage ponds (WSPs) are used in animal production agriculture for the purpose of containing liquid animal waste until such time that the waste can be utilized as a soil nutrient amendment for crop production. The Washington State Department of Agriculture (WSDA) is assigned the responsibility of statewide inspection and enforcement of Dairy facilities. If WSDA identifies a water quality concern, the operator is directed to NRCS and/or the local Conservation District (CD) for technical assistance. On a voluntary basis, NRCS and/or the CD collaborate with the Dairy operator to address the identified water quality concerns.

A WSP is a common component of a Dairy waste management system. Most often the existing WSP structure condition and performance is unknown. Information is needed in order to develop technically sound comprehensive nutrient management plan alternatives for the dairy operation. This technical note provides a standardized procedure for completing a assessment of, and recommendations for existing WSP's.

PROCEDURE

Through this procedure, NRCS personnel will establish an overall assessment category of a WSP according to observed factors that may contribute to the risk of water resource degradation. NRCS personnel will assign one of four rating categories and corresponding subcategory.

This Technical Note describes a three phase procedure that must be completed in order to assign an overall rating category to an existing WSP. Phase 1 consists of documenting the existing WSP and physical site features and includes a series of forms listed in the table below. Phase 2 documents whether the WSP complies with NRCS practice standard criteria. Phase 3 consists of assessment procedures.

The series of forms have been developed for conducting the assessment of the:

- Existing WSP
- Site
- The combined WSP/Site

Phases 1 and 2 must be completed before conducting Phase 3.

Table 1. Overview of Phase 1, 2 and 3 activities

Phase	Form	Name	Subparts
1	**SSIF**	WSP Site and Structure Inventory Forms	1. General Site Information Form 2. Site Soils Form 3. Site Attributes Form 4. Structure Attributes Form 5. Structure Condition Form 6. Operation and Maintenance Form 7. Structure Modification Form
2	**PSCRF**	Practice Standard Compliance Report Form	None
3	**AF**	Assessment Forms	1. Site Assessment Form 2. Structure Assessment Form 3. Overall Assessment Form

PHASE 1 – WSP SITE AND STRUCTURE INVENTORIES

*WSP Site and Structure Inventory Forms (**SSIF**)*

Purpose: These forms document the current WSP site and structure conditions.

1. General Site Information: This form is used to document the general information regarding the existing WSP (e.g.: landowner, Address, Location, etc.). General weather and field surface conditions are documented as the accuracy of the data collection effort may be hampered depending on these conditions.
2. Site Soils Form: This form is used to inventory and record the natural ground site soil properties and water table conditions.
3. Site Attributes Form: This form is used to collect and document the WSP site information.
4. Structure Attributes Form: This form is used to document the physical characteristics of the existing WSP. Information collected for this step include a measure of the; embankment height, side slopes, top width, pond depth, etc. It may be necessary to utilize survey equipment to gather this information. The review person should document how the data was collected so that the users of the information can determine if further data collection would be needed in the future.
5. Structure Condition Form: This form is used for the "Near Full" or "Near Empty" condition to document waste storage pond observations made during a site visit such as; erosion, liner and embankment condition.
6. Operation and Maintenance Inventory Form: This form is used for the "Near Full" or "Near Empty" condition to document waste storage pond O&M activities and the resulting effectiveness. Document whether or not there are minor or major repair needs.
7. Structure Modification Form: This form is used to document modifications that have been made to the WSP either through visual inspection or conversation with the operator.

PHASE 2 – PRACTICE STANDARD COMPLIANCE

*Practice Standard Compliance Report Form (**PSCRF**)*

Purpose: This form is used to compare the existing WSP or the most recent structure modification against NRCS criteria in place at the time of construction. The current NRCS design criteria for this practice is found in the NRCS Practice Standard 313- Waste Storage Facility. The preceding standard for this practice was the NRCS Practice Standard 425 - Waste Storage Pond. A table listing critical changes to the NRCS Practice Standard design criteria for all of the pertinent revisions is located in Appendix 1.

When completing the form, document whether or not the WSP is performing in accordance with NRCS practice standard in place at the time of construction.

PHASE 3 – ASSESSMENT

*Assessment Forms (**AF**)*

Purpose: These series of forms are used to complete the Site, Structure and Overall assessments.

1. Site Assessment Form: The Site Assessment takes into consideration the existing saturated hydraulic conductivity, presence of wells, distance to the nearest body of water, EPA Region 10 sole source aquifer designations and the WSDA Aquifer Susceptibility Maps. Risk ratings of “Low”, “Medium” or “High” are assigned and are defined as:

   “Low Risk” - Located in an area that is highly unlikely to have water resources affected by the WSP.

   “Medium Risk” - Located in an area that may have water resources that could be affected by the WSP, however the site could be modified to protect water resources.

   “High Risk” - Located in an area where water resources are highly vulnerable to contamination and the site cannot be easily modified to protect water resources.

2. Structure Assessment Form: The Structure Assessment takes into account compliance with the NRCS practice standard in place at the time of construction and the inherent associated risk to the protection of water resources. Risk ratings of “Low”, “Medium” or “High” are assigned and are defined as:

   “Low Risk” - Waste Storage Pond complies with the NRCS practice standard in use at the time when constructed.

   “Medium Risk” - Waste Storage Pond complies with the NRCS practice standard in use at the time when constructed, however there are minor corrective actions necessary in order to restore the WSP to full functionality.

   “**High Risk”** - Waste Storage Pond does not comply with the NRCS practice standard in use at the time when constructed. Major corrective actions are necessary in order to restore the WSP to full functionality.

3. Overall Assessment Form: The Overall Assessment takes into account the Site and Structure assessment. There are four Categories with subcategories that are defined as:

   Category 1A - NRCS recommends utilizing the WSP for the purpose of waste storage.

   Category 1B - NRCS recommends utilizing the WSP for the purpose of waste storage, however the site may benefit from additional practices to reduce discharge potential in the situation of a structure failure.

   Category 2A - NRCS recommends utilizing the WSP for the purpose of waste storage, however the site would benefit from additional practices to reduce discharge potential in the situation of a structure failure.

   Category 2B - NRCS recommends discontinued use of the WSP for the purpose of waste storage until minor repairs and/or improvements have been completed in accordance with the NRCS practice standard in place at the time of construction and the site may benefit from additional practices to reduce discharge potential in the situation of a structure failure.

   Category 2C - NRCS recommends discontinued use of the WSP for the purpose of waste storage until minor repairs and/or improvements have been completed in accordance with the NRCS practice standard in place at the time of construction.

   Category 3A - NRCS recommends discontinued use of the WSP for the purpose of waste storage until major repairs or possible replacement of the existing WSP meeting the current NRCS Conservation Practice Standard – 313, Waste Storage Facility.

   Category 3B - NRCS recommends discontinued use of the WSP for the purpose of waste storage until major repairs or possible replacement of the existing WSP meeting the current NRCS Conservation Practice Standard – 313, Waste Storage Facility and the site may benefit from additional practices to reduce discharge potential in the situation of a structure failure.

   Category 3C - NRCS recommends discontinued use of the WSP for the purpose of waste storage until minor repairs and/or improvements have been completed for the waste storage pond structure and the site would benefit from additional practices to reduce discharge potential in the situation of a structure failure with structure relocation being considered.

   Category 4 - NRCS recommends discontinued use of the WSP for the purpose of waste storage until major repairs or possible replacement of the existing WSP meeting the current NRCS Conservation Practice Standard – 313, Waste Storage Facility and the site would benefit from additional practices to reduce discharge potential in the situation of a structure failure with structure relocation being considered.

OTHER CONSIDERATIONS/ CRITERIA

An existing WSP that stores more than 10 acre-feet above the ground surface must also be evaluated in accordance with the Washington Department of Ecology (DOE), Dam Safety Office (DSO) regulatory requirements. The DOE Dam Safety Office schedule regular review and inspection of jurisdictional WSP projects focused on configuring the WSP to survive suitable design floods and earthquakes. The DSO does not evaluate the adequacy of jurisdictional WSP's in meeting ground water quality performance requirements.

This Technical Note does not evaluate compliance with WA DOE Dam Safety criteria. If the WSP is a state regulated structure the DSO criteria will need to be met in addition to NRCS criteria.

REFERENCES:

1. "Earthen Manure Storage Seepage: A Study of Five Typical Sites," Prepared by: Principal investigator, Bill MacMillan with Study Summary by, Robert Borg and Peter Llewellyn, Agri-Facts, Practical Information for Alberta's Agriculture Industry, July 2001, Agdex 729-1

2. "Seepage Evaluation of Older Swine Lagoons in North Carolina," By R.L. Huffman, 2004 American Society of Agricultural Engineers, Vol. 47(5): pp 1507-1512.

3. "Measurement of Seepage from Earthen Waste Storage Structures in Iowa", T.D. Glanville, J.L. Baker, S.W. Melvin and M.M. Agua, 1999, Department of Agricultural & Biosystems Engineering, Iowa State University, Ames, Iowa 50011

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5. "Geologic and Ground Water Considerations," Chapter 7, Agricultural Waste Management Field Handbook, National Engineering Handbook (NEH),Part 657.07, Natural Resources Conservation Service, June, 1999.

6. "Agricultural Waste Management System Component Design," Chapter 10, Agricultural Waste Management Field Handbook, Amendment 31, National Engineering Handbook (NEH),Part 657.07, Natural Resources Conservation Service, August 2009.

7. "Design and Construction Guidelines for Impoundments Lined with Clay or Amendment-treated Soil," Appendix 10D, Agricultural Waste Management Field Handbook, Amendment 31, National Engineering Handbook (NEH),Part 657.07, Natural Resources Conservation Service, August 2009.

8. "Ground Water/Surface Water Interactions and Quality of Discharging Ground Water in Streams of the Lower Nooksack River Basin, Whatcom County, Washington", Stephen E. Cox, USGS; William Simonds, USGS; Llyn Doremus, Nooksack Indian Tribe, et. al. Scientific Investigations Report 2005-5255, U.S. Department of the Interior, U.S. Geological Survey.

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11. "Subsurface Investigations for Waste Storage Facilities", 04/22/2009, Michigan NRCS, Animal Waste Management website. http://www.mi.nrcs.usda.gov/technical/engineering/animal_waste.html

12. "An AEM Tool for the Evaluation of Un-Designed Waste Storage Facilities", Agricultural Environmental Management, New York State, Soil & Water Conservation Committee, Department of Agriculture and Markets.

13. "Evaluation of Existing Waste Storage Facilities", William Reck PE, Darren Hickman PE, William Boyd PE, USDA-NRCS National Technical Service Center(s), 2006.

14. "Water Quality Indicator Tools", Water Quality Technical Note 1, Washington State NRCS, July 2000.

15. "Waste Storage Facility, Conservation Practice Standard, Code 313", USDA-NRCS, Washington State.

16. EPA Region 10 Sole Source Aquifer Maps, http://yosemite.epa.gov/r10/water.nsf/Sole+Source+Aquifers/ssamaps

SITE AND STRUCTURE INVENTORY FORMS (SSIF)

INSTRUCTIONS: The Site and Structure Inventory Forms are used to document the existing condition, physical features, evidence of operation / maintenance activities and the physical attributes of the WSP. The information collected through this process is used to complete the assessments for an existing WSP.

GENERAL SITE INFORMATION FORM:

Step 1: Document the landowner/farm name, address and the specific WSP location.

Step 2: Check the appropriate box for the review being completed, “WSP is near FULL or “WSP is near EMPTY”.

Step 3: Complete the climatic condition section. This data is very important as it conveys the limitations present during the inventory process.

SITE SOILS FORM:

The Site Soils Form is used to document the existing WSP Site Soils. If there are different site soil types, it may be necessary to complete multiple reports.

SITE ATTRIBUTES FORM:

Information is either measured in the field, from maps, appendices of this technical note or from other previously completed forms of this technical note.

STRUCTURE ATTRIBUTES FORM:

Information is measured during the site visit or gathered from as-built documents. Provide comments pertinent to the site or structure for consideration during the assessment phase.

STRUCTURE CONDITION FORM:

Responses are either yes, no or N/A. The form was set up to address the Full or Empty condition, some of the questions may not apply depending on which condition is being evaluated.

SITE AND STRUCTURE INVENTORY FORMS (SSIF)

INSTRUCTIONS: (Continued)

OPERATION AND MAINTENANCE INVENTORY FORM:

Read each question and provide the appropriate response. Responses are either yes, no or N/A. The form was set up to address the Full or Empty condition, some of the questions may not apply depending on which condition is being evaluated.

WSP - MODIFICATIONS:

All WSP modifications shall be documented and an impact assessment shall be included.

SIGNATURE BLOCK:

The technically responsible staff person completing the forms shall print and sign their name. The Engineering Job Approval Authority for PS 313, “Design” will be included when completed by NRCS staff.

NRCS (SSIF 3/10)

SITE AND STRUCTURE INVENTORY FORMS (SSIF)

GENERAL SITE INFORMATION FORM

LANDOWNER/FARM NAME: ____

ADDRESS:________________________________ STATE:______ ZIP: ___________

WSP LOCATION: Sec _________ T ____ R ____ **(or)** Lat ___________ Long ___________

NRCS JOB CLASS: _____________

CHECK REVIEW CONDITION BELOW:

☐ WSP is FULL (Typically late winter or early spring)

☐ WSP is near EMPTY (Typically late summer or early fall)

MANURE/ EFFLUENT LEVEL and Other Observations: ___________________________

____

TODAY: Liquid Level BELOW Top of Embankment or Spillway Elevation: ________ FT.

CLIMATIC CONDITIONS	
Weather:	Temperature:
Soil Surface Conditions (circle all that apply): Dry / Moist / Wet / Saturated / Standing Water/ Frozen/ Snow Covered	
Additional Information:	

SITE AND STRUCTURE INVENTORY FORMS (SSIF)

SITE SOILS FORM

INSTRUCTIONS: The Site Soils Report Form is used to document the existing WSP Site Soils. If there are different site soil types within the footprint of the structure or nearby it may be necessary to complete multiple reports.

Step 1: The landowner/farm name, address as well at the specific WSP location shall be documented.

Note: Attaching a soils map with the WSP location for documentation purposes is recommended.

Step 2: The soil type and soil profile propertied are retrieved from the NRCS Web Soil Survey (WSS). Aerial photos may also be used to document the surface water section of the site soils report.

It will be necessary to document the USCS classification for soils below the pond bottom surface. If there are two or more soil permeability rate values below the pond bottom surface, it is recommended to use the greatest permeability rate.

Step 3: Upon conducting a site visit it is recommended to verify any data obtained electronically when at the site. This is completed by digging soil pits or using a hand held soil auger.

SITE SOILS COMMENTS / NOTES

SITE AND STRUCTURE INVENTORY FORMS (SSIF)

Site Soils Report

Dominant Soil Type

Soil Survey Area Name

Map Unit Symbol

Map Unit Name

Soil Profile

Top Depth (in)	Bottom Depth (in)	Unified Soil Classification	K_{sat} low (µm/sec)	K_{sat} high (µm/sec)

Maximum Hydraulic conductivity (K_{sat}) below WSP bottom surface (µm/sec)

Depth to water table (in)

SITE AND STRUCTURE INVENTORY FORMS (SSIF)

WSP - SITE ATTRIBUTES FORM

SITE INVENTORY QUESTIONS	RESPONSE
1. Saturated Hydraulic Conductivity (K_{sat}) of the Existing WSP site soils below the WSP surface **(Refer to SSRF)**	
2. Distance from the nearest edge of WSP to the nearest groundwater water supply wells	
a. Depth to groundwater source if distance is less than 100 feet from the nearest edge of the WSP. **(Refer to DOE well log data sheet or estimate from the landowner)**	
3. Distance from nearest toe of WSP to nearest surface water flow or body	
a. If distance is less than 300 feet is there a natural secondary barrier or containment dike between the WSP and the Surface water of concern?	
4. WSP located within an EPA Region 10 Sole Source Aquifer or Source Area? **(Refer to Appendix 3 for Regional Map. For more detailed maps visit EPA Region 10 website at:** http://yosemite.epa.gov/r10/water.nsf/Sole+Source+Aquifers/ssamaps)	(Circle One) **Yes / No**
5. WSDA Aquifer Susceptibility Rating? **(Refer to Appendix 2 for State Map.)**	(Circle One) **Very Low** **Low** **Medium** **High**

SITE AND STRUCTURE INVENTORY FORMS (SSIF)

WSP - STRUCTURE ATTRIBUTES FORM	
WSP STRUCTURE ATTRIBUTES	**NOTES**
1. WSP - Inside Top – Average Width (ft)	
2. WSP - Inside Top – Average Length (ft)	
3. WSP Storage Capacity (cu ft)	
4. Embankment - Inside SS (X:1)	
5. Embankment - Outside SS (Y:1)	
6. Embankment – Top Width (ft)	
7. Combined Side Slope (Outside SS + Inside SS)	
8. Embankment – Maximum Fill Height (ft)	
9. Maximum Excavation Depth (ft)	
10. Total Pond Depth (ft)	
11. Liner Type and Thickness (in)	
12. Inlet Type and Location	
13. WSP Interior-Outlet Ramp Slope (z:1)	
14. Distance to Nearest Well / Water Depth in well(ft)	
15. Failure Impacts; Farm Building, Homes, Roads, Water Course	
16. Emptying Feature is provided to protect against accidental release. (yes/no) If yes please describe in the note section.	
17. Distance to Nearest Home/Dwelling (ft)	
18. Distance to Nearest Water Course (ft)	
WSP – STRUCTURE COMMENTS / NOTES	

SITE AND STRUCTURE INVENTORY FORMS (SSIF)

WSP - STRUCTURE CONDITION FORM

If any boxes checked **"YES"**; make notes of items for concern, possible extent of damage, identify options to repair, stabilize or address in the **REPORT** section.

SITE INVENTORY QUESTIONS		YES	NO	NA
Liner	Liner type: None / Compacted Clay / Flexible Membrane / Bentonite Amendment **(Circle One)**			
	Evidence of liner slumps, bulges, boils, or whales?			
	If applicable; Are perimeter drain(s) plugged or blocked?			
Embankment – Crest, Exterior Slope and Toe[1]	Evidence of cracks in embankment soils?			
	Damp, soft, or slumping areas?			
	Evidence of seepage on the embankment slope?			
	Evidence of seepage around pipes through berm?			
	Evidence of differential (uneven) settlement?			
	Evidence of seepage at the toe of the embankment?			
	Evidence of sand boils on the slope, along the toe or near the toe?			
WSP – Interior Surface	Interior erosion due to wave action?			
	Interior erosion from rainfall?			

[1] Complete inventory questions appropriate to structure, *if no embankment, as in a pit pond, show NA.*

NOTES:

NRCS

SITE AND STRUCTURE INVENTORY FORMS (SSIF)

WSP - OPERATION AND MAINTENANCE INVENTORY FORM

If any boxes checked **"YES"**; make notes of location and identify O & M task to improve management in **REPORT** section.

SITE INVENTORY QUESTIONS		YES	NO	NA
Embankment – Crest, Exterior Slope and Toe[1]	Damage from burrowing animals?			
	Evidence of overtopping of embankment?			
	Evidence of soil erosion or gully on embankment?			
	Pond transfer pipe/structure is obstructed?			
	Presence of trees or woody vegetation?			
	Waste storage pond access is not fenced and properly marked? If not required for structure then n/a.			
WSP Interior/Liner	Interior erosion in vicinity of waste inlet structure?			
	Interior erosion near agitation equipment access points?			
	General erosion of liner material?			
	Damaged liner material (holes, tears, seams)?			
Waste Transfer	Any pumps or transfer pipes are not functional?			
	Any recycling pumps or transfer pipes are not functional?			
Odor	Downwind odor from WSP is strong or unbearable?			

[1] Complete inventory questions appropriate to structure, *if no embankment, as in a pit pond, show NA.*

NOTES:

STRUCTURE and O&M CONDITION CONCERNS	YES	NO
Was any abnormal condition or practice observed that requires corrective action (If yes then answer 1 and 2 below):		
1. Minor repair or change in practice would bring the WSP into compliance with accepted practice.		
2. Major repair or change in practice would bring the WSP into compliance with accepted practice.		

SITE AND STRUCTURE INVENTORY FORMS (SSIF)

WSP - STRUCTURE MODIFICATION FORM

			Yes	No
HAS THE WSP BEEN STRUCTURALLY MODIFIED? ***(If "Yes" complete 1 through 5 below)***				
1	Was the WSP modification designed by a qualified individual?			
	Date design of modification			
	Designer (If applicable)			
2	Date of modification construction			
3	Description of structural modification:			
	Did the modification meet the NRCS practice standard in place at the time of construction?			
4	Describe impact of the modification on structural integrity:			
5	Describe impact of the modification on storage depth and storage volume:			

WSP Inventory Completed by			
Name:		JAA	
Signature:		Date:	

PRACTICE STANDARD COMPLIANCE REPORT FORM (PSCRF)

INSTRUCTIONS: The Practice Standard Compliance Report Form compares the WSP inventory data to the benchmark condition.

PRACTICE STANDARD COMPLIANCE REPORT FORM:

Step 1: Document the landowner/farm name, address as well at the specific WSP location.

Step 2: Fill in all fields if applicable otherwise place N/A.

Step 3: Complete the physical attributes table for “Current Conditions” by copying forward information from the “WSP Physical Attributes Table”.

Step 4: Complete the NRCS Practice Standard Criteria section referring to Appendix 1, NRCS practice standard criteria for WSP’s. Place the relative NRCS criteria based on the year the WSP was constructed or when the last modification was completed. If the WSP was constructed prior to 1979, then the 1979 criteria shall apply.

SIGNATURE BLOCK:

The technically responsible staff person completing the forms shall print and sign their name. The Engineering Job Approval Authority for PS 313, “Design” will be included when completed by NRCS staff.

NRCS

(PSCRF -2/3)

PRACTICE STANDARD COMPLIANCE REPORT FORM (PSCRF)

LANDOWNER/FARM NAME: ____________________

ADDRESS: ____________________ STATE: ______ ZIP: ________

WSP LOCATION: Sec ________ T _____ R _____ **(or)** Lat ________ Long ________

DATE ORIGINAL WASTE STORAGE POND or MODIFICATION COMPLETED: ________

NRCS Practice Standard 313 Compliance Check

PHYSICAL WSP ATTRIBUTES	CURRENT CONDITIONS	NRCS Practice Standard criteria[1]	Complies NRCS Practice Standard Criteria? (Circle One)
1. Embankment height. (Ref SSIF 7/10 – 8.0)			Yes - No - N/A
2. Failure of WSP would result in damages limited to farm buildings, ag-land, or country roads. (Ref SSIF 7/10 - 15.0)			Yes - No - N/A
3. WSP embankment elevation above 25 yr. floodplain. (Estimated)			Yes - No - N/A
4. Inlet permanent and resists; corrosion, plugging, freeze damage and is UV protected. (Ref SSIF 7/10 - 12.0)			Yes - No - N/A
5. Emptying features are provided and are protected against erosion and accidental release. (Ref SSIF 7/10 - 16.0)			Yes - No - N/A
6. Slurry or solid storage ramp slope. (Ref SSIF 7/10 – 13.0)			Yes - No - N/A
7. Fencing necessary for protection of humans and livestock. (Ref SSIF 9/10)			Yes - No - N/A
8. WSP embankment protected against erosion. (Ref SSIF 8/10 & 9/10)			Yes - No - N/A
9. Separation distance from WSP bottom and SHGWT. (Ref SSIF 5/10)			Yes - No - N/A
10. Liner. (Ref SSIF 8/10 & 9/10)			Yes - No - N/A
11. Liner type (Ref PS 521). (Ref SSIF 8/10)			Yes - No - N/A
12. If no liner, foundation soils permeability. (Ref SSIF 5/10)			Yes - No - N/A

[1] Appendix 1: Refer to the NRCS practice standard design criteria by date of adoption for current and archived NRCS practice standards used for Waste Storage Pond design and construction in WA State.

PRACTICE STANDARD COMPLIANCE REPORT FORM

NRCS Practice Standard 313 Compliance Check (***Continued***)			
PHYSICAL WSP ATTRIBUTES	**CURRENT CONDITIONS**	**NRCS Practice Standard criteria[2]**	**Complies NRCS Practice Standard Criteria?**
13. Embankment inside side slope. (Ref SSIF 7/10 – 4.0)			Yes - No - N/A
14. Embankment outside side slope. (Ref SSIF 7/10 – 5.0)			Yes - No - N/A
15. Combined embankment side slope. (Ref SSIF 7/10 – 7.0)			Yes - No - N/A
16. WSP above ground volumetric storage. (Estimated)			Yes - No - N/A
17. Minimum distance to dwellings. (Ref SSIF 7/10 – 17.0)			Yes - No - N/A
18. Embankment top width. (Ref SSIF 7/10 – 6.0)			Yes - No - N/A
19. Minimum distance to water well. (Ref SSIF 7/10 – 14.0)			Yes - No - N/A
20. Minimum distance to water course. (Ref SSIF 7/10 – 18.0)			Yes - No - N/A

Compliance Check Results	YES	NO
Does the WSP comply with NRCS practice standards at the time of construction or modification?		

WSP Compliance Review Completed by (Print): _______________________ JAA: _____

Signature ____Date:_____________

[2] Appendix 1: Refer to the NRCS practice standard design criteria by date of adoption for current and archived NRCS practice standards used for Waste Storage Pond design and construction in WA State.

NRCS

WSP ASSESSMENT FORMS (AF)

INSTRUCTIONS: The assessment forms provide a standardized procedure for assigning a category that ranks a WSP according to observed factors that may contribute to the risk of degradation to water resources.

SITE ASSESSMENT FORM:

The information that is utilized for the Site Assessment is the completed data located on the Site and Structure Inventory Form.

Step 1: Carefully read each question and check corresponding box.

Step 2: Record the score points in the right hand column for each question.

Step 3: Total the score points and assign the corresponding risk rating.

STRUCTURE ASSESSMENT FORM:

The information that is utilized for the Structure Assessment is the completed data located on the Site and Structure Inventory Form and the Practice Standard Compliance Report Form.

Step 1: Carefully read each question and check corresponding box.

Step 2: Record the score points in the right hand column for each question.

Step 3: Total the score points and assign the corresponding risk rating.

OVERALL ASSESSMENT FORM:

The Overall Assessment Form is completed utilizing the results on the Site and Structure Assessment Forms.

Step 1: On the “Risk Probability Matrix for Water Resource Degradation” plot the “Site Risk” rating and the “Structure Risk” rating.

Step 2: Circle the resulting combined risk factor on the matrix.

Step 3: From the Risk Probability Matrix for Groundwater Degradation check the corresponding box to document recommended actions for the Existing Waste Storage Pond.

SIGNATURE BLOCK:

The technically responsible staff person completing the forms shall print and sign their name. The Engineering Job Approval Authority for PS 313, “Design” will be included when completed by NRCS staff.

WSP ASSESSMENT FORMS

SITE ASSESSMENT FORM				
Consideration	**Categories (Check appropriate box for each consideration and record points in the right hand column)**			**Score**
Saturated Hydraulic Conductivity (K_{sat}) of the soils below the WSP bottom surface	Less than 2 µm/sec	Between 2 and 20 µm/sec	Greater than 20 µm/sec	
	☐ **0 points**	☐ **1 points**	☐ **3 points**	
Shallow (< 145 feet deep) groundwater water supply wells within 100 feet of the nearest edge of the WSP	No	Yes, but it **is** technically feasible to decommission or relocate the shallow groundwater well	Yes, but it **is not** technically feasible to decommission or relocate the shallow groundwater well	
	☐ **0 points**	☐ **1 points**	☐ **3 points**	
Distance from the nearest surface water flow or body to the toe of the WSP	Greater than 300 ft	Less than 300 ft. but technically feasible to construct a secondary barrier or containment dike between the WSP and the surface water of concern.	Less than 300 ft. but not technically feasible to construct a secondary barrier or containment dike between the WSP and the surface water of concern.	
	☐ **0 points**	☐ **1 points**	☐ **3 points**	
Location with respect to an EPA Region 10 Sole Source Aquifer or Source Area **and** Medium to High Aquifer Susceptibility according to the WSDA Aquifer Susceptibility Map	Not located in either	Located in one, but not the other	Located in both.	
	☐ **0 points**	☐ **3 points**	☐ **6 points**	
			Total Score	
			Risk	

Total Score	**Risk Rating**
2 points or less =	**Low Risk**
3 to 5 points =	**Medium Risk**
6 points or more =	**High Risk**

WSP ASSESSMENT FORMS

STRUCTURE ASSESSMENT FORM				
Consideration	**Categories (Check appropriate box for each consideration and record points in the right hand column)**			**Score**
WSP complies with NRCS practice standard criteria (PSCRF 3/3)	Yes		No	
	☐ **0 points**	**N/A**	☐ **6 points**	
Earthen structural condition questions (SSIF 8/10)	All questions answered "NO" or "NA"	One or more of the questions answered "YES"; repairs require **minor** restoration effort[1].	One or more of the questions answered "YES"; repairs require **major** restoration effort[2].	
	☐ **0 points**	☐ **3 points**	☐ **6 points**	
Operation and maintenance questions (SSIF 9/10)	All questions answered "NO" or "NA"	One or more of the questions answered "YES"; repairs require **minor** restoration effort[1].	One or more of the questions answered "YES"; repairs require **major** restoration effort[2].	
	☐ **0 points**	☐ **2 points**	☐ **4 points**	
Structural modifications	Constructed in accordance with NRCS practice standard criteria	Not constructed in accordance with NRCS practice standard criteria in place at the time; repairs require **minor** restoration effort[1].	Not constructed in accordance with NRCS practice standard criteria in place at the time; repairs require **major** restoration effort[2].	
	☐ **0 points**	☐ **3 points**	☐ **6 points**	

Total Score	
Risk Rating	

Total Score	**Risk Rating**
2 points or less =	**Low Risk**
3 to 5 points =	**Medium Risk**
6 points or more =	**High Risk**

1. Minor restoration effort – Restorative activities can be completed without significant disturbance to the WSP.

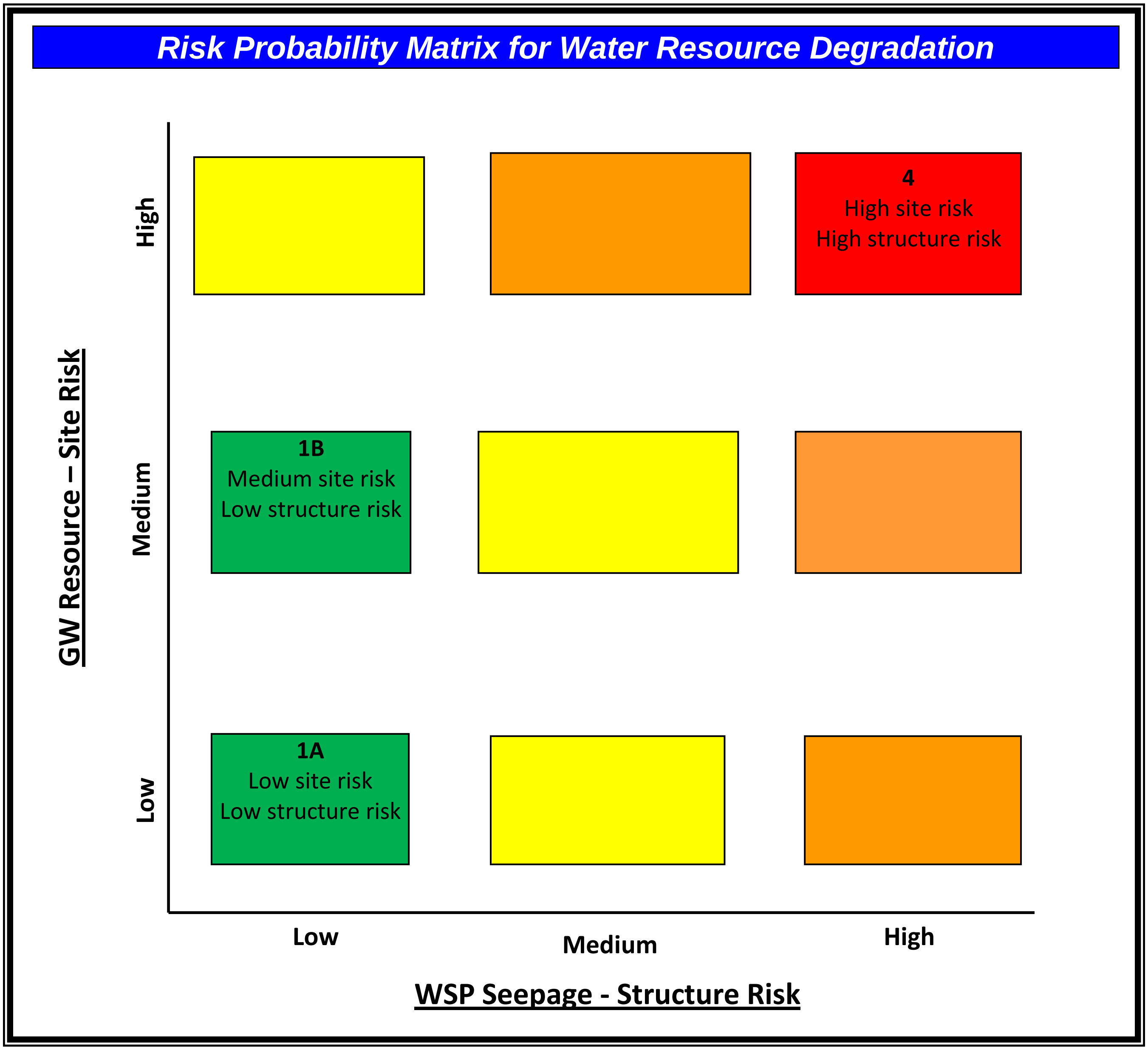
2. Major restoration effort – Restorative activities cannot be completed without significant disturbance to the WSP.

WSP ASSESSMENT FORMS

OVERALL ASSESSMENT FORM

Instructions: On the "Risk Probability Matrix for Water Resource Degradation" plot the following factors and circle the resulting combined risk factor on the matrix.

1. ***Ground Water Resource - Site Risk*** on the Y axis
2. ***WSP Seepage - Structure Risk*** on the X axis



WSP ASSESSMENT FORMS

Instructions: From the Risk Probability Matrix for Water Resource Degradation check the corresponding box to document recommended actions for the existing Waste Storage Pond.

Category 1

	A	B
☐	Low site risk Low structure risk	Medium site risk Low structure risk

Category 1A - NRCS recommends utilizing the WSP for the purposes of waste storage.

Category 1B - NRCS recommends utilizing the WSP for the purposes of waste storage, however the site may benefit from additional practices to reduce discharge potential in the situation of a structure failure.

Category 2

	A	B	C
☐	High site risk Low structure risk	Medium site risk Medium structure	Low site risk Medium structure risk

Category 2A - NRCS recommends utilizing the WSP for the purposes of waste storage, however the site would benefit from additional practices to reduce discharge potential in the situation of a structure failure.

Category 2B - NRCS recommends discontinued use of the WSP for the purposes of waste storage until minor repairs and/or improvements have been completed in accordance with the NRCS practice standard in place at the time of construction and the site may benefit from additional practices to reduce discharge potential in the situation of a structure failure.

Category 2C - NRCS recommends discontinued use of the WSP for the purposes of waste storage until minor repairs and/or improvements have been completed in accordance with the NRCS practice standard in place at the time of construction.

*****CONTINUED NEXT PAGE*****

WSP ASSESSMENT FORMS

CONTINUED FROM PREVIOUS PAGE

Category 3

	A	B	C
☐	Low site risk High structure risk	Medium site risk High structure risk	High site risk Medium structure

Category 3A - NRCS recommends discontinued use of the WSP for the purposes of waste storage until major repairs or possible replacement of the existing WSP meeting the current NRCS Conservation Practice Standard – 313, Waste Storage Facility.

Category 3B - NRCS recommends discontinued use of the WSP for the purposes of waste storage until major repairs or possible replacement of the existing WSP meeting the current NRCS Conservation Practice Standard – 313, Waste Storage Facility and the site may benefit from additional practices to reduce discharge potential in the situation of a structure failure.

Category 3C - NRCS recommends discontinued use of the WSP for the purposes of waste storage until minor repairs and/or improvements have been completed for the waste storage pond structure and the site would benefit from additional practices to reduce discharge potential in the situation of a structure failure with structure relocation being considered.

Category 4

☐	High site risk High structure risk

Category 4 - NRCS recommends discontinued use of the WSP for the purposes of waste storage until major repairs or possible replacement of the existing WSP meeting the current NRCS Conservation Practice Standard – 313, Waste Storage Facility and the site would benefit from additional practices to reduce discharge potential in the situation of a structure failure with structure relocation being considered.

SIGNATURE BLOCK

THE WSP INTEGRITY ASSESSMENT REPORT WAS COMPLETED BY:

Evaluating Personnel: ______________________________ **Date:** ____________

Agency: ____

PS 313 Assigned Job Approval Authority for “WSP Review Assessment”: ____________

Appendix 1

WSP Practice Standard Criteria Reference Documents

Table outline for – NRCS Practice Standard Criteria Revisions and WA State Supplements

Waste Storage Pond, PS-425, Dated: 1979 -1994

Waste Storage Facility, PS-313, Dated 2000 - Current

Washington State NRCS REVISION and Supplement Dates:

- April 1979 -
- February 1987 – State Supplement
- January 1994 – State Supplement
- February 2000
- June 2001
- December 2004

Earth pond construction dimension criteria for all WSP practices and all revisions: April 1979 to December 2004

Practice Standard Code/Name	PS 425 Waste Storage pond			PS 313 Waste Storage Facility		
Release Date	1979, April			2000, February	2001, June	2004, December
Supplement Release Date		1987, February	1994, January			
1. Embankment Height.	35 feet or Less	35 feet or Less	35 feet or Less	35 feet or Less	35 feet or Less	35 feet or Less
2. Failure of WSP would result in damages limited to farm buildings, Ag-Land, or country roads.	N/A	N/A	N/A	Yes	Yes	Yes
3. WSP Embankment Elevation above Floodplain?	25 Yr	25 Yr	25 Yr	25 Yr	25 Yr	25 Yr
4. Inlet permanent and resists; corrosion, plugging, freeze damage and is UV protected?	Yes	Yes	Yes	Yes	Yes	Yes
5. Emptying features are provided and are protected against erosion and accidental release?	Yes	Yes	Yes	Yes	Yes	Yes
6. Liquid Storage Ramp slope.	4:1	4:1	4:1	4:1	4:1	4:1
7. If the WSP creates a safety hazard fencing is necessary for protection of Humans and livestock.	Yes	Yes	Yes	Yes	Yes	Yes
8. WSP Embankment protected against erosion.	Yes	Yes	Yes	Yes	Yes	Yes
9. Separation distance from WSP Bottom and SHGWT.	0 Inches	6 inches	6 inches	24 inches	24 inches	24 inches
10. Liner	Only if Self Sealing is not anticipated	Required for all foundation material, except glacial till, when closer than 300 feet to a domestic well.	Required for all WSP's	Required for all WSP's	Required for all WSP's if wetted surface permeability rate is less than $1x10^{-6}$ cm/s	Required for all WSP's if wetted surface permeability rate is less than $1x10^{-6}$ cm/s

****(CONTINUED)****

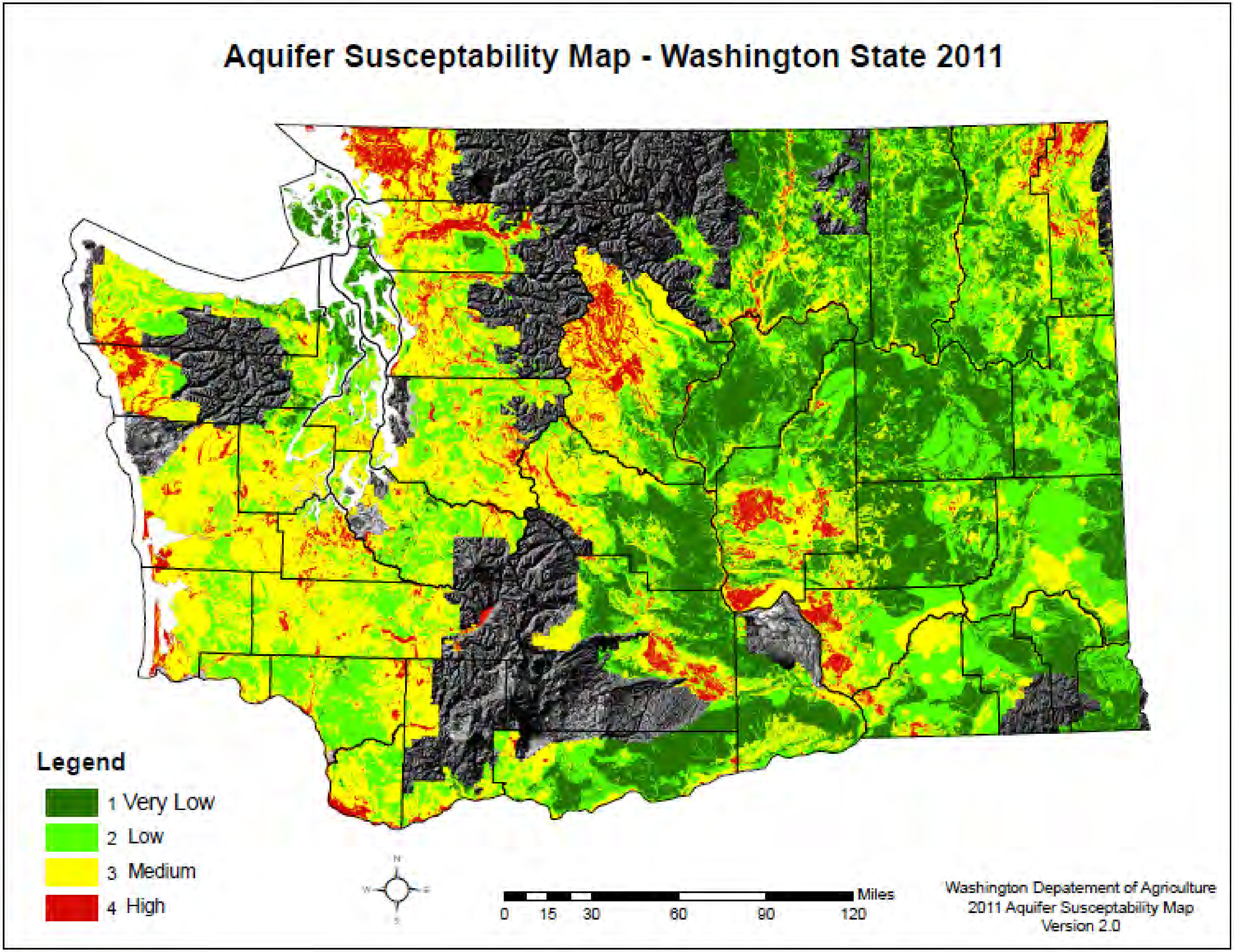
Earth pond construction dimension criteria for all WSP practices and all revisions: April 1979 to December 2004

Practice Standard Code/Name	PS 425 Waste Storage pond			PS 313 Waste Storage Facility		
Release Date	1979, April			2000, February	2001, June	2004, December
Supplement Release Date		1987, February	1994, January			
11. Liner type (Ref PS 521)	If Required	Minimum <u>Requirements</u> GM – 12” thick GC – 9” thick SM – 12” thick SC – 9” thick ML – 12” thick CL – 6” thick CH – 6” thick	12” Minimum thickness & soils requirement GM-w/20% fines GC-w/20% fines SM-w/20% fines SC-w/20% fines (or Amended) ML MH CL CH	12” Minimum thickness & soils requirement GM-w/20% fines GC-w/20% fines SM-w/20% fines SC-w/20% fines (or Amended) ML MH CL CH	12” Minimum thickness & soils requirement of permeability rate is less than $1x10^{-6}$ cm/s	12” Minimum thickness & soils requirement of permeability rate is less than $1x10^{-6}$ cm/s
12. If no liner, foundation soils permeability.	Low to Moderate	Low to Moderate	Must be equivalent to liner requirement	Must be equivalent to liner requirement	Must be equivalent to liner requirement	Must be equivalent to liner requirement
13. Maximum operating level marker	N/A	N/A	N/A	N/A	Yes	Yes
14. Embankment Top Width (minimum)	8 feet	8 feet	8 feet	8 feet	Embankment <u>Height / Width</u> 15’ or Less / 8’ 15’-20’ / 10’ 20’-25’ / 12’ 25’-30’ / 14’ 30’-35’ / 15’	Embankment <u>Height / Width</u> 15’ or Less / 8’ 15’-20’ / 10’ 20’-25’ / 12’ 25’-30’ / 14’ 30’-35’ / 15’
15. Embankment Inside Side Slope	N/A	N/A	N/A	No Steeper Than 2:1	No Steeper Than 2:1	No Steeper Than 2:1
16. Embankment Outside Side Slope	N/A	N/A	N/A	No Steeper Than 2:1	No Steeper Than 2:1	No Steeper Than 2:1
17. Combined Embankment Side Slope (minimum)	5:1	5:1	5:1	5:1	5:1	5:1
18. WSP Above Ground Volumetric Storage[3]	If over 10 ac-ft above ground storage refer to DOE Dam Safety Criteria	If over 10 ac-ft above ground storage refer to DOE Dam Safety Criteria	If over 10 ac-ft above ground storage refer to DOE Dam Safety Criteria	If over 10 ac-ft above ground storage refer to DOE Dam Safety Criteria	If over 10 ac-ft above ground storage refer to DOE Dam Safety Criteria	If over 10 ac-ft above ground storage refer to DOE Dam Safety Criteria
19. Minimum Distance to Dwellings	100 feet	100 feet	100 feet	N/A	N/A	N/A
20. Minimum Distance to water well	N/A	100 ft., 200 ft. for unconfined aquifers	300 feet	300 feet	300 feet	100 feet
21. Minimum distance to water course	N/A	25 feet	25 feet	N/A	N/A	N/A

[3] The storage threshold is the theoretical volume contained in the WSP with the fluid level at the top of the embankment, not at the operating level.

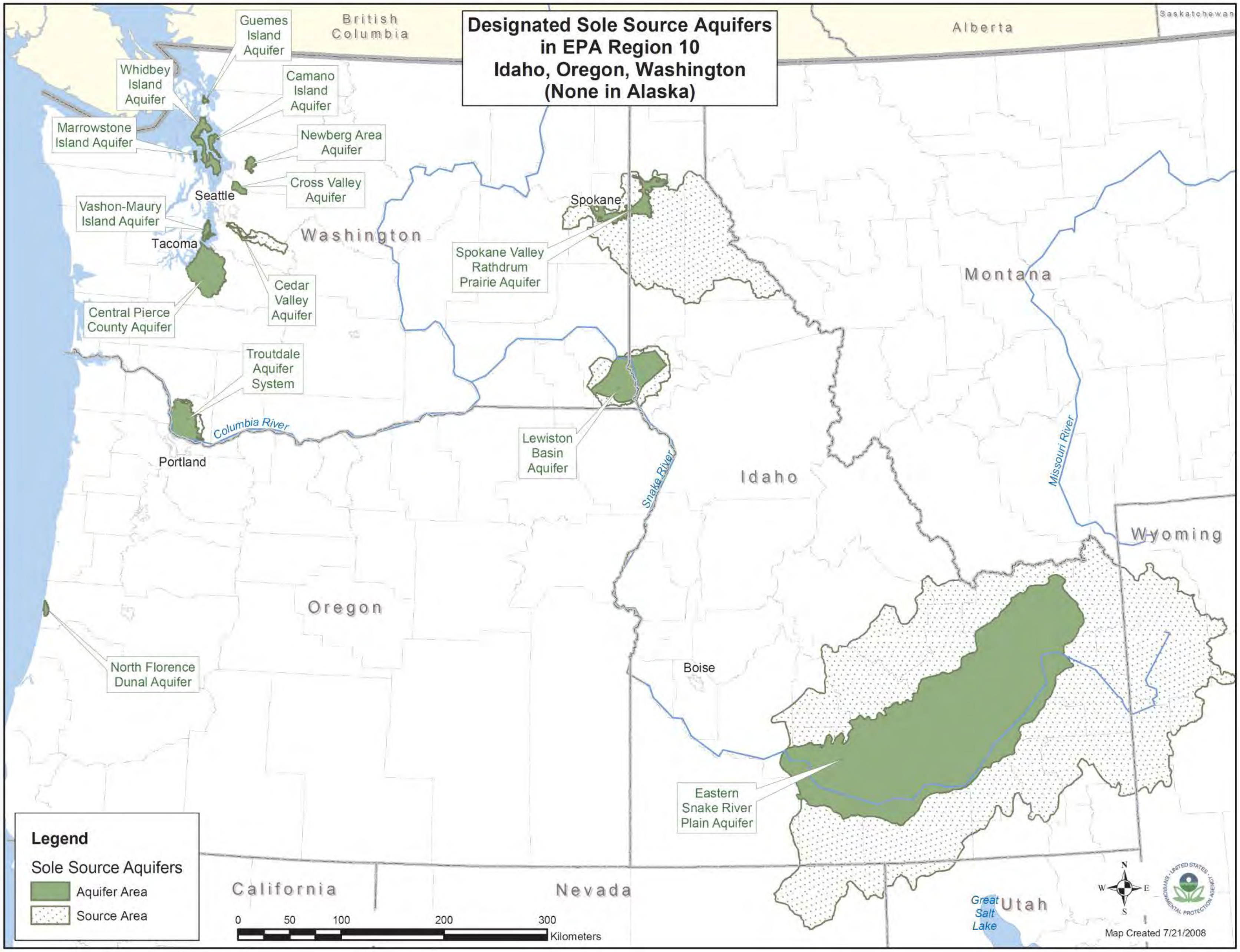
Appendix 2

WSDA Aquifer Susceptibility Map


Aquifer Susceptability Map - Washington State 2011
Legend
1 Very Low
2 Low
3 Medium
4 High
Miles
0 15 30 60 90 120
Washington Depatement of Agriculture
2011 Aquifer Susceptability Map
Version 2.0

Appendix 3

Designated Sole Source Aquifer Map for EPA Region 10



Draft Permit - Does Not Authorize Discharge

Appendix 4

WSP Volume Estimating Spreadsheet

INSTRUCTIONS

A spreadsheet has been developed to calculate the estimated volume of a square or rectangular WSP.

SPREADSHEET INPUTS

The spreadsheet requires six inputs in order to compute the approximate volume of the WSP.

L1 and L2 are Top of Pond dimensions as shown in feet.

W1 and W2 are Top of Pond dimensions as shown in feet.

h = Depth of WSP measured from crest to pond bottom surface in feet.

SS = Internal side slope of WSP.

h_{out} = Depth of WSP above ground measured from crest to lowest outside toe in feet

SPREADSHEET COMPUTATIONS

The spreadsheet computes the volume utilizing the prismoidal formula. All formula variables can be computed from the inputs and the intermediate results are shown in the output window of the spreadsheet.

$$V = h/6\,(A_t + 4M + A_b)$$

Where:

V - Volume of the truncated pyramid
h - WSP Depth (Crest to Bottom)
A_t - Top Surface Area, WSP Crest
M - Cross Section Area, Mid-Depth
A_b - Bottom Surface Area, WSP Base
h_{out} - Depth of pond above ground from lowest outside toe to top of crest
$V_{ab\text{-}gnd}$ - Volume stored above ground
SS - Internal Sideslope of the WSP
L_1 and L_2 are Top of Pond dimensions as shown
W_1 and W_2 are Top of Pond dimensions as shown

SPREADSHEET OUTPUTS

The spreadsheet provides a quick assessment of the estimated WSP volume. Three examples are provided for review.

See Example #1: The user inputs the information that is captured during the SSIF forms. The volume is computed and displayed in the output window. The estimated volume can be used to populate the "WSP Structure Attributes" field for waste storage capacity on SSIF page 7/10.

See Example #2: The user inputs the information that is captured during the SSIF forms. The volume is computed and displayed in the output window. The estimated volume can be used to populate the "WSP Structure Attributes" field for waste storage capacity on SSIF page 7/10.

In addition, a note is displayed when the computed volume is greater than 10 ac-ft. If the above ground storage is greater than 10 ac-ft, the WA State Dam Safety Office has regulatory authority over the facility and the State Dam Safety Standards prevail. NRCS Technical Note 23 does not determine compliance with WA State regulated dams.

See Example #3: The user inputs the information that is captured during the SSIF forms. In this case the volume cannot be computed or displayed in the output window. If the computed length or width of the bottom of the pond is less than zero (0), the results in the intermediate computation field for l or w reports "n.g.". Either a different method will need to be utilized to compute the volume or the depth may be in error. It is recommended to verify that all of the input fields are correct.

<u>Example 1:</u> Determine the estimated WSP volume

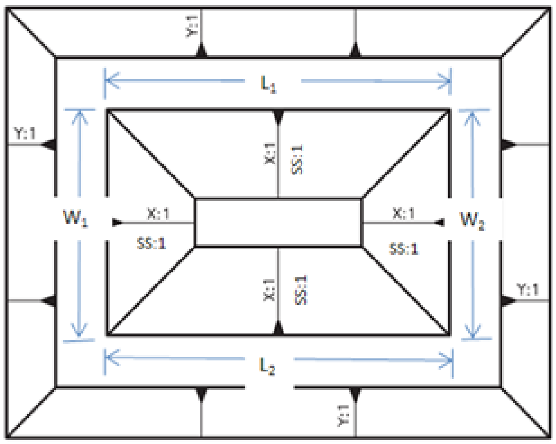
Computation Sheet

WA NRCS-ENG-Computation

U.S. Department of Agriculture
Natural Resources Conservation Service

State	Project			
Washington	Example #1			
By: NRCS	Date: 1/4/2013	Checked By	Date	Job No.
Subject: Estimated WSP Prismoidal Volume				Sheet ______ of ______

Waste Storage Pond



PLAN VIEW

Volume of a Truncated Pyramid Prism with a Rectangular Base

with two parallel polygonal bases joined to one another by straight edges

$$V = h/6\ (A_t + 4M + A_b)$$

<u>Where:</u>

- *V - Volume of the truncated pyramid*
- *h - WSP Depth (Crest to Bottom)*
- *A_t - Top Surface Area, WSP Crest*
- *M - Cross Section Area, Mid-Depth*
- *A_b - Bottom Surface Area, WSP Base*
- *h_{out} - Depth of pond above ground from lowest outside toe to top of crest*
- *$V_{ab\text{-}gnd}$ - Volume stored above ground*
- *SS - Internal Sideslope of the WSP*
- *L_1 and L_2 are Top of Pond dimensions as shown*
- *W_1 and W_2 are Top of Pond dimensions as shown*

Definitions	Inputs		
ft. = Feet	$L_{side\ 1}$ =	210	ft.
s.f. = Square Feet	$L_{side\ 2}$ =	185	ft.
c.f. = Cubic Feet	$W_{side\ 1}$ =	100	ft.
a.f. = Acre-Feet	$W_{side\ 2}$ =	125	ft.
n.g. = Results are No Good	h =	11	ft.
	SS =	2.5	
	h_{out} =	5	

Data Input Field

Outputs					
Intermediate Computations			Estimated WSP Volume		
A_t =	22,219	s.f.	$V = h/6\ (A_t + 4M + A_b)$		
M =	14,450	s.f.	V_{total} =	161,723	c.f.
A_b =	8,194	s.f.	V_{total} =	3.7	a.f.
$M_{ab\text{-}gnd}$ =	18,500	s.f.	and		
$A_{b\ ab\text{-}gnd}$ =	15,094	s.f.	$V_{ab\text{-}gnd}$ =	92,760	c.f.
			$V_{ab\text{-}gnd}$ =	2.1	a.f.

Pond Storage Volume

Above Ground Pond Storage Volume

<u>Example 2:</u> Determine the estimated WSP volume

Computation Sheet
WA NRCS-ENG-Computation

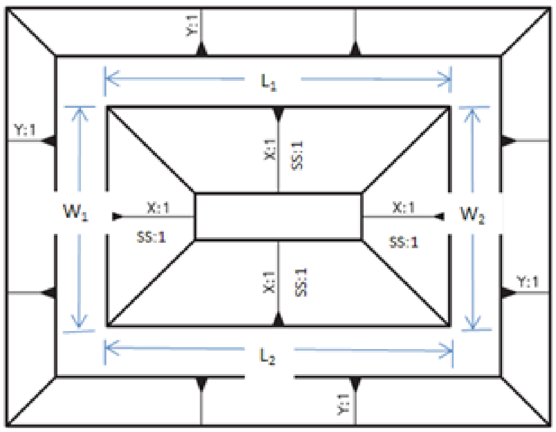
U.S. Department of Agriculture
Natural Resources Conservation Service

State	Project		
Washington	Example #2		

By	Date	Checked By	Date	Job No.
NRCS	1/4/2013			

Subject: **Estimated WSP Prismoidal Volume** — Sheet ______ of ______

Waste Storage Pond



PLAN VIEW

Volume of a Truncated Pyramid Prism with a Rectangular Base

with two parallel polygonal bases joined to one another by straight edges

$$V = h/6\,(A_t + 4M + A_b)$$

<u>Where:</u>

- *V - Volume of the truncated pyramid*
- *h - WSP Depth (Crest to Bottom)*
- *A_t - Top Surface Area, WSP Crest*
- *M - Cross Section Area, Mid-Depth*
- *A_b - Bottom Surface Area, WSP Base*
- *h_{out} - Depth of pond above ground from lowest outside toe to top of crest*
- *$V_{ab\text{-}gnd}$ - Volume stored above ground*
- *SS - Internal Sideslope of the WSP*

L_1 and L_2 are Top of Pond dimensions as shown
W_1 and W_2 are Top of Pond dimensions as shown

Definitions	Inputs		
ft. = Feet	$L_{side\,1}$ =	300	ft.
s.f. = Square Feet	$L_{side\,2}$ =	325	ft.
c.f. = Cubic Feet	$W_{side\,1}$ =	250	ft.
a.f. = Acre-Feet	$W_{side\,2}$ =	200	ft.
n.g. = Results are No Good	h =	15	ft.
	SS =	2.5	
	h_{out} =	7.5	

Data Input Field

Outputs			
Intermediate Computations		Estimated WSP Volume	
A_t =	70,313 s.f.	$V = h/6\,(A_t + 4M + A_b)$	
M =	51,563 s.f.		
A_b =	35,625 s.f.	V_{total} = 780,469	c.f.
$M_{ab\text{-}gnd}$ =	60,586 s.f.	V_{total} = 17.9	a.f.
$A_{b\ ab\text{-}gnd}$ =	51,563 s.f.	<u>and</u>	
		$V_{ab\text{-}gnd}$ = 455,273	c.f.
		$V_{ab\text{-}gnd}$ = 10.5	a.f.
		NOTE: Exceeds 10 Acre-Feet stored above ground	

Pond Storage Volume

This notification is displayed when the above ground volume is greater than 10 ac-ft

<u>Example 3:</u> Determine the estimated WSP volume

Computation Sheet
WA NRCS-ENG-Computation

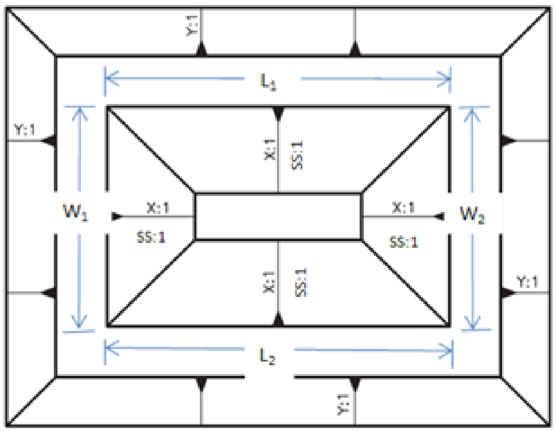
U.S. Department of Agriculture
Natural Resources Conservation Service

State	Project		
Washington	Example #3		

By	Date	Checked By	Date	Job No.
NRCS	1/4/2013			

Subject	
Estimated WSP Prismoidal Volume	Sheet ______ of ______

Waste Storage Pond



PLAN VIEW

Volume of a Truncated Pyramid Prism with a Rectangular Base

with two parallel polygonal bases joined to one another by straight edges

$$V = h/6\ (A_t + 4M + A_b)$$

<u>Where:</u>

- *V - Volume of the truncated pyramid*
- *h - WSP Depth (Crest to Bottom)*
- *A_t - Top Surface Area, WSP Crest*
- *M - Cross Section Area, Mid-Depth*
- *A_b - Bottom Surface Area, WSP Base*
- *h_{out} - Depth of pond above ground from lowest outside toe to top of crest*
- *$V_{ab\text{-}gnd}$ - Volume stored above ground*
- *SS - Internal Sideslope of the WSP*
- *L_1 and L_2 are Top of Pond dimensions as shown*
- *W_1 and W_2 are Top of Pond dimensions as shown*

Definitions	Inputs		
ft. = Feet	$L_{side\ 1}$ =	100	ft.
s.f. = Square Feet	$L_{side\ 2}$ =	90	ft.
c.f. = Cubic Feet	$W_{side\ 1}$ =	50	ft.
a.f. = Acre-Feet	$W_{side\ 2}$ =	50	ft.
n.g. = Results are No Good	h =	9	ft.
	SS =	3	
	h_{out} =	4	

Data Input Field

Outputs					
Intermediate Computations			Estimated WSP Volume		
A_t =	4,750	s.f.	$V = h/6\ (A_t + 4M + A_b)$		
M =	1,564	s.f.			
A_b =	n.g.	s.f.	V_{total} =	n.g.	c.f.
$M_{ab\text{-}gnd}$ =	3,154	s.f.	V_{total} =	n.g.	a.f.
$A_{b\ ab\text{-}gnd}$ =	1,846	s.f.	<u>and</u>		
			$V_{ab\text{-}gnd}$ =	12,808	c.f.
			$V_{ab\text{-}gnd}$ =	0.3	a.f.

Output field displays "n.g." when the pond bottom length or width is <0 ft.

APPENDIX E - ID NRCS WATER QUALITY TECHNICAL NOTE #6

TECHNICAL NOTES

USDA-Natural Resources Conservation Service
Boise, Idaho

TN - Water Quality No. 6 ***July 2006***

IDAHO NUTRIENT TRANSPORT RISK ASSESSMENT (INTRA)
A Water Quality Risk Assessment Tool for Conservation Planning

The Idaho Nutrient Transport Risk Assessment (INTRA) uses a limited number of landform, site and management characteristics to determine the probability of off-site transport of nutrients (primarily nitrogen and phosphorus). The purpose of the Risk Assessment is to provide planners with a tool to evaluate the various landforms and management practices for potential risk of nutrient movement to surface and ground water. The assessment tool is used during the planning process to determine if surface and/or ground water quality concerns exist. The tool is similar to the risk assessment within ONEPLAN, but is modified to use with conservation management units, not individual fields. The tool was field-tested in both northern and southern Idaho in a number of different landuse-operation scenarios. The tool provides recommendations to assist the planner in selecting appropriate conservation practices that address individual and multiple risk factors to protect or enhance water quality. These mitigating practices are required in order to meet quality criteria for nutrients and organics in surface and ground water if the final risk level is greater than LOW. A brief summary of nutrient movement in agricultural systems, primarily phosphorus and nitrogen, follows. For a more detailed description, refer to *Idaho Water Quality Technical Notes No. 4 and 5.*

Summary of Nutrient Movement in Agricultural Systems

Phosphorus

Phosphorus movement in runoff occurs as particulate P and dissolved P. Particulate P is attached to mineral and organic sediment as it moves with the runoff. Dissolved P is in the water solution. In general, particulate P is the major portion (75-90%) of the P transported in runoff from cultivated land. Dissolved P makes up a larger portion of the total P in runoff from non-cultivated lands such as pastures and fields with reduced tillage.

As runoff moves from the landscape toward surface water, phosphorus may become more bioavailable by the sorption and desorption processes, and by the preferential transport of clay-sized material as sediment moves over the landscape (enrichment). The interaction between the particulate and dissolved P in the runoff is very dynamic and the mechanism of transport is complex. Additionally, dissolved P can move laterally towards surface water bodies as subsurface flow, or downwards, as the soil reaches P saturation. Therefore, it is difficult to predict the transformation and ultimate fate of P as it moves through the landscape (Sharpley et al. 2003).

Nitrogen

Nitrogen is one of the most dynamic and mobile nutrients in the plant-soil-air continuum, with many pathways for loss. There is a large reservoir of N in soil, but most of this is in the organic form. It is estimated that only 2-3% of organic N is mineralized annually. The mineralized form of N (nitrate and ammonium) is readily available for uptake by plants. The N cycle is both spatially and temporally variable within agricultural systems. Variability of soil properties impacts nitrogen movement and loss within agricultural operations, including soil organic matter, residual nitrate, crop residue amount, crop yield variability, and changes in soil chemical and physical properties across the field. The primary loss mechanism of nitrogen in agricultural systems is leaching of nitrate below the root zone. However, losses of nitrogen to the air and by overland flow also occur.

Management plays a critical role in reducing N loss to the environment, and management is the dominant factor influencing long-term nitrate leaching (Shaffer and Delgado 2002). Soil, climate, watershed and aquifer characteristics must also be taken into account in order to minimize nitrate leaching. Loss of nitrate from agricultural systems can range from 0 - 60% of N applied (Meisinger and Delgado 2002). Leaching loss is dependent on the concentration of N in soil solution and the volume of water leached. Over-irrigation can lead to nitrate leaching, especially with shallow rooted crops. Effective management is therefore aimed at reducing transport through proper irrigation water management, and optimizing N application amounts and timing in concert with crop uptake. Crop type and cultivation are also important considerations.

The Idaho Nutrient Transport Risk Assessment: Risk Factors

The main factors influencing nutrient movement in agricultural systems can be separated into transport, source and management factors. Transport factors include the mechanisms by which nutrients move within the landscape. These are rainfall, irrigation, erosion and runoff, and deep percolation. Factors which influence the source and amount of nutrients available for transport include soil nutrient content and form of nutrient applied. Management factors include the method of application, timing and placement in the landscape as influenced by the management of application equipment and tillage.

When the factors of the assessment are analyzed, it will be apparent when an individual factor (or factors) is influencing the assessment disproportionately. These identified factors are the basis for planning corrective soil and water conservation practices and management techniques.

The soil, hydrology, climate and land management site characteristics that have a major influence on nutrient availability, retention, management and movement are listed below. The number in parentheses after each factor is the relative weighting factor.

- Soil test P (available phosphorus in soil laboratory test units relative to the 0-12” soil layer *Phosphorus Threshold* per Idaho Nutrient Management Practice Standard 590) (1.0)
- P fertilizer application rates (in pounds available phosphate per acre) (0.75)
- P fertilizer application methods (0.5)
- Organic P source application rates (in pounds available phosphates per acre) (1.0)

- Organic P source application methods (0.75)
- N fertilizer application rate (1.0)
- N application timing (1.00 if non-irrigated, 0.75 if irrigated)
- N fertilizer application method (0.75)
- Irrigation runoff index (0.5)
- Runoff class (0.5)
- Runoff conservation practices (-1.0)
- Sheet and rill and/or irrigation-induced soil erosion (in tons per acre per year) (1.0)
- Distance to the nearest receiving water body (1.0)
- Irrigation index (for deep percolation) (1.5)
- Leaching index (0.5 irrigated, 1.5 not irrigated)
- Water table depth, geologic features, and hydrologic group (1.00 if irrigated, 1.5 if non-irrigated)

Field-specific data for the site characteristics selected for this version of the Risk Assessment (Table 1) are readily available at the conservation management unit level. Some analytical testing of the soil and organic material is required to determine the rating levels. This soil and organic material analysis is considered essential as a basis for the assessment.

The factors (described below) used in the assessment are rated as VERY LOW, LOW, MEDIUM, HIGH, or VERY HIGH (and some use CRITICAL) by determining the range for each category. The sum of the site characteristic rankings provides an index for surface water quality (Table 2) and an index for ground water quality (Table 3).

Soil P Test
A soil sample (0-12”) from the site is necessary to assess the relative level of "plant available P" in the surface layer of the soil. The plant available P is the level customarily given in a soil test analysis by the Cooperative Extension Service or commercial soil test laboratories. The Assessment uses ranges of soil test P. The Olsen (bicarbonate), Bray I, or Morgan (sodium acetate) soil test P methods are required by the NRCS Idaho Nutrient Management Standard depending upon the soil pH. The soil test level for "plant available P" does not ascertain the total P in the surface soil. Rather, it gives an indication of the relative amount of total P that may be present because of the general relationship between the forms of P (organic, adsorbed, and labile P) and the solution P available for plant uptake. If a soil test P result is above the phosphorus threshold as identified in the Idaho Nutrient Management Standard (590), the rating automatically defaults to CRITICAL.

P Fertilizer Application Rate
The P fertilizer application rate is the amount, in pounds per acre (lbs/ac), of commercial phosphate fertilizer (P_20_5) applied to the soil. This phosphate fertilizer does not include phosphorus from organic sources that are recorded in Organic P Sources Application Rate.

P Fertilizer Application Method
The manner in which P fertilizer is applied to the soil affects potential P movement. Incorporation implies that the fertilizer P is buried below the soil surface. If fertilizer is surface applied on a field with surface runoff (natural or from irrigation) and there is no incorporation, it is considered a significant risk and therefore the rating automatically defaults to CRITICAL.

Organic P Source Application Rate
The organic P application rate is the amount, in pounds per acre (lbs/ac), of potential phosphate (P_20_5) contained in the manure and applied to the soil. This organic phosphate source does not include phosphorus from fertilizer sources that are recorded in P Fertilizer Application Rate.

Organic P Source Application Method
The manner in which organic P material is applied to the soil can determine potential P movement. Incorporation implies that the organic P material is buried below the soil surface. If manure is surface applied on a field with surface runoff (natural or from irrigation) and there is no incorporation, it is considered to be a discharge and a violation of existing regulations. Because of this, the rating automatically defaults to CRITICAL.

Runoff Class and Irrigation Runoff Index

Runoff Class: The runoff class of the site is used to determine the risk of runoff from storm events. One method to determine the runoff class is based on the soil permeability and the percent slope of the site (USDA-NRCS Soil Survey Manual, Agricultural Handbook 18, 1993). The matrix relating soil permeability class and slope (Table 4) provides the appropriate value category. This information is available in the SSURGO soils database (physical properties report).

Runoff Index: The irrigation runoff index of the site is used for irrigated lands. For sprinkler irrigated lands, the runoff index is simply based on a user supplied assessment of whether or not runoff (overland flow) exists and, if so, whether or not it leaves the field. For surface irrigated lands, the runoff index is based on the typical percent of the irrigation set time that runoff from the furrow/field occurs; the user enters whether it is more or less than 50%.

Runoff Conservation Practices
Runoff conservation practices include any conservation practices which serve to reduce runoff and the movement of soil, thereby reducing potential for dissolved and particulate phosphorus movement across the landscape toward a receiving water body. Credit (negative point value) is applied depending on the number of conservation practices implemented, so multiple practices receive greater credit than a single practice. Also, runoff conservation practices that filter or trap nutrients (such as buffers, borders, filter strips, and grassed waterways) receive greater credit than those that simply reduce runoff. Certain practices (e.g., tail-water recovery systems with sediment basins) eliminate runoff and sediment loss from the field.

Soil Erosion (Total Water-Induced Soil Erosion)
Soil erosion is defined as the loss of soil along the slope or unsheltered distance caused by the processes of water and wind. Soil erosion is estimated from erosion prediction models including the Revised Universal Soil Loss Equation (RUSLE/RUSLE2) for water erosion from non-irrigated lands (and sprinkler irrigated lands if runoff exists) and the Surface Irrigation Soil Loss equation (SISL) for water erosion from surface irrigated lands. The Wind Erosion Equation (WEQ) is not used in this assessment. The value category is given in tons of soil loss per acre per year (ton/ac/yr). These soil loss prediction models do not predict sediment delivery rates from the end of a field to a water body. The prediction models are used in this assessment to

indicate the <u>potential</u> for sediment and attached nutrient movement across the slope or unsheltered distance toward surface waters.

Distance to Nearest Receiving Water Body
The distance to the nearest receiving water body is the distance in feet between the edge of the field and the nearest receiving water. This is typically a ditch, canal, waterway, drain, etc. – *any water body or water way which has connection (perennial or ephemeral) with a stream, river, pond or lake*. The closer the distance, the greater the likelihood nutrients lost from the field will reach the receiving water body.

Leaching Index
Deep percolation is dependent on numerous factors, including climate and soil type. The leaching index is based on the Nitrogen Leaching Index (Czymmek et al. 2003, Williams and Kissel 1991) which is essentially a water percolation index based on soil water storage. Slight modifications were made to some of the percolation index equations to adjust for low precipitation zones found in areas of Idaho. Total annual precipitation for specific locations is determined from local climate station data, as is winter precipitation. The percolation index is based on precipitation and hydrologic soil group. A seasonal index is calculated as the ratio of winter precipitation to annual precipitation. The leaching index is then calculated as the product of the percolation index and seasonal index. For irrigated lands, the leaching index is low if the irrigation index is low. If not, then the leaching index is based on amount of winter precipitation.

Irrigation Index
Managing irrigation water will minimize nutrient losses from leaching and surface runoff. Potential system application efficiency and irrigation water management have significant impacts on actual water movement through the root zone. Five different factors are used in the irrigation index to determine the potential for irrigation water to transport nutrients to ground water. The irrigation system is the primary rating factor, and the other variables modify that rating based on the level of management for each. These additional factors are water control and measurement, irrigation scheduling and soil moisture monitoring, use of pre- and/or post-season irrigation, and soil condition index (SCI).

N Application Index
Crop nitrogen requirement is determined based on crop yield and University of Idaho fertilizer recommendations. The nitrogen application rate is the percent nitrogen applied compared to the total crop nitrogen requirement according to the fertilizer guides <u>prior to</u> any credits or debits for previous crop and residual nitrogen.

N Application Timing
Timing of N application directly influences potential transport due to the high mobility of nitrate in soils. The appropriate timing of N application is complicated by the soil processes of nitrification, volitization, and mobilization, which affect N plant availability. Split applications of N throughout the growing season better match crop growth requirements, reducing the likelihood of loss. Fall application in most instances has the greatest potential for loss prior to the planting season; additional N applications are often required to meet crop demand when losses occur.

Water Table Depth/Soil Type
Soils can stop or slow nutrient movement depending on their chemical and physical characteristics. Depth of soils, depth to water tables and limiting layers such as hard pans will influence rooting depth, nitrogen movement, and leaching potential. Fine textured soils (Hydrologic Group D) have a lower potential for leaching due to reduced permeability and high water holding capacity, while coarse textured soils (Hydrologic Group A) have a higher likelihood of nitrate leaching due to low water holding capacity and the rapid infiltration and movement of water through the profile.

If a water table is present within five feet of the surface, the potential for ground water contamination is high regardless of the soil type.

Using the Idaho Nutrient Transport Risk Assessment

The Assessment applies on Cropland, Hayland, and Pasture where nutrients are applied. Use of the Risk Assessment for planning should begin during the initial field visit and interview with the producer. However, some of the information needed for the factors will be obtained from other planning tools (for instance, SISL or RUSLE2, soils database, etc.). **A field data sheet is provided in the spreadsheet, but required calculations and look-up information is performed by the spreadsheet, so entering information from the field data sheet into the spreadsheet (or taking the computer to the field) is required**. Steps for using the assessment tool are:

1) An assessment is developed for each land use, conservation management unit, or cropping system.

   Example: An operation includes 3 cropping systems or conservation management units:

   1. Hay in rotation with row crops and cereals, where commercial fertilizer is applied.
   2. Hay in rotation with row crops and cereals where animal waste is applied in addition to commercial fertilizer.
   3. Pasture where commercial fertilizer is applied.

   An assessment is required for each system/management unit.

2) Identify the critical crop in each system. The critical crop is the crop in which the highest potential for off-site transport of nutrients exists. For example, a rotation being evaluated includes winter wheat, spring barley and summer fallow. All the nitrogen for winter wheat is applied in the fall prior to planting the crop. The critical crop is winter wheat. The assessment is made using information which relates to the winter wheat crop.

3) The planner must obtain the following information from the producer.
   1. Typical rotation.
   2. For the critical crop:

a) Soil test data using the appropriate analysis method (Olson, Bray or Sodium Acetate). Note: If no soil test has been done in the last 5 years, the input value is automatically a VERY HIGH.
b) Phosphorus fertilizer application rate (lbs/ac/yr).
c) Phosphorus fertilizer application method.
d) Organic phosphorus application rate (lbs/ac/yr). Note: If the producer can not provide this information, the input value is automatically a VERY HIGH.
e) Organic phosphorus fertilizer application method.
f) Nitrogen application rate (% of Crop Requirement) requires 2 factors. The actual lbs/ac/yr of Nitrogen applied and the target yield. The program uses these 2 values to generate the rating.
g) Nitrogen fertilizer application method.
h) Runoff Index (Surface Irrigated). This value is qualitative. The planner determines the input by asking the producer whether water runs off less than or more than 50% of the set time.
i) Runoff Index (Sprinkler Irrigated). This value is qualitative. The planner determines the input with on site observation and/or asking the producer. Does water move across the field surface during irrigation? Does water leave the field via overland flow?

4) Other Information: Factors like hydrologic soil group, average field slope, permeability, soil erosion, and distance to surface waters are required and should be representative of the cropping scenario/conservation management unit being evaluated.

Requirements for Meeting Quality Criteria

- Quality Criteria is met when an overall rating of LOW is obtained. No mitigating practices are required.
- Quality Criteria is not met when an overall rating of MEDIUM or greater is obtained. Mitigating practices are required. If <u>all</u> possible mitigating practices have already been implemented, then Quality Criteria are considered met. <u>This must be documented in the plan.</u>

Identification of Mitigating Practices

The rating for each site characteristic (factor) is displayed on the Assessment Report. If any site characteristic has a MEDIUM or higher rating, then mitigating practices are required. Mitigating practices are not required for any site characteristic which has a rating of LOW, however "Recommended" practices might be suggested. "Recommended" and "Required" practices are identified on the report in the column titled "Mitigating Practices".

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Table 1. Idaho Nutrient Transport Risk Assessment for Planning (Field Sheet). The weighting for each factor is incorporated into the point value.

Surface Water Quality							
Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 1	Medium 2	High 4	Very High 8	Critical 10	
Soil Test P (ppm) Olsen Method 0 – 12”	< 8	8 - 15	16 - 25	26 - 35	36 – 40 (or no soil test)	> 40	
Soil Test P (ppm) Bray Method 0 – 12”	< 10	10 - 20	21 - 40	41 - 50	51- 60 (or no soil test)	> 60	
Soil Test P (ppm) Morgan Method (NaOAc) 0 – 12”	< 1.0	1.0 – 2.0	2.1 – 4.0	4.1 – 5.0	5.1- 6.0 (or no soil test)	> 6.0	
Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 0.75	Medium 1.5	High 3	Very High 6	Critical	
Phosphorus Fertilizer Application Rate (lbs/ac P_2O_5)	0	< 60	60 - 150	151- 300	> 300		
Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 0.5	Medium 1.0	High 2	Very High 4	Critical 10	
Phosphorus Fertilizer Application Method	None applied	Placed with planter (banded) or injected > 2" or plowed	Incorporated > 3" by disking or chiseling, etc.	Chemigated, or incorporated < 3" by harrowing, etc.	Surface applied, no incorporation	Surface applied on a field with surface runoff (natural or from irrigation) and no incorporation	
Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 1	Medium 2	High 4	Very High 8	Critical	
Organic Phosphorus Application Rate (lbs/ac P_2O_5)	0	< 40	40 - 100	101 – 200	> 200 (or unknown)		

Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 0.75	Medium 1.5	High 3	Very High 6	Critical 10	
Organic Phosphorus Application Method	None applied	Placed with planter (banded) or injected > 2" or plowed	Incorporated > 3" by disking or chiseling, etc.	Chemigated, or incorporated < 3" by harrowing, etc.	Surface applied, no incorporation	Surface applied on a field with surface runoff (natural or from irrigation) and no incorporation	

Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 1	Medium 2	High 4	Very High 8	Critical	
Nitrogen Application Rate (% of Crop Requirement)	< 40	40 - 60	60 - 100	100 - 120	> 120		

Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 0.75	Medium 1.5	High 3	Very High 6	Critical 10	
Nitrogen Fertilizer Application Method (prior to critical runoff period)	None applied	Placed with planter (banded) or injected > 2" or plowed	Incorporated > 3" by disking or chiseling, etc.	Chemigated, or incorporated < 3" by harrowing, etc.	Surface applied, no incorporation	Surface applied on a field with surface runoff (natural or from irrigation) and no incorporation	

Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 0.5	Medium 1.0	High 2	Very High 4	Critical	
Runoff Index (Surface Irrigated)	No runoff occurs	-----	Water runs off the field less than 50% of the set time	-----	Water runs off the field 50% or more of the set time		
Runoff (Sprinkler Irrigated)	No runoff occurs	Water moves across the surface but not off the field	-----	Runoff leaves the field	----		
Runoff Class	Negligible	Very low or low	Medium	High	Very High		

Site Characteristic	**Rating and Point Value**					**SELECTED RATING**
	Very Low 0	Low -1	Medium -2	High -4	Very High -8	Critical	
Runoff BMPs (Only applies if runoff occurs)	No conservation practices	One or two on-field conservation practices that reduces runoff	Multiple conservation practices that reduce runoff or trap nutrients	Multiple conservation practices that reduce runoff and trap/filter pollutants	Conservation practice(s) that eliminates runoff		
Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 1	Medium 2	High 4	Very High 8	Critical	
Average Total Soil Erosion due to Water (tons/ac/year)	< 1 ton/acre	1 - 5 tons/acre	5 - 10 tons/acre	10 - 15 tons/acre	> 15 tons/acre		
Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 1	Medium 2	High 4	Very High 8	Critical	
Distance to Surface Water	> 2640 feet (> 0.5 mile)	2640 - 1320 feet	1319 - 600 feet	599 - 200 feet	< 200 feet		
TOTAL POINTS FOR SURFACE WATER QUALITY (Less than 12 is a LOW rating)							

Ground Water Quality							
Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 1	Medium 2	High 4	Very High 8	Critical	
Nitrogen Application Rate (% of Crop Requirement)	< 40	40 - 60	60 - 100	100 - 120	> 120		
Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
Irrigated> **Not Irrigated>**	Very Low 0 0	Low 0.75 1	Medium 1.5 2	High 3 4	Very High 6 8	Critical	
Nitrogen Application Timing	None applied	Nitrogen applied in several applications during the primary growing season, the first application no greater than 30 days of start of primary growing season	Majority of nitrogen is applied within 30 days of, or during, the primary growing season. Nitrogen applied outside this time frame is less than 50 lbs and is applied with a nitrification inhibitor or when soil temperatures are less than 50 deg. F.	Nitrogen is applied as a single application within 90 days of the primary growing season OR a split application is made which does not meet the conditions described for LOW or MEDIUM.	Nitrogen is applied as a single application more than 90 days prior to the primary growing season.		

Site Characteristic	Rating and Point Value						SELECTED RATING
	Very Low 0	Low 1.5	Medium 3	High 6	Very High 12	Critical	
Irrigation Index	> 79	70 - 79	60 - 69	50-59	< 50		
This index requires information on the irrigation system type, water measurement and distribution, irrigation scheduling, SCI, and whether pre or post season irrigation is used. Circle the most appropriate selection in each category.							

Irrigation System	**Irrigation Scheduling**	**Water Control and Measurement**
Surface - Graded Border	Use a set irrigation schedule each year	
Surface - Level Border (Basin)	Irrigation based on visual observation of crop stress	Poor - no water measurement AND poor control of water due to inadequate water control structures throughout the conveyance system
Surface - Graded Furrow or Corrugates	Soil moisture by NRCS feel method	
Surface - Surge	Check book scheduling, irrigation scheduler, etc.	
Surface - Controlled with contour ditch, turnouts, canvas dams, etc.	Irrigation scheduling via pan evaporation of atmometer in field	Fair - manually recorded water measurement at delivery point to farm AND poor control of water due to inadequate control structures throughout the conveyance system
Surface - Uncontrolled (wild flood, no control with turnouts, etc.)	Irrigation scheduling via regional weather network (e.g. AgriMet)	
Sprinkler - Big gun or boom	Soil moisture monitoring using Gypsum blocks, moisture probes, etc.	
Sprinkler - Periodic Move (hand line or wheel line)	Continuous measurement of soil moisture, water applied, and ET	Average - manual recordings somewhere in the system OR good control of water with effective water control structures throughout the conveyance system
Sprinkler - Solid set		
Sprinkler - Center pivot	**Pre/Post Irrigation**	
Sprinkler - Lateral/linear move	Pre- and post-season irrigations based on standard run time	Good - manual recordings somewhere in the system AND good control of water with effective water control structures throughout the conveyance system
Micro Irrigation - Sprays and Bubblers	Pre-season OR post-season irrigations based on standard run time	
Micro Irrigation - Tubing or tape w/ integrated or punched-in emitters	Pre- and post-season irrigations based on soil moisture assessment	
	Pre- OR post-season irrigations based on soil moisture assessment	Excellent - Continuous recording water measurement device(s) AND good control of water with effective water control structures throughout the conveyance system
	No irrigation outside crop growing season	

Leaching Index (Irrigated) (applies only if Irrigation Index > LOW)	< 9	9 - 12	13 - 16	17 - 20	> 20	[redacted]	
Leaching Index (Not Irrigated)	0	0 – 2	2 – 5	5 – 10	>10		
Site Characteristic	**Rating and Point Value**						**SELECTED RATING**
	Very Low 0	Low 1	Medium 2	High 4	Very High 8	Critical	
Water Table/Geologic Feature Depth and Soil Type	Water table or geologic feature > 5 feet from surface, Hydrologic Group D	Water table or geologic feature > 5 feet from surface, Hydrologic Group C	Water table or geologic feature > 5 feet from surface, Hydrologic Groups A, B	Water table or geologic feature < 5 feet to surface, Hydrologic Groups C, D	Water table or geologic feature < 5 feet to surface, Hydrologic Groups A, B	[redacted]	
TOTAL POINTS FOR GROUND WATER QUALITY (Less than 9 is a LOW rating)							

Table 2. Surface Water Quality Nutrient Transport Risk Assessment Index rating and sit e vulnerability.

Surface Water Risk Assessment Rating	Total	Site Vulnerability Chart
LOW	< 12	Low potential for nutrient loss if current farming practices are maintained.
MEDIUM	12 - 20	Medium potential for nutrient loss. Some remediation measures should be undertaken to minimize the probability of nutrient loss.
HIGH	21 - 40	High potential for nutrient loss and adverse effects on surface and/or ground waters. Soil and water conservation measures and phosphorus management plans are needed to reduce the probability of nutrient loss.
VERY HIGH	> 40	Very high potential for nutrient loss and adverse effects on surface and/or ground waters. All necessary soil and water conservation measures and a nutrient management plan must be implemented to minimize nutrient loss.

Table 3. Ground Water Quality Nutrient Transport Risk Assessment Index rating and sit e vulnerability.

Ground Water Risk Assessment Index Rating	Total	Site Vulnerability Chart
LOW	< 9	Low potential for nutrient loss if current farming practices are maintained.
MEDIUM	9 - 16	Medium potential for nutrient loss. Some remediation measures should be undertaken to minimize the probability of loss.
HIGH	16 - 25	High potential for nutrient loss and adverse effects on ground water. Soil and water conservation measures and nutrient management plans are needed to reduce the probability of loss.
VERY HIGH	>25	Very high potential for nutrient loss and adverse effects on ground water. All necessary soil and water conservation measures and a nutrient management plan must be implemented to minimize loss.

Table 4. The surface RUNOFF CLASS site characteristic determined from the relationship of the soil permeability class and field slope. Adapted from NRCS Soil Survey Manual (1993) Table 3-10.

Slope (%)	Soil Permeability Class [1] *(in/hr)*				
	Very Rapid *(>20.00 in/hr)*	Moderately Rapid and Rapid *(2.00 – 20.00)*	Moderately Slow and Moderate *(0.20 – 2.00)*	Slow *(0.06 - 0.20)*	Very Slow *(< 0.06 in/hr)*
	Runoff Class [3]				
Concave [2]	N	N	N	N	N
< 1	N	N	N	L	M
1 - 5	N	VL	L	M	H
5 - 10	VL	L	M	H	VH
10 - 20	VL	L	M	H	VH
> 20	L	M	H	VH	VH

[1] Permeability class of the least permeable layer within the upper 39 inches (one meter) of the soil profile. Permeability classes for specific soils can be obtained from a published soil survey or from local USDA-NRCS field offices (soils database).
[2] Area from which no or very little water escapes by overland flow.
[3] RUNOFF CLASS: N = negligible, VL = very low, L = low, M = medium, H = high, VH = very high.

ATTACHMENT 1: Example for Conservation Planning

Benchmark condition is sprinkler irrigated potato-sugarbeet-winter wheat in southeast Idaho with manure application.

Site Characteristic and Ranking	Factor Weighting X Rating Value
Soil P test is 35 ppm using an Olsen Test =HIGH	1.0 x 4 = 4.0
P fertilizer application rate is 50 lbs/ac P_2O_5 =LOW	0.75 x 1 = 0.75
P fertilizer application method is placed with planter =LOW	0.5 x 1 = 0.5
Organic P source application rate is 210 lbs/ac =VERY HIGH	1.0 x 8 = 8.0
Organic P source application method is incorporated less than 3 inches by harrowing, etc. =HIGH	0.75 x 4 = 3.0
N fertilizer application rate is 80% of crop requirement prior to debits/credits =MEDIUM	1.0 x 2 = 2.0
N fertilizer application method is broadcast and incorporated greater than 3" =LOW	0.75 x 1 = 0.75
N fertilizer application timing is single application in spring, > 30 days prior to growing season =HIGH	0.75 x 4 = 3
Irrigation Runoff Index for sprinkler irrigated, no runoff occurs but overland flow within field does occur. = LOW	0.5 x 1 = .5
Runoff class from Table 3 is Medium =MEDIUM	0.5 x 2 = 1.0
No runoff conservation practices in place =VERY LOW	1.0 x 0 = 0

Soil erosion is 7.5 tons/ac/yr = MEDIUM	1.0 x 2 = 2.0
Distance to nearest receiving water body is 300 feet =HIGH	1.0 x 4 = 4.0
Irrigation Index calculated at 68 for center pivot with visual observation of crop stress, pre-season irrigation and average control of water =MEDIUM	1.5 x 2 = 3
Leaching Index for Pocatello =LOW	0.75 x 1 = 0.75
Water table/soils for Hydrologic Group C with no water table or geologic feature within 5 feet =LOW	1.0 x 1 = 1.0
Total Points for Surface Water Quality	**26.5**
Total Points for Ground Water Quality	**9.75**

Ranking for Surface Water - the site has a **HIGH** potential for nutrient loss and adverse effects on surface waters.

Ranking for Ground Water – the site has a **MEDIUM** potential for nutrient loss and impact to ground water.

Using the individual site characteristics, identify some factors of concern and management options that could be used to reduce this site vulnerability (mitigation):

Soil P Test – The soil P test was HIGH. Remember that the soil test level for "available P" does not ascertain the total P in the surface soil. It does, however, give an indication of the amount of total P that may be present because of the general relationship between the forms of P and the solution P available for crop uptake. Research has conclusively shown that the higher the soil test P level of a site, the proportionately higher the potential P loss will be from that site. Therefore the long-term goal should be to conduct a comprehensive soil testing program on the entire farm and implement nutrient management on individual fields using ONEPLAN. Estimates should be made to determine the time required to deplete the soil P to optimum levels.

Organic P Source Application Rate – The organic P source application rate was > 200 lbs/ac, falling in the VERY HIGH category. This particular site characteristic is especially important. Here we have a management unit with a soil test P level that is already high and very high rates of organic P are being applied. Considering the long-term management options discussed under

Soil P Test, the organic P application rate should either be reduced to crop P uptake or less, or no organic P should be applied ntil the soil P is depleted back to an optimal level. The ONEPLAN nutrient management program can help identify fields with lower soil P test and lower risk assessment values where the organic material could be applied.

Organic P Source Application Method – The organic P source application method was incorporated less than 3 inches with a harrow, etc. putting it in the HIGH category. Remember that the manner in which organic P material is applied to the soil can determine potential P movement. Since the organic P was only minimally incorporated, the organic P would still have a substantial surface exposure. Mechanical incorporation reduces the amount of nutrients in the thin mixing zone at the soil surface and/or on crop residue or foliage, thus reducing the interaction with and transfer of nutrients to runoff water. With incorporation, other environmental losses may also be reduced, and nutrient management may be improved. However, mechanical incorporation with tillage may reduce soil-protecting crop residue and increase erosion. Incorporated material may be subject to downward movement. Leaching losses may be increased, and the relative importance of the different loss pathways needs to be considered. The organic P material should be injected or plowed greater than 2 inches if possible, and applied immediately before the crop is planted.

Runoff Conservation Practices – No runoff practices are currently in place, so level of use is VERY LOW. Implementing irrigation water management and use of surface roughening (dam-dike) and buffers would help reduce runoff and sediment loss. (see Soil Erosion).

Soil Erosion – The soil erosion rate was 7.5 tons/ac/yr (MEDIUM category). Prediction models are used in the assessment to indicate a movement of soil, thus potential for sediment and attached phosphorus movement across the slope or unsheltered distance and to a water body. Conservation measures such as residue management or reduced tillage should be considered as a way to reduce erosion. In addition, other conservation measures like field borders or buffers should be considered as a means to mitigate off-site transport and improve the quality of runoff leaving the field.

Irrigation Index – Despite the use of a center pivot system, the irrigation index rated MEDIUM because of pre-season irrigation practices and a low level of irrigation scheduling. Following appropriate irrigation water management techniques could significantly improve efficient use of water and reduce the potential for leaching losses.

Nitrogen Application Timing – Applying nitrogen as a single application more than 30 days prior to the start of the growing season increases the risk of loss during spring. Apply the nitrogen closer to the growing season and consider splitting applications for better crop use efficiency.

APPENDIX F - UNIVERSITY OF IDAHO CIS 1139

University of Idaho
College of Agricultural and Life Sciences

CIS 1139

Manure and Wastewater Sampling

by Ron E. Sheffield and Richard J. Norell

Nutrient concentrations vary within most types of manure. A review of samples from 42 dairies in Idaho (Table 1) showed that nitrogen (N) and phosphorus (P) in wastewater lagoons vary greatly between farms. For example, on small open lot dairies (< 1,000 head), P can range from 16 to 28 pounds/per acre-inch while on large open lot dairies (> 1,000 head), the range is 12 to 20 pounds per acre-inch.

Phosphorus concentrations on freestall flush dairies ranged from 23 to 31 pounds per acre-inch, while scraped freestall dairies ranged from 17 to 39 pounds per acre-inch. This is a broad range of nutrient levels with the maximum and minimum values differing by more than a factor of two.

These numbers should send a clear message: Average nutrient estimates may be suitable for the purposes of developing a manure utilization plan, but these averages are not adequate for calculating proper application rates.

Do not base your application rates on laboratory test results from previous years because nutrient concentrations can change significantly, particularly when the manure has been exposed to the environment. For example, nutrient levels in a lagoon or storage pond can be greatly diluted by more rainfall than normal or concentrated due to excessive summertime evaporation.

Manure should be tested as close to the date of application as practical. Preferably, the sample should be taken as near the application time as possible prior to the manure application, or within 30 days of application. However, if you urgently need to pump down a full lagoon or storage pond, you should not wait until you can sample and obtain the results. Instead, you should sample the day of irrigation. The results can later be used to determine the nutrients applied to the fields and identify the need for additional nutrients to complete crop production.

Producers who do not test each manure source before or just after land application are faced with a number of questions they simply may not be able to answer:

- Am I supplying plants with adequate nutrients?
- Am I building up excess nutrients that may ultimately move to surface waters or groundwater?
- Am I applying heavy metals at levels that may be toxic to plants and permanently alter soil productivity?

Because environmental damage and losses in plant yield and quality often happen before visible plant symptoms, always have your manure analyzed by a competent lab. Certified labs in Idaho can analyze manure samples and may be able to make agronomic recommendations regarding the use of the manure as a fertilizer.

Manure sampling

Proper sampling is the key to reliable manure analysis. Although lab procedures are accurate, they have little value if the sample fails to represent the manure product.

Manure samples submitted to a lab should represent the average composition of the material that will be applied to the field. Reliable samples typically consist of material collected from a number of locations. Precise sampling methods vary according to the type of manure. The lab, county extension agent, or crop consultant should have specific instructions on sampling, including proper containers to use and maximum holding or shipping times. General sampling recommendations follow.

Preparing liquid manure for lab analysis. Liquid manure samples submitted for analysis should meet the following requirements:

- Place sample in a sealed, clean plastic container with about a 1-pint volume. Glass is not suitable because it is breakable and may contain contaminants.

Table 1. Average lagoon wastewater concentrations from various types of Idaho dairies.

Farm Type[1]	Ammonia (NH_3) lb/ac-in	Total Kjeldahl Nitrogen (TKN) lb/ac-in	Total Phosphorus (TP) lb/ac-in	Total Solids (TS) mg/l	Biochemical Oxygen Demand (BOD) mg/l
OL < 1,000 hd	40 +/- 2	119 +/- 29	22 +/- 6	29,291 +/- 12,098	21,067 +/- 20,240
OL > 1,000 hd	61 +/- 22	92 +/- 36	16 +/- 4	5,087 +/- 1,386	1,068 +/-192
FS Scrape	175 +/- 75	181 +/- 75	28 +/- 11	24,122 +/- 13,826	2,135 +/- 968
FS Flush	149 +/- 23	162 +/- 24	27 +/- 4	10,770 +/- 2,138	1,912 +/- 481

[1] Farm Type: OL = Open Lot Dairy; FS = Freestall Dairy; hd = head.
[2] Average values +/- standard error.

- Leave at least 1 inch of air space in the plastic container to allow for expansion caused by the release of gas from the manure material.
- Refrigerate or freeze samples that cannot be shipped on the day they are collected, minimizing chemical reactions and pressure buildup from gases.

Ideally, liquid manure should be sampled after it is thoroughly mixed. Because this is sometimes impractical, samples can also be taken in accordance with the suggestions that follow.

Lagoon liquid. Premixing the surface liquid in the lagoon is not needed, provided it is the only component that is being pumped. Growers with multistage systems should draw samples from the lagoon they intend to pump for crop irrigation.

Samples should be collected using a clean, plastic container similar to the one shown in **Figure 1.** One pint of material should be taken from at least eight sites around the lagoon and then mixed in the larger clean, plastic container. Effluent should be collected at least 6 feet from the lagoon's edge at a depth of about a foot. Shallower samples from anaerobic lagoons may be less representative than deep samples because oxygen transfer near the surface sometimes alters the chemistry of the solution. Floating debris and scum should be avoided. One pint of mixed material should be sent to the lab. Galvanized containers should never be used for collection, mixing, or storage due to the risk of contamination from metals like zinc in the container.

A University of Idaho study compared nutrient composition from two sampling locations: direct from storage and during land application. Nitrogen concentration averaged 15 pounds per acre-inch higher in storage samples than from land application samples. Conversely, phosphorus and potassium concentrations were similar between storage and land application samples. Nitrogen application rates may be overestimated if based on nutrient analysis from storage samples.

These recommendations are adequate for average irrigation volumes. If an entire storage structure is to be emptied by such means as furrow irrigation, more frequent sampling with many more sampling points is recommended.

Liquid slurry. Manure materials applied as a slurry (approximately 5 to 12 percent solids) from a pit, storage pond, or vacuumed from a feed alley should be mixed prior to sampling. If you agitate your pit or basin prior to sampling, a sampling device pictured in **Figure 1** can be used. If you wish to sample a storage structure without agitation, you must use a composite sampling device as shown in **Figure 2**. Manure should be collected from approximately eight areas around the pit or pond and mixed thoroughly in a clean, plastic container. An 8- to 10-foot section of 0.5- to 0.75-inch plastic pipe can also be used: extend the pipe into the pit with ball plug open, pull up the ball plug (or press your thumb over the end to form an air lock), and remove the pipe from the manure, releasing the air lock to deposit the manure in the plastic container.

Lagoon sludge. The best time to take a sludge sample is while measuring for volume of sludge in a lagoon. This allows samples to be collected from several points around the interior of the lagoon. How the sample is collected depends on how the sludge will be removed. Depending on the density and nutrient concentration of the lagoon effluent, the samples may differ by up to 100 percent from point to point.

To draw a sample, use the same type of sampler as described above for manure slurry (**Figure 2**) and lower the sampler until it almost reaches the bottom. Avoid using a commercial "sludge-judge," because experience has shown that these devices do not work well on thick manure sludge and settled solids.

Wearing plastic or latex gloves, collect a core or profile of lagoon effluent and sludge. Once the pipe is over a clean 5-gallon plastic bucket, slowly break the vacuum by removing your finger from the end of the pipe. If the entire lagoon is going to be agitated during sludge removal, the entire core of collected sludge and effluent should be sent to the laboratory. If the lagoon effluent is going to be drawn down and primarily only sludge pumped out, then just the collected sludge should be sent to the lab. If you are unsure how the sludge will be removed, take samples using both methods, label them separately, and have both analyzed.

Place several samples in the bucket and mix thoroughly before removing a sub-sample for analysis. Consider using a plastic, wide-mouth bottle when shipping samples to the laboratory.

Solid Manure. Solid manure samples should represent the manure's average moisture content. If the material varies

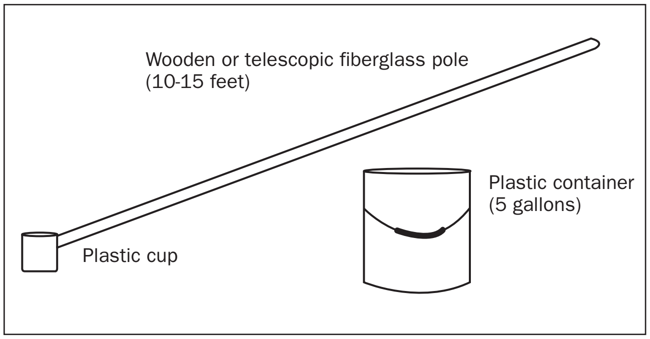

Figure 1. Liquid manure sampling devices like these can be purchased or made.

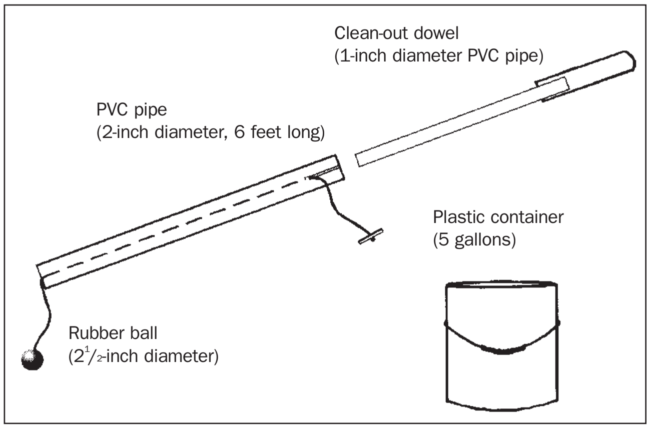

Figure 2. Composite sampler for slurries and lagoon sludge or settled solids includes a collecting PVC pipe and a clean-out dowel (smaller PVC pipe), string, and a rubber ball big enough to cover one end of the collecting pipe.

greatly in its moisture content, you should submit at least 3 samples to a laboratory and take an average of each analysis.

A 1-quart sample is adequate for analysis. Samples should be taken from approximately 8 different areas in the manure pile, placed in a clean plastic container, and thoroughly mixed. Samples should be taken wearing plastic or latex gloves and using a plastic or stainless steel hand shovel or trowel. Do not use galvanized trowels or buckets because they will likely contaminate the sample, rendering falsely high concentrations of metals like zinc in the analysis. Approximately 1 quart of the mixed sample should be placed in a plastic bag, sealed, and shipped directly to the lab. Samples stored for more than 1 day should be refrigerated.

Stockpiled manure or litter. Ideally, stockpiled manure and separated solids should be stored under cover on an impervious surface. The weathered exterior of uncovered waste may not accurately represent the majority of the material. Additionally, rainfall will move water-soluble nutrients down into the pile. If an unprotected stockpile is applied over an extended period, it should be sampled before each application.

Stockpiled manure should be sampled at a depth of at least 18 inches at 6 or more locations around the pile. The collected material should be combined in a plastic container and mixed thoroughly. The 1-quart lab sample should be taken from this mixture, placed in a plastic container or bag, sealed, and shipped to the lab for analysis. If the sample cannot be shipped within one day of sampling, it should be refrigerated.

Surface-scraped manure. Surface-scraped and piled materials should be treated like stockpiled manure. Follow the same procedures for taking samples. Ideally, surface-scraped materials should be protected from the weather unless they are used immediately.

Composted manure. Ideally, composted manure should be stored under cover on an impervious surface. Although nutrients are somewhat stabilized in these materials, some nutrients can leach out during rains. When compost is left unprotected, samples should be submitted to the lab each time the material is applied. Sampling procedures are the same as those described for stockpiled manure.

Who can analyze my manure sample?

Both public and private labs analyze manure samples. Use only labs that are certified or conduct their analysis according to the North American Proficiency Testing – Manure Assessment Program (NAPT-MAP) to test manure and wastewater, or the North American Proficiency Testing – Compost Assessment Program (NAPT-CAP) to test compost. Private labs can be found through local Cooperative Extension Service (CES) agents, state regulators, or on the NAPT-MAP Web site: *http://ghex.colostate.edu/map/*.

Deciding which lab to use depends on several factors:

- Is the lab certified or does it conduct its analysis according to NAPT-MAP or NAPT-CAP guidelines?
- What is the cost to run the sample?
- How long will it take to get your results?
- Does the lab offer all parameters needed for your operation?
- Can you get your sample to the lab in the required time?

When you have selected a lab to analyze the manure, you need to follow its specific sample requirements. Many labs offer sample containers that they ask you to use. Sample collection procedures, including holding times allowed and refrigeration and shipping requirements, must be closely followed to obtain accurate results. One standard that applies to all labs and sampling recommendations is to sample as close to the application time as possible.

Essential analyses include concentrations of essential plant nutrients, including nitrogen as ammonium (NH_4-N), and Total Kjeldahl Nitrogen (TKN), Total phosphorus (TP) and potassium (K). Additionally, you may consider sampling for nitrate (NO_3-N), dissolved phosphorus (PO_4-), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), dry matter content or total solids (TS), pH, and electrical conductivity (for liquid samples). Where applicable, check your NPDES permit (National Pollutant Discharge Elimination System) for specific sampling requirements.

What does my manure analysis report tell me?

Lab results may be presented in a number of ways. The easiest to use is a wet, "as-is" basis in pounds of available nutrient (N, P, or K) (1) per ton; (2) per 1,000 gallons of manure or wastewater; or (3) per acre-inch of manure or wastewater.

If a lab reports results on a dry basis, you must have the moisture content of the manure to convert the results back to a wet basis. A lab may also give results as a concentration (parts per million [ppm] or milligram per liter [mg/l]), which likewise requires conversion factors to get the results into a usable form based on how you apply the manure. Finally, if a lab reports P and K as elemental P and K, you must convert them to the fertilizer basis of P_2O_5 or K_2O. This can be done with the following conversions:

$P \times 2.29 = P_2O_5$
$K \times 1.20 = K_2O$

Select a lab that reports an analysis on an "as-is" basis in the units of measure most useful to your operation.

Most useful information

The most useful information is predicted nutrients available for the first crop. Nutrient availability is predicted based on estimates of manure breakdown and nutrient loss according to application method. If the lab does not report plant-available nutrients, contact your nutrient management planner, a certified crop advisor, or your local extension office for assistance.

Of the total nutrients predicted to be available for the first crop, 50 to 75 percent will likely become available during the first month. It is, therefore, important to apply manure near the time nutrients are required by plants. The remaining nutrients gradually become available over the next three months. Nutrients not available for the first crop are slowly released to available forms over time. In soils that do not readily leach with heavy rainfall, nutrients may accumulate to significant quantities over time.

You should review the report to see if the analysis is within the expected ranges for your manure. It is common for manure analyses to vary between seasons, due to excess rainfall, drought, or changes in management practices. However, you should compare your results to the results from previous manure reports to ensure that they appear reasonable. If your results are significantly different from what you expected, it is advisable to resample the manure. The original sample may have been mislabeled or improperly collected, and thus not be representative of the manure.

To meet a specific plant nutrient requirement, nutrients listed in the report or calculated as "available for the first crop" should be used in determining the actual application rate. For the availability prediction to be reliable, you must have properly identified the type of manure and the application method on the information sheet submitted to the lab. It is important to understand that nutrient availability cannot be determined with 100 percent accuracy. Many variables, including the type of manure product and environmental factors (i.e., soil type, rainfall, temperature, and general soil conditions), influence the breakdown of the manure and nutrient loss. Remember, the worst sample of your manure is always better than the best book value.

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APPENDIX G - UNIVERSITY OF IDAHO BULLETIN #704 (REVISED)

Soil Sampling

Bulletin 704 (revised)

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College of Agriculture
University of Idaho
Cooperative Extension System

Soil Sampling

Environmental concerns have brought nutrient management in agriculture under increased scrutiny. A goal of sound nutrient management is to maximize the proportion of applied nutrients that is used by the crop (nutrient use efficiency). Soil sampling is a best management practice (BMP) for fertilizer management that will help improve nutrient use efficiency and protect the environment.

Soil sampling is also one of the most important steps in a sound crop fertilization program. Poor soil sampling procedures account for more than 90 percent of all errors in fertilizer recommendations based on soil tests. Soil test results are only as good as the soil sample. Once you take a good sample, you must also handle it properly for it to remain a good sample.

A good soil testing program can be divided into four operations: (1) taking the sample, (2) analyzing the sample, (3) interpreting the sample analyses, and (4) making the fertilizer recommendations. This publication focuses on the first step, collecting the soil sample.

Once you take a sample, you must send it to a laboratory for analysis. Then the Extension agricultural educator or fertilizer fieldman in your county can interpret the analysis and make specific fertilizer recommendations. Fertilizer guides from the University of Idaho Cooperative Extension System are also available to help you select the correct fertilizer application rate.

The soil sampling guidelines in this publication meet sampling standards suggested by federal, state, and local nutrient management programs in Idaho.

What is a soil test?

A soil test is a chemical evaluation of the nutrient-supplying capability of a soil at the time of sampling. Not all soil-testing methods are alike nor are all fertilizer recommendations based on those soil tests equally reliable.

Reliable fertilizer recommendations are developed through research by calibrating laboratory soil test values and correlating them with crop responses to fertilizer rates. These soil test correlation trials must be conducted for several years on a particular crop growing on a specific soil type. If soil test calibration is incomplete, fertilizer recommendations based on soil-test results still can only be best guesses.

A soil test does not measure the total amount of a specific nutrient in the soil. There is usually little relationship between the total amount of a nutrient in the soil and the amount of a nutrient that plants can obtain.

A soil test also does not measure the amount of plant-available nutrients in the soil because not all the nutrients in the soil are in a form readily usable by plants. Through research, however, a relationship can usually be established between soil test nutrient levels and the total amount of a nutrient in the soil.

What does a soil test measure?

Present soil-testing methods measure a certain portion of the total nutrient content of the soil. During testing, this portion is removed from the soil by an extracting solution that is mixed with the soil for a given length of time. The solution containing the extracted portion of the nutrient is separated from the soil by filtration, and then the solution is analyzed.

A low soil-test value for a particular nutrient means the crop will be unable to obtain enough of that nutrient from the soil to produce the highest yield under average soil and climatic conditions. A nutrient deficiency should be corrected by adding the nutrient as a fertilizer. The amount of nutrient that needs to be added for a given soil-test value is calculated based on results from the correlation research test plots.

Sampling timing

Because nutrient concentrations in the soil vary with the season, you should take soil samples as close as possible to planting or to the time of crop need for the nutrient. Ideally, take the soil samples 2 to 4 weeks before planting or fertilizing the crop. It usually requires 1 to 3 weeks to take a soil sample, get the sample to the testing laboratory, and obtain results.

Sampling very wet, very dry, or frozen soils will not affect soil test results though collecting soil samples under these conditions is difficult. Do not sample snow–covered fields. The snow makes it difficult to recognize and avoid unusual areas in the field, so you may not get a representative sample.

Sampling frequency

For best soil fertility management, especially for the mobile nutrients, sample each year and fertilize for the potential yield of the intended crop. Having an analysis performed for every nutrient each year is not necessary. Whether you need an analysis of a nutrient depends on such things as its mobility in the soil and the nutrient requirements of the crop.

Take soil samples at least once during each crop rotation cycle. Maintain a record of soil test results on each field to evaluate long-term trends in nutrient levels.

Sampling procedure

One of the most important steps in a soil testing program is to collect a soil sample that represents the area to be fertilized. If the soil sample is not representative, the test results and recommendations can be misleading.

The correct steps in soil sampling are illustrated in figure 1. Before sampling, obtain necessary information, materials, and equipment from the Extension agricultural educator or fertilizer fieldman in your county.

Use proper soil sampling tools. A soil auger or probe is most convenient, but you can use a shovel or spade for shallow samples. You will need a plastic bucket or other container for each sample to help you collect and mix a composite sample.

Be sure that all equipment is clean, and especially be sure it is free of fertilizer. Even a small amount of fertilizer dust can result in a highly erroneous analysis. Do not use a galvanized bucket when analyzing for zinc (Zn) or a rusty shovel or bucket when analyzing for iron (Fe). If the sample will be analyzed for Fe or manganese (Mn), do not dry the soil sample before shipping.

When sampling, avoid unusual areas such as eroded sections, dead furrows, and fence lines. If the field to be sampled covers a large area with

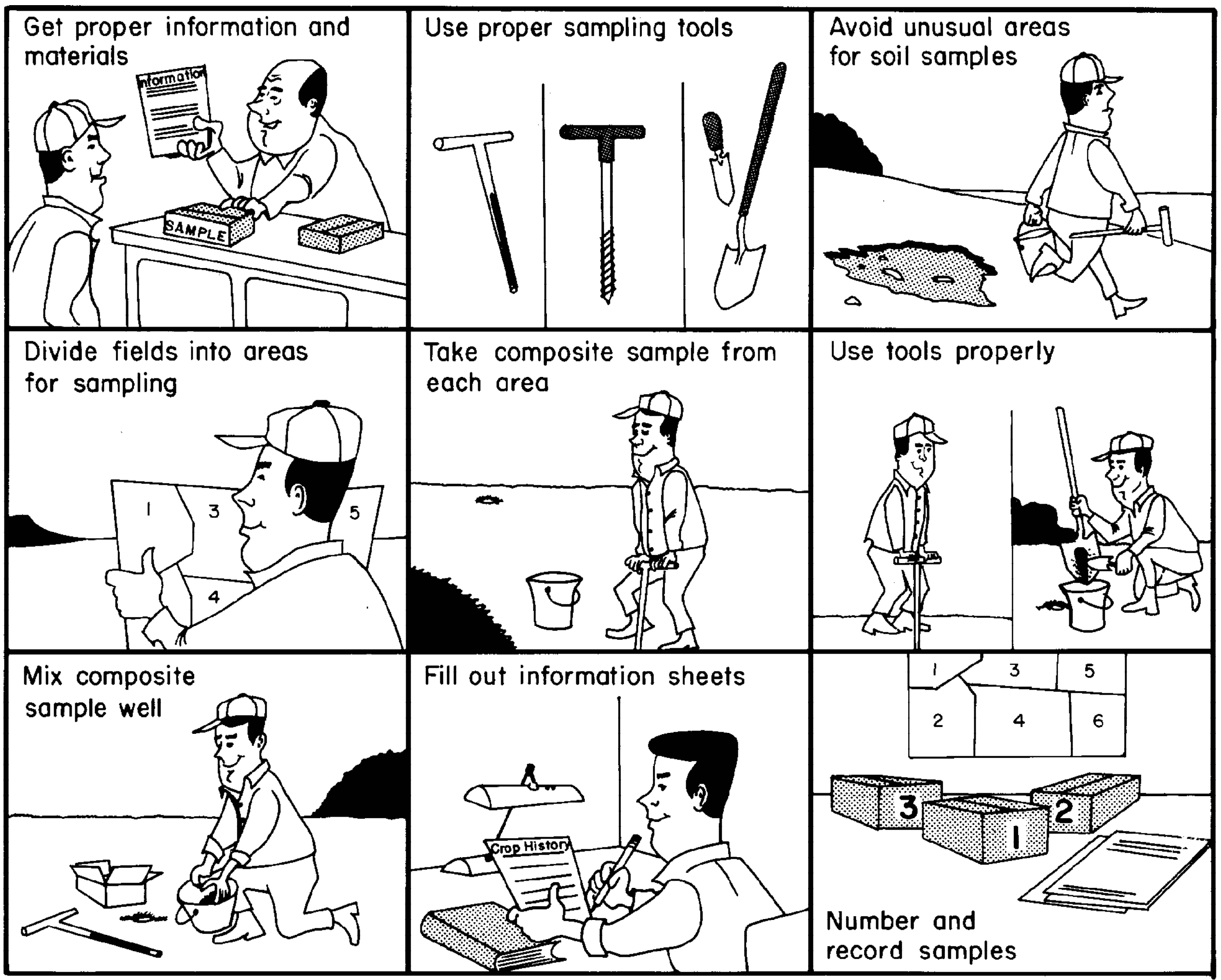

Fig. 1. Follow these steps to obtain a good sample for testing (redrawn courtesy of the National Fertilizer Institute).

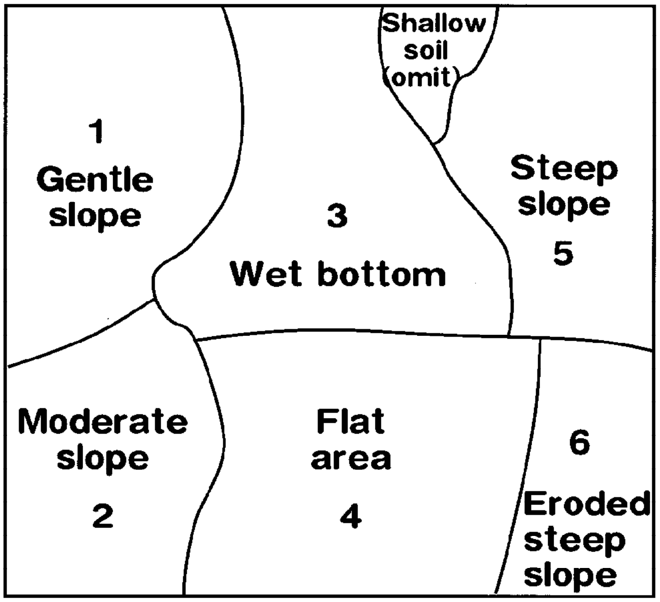

Fig. 2. A field with areas identified as sampling units.

Table 2. Effective rooting depth for some common Idaho crops.

Crop	Depth (feet)
Cereals (wheat, barley, oats)	5 to 6
Corn	5 to 6
Alfalfa, rapeseed	4 to 5
Hops, grapes, tree fruits	4 to 5
Sugarbeets	2 to 3
Peas, beans, lentils, onions, potatoes, mint	2
Vegetable seed	1 to $1^1/_2$

varied topography, subdivide it into relatively uniform sampling units (fig. 2). Sampling subdivision units that are too small to fertilize separately may be of interest, but impractical if you do not treat the small units differently from the rest of the field. Omit these areas from the sampling.

Within each sampling unit take soil samples from several different locations and mix these subsamples into one composite sample. The number of subsamples needed to obtain a representative composite sample depends on the uniformity and size of the sampling unit (table 1). Although the numbers of subsamples in table 1 give the best results, they may be unrealistic if you plan to take a great number of samples. An absolute minimum of 10 subsamples from each sampling unit is necessary to obtain an acceptable sample. The more subsamples you take, the better the representation of the area sampled.

Take all subsamples randomly from the sampling unit, but be sure to distribute subsample sites throughout the sampling unit. Meander or zig-zag throughout each sampling unit to sample the area. Special considerations are necessary in eroded areas, furrow irrigation, under no-till, and where fertilizer is banded (see "Special Sampling").

The total amount of soil you collect from the sampling unit may be more than you need for analyses. Mix the individual subsamples together thoroughly and take the soil sample from the composite mixture. The composite sample should be at least 1 pint—about 1 pound—in size.

Sampling depth

Depth of sampling is critical because tillage and nutrient mobility in the soil can greatly influence nutrient levels in different soil zones (fig. 3). Sampling depth depends on the crop. cultural practices, tillage depth, and the nutrients to be analyzed.

Because the greatest abundance of plant roots, greatest biological activity,

Table 1. Number of subsamples recommended for a representative composite sample based on field size.

Field size (acres)	Number of subsamples
fewer than 5	15
5 to 10	18
10 to 25	20
25 to 50	25
more than 50	30

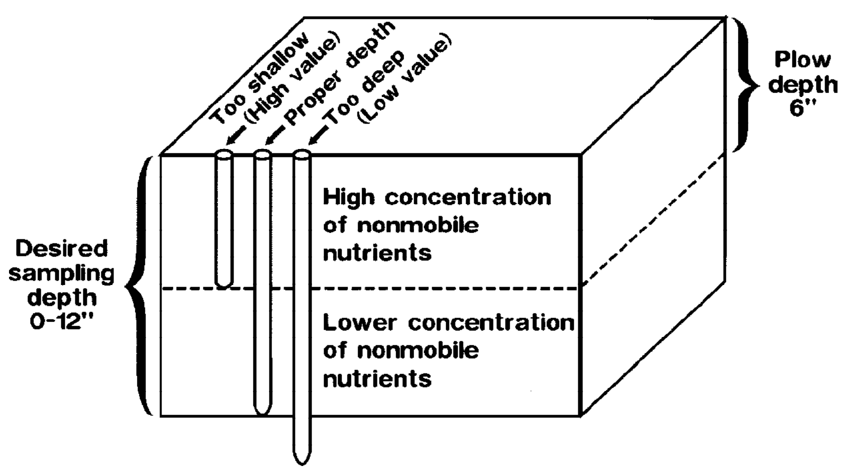

Fig. 3. Too deep or shallow a sampling depth can produce inaccurate soil test results. The plow layer is usually higher in nonmobile nutrients than the soil layers below it.

and highest nutrient levels occur in the surface layers, the upper 12 inches of soil are used for most analyses. The analyses run on the surface sample include soil reaction (pH), phosphorus (P), potassium (K), organic matter, sulfur (S), boron (B), zinc (Zn), and other micronutrients.

Sampling depth is especially critical for nonmobile nutrients such as P and K. The recommended sampling depth for nonmobile nutrients is 12 inches (fig. 3).

The tillage zone, typically 6 to 8 inches deep, usually contains a relatively uniform, high concentration of nonmobile nutrients. Below the tillage zone the concentration is usually lower. Therefore, a sample from the tillage zone will usually have a higher content of nonmobile nutrients than a sample from the desired 0- to 12-inch sample depth. This can lead to erroneous results.

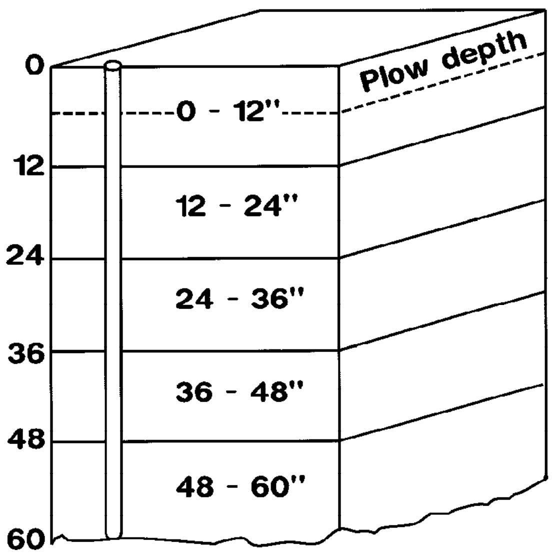

Fig. 4. Depth sampling (successive samples by 12-inch increments) for mobile nutrients (especially N) should be continued to rooting depth, which may be 5 to 6 feet for some crops.

Depth sampling

When sampling for mobile nutrients such as nitrogen (N), boron (B), and sulfur (S), take samples by 1-foot increments to the effective rooting depth of the crop (fig. 4). This can be a depth of 5 to 6 feet (table 2) unless the soil has a root-limiting layer such as bedrock or hardpan. For each foot depth, take 10 or more subsamples at random from the sampling unit.

If you plan to sample less than a year after banding or injecting fertilizer or if you have any question about fertilizer placement, use the sampling technique described under "Areas Where Fertilizer Has Been Banded." Irrigation or precipitation should disperse mobile nutrients over a period of a year.

Sample handling

Soil samples need special handling to ensure accurate results and minimize changes in nutrient levels because of biological activity. Keep moist soil samples cool at all times during and after sampling. Samples can be frozen or refrigerated for extended periods of time without adverse effects.

If the samples cannot be refrigerated or frozen soon after collection, air dry them or take them directly to the soil testing laboratory. Air dry by spreading the sample in a thin layer on a plastic sheet. Break up all clods or lumps, and spread the soil in a layer about 1/4 inch deep. Dry at room temperature. If a circulating fan is available, position it to move the air over the sample for rapid drying.

Caution: Do not dry where agricultural chemical or fertilizer fumes or dust will come in contact with the samples. Do not use artificial heat in drying. Ask the Extension agricultural educator or fertilizer fieldman in your county for more details concerning special handling of soil samples.

When the soil samples are dry, mix the soil thoroughly, crushing any coarse lumps. Take from the sample about 1 pint (roughly 1 pound) of well-mixed soil and place it in a soil sample bag or other container. Soil sample bags and soil test report forms are available from the Cooperative Extension System office in your county or from a fertilizer fieldman.

Label the bag carefully with your name, the sample number, sample depth, and field number. The field number should correspond with a field or farm map showing the areas

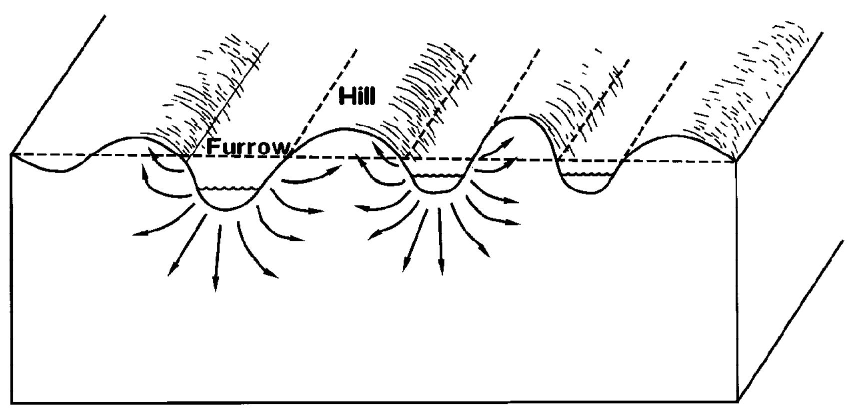

Fig. 5. Movement of mobile nutrients in furrow-irrigated fields.

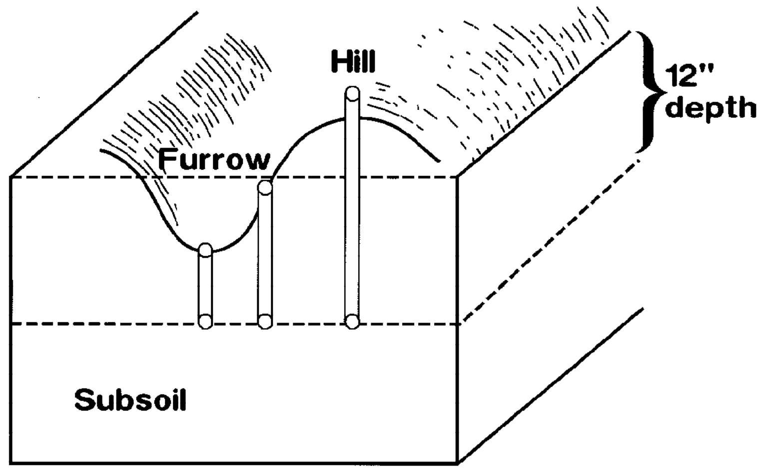

Fig. 6. Special sampling techniques are required when soil sampling furrow-irrigated fields. Take a sample from the hilltop, the furrow bottom, and at the midpoint between the hilltop and furrow bottom. The 12-inch sampling depth is based on the midpoint sampling location.

sampled. This will help you keep an accurate record of soil test reports. Provide information on crop to be grown, yield potential, recent history of crops grown, yields, fertilizer applied, and other information.

Sample analysis

Analyze regularly only for those nutrients that have been shown to be yield limiting in your area or for the crop to be grown. In general, all soils should be analyzed for N, P, K, and S . For determination of potential need for micronutrients, refer to PNW 276, *Current Nutrient Status of Soils in Idaho, Oregon, and Washington*. Occasional analyses for micronutrient concentrations may be advisable.

Special sampling

Special sampling problems occur in fields that have been leveled for irrigation, fields that have lost all or most topsoil as a result of erosion, fields that are surface (furrow) irrigated, fields that have had a fertilizer band applied, and fields that are not thoroughly tilled.

Land-leveled and eroded areas

Areas that have been eroded or artificially leveled for irrigation usually have little or no original topsoil. The soil surface may be exposed subsoil material. These areas should be sampled separately if they are large enough to be managed differently from where topsoil has not been removed. Subsoil material is usually low in organic matter and can be high in clay, calcium carbonate (lime), or both.

Furrow-irrigated fields

For a representative soil sample, sample furrow-irrigated fields before the furrowing operation. If furrowing has already been completed, follow the special sampling procedures described here.

The movement of water and dissolved plant nutrients can create unique nutrient distribution patterns in the hills between the furrows (fig. 5). To obtain a representative sample, you need to be aware of furrow direction, spacing, and location, and to take closely spaced soil samples perpendicular to the furrow (fig. 6).

Approximately 20 sites (with at least three samples per site) are needed for a representative composite soil sample. At each sampling site, take a sample from the hilltop, from the midpoint between the hilltop and furrow, and from the furrow bottom. The sampling depth at the midpoint between the hilltop and furrow bottom should be 12 inches. The bottom point of this sample should be the same as for the furrow and hilltop samples. Thus, the furrow sampling depth will be less than 12 inches, while the hilltop sampling depth will be more than 12 inches (fig. 6).

Mix the hilltop, midpoint, and furrow samples to make a composite sample for each site. Mix the site samples for a representative composite field soil

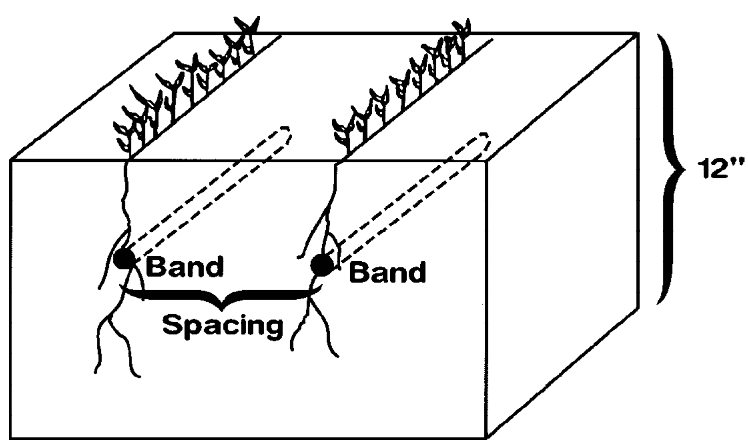

Fig. 7. Diagram of fertilizer location in soil where fertilizer has been banded.

sample to be analyzed for nonmobile nutrients (P, K, and micronutrients). Deeper profile sampling (depth sampling) is recommended for mobile nutrients (N and S).

Areas where fertilizer has been banded

Banding of fertilizers is becoming a more common practice (fig. 7). In fields where fertilizers have been banded and tillage has occurred before soil sampling, regular sampling procedures can be followed. However, if tillage has not adequately mixed the soil, special soil sampling is required. If a field has had a banded fertilizer application the previous growing season and has not been plowed, an ideal sample would be a continuous slice 1 to 2 inches thick and 12 inches deep extending from the center of one band to the center of the next band.

Little research has been conducted to determine the best method of sampling banded fields. Currently three different approaches are used widely. Each method produces a satisfactory representative sample, but the effort required to obtain these samples differs considerably.

Systematic sampling method. If you know the direction, depth, and spacing of the fertilizer band, you can obtain a representative soil sample with this sampling procedure. Take 5 to 10 soil samples perpendicular to the band row beginning in the edge of a fertilizer band and ending at the edge of an adjacent band (fig. 8). Follow this procedure on at least 20 sampling sites in each field or portion of a field being sampled. Mix and composite the soils collected from each site to obtain a representative soil sample.

Controlled sampling method. You also should know the direction, depth, and spacing of the fertilizer bands to obtain a representative soil sample with this method. Take 20 to 30 soil cores from locations scattered throughout the field or portion of the field. Avoid sampling directly in a fertilizer band.

The composite sample should adequately represent the area being sampled. This method may result in slightly lower soil test values of nonmobile nutrients (P, K, and micronutrients) than the systematic and random sampling methods.

Random sampling method. Use this sampling method when the location of the previous season's fertilizer bands is not known. Take 40 to 60 random soil cores to form a composite sample of the area being sampled.

Reduced tillage or no-till fields

You may need special approaches to soil sampling with reduced tillage or no-till fields because the soil has been disturbed so little that fertilizer, whether broadcast on the surface or banded below the surface, is not mixed into the soil. You need to know the history of fertilization, tillage, and other management practices to determine how to obtain a representative sample.

If nonmobile nutrients (P, K, and micronutrients other than B) have been surface broadcast and little or no tillage has been used since their application, remove the surface 1 inch of soil before sampling. Nutrients in the top inch of soil will probably not be available to the growing crop.

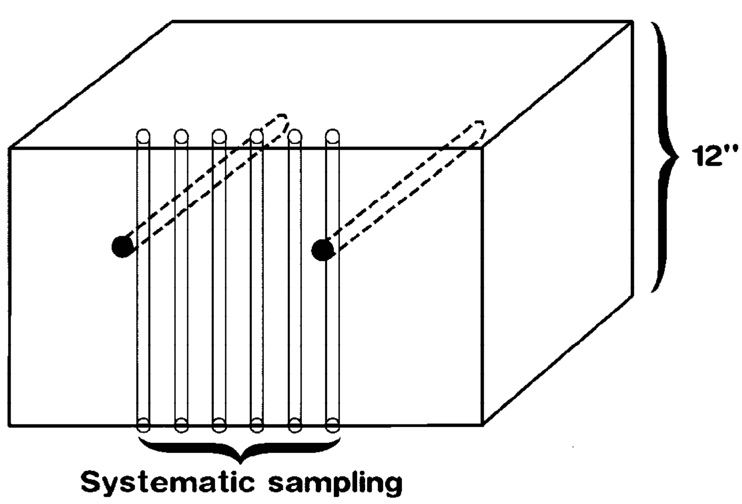

Fig. 8. Systematic soil sampling in a field where fertilizer has been banded (sampling method 1).

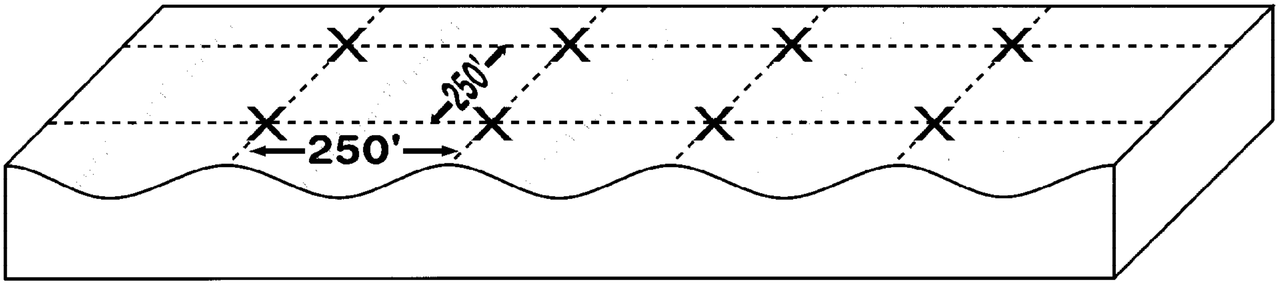

Fig. 9. Grid soil sampling pattern where samples are collected every 250 feet. Note that a complete soil sample is collected at each spot marked with an X.

If fertilizer has been banded with the no-till system, consider methods suggested in "Areas Where Fertilizer Has Been Banded." If a field has been under a continuous no-till system for a long time, determine the pH of the surface foot at 3-inch intervals (0 to 3, 3 to 6, 6 to 9, 9 to 12 inches) every 3 to 5 years. Soil pH will affect the availability of fertilizer nutrients as well as the activity of commonly used herbicides, insecticides, and fungicides.

Grid sampling in nonuniform fields

Many fields are not uniform and vary both horizontally and vertically across landscapes. Traditional soil sampling procedures average nutrient levels in soil subsamples to determine average nutrient levels in the field. The nutrient values obtained are good, but the manager must realize that many of the values in the field are either less than or greater than the values determined. When fields are broken into grids with shorter distances between the sampling points a more precise soil map can be developed to determine nutrient needs.

The technology is now available to combine grid sampling with variable rate fertilizer application to handle spatial variability within a field. These application techniques make fertilizer nutrient application more precise, resulting in greater nutrient use efficiency and reducing pollution potential.

Irrigated fields including individual pivots should be set up in a 200- to 300-foot grid for potato, sugarbeets, corn, and other potentially high-N-use crops (fig. 9). A wider grid of 400 feet may be used for small grains, beans, and other crops where N management is less intensive or under dryland conditions.

Soil nutrient needs for each segment of the grid are entered into a computer-driven system mounted on specialized commercial fertilizer application equipment. Variable rates of nutrients are then applied based on individual soil samples over the entire field.

A similar system designed for fertilizer applications through pivot sprinklers is being developed by the University of Idaho. This system has the potential to apply variable rates of nutrients and water specifically related to changes across individual fields.

The Soil Conservation Service has a digitized soil survey information system (SSIS), which when combined with the results of grid sampling provides specific information and recommendations for soils and soil types within a field. The SSIS can locate pockets of sandy or coarse-textured soils where leaching is a major concern or areas of finer-textured soils where pockets of residual N may occur. The SSIS also indicates where erosion or surface runoff may be high and where areas should be targeted for federal programs such as the Conservation Reserve Program.

Another computer-mapping technique, Geographic Information Systems (GIS), can be combined with the results of grid sampling to provide growers and land managers with information for land-use planning.

Additional information on proper soil sampling procedures can be obtained from the Extension agricultural educator or fertilizer fieldman in your county.

The authors—Robert L. Mahler, soil scientist, Moscow, and Terry A. Tindall, former Extension soil scientist, Twin Falls Research and Extension Center; both with the University of Idaho Department of Plant, Soil, and Entomological Sciences.

Issued in furtherance of cooperative extension work in agriculture and home economics, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, LeRoy D. Luft, Director of Cooperative Extension System, University of Idaho, Moscow, Idaho 83844. The University of Idaho provides equal opportunity in education and employment on the basis of race, color, religion, national origin, age, gender, disability, or status as a Vietnam-era veteran, as required by state and federal laws.

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APPENDIX H - ANNUAL REPORT TEMPLATE

CAFO ANNUAL REPORT FORM

Submit a copy of this form to the U.S. Environmental Protection Agency (EPA), Region 10, by March 1st of each year to report data for the previous calendar year:

EPA Region 10
Attn: NPDES Compliance Unit
Office of Compliance and Enforcement
1200 6th Avenue, Suite 900
Mail Stop: OCE-133
Seattle, WA 98101

Also submit a copy of the form to the Idaho State Department of Agriculture (ISDA):

ISDA
Division of Animal Industries
P.O. Box 790
Boise, ID 83701

The reporting period for the information list below is January 1 – December 31, ____________.

1. Facility Information

a. Name of CAFO (as listed in the facility's written notification of permit coverage)

____

b. Permit Number (as listed in the facility's written notification of permit coverage)

____

Contact Information (provide the name, telephone number, and email address of the person to be contacted about the information contained in this report)

c. Name: ____

d. Telephone: (____________)_____________-____________________________________

e. Email: ____

2. Animal Inventory

For each type of animal confined at this facility, whether in open confinement or housed under roof, list the type and maximum number confined during the year.

Animal Type	Number Confined

3. Manure, Litter, and Process Wastewater Generated and Transferred

Estimate the total amount of manure, litter, and process wastewater generated at this facility and transferred to other persons (i.e., for use on land not under the control of the permitted CAFO or other use or disposal not under the CAFO's control) during the reporting period. Indicate the units (tons or cubic feet) for manure and litter.

	Units	Amount Generated	Amount Transferred
Manure	☐ tons or ☐ ft^3		
Litter	☐ tons or ☐ ft^3		
Process Wastewater	☐ gallons or ☐ ft^3		

4. Production Area Discharges

For each discharge of manure, litter, or process wastewater from the production area during the reporting period, list the date, time, and approximate volume of the discharge.

Discharge date (mm/dd/yyyy)	Time (specify AM or PM)	Approximate volume (specify gallons or other units)

5. Nutrient Management Plan

Was the current version of the CAFO's NMP developed or approved by a certified nutrient management planner?

☐ Yes ☐ No

6. Acres for Land Application

a. Total number of acres for land application covered by the CAFO's nutrient management plan (NMP)

_____________________ Acres

b. Total number of acres under the control of the CAFO used for land application of manure, litter, or process wastewater during the reporting period

_____________________ Acres

7. Crops and Yields

For each field, list the field ID as listed in the CAFO's NMP, the actual crop(s) planted, and the actual yield for each crop harvested during the reporting period. Use multiple lines for double cropping or cover crops. In the last column, check the box to indicate whether the crop was seeded during the year prior to the period covered by this report. Use Table A.7 in Attachment A to list additional fields and crops if needed.

☐ Check here to indicate whether additional fields and crops are listed in Attachment A.

Field ID	Crop	Yield (specify units per acre, e.g., tons, bushels, cwt)	Seeded in previous year?
			▣
			▣
			☐
			☐
			☐
			☐
			☐
			☐
			☐
			☐
			☐
			☐

8. Manure, Litter, and Process Wastewater Application

Provide the total amount of manure, litter, and process wastewater applied to each field during this reporting period. Indicate the units used for manure and litter. Also list the amount of plant-available nitrogen and phosphorus from manure, litter, and process wastewater applied to each field during the reporting period. Use Table A.8 in Attachment A to list additional fields if needed.

☐ Check here to indicate whether additional fields are listed in Attachment A.

Field ID	**Manure applied** (☐ tons/acre or ☐ ft³/acre)	**Litter applied** (☐ tons/acre or ☐ ft³/acre)	**Wastewater applied** (gallons/acre)	**Nutrients applied*** (pounds/acre)	
				PAN	**P**

*Total pounds of plant-available nitrogen (PAN) and phosphorus (P) applied per acre. For PAN, include NO_3, NH_4, and the portion of organic N applied (if any) that is expected to be available to the current crop, determined consistent with the annual nutrient budget.

9. Soil Sample Analyses

For each field, list the analytical results for the most recent soil analysis for pH, soil organic matter (SOM), nitrate (NO_3-N), ammonium (NH_4-N), and phosphorus (P). Include units. Use Table A.9 in Attachment A to list additional fields if needed.

☐ Check here to indicate whether additional fields are listed in Attachment A.

Field ID	**pH**	**SOM**	**NO_3 N**	**NH_4 N**	**P**

10. Manure, Litter, and Process Wastewater Sample Analyses

For each source of manure, litter, or process wastewater land applied during the reporting period, list the analytical results for the most recent analysis. Include units.

Source of manure or wastewater (e.g., storage structure)		NH_4 N	TKN	NO_3 N	P	☐ Total Solids or ☐ Dry Matter
	Units:					

11. Nutrient Budgets

For each field provide the calculated amount manure, litter, and process wastewater, as well as plant-available nitrogen and phosphorus to be applied (in lbs/acre), based on the annual nutrient budget included in the NMP. Indicate the units for manure and litter. Use Table A.11 in Attachment A to list additional fields if needed.

☐ Check here to indicate whether additional fields are listed in Attachment A.

Field ID	Manure (☐ tons/acre or ☐ ft^3/acre)	Litter (☐ tons/acre or ☐ ft^3/acre)	Wastewater (gallons/acre)	Nutrients * (pounds/acre)	
				PAN	P

*Total pounds of plant-available nitrogen (PAN) and phosphorus (P) planned per acre. For PAN, include NO_3, NH_4, and the portion of organic N applied (if any) that is expected to be available to the current crop, from the annual nutrient budget.

12. Certification

Print the form and sign the certification statement below before submittal.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

____

Name of Certifying Official (print or type)

____

Signature

____

Date Signed

NOTE: This report must be signed and certified by a responsible corporate officer (corporation), a general partner (partnership), or the proprietor (sole proprietorship). The report may be signed by a duly authorized representative of the corporate officer, general partner, or proprietor if:

i. The authorization is made in writing by the corporate officer, general partner, or proprietor, and
ii. The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated facility or activity, or an individual or position having overall responsibility for environmental matters for the company; and
iii. The written authorization is submitted to the Director of EPA Region 10’s Office of Compliance and Enforcement.

Attachment A – Additional Data Tables

Use the tables below if additional rows are needed to provide the information requested in the form.

Table A.7. Crops and Yields

Field ID	**Crop**	**Yield** (specify units per acre, e.g., tons, bushels, cwt)	**Seeded in previous year?**
			☐
			☐
			☐
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Field ID	Crop	Yield (specify units per acre, e.g., tons, bushels, cwt)	Seeded in previous year?
			☐
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			☐

A.8. Manure, Littler, and Process Wastewater Application

Field ID	Manure applied (☐ tons/acre or ☐ ft^3/acre)	Litter applied (☐ tons/acre or ☐ ft^3/acre)	Wastewater applied (gallons/acre)	Nutrients applied* (pounds/acre)	
				PAN	P

Field ID	Manure applied (☐ tons/acre or ☐ ft^3/acre)	Litter applied (☐ tons/acre or ☐ ft^3/acre)	Wastewater applied (gallons/acre)	Nutrients applied* (pounds/acre)	
				PAN	P

A.9. Soil Sample Analysis

Field ID	pH	SOM	NO_3 N	NH_4 N	P

Field ID	pH	SOM	NO_3 N	NH_4 N	P

A.11. Nutrient Budgets

Field ID	Manure (☐ tons/acre or ☐ ft^3/acre)	Litter (☐ tons/acre or ☐ ft^3/acre)	Wastewater (gallons/acre)	Nutrients * (pounds/acre)	
				PAN	P

Field ID	**Manure** (☐ tons/acre or ☐ ft^3/acre)	**Litter** (☐ tons/acre or ☐ ft^3/acre)	**Wastewater** (gallons/acre)	**Nutrients *** (pounds/acre)	
				PAN	**P**

APPENDIX I - IDAHO PHOSPHORUS SITE INDEX

The Phosphorus Site Index:

A Systematic Approach to Assess the Risk of Nonpoint Source Pollution of Idaho Waters by Agricultural Phosphorus

Dr. April Leytem
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USDA- ARS

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Supervisory Agricultural Engineer
USDA-ARS

Dr. David Tarkalson
Research System Agronomist
USDA-ARS

2017

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INTRODUCTION

Why is phosphorus a concern for Idaho?

Water quality in Idaho has been negatively impacted by the inputs of nutrients from both point and nonpoint sources. The two nutrients of greatest concern are nitrogen (N) and phosphorus (P). Efforts to reduce nutrient enrichment of ground and surface waters have become a high priority for state and federal agencies and a matter of considerable importance to all nutrient users and nutrient generators in the state. Two actions in particular highlight the importance of this issue in Idaho:

- Total Maximum Daily Load (TMDL) Program: Section 303(d) of the Federal Clean Water Act (CWA) of 1972 requires states to develop a list of water bodies that need pollution reduction beyond that achievable with existing control measures. These water bodies are referred to as "Water Quality Limited" and are compiled by each state on a "303(d) list". States are required to develop a "total maximum daily load (TMDL)" for a number of pollutants, including nutrients for these "water quality limited" waters. A TMDL is defined as "the level of pollution or pollutant load below which a water body will meet water quality standards and thereby allow use goals such as drinking water supply, swimming and fishing, or shellfish harvesting". In ID, approximately 36% of streams were identified as not meeting water quality standards. The TMDL for the upper and middle Snake River was set at 0.075 mg total P L^{-1}.

- Idaho Statute Title 37 Chapter 4 Section 37-40, passed in 1999 requires that all dairy farms shall have a nutrient management plan approved by the Idaho State Department of Agriculture. The nutrient management plan shall cover the dairy farm site and other land owned and operated by the dairy farm owner or operator. Nutrient management plans submitted to the department by the dairy farm shall include the names and addresses of each recipient of that dairy farm's livestock waste, the number of acres to which the livestock waste is applied and the amount of such livestock waste received by each recipient. The information provided in this subsection shall be available to the county in which the dairy farm, or the land upon which the livestock waste is applied, is located. If livestock waste is converted to compost before it leaves the dairy farm, only the first recipient of the compost must be listed in the nutrient management plan as a recipient of livestock waste from the dairy farm. Existing dairy farms were required to submit a nutrient management plan to the department on or before July 1, 2001, and plans are required to be updated every 5 years.

What is a Phosphorus Site Index?

In the early 1990's the U.S. Department of Agriculture (USDA) began to develop assessment tools for areas with water quality problems. While some models such as the Universal Soil Loss Equation (USLE) for erosion, and Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) for ground water pollution, were already being used to screen watersheds for potential agricultural impacts on water quality, there was no model considered suitable for the field-scale assessment of the potential movement of P from soil to water. A group of scientists from universities and governmental agencies met in 1990 to discuss the potential movement of P from soil to water, and later formed a national work group (PICT: Phosphorus Index Core Team) to more formally address this problem. Members of the PICT soon realized that despite the many scientists conducting independent research on soil P, there was a lack of integrated research that could be used to develop the field scale assessment tool for P needed by USDA. Consequently, the first priority of PICT was a simple, field-based, planning tool that could integrate through a multi-parameter matrix, the soil properties, hydrology, and agricultural management practices within a defined geographic area, and thus to assess, in a relative way, the risk for P movement from soil to water. The initial goals of the PICT team were:

- *To develop an easily used field rating system (the **Phosphorus Site Index**) for Cooperative Extension, Natural Resource Conservation Service (NRCS) technical staff, crop consultants, farmers or others that rates soils according to the potential for P loss to surface waters*

- *To relate the P Site Index to the sensitivity of receiving waters to eutrophication.* This is a vital task because soil P is only an environmental concern if a transport process exists that can carry particulate or soluble P to surface waters where eutrophication is limited by P.

- *To facilitate adaptation of the P Site Index to site specific situations.* The variability in soils, crops, climates and surface waters makes it essential that each state or region modify the parameters and interpretation given in the original P Index to best fit local conditions.

- *To develop agricultural management practices that will minimize the buildup of soil P to excessive levels and the transport of P from soils to sensitive water bodies.*

The *P Site Index* is designed to provide a systematic assessment of the risks of P loss from soils, but does not attempt to estimate the actual quantity of P lost in runoff. Knowledge of this risk not only allows us to design best management practices (BMPs) that can reduce agricultural P losses to surface waters, but to more effectively prioritize the locations where their implementation will have the greatest water quality benefits.

It has long been known that P loss depends on not only the amount of P in or added to a soil but the transport processes that control soil and water movement from fields to waterways. Therefore, when assessing the risk of P loss from soil to water, it is important that we not focus strictly on measures of P, such as agronomic soil test P value. Rather a much broader, multi-disciplinary approach is needed; one that recognizes that P loss will vary among watersheds and soils, due to the rate and type of soil amendments used, and due to the wide diversity in soils, crop management practices, topography, and hydrology. At a minimum, any risk assessment process for soil P shall include the following:

- Characteristics of the P source (fertilizer, manure, biosolids) that influence its solubility and thus the potential for movement or retention of P once the source has been applied to a soil.

- The concentration and bioavailability of P in soils susceptible to loss by erosion.

- The potential for soluble P release from soils into surface runoff or subsurface drainage.

- The effect of other factors, such as hydrology, topography, soil, crop, and P source management practices, on the potential for P movement from soil to water.

- Any "channel processes" occurring in streams, field ditches, etc. that mitigate or enhance P transport into surface waters.

- The sensitivity of surface waters to P and the proximity of these waters to agricultural soils.

In summary, when resources are limited, it is critical to target areas where the interaction of P source, P management, and P transport processes result in the most serious risk of losses of P to surface and shallow ground waters. This is the fundamental goal of the *P Site Index*.

Phosphorus Site Index

The *P Site Index* has two separate components (Table 1). Part A characterizes the risk of P loss based on site-specific soil properties and hydrologic considerations. Part B characterizes the risk of P loss based on site-specific past and current nutrient management practices that affect the concentration of P in the soil (soil test P) and the potential for P loss due to management of inorganic (fertilizer) and organic (manures, composts, etc.) P sources. Parts A and B are summarized below, followed by a detailed discussion and descriptions of each component of the two parts. Generalized interpretations of the *P Site Index* values are given in Table 2.

Part A: Phosphorus Loss Potential Due to Site and Transport Characteristics

Surface transport mechanisms, i.e. soil erosion and runoff are generally the main mechanisms by which P is exported from agricultural fields to receiving waters. In some areas, leaching of P can also be a significant method of P export, especially in areas with artificial subsurface drainage (e.g. tiles, mole drains) high water tables, or shallow soils overlying basalt. Therefore, the considerations of the methods of P transport factors affecting these transport mechanisms are critical to an understanding of P losses from watersheds. Part A includes the following four factors: (i) soil erodibility; (ii) soil surface runoff index; (iii) leaching potential; and (iv) distance from edge of field to surface water.

Part B: Phosphorus Loss Potential Due to P Source and Management Practices

Phosphorus losses are also related to the amount and forms of P at a site which can potentially be transported to ground or surface waters. The main sources of P at any site that must be considered in assessing the risk of P loss are (i) soil P (particulate and dissolved), a reflection of natural soil properties and past management practices: and (ii) P inputs such as inorganic fertilizers and organic P sources (manures, composts, biosolids). Also of importance are the management practices used for all P inputs, such as the rate, method, and timing of fertilizer and manure applications, as these factors will influence whether or not P sources will have negative impacts on water quality. Part B includes the following three factors: (i) soil test P value; (ii) P applications rate; and (iii) P application method.

Table 1. The *Phosphorus Site Index* proposed for use in Idaho

Part A: Phosphorus loss potential due to site and transport characteristics

Characteristics	**Phosphorus Loss Rating**					**Field Value**
Soil Erodibility	Very Low **0**	Low **1**	Medium **2**	High **4**	Very High **8**	
Soil Surface Runoff Index – Surface Irrigated	No Runoff **0**	Water runs off less than 50% of the irrigation set time **4**		Water runs off more than 50% of the irrigation set time **8**		
Soil Surface Runoff Index – Sprinkler or Non-Irrigated	Very Low **0**	Low **1**	Medium **2**	High **4**	Very High **8**	
Leaching Potential	Low **1**		Medium **2**	High **4**		
Distance from Edge of Field to Surface Water	> 2,640' **0**		200-2,640' **2**	< 200' **8**		

Part B: Phosphorus loss potential due to P source and management practices.

Characteristics	**Phosphorus Loss Rating**					**Field Value**
	Very Low	Low	Medium	High	Very High	
Soil Test P value	**0.05** x [Olsen Soil Test P (ppm)] **0.025** x Bray Soil Test P (ppm)]					
P Application Rate (lbs P_2O_5 applied per acre)	No Application **0**	< 60 **1**	60 – 150 **2**	151 – 300 **4**	>300 **8**	
P Application Method	None Applied **0**	Incorporated within 2 days or injected/banded below surface at least 3" **1**	Incorporated within 7 days of application **2**	Incorporated > 7 days or no incorporation when applied between February 16 and December 15 **4**	Application between December 16 and February 15 **8**	

Table 2. Generalized interpretations of the *P Site Index.*

***P Site Index* Value**	**Generalized Interpretation of the *P Site Index* Value**
< 75	**LOW** potential for P movement from this site given current management practices and site characteristics. There is a low probability of an adverse impact to surface waters from P losses from this site. Nitrogen-based nutrient management planning is satisfactory for this site. Soil P levels and P loss potential may increase in the future due to N-based nutrient management planning.
75 - 150	**MEDIUM** potential for P movement from this site given current management practices and site characteristics. Phosphorus applications shall be limited to the amount expected to be removed from the field by crop harvest (crop uptake) or soil test-based P application recommendations. Testing of manure P prior to application is required.
151 – 225	**HIGH** potential for P movement from this site given the current management practices and site characteristics. Phosphorus applications shall be limited to 50% of crop P uptake. Testing of manure P prior to application is required.
> 225	**VERY HIGH** potential for P movement from this site given current management practices and site characteristics. No P shall be applied to this site.

Usage of the Idaho *Phosphorus Site Index*

The Phosphorus Site Index is a risk assessment tool to help determine the potential for off-site transport of phosphorus from agricultural fields. It is intended to be used as an integral and interactive part of the nutrient management plan to help guide applications of manure and fertilizers to minimize potential P losses from agricultural fields, and to identify fields that may require additional management to reduce P losses even when P applications are not planned. The PSI is also a valuable educational tool to assist producers in recognizing high risk areas, allowing them to focus conservation practices where they would be of most value.

A PSI rating shall be done for each field. Fields that do not receive manure and fertilizer shall only be assessed once until there is a planned application of P. The PSI shall be calculated prior to P application for each field using the planned management and P application rate along with current soil test P results. The risk rating will determine whether or not the P application on the field is allowable, given the current management. For example, if the risk assessment was completed with inputs for the field source factors (soil test P, planned P application rates, and planned application method and timing) and the field received a low rating, then application and management can continue according to plan. If, however, the risk rating is in a medium category, P application will be limited to crop uptake. If the risk rating is in a higher category, BMPs will need to be implemented on the field in order to reduce the potential for P loss, and/or the P application rates must be limited or prohibited in order to reduce the risk of P losses from the field. Producers can receive full credit for maximum of two (2) BPMs per field at any given time. In addition, testing of manure prior to application will be required for fields having a risk rating above low.

When a perennial crop such as alfalfa is part of the rotation, or when allowable manure application rates are below a reasonable application rate (<10 tons/acre for manure and <5 tons/acre for composted manure) then a producer may be allowed to apply up to a four year application rate at one time with no further application over the remainder of the time period that the nutrients have been allocated to. For example, a field with a medium rating beginning a four-year rotation of alfalfa could apply a maximum of four times the annual excepted crop P uptake rate in the first year with no additional P application for the next three years; or a field with a high rating beginning a four-year rotation of alfalfa could apply a maximum of two times the annual expected crop P uptake rate in the first year, and the following three years of alfalfa could receive no additional P.

Phosphorus Site Index:
Part A: Phosphorus Loss Potential Due to Site and Transport Characteristics

Soil Erosion

Phosphorus is strongly sorbed by soils, therefore erosion of soil materials dominates the movement of particulate P in landscapes (Bjorneberg et al., 2002; Leytem and Westermann, 2003). Up to 90% of the P transported from surface irrigated crops is transported with eroded sediment (Berg and Carter, 1980). In contrast to rainfall, irrigation is a managed event. Runoff and soil erosion should be minimal from properly managed sprinkler irrigation or drip irrigation. Water flowing over soil during surface irrigation will detach and transport sediment. Annual soil loss from furrow irrigated fields can range from less than 1 to greater than 100 tons per acre (Berg and Carter, 1980; Koluvek et al., 1993). Typically, greater than 90% of the P in surface irrigation runoff from clean-tilled row-crop fields is transported with eroded sediment. Conversely, when erosion is minimal from crops such as alfalfa and pasture, greater than 90% of the total P is dissolved in the runoff water (Berg and Carter, 1980). Total P concentration in surface irrigation runoff correlates directly with sediment concentration (Fitzsimmons et al., 1972, Westermann et al., 2001). Dissolved reactive P concentration in surface irrigation runoff, on the other hand, correlates with soil test P concentration, but not with sediment concentration (Westermann et al., 2001). During detachment and movement of sediment in runoff, the finer-sized fractions of source material are preferentially eroded. Thus, the P content and reactivity of eroded particulate material is usually greater than the source soil (Carter et al., 1974; Sharpley et al., 1985). Therefore, to minimize P loss in the landscape, it is essential to control soil erosion. Particulate P movement in the landscape is a complex function of rainfall, irrigation, soil properties affecting infiltration and runoff of irrigation/rainfall/snowmelt, and soil management factors affecting erosion. Numerous management practices that minimize P loss by erosion are available including filter strips, contour tillage, cover crops, use of polyacrylamide and impoundments or small reservoirs.

Soil erosion can be estimated from erosion prediction models such as the Universal Soil Loss Equation (USLE) or the Revised Universal Soil Loss Equation (RUSLE) for water erosion and Wind Erosion Equation (WEQ) for wind erosion. However, neither USLE nor RUSLE can accurately predict irrigation erosion. Therefore, the potential for soil erosion is based on the erodibility of the soil along with the predominant slope of the field. While this factor does not predict sediment transport and delivery to a water body, it does indicate the potential for sediment and attached P movement across the slope or unsheltered distance toward a water body.

For the *Phosphorous Site Index*, the potential for soil erosion loss is determined by the erodibility of the soil (K_w factor) along with the slope of the field Table 3.

Table 3. Soil erodibility factor

Kw factor - surface mineral layer Whole Soil	Slope Gradients				
	< 2%	2 – 5%	5 – 10%	10 – 15%	> 15%
<= 0.10 Very low erodibility	Very Low	Very Low	Very Low	Very Low	Low
0.11 – 0.20 Low erodibility	Very Low	Very Low	Very Low	Low	Medium
0.21 – 0.32 Moderate erodibility	Very Low	Low	Low	Medium	High
0.33 – 0.43 High erodibility	Low	Low	Medium	High	Very High
0.44 – 0.64 Very high erodibility	Low	Medium	High	Very High	Very High

All factors shall be determined by using the NRCS soil survey data (Web Soil Survey) with field verification of the predominant slope in the field. **The soil erodibility value will range from very low to very high and shall be assigned a value of 0 (very low) to 8 (very high) and used in the calculation of the *P Site Index* (Table 1).**

Runoff Index

Dissolved P (DP) is another important source of P that is transported in surface runoff. Dissolved P exists mainly in the form of orthophosphate, which is available immediately for uptake by algae and other aquatic plants. The first step in the movement of DP in runoff is the desorption, dissolution, and extraction of P from soils, crop residues, and surface applied fertilizer and manure (Sharpley et al., 1994). These processes occur as irrigation water, rainfall, or snowmelt water interacts with a thin layer of surface soil (0.04 to 0.12 in) before leaving the field as runoff or leaching downward in the soil profile (Sharpley, 1995). The soil test P content of surface soils has been found to be directly related to DP concentrations in runoff. Field studies have shown that P losses by surface runoff are greater when soil test P values are above the agronomic optimum range (Turner et al., 2004). Laboratory research has also shown that soils with high agronomic soil test P values are more likely to have high concentrations of soluble, desorbable, and bioavailable P (Paulter and sims, 2000; Sibbensen and Sharpley, 1997; Sims, 1998b). In furrow irrigation runoff, even soil with low soil test P can have high runoff DP concentrations (Westermann et al., 2001).

For the *P Site Index*, soil runoff index is determined differently for surface irrigated vs sprinkler irrigated or fields with no irrigation. For surface irrigated fields use Table 4, for sprinkler irrigated or non-irrigated fields use Table 5.

Table 4. Runoff index for surface irrigated fields:

Criteria	**Value**
Fields with no runoff	0
Fields with water running off less than 50% of the irrigation set time	4
Fields with water running off 50% or more of the irrigation set time	8

Table 5. Runoff index for sprinkler or non-irrigated fields.

Hydrologic Soil Group	Slope Gradients				
	< 2%	2 – 5%	5 – 10%	10 – 15%	> 15%
A: Low Runoff Potential	Very Low	Very Low	Low	Medium	High
B: Moderately Low Runoff Potential	Very Low	Low	Medium	High	High
C: Moderately High Runoff Potential	Very Low	Medium	Medium	High	Very High
D, A/D, B/D, C/D: High Runoff Potential	Low	Medium	High	Very High	Very High

All factors shall be determined by using the NRCS soil survey data (Web Soil Survey) with field verification of the predominant slope in the field.

Leaching Potential

While surface transport processes are the major contributing factors in P transport from soil to water in most cases, leaching of P can contribute significant amounts of P to surface waters in some situations, such as in areas where there is relatively flat topography, high water tables, shallow soils over basalt and any artificial drainage system (e.g. ditches, subsurface drains). While P leaching is typically considered to be small there is potential for significant movement of P through the soil profile when soil P values increase to very high or excessive values due to long-term over-fertilization or manuring (Sims et al., 1998). Whether this leached P will reach surface waters depends on the depth to which it has leached and the hydrology of the site in question. In flat areas with shallow groundwater levels, P loss by leaching through soils contributes significantly to the phosphorus loads of streams (Culley et al., 1983; Heathwaite & Dils, 2000). Soils that are poorly drained with high water tables have a higher possibility of P loss than soils that are well drained with deep water tables. Also soils that are shallow (<24”) overlying basalt have a higher possibility of P loss than deeper soils. It is common in poorly drained soils to have water tables rise to the soil surface during the winter and spring months, during this time there is the potential for release of P into these drainage waters which can then be carried to nearby streams via subsurface flow. When soils are wet (during spring and late fall) or during time periods when irrigation exceeds ET, shallow soils can potentially leach P into the underlying basalt which can then be carried to surface waters (i.e. springs).

For the *P Site Index*, leaching potential shall be based on a USDA-NRCS categorization scheme based on the soil hydrologic group, predominant slope, saturated hydraulic conductivity, depth to high water table (HWT) and depth to bedrock Table 6. This information shall be determined through site inspection and the NRCS Web Soil Survey.

Table 6. Leaching potential.

Soil Leaching Potential	Hydrologic Group A	Hydrologic Group B	Hydrologic Group C	Hydrologic Group D
Low	NA	NA	NA	All **except**: • Apparent HWT • Depth to bedrock < 24”
Medium	• Slope > 6% • No apparent HWT and Depth to bedrock > 24”	• Slope > 6% or slope ≤ 6% with K_{sat} < 0.24 in/hr • No apparent HWT and Depth to bedrock > 24”	All **except**: • Apparent HWT • Depth to bedrock < 24”	NA
High	• Slope < 6% • Apparent HWT or Depth to bedrock < 24”	• Slope < 6% with K_{sat} > 0.24 in/hr • Apparent HWT or Depth to bedrock < 24”	• Apparent HWT • Depth to bedrock < 24”	• Apparent HWT • Depth to bedrock < 24”

High Water Table (HWT) is defined as a saturated layer < 24” from the surface anytime during the year.

Distance from Edge of Field to Surface Water

Another factor that affects the risk of P transport from soils to surface waters is the distance between the P source (i.e., the field) and the receiving waters. In some areas, the nearest water body may be a mile or more from the field being evaluated with no connectivity between the field and surface water; in these cases, even high levels of soil P may have low risk for nonpoint source pollution since the potential for transport to the water body is low. On the other hand, fields that are directly connected to surface water, such as surface irrigated fields with tailwater ditches, directly convey runoff water to surface water bodies through the return flow system. In these cases, even fields with low soil P can convey a large amount of both particulate and soluble P to surface waters.

The *P Site Index* shall take into account the distance from field edge to the nearest surface water body or other conveyance system connected to surface water (tailwater ditches, return flow ditches, laterals (Table 7).

Table 7. Distance from edge of field to surface water

Distance From Edge of Field to Surface Water	Value
> 2,640' (0.5 mile)	0
200' to 2,640'	2
< 200'	8

Best Management Practices for Reducing Transport Losses of P

There are several best management practices (BMPs) that can reduce the transport and loss of P from agricultural fields. In many situations, a combination of management practices is more effective than one BMP alone. To account for the effect of BMPs on the off-site transport of P from agricultural fields, a reduction in the overall transport factor is applied with varying BMPs that could be implemented on farm.

Contour farming, i.e. planting across the slope instead of up and down the hill can reduce soil erosion significantly. It is estimated that contour farming can reduce sediment loss by 20 to 50% depending on the slope of the field (Wischmeier and Smith, 1978). Keeping soil surfaces covered through cover or green manure crops can reduce losses of P by reducing erosion losses, however in some cases soluble P is either not affected or can increase. Sharpley and Smith (1991) reported reductions in total P losses of 54 to 66% with the use of cover crops while soluble P was reduced by 0 to 63%. The use of perennial crops such as alfalfa will also reduce the amount of sediment and therefore P leaving the field.

The installation of a dike or a berm that captures runoff from the field will prevent the loss of both soluble and total P. The effectiveness will depend on the holding capacity of the retention area. The use of drip irrigation vs. surface irrigation can significantly reduce the amount of runoff and therefore P that is transported off site. Mchugh et al. (2008) reported a 90% reduction in total P loss from fields with subsurface drip irrigation vs. furrow irrigation. Vegetative filter strips can trap sediment thereby reducing the offsite transport of P. Abu-Zreig et al. (2003) found that filter strips removed 31 to 89% of total P with filter length being the predominant factor affecting filter strip efficacy. The use of polyacrylamide (PAM) with irrigation has been shown to reduce losses of P from both furrow and sprinkler irrigated fields. Applying PAM with irrigation water or directly to furrow soil reduced soil erosion more than 90% on research plots (Lentz et al. 1992, Sojka and Lentz 1997, Trout et al. 1995). A conservative estimate for production fields is 50% to 80% reduction in soil loss. By reducing soil erosion, PAM treatment also reduced total P concentrations in runoff water (Lentz et al. 1998) but had little impact on dissolved P concentrations (Bjorneberg and Lentz, 2005). When used with sprinkler irrigation PAM has been shown to reduce P losses by 30%, but the effectiveness of PAM is minimal after three irrigations (Bjorneberg et al., 2000). Conservation tillage can also reduce soil erodibility and increase residue in furrows, both of which reduce soil loss to irrigation return flow (Carter and Berg 1991).

Sediment ponds remove suspended material from water by reducing flow velocity to allow particles to settle. Sediment ponds also remove nutrients associated with sediment particles. A large pond removed 65% to 75% of the sediment and 25% to 33% of the total P that entered the pond (Brown et al. 1981). A smaller percentage of total P was removed because only the P associated with sediment was removed and a large portion of the total P flowing into the pond was dissolved. Average total P concentrations significantly decreased by 13 to 42% in five ponds with 2 to 15 hour retention times, while dissolved P concentrations only decreased 7 to 16% in thee of the five ponds (Bjorneberg et al., 2015). Dissolved P concentration may actually be greater in pond outflow than pond inflow because P may continue to desorb from sediment as water flows through the pond. Implementing sediment control practices on an 800 ha (2,000 ac) irrigation tract in the Columbia Basin of Washington reduced P discharges by 50% (King et al. 1982). Tailwater recovery systems that capture runoff from furrow irrigated fields and pump it back for re-use as irrigation water should eliminate the loss of P from the system during the irrigation system, provided that no water leaves the field.

The reduction in transport factor due to the implementation of BMPs is listed in Table 8. For each BMP implemented, the transport factor shall be reduced by the amounts listed in the tables. Combinations of BMPs will reduce the transport factor sequentially, for example if you had a score of 36 and you implemented contour farming and a sediment basin your score would then be:

36 – (0.2 x 36) = 28.8 – (0.6 x 28.8) = **11.5**

Table 8. Management practices to reduce the loss of P from fields.

Management Practice[1]	BMP Coefficient
Contour Farming	0.20
Cover & Green Manure Crop	0.30
Dike or Berm	0.40 or 0.80
Drip Irrigation	0.80
Filter Strip[3]	0.35
PAM - Furrow Irrigation	0.60
PAM – Sprinkler Irrigation	0.30
Residue Management/Conservation Tillage[4]	0.30
Sediment Basin	0.30
Tailwater Recovery & Pumpback Systems[2]	0.80
Established Perennial Crop[5]	0.50

[1]BMPs designed by NRCS can receive full credit; otherwise the BMPs must meet the requirements set out in the BMP definition section.

Phosphorus Site Index

Part A: Phosphorus Loss Potential Due to Site and Transport Characteristics

Sample Calculation

Part A: Phosphorus Loss Potential Due to Site and Transport Characteristics

Calculation of the Total Site and Transport Value for Part A of the P Site Index

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Once the values for soil erodibility, soil surface runoff, leaching potential and distance from edge of field to surface water have been obtained, these values shall be added together to obtain a total site and transport value (sum for Part A).

EXAMPLE:

A field located in the Magic Valley with a Portneuf silt loam soil, 1.5% slope, that is surface irrigated with water running off of the field >50% of the irrigation set time. Hydrologic soil group C, K_w factor for erosion is 0.43, K_{sat} 0.2 to 0.6 in/hr, depth to water table > 80". The surface irrigation runoff flows directly into the return flow system.

Soil Erodibility
Using Table 3, a K_w factor of 0.43 with a slope of < 2% puts this in the "Low" category, with a value of **1** (Table 1).

Soil Surface Runoff
This field is surface irrigated with runoff >50% of the set time, which is a value of **8** (Table 1).

Leaching Potential
This soil is in Hydrologic Group C without a high water table and is not a shallow soil, which is a medium risk (Table 6) with a value of **2** (Table 1).

Distance from edge of field to surface water
Since the runoff from this field flows directly into the return flow system the distance from edge of field to surface water is 0' which would be a value of **8** (Table 1).

All of the field values in Part A are then added together to obtain the Total Site Transport Value

1 + 8 + 2 + 8 = 19

**If this site had a tailwater recovery and pumpback system the transport value would be reduced by 80%*

19 – (19 x 0.8) = 3.8

Sum of Part A = 3.8

Phosphorus Site Index

Part B: Phosphorus Loss Potential Due to P Source and Management Practices

Soil Test Phosphorus

Phosphorus exists in many forms in the soil, both inorganic and organic. Major inorganic forms are soluble, adsorbed, precipitated and minerals containing Al, Ca, and Fe. Each "pool" of soil P has a characteristic reactivity and potential for movement in either soluble or particulate forms. Iron and aluminum oxides, prevalent in most soils, strongly adsorb P under acidic conditions; under alkaline conditions, adsorption and precipitation are fostered by the presence of free calcium ions and calcium carbonate (Leytem and Westermann, 2003). Microorganisms and plant uptake can immobilize inorganic P by incorporation into biomass. Conversely, as organic materials decompose, soluble P can be released and made available for transport. How much P exists in each of these pools is determined by soil type, mineralogy, microbial activity, cropping, and fertilization practices (with both inorganic and organic sources of P).

Past and present research has demonstrated that there is a positive relationship between soil test P and dissolved P in surface runoff; that is, as soil test P increases, dissolved P in runoff also increases (Westermann et al., 2001; Turner et al., 2004). However, this relationship varies with soil type, cropping system and nature of the runoff episode. In addition to impacting P levels in surface waters, soil test P has also been found to affect P loss in drainage waters (Heckrath et al., 1995; Sims et al, 1998). Thus, as soils are fertilized to levels exceeding the soil test P values considered optimum for plant growth, the potential for P to be released to soil solution and transported by surface runoff, leaching, subsurface movement and even groundwater increases. Therefore, it is important to include a measure of the current soil test P values in any risk assessment tool for P.

For the *P Site Index,* soil test P values are expressed in ppm of either Olsen or Bray P. Olsen P is the most common (and appropriate) soil test for Idaho's calcareous soils. However certain regions of the state with lower soil pH (<7.4) may also use the Bray method for determination of soil test P.

P Site Index Value For Table 1 = 0.05 x Olsen Soil Test P (ppm), or

P Site Index Value For Table 1 = 0.025 x Bray Soil Test P (ppm)

Phosphorus Application Rate

The addition of fertilizer P or organic P to a field will usually increase the amount of P available for transport to surface waters. The potential for P loss when fertilizers, manures, or other P sources are applied is influenced by the rate, timing, and method of application and by the form of the P source (e.g. organic vs. inorganic). These factors also interact with others, such as the timing and duration of subsequent irrigation, rainfall or snowmelt and the type of soil cover present (vegetation, crop residues, etc.; Sharpley et al., 1993). Past research has established a clear relationship between the rate of fertilizer P applied and the amount of P transported in runoff (Baker and Laflen, 1982; Romkens and Nelson, 1974). These studies showed a linear relationship between the amount of P added as superphosphate fertilizer and P loss in runoff. Using manure as the source of P, Westerman et al. (1983) also demonstrated a direct relationship between the quality of runoff water and the application of manure. Therefore, it is important that the amount of P added to a site is accounted for in any risk assessment for nonpoint source pollution by P.

The P application rate is the amount of P in pounds P_2O_5 per acre that is applied to the crop. The amount of P in manures shall be determined either by sample submission for testing by a certified laboratory or calculated using Table 10.

Table 9. Phosphorus application rate. Corresponding value to be included in the *P Site Index (Table 1).*

P Application Rate (lbs P_2O_5 applied per acre)	Value
No Application	0
< 60	1
60 - 150	2
151 - 300	4
> 300	8

Table 10. Phosphorus concentration of dairy manure

Dairy Manure Type	% P_2O_5 on a wet basis
Solid stacked	0.57
Composted	0.69
Lagoon liquid	0.03
Slurry	0.30

Phosphorus Application Method

Directly related to the amount of fertilizer and organic P sources applied to a field is the method and timing of the application. Baker and Laflen (1982) determined that the dissolved P concentrations of runoff from areas receiving broadcast fertilizer P average 100 times more than from areas where comparable rates were applied 5cm below the soil surface. Muller et al (1984) showed that incorporation of dairy manure reduced total P losses in runoff five-fold compared to areas with broadcast applications. Surface applications of fertilizers and manures decrease the potential interaction of P with the soil, and therefore increase the availability of P for runoff from the site. When fertilizers and manures are incorporated into the soil, the soil is better able to absorb the added P and thus decrease the likelihood of P loss. It is particularly important that fertilizers and manures are not surface applied during times when there is no plant growth, when the soil is frozen, during or shortly before periods of irrigation, intense storms or times of the year when fields are generally flooded due to snowmelt. The major portion of annual P loss in runoff generally results from one or two intense transport periods. If P applications are made during any of these high risk times, the percentage of applied P lost would be higher than if applications are made when runoff probabilities are lower (Edwards et al., 1992). Also, the time between application of P and the first runoff even is important. Westerman and Overcash (1980) applied manure to plots and simulated rainfall at intervals ranging from one to three days following manure application. Total P concentrations in the runoff were reduced by 90% by delaying the first runoff event for three days. In order to manage manure and fertilizers to decrease potential for P transport off-site, they must be either applied below the surface or incorporated into the soil within a short period of time and also be applied shortly before the growing season when available P can be utilized by the plant.

For the *P site Index*: To determine the field value for application methods of P sources, information about the time of year and method of application must be obtained from the nutrient user and assigned values using Table 11.

Table 11. Values of P application methods for inclusion in *P Site Index (Table 1)*.

P Application Method	Value
None applied	0
Incorporated within 2 day or injected/banded below surface at least 2”	1
Incorporated within 7 days of application	2
Incorporated >7 days or no incorporation when applied between February 16 and December 15	4
Application between December 16 and February 15	8

The Phosphorus Site Index
Part B: Phosphorus Loss Potential Due to P Source and Management Practices

Sample Calculation

Part B: Phosphorus Loss Potential Due to P Source and Management Practices

Calculation of the Total P Source and Management Value for Part B of the P Site Index

Once the values for soil test P, P application rate and P application method have been obtained, these values shall be added together to obtain a total P source and management practice value (sum for Part B).

EXAMPLE:
The field described for calculation of Part A has an Olsen soil test P value of 80 and solid manure is applied at 50 tons/acre in October and is not incorporated.

Soil Test P value
Olsen P of 80 x 0.05 = **4**

P Application Rate
50 tons/acre = (50 x 2,000 x (0.57/100)) = 570, this would be a value of **8**

P Application Method
Surface applied between Feb 16 and Dec 15 and not incorporated, this is a value of **4**

All of the field values in Part B are then added together to obtain the Total P Source and Management Value

4 + 8 + 4 = 16

Sum of Part B = 16

The Phosphorus Site Index

Calculation and Interpretation of the Overall P Loss Rating for a Site

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To find the overall *P Loss Rating* for a site (the final *P Site Index Value*), multiply the total site and transport value from Part A by the total management and source value from Part B as follows:

***P Site Index* = [Sum of Part A] x [Sum of Part B]**

Sum of Part A = 19

Sum of Part B = 16

***P Site Index* = 19 x 16 or 304**

A *P Site Index* value of **304** is classified as **Very High (See Tables 2 or 12)**

*If a tailwater recover with a pumpback system was used as a BMP then the P Site Index value would be

Sum of Part A = 3.8

Sum of Part B = 16

***P Site Index* = 3.8 x 16 or 61**

A *P Site Index* value of **61** is classified as **Low (See Tables 2 or 12)**

<u>Interpretation of the *P Site Index* Value</u>

Compare the *P Site Index* value calculated as show above with the ranges given in Table 12 for Low, Medium, High, or Very High risk of P loss. **It is important to remember that a P Site Index value is an indication of the degree of risk of P loss, not a quantitative prediction of the actual amount of P lost from a given field.** Fields in the "Low" category are expected to have a lower potential for P losses than fields in the "Medium P loss rating category, while fields in the "Medium P loss rating category are expected to have a relatively lower potential for P loss than fields in the "High" P loss rating category, and so on. The numeric values used in Table 12 to separate the various P loss categories are based on the best professional judgement of the individuals involved in the development of the *P Site Index* using data from fields and farms in Idaho where field evaluations were conducted in 2017.

Table 12. Interpretation of the *Phosphorus Site Index* Value

P Site Index **Value**	**Generalized Interpretation of the *P Site Index* Value**
< 75	**LOW** potential for P movement from this site given current management practices and site characteristics. There is a low probability of an adverse impact to surface waters from P losses from this site. Nitrogen-based nutrient management planning is satisfactory for this site. Soil P levels and P loss potential may increase in the future due to N-based nutrient management planning.
75 - 150	**MEDIUM** potential for P movement from this site given current management practices and site characteristics. Phosphorus applications shall be limited to the amount expected to be removed from the field by crop harvest (crop uptake) or soil test-based P application recommendations. Testing of manure P prior to application is required.
151 – 225	**HIGH** potential for P movement from this site given the current management practices and site characteristics. Phosphorus applications shall be limited to 50% of crop P uptake. Testing of manure P prior to application is required.
> 225	**VERY HIGH** potential for P movement from this site given current management practices and site characteristics. No P shall be applied to this site.

Best Management Practice Definitions

Contour Farming. Farming sloping land in such a way that planting is done on the contour (perpendicular to the slope direction). This practice would apply to fields having a slope of 2% or greater. When converting from surface to sprinkler irrigation, this can be as simple as planting across the direction of the surface water flow. For other more complex settings, the maximum row grade shall not exceed half of the downslope grade up to a maximum of 4%. The minimum ridge height shall be 2 inches for row spacing greater than 10 inches and 1 inch for row spacing less than 10 inches.

Cover & Green Manure Crop. A cover and/or green manure crop is a close-growing crop primarily for seasonal protection and soil improvement. This practice reduces erosion by protecting the soil surface. Cover crops must be established (have vegetative cover over a minimum of 30% of the soil) by November 1 and must be maintained to within 30 days prior to planting the following crop. There shall be a minimum of 2 to 3 plants per square foot (about 100,000 plants/acre).

Dike or Berm. This practice applies to non-surface irrigated fields only and is comprised of an embankment to retain water on the field. The dike or berm must be engineered to retain runoff from a 25 year 24 hour storm event (0.8 BMP coefficient) or from 1 inch of runoff from the field (0.4 BMP coefficient).

Drip Irrigation. The credit for implementing this practice only applies when switching from surface irrigation to drip irrigation. A drip irrigation system shall be comprised of an irrigation system with orifices, emitters or perforated pipe that applies water directly to the root zone or soil surface. This practice efficiently applies water to the soil surface with low probability of runoff, as determined using the calculation in Table 5.

Filter Strip. A filter strip is a strip of permanent herbaceous dense vegetation in an area where runoff occurs. A filter strip can only be used on fields having < 10% slope. Ideally they are perpendicular to the flow of water and the runoff from the source area is such that flow through the strip is in the form of sheet runoff. Channeling of water through a filter strip will severely reduce its effectiveness. Filter strips must be a minimum of 20 feet in length. If the length of the field contributing runoff to the filter strip is greater than 1000 feet, then the minimum filter strip width shall be 50 feet. They must be irrigated and maintained so that there is a minimum of 75% vegetative cover. The seeding rate shall be sufficient to ensure that the plant spacing does not exceed 4 inches (about 16-18 plants per square foot).

Polyacrylamide (PAM). PAM is an organic polymer that stabilizes the soil surface when applied with irrigation water. This practice can increase infiltration and reduce soil erosion. The PAM must be a soluble anionic polyacrylamide. Standards for proper implementation of this BMP shall follow the NRCS Conservation Practice Standard “Anionic Polyacrylamide (PAM) Application” (450-CPS-1).

Residue Management/Conservation Tillage. is any method of soil cultivation that leaves the previous year crop residue cover on the soil surface (such as corn stock or wheat stubble).. Conservation tillage must result in crop residue remaining on at least 30% of the soil surface. This practice reduces soil erosion by protecting the soil surface.

Sediment Basin. A basin or pond constructed to collect and retain sediment. This practice slows the velocity of flowing water which allows sediment to settle in the basin. Sediment basin size must be at least 500 cubic feet per acre of drainage area (20,000 ft^3 for 40 acre field or 20 ft x 200 ft x 5 ft). The length-to-width ratio shall be 2 to 1 or greater with a minimum depth of 3 feet. Sediment basins must be cleaned on an annual basis or more frequently.

Tailwater Recovery & Pumpback Systems. This practice applies to surface irrigated fields only. Design standards and management must follow the ASABE Engineering Practice Standard 408.3 "Surface Irrigation Runoff Reuse Systems". Irrigation runoff reuse systems have four basic components: 1) runoff collection and conveyance channels (tailwater ditches, drains), 2) storage reservoir (tailwater pit, pond, sump), 3) pumping plant (reuse, return, pumpback pump), and 4) delivery pipe (return, pumpback pipe). Runoff from irrigated fields is intercepted by a system of open channels or pipelines and conveyed by gravity to a storage reservoir or pumping plant. Capacity of the channels and pipelines shall be sufficient to convey the maximum expected runoff rate from irrigation. Also, the collection system must be able to safely convey or bypass runoff from precipitation. Reuse systems designed to capture 50% of the application volume will usually capture a large percentage of the total irrigation runoff.

Established Perennial Crop. This is a crop that is grown for more than one year. Perennial crop is considered to be "established" the season after it was seeded.

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NITROGEN MANAGEMENT PLAN WORKSHEET

NAME ______________________________

Crop Year (Harvested) ____________________

Field ID ______________________________

Acres ______________________________

Crop Nitrogen Management Planning	
1. Crop	
2. Production Unit	
3. Projected Yield (units/acre)	
4. N Recommended (lbs/acre)	
Post Production Actuals	
5. Actual Yield (units/acre)	
6. Total N Applied (lbs/acre)	
7. N Removed (lbs/acre)	
Notes:	
PSNT Test:	

N Applications/Credits	Recommended/ Planned N	Actual N
Manure/Organic Material N		
8. Available N in Manure/Compost (lbs/acre)		
Nitrogen Fertilizers		
9. Dry/Liquid N (lbs/acre)		
10. Foliar N (lbs/acre)		
11. Total Available N Applied (lbs/acre)		
Nitrogen Credits		
12. Available N in soil (lbs/acre)		
13. N in Irrigation Water (lbs/acre)		
14. Total N Credits (lbs/acre)		
15. Total N Applied & Available		

Certified By:	
Date:	

Instructions

1. This is the crop that is planted in the year for which the information is recorded.
2. This is the crop yield units ie. bushels, tons, cwt, etc.
3. Projected yield (units/acre). This is the yield that you are anticipating for this crop in this year.
4. N Recommended (lbs/acre). This is the amount of N recommended based on the projected yield.
5. Actual Yield (units/acre). The actual harvested yield on this field for this crop.
6. Total N Applied (lbs/acre). The actual amount of total N that was applied to this crop during this season from line 11.
7. N Removed (lbs/acre). The amount of N that was removed with the crop (calculated by summing all of the biomass removed multiplied by the tissue N concentration of the different biomass pools)
8. Available N in Manure/Compost (lbs/acre). This is the total amount of plant available N applied for the growing season including previous fall applications. Use Table 1 to determine the % PAN of total N in manure/compost/liquid/slurry etc.
9. Dry/Liquid N (lbs/acre). This is the total amount of N applied as fertilizer including starter fertilizer, broadcast applications, in season side-dress applications and any N applied with irrigation.
10. Foliar N (lbs/acre). This is the total amount of N applied as a foliar spray during the growing season.
11. Total Available N Applied (lbs/acre). This is the sum of blocks 8, 9 and 10.
12. Available N in soil (lbs/acre). This is determined from soil samples collected within 8 months of planting. It is preferential to collect a pre-plant soil sample within 3 weeks of planting for the most accurate accounting of N in soil. This must include soils from 0 to 12". The lbs/acre is calculated by multiplying the average ppm N (NH_4 + NO_3) in the 0 to 12" sample by 4. It is preferential to account for the N in the top 2' of soil. If you have soil samples from 0 to 12" and 12 to 24" you would multiply each sample by 4 and then add them together (0 to 12" ppm N x 4) + (12 to 24" ppm N x 4). Alternatively, if you only have a 0 to 12" soil sample you could multiply the ppm N x 8 to represent the first 2', however this is not as accurate.
13. N in irrigation water (lbs/acre). If irrigation water contains N, the N applied with irrigation water must be included.
14. Total N Credits (lbs/acre). This is the sum of blocks 12 and 13.
15. Total N Applied and Available. This is the sum of blocks 11 and 14.

Table 1. Plant available N in manure

Manure Source	N available (%)
Lagoon Liquid	80
Lagoon Slurry/Sludge	60
Solid Stacked Manure (corral)	30
Composted Manure	10

Appendix 10D Design and Construction Guidelines for Impoundments Lined with Clay or Amendment-treated Soil

Introduction

Waste storage ponds and treatment lagoons are used in agricultural waste management systems to protect surface and ground water and as a component in a system for properly utilizing wastes. Seepage from these structures has the potential to pollute surface water and underground aquifers. The principal factors determining the potential for downward and/or lateral seepage of the stored wastes are the:

- permeability of the soil and bedrock horizons near the excavated limits of a constructed waste treatment lagoon or waste storage pond
- depth of liquid in the pond that furnishes a driving hydraulic force to cause seepage
- thickness and permeability of horizons between the boundary of the lagoon bottom and sides to the aquifer or water table

In some circumstances, where permitted by local and/or State regulations, designers may consider whether seepage may be reduced from the introduction of manure solids into the reservoir. Physical, chemical, and biological processes can occur that reduce the permeability of the soil-liquid interface. Suspended solids settle out and physically clog the pores of the soil mass. Anaerobic bacteria produce by-products that accumulate at the soil-liquid interface and reinforce the seal. The soil structure can also be altered in the process of metabolizing organic material.

Chemicals in waste, such as salts, can disperse soil, which may also be beneficial in reducing seepage. Researchers have reported that, under some conditions, the seepage rates from ponds can be decreased by up to an order of magnitude (reduced 1/10th) within a year following filling of the waste storage pond or treatment lagoon with manure. Manure with higher solids content is more effective in reducing seepage than manure with fewer solids content. Research has shown that manure sealing only occurs when soils have a minimal clay content or greater. A rule of thumb supported by research is that manure sealing is not effective unless soils have at least 15 percent clay content for monogastric animal generated waste and 5 percent clay content for ruminant animal generated waste (Barrington, Jutras, and Broughton 1987a, 1987b). Manure sealing is not considered effective on relatively clean sands and gravels, and these soils always require a liner as described in the following sections.

Animal waste storage ponds designed prior to about 1990 assumed that seepage from the pond would be minimized by the accumulation of manure solids and a biological seal at the foundation surface. Figure 10D–1 shows one of these early sites, where the soils at grade were somewhat permeable sands. Monitoring wells installed at some sites with very sandy soils showed that seepage containing constituents from the pond was still occurring even after enough time had passed that manure sealing should have occurred.

This evidence caused U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) engineers to reconsider guidance on suitable soils for siting an animal waste storage pond. In the late 1980s guidance was developed that designs should not rely solely on the seepage reduction that might occur from the accumulation of manure solids in the bottom and on the sides of the finished structure. That initial design document was entitled "South National Technical Center (SNTC) Technical Guide 716." It suggested that if any of four site conditions were present at a proposed structure location, a clay liner or other method of reducing seepage would be used in NRCS designs. A few revisions were made, and the document was re-issued in September 1993.

Figure 10D–1 Animal waste storage pond constructed before the implementation of modern design guidelines

NRCS was reorganized in 1994, and guidance in old SNTC documents was not part of the revised document system of the Agency. Consequently, the 716 document was revised considerably, and the revised material was incorporated into appendix 10D of the Agricultural Waste Field Management Handbook (AWMFH) in October 1998. This 2008 version of appendix 10D continues to update and clarify the process of designing an animal waste storage pond that will meet NRCS-specified engineering design criteria and stated specified permeability requirements.

General design considerations

Limiting seepage from an agricultural waste storage pond has two primary goals. The first is to prevent any virus or bacteria from migrating out of the storage facility to an aquifer or water source. The second is to prevent the conversion of ammonia to nitrate in the vadose zone. Nitrates are very mobile once they are formed by the nitrification process. They can then accumulate significantly in ground water. The National drinking water standard for nitrate is 10 parts per million, and excessive seepage from animal waste storage ponds could increase the level of nitrates in ground water above this threshold. Other constituents in the liquid manure stored in ponds may also be potential contaminants if the seepage from the pond is unacceptably high.

Defining an acceptable seepage rate is not a simple task. Appendix 10D recommends an allowable seepage quantity that is based on a historically accepted tenet of clay liner design, which is that a coefficient of permeability of 1×10^{-7} centimeters per second is reasonable and prudent for clay liners. This value, rightly or wrongly, has a long history of acceptability in design of impoundments of various types, including sanitary landfills.

Assuming that a typical NRCS waste impoundment has a maximum liquid depth of 9 feet, a compacted clay liner thickness of 1 foot, and a one order of magnitude reduction in seepage due to manure sealing effects, the resulting seepage associated with this historically accepted permeability rate is about 1×10^{-6} centimeters per second, or about 9,240 gallons per acre per day. However, the NRCS no longer recommends basing design decisions on the assumption that a full one order of magnitude reduction will be achieved. The following criteria should be used in assessing the adequacy of a compacted clay liner system:

- When credit for a reduction of seepage from manure sealing (described later in the document) is allowed, NRCS guidance considers an acceptable initial seepage rate to be 5,000 gallons per acre per day. This higher value used for design assumes that manure sealing will result in at least a half order of magnitude reduction in the initial seepage. If State or local regulations are more restrictive, those requirements should be followed.
- If State or local regulations prohibit designs from taking credit for future reductions in seepage from manure sealing, then NRCS recommends the initial design for the site be based on a seepage rate of 1,000 gallons per acre per day. Applying an additional safety factor to this value is not recommended because it conservatively ignores the potential benefits of manure sealing.

One problem with basing designs on a unit seepage value is that the approach considers only unit area seepage. The same criterion applies for small and large facilities. More involved three-dimensional type analyses would be required to evaluate the potential impact of seepage on ground water regimes on a whole-site basis. In addition to unit seepage, studies for large storage facilities should consider regional ground water flow, depth to the aquifer likely to be affected, and other factors.

The procedures in appendix 10D to the AWMFH provide a rational approach to selecting an optimal combination of liner thickness and permeability to achieve a relatively economical, but effective, liner design. It recognizes that manipulating the permeability of the soil liner is usually the most cost-effective approach to reduce seepage quantity. While clay liners obviously allow some seepage, the limited seepage from a properly designed site should have minimal impact on ground water quality. Numerous studies, such as those done by Kansas State University (2000), have shown that waste storage ponds located in low permeability soils of sufficient thickness have a limited impact on the quality of ground water.

If regulations or other considerations require that unit seepage be less than 500 gallons per acre per day (1/56 inch per day), synthetic liners such as high-density polyethylene (HDPE), linear low-density polyethylene (LLDPE), ethylene propylene diene monomer (EPDM), or geosynthetic clay liners (GCL), concrete liners, or aboveground storage tanks may be more feasible and economical and should be considered. Figure 10D–2 shows a pond lined with a synthetic liner, figure 10D–3 shows a concrete-lined excavated pond, and figure 10D–4 shows an aboveground concrete tank. Above-ground tanks may be also constructed of fiberglass-lined steel. NRCS has significant expertise in the selection, specification, and construction of sites using these products in addition to clay liners. Guidance on these other technologies is contained in other chapters of the AWMFH.

Figure 10D–2 Pond with synthetic liner *(Photo credit NRCS)*

Figure 10D–3 Excavated animal waste storage pond with concrete liner *(Photo credit NRCS)*

Figure 10D–4 Aboveground storage tank for animal waste *(Photo credit Mitch Cummings, Oregon NRCS)*

Progressive design

Waste storage ponds and waste treatment lagoons are usually designed with specific objectives that include cost, allowable seepage, aesthetics, and other considerations. Designs are usually evaluated in a progressive manner, with less costly and simple methods considered first, and more costly and complex methods considered next. These design concepts should generally be considered in the order listed to provide the most economical, yet effective, design of these structures. The following descriptions cover details on design and installation of these individual design measures.

- The least expensive and least complex design is to locate a waste impoundment in soils that have a naturally low permeability and where horizons are thick enough to reduce seepage to acceptable levels. The site should also be located where the distance to the water table conforms to requirements of any applicable regulations.
- Soils underlying the excavated boundaries of the pond may not be thick enough or slowly permeable enough to limit seepage to acceptably low values. In this case, the next type of design often considered is a liner constructed of compacted clay or other soils with appropriate amendments. This type of liner may be constructed with soils from the excavation itself or soil may be imported from nearby borrow sources. If the soils require amendments such as bentonite or soil dispersants, the unit cost of the compacted liner will be significantly higher than for a liner that only requires compaction to achieve a satisfactorily low permeability.
- A synthetic liner may be used to line the impoundment to reduce seepage to acceptable levels. Various types of synthetic materials are available.
- A liner may be constructed of concrete, or a concrete or fiberglass-lined steel tank can be constructed above ground to store the wastes.

A useful tool in comparing design alternatives is to evaluate unit costs. Benefits of alternatives may then be compared against unit costs to aid in selecting a design alternative. Benefits may include reduced seepage, aesthetics, or other considerations. Many geomembrane suppliers may be able to provide rough cost estimates based on the size and locale of the site. In estimating the cost of a compacted clay liner, one should evaluate the volume of compacted fill involved in a liner of given thickness. Table 10D–1 illustrates a cost comparison for different thicknesses of compacted clay liners. If methods other than compacted clay liners are used, higher unit costs may apply (table 10D–2).

Table 10D–1 Cost comparisons of design options for compacted clay liner

Thickness of compacted liner (ft)	Number of cubic yards of fill per square foot (yd^3)	Assumed cost of compacted fill, per cubic yard ($)	Unit cost of stated thickness liner ($\$/ft^2$)
1.0	0.037037	3.00–5.00	0.11–0.19
1.5	0.055555	3.00–5.00	0.17–0.28
2.0	0.074074	3.00–5.00	0.22–0.37
3.0	0.111111	3.00–5.00	0.33–0.56

Table 10D–2 Cost comparison for other design options

Liner type	Unit costs ($\$/ft^2$)
Geosynthethic	0.50–1.25
Concrete, reinforced 5 inches thick	7.50–8.00

Soil properties

The permeability of soils at the boundary of a waste storage pond depends on several factors. The most important factors are those used in soil classification systems such as the Unified Soil Classification System (USCS). The USCS groups soils into similar engineering behavioral groups. The two most important factors that determine a soil's permeability are:

- The percentage of the sample which is finer than the No. 200 sieve size, 0.075 millimeters. The USCS has the following important categories of percentage fines:
  - Soils with less than 5 percent fines are the most permeable soils.
  - Soils with between 5 and 12 percent fines are next in permeability.
  - Soils with more than 12 percent fines but less than 50 percent fines are next in order of permeability.
  - Soils with 50 percent or more fines are the least permeable.
- The plasticity index (PI) of soils is another parameter that strongly correlates with permeability.

When considered together with percent fines, a grouping of soils into four categories of permeability is possible. The following grouping of soils is based on the experience of NRCS engineers. It may be used to classify soils at grade as an initial screening tool. Estimating permeability is difficult because so many factors determine the value for a soil. For *in situ* soils, the following factors, in addition to percent fines and PI, affect the permeability of the natural soils:

- The dry density of the natural soil affects the permeability. Soils with lower dry densities have higher percentage of voids (porosity) than more dense soils.
- Structure strongly affects permeability. Many clay soils, particularly those with PI values above 20, develop a blocky structure from desiccation. The blocky structure creates preferential flow paths that can cause soils to have an unexpectedly high permeability. Albrecht and Benson (2001) and Daniel and Wu (1993) describe the effect of desiccation on the permeability of compacted clay liners.
- While not considered in the USCS, the chemical composition of soils with clay content strongly affects permeability. Soils with a preponderance of calcium or magnesium ions on the clay particles often have a flocculated structure that causes the soils to be more permeable than expected based simply on percent fines and PI. Soils with a preponderance of sodium or potassium ions on the clay particles often have a dispersive structure that causes the soils to be less permeable than soils with similar values of percent fines and PI. The NRCS publication TR–28, Clay Minerals, describes this as follows:

  > *In clay materials, permeability is also influenced to a large extent by the exchangeable ions present. If, for example, the Ca (calcium) ions in a montmorillonite are replaced by Na (sodium) ions, the permeability becomes many times less than its original value. The replacement with sodium ions reduces the permeability in several ways. For one thing, the sodium causes dispersion (disaggregation) reducing the effective particle size of the clay minerals. Another condition reducing permeability is the greater thickness of water adsorbed on the sodium-saturated montmorillonite surfaces which diminishes the effective pore diameter and retards the movement of fluid water.*

- Alluvial soils may have thin laminations of silt or sand that cause them to have a much higher horizontal permeability than vertical permeability. This property is termed anisotropy and should be considered in flow net analyses of seepage.
- Other types of deposits may have structure resulting from their mode of deposition. Loess soils often have a high vertical permeability resulting from their structure. Glacial tills may contain fissures and cracks that cause them to have a permeability higher than might be expected based only on their density, percent fines and PI of the fines.

The grouping of soils in table 10D–3 is based on the percent passing the No. 200 sieve and PI of the soils. Table 10D–4 is useful to correlate the USCS groups to one of the four permeability groups.

Table 10D–3 Grouping of soils according to their estimated permeability. Group I soils are the most permeable, and soils in groups III and IV are the least permeable soils

Group	Description
I	Soils that have less than 20 percent passing a No. 200 sieve and have a PI less than 5
II	Soils that have 20 percent or more passing a No. 200 sieve and have PI less than or equal to 15. Also included in this group are soils with less than 20 percent passing the No. 200 sieve with fines having a PI of 5 or greater
III	Soils that have 20 percent or more passing a No. 200 sieve and have a PI of 16 to 30
IV	Soils that have 20 percent or more passing a No. 200 sieve and have a PI of more than 30

Table 10D–4 Unified classification versus soil permeability groups [1/]

Unified Soil Classification System Group Name	Soil permeability group number and occurrence of USCS group in that soil			
	I	II	III	IV
CH	N	N	S	U
MH	N	S	U	S
CL	N	S	U	S
ML	N	U	S	N
CL–ML	N	A	N	N
GC	N	S	U	S
GM	S	U	S	S
GW	A	N	N	N
SM	S	U	S	S
SC	N	S	U	S
SW	A	N	N	N
SP	A	N	N	N
GP	A	N	N	N

1/ ASTM Method D–2488 has criteria for use of index test data to classify soils by the USCS.
A = Always in this permeability group
N = Never in this permeability group
S = Sometimes in this permeability group (less than 10 percent of samples fall in this group)
U = Usually in this permeability group (more than 90 percent of samples fall in this group)

Permeability of soils

Table 10D–5 shows an approximate range of estimated permeability values for each group of soils in table 10D–3. The ranges are wide because the classification system does not consider other factors that affect the permeability of soils, such as the electrochemical nature of the clay in the soils. Two soils may have similar percent finer than the No. 200 sieves and PI values but have very different permeability because of their different electrochemical makeup. The difference can easily be two orders of magnitude (a factor of 100). The most dramatic differences are between clays that have a predominance of sodium compared to those with a preponderance of calcium or magnesium. High calcium soils are more permeable than high sodium soils.

Table 10D–5 summarizes the experienced judgment of NRCS engineers and generally used empirical correlations of other engineers. The correlations are for *in situ* soils at medium density and without significant structure or chemical content. Information shown in figure 10D–5 is also valuable in gaining insight into the probable permeability characteristics of various soil and rock types.

Some soils in groups III and IV may have a higher permeability than indicated in table 10D–5 because they contain a high amount of calcium. High amounts of calcium result in a flocculated or aggregated structure in soils. These soils often result from the weathering

Table 10D–5 Grouping of soils according to their estimated permeability. Group I soils are the most permeable and soils in groups III and IV are the least permeable soils.

Group	Percent fines	PI	Estimated range of permeability, cm/s	
			Low	High
I	< 20	< 5	3×10^{-3}	2
II	≥ 20	≤ 15	5×10^{-6}	5×10^{-4}
	< 20	≥ 5		
III	≥ 20	16 ≤ PI ≤ 30	5×10^{-8}	1×10^{-6}
IV	≥ 20	> 30	1×10^{-9}	1×10^{-7}

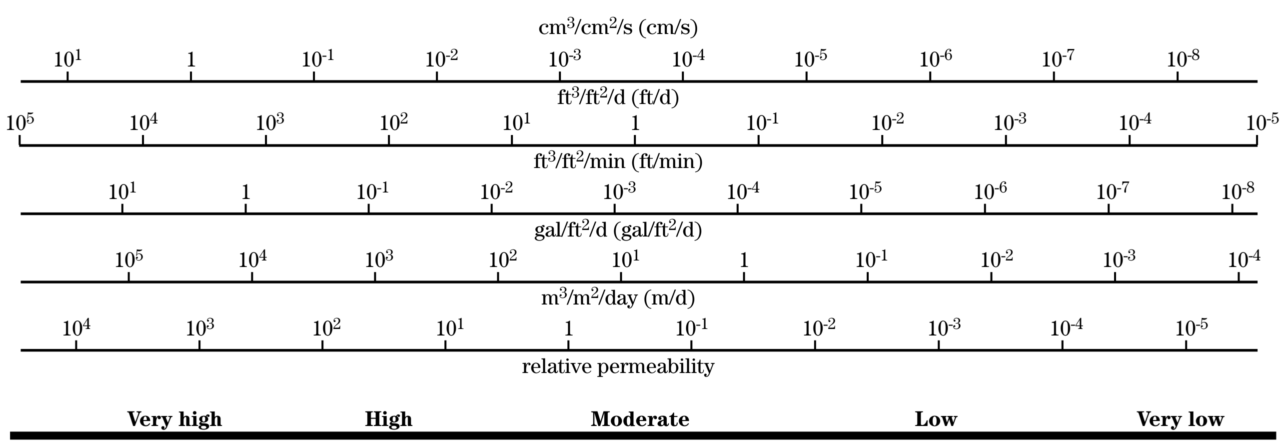
of high calcium parent rock, such as limestone. Soil scientists and published soil surveys are helpful in identifying these soil types.

High calcium clays should usually be modified with soil dispersants to achieve the target permeability goals. Dispersants, such as tetrasodium polyphosphate, can alter the flocculated structure of these soils by replacement of the calcium with sodium. Because manure contains salts, it can aid in dispersing the structure of these soils, but design should not rely on manure as the only additive for these soil types.

Soils in group IV usually have a very low permeability. However, because of their sometimes blocky structure, caused by desiccation, high seepage losses can occur through cracks that can develop when the soil is allowed to dry. These soils possess good attenuation properties if the seepage does not move through cracks in the soil mass. Soils with extensive desiccation cracks should be disked, watered, and recompacted to destroy the structure in the soils to provide an acceptable permeability. The depth of the treatment required should be based on design guidance given in the section **Construction considerations for compacted clay liners.**

High plasticity soils like those in group IV should be protected from desiccation in the interim period between construction and filling the pond. Ponds with intermittent storage should also consider protection for high PI liners in their design.

Figure 10D–5 Permeability of various geologic material (from Freeze and Cherry 1979)



Representative materials

	Very high	High	Moderate	Low	Very low
Soil types	Clean gravel (GP)	Clean sand, clean sand and gravel mixes (GW, GP, SW, SP, SM)	Fine sand, silty sand and gravel mixes (SP, SM, GM, GW–GM, GP–GM, SW–SM, SP–SM)	Silt, clay, and sand-silt-clay mixes, organic silts, organic clays (GM, GC, SM, SC, MH, ML, ML–CL, OL, OH, GW–GC, GC–GM, SW-SC, SP–SC, SC–SM)	Massive clay, no soil joints or other macropores (CL, CH)
			Any soil mass with joints, cracks or other macroporosity		
Rock types		Cavernous and karst limestones and dolomites, permeable basalts	Limestones, dolomites, clean sandstones	Interbedded sandstones, siltstones, and shales	Most massive rocks, unfractured and unweathered
			Fractured igneous and metamorphic rocks		

In situ soils with acceptable permeability

For screening purposes, NRCS engineers have determined that if the boundaries of a planned pond are underlain on the sides and bottom both by a minimum thickness of natural soil in permeability groups III or IV, the seepage from those ponds is generally low enough to cause no degradation of ground water. This assumes that soils do not have a flocculated structure. Unless State regulations or other requirements dictate a more conservative method of limiting seepage, it is the position of NRCS that special design measures generally are not necessary where agricultural waste storage ponds or treatment lagoons are constructed in these soils, provided that:

- at least 2 feet of natural soil in groups III or IV occur below the bottom and sides of the lagoon
- the soils are not flocculated (high calcium)
- no highly unfavorable geologic conditions, such as karst formations, occur at the site
- the planned depth of storage is less than 15 feet

Ponds with more than 15 feet of liquid should be evaluated by more precise methods. If the permeability and thickness of horizons beneath a structure are known, the predicted seepage quantities may be estimated more precisely. In some cases, even though a site is underlain by 2 feet of naturally low permeability soil, an acceptably low seepage rate satisfactory for some State requirements cannot be documented. In those cases, more precise testing and analyses are suggested. The accumulation of manure can provide a further decrease in the seepage rate of ponds by up to 1 order of magnitude as noted previously. If regulations permit considering this reduction, a lower predicted seepage can be assumed by designers.

Definition of pond liner

Compacted clay liner—Compacted clay liners are relatively impervious layers of compacted soil used to reduce seepage losses to an acceptable level. A liner for a waste impoundment can be constructed in several ways. When soil alone is used as a liner, it is often called a clay blanket or impervious blanket. A simple method of providing a liner for a waste storage structure is to improve a layer of the soils at the excavated grade by disking, watering, and compacting the soil to a thickness indicated by guidelines in following sections. Compaction is often the most economical method for constructing liners if suitable soils are available nearby or if soils excavated during construction of the pond can be reused to make a compacted liner. Soils with suitable properties can make excellent liners, but the liners must be designed and installed correctly. Soil has an added benefit in that it provides an attenuation medium for many types of pollutants. NRCS Conservation Practice Standard (CPS) 521D, Pond Sealing or Lining Compacted Clay Treatment, addresses general design guidance for compacted clay liners for ponds.

If the available soils cannot be compacted to a density and water content that will produce an acceptably low permeability, several options are available, and described in the following section. The options involve soil additives to improve the permeability of the soils and adding liners constructed of materials other than natural soils.

Treat the soil at grade with bentonite or a soil dispersant—Designers must be aware of which amendment is appropriate for adding to specific soils at a site. In the past, bentonite has been inappropriately used to treat clay soils and soil dispersants have inappropriately been used to treat sands with a small clay content.

The following guidelines are helpful and should be closely followed.

- ***When to use bentonite***—Soils in groups I and II have unacceptably high permeability because they contain an insufficient quantity of clay or the clay in the soils is less active than required. A useful rule of thumb is that soils amenable for treatment with bentonite will have PI values less than 7, or they will have less than 30 percent finer than the No. 200 sieve, or both.

  Bentonite is essentially a highly concentrated clay product that can be added in small quantities to a sand or slightly plastic silt to make it relatively low in permeability. CPS 521C, Pond Sealing or Lining Bentonite Treatment, covers this practice. NRCS soil mechanics laboratories have found it important to use the same type and quality of bentonite planned for construction in the laboratory permeability tests used to design the soil-bentonite mixture. Both the quality of the bentonite and how finely ground the product is before mixing with the soil will strongly affect the final permeability rate of the mixture. It is important to work closely with both the bentonite supplier and the soil testing facility when designing treated soil liners.

- **When to use soil dispersants**—Soils in groups III and IV may have unacceptably high permeability because they contain a preponderance of calcium or magnesium on the clay particles. Unfortunately, field or lab tests to determine when soils are likely to have this problem are not available. High calcium soils often occur when parent materials have excessive calcium. Many soils developed from weathering of limestone and gypsum may have this problem. See the section Design and construction of clay liners treated with soil dispersants, for more detail. Some States require the routine use of soil dispersants in areas that are known to have high calcium clay soils.

Use of concrete or synthetic materials such as geomembranes and geosynthetic clay liners (GCLs)—Concrete has advantages and disadvantages for use as a liner. A disadvantage is that it will not flex to conform to settlement or shifting of the earth. In addition, some concrete aggregates may be susceptible to attack by continued exposure to chemicals contained in or generated by the waste. An advantage is that concrete serves as an excellent floor from which to scrape solids. It also provides a solid support for equipment such as tractors or loaders.

Figure 10D–6 Agricultural waste storage impoundment lined with a geomembrane *(Photo credit NRCS)*

Geomembranes and GCLs are the most impervious types of liners if designed and installed correctly. Care must be exercised both during construction and operation of the waste impoundment to prevent punctures and tears. The most common defects in these liners arise from problems during construction. Forming seams in the field for geomembranes can require special expertise. GCLs have the advantage of not requiring field seaming, but overlap is required to provide a seal at the seams. Geomembranes must contain ultraviolet inhibitors if exposed to sunlight. Designs should include provision for protection from damage during cleaning operations. Concrete pads, double liners, and soil covering are examples of protective measures. Figure 10D–6 shows an agricultural waste storage facility with a geomembrane liner with ultraviolet inhibitors.

When a liner should be considered

A constructed liner may be required if any of the conditions listed are present at a planned impoundment.

Proposed impoundment is located where any underlying aquifer is at a shallow depth and not confined and/or the underlying aquifer is a domestic or ecologically vital water supply—State or local regulations may prevent locating a waste storage impoundment within a specified distance from such features. Even if the pond bottom and sides are underlain by 2 feet of naturally low permeability soil, if the depth of liquid in the pond is high enough, computed seepage losses may be greater than acceptable. The highest level of investigation and design is required on sites like those described. This will ensure that seepage will not degrade aquifers at shallow depth or aquifers that are of vital importance as domestic water sources.

Excavation boundary of an impoundment is underlain by less than 2 feet of suitably low permeability soil, or an equivalent thickness of soil with commensurate permeability, over bedrock—Bedrock that is near the soil surface is often fractured or jointed because of weathering and stress relief.

Many rural domestic and stock water wells are developed in fractured rock at a depth of less than 300 feet. Some rock types, such as limestone and gypsum, may have wide, open solution channels caused by chemical action of the ground water. Soil liners may not be adequate to protect against excessive leakage in these bedrock types. Concrete or geomembrane liners may be appropriate for these sites. However, even hairline openings in rock can provide avenues for seepage to move downward and contaminate subsurface water supplies. Thus, a site that is shallow to bedrock can pose a potential problem and merits the consideration of a liner. Bedrock at a shallow depth may not pose a hazard if it has a very low permeability and has no unfavorable structural features. An example is massive siltstone.

Excavation boundary of an impoundment is underlain by soils in group I—Coarse grained soils with less than 20 percent low plasticity fines generally have higher permeability and have the potential to allow rapid movement of polluted water. The soils are also deficient in adsorptive properties because of their lack of clay. Relying solely on the sealing resulting from manure solids when group I soils are encountered is not advisable. While the reduction in permeability from manure sealing may be one order of magnitude, the final resultant seepage losses are still likely to be excessive, and a liner should be used if the boundaries of the excavated pond are in this soil group.

Excavation boundary of an impoundment is underlain by some soils in group II or problem soils in group III (flocculated clays) and group IV (highly plastic clays that have a blocky structure)—Soils in group II may or may not require a liner. Documentation through laboratory or field permeability testing and computations of specific discharge (unit seepage quantities) is advised. Higher than normal permeability can occur when soils in group III or IV are flocculated or have a blocky structure. These are special cases, and most soils in groups III and IV will not need a liner provided the natural formation is thick enough to result in acceptable predicted seepage quantities.

These conditions do not always dictate a need for a liner. Specific site conditions can reduce the potential risks otherwise indicated by the presence of one of these conditions. For example, a thin layer of soil over high quality rock, such as an intact shale, is less risky than if the thin layer occurs over fractured or fissured rock. If the site is underlain by many feet of intermediate permeability soil, that site could have equivalent seepage losses as one underlain by only 2 feet of low permeability soil.

Some bedrock may contain large openings caused by solutioning and dissolving of the bedrock by ground water. Common types of solutionized bedrock are limestone and gypsum. When sinks or openings are known or identified during the site investigation, these areas should be avoided and the proposed facility located elsewhere. However, when these conditions are discovered during construction or alternate sites are not available, concrete or geosynthetic liners may be required, but only after the openings have been properly cleaned out and backfilled with concrete.

Specific discharge

Introduction

One way to require a minimal design at a site is to require a minimum thickness of a given permeability soil for a natural or constructed liner. An example of this would be to require that a clay liner constructed at a waste storage pond should be at least 1 foot thick, and the soil should have a coefficient of permeability of 1×10^{-7} centimeters per second or less.

However, using only permeability and thickness of a boundary horizon as a criterion ignores the effect of the depth of liquid on the predicted quantity of seepage from an impoundment. Using this approach would mean that the same design would be used for a site with 30 feet of water as one with 8 feet of water, for instance. A more rational method for stating a limiting design requirement is to compute seepage using Darcy's law for a unit area of the pond bottom.

A rational method of comparing design alternatives at a given site is needed. Such a method allows designers to evaluate the effect of changing one or more of the design elements in a site on the predicted seepage quantities. This document presents methods for computing the term "specific discharge" to use in comparing alternatives and to document a given design goal for a site. Specific discharge is defined as unit seepage.

It does not reflect the total seepage from a site, but rather provides a value of seepage per square unit area of pond bottom.

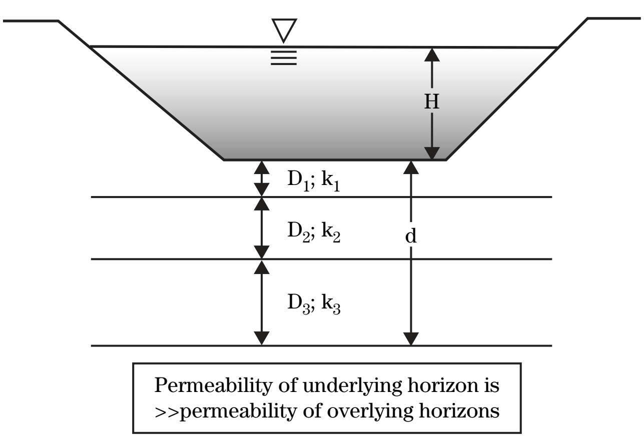
This document uses calculations of specific discharge to compare design alternatives and to determine if a given design meets regulatory requirements and guidelines. In some cases, the total seepage from a pond may be of interest, particularly for larger ponds in highly environmentally sensitive environments.

In those cases, more elaborate three-dimensional seepage computations using sophisticated finite-element computer programs may be warranted. It is outside the scope of this document to describe these types of analyses. Specialists who are experienced in using the complex software used for these computations should be consulted.

The parameters that affect the seepage from a pond with a natural or constructed clay liner are:

- The size of the pond—The total bottom area and area of the exposed sides of the pond holding the stored waste solids and liquids.
- The thickness of low permeability soil at the excavation limits of the pond—For design, the thickness of the soil at the bottom of the pond is often used because that is where seepage is likely to be highest. In some cases, however, seepage from the sides of the pond may also be an important factor. Seepage from the sides of ponds is best analyzed using finite element flow net programs. In some cases, rather than a single horizon, multiple horizons may be present.
- The depth of liquid in the pond—The depth of liquid at the top of the reservoir when pumping should commence is normally used.
- The coefficient of permeability of the soil forming the bottom and sides of the pond—In layered systems, an average or weighted permeability may be determined as shown in figure 10D–7.

Figure 10D–7 Conversion of permeability in layered profile to single value



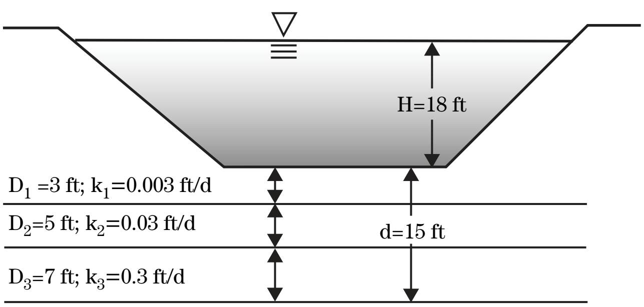
$$k_{average} = \frac{d}{\frac{D_1}{k_1} + \frac{D_2}{k_2} + \frac{D_3}{k_3}}$$

Example 10D–1 shows how to convert a multiple layer system into a single equivalent permeability. Using this method allows a designer to compute specific discharge when several horizons of constructed or natural soils occur below a site.

Example 10D–1

The excavated pond is underlain by 15 feet of soil consisting of three different horizons (fig. 10D–8). The thickness and permeability of each horizon is shown in the sketch. Compute the average vertical permeability of the 15 feet of soil.

Figure 10D–8 Idealized soil profile for example 10D–1



Solution

$$k_{average} = \frac{d}{\frac{D_1}{k_1} + \frac{D_2}{k_2} + \frac{D_3}{k_3}}$$

$$k_{average} = \frac{15}{\frac{3}{0.003} + \frac{5}{0.03} + \frac{7}{0.3}} = 0.0126 \text{ ft/d}$$

Definition of specific discharge

The term “specific discharge” has been coined to denote the unit seepage that will occur through the bottom of a pond with a finite layer of impervious soil. Specific discharge is the seepage rate for a unit cross-sectional area of a pond. It is derived from Darcy’s law as follows. First, consider Darcy’s law.

$$Q = k \times i \times A$$

For a pond with either a natural or constructed liner, the hydraulic gradient is the term i in the equation, and it is defined in figure 10D–9 as equal to (H+d)/d.

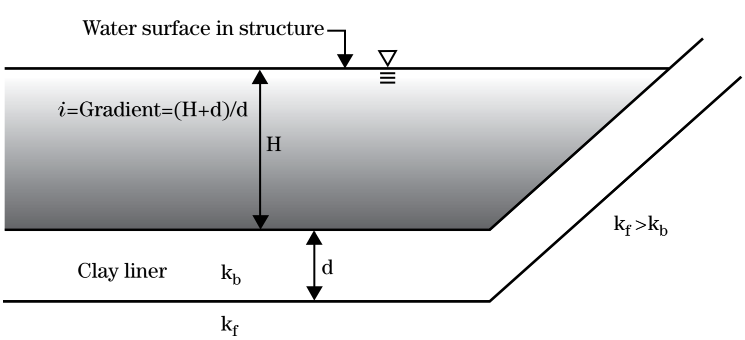
Given:
The Darcy’s law for this situation becomes:

$$Q = k \times \frac{H+d}{d} \times A$$

where:

Q	=	total seepage through area A	(L^3/T)
k	=	coefficient of permeability (hydraulic conductivity)	(L^3/L^2/T)
i	=	hydraulic gradient	(L/L)
H	=	vertical distance measured between the top of the liner and top of the liquid storage of the waste impoundment (fig. 10D–9)	(L)
d	=	thickness of the soil liner (fig. 10D–9)	(L)
A	=	cross-sectional area perpendicular to flow	(L^2)
L	=	length	
T	=	time	

Figure 10D–9 Definition of terms for clay liner and seepage calculations



Rearrange terms:

$$\frac{Q}{A} = \frac{k(H+d)}{d} \qquad (L/T)$$

By definition, unit seepage or specific discharge, is Q÷A. The symbol ν is used for specific discharge:

$$\nu = \frac{k(H+d)}{d} \qquad (L^3/L^2/T)$$

Specific discharge may be confused with permeability because the units are the same. In the metric system, specific discharge and permeability are often expressed in units of centimeters per second. The actual units are cubic centimeters of flow per square centimeter of cross section per second, but this reduces to centimeters per second. Specific discharge is different than permeability because specific discharge is an actual flow rate of liquid through a cross section of a soil mass, whereas permeability is a property of the soil mass itself. Permeability is independent of the hydraulic gradient in a particular site, whereas specific discharge accounts for both permeability of the soil and the gradient causing the flow, as illustrated in figure 10D–9. Because hydraulic gradient is dimensionless, the units of specific discharge and permeability are then the same.

Because specific discharge expressed as L/T has the same units as velocity, specific discharge is often misunderstood as representing the average rate or velocity of water moving through a soil body rather than a quantity rate flowing through the soil. Because the water flows only through the soil pores, the actual cross-sectional area of flow is computed by multiplying the soil cross section (A) by the porosity (n). The seepage velocity is then equal to the unit seepage or specific discharge, ν, divided by the porosity of the soil, n. Seepage velocity = (ν/n). In compacted liners, the porosity usually ranges from 0.3 to 0.5. The result is that the average linear velocity of seepage flow is two to three times the specific discharge value. The units of seepage velocity are L/T.

To avoid confusion between specific discharge and permeability, one possibility is to use different units for specific discharge than for the coefficient of permeability. Common units for permeability are recommended to be in feet per day or centimeters per second. Units for specific discharge should be in gallons per acre per day, acre-feet per acre per day, or acre-inches per acre per day.

To illustrate a typical computation for specific discharge, assume the following:

- A site has a liquid depth of 12 feet.
- The site is underlain by 2 feet of soil that has a coefficient of permeability of 1×10^{-6} centimeters per second (assume that a sample was obtained at the grade of the pond and sent to a laboratory where a flexible wall permeability test was performed on it).
- Compute the specific discharge, ν. First, the coefficient of permeability may be converted to units of feet per day by multiplying the given units of centimeters per second by 2,835.

$$k = \left(1\times10^{-6}\ \text{cm/s}\right)\times 2{,}835 = 0.002835\ \text{ft/d}$$

Then, the specific discharge ν is computed as follows:

$$\begin{aligned}\nu &= k\times\frac{H+d}{d}\\ &= 0.002835\times\frac{12+2}{2}\\ &\cong 0.02\ \text{ft}^3/\text{ft}^2/\text{d}\\ &\cong 0.02\ \text{ft/d}\end{aligned}$$

Conversion factors for specific discharge are given in table 10D–6.

Table 10D–6 Conversion factors for specific discharge

To convert from	To units of	Multiply by
$ft^3/ft^2/d$	$in^3/in^2/d$	12
$ft^3/ft^2/d$	gal/acre/d	325,829
$in^3/in^2/d$	gal/acre/d	27,152.4
$in^3/in^2/d$	$cm^3/cm^2/s$	2.94×10^{-5}
$cm^3/cm^2/s$	gal/acre/d	9.24×10^{8}
$cm^3/cm^2/s$	$in^3/in^2/d$	34,015
$cm^3/cm^2/s$	$ft^3/ft^2/d$	2,835

To convert the computed specific discharge in the example into units of gallons per acre per day and cubic inches per square inch per day (in/d), use conversion factors given in table 10D–6.

- 0.02 foot per day×325,829 ≅ 6,500 gallons per acre per day
- 0.02 foot per day×12 = 0.24 cubic inch per square inch per day

A variety of guidelines have been used and regulatory requirements stated for specific discharge. Usually, guidelines require the specific discharge for a given waste storage structure to be no higher than a stated value. The following example demonstrates the unit seepage that will result from a typical size animal waste storage lagoon or storage pond with 2 feet of either very good natural soil or a very well constructed, 2-foot-thick clay liner in the bottom of the lagoon. A practical lower limit for the assumed permeability of a compacted clay or a very good natural liner is a coefficient of permeability equal to 5×10^{-8} centimeters per second. This is based on considerable literature on field and laboratory tests for compacted clay liners used in sanitary landfills.

The specific discharge for this ideal condition follows, assuming:

- The pond has a liquid depth of 15 feet.
- The site is underlain by 2 feet of soil (either a natural layer or a constructed clay liner) that has a coefficient of permeability of 5×10^{-8} centimeters per second
- Compute the specific discharge, ν. First, the coefficient of permeability is converted to units of feet per day by multiplying the given units of centimeters per second by 2,835. Then,

$$k = \left(1\times10^{-6}\ \text{cm/s}\right)\times 2,835 = 0.002835\ \text{ft/d}$$

Then, the specific discharge ν is computed as follows:

$$\begin{aligned} \nu &= k\times\frac{H+d}{d} \\ &= 1.42\times10^{-4}\ \text{ft/d}\times\frac{15\ \text{ft}+2\ \text{ft}}{2\ \text{ft}} \\ &\cong 0.0012\ \text{ft}^3/\text{ft}^2/\text{d} \\ &\cong 0.0012\ \text{ft/d} \end{aligned}$$

Converting this into units of gallons per acre per day:

$$0.0012\ \text{ft/d}\times 325,829 \cong 393\ \text{gal/acre/d}$$

Table 10D–7 lists typical specific discharge values used by State regulatory agencies. Requirements vary from State to State. Individual designers may regard minimum requirements as too permissive. Some States permit a designer to assume that the initial computed seepage rate will be reduced in the future by an order of magnitude by taking credit for a reduction in permeability resulting from manure sealing. Although the State or local regulations should be used in design for a specific site, the NRCS no longer recommends assuming that manure sealing will result in one order of magnitude reduction. A more conservative assumption described previously allows an initial seepage rate of 5,000 gallons per acre per day, which for the assumed typical site dimensions of 9 feet of liquid and 1 foot thickness of liner, assumes a one half order of magnitude reduction.

Table 10D–7 Typical requirement for specific discharge used by State regulatory agencies

Example specific discharge value	Equivalent value in gallons per acre per day
1/56 $in^3/in^2/d$	485
1/8 $in^3/in^2/d$	3,394
1/4 $in^3/in^2/d$	6,788
1×10^{-6} $cm^3/cm^2/s$	924

Design of compacted clay liners

If a site does not have a sufficient thickness of *in situ* low permeability soil horizons to limit seepage to an acceptably low value, a clay liner may be required. Some State regulations may also require a constructed clay liner regardless of the nature of the *in situ* soils at a site. Regulations sometimes require a specific thickness of a compacted soil with a documented permeability of a given value. An example of this is a State requirement that a waste storage pond must have in the bottom and sides of the pond at least 2 feet of compacted clay with a documented coefficient of permeability of 1×10^{-7} centimeters per second.

Clay liners may also be designed based on a stated allowable specific discharge value. Computations may be performed as detailed in following sections to determine a design that will meet a design specific discharge goal.

Detailed design steps for clay liners

The suggested steps for design of a compacted clay or amendment-treated liner are:

Step 1—Size the impoundment to achieve the desired storage requirements within the available construction limits and determine this depth or the height, H, of storage needed.

Step 2—Determine (from a geologic investigation) the thickness and permeability of horizons of natural clay underlying the bottom of the planned excavated pond. Investigate to a minimum of 2 feet below the planned grade of the pond or to depths required by State regulations, if greater. If natural low permeability horizons at least 2 feet thick or an equivalent thickness of soil with different permeability do not underlie the site, assume that a compacted clay liner (with or without amendments) will be constructed. The liner may be constructed of soils from the excavation if they are suitable for use, or soil may be imported from a nearby borrow source.

Step 3—Measure or estimate the permeability of the natural horizons or the compacted liner planned at the site. Use procedures shown in example 10D–1 to obtain a weighted permeability for the natural horizons.

Step 4—Compute the specific discharge using the values of head in the pond and thickness of natural horizons and their equivalent permeability in the specific discharge equation. If State or local regulations provide a required value for allowable specific discharge, design on the basis of those regulations. Currently, State regulations for specific discharge range from a low of about 500 gallons per acre per day (1/56 inch per day) to a high of about 6,800 gallons per acre per day (1/4 inch per day). If no regulations exist, a value of 5,000 gallons per acre per day may be used. If a designer feels that more conservative limiting seepage is advisable, that rate should be used in computations. It is seldom technically or economically feasible to meet a design specific discharge value of less than 500 gallons per acre per day using compacted clay liners or amendment-treated soil liners. To achieve lower values of unit seepage usually requires synthetic liners, concrete liners, or aboveground storage tanks.

Step 5—If the computed specific discharge meets design objectives, the site is satisfactory without additional design and may be designed and constructed.

Step 6—If the computed specific discharge at the site does not meet design objectives, use either method A or method B shown in following sections to design a compacted clay liner or a liner with soil amendment.

Notes to design steps:

- The calculated thickness of the soil liner required is sensitive to the relative values of soil permeability and the assumed allowable specific discharge value.
- The best and most economical way to reduce the required liner thickness is by reducing the soil's permeability. Liner permeability may be reduced by compacting soils to a higher degree, compacting them at a higher water content, and by using an appropriate additive such as bentonite or soil dispersants.
- By using higher compaction water contents and compacting soils to a high degree of saturation, permeability often can be reduced by a factor of 1/100.
- The liner soil must be filter compatible with the natural foundation upon which it is compacted. Filter compatibility is determined by criteria in NEH 633, chapter 26. As long as the liner soil will not pipe into the foundation, the magnitude of hydraulic gradient across the liner need not be limited.
- Filter compatibility is most likely to be a significant problem when a liner is constructed directly on top of very coarse soil, such as poorly graded gravels and gravelly sands.
- The minimum recommended thickness of a compacted clay liner is given in CPS 521D. The

minimum thickness varies with the depth of liquid in the pond.

- Clay liners constructed by mixing bentonite with the natural soils at a site should have a minimum thickness shown in CPS 521C. These minimum thicknesses are based on construction considerations rather than calculated values for liner thickness requirement from the specific discharge equations. In other words, if the specific discharge equations indicate a 7-inch thickness of compacted bentonite-treated liner is needed to meet suggested seepage criteria, the CPS 521C could dictate a thicker liner. That guidance should be considered in addition to the specific discharge computations.
- Natural and constructed liners must be protected against damage by mechanical agitators or other equipment used for cleaning accumulated solids from the bottom of the structure. Liners should also be protected from the erosive forces of waste liquid flowing from pipes during filling operations. CPSs provide guidance for protection.
- Soil liners may not provide adequate confidence against ground water contamination if foundation bedrock beneath the pond contains large, connected openings. Collapse of overlying soils into the openings could occur. Structural liners of reinforced concrete or geomembranes should be considered because the potential hazard of direct contamination of ground water is significant.
- Liners should be protected against puncture from animal traffic and roots from trees and large shrubs. The subgrade must be cleared of stumps and large angular rocks before construction of the liner.
- If a clay liner (or a bentonite-treated liner) is allowed to dry, it may develop drying cracks or a blocky structure. Desiccation can occur during the initial filling of the waste impoundment and later when the impoundment is emptied for cleaning or routine pumping. Disking, adding water, and compaction are required to destroy this structure created by desiccation. A protective insulating blanket of less plastic soil may be effective in protecting underlying more plastic soil from desiccation during these times the liner is exposed. CPSs address this important consideration.
- Federal and State regulations may be more stringent than the design guidelines given, and they must be considered in the design. Examples later in this section address consideration of alternative guidelines.

Two methods for designing constructed clay liner

Two methods for designing a clay liner are available. In method A, designers begin with an assumed or required value for allowable specific discharge. Using the depth of liquid storage in the pond and known or estimated values of the liner's coefficient of permeability, a required thickness of liner is computed. If the value obtained is unrealistic, different values for the liner permeability are evaluated to determine what values produce a desirable thickness of liner. CPSs also determine minimum liner thicknesses.

In method B, designers begin with a desired thickness of liner and an assumed or required value for specific discharge. Using the depth of liquid storage in the pond and the desired thickness of liner, a required coefficient of permeability for the liner is computed. If the value obtained is unrealistic, different values for the liner thickness are evaluated to determine what values produce an achievable permeability. Coordinating with soil testing laboratories is helpful in evaluating alternatives that can provide the required permeability for the liner.

Each of these methods is illustrated with detailed design examples as follows:

Method A—Using assumed values for the coefficient of permeability of a compacted clay based on laboratory tests of the proposed liner soil, compute the required thickness of a liner to meet the given specific discharge design goal. In the absence of more restrictive State regulations, assume an acceptable specific discharge of 5,000 gallons per acre per day.

The required thickness of a compacted liner can be determined by algebraically rearranging the specific discharge equation, as follows. Terms have been previously defined.

$$d = \frac{k \times H}{\nu - k}$$

Note: If the k value assumed for the liner is equal to or greater than the assumed allowable specific discharge, meaningless results are attained for d, the calculated thickness of the liner in the last equation. The reason is that the denominator would be zero, or a negative number. Another way of stating this is that the allowable specific discharge goal cannot be met if the liner soils have k values equal to or larger than the assumed allowable specific discharge, in consistent units. Note also that CPS 521D has requirements for minimum thickness of compacted clay liners. If the computed value for the required thickness is less than that given in CPS 521D, then the values in the CPS must be used.

Example 10D–2—Design a clay liner using method A

Given:
Site design has a required depth of waste liquid, H, in the constructed waste impoundment of 12 feet. A soil sample was obtained and submitted to a soil mechanics laboratory for testing. A permeability test on a sample of proposed clay liner soil resulted in a permeability value of 6.5×10^{-7} centimeters per second (0.00184 ft/d) for soils compacted to 95 percent of maximum Standard Proctor dry density at a water content 2 percent wet of optimum. The State requirement for the site requires a specific discharge no greater than an eighth of an inch per day. Compute the required thickness of liner to be constructed of soil having the stated permeability that will achieve this specific discharge.

Solution:
First, convert the required specific discharge into the same units as will be used for the coefficient of permeability. Using values for permeability of feet per day, convert the stated eighth of an inch per day specific discharge requirement into feet per day. To convert, divide an eighth by 12 to obtain a specific discharge requirement of 0.010417 foot per day. It is given that the k value at the design density and water content is 0.00184 foot per day. Calculate the required minimum thickness of compacted liner as follows:

The equation for required d is:

$$d = \frac{k \times H}{\nu - k}$$

Using English system units, substituting the given values for H and k, assuming an allowable specific discharge, ν, of 0.010417 foot per day, then

$$d = \frac{0.00184 \text{ ft/d} \times 12 \text{ ft}}{0.010417 \text{ ft/d} - .00184 \text{ ft/d}} = 2.6 \text{ ft}$$

CPS 521D requires a pond with a depth of water of 12 feet to have a minimum thickness liner of 1 foot, so the 2.6 foot requirement governs.

Method B—Using a given value for depth of liquid in the pond, assumed values for the thickness of a compacted clay based on construction considerations, CPS 521D requirements, State regulations, or the preference of the designer, compute the required permeability of a liner to meet the given specific discharge design goal. In the absence of more restrictive State regulations, assume an acceptable specific discharge of 5,000 gallons per acre per day. The required permeability of a compacted liner can be determined by algebraically rearranging the specific discharge equation as follows. Terms have been previously defined.

$$k = \frac{\nu \times d}{H + d}$$

If the computed value for the required permeability is less than 5×10^{-8} centimeters per second (1.4×10^{-4} ft/d), NRCS engineers' experience is that lower values are not practically obtainable and a thicker liner or synthetic liners should be used to achieve design goals.

Example 10D–3—Design a clay liner using method B

Given:
Site design has a required depth of waste liquid, H, in the constructed waste impoundment of 19 feet. CPS 521D requires a liner that is at least 18 inches (1.5 feet) thick. The site is in a State that allows NRCS design guidance of 5,000 gallons per acre per day to be used in the design. The NRCS guidance assumes that manure sealing will reduce this seepage value further and no additional credit should be taken.

Solution:

Step 1 First, convert the required specific discharge into the same units as will be used for the coefficient of permeability. Using values for permeability of feet per day, convert the stated 5,000 gallons per acre per day specific discharge requirement into feet per day. To convert using conversions shown in table 10D–6, divide 5,000 by 325,829 to obtain a specific discharge requirement of 0.0154 foot per day. The thickness of liner is given to be 1.5 feet. Calculate the required coefficient of permeability of the compacted liner as follows:

$$k = \frac{\nu \times d}{H + d}$$

Using English system units, substituting the given values for H of 19 feet and for d of 1.5 feet, assuming an allowable specific discharge, ν, of 0.0154 foot per day, then:

$$k = \frac{.0154 \text{ ft/d} \times 1.5 \text{ ft}}{19 \text{ ft} + 1.5 \text{ ft}}$$
$$= 1.1 \times 10^{-3} \text{ ft/d}$$

Convert to centimeters per second by dividing by 2,835.

$$k = \frac{1.1 \times 10^{-3} \text{ ft/d}}{2,835}$$
$$k = 4.0 \times 10^{-7} \text{ cm/s}$$

Step 2—The designer should coordinate testing with a laboratory to determine what combinations of degree of compaction and placement water content will result in this value of permeability or less. Design of the 1.5-foot-thick liner may proceed with those recommendations.

Construction considerations for compacted clay liners

Thickness of loose lifts

The permissible loose lift thickness of clay liners depends on the type of compaction roller used. If a tamping or sheepsfoot roller is used, the roller teeth should fully penetrate through the loose lift being compacted into the previously compacted lift to achieve bonding of the lifts. A loose lift thickness of 9 inches is commonly used by NRCS specifications. If the feet on rollers cannot penetrate the entire lift during compaction, longer feet or a thinner lift should be specified. A loose layer thickness of 6 inches may be needed for some tamping rollers that have larger pad type feet that do not penetrate as well.

Method of construction

Several methods are available for constructing a clay liner in an animal waste impoundment. Each has its advantages and disadvantages as described in following sections. A designer should consider the experience of local contractors and the relative costs of the methods in selecting the most appropriate design for a given site. The thickness of the planned soil liner, haul distance, planned side slopes for the pond, and other factors also guide a designer's decision on the best method to use.

Bathtub construction

This method of construction consists of a continuous thickness of soil compacted up and down or across the slopes. Figure 10D–10 shows the orientation of the lifts of a compacted liner constructed using this method, as contrasted to the stair step method, which is covered next. Figure 10D–11 shows two sites where the bathtub method of construction is being used.

This construction method has the following advantages over the stair-step method:

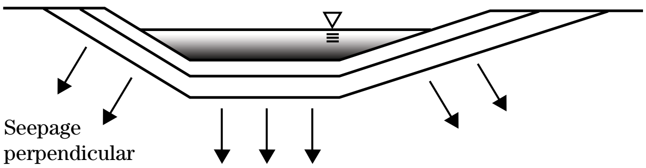
- The layers of compacted clay are oriented perpendicular to flow through the liner in this method. If the lifts making up the liner are not bonded well, the effect on seepage is minor, compared to the stair-step method.
- This method lends itself to constructing thinner lifts, which is more economical.

The bathtub construction method has the following disadvantages compared to the stair-step method:

- Side slopes must be considerably flatter than for the stair-step method, creating a pond with a larger surface area. A pond with a larger surface area has to store more precipitation falling on it, which could be considered an extra cost of the method.
- To permit equipment traversing up and down the slopes, slopes must be an absolute minimum of 3H:1V. Shearing of the soil by the equipment on steeper slopes is a concern. To prevent shearing of the compacted soil, the slopes of

Figure 10D–10 Methods of liner construction (after Boutwell 1990)

Bathtub construction



Stair-step construction

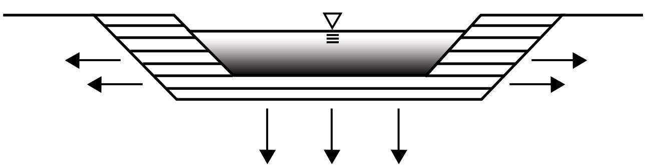


Figure 10D–11 Bathtub construction of clay liner *(photo courtesy of NRCS Virginia (top) and NRCS Nebraska (bottom))*

many compacted liners in ponds constructed using this method use 4H:1V slopes so that equipment will exert more normal pressure on the slope than downslope pressure.

Stair-step construction

The stair-step method of construction is illustrated in figure 10D–10. Construction of the liner consists of compacting lifts of soil around the perimeter of the liner in a stair-step fashion, finishing the job by shaving off some of the side liner and placing it in the bottom of the pond. This method of construction is required if the side slopes of the pond are any steeper than about 3H:1V. Advantages of this method of construction are:

- A thicker blanket, measured normal to the slope, will result compared to the bathtub method of construction (fig. 10D–10). This is a positive factor in seepage reduction.
- It allows steeper side slopes, and thus the surface area of the pond exposed to rainwater accumulation is smaller than a bathtub construction would permit.
- The thicker blanket reduces the impact of shrinkage cracks, erosive forces, and potential mechanical damage to the liner.
- Ponds constructed with this method are deeper for a given volume of waste than ponds constructed with the bathtub method, which favors anaerobic processes in the pond.

Disadvantages of the method are:

- This method may be more expensive than the bathtub method because the liner on the sides of the pond are thicker.
- Flow is parallel to the orientation of the layers forming the compacted liner on the pond sides. If care is not taken to obtain good bonding between lifts, seepage through the interface between lifts could be higher than expected.
- Contractors may be less familiar with this method of operation of equipment.

In the stair-step method of construction, the pond is first excavated. Borrow soil is then imported with a truck or scraper and spread in thin lifts (8 to 9 in thick) prior to compaction. Figure 10D–12a shows the first layer being constructed on the sides of the pond. This pond used a bentonite application. Each lift of soil is compacted with a sheepsfoot roller to obtain the desired dry density at the specified water content (fig. 10D–12b). The interior liner is constructed by bringing up lifts the full depth of the pond. Photo 10D–12c provides an overview of the stair-step process of constructing a clay liner in an animal waste storage pond. After the sides are constructed, some of the liner is shaved off and used to construct a liner in the bottom of the pond (fig. 10D–12c).

Soil type

Soils in groups III and IV are the most desirable for constructing a clay liner (table 10D–3). Some soils in group II may also be good materials for a clay liner, but definitely require laboratory testing to document their permeability characteristics. Soils in group I always require bentonite to form a liner with acceptably low permeability. Some soils in group II may also require bentonite to be an acceptable material for a liner. Some soils in groups III and IV require a soil dispersant to create an acceptably low permeability.

Classification

The most ideal soils for compacted liners are those in group III. The soils have adequate plasticity to provide a low permeability, but the permeability is not excessively high to cause poor workability. Group IV soils can be useful for a clay liner, but their higher plasticity index (PI greater than 30) means they are more susceptible to desiccation. If clay liners are exposed to hot dry periods before the pond can be filled, desiccation and cracking of the liner can result in an increase in permeability of the liner. A protective layer of lower PI soils is often specified for protection of higher PI clay liners to prevent this problem from developing.

Highly plastic clays like those in group IV are also difficult to compact properly. Special effort should be directed to processing the fill and degrading any clods in high plasticity clays to prevent this problem.

Size of clods

The size and dry strength of clay clods in soil prior to compaction have a significant effect on the final quality of a clay liner. Soil containing hard clayey clods is difficult to break down and moisten thoroughly. Adding water to the soil is difficult because water penetrates the clods slowly. High speed rotary pulverizers are sometimes needed if conditions are especially unfavorable. If soils containing large clay clods are

Figure 10D–12 Stair-step method *(Photo credit John Zaginaylo, PA, NRCS)*

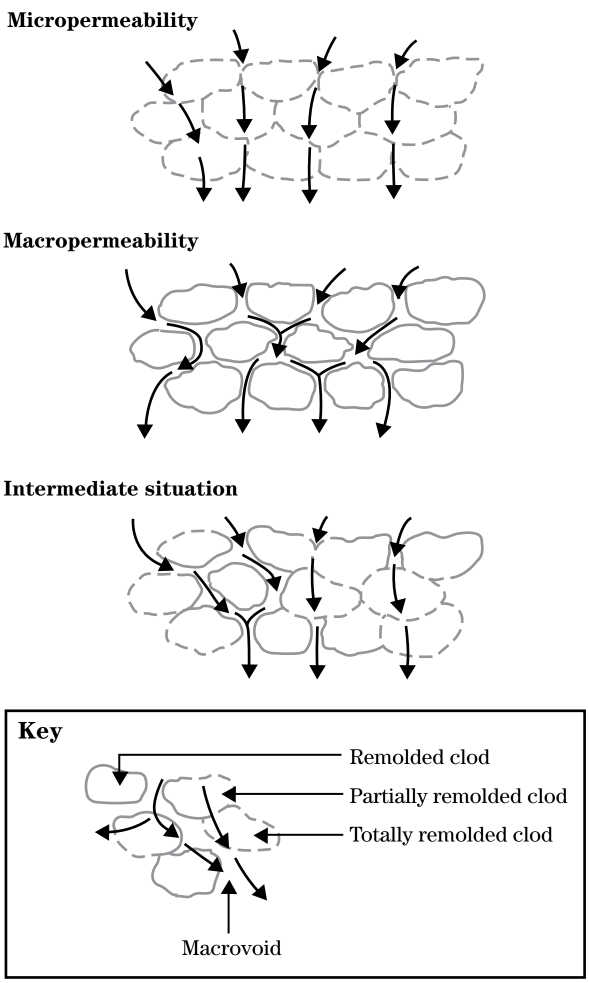
(a)

(b)

(c)

not treated properly, the resultant permeability will be much higher than might otherwise be true. Figure 10D–13 shows the structure that results from compacting soils containing clods that are not adequately broken down.

Figure 10D–13 Macrostructure in highly plastic clays with poor construction techniques (from Hermann and Elsbury 1987)



Natural water content of borrow

The water content of soils used to construct a clay liner is the most important factor in obtaining a low permeability liner for a given soil. If soils are too dry, they cannot effectively be compacted to a condition where their structure is acceptable and their permeability may be higher than desirable. Compacting a soil at the proper water content creates a structure that is most favorable to a low permeability. Adding water to compacted clay liners is an additional expense that must be considered. A good rule of thumb is that it requires about 3.2 gallons of water to increase the water content of a cubic yard of compacted soil by 1 percent.

Dry conditions in the borrow

If soils in the borrow area are dry, several problems may need to be addressed. If the soils are clays with relatively high plasticity (PI values greater than about 20), they are likely to be very cloddy when excavated. Water is slow to penetrate the clods and compaction is less likely to degrade clods if enough time has not elapsed between adding the water and compaction. More descriptions follow in subsequent sections, and figure 10D–13 illustrates how clods left in the compacted fill will likely cause the soil to have a higher than expected permeability.

If the water content of borrow soils is more than 3 or 4 percent drier than required for specified compaction conditions, consideration should be given to wetting the soils in the borrow prior to construction. Adding large amounts of water during processing on the fill is difficult and inefficient. Sprinklers can be set up in the borrow some time before construction is planned and then time will allow water to soak into the soils more thoroughly.

Wet conditions in the borrow

If the natural water content of the borrow soil is significantly higher than optimum water content, achieving the required degree of compaction may be difficult. A good rule of thumb is that a soil will be difficult to compact if its natural water content exceeds about 90 percent of the theoretical saturated water content at the dry density to be attained. The following procedure can help to determine if the soils in the borrow are too wet for effectively compacting them.

Step 1 Measure the natural water content of the soil to be used as a borrow source for the clay liner being compacted.

Step 2 Compute the highest dry density to which the soil can be compacted at this water content using the following equation, which assumes that the highest degree of saturation achievable is 90 percent:

$$\text{Achievable } \gamma_{dry} \text{ lb/ft}^3 = \frac{62.4}{\frac{w_n\%}{90} + \frac{1}{G_s}}$$

where:
w_n(%) = natural water content of borrow soils, %
G_s = specific gravity of the soil solids (dimensionless)

Specific gravity values are obtained by ASTM Standard Test Method D854. An average value for specific gravity is often assumed to be 2.68. However, soils with unusual mineralogy may have values significantly different. Soils with volcanic ash may have specific gravity values as low as 2.3, and soils with hematite in them may have values as high as 3.3, based on NRCS laboratory results.

Step 3 Perform a Standard Proctor (ASTM D698) compaction test on the same soil and determine the maximum dry density value. Compute the achievable degree of compaction by dividing the computed value of achievable dry density by the maximum Standard Proctor dry density.

Step 4 If the computed achievable degree of compaction is less than 95 percent, then drying of the sample will probably be required. In rare cases, compaction to a lower degree, such as 90 percent of Standard Proctor, at higher water contents will achieve an acceptably low permeability. Laboratory tests should be performed to evaluate whether a lower degree of compaction will result in an acceptable permeability value.

Note: The experience of NRCS engineers is that when the natural water content of a soil is more than 4 percent above optimum water content, it is not possible to achieve 95 percent compaction. Computations should always be performed, as this rule of thumb sometimes has exceptions. In most cases, drying clay soils by only disking is somewhat ineffective, and it is difficult to reduce their water content by more than 2 or 3 percent with normal effort. It may be more practical to delay construction to a drier part of the year when the borrow source is at a lower water content. In some cases, the borrow area can be drained several months before construction. This would allow gravity drainage to decrease the water content to an acceptable level.

Step 5 Another way of examining this problem is to assume that soils must be compacted to 95 percent of their Standard Proctor (ASTM D698) dry density and then compute the highest water content at which this density is achievable. Commonly, soils are difficult to compact to a point where they are more than 90 percent saturated. The following equation is used to determine the highest feasible placement water content at which the dry density goal is achievable:

$$\text{Highest placement w(\%)} = \frac{90(\%)}{100} \times \left[\frac{62.4}{\gamma_{dry} \text{ lb/ft}^3} - \frac{1}{G_s} \right]$$

Example 10D–4—Compute the achievable dry density of a potential borrow source

Given:
A borrow source is located and found to be in a desirable group III type soil. The soil has 65 percent finer than the No. 200 sieve and a PI of 18. The soil was sampled and placed in a water tight container and shipped to a soils laboratory. The natural water content of the soil was measured to be 21.8 percent. The lab also performed a specific gravity (G_s) test on the soil, and measured a value of 2.72. A Standard Proctor Test was performed on the sample and values for maximum dry density of 108.5 pounds per cubic foot and an optimum water content of 17.0 percent were measured.

Solution:
The maximum degree of compaction of this soil at the measured water content. If the soil is too wet to be compacted to 95 percent of maximum standard Proctor dry density, how much will it have to be dried to achieve compaction to 95 percent of maximum density?

$$\text{Achievable } \gamma_{dry} \text{ lb/ft}^3 = \frac{62.4}{\frac{w_n\%}{90} + \frac{1}{G_s}}$$

$$\text{Achievable } \gamma_{dry} \text{ lb/ft}^3 = \frac{62.4}{\frac{21.8\%}{90} + \frac{1}{2.72}} = 102.3 \text{ lb/ft}^3$$

Next, compute the achievable degree of compaction by dividing the achievable dry density by the maximum Standard Proctor dry density, expressed as a percentage. The achievable degree of compaction is then equal to 102.3 divided by 108.5×100=94.3 percent.

Now, determine how wet the sample could be and still achieve 95 percent compaction. Ninety-five percent of the maximum Standard Proctor dry density is 0.95×108.5=103.1 pounds per cubic foot. Substitute this value into the equation given:

$$\text{Highest placement w\%} = \frac{90}{100} \times \left[\frac{62.4}{\gamma_{dry} \text{ lb/ft}^3} - \frac{1}{G_S}\right]$$

$$\text{Highest placement w\%} = \frac{90}{100} \times \left[\frac{62.4}{103.1 \text{ lb/ft}^3} - \frac{1}{2.72}\right] = 21.4\%$$

This computation confirms the rule of thumb given that it is difficult to achieve 95 percent degree of compaction if the natural water content is greater than 4 percent above optimum. The stated value for optimum water content is 17.0 percent, so the rule of thumb says that if the natural water content exceeds 21.0 percent, achieving 95 percent degree of compaction will be difficult.

Methods of excavating and processing clay for liners

Clods in borrow soil

If borrow soils are plastic clays at a low water content, the soil will probably have large, durable clods. Disking may be effective for some soils at the proper water content, but pulverizer machines may also be required. To attain the highest quality liner, the transported fill should be processed by adding water and then turned with either a disk or a high-speed rotary mixer before using a tamping roller. Equipment requirements depend on the strength and size of clods and the water content of the soil.

Placement of lifts

Individual lifts of soil usually consist of an equipment width (often about 8 to 10 feet wide) layer of soil about 6 inches thick, after compaction. These lifts should be staggered to prevent preferential flow along the inter-lift boundaries. Figure 10D–14(a) shows the preferred way of offsetting the lifts. Figure 10D–14(b) shows a method that should be avoided. Bonding between the 6-inch lifts is also important so that if water does find its way down the boundary between two lanes of compacted soil that it cannot flow laterally and find the offset boundary.

Macrostructure in plastic clay soils

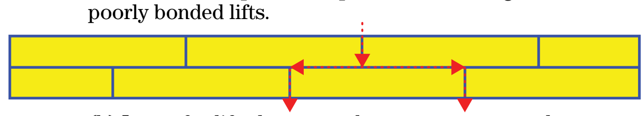
Clods can create a macrostructure in a soil that results in higher than expected permeability because of preferential flow along the interfaces between clods. Figure 10D–13 illustrates the structure that can result from inadequate wetting and processing of plastic clay. The permeability of intact clay particles may be quite low, but the overall permeability of the mass is high because of flow between the intact particles.

Dry density and optimum water content

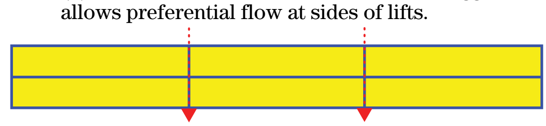
Compaction specifications for most earthfill projects normally require a minimum dry density (usually referenced to a specified compaction test procedure) and an accompanying range of acceptable water contents (referenced to the same compaction test procedure). This method of fill specification is usually based on en-

Figure 10D–14 Construction methods to limit interlift preferential flow paths

(a) Lanes for lift placement should be staggered to prevent preferential flow at sides of lifts. Bonding of lifts is also important to prevent flow along poorly bonded lifts.



(b) Lanes for lift placement that are not staggered allows preferential flow at sides of lifts.



gineering property tests such as shear strength, bearing capacity, and permeability. When permeability is the primary engineering property of interest, as would be the case for a compacted clay liner, an alternative type of compaction specification should be considered. The reason for this is a given permeability value can be attained for many combinations of compacted density and water contents (Daniels and Benson 1990). Figure 10D–15 illustrates a window of compacted dry density and water content in which a given permeability could be obtained for an example soil. The principles involved can be illustrated as follows.

Assume that a given soil is being used to construct a clay liner for an animal waste impoundment. A moderately plastic silty clay classifying as CL in the USCS is used. In case 1, the soil being obtained from a nearby borrow area has a relatively high natural water content. The contractor elects to use lighter construction equipment that applies a relatively low energy in compacting the soil. The result is the soil is compacted to a condition where the compacted density is relatively low and the placement water content is relatively high. This is labeled as point 1 in the figure 10D–15. In case 2, the same soil is being used, but the site is being constructed in a drier time of year. The contractor elects to use a larger sheepsfoot roller and apply more passes of the equipment to achieve the desired product. This time the same soil is compacted to a significantly higher density at a significantly lower water content. This is labeled point 2 in the figure 10D–15.

Laboratory tests can be used to establish the boundary conditions and arrive at a window of acceptable densities and water contents for a clay liner. Figure 10D–16 shows how a different structure results between soils compacted wet of optimum and those compacted dry of optimum water content. It also illustrates that soils compacted with a higher compactive effort or energy have a different structure than those compacted with low energy.

Mitchell (1965) was instrumental in explaining how the permeability of clay soils is affected by the conditions under which they were compacted. Figure 10D–17 illustrates results of one series of experiments summarized in the study. Two samples of a soil were compacted using different energy at different water contents and their permeability was measured. Soil C was compacted using higher energy, like that used when a heavy sheepsfoot roller passed over each compacted lift multiple times. Soil B was compacted using a lower energy, equating to a smaller roller with a smaller number of passes used in the compaction process.

Figure 10D–15 Range at acceptable moisture/density for a typical clay liner

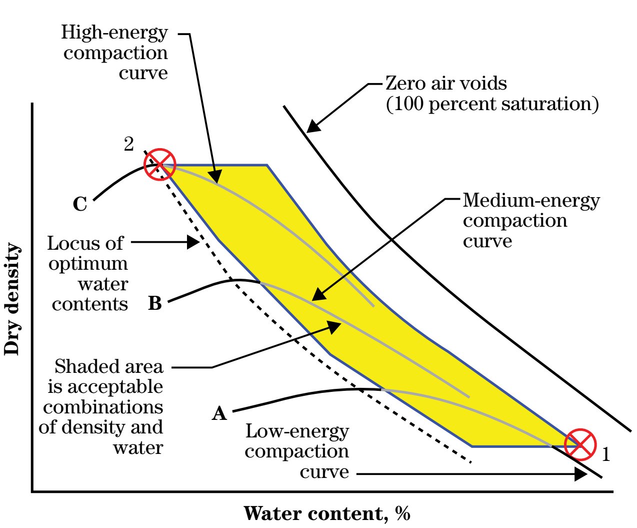
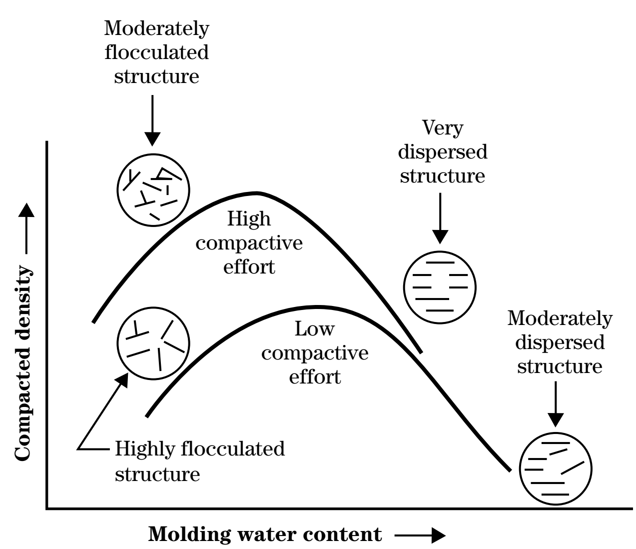


Figure 10D–16 Effect of water content and compactive effort on remolding of soil structure in clays (from Lambe 1958)

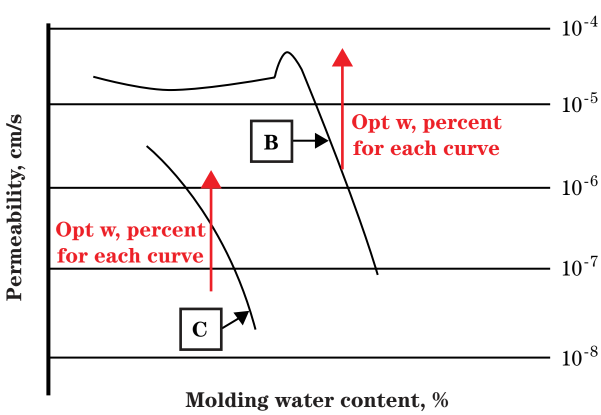


The curves show the relationship between the permeability of the compacted soil and the compaction water content, for the two energies used. The following general principles are seen:

- The permeability of the low energy soil (curve B) is high unless the compaction water content is significantly wet of optimum. Very high permeability results for compaction dry of optimum.
- The permeability of the higher energy soil (curve C) is relatively high for water contents less than optimum.

Lambe (1958) explains how the energy used and the water content of the soil at the time of compaction affect the permeability of the soil by creating structure in the soil. Figure 10D–16 summarizes his explanation of how different soil structures results from these two factors. Soils compacted with higher energy (heavier equipment and numerous passes of the equipment) at a higher water content have a dispersed structure. This structure creates very small plate-shaped voids that are resistant to water flow. Soils that are compacted with lower energy and/or lower water contents have a flocculated structure. This structure involves larger voids that are more conducive to water flow.

Figure 10D–17 Plot showing effect of molding water content on permeability (Mitchell 1965)



Percent saturation importance

Benson and Boutwell (2000) studied the correlation between field measured permeability values on compacted liners with laboratory measured values. The study found that when soils were compacted at drier water contents, even if a high density were obtained, that correlation between field and lab permeability test values was poor. The study found good correlation when soils were compacted at relatively higher water contents. Clods in clay soils are probably not broken down as well at lower compaction water contents which explains the higher permeability in the field. In lab tests, breaking down clods and obtaining test specimens without a structure is easier than done with field compaction procedures.

The conclusions of Benson and Boutwell's research were that if a designer is going to rely on laboratory permeability tests to predict the permeability of a compacted clay liner, the following rules of thumb apply.

- Soils should generally be compacted wet of the line of optimums. The line of optimums is illustrated in figure 10D–15. It is the locus of optimum water content values for a given soil for a range of compactive energy. A soil compacted with a low energy (like that resulting from a small sheepsfoot roller), curve A in figure 10D–15, will have a relatively low maximum density and high optimum water content. A soil compacted with a high energy (like that resulting from using a large heavy tamping roller), curve C in figure 10D–15, will have a high value for maximum density and a low value of optimum water content. The line of optimums is the locus of points connecting the values of optimum water content. Remember that optimum water content depends on the energy used and that Standard Proctor (ASTM D698) is only one standard type of compaction test. ASTM D1557, the modified energy test is also used for design of some clay liners.
- Eighty percent of field tests of dry density and water content should plot to the right of the line of optimums if the field permeability is expected to reflect the same values obtained in laboratory testing.
- The average water content of all quality control tests should be from 2 to 4 percent wetter than the line of optimums as defined.

Energy level of compaction

The relationship of maximum dry density and optimum water content varies with the compactive energy used to compact a soil. Higher compactive energy results in higher values of maximum dry unit weight and lower values of optimum water content. Lower compactive energy results in lower values of maximum dry unit weight and higher values of optimum water content. Because optimum water content varies with the energy used in compaction, its nomenclature can be misleading. The optimum water content of a soil varies with the particular energy used in the test to measure it.

Compactive energy is a function of the weight of the roller used, thickness of the lift, and number of passes of the roller over each lift. Rollers should be heavy enough to cause the projections (teeth or pads) on the roller to penetrate or almost penetrate the compacted lift. Enough passes must be used to attain coverage and break up any clods. Additional passes do not compensate for rollers that are too light.

Roller size is often specified in terms of contact pressure exerted by the feet on sheepsfoot or tamping rollers. Light rollers have contact pressures less than 200 pounds per square inch, while heavy rollers have contact pressures greater than 400 pounds per square inch.

Limited data are available for various sizes of equipment to correlate the number of passes required to attain different degrees of compaction. Typically, from 4 to 8 passes of a tamping roller with feet contact pressures of 200 to 400 pounds per square inch are required to attain degrees of compaction of from 90 to 100 percent of maximum Standard Proctor dry density. However, this may vary widely with the soil type and weight of roller used. Specific site testing should be used when possible.

Equipment considerations

Size and shape of teeth on roller

Older style sheepsfoot-type projections on rollers are best suited for compacting clay soils to achieve the lowest possible permeability. They are better suited than the modern style rollers called tamping rollers that have more square, larger area projections. The longer teeth on the older style sheepsfoot rollers are better at remolding plastic clay soils that are wet of optimum water content, and they are better at degrading clods in the soils (fig. 10D–18). The modern tamping-type rollers are effective in compacting soils at a drier water content when high bearing capacity is needed, like soils being compacted for highway subgrades (fig. 10D–19). The older style of sheepsfoot roller compactors are better suited for compaction to achieve low permeability.

Total weight of roller

To attain penetration of the specified loose lift, the roller weight must be appropriate to the specified thickness and the shape of the roller projections. Many modern rollers are too heavy to compact soils that are more than 1 or 2 percent wet of optimum water content. When the specified compaction water content is 2 percent or more wet of optimum water content, lighter rollers are essential. Permeability of clays is minimized by compaction at water contents wet of optimum.

Speed of operation

Heavy rollers operated at excessive speed can shear the soil lifts being compacted, which may result in higher permeability. Close inspection of construction operations should indicate if this problem is occurring, and adjustments to equipment or the mode of operation should then be made.

Vibratory versus nonvibratory sheepsfoot and tamping rollers

Some sheepsfoot and tamping rollers have an added feature, a vibratory action. This feature can usually be activated or deactivated while soils are being compacted. Vibratory energy adds little to the effectiveness of these rollers when the soils being compacted are clays. At the same time, the vibration of the equipment is not usually detrimental. One condition in which the vibratory energy of this type of equipment might be detrimental is when a clay liner is being constructed on a subgrade of low plasticity silts or sands that are saturated. The vibration of the equipment often causes these types of foundation soils to become dilatant as they densify, and the water expelled in this process can create a trafficability problem. For this reason, when subgrade soils are saturated low plasticity silts and sands, the vibratory action of the compaction equipment should be disabled.

Vibratory smooth-wheeled rollers

Vibratory smooth-wheeled rollers are well suited to compacting bentonite-treated liners. They should not be used for compacting clay liners, however. The smooth surface of the roller results in poor bonding between lifts and can cause problems like those shown in figure 10D–14. The load distribution of the rollers also causes the top of a lift to be compacted well but the bottom of the lift not as well, when fine-grained soils are being compacted. A vibratory smooth wheeled roller is shown in figure 10D–20.

Figure 10D–18 Longer style of teeth preferable for compacting soils for clay liner

Figure 10D–19 Modern type of tamping roller less well suited for compacting soils for clay liner

Freeze-thaw and desiccation

Freeze-thaw

Compacted clay liners may become damaged when the liner is exposed during freezing weather. Articles by Kim and Daniel (1992) and Benson and Othman (1993) describe the effects of freezing on clay liners and how the damage resulting from freezing may be permanent. Laboratory tests show that permeability rates may increase by 2 to 3 orders of magnitude (100–1,000 times). Freeze-thaw damage is more likely to affect the side slopes of a clay-lined pond than it will the bottom of the pond after it is filled. If freeze-thaw damage is regarded as likely to increase the permeability of the

Figure 10D–20 Smooth-wheeled steel roller compactor

soils on the side slopes of the pond, a thicker liner or protective cap of cover soil should be considered. The extra cost of freeze-thaw protection may cause a designer to consider a synthetic liner alternative for reasons of economy and confidence in the low permeability of the synthetic liner. For instance, Minnesota designs often include the use of GCL liners for this reason.

Desiccation

Compacted clay liners may also be damaged when the liner is exposed during hot, dry weather after construction and before the pond is filled. Desiccation may also occur during periods the pond is emptied. Articles by Daniel and Wu (1993) and Kleppe and Olson (1985) describe factors that affect desiccation. Using the sandiest soil available that will be adequately impermeable is helpful. Compacting the soil as dense and dry as practical while still achieving the design permeability goal is also helpful. Protective layers must be at least 12 inches thick to be effective, and even thicker layers may be needed for more plastic clay liners, those with PI values of 30 or higher.

Design and construction of bentonite amended liners

When soils at grade of an excavated pond are low plasticity sands and silts in groups I or II of table 10D–3, an unlined pond will result in unacceptably high seepage losses. Several design options are normally considered for this situation. The options are listed as follows in order of increasing cost:

- Clay soils suitable for a clay liner are located in a nearby borrow area and imported to the site to construct a compacted clay liner. CPS 521D applies to this practice.
- Soils from the excavation and at the excavated subgrade are treated with bentonite to create a compacted liner with the required permeability and thickness. CPS 521C applies to this practice.
- The pond may be lined with geosynthetic, a GCL, or lined with concrete. An aboveground storage tank is also an option.

Bentonite type and quality

Several types of bentonite are mined and marketed for use in treating soils to produce a low permeability liner. The most effective type of bentonite (less volume required per cubic foot of treated soil) is finely ground sodium bentonite that is mined in the area of northeast Wyoming, southeast Montana, and western South Dakota. This sodium bentonite is derived from weathered volcanic ash. Sodium bentonite is a smectite clay composed primarily of the mineral montmorillonite (Bentofix 2007). It has the ability to swell up to 10 to 15 times its dry natural volume when exposed to water. Other types of bentonite, usually calcium bentonite are also mined and marketed for treating soils. These types of bentonites are less active (less free swell potential) and more volume of bentonite per treated cubic yard of soil will be required to produce a target permeability than would be required if sodium bentonite were used.

Two methods of evaluating a bentonite source being considered for use as an additive for a liner has high swell properties exist. They are:

- Determine the level of activity based on its Atterberg limit values as determined in a soil testing laboratory. High-quality sodium bentonite has LL values greater than 600 and PI values greater than 550.
- High-quality sodium bentonite has a free swell value of 22 milliliter or higher, based on experience of NRCS engineers and generally accepted guidance. An ASTM Standard test method to evaluate the free swell potential of bentonite is used to verify the quality of bentonite used in GCL liners and is also suitable for evaluating bentonite proposed for a liner being constructed using CPS 521C. The ASTM method is D5890. A summary of the method follows.
  - — Prepare a sample for testing that consists of material from the total sample that is smaller than a No. 100 sieve.
  - — Partially fill a 100-milliliter graduated cylinder with 90 milliliters of distilled water.
  - — Add 2 grams of bentonite in small increments to the cylinder. The bentonite will sink to the bottom of the cylinder and

swell as it hydrates. Wash the sides of the cylinder and fill to the 100-milliliter level.

— After 2 hours, inspect the hydrating bentonite column for trapped air or water separation in the column. If present, gently tip the cylinder at a 45-degree angle and roll slowly to homogenize the settled bentonite mass.

— After 16 hours from the time the last of sample was added to the cylinder, record the volume level in milliliters at the top of the settled bentonite. Record the volume of free swell, for example, 22 milliliters free swell in 24 hours.

Figure 10D–21 shows an excellent quality bentonite reaction to the test. It has a free swell of about 27 milliliters.

Bentonite is furnished in a range of particle sizes for different uses. Fineness provided by the bentonite industry ranges from very finely ground, with most particles finer than a No. 200 sieve, to a granular form, with particles about the size of a No. 40 sieve. Laboratory permeability tests have shown that even though the same bentonite is applied at the same volumetric rate to a sample, a dramatic difference in the resulting permeability can occur between a fine and a coarse bentonite. It is important to use in construction the same quality and fineness as was used by the soils laboratory for the permeability tests to arrive at recommendations. Fineness for use in treating liners for waste impoundment can also be specified by an acceptable bentonite by supplier and designation, or equivalent. An example specification is Wyo Ben type Envirogel 200, CETCO type BS–1, or equivalent.

Figure 10D–21 Free swell test for bentonite ASTM D5890

Design details for bentonite liner

The criteria given in CPS 521C, Pond Sealing or Lining, Bentonite Treatment, provide minimum required liner thicknesses for various depth of liquids.

CPS 521C provides guidance on rates of application of bentonite for preliminary planning purposes or where the size and scope of the project does not warrant obtaining samples and having laboratory tests performed. These preliminary recommended rates of application are based on using high-quality sodium bentonite that is finely ground. The CPS 521C includes a table that shows a range of recommended application rates which vary with the type of soil being treated. Higher rates of application are needed for coarse, clean sands and lower rates for silts. The table shows a recommended application rate expressed in pounds of bentonite per square foot per inch of liner to be built. For example, a typical rate of application for a relatively clean sand would be about 0.625 pounds per square foot per inch of compacted bentonite-treated liner. The most up-to-date CPS 521C should always be consulted for recommended rates, in case they have changed since this document was written.

For planning purposes, using these recommended rates, the amount of bentonite needed for a job can be estimated. For example, assume that a pond is to be constructed with an area of the sides and bottom totaling one acre. Assume that considering the planned depth of water in the pond, a design has been formulated that calls for a 1-foot-thick bentonite-treated liner and that an application rate of 0.625 pounds per square foot per inch is needed. The total amount of bentonite required per square foot will be

$$0.625 \text{ lb/ft}^2 \times 12 \text{ in/ft} = 7.5 \text{ lb}$$

of bentonite per square foot. For an acre of pond area, the total amount needed will be

$$\begin{aligned} 7.5 \text{ lb/ft}^2 \times 43{,}560 \text{ ft}^2\text{/acre} &= 326{,}700 \text{ lb} \\ &= 163 \text{ tons} \end{aligned}$$

The cost of bentonite is affected strongly by freight, and the further a site is from the area of the United States where bentonite is produced, the more costly it will be. Better unit prices are available for larger quantities.

Remember that the preliminary rates of application provided in CPS 521C assume that finely ground high-swell sodium bentonite is used. If plans anticipate that a lower quality bentonite with a free swell less than about 22 milliliters or a coarsely ground bentonite may be used, laboratory testing is required to establish a rate of application that will create a suitably low permeability. Design using the specific discharge approach will establish what the target permeability value should be.

The recommended procedure to arrive at a design for a bentonite-treated liner then is as follows:

Step 1 Obtain a sample of the soil to which the bentonite is to be added. Have the sample tested in a soils laboratory to determine its basic index properties, including percent fines and plasticity.

Step 2 Have a standard Proctor (ASTM D698) test performed to determine the maximum dry density and optimum water content.

Step 3 From the preliminary design of the site, determine the depth of water in the structure. Use CPS 521C to determine the minimum thickness of liner required.

Step 4 Using given or assumed values for allowable specific discharge, compute the required permeability of the bentonite-treated liner.

Step 5 Coordinate with a soils laboratory on testing to determine what degree of compaction, water content, and rate of application of the proposed additive is required to obtain this permeability. Consider whether high quality (free swell > 22 mL) is being used and whether finely ground or coarsely ground bentonite is proposed.

Step 6 Design the final liner based on the results of step 5.

Example 10D–5—Design of a bentonite-treated liner

Given:

A waste storage pond is planned with a depth of liquid of 21 feet. The State requirement for the location is a specific discharge no greater than one-fifty-sixth of an inch per day of seepage. Assume the soils at grade have been tested and found to be suitable for bentonite treatment. Find the minimum thickness liner required according to CPS 521C, and determine the required permeability to meet this specific discharge requirement.

First, consult CPS 521C to determine the minimum required thickness. Assume the current CPS requires a liner that is 18 inches thick (1.5 ft).

Convert the specified unit seepage rate (specific discharge) of one-fifty-sixth of an inch per day into the same units as will be used for permeability (centimeters per second). To convert, use conversion values shown in table 10D–6, multiply:

$$\nu = \frac{1}{56}\ \text{in/d} \times 2.94 \times 10^{-5} = 5.25 \times 10^{-7}\ \text{cm/s}$$

The thickness of the liner and depth of liquid in the pond must also be converted to metric units. To convert the liner thickness of 18 inches to centimeters, multiply by 2.54, which equals a liner thickness, d, of 45.72 centimeters. The liquid depth, H, of 21 feet is equal to

$$H = 21\ \text{ft} \times 12\ \text{in/ft} \times 2.54\ \text{cm/in} = 640.1\ \text{cm}$$

Using the equation described previously, solve for the required permeability:

$$k = \frac{\nu \times d}{H + d}$$

$$k = \frac{5.25 \times 10^{-7}\ \text{cm/s} \times 45.72\ \text{cm}}{640.1\ \text{cm} + 45.72\ \text{cm}} = 3.5 \times 10^{-8}\ \text{cm/s}$$

The designer should coordinate with a soils laboratory to determine how much bentonite of given quality is required to obtain this low a permeability. In the experience of NRCS engineers, relying on this low a permeability means that construction quality control must be excellent and all the procedures and materials used are of highest quality. Seldom should designs for clay liners rely on a design permeability much lower than 5×10^{-8} centimeters per second. A designer might want to proceed with this design but require a slightly thicker liner (24 in) to provide additional assurance of obtaining the design specific discharge.

Considerations for protective cover

CPS 521C recommends considering the addition of a protective soil cover over the bentonite-treated compacted liner in waste impoundments. There are several reasons why a soil cover should be provided:

- Desiccation cracking of the liner after construction and prior to filling is a significant problem because the bentonite used in treatment is highly plastic.
- Desiccation cracking of the liner on the side slopes may occur during periods when the impoundment is drawn down for waste utilization or sludge removal. Desiccation cracking would significantly change the permeability of the liner. Rewetting generally does not completely heal the cracks.
- Bentonite-treated liners are generally thinner than compacted clay liners. Because the liner is thin, it can be more easily damaged by erosion from rainfall and runoff while the pond is empty. Rills in a thin liner provide a direct pathway for seepage.
- Over excavation by mechanical equipment during sludge removal can damage the liner. A minimum thickness of 12 inches measured normal to the slope and bottom is recommended for a protective cover. The protective cover should be compacted to reduce its erodibility.

Construction specifications for bentonite liner

The best equipment for compacting bentonite-treated liners is smooth-wheeled steel rollers, as shown in figure 10D–20. Crawler tractor treads are also effective. Sheepsfoot rollers that are often used in constructing clay liners are not as effective. CPS 521C specifies that for mixed layers, the material shall be thoroughly mixed to the specified depth with disk, rototiller, or similar equipment. In addition, intimate mixing of the bentonite is essential to constructing an effective liner. If a standard disk is used, several passes should be specified. A high-speed rotary mixer is the best method of obtaining the desired mix (fig. 10D–22). A minimum of two passes of the equipment is recommended to assure good mixing. When multiple passes of equipment are used for applying and mixing the bentonite, the passes should be in directions perpendicular to each other. This encourages a more homogeneous mixture.

Another construction consideration is the moisture condition of the soil into which the bentonite is to be mixed. Unless the soil is somewhat dry, the bentonite will most likely ball up and be difficult to thoroughly mix. Ideally, bentonite should be spread on a relatively dry soil, mixed thoroughly, then watered and compacted.

Depending on the type of equipment used, tearing of the liner during compaction can occur on slopes of 3H:1V or steeper. Compacting along, rather than up and down slopes, could be unsafe on 3H:1V or steeper side slopes. For most sites, slopes of 3.5H:1V or 4H:1V should be considered.

Bentonite-treated liners are often constructed in lifts that are 4-inch compacted thickness. Liners should be designed in multiples of 4 inches for this reason. Often, the first layer of bentonite-treated soil is the soil exposed in the bottom of the excavation. By applying bentonite to the exposed grade, disking it in to a depth of about 6 inches, and compacting it, the first layer is formed. Subsequent lifts are formed by importing loose fill adequate to form additional 4-inch-thick lifts.

Figure 10D–22 Pulvermixer (high-speed rotary mixer) (*Photo credit Stacy Modelski, NRCS*)

Design and construction of clay liners treated with soil dispersants

Previous sections of this appendix caution that soils in groups III and IV containing high amounts of calcium may be more permeable than indicated by the percent fines and PI values. Groups III and IV soils predominated by calcium usually require some type of treatment to serve as an acceptable liner. The most common method of treatment to reduce the permeability of these soils is use of a soil dispersant additive containing sodium.

Types of dispersants

The dispersants most commonly used to treat high calcium clays are soda ash (Na_2CO_3) and polyphosphates. The two most common polyphosphates are tetrasodium pyrophosphate (TSPP), and sodium tripolyphosphate (STPP). Common salt (NaCl) has been used in the past, but it is considered less permanent than other chemicals and is not permitted in the current CPS 521B. NRCS experience has shown that usually about twice as much soda ash is required to effectively treat a given clay when compared to the other two dispersants. However, because soda ash is often less expensive, it may be the most economical choice in many applications.

Design details for dispersant-treated clay liner

CPS 521B, Pond Sealing or Lining, Soil Dispersant, provides minimum thicknesses of liners using the dispersant-treated layer method, based on the depth of liquid in the pond. CPS 521B provides guidance on approximate rates of application of soil dispersants based on testing performed by the NRCS laboratories. Rates provided in the CPS are in terms of pounds of dispersant required per 100 square feet for each 6-inch layer of liner. The total amount of dispersant per 100 square feet is then equal to the number of 6-inch lifts in the completed liner multiplied by the rate per lift.

Example 10D–6—Steps in design of a dispersant-treated liner

Assume for the purposes of this example that a soil has been tested at a site and found to be a flocculated clay with an unacceptably high permeability. The designer chooses to evaluate a soda ash-treated liner. Consult the current CPS 521B for guidance on application rates for soda ash. Assume that the current CPS suggests an application rate of 15 pounds of soda ash per 100 square feet of liner for each 6-inch-thick lift of finished liner. Next, assume that based on the depth of water in the pond that the CPS 521B requires a total liner thickness of 12 inches. Then, because each 6-inch-thick lift requires 15 pounds of soda ash per 100 square feet, the total amount of soda ash required for this example would be 30 pounds of soda ash per 100 square feet. The most up-to-date CPS 521B should always be consulted for recommended rates, in case they have changed since this document was written.

The recommended rates of application of dispersants in CPS 521B are based on the most up-to-date information from the NRCS soils testing laboratories. The rates are in general conservative, and if a designer wanted to evaluate lower rates of application, samples should be obtained and sent to a laboratory for documenting the efficacy of lower rates. If this procedure is followed, the following steps are usually implemented.

Step 1 Obtain a sample of the soil to which the dispersant is to be added. Have the sample tested in a soils laboratory to determine its basic index properties, including percent fines and plasticity.

Step 2 A standard Proctor (ASTM D698) test is performed to determine the maximum dry density and optimum water content.

Step 3 From the preliminary design of the site, determine the depth of water in the structure and use CPS 521B to determine the minimum thickness of liner required.

Step 4 Using given or assumed values for allowable specific discharge, compute the required permeability of the dispersant-treated liner.

Step 5 Coordinate with a soils laboratory on testing to determine what degree of compaction, water content, and rate of application of the proposed additive is required to obtain this permeability. Consider local practice and consult suppliers to determine the relative costs of soda ash versus polyphosphates.

Step 6 Design the final liner based on the results from previous steps.

Example 10D–7—Comprehensive example for a dispersant-treated liner

Given:
A waste storage pond is planned with a depth of liquid of 18 feet. The State requirement for the location is a specific discharge no greater than 2,000 gallons per acre per day of seepage. Assume the soils at grade have been tested and found to require dispersant treatment. Assume that the current CPS 521B requires a minimum liner thickness of 1.5 feet. The example problem is to determine what permeability is required to meet the stated specific discharge requirement.

Solution:
First, the required specific discharge value, which is given in units of gallons per acre per day has to be converted the same units that will be used for required permeability. Assume that permeability will be expressed in centimeters per second, so use table 10D–6 to convert the value of 2,000 gallons per acre per day to centimeters per second as follows:

$$\nu = \frac{2{,}000 \text{ gal/acre/d}}{9.24 \times 10^{8}} = 2.2 \times 10^{-6} \text{ cm/s}$$

Next, convert the liner thickness and depth of liquid from units of feet to centimeters:

$$d = 18 \text{ in} \times 2.54 \text{ cm/in} = 45.72 \text{ cm}$$

$$H = 18 \text{ ft} \times 12 \times 2.54 \text{ cm/ft} = 548.64 \text{ cm}$$

Using the equation described previously, solve for the required permeability:

$$\begin{aligned} k &= \frac{\nu \times d}{H + d} \\ &= \frac{2.2 \times 10^{-6} \text{ cm/s} \times 45.72 \text{ cm}}{548.64 \text{ cm} + 45.72 \text{ cm}} \\ &= 1.7 \times 10^{-7} \text{ cm/s} \end{aligned}$$

The designer should coordinate with a soils laboratory to determine how much soil dispersant of the desired type is required to obtain this low a permeability. In the experience of NRCS engineers, obtaining this value of permeability using a soil dispersant should not require special effort or unusual amounts of additive. At the same time, seldom should designs for dispersant-treated clay liners rely on a design permeability much lower than 5×10^{-8} centimeters per second. A designer should proceed with this design specifying the application rate recommended by the soils lab and a 1.5-foot-thick liner to obtain the design specific discharge.

Construction specifications for a dispersant-treated clay liner

The best equipment for compacting clays treated with dispersants is a sheepsfoot or tamping type of roller. CPS 521B specifies that the material shall be thoroughly mixed to the specified depth with a disk, high speed rotary mixer, or similar equipment. Because small quantities of soil dispersants are commonly used, uniform mixing of the dispersants is essential to constructing an effective liner. If a standard disk plow is used, several passes should be specified. A high-speed rotary mixer is also essential to obtain a thorough mixture of the dispersant with the clay being amended. Figure 10D–23 shows this type of equipment. At least two passes of the equipment is recommended to assure good mixing.

Other construction considerations are also important. Using the bathtub method of construction on slopes of 3H:1V or steeper can cause tearing of the liner during compaction and reduce the effectiveness of compac-

Figure 10D–23 High-speed rotary mixer used to mix dispersants into clays (*Photo credit Jody Kraenzel, NRCS*)

tion equipment. Slopes as flat as 3.5H:1V or 4H:1V should be considered for this factor alone, for bathtub type construction.

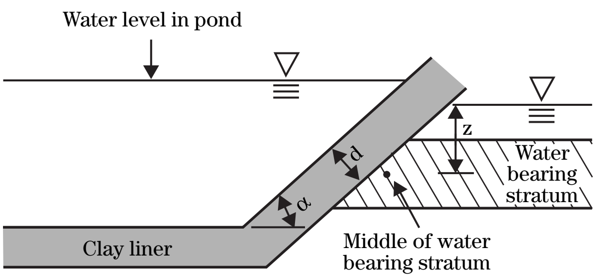
Current CPSs usually require a liner thicker than 6 inches. A liner generally can be satisfactorily constructed in a series of lifts by mixing in the required amount of soil dispersant to a 9-inch-thick loose depth and then compacting it to the 6 inches. Thicker liners should be constructed in multiple lifts, with the final compacted thickness of each lift being no greater than 6 inches.

Uplift pressures beneath clay blankets

A clay blanket may be subject to uplift pressure from a seasonal high water table in the foundation soil underneath the clay liner. The uplift pressure in these cases can exceed the weight of the clay liner, and failure in the clay blanket can occur (fig. 10D–24). This problem is most likely to occur during the period before the waste impoundment is filled and during periods when the impoundment may be emptied for maintenance and cleaning. Figure 10D–25 illustrates the parameters involved in calculating uplift pressures for a clay blanket. The most critical condition for analysis typically occurs when the pond is emptied. Thicker blankets to attain a satisfactory safety factor should be used if they are required.

Figure 10D–24 Failure of compacted liner from uplift forces below clay blanket *(Photo credits NRCS, TX)*

Figure 10D–25 Uplift calculations for high water table and clay blanket (from Oakley 1987)



The factor of safety against uplift is the ratio of the pressure exerted by a column of soil to the pressure of the ground water under the liner. It is given by the equation:

$$FS = \frac{\gamma_{sat} \times d \times \cos(\alpha)}{z \times \gamma_{water}}$$

where:

- d = thickness of liner, measured normal to the slope
- α = slope angle
- γ_{water} = unit weight or density of water
- γ_{sat} = saturated unit weight of clay liner
- z = vertical distance from middle of clay liner to the seasonal high water table

A factor of safety of at least 1.1 should be attained. The safety factor can be increased by using a thicker blanket or providing some means of intercepting the ground water gradient and lowering the potential head behind the blanket. Often, sites where seasonal high water tables are anticipated designs include a perimeter drain to collect the water and prevent this type of damage. Another option is a concrete structure above ground.

Another situation where a clay liner may be damaged from hydrostatic pressure is one where a site is located in a flood plain of a stream or river. The site may have to be built above ground level in this location to avoid a seasonal high water table. Figure 10D–26 illustrates the problem that may occur that must be considered by designers. A temporary flood condition in the flood plain can subject the agricultural waste impoundment to a differential head when the pond is empty. The pond could be empty shortly following construction or it could be empty to apply waste to crops. Uplift pressure may cause piping of sandy horizons underlying the site and boils, and sloughing of side slopes can occur as shown in figure 10D–26. The photo shows a clay-lined animal waste impoundment where the clay liner was damaged from excessive hydrostatic uplift forces caused by temporary storage of flood waters outside the embankment. The liner must be thick enough to resist predicted buoyant forces if it is possible for the pond to be empty or near empty during a flood. Drains will be ineffective because in a flood, outlets will be submerged.

Figure 10D–26 Uplift conditions caused by temporary flood stage outside lagoon (*Photo credit NRCS, WA*)

Perimeter drains for animal waste storage ponds

When a high water table is anticipated and uplift pressures are anticipated, one approach to solving the problem is to install a drain around the pond. The drain may completely encircle the pond if a designer anticipates a general elevated water table in the site vicinity. At other sites with a more sloping ground surface, the perimeter drain may only be installed on the side(s) of the impoundment where the elevated water table is anticipated. Drains may be used both for clay liners and geosynthetic liners.

Drains usually are constructed by
- digging a trench to the depth needed to draw down the water table
- placing a perforated or slotted drainage pipe
- surrounding the drain with granular material that is compatible with both the slot size in the pipe and the gradation of the surrounding foundation soils

Pipes with small slots that are compatible with a filter sand like ASTM C–33 are preferred to avoid having to use two filter gradations. If pipes with larger perforations are used, they should be surrounded with gravel to prevent particles from moving into the pipe. Figure 10D–27 (a, b, and c) show typical installations where a single filter and perforated pipe is used. Another approach to installing a drain is to dig a trench, line it with geotextile, and after putting a slotted collector pipe in the trench, filling it with gravel. Figure 10D–28 shows this type of installation.

Several types of drain pipe may be used. One type is a low strength corrugated pipe with slots or perforations surrounded by a filter envelope of granular material. Figure 10D–29 is an example of this type of collector pipe. If a higher strength pipe is required, figure 10D–30 shows another type of pipe that is sometimes used for these types of installations.

Figure 10D–27 Typical drain installations using single filter with well-screened collector pipe

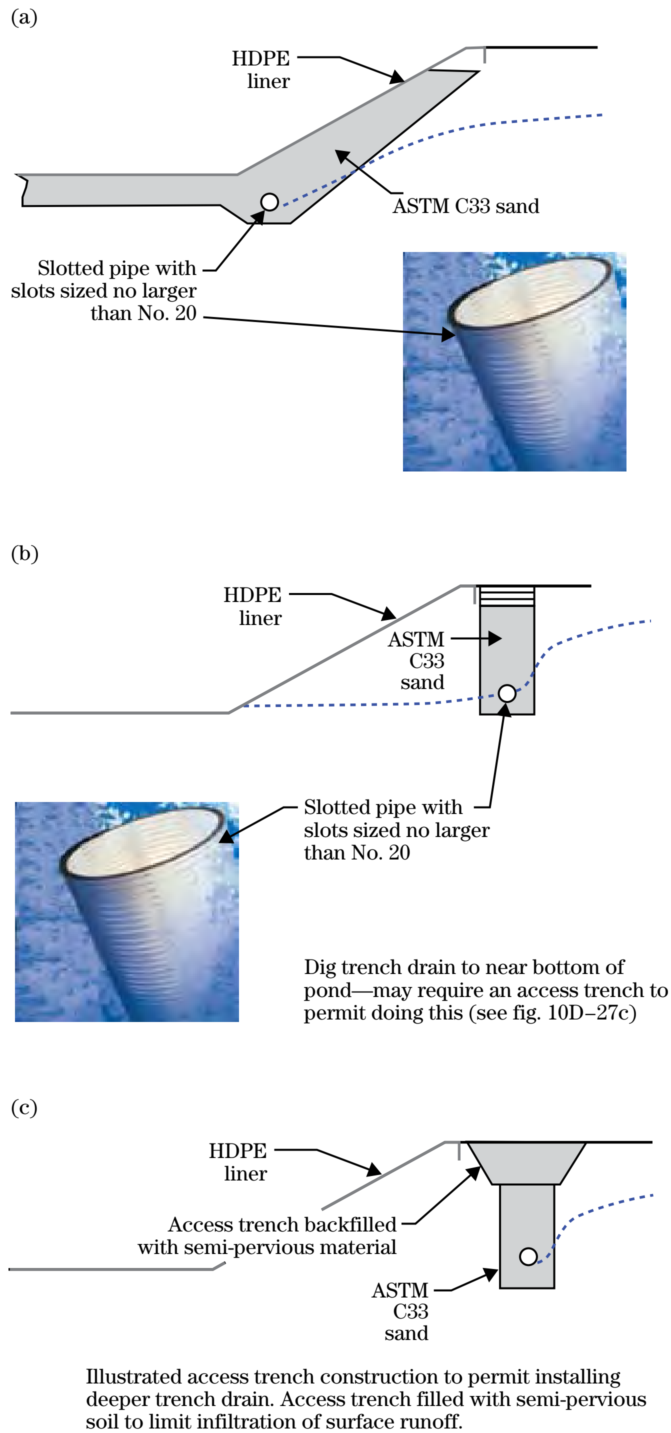


Figure 10D–28 Perforated collector pipe installed the gravel envelope with trench lined with geotextile

Figure 10D–30 Corrugated drainage pipe with slots, doubled walled pipes may be specified if higher strengths are needed

Figure 10D–29 Low-strength perforated drainage tubes

Soil mechanics testing for documentation

Laboratory soil testing may be required by regulations for design, or a designer may not choose to rely on correlated permeability test values. The NRCS National Soil Mechanics Center Laboratories have the capability to perform the necessary tests. Similar testing is also available at many commercial labs. The accepted method of permeability testing is by ASTM Standard Test Method D5084, Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter. Figure 10D–31 shows the equipment used for performing the test.

Contact the labs for more detailed information on documentation needed and for procedures for submitting samples.

Figure 10D–31 Equipment used for performing ASTM D5084

Molding a sample for a flexible wall permeability test

Disassembled mold with compacted specimen

Preparing sample in cell for flexible wall permeability test

Molded sample after dissembling mold

If the only tests requested are gradation and Atterberg limit tests, smaller samples are needed. The size of sample that should be submitted depends on the gravel content. The following recommendations should be adhered to:

Estimated gravel content of the sample 1/ (%)	Sample moist weight (lb)
0–10	5
10–50	20
>50	40

1/ The sample includes the gravel plus the soil material that passes the No. 4 sieve (approx. 1/4-inch mesh).

If gradation analysis, Atterberg limits, compaction, and permeability testing are requested, considerably larger samples are required. When all these tests are needed, the sample size should be as follows:

Estimated gravel content of the sample 1/ (%)	Sample moist weight (lb)
0–10	50
10–50	75
>50	100

1/ The sample includes the gravel plus the soil material that passes the No. 4 sieve (approx. 1/4-inch mesh).

Submitting samples at their natural water content is important so designers can compare the natural water content to reference compaction test values. Samples should always be shipped in moisture proof containers for this reason. The best container for this purpose is a 5-gallon plastic pail commonly obtained in hardware stores. These pails have tight fitting lids with a rubber gasket that ensures maintenance of the water content in the samples during shipping. These 5-gallon pail containers are much more robust and less likely to be damaged during shipment than cardboard containers.

If designs rely on a minimum degree of compaction and water content to achieve stated permeability goals in a clay liner, testing of the clay liner during construction may be advisable to verify that design goals have been achieved. Field density and water content measurements are routinely made using procedures shown in NEH, Section 19, Construction Inspection.

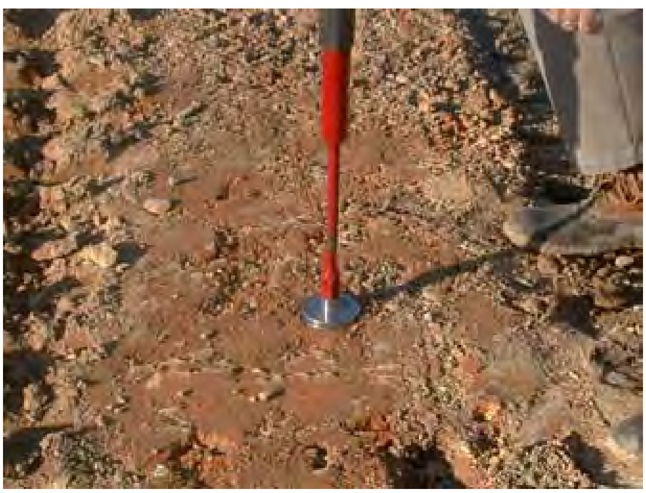
Other methods for documenting liner seepage

Performing density/water content tests during construction is a generally accepted method of documenting that a clay liner has been constructed according to specifications. If the liner is found to meet the requirements of the compaction specifications, the assumption is that the permeability values documented from laboratory testing on samples that were compacted at the specified density and water content will be achieved. In some cases, no additional documentation is required. In other cases, regulations require obtaining samples of the completed liner and performing permeability tests on them. Figure 10D–32 shows one way that a Shelby tube type of sample may be obtained without mobilizing a drilling rig. The Shelby tube used is typically a standard tube with a 3-inch outside diameter and 2 7/8-inch inside diameter. This size sample can be placed directly in a flexible wall permeameter for testing, after extrusion in the laboratory.

Another method for obtaining a sample of a compacted clay liner is with a drive sampler like that shown in figure 10D–33.

Figure 10D–32 Shelby tube sample being obtained with backhoe bucket used to force tube into clay liner *(Photo credit Jody Kraenzel, NRCS, NE)*

Figure 10D–33 Obtaining undisturbed sample of compacted clay liner using thin-walled drive cylinder



In the situation where a storage pond was constructed several years before documentation on quality of construction and permeability was required, studies are sometimes made in an attempt to measure seepage losses directly. One approach that has been used was developed by researchers at Kansas State University. This approach involves installing precise water level monitoring devices and evaporation stations. Seepage losses can be estimated by carefully monitoring the levels in the pond during periods when no waste is introduced into the pond and no rainfall occurs. After estimating the amount of evaporation, and subtracting that from the total decline in the level of the pond during that period, seepage loss can be estimated. Figure 10D–34 shows equipment for measuring evaporation in a pond.

Figure 10D–34 Equipment used to monitor evaporation at an agriculture waste storage lagoon. Measurements are used in total lagoon seepage evaluations.

Summary

- The reduction in the quantity of seepage that occurs as manure solids accumulate in the bottom and on the sides of storage ponds and treatment lagoons is well documented. However, manure sealing is not effective for soils with a low clay content. Its effectiveness is not accepted by all designers and cannot be used in the designs of storage ponds by some State and local regulations.
- Soils can be divided into four permeability groups based on their percent fines (percent finer than the No. 200 sieve) and plasticity index (PI). Soils in groups III and IV may be assumed to have a coefficient of permeability of 1×10^{-6} centimeters per second or lower unless they have an unusual clay chemistry (high calcium), or they have a very blocky structure.
- Group I soils will generally require a liner. Soils in group II will need permeability tests or other documentation to determine whether a desirable permeability rate can be achieved for a particular soil.
- If natural clay blankets are present at a site below planned grade of an excavated pond, the seepage rate should be estimated based on measured or estimated permeability values of the low permeability horizons beneath the liner and above an aquifer. If the estimated seepage rate is less than that given in NRCS guidance or State regulations, no special compacted liner may be required. If the soils at grade are not of sufficient thickness and permeability to produce a desirably low seepage rate, a liner should be designed to achieve the seepage rate that is the design goal.
- Guidance is given on factors to consider whether a constructed liner may be required. Four conditions are listed in which a liner should definitely be considered.
- Allowable specific discharge values are discussed and guidance is provided on reasonable values to use for design when other regulatory requirements are not specified.
- Flexibility is built into the design process. The depth of the liquid, the permeability, and thickness of the soil liner can be varied to provide an acceptable specific discharge.
- The guidelines provided for design of clay liners in this appendix provide designers with the tools to evaluate the probable unit seepage or specific discharge through a clay liner. The methods presented allow a designer to determine what treatment is required to achieve specific discharge or permeability goals.
- Methods provide designers with the ability to evaluate the effect of changes in a proposed design on the estimated unit seepage rate.
- As additional research becomes available, practice standards and guidance in this document may warrant revision.

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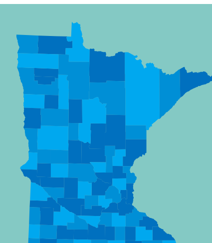
Groundwater

April 2019

Best Management Practices and Data Needs for Groundwater Protection

The MPCA promotes the development of best management practices that prevent, minimize, reduce and eliminate sources of groundwater degradation.

MINNESOTA POLLUTION CONTROL AGENCY



Legislative charge

The Groundwater Protection Act of 1989 (GWPA) requires the Minnesota Pollution Control Agency (MPCA) to develop, promote and monitor the effectiveness of best management practices (BMPs) that prevent, minimize, reduce, and eliminate sources of groundwater degradation. These requirements apply to MPCA programs with activities that may cause or contribute to groundwater pollution for non-agricultural pollutants (https://www.revisor.mn.gov/statutes/cite/103H.001).

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Contents

Executive summary

The Groundwater Protection Act of 1989 (GWPA) requires the Minnesota Pollution Control Agency (MPCA) to develop, promote, and monitor the effectiveness of best management practices (BMPs) that prevent, minimize, reduce, and eliminate sources of groundwater degradation. These requirements apply to MPCA programs with activities that may cause or contribute to groundwater pollution for non-agricultural pollutants.

To address the requirements of the GWPA, the MPCA has set goals in its groundwater program and work plans to identify and evaluate groundwater BMP effectiveness. The goals direct the MPCA to: 1) identify groundwater BMPs, 2) highlight BMPs where more data are needed to evaluate their effectiveness, and 3) develop a plan to address data needs that will enhance program groundwater BMPs.

This report provides a review of MPCA programs that identifies 1) groundwater BMPs, and 2) highlights areas where additional data is needed to evaluate the effectiveness of BMPs in preventing groundwater contamination. The report focuses on MPCA programs that typically conduct less groundwater monitoring or have limited information about their program's impacts to groundwater quality. These include the following programs:

- Subsurface Sewage Treatment Systems (SSTS)
- Animal Feedlots
- Biosolids
- Land and Water Quality Permits for land applied industrial wastewaters and by–products
- Stormwater
- Solid Waste Demolition Landfills
- Municipal Inflow and Infiltration (I&I)

A review of the MPCA remediation programs was not included in this effort because these programs routinely collect and analyze an extensive amount of groundwater data to verify that their program practices are effectively protecting groundwater resources with the objective of meeting health-risk based drinking water standards.

Individualized program reviews were conducted by gathering information about groundwater BMPs from program documents that included: fact sheets, permits, policy and rule; and through interviews with program staff to identify program data needs. The interviews with program staff highlighted program data needs that can be used to prioritize data collection efforts to evaluate the effectiveness of program BMPs. The data needs analysis will also serve as a framework to develop plans to evaluate MPCA program groundwater BMPs to address the third goal of the MPCA's strategic plan.

Minnesota Pollution Control Agency groundwater best management practices

The MPCA programs use numerous BMPs to prevent groundwater contamination that are incorporated into their programs' rules, permits, policies, and guidelines. These program BMPs are specifically designed to address the contaminants of concern managed by each of the programs and contain additional requirements that address sensitive groundwater settings, a key requirement of the GWPA.

Examples of BMPs that apply to sensitive groundwater settings include: setback distances for land applied manure, biosolids and industrial by-products (Industrial by-products); locational restrictions for manure storage and demolition landfills based on groundwater sensitivity; design guidelines for stormwater infiltration in the Minnesota Stormwater Manual; more stringent nitrogen application rates on highly permeable soils for biosolids, and more rigorous design guidelines for SSTS that are based on aquifer sensitivity.

Summaries of program groundwater BMPs are presented within individual program write-ups under the heading "Program practices used to protect groundwater" under the "Program Best Management Practices and Data Needs" section of the report.

Data needs

Several programs have recommended the collection of groundwater quality data to evaluate the impacts of their program BMPs. More specifically, BMP effectiveness could be evaluated from additional groundwater data collection at: mid to large-sized SSTS sites, select animal feedlot drain-tile discharge and manure storage basins, stormwater infiltration sites in sensitive groundwater settings, and at industrial wastewater sprayfield land application sites.

Programs that manage land-applied solid waste do not require the collection of groundwater quality data because their BMPs have been specifically designed to prevent groundwater contamination (biosolids, land-applied manure from feedlots, and industrial by-products). These programs have not recommended groundwater monitoring, as a priority data need. Research suggests that when these program BMPs are properly applied, impacts to groundwater quality are minimal, though there is recognition that more study needs to be done on the possible presence of pharmaceuticals, steroids, and hormones.

Analysis of water quality data was also identified as a need, to assess the impacts and effectiveness of ongoing program BMPs. The Demolition Landfill Program has a need to conduct a statistical analysis of groundwater monitoring data collected over the last eight to ten years at demolition landfills to assess the impacts of program BMPs contained in their Demolition Landfill Guidelines. The Animal Feedlot Program would also benefit from a follow-up sampling and analysis of water quality data collected from larger permitted facilities from a limited number of monitoring wells and tile drainage stations.

An important change noted in this update in 2018 is that most of the programs discussed here have stopped storing basic data in a centralized system at the Agency. Where they once used the now-retired Delta database, they no longer store these data in its replacement, Tempo. Staff are uniform in their hope that data storage will begin within the next few years to rectify this lack, to be available for review and analysis, but no mention is made of specific Agency plans.

An abbreviated list of the program data needs is included in the table below and repeated in Appendix A. More detailed descriptions are provided at the end of each individual program write-up and in the report summary.

Information on the Groundwater Protection Act of 1989 and Minn. Stat. ch. 103H is available at: https://www.revisor.mn.gov/statutes/cite/103H.001. The Degradation Prevention Goal of the law states:

> It is the goal of the state that groundwater be maintained in its natural condition, free from any degradation caused by human activities. It is recognized that for some human activities this degradation prevention goal cannot be practicably achieved. However, where prevention is practicable, it is intended that it be achieved. Where it is not currently practicable, the development of methods and technology that will make prevention practicable is encouraged.

Table 1. Program data needs and recommendations

MPCA Programs	Program data needs and recommendations
Solid Waste Demolition Landfill	• Encourage reuse of demolition materials to reduce reliance on unlined facilities • Provide incentives to owners of unlined landfills to move to facilities that are more protective of degradation through using liners and leachate collection systems • Seek funding for these changes in the State of Minnesota 2018-19 Biennial Budget
Subsurface Sewage Treatment Systems (SSTS)	• Groundwater monitoring at MSTS sites • Assess impacts of smaller ISTS to groundwater monitoring for CECs • Reduce the intentional flushing of unused pharmaceuticals from home and farm
Animal Feedlot	• Follow-up testing and analysis of the drain tile discharge water sampling performed at feedlots, whose permits require testing • Evaluate older manure storage basins lacking double liners in SE Minnesota karst region • Investigate groundwater quality at larger manure storage basins
Land Application of Industrial Wastewaters and IBPs	• Unusual wastes and their environmental fate for land application scenarios are currently (2018) being investigated by the USGS Toxic Substances program • Loading rates at high BOD irrigation sites in Minnesota are much less than similar sites in other states such as MI, which may lead to further study • Site information related to application that used to be entered in the now-retired Delta database is not currently entered in its replacement, Tempo, as of 2018. There will be an attempt to once again capture this information in the future.
Stormwater	• Promote creation of statewide GIS layers to evaluate options to infiltrate stormwater in new development & redevelopment areas in context of vulnerable aquifers • Develop case studies to assess groundwater impacts for stormwater infiltration BMPs (e.g. the Minnesota Stormwater Manual; consider Cl, pathogens, infiltration at brownfields, etc.) • Data collection for stormwater infiltration projects
Biosolids	• No specific recommendations for groundwater monitoring • Biosolids annual reports have been scanned into Tempo, but the data is not in a readily accessible format. New biosolids site approvals and cumulative metals loading data have not been stored electronically since the switch to Tempo. There is a recognized program need to store this data within Tempo. • There is a recognition that the fate of persistent organic compounds (i.e. pharmaceuticals, personal care products, steroids, PFAS, and hormones) in biosolids is important; however, the financial and staff resources necessary to conduct this type of work are beyond the scope of the program’s current resources.
Inflow and Infiltration (I&I)	• Limited groundwater impact concerns. Concerns relate to groundwater leaking into wastewater infrastructure. • Investigating leakage to groundwater would be difficult and has not been done in the Municipal Program.

A. Solid Waste Demolition Landfill Program

This program review includes an overview of the best management practices (BMPs) used by the MPCA's Solid Waste Demolition Landfill Program (SWDLP) to prevent groundwater contamination from construction and demolition landfills (C&D landfills). It also presents the nature of groundwater quality impacts, which occur at unlined demolition landfills across the state. Finally, it identifies the steps needed to evaluate groundwater quality data from demolition landfills to better evaluate the effectiveness of program practices in the protection of groundwater resources.

Program BMPs used to protect groundwater

The SWDLP uses a combination of regulatory tools to protect groundwater resources at C&D landfills, including the Demolition Landfill Guidance (DLG), permit requirements, and policies that emulate the mixed municipal solid waste landfill rules. Other regulatory tools used by the SWDLP that indirectly protect groundwater resources include: environmental and technical reviews, facility inspections, operator training, technical assistance, compliance and enforcement, fact sheets, and guidance documents. The DLG and the Landfill Report describe many of the program practices that protect groundwater resources, as described below.

Locational requirements and site evaluations

The DLG states, "The single most effective action that owners/operators of demolition Landfills can take is to locate the demolition Landfills in areas that will inherently protect ground water and surface water from the risks of contamination. Prohibited locations which must be avoided include active karst topography, flood plains and other areas likely to result in groundwater contamination."

- The Solid Waste Rules prohibit the placement of demolition landfills in areas that would result in groundwater contamination. An existing permitted Landfill that does not meet the location standards above will not be re-permitted.
- Permitting or re-permitting a C&D landfill requires that a site evaluation be conducted to identify potential risks and the need for groundwater monitoring. The site evaluation must verify whether a site meets location standards, has an adequate separation distance between the fill and water table, and provides sufficient information on groundwater flow directions.

Facility classification

The MPCA has developed a three-class system to better manage the potential risks to groundwater from C&D landfills. The three-class system sets different groundwater monitoring and design requirements, and waste acceptance criteria for C&D landfills that are based on waste characteristics and hydrogeologic setting.

- In general, larger C&D landfills have more significant safeguards, such as liners, leachate collection systems, and groundwater monitoring. These landfills are primarily located within the Twin Cities Metropolitan Area. Many smaller C&D landfills are located in rural areas and serve fewer businesses and people and are less likely to have liners or groundwater monitoring; however, operators use more rigorous waste screening practices to control unacceptable wastes that could contaminate the groundwater.
- The DLG sets BMPs for waste screening for the different classes of C&D landfills and defines acceptable waste streams and the requirements for waste stream screening procedures, and Industrial Solid Waste Plans.

Groundwater monitoring

The SWDLP policy states that "all Class II and III Landfills should conduct groundwater monitoring."

- The DLG provides a groundwater monitoring decision matrix to determine whether monitoring is necessary, based on the depth to the water table and the soil type beneath the C&D landfill.
- Decisions to require groundwater monitoring are made upon initial permit issuance or during permit reissuance, which occurs on a 10-year cycle. As noted previously, roughly 65% of all C&D landfills now have some type of groundwater monitoring in place.
- Groundwater monitoring information is reviewed annually and is used to determine if a facility is impacting groundwater quality. Exceedances of groundwater performance standards can lead to permit-required actions to reduce and prevent contaminant impacts. Actions may include: additional monitoring, addition of a less permeable cover atop landfill wastes, or possibly installation of liners beneath the waste to prevent and reduce leaching of contaminants to groundwater.
- In addition to groundwater monitoring requirements, some C&D landfill facilities must also conduct groundwater receptor surveys to identify groundwater users in the vicinity of their facility that may potentially be impacted.

Nature of concern related to groundwater quality

C&D landfills are located in a number of different hydrogeologic settings across the state and vary in size, design and in their contents of construction and demolition debris. C&D landfills may impact groundwater quality through leaching of contaminants from landfill wastes through the soil to groundwater. The degree to which this occurs is greatly affected by the characteristics of the wastes, hydrogeologic setting, and engineering controls at the landfill. These concerns are presented in greater detail in the report to the Minnesota Legislature on "Management of Industrial Solid Waste and Construction and Demolition Debris in Land Disposal Facilities", January 15, 2009 (Landfill Report), pages 15-17, at the web link http://www.pca.state.mn.us/index.php/view-document.html?gid=41.

To protect groundwater as a source of drinking water the SWDLP applies health-based drinking water limits at C&D landfills and may also apply surface water quality standards for groundwater that may discharge to surface waters of the state. Exceeding these limits triggers permit required actions at the compliance boundary of a C&D landfill, as set forth in Minnesota Solid Waste Rules 7035, subp. 4.

Groundwater quality concerns

Rationale/Background - when the state's 88 unlined C&D landfills were created, it was believed that disposal of standard construction materials such as brick, mortar, wood, metal, etc. would not pose a groundwater threat (Figure 1). As a result, these landfills were not required to be lined or to have leachate collection systems. Over time, construction materials have changed to include more chemicals, adhesives, and plastics – all of which behave differently than wood, metal and brick when subjected to conditions found in landfills. Today, as precipitation percolates through C&D debris and continues to flow out of landfills, the result is frequently contaminated groundwater.

Groundwater monitoring shows that these unlined demolition landfills are contaminating groundwater. Of the state's 88 unlined C&D landfills, 67 have groundwater monitoring on site, and 42 (63%) of those show groundwater contamination that exceeds Minnesota Department of Health (MDH) and U.S. Environmental Protection Agency (EPA) standards. Only four of the monitored sites have shown no contamination at all. Clearly, C&D landfills can generate releases to groundwater, with potential consequences to the environment and public health.

Table 2. Unlined demolition activities

Open permitted unlined demolition activities

MPCA Solid Waste Demolition Landfill Program	No Groundwater Monitoring	Confirmed No Exceedance	Confirmed Intervention Limit Exceedance	Confirmed EPA/MDH Limit Exceedance	Evaluating Groundwater Compliance	Total
Demolition - Class 1	20	3	1	33	16	73
Demolition - Class 2	-	1	1	9	3	14
Demolition - Class 3	-	-	-	-	-	-
Demo - Pre-Guidance	1	-	-	-	-	1
Total	21	4	2	42	19	88

The problem happens by two processes. The first process occurs when the water and organic materials from the landfills enter the ground. This serves to mobilize and concentrate low levels of metals naturally occurring in the soils (i.e. arsenic and manganese), allowing these metals to "flow" into and contaminate the groundwater. The second process occurs when water contaminated by materials in the landfill (i.e. boron and vinyl chloride) seeps through the ground and contaminates groundwater. One or both of these processes may be happening over time in a landfill.

Boron is a major contaminant of concern and is believed to be from flame retardants used to treat sheetrock, lumber and insulation. Nitrates have also been detected in C&D landfill groundwater monitoring systems, but are more likely a result of regional anthropogenic sources and less likely due to wastes contained in the C&D landfills. Testing for volatile organic compounds (VOCs) has shown a limited number of detections at relatively low concentrations at most facilities that include: tetrahydrofuran, vinyl chloride and infrequent detections of Freon and hydrocarbon compounds. More recent testing of groundwater has also identified the presence of per and poly-fluoroalkyl substances (PFAS) at concentrations significantly below groundwater intervention limits for most sites.

MPCA staff have also reviewed C&D landfill leachate data, which provides an indication of what contaminants could potentially enter groundwater systems. Results from this review show that several metal and VOC contaminants are present; however, few of these contaminants have been detected in the groundwater systems at these facilities. This indicates that where facilities have liners they appear to be providing a high degree of protection to groundwater resources.

It is important to note that all significant detections of groundwater contamination are from unlined landfills that pre-date the MPCA's current regulatory regime. Current landfill practices, including more rigorous waste screening procedures, increased use of liners and landfill cover, and groundwater monitoring, all help to reduce and prevent impacts to groundwater resources at C&D landfills. Overall, groundwater-monitoring data from C&D landfills indicates limited impacts to groundwater resources and currently there are no known impacts to private or municipal wells from these facilities.

Program data needs and BMP recommendations

The SWDLP is currently working on a proposal that would address current threats to groundwater posed by construction and demolition (C&D) debris in unlined landfills and expand the reuse of demolition materials to reduce the need for these landfills in the future. The proposal would offer grants and loans to private and public owners of unlined C&D landfills to help divert waste from these landfills and enable a transition to facilities that are more protective of human health and the environment. If funded the following would be allowable uses of the grants or loans:

- To establish or expand programs to recycle/reuse demolition materials, thus reducing the flow of waste into landfills and reducing the threat to groundwater.
- To enhance monitoring for the purpose of better understanding the nature and extent of existing groundwater contamination.
- To incentivize protective actions while the new regulatory system is being created:
    - Cap and close C&D landfills as appropriate to prevent contamination of groundwater.
    - Install liners and leachate collection systems as appropriate at new/expanding facilities.
    - Convert C&D landfills to become C&D transfer stations.

In addition to the above proposal, the MPCA SWDLP must prepare a report that evaluates groundwater quality data from demolition debris land disposal facilities. In evaluating groundwater quality data, comparisons must include at least the following:

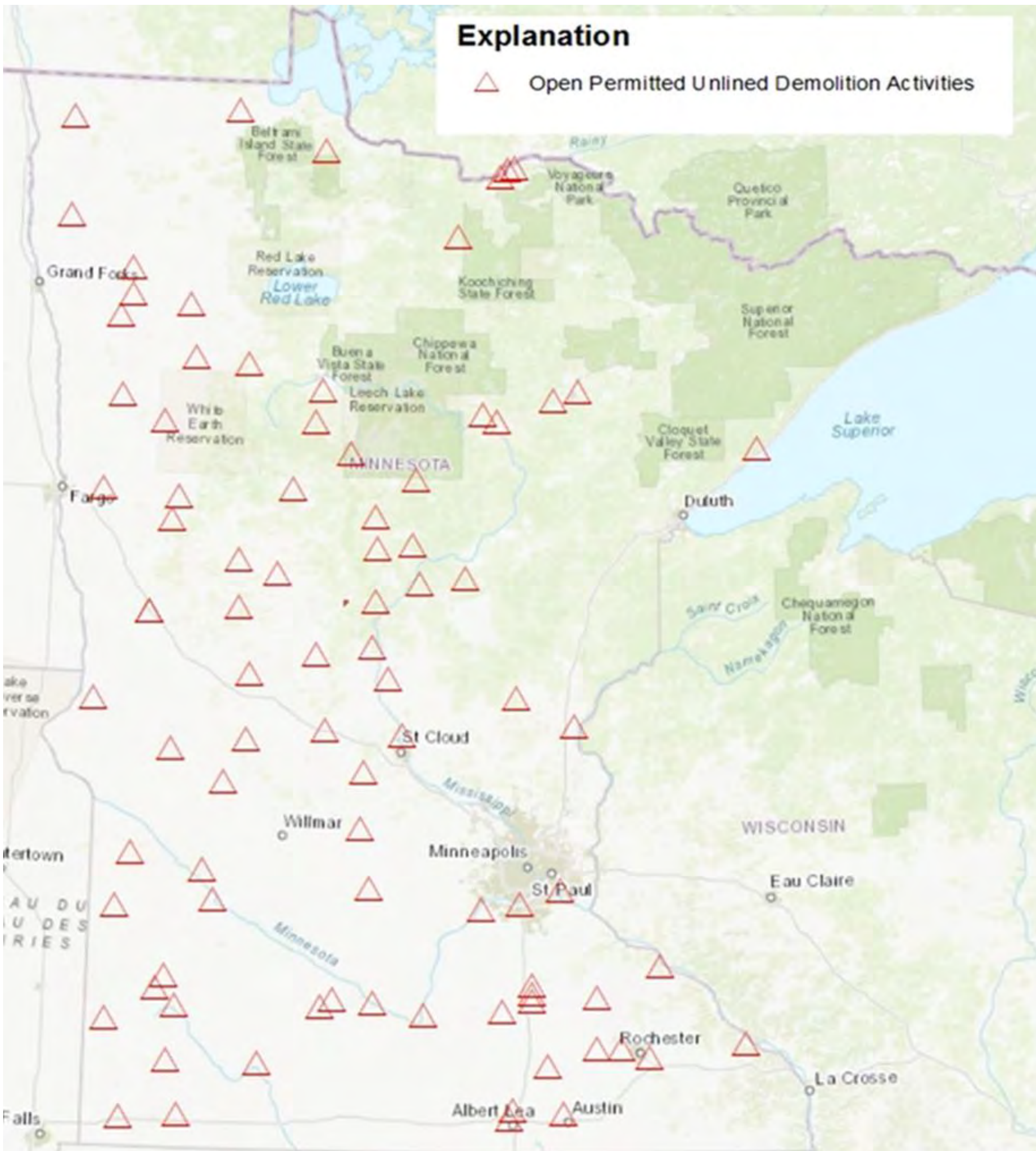
- Adopted health risk limits established in Minn. R. 4717.7500 and Minn. R. 4717.7860.
- Adopted standards, and health advisories & values from both federal and state governments.
- State solid waste intervention limits.

The report must also examine at least:

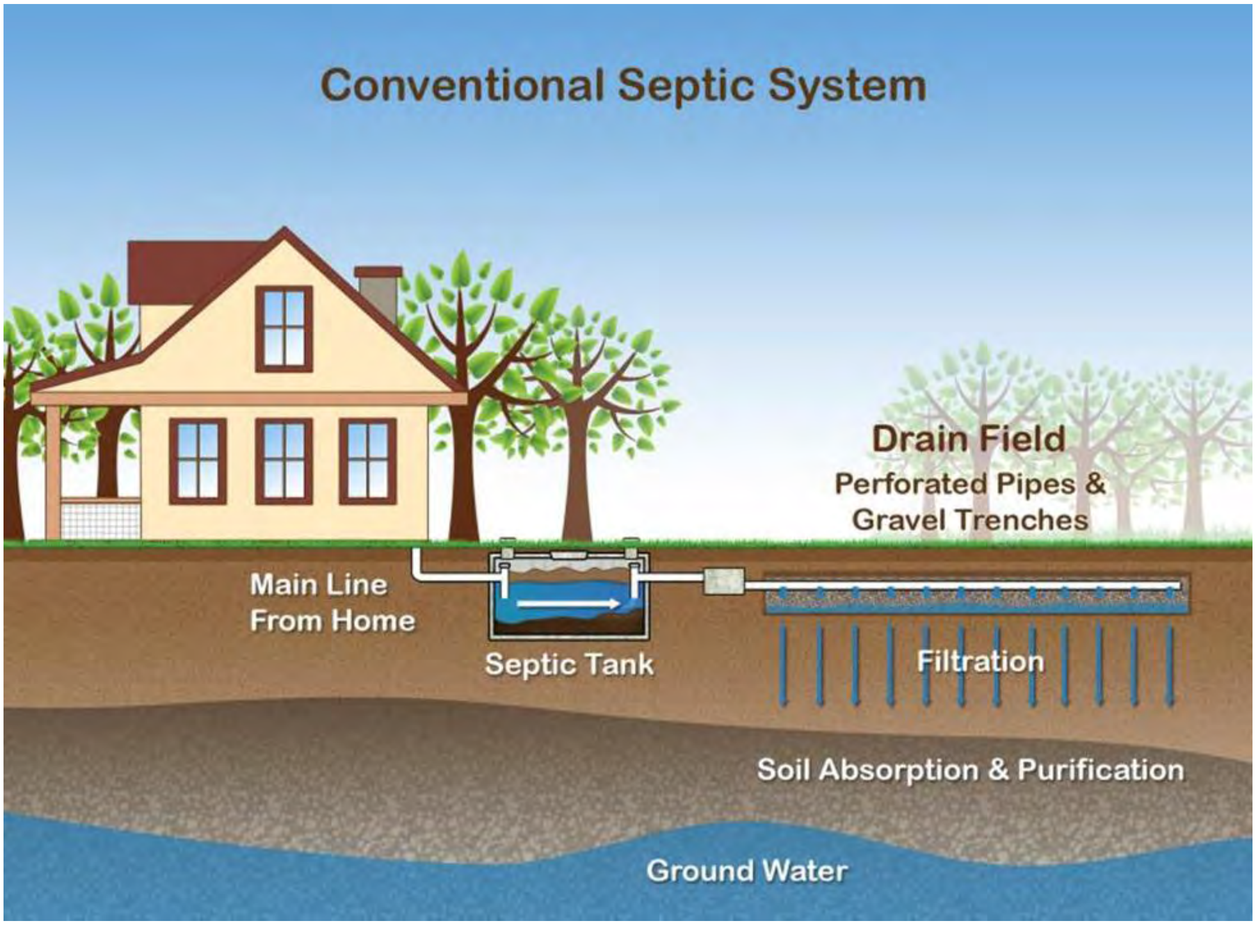
- The role oxidation-reduction reactions have in groundwater chemistry at permitted demolition debris land disposal facilities and compare the role oxidation-reduction reactions have in general to other regulated facilities such as septic systems, surface impoundments, and lined land disposal facilities.
- Compare concentrations to groundwater quality data from other local, regional, and statewide wells, including domestic wells, not associated with landfills.

The findings from this report will be used by the MPCA SWDLP to further evaluate the effectiveness of program BMPs that prevent, minimize, reduce and eliminate sources of groundwater degradation from unlined demolition landfills.

Figure 1. Open permitted unlined demolition activities



B. Subsurface Sewage Treatment Systems

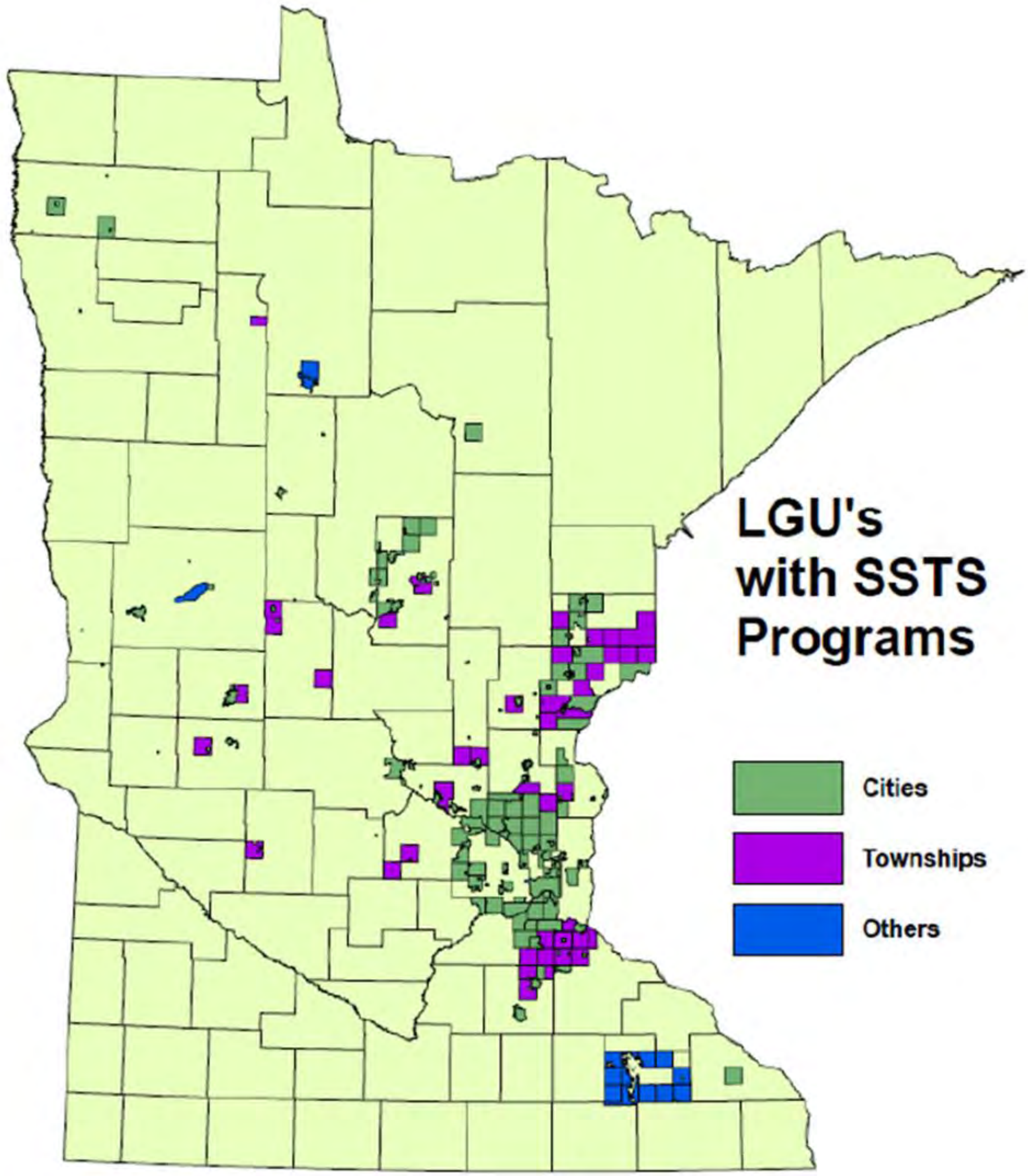


This program review identifies program practices implemented by the MPCA's Subsurface Sewage Treatment Systems (SSTS) program to prevent the contamination of groundwater. It also identifies program areas where additional data are needed to better evaluate the effectiveness of SSTS program practices to protect groundwater resources and makes recommendations to address some of these data gaps.

Overview

The SSTS program oversees the treatment of sewage discharge to SSTS in accordance with state statute (Minn. Stat. 115.55) and rules (Minn. R. ch. 7080-7083). Subsurface or soil-based treatment systems treat approximately one quarter of Minnesota's domestic wastewater (sewage). In 2017, 211 Local Government Units (LGU) reported 537,354 SSTSs in Minnesota. There were 10,906 construction permits issued for both new or replacement systems and 770 SSTS repairs for a grand total of 11,676 SSTS related permits. Over a period of 16 years, from 2002 to 2017, LGUs reported that over 187,766 construction permits were issued. A map showing locations of known SSTS programs is shown in Figure 2. Roughly 98% of these systems are smaller individual sewage treatment systems (ISTS) serving flows of 2,500 gallons per day (gpd) or less. The remaining 2% include mid-sized sewage treatment systems (MSTS) serving flows between 2,501 and 10,000 gpd, and large sewage treatment systems (LSTS) serving flows of 10,000 gpd or greater. Individual sewage treatment systems and MSTS are regulated by local units of government (i.e. city, township, or county). All counties except Ramsey oversee SSTS programs. Minnesota rules require the MPCA to regulate LSTS due to the greater volume of wastewater treated and their associated potential for environmental and health risks. Overall,

Figure 2. Location of county, city, township and other known SSTS programs in 2017



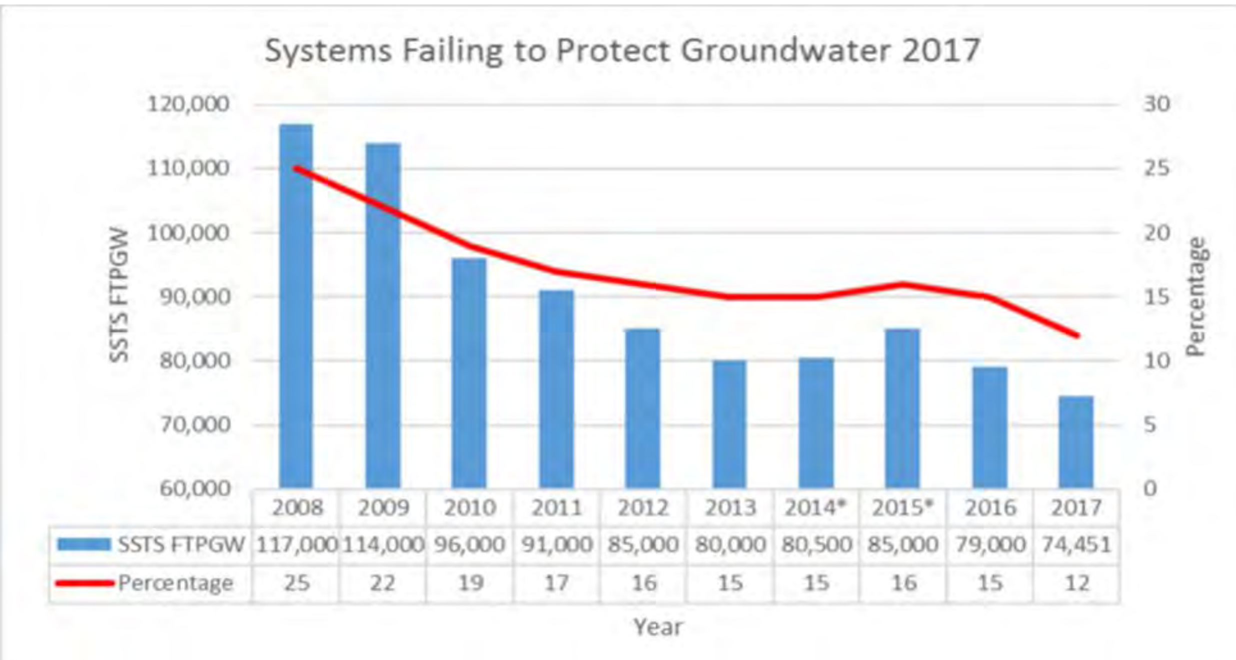
groundwater protection increases based on SSTS size and proximity to vulnerable aquifers. Larger systems have additional monitoring requirements, permit conditions, and BMPs applied to their location, design, installation, use and maintenance.

Nature of concern related to groundwater

Subsurface Sewage Treatment Systems discharge sewage into the ground, where it is treated before mixing with groundwater and surface waters. The wastewater in SSTS contains organic matter and solids, pathogenic organisms (bacteria, viruses, and parasites), nutrients, and some chemicals. A properly operating SSTS will convert a large percentage of the total nitrogen in the sewage to nitrate. Once the nitrate-laden effluent reaches the groundwater, concerns arise about use of that groundwater as a drinking water supply.

LGUs were asked to provide their best estimates of SSTS compliance information as part of the MPCA 2017 SSTS Annual Report, including total number of SSTS in their jurisdiction, the number estimated in compliance, the number estimated to be an imminent threat to public health and safety, and the number estimated to be failing to protect groundwater. The percent of compliant SSTS has increased from 75% in 2008 to 82% in 2017, and the estimated number of systems failing to protect groundwater decreased over the same time period from 117,000 (25%) to 74,451 (12%) systems in 2017; a decrease of 42,549 systems (Figure 3).

Figure 3. The estimated number of systems failing to protect groundwater (FTPGW).



Existing SSTS compliance inspections

Groundwater quality depends not just on the regulations controlling SSTS systems, but also on compliance inspections, to ensure that the SSTS systems are functioning as planned. Out of the total 537,354 SSTS reported in Minnesota in 2017, approximately 2.8% of the existing septic systems were reported to have been inspected in the prior year. Inspections are an important part of addressing existing systems that pose an environmental or human health risk. Local governments include inspection triggers, such as at the time of property transfer or when a building permit is sought, in their ordinances to create a mechanism for verifying system conformance and correcting nonconforming systems within the timeframes specified through state statute or local ordinance.

There were 15,250 compliance inspections of existing systems reported by local SSTS programs representing a 2.7% increase from 2016 (14,847).

Contaminants of concern

Nitrate/nitrogen is the main concern for septic system impacts to groundwater. Nitrates, once formed, will move with groundwater and will likely not denitrify, except in some favorable soil and groundwater conditions. Pathogens and phosphorus generally adsorb to the soil and are treated adequately by these systems. Pathogens are usually attenuated in soil treatment systems; there are a few cases of bacterial and viral transport in groundwater. Phosphorus typically precipitates in the unsaturated zone or is adsorbed in the aquifer close to drain fields; this is less so in older systems where phosphorus saturation can occur.

In addition to pathogen and nutrient concerns noted above, contaminants of emerging concern, such as pharmaceuticals, personal care products, and endocrine active compounds are present in septic effluents. Though the SSTS program has limited capacity to assess the presence of many of these compounds, and has typically made their focus the control and prevention of nitrate/nitrogen and pathogens from entering the groundwater, progress has been recently made on pharmaceuticals and groundwater.

Pharmaceuticals

Pharmaceuticals wind up in STSS via excretion from normal use by people (i.e. because not all of the drug is fully metabolized in the body) and through improper disposal of unused medications by flushing, both at homes and at care facilities.

Pharmaceuticals are commonly detected in Minnesota surface water, groundwater and sediment. The concentrations detected are low relative to other contaminants, but they can have potential negative impacts on the environment, aquatic species, and human health. It is extremely difficult and costly to remove these compounds from wastewater and drinking water once they are present. Preventing entry to the environment is the best way to address potential impacts of pharmaceuticals. Two approaches to doing this are: 1) minimizing input to SSTS and 2) promoting education and support for care providers, pharmacists, and prescribing practitioners about the pharmaceutical “footprint”.

The MPCA, the U.S. Drug Enforcement Agency (DEA) and the Minnesota Board of Pharmacy worked together to develop the regulatory framework that has allowed over 300 pharmacies and law enforcement agencies to begin voluntary collection of unused medications. There are several independent and chain operated pharmacies that began collection within the past two years after the DEA and state regulations were revised. Sites continue to come online with very few discontinuing collection.

Through this system, over 600,000 pounds of unused drugs were collected in Minnesota between 2007 and 2017. The amount of unused drugs collected annually grew tremendously between 2013 and 2017, with the total for 2017 at over 175,000 pounds.

Voluntary collection of unused pharmaceuticals will increase with further with expansion of the collection network and outreach and education to the general public, doctors, and pharmacies. As of 2018, there were only two counties in Minnesota without a local collection option, but the MPCA is working on a grant to help bring collection to those counties as well as other currently underserved areas.

Manufacturers, health care facilities of all types (including long-term care facilities), and animal health facilities may flush waste medications if allowed by their local treatment plants. Because flushing involves no cost, it is still used by many of these operations.

Pollution prevention efforts for medications at this point in time mainly means reducing the overuse of medications, which will reduce what is directly excreted and released into the environment. The changes in prescribing recommendations for antibiotics, and for opioids and other controlled substances, should reduce the amount of medications released into the environment from excretion.

This is especially true looking at the "preventive" use of antibiotics in livestock. This is being studied at the federal level, as well as in Minnesota chiefly through the Department of Health's One Health Antibiotic Stewardship Collaborative. The European Union has banned "off label" use of antibiotics and hormones in livestock, which presumably reduced the use of the drugs and the resulting discharge into the environment. Livestock in the US consume roughly 70% of the antibiotics produced for use. You can view the work efforts and components of the collaborative here: http://www.health.state.mn.us/onehealthabx/.

Manufacturers are putting some effort into more effective drug delivery systems, which may reduce the amount of medication released through excretion, but those efforts will take years to produce measurable results.

Other program practices used to protect groundwater

As noted previously, the SSTS program applies Minn. R. ch.7080 through 7083 to oversee the treatment and dispersal of sewage discharge to subsurface treatment systems. These rules include a large number of requirements for the proper location, design, installation, use and maintenance of SSTS systems to protect our state's water resources from the discharge of treated sewage to the groundwater, that include the following:

- Nitrogen BMPs for MSTS and LSTS based on system size and the sensitivity of the aquifer.
- Registration of treatment products for nitrogen and phosphorus reduction.
- Identifying imminent threats to public health and safety from uncontrolled surface discharges.
- A plan to strengthen local county programs to continue to reduce the percentage of failing SSTS, which have fallen in nine years from 39% to 12%, with a goal to eventually get the percentage of failing systems below five.
- Design guidelines for larger ISTS and MSTS that require the assessment of soil and groundwater conditions so that systems are protective of groundwater resources. Guidelines include:
  - Groundwater sensitivity and mounding assessments.
  - Nitrogen modeling and nitrogen BMPs to reduce total nitrogen, and nitrogen limits.
  - Determining whether a site is located in a Drinking Water Supply Management Area.
  - Vertical separation distances to groundwater.
  - System design criteria based on the above factors.
- A groundwater nitrate nitrogen policy that provides a technical basis for permitting decisions as well as a means to ensure the best, reasonable protection of groundwater resources.
- Well testing (nitrates), point of sale requirement (not a state requirement).
- Education, certification, and training.
- Compliance and enforcement.

Program data needs and recommendations

- Mid-sized sewage treatment systems – The SSTS program would greatly benefit from groundwater monitoring data collected at MSTS sites to verify whether these systems are meeting groundwater nitrogen limits set in design guidance. In addition, monitoring of groundwater mounding is needed to evaluate system performance and to compare these results to predictions from numerical (MODFLOW) and analytical (Kahn & Hantush) groundwater models. This type of research is needed in both sand, gravel, and finer textured glacial till soils that occur across the state. Assessment of the predictive ability of groundwater mounding models in different geologic settings will help support program decisions regarding system performance and ultimately lead to reduced review times and site assessment work.
- Individual sewage treatment systems – The assessment of impacts to groundwater from smaller ISTS is also needed because of their large numbers. There is little to no groundwater monitoring conducted for these types of systems, and many were installed prior to the enactment of minimum statewide standards for ISTS in 1996.
- Monitoring for contaminants of emerging concern – As noted previously, the SSTS program does not have the capacity to test for contaminants of emerging concern (CECs) including endocrine active compounds. It is known that sewage effluent contains CECs; however, their occurrence has not been investigated for SSTS in Minnesota.
- Pharmaceuticals - work needs to continue to cut down on the flushing of unused drugs into treatment systems of all types, by including more collection facilities in the effort, both for human and livestock use (and overuse).
- Land application of solids removed from SSTS systems – monitoring could be added to track the possible migration of contaminants into groundwater.

Based on discussions with program staff, the most immediate data needs, with respect to groundwater protection concerns, are for MSTS as described in the first bullet above. Next would most likely be groundwater data from ISTS sites; however, a number of homes and businesses have straight pipe discharges of sewage effluent to surface waters, which represents an even greater immediate concern to surface water resources. Currently, the SSTS program has limited capacity to investigate the above listed data gaps and any work in these areas would need to be conducted with local partners and stakeholders outside of the program.

C. Animal Feedlot Program

This program review identifies some of the program practices and BMPs used by the MPCA's Animal Feedlot Program (Feedlot Program) to prevent the contamination of groundwater resources. It also identifies program areas where additional data is needed to better evaluate the effectiveness of feedlot program practices to protect groundwater resources and makes recommendations to address some of these data gaps.

Overview

The Feedlot Program regulates the land application and storage of animal manure for over 25,000 registered feedlots in Minnesota in accordance with Minn. R. ch.7020. In addition, there are approximately 5,000 to 10,000 smaller, unregistered feedlots across the state. Overall, there are more feedlot sites than can be evaluated on an individual basis, and therefore, there is limited monitoring of their impacts on groundwater quality, with the exception of a few of the larger facilities.

Feedlots are located in agricultural areas across Minnesota with the greatest number occurring in the southern and central portions of the state. Feedlots vary in size, as measured by the number of animals they manage (animal units), and in the quantity of manure they land apply or store in manure storage basins. In general, larger feedlots have more rules and regulations they must follow to protect groundwater resources.

Nature of concern related to groundwater

Groundwater can be contaminated by nutrients (primarily nitrate-nitrogen) and microbial pathogens from animal manure. Animal manure contains significant quantities of nitrogen and if not properly managed, can lead to nitrate contamination of groundwater. The main concern regarding feedlot contaminant impacts to groundwater systems is through the application of manure to the land and its storage in manure storage basins. The land application of manure, if not conducted properly, can overload the soil/crop system and lead to leaching of contaminants to the groundwater. In addition, the design, construction, and maintenance of manure storage basins and their location relative to vulnerable groundwater settings play big roles in whether manure storage systems are likely to affect groundwater quality.

Many feedlots are located in areas of the state with vulnerable aquifers where groundwater quality is highly susceptible to contamination from land surface activities. Nitrate contamination of groundwater has been shown to be a problem in areas having coarse-textured soils with shallow groundwater and solution weathered bedrock. Pathogens can also move directly to groundwater through cracks in the soil, especially near old wells, sinkholes, quarries, and areas having shallow soils over fractured bedrock.

Contaminants of concern

As stated above, nitrate-nitrogen and pathogens have been identified as the contaminants of greatest concern from feedlots that may impact groundwater quality. Groundwater studies of manure storage systems by the MPCA have also identified high concentrations of ammonia, organic nitrogen, phosphorus, organic carbon, potassium, chloride, manganese, and iron in groundwater plumes downgradient of manure storage areas. In these same studies, high nitrate concentrations were measured where sites were underlain with a thick unsaturated zone, indicating the conversion of organic nitrogen and ammonia most likely resulted in the higher nitrate concentrations. In general, MPCA studies showed the greatest impacts to groundwater quality occurred at sites lacking a constructed liner for their manure storage basins.

Moreover, as was mentioned in the previous section on Surface Sewage Treatment Systems, the use (and overuse) of antibiotics as a preventive measure in the treatment of livestock must be considered a likely source of the contamination of groundwater. This possible misuse of antibiotics is being studied at the federal level, as well as in Minnesota chiefly through the Department of Health’s One Health Antibiotic Stewardship Collaborative. The European Union has banned “off label” use of antibiotics and hormones in livestock. Off label use is the practice of proscribing drugs for an unapproved purpose, a practice that boosts antibiotic use in livestock. Livestock in the US consume roughly 70% of the antibiotics produced for use. More information available at: http://www.health.state.mn.us/onehealthabx/.

Program practices used to protect groundwater

The Feedlot Program protects groundwater quality primarily through the application of Minn. R. ch. 7020, in addition to a mix of BMPs, program policies, fact sheets, and guidelines that contain specific requirements and recommendations for water quality protection. Some examples of Feedlot Program practices that protect groundwater quality, and how they do so, are listed below.

- Manure management plans are considered one of the primary program practices that protect groundwater quality. Manure management plans regulate the rate and timing of the land application of manure to prevent overloading the soil/crop system with excess nitrogen and phosphorus, reducing the potential for nitrogen leaching to groundwater.

- Feedlot general permit conditions place additional constraints on manure applications in areas with vulnerable aquifers (sand and gravel aquifers) and restrict applications in the winter for concentrated animal feedlot operations.
- Rules for liquid manure storage basins (7020.2100) set the liner design standards and location restrictions for feedlots to prevent leakage of liquid manure to underlying soils and groundwater.
- Feedlot water quality discharge standards (7020.2003) require that manure, its runoff and process wastewaters are prohibited from flowing into a sinkhole, fractured bedrock, well, surface tile intake, mine or quarry. Feedlots and manure storage areas must comply with Minn. R. ch. 7050 effluent limit standards.
- Location restrictions and expansion limitations (7020.2005) apply to new animal feedlots or manure storage areas within a shoreland, a floodplain, 300 feet of a sinkhole, 100 feet of a private well, or 1,000 feet of a community water supply well, or other wells serving schools or day care centers.
- Groundwater monitoring is required as laid out in a program policy memorandum from June 2008 - “MPCA Feedlot Program Ground Water Monitoring at New Liquid Manure Storage Areas”.
- Guidelines for the land application of manure, “Applying Manure in Sensitive Areas” developed by the MPCA and Natural Resources Conservation Service (NRCS), provides feedlot operators with a user-friendly overview of state requirements and recommended program practices to protect water quality.

Program data needs and recommendations

Feedlot Program staff identified several areas where additional data would be helpful in determining the effects of feedlot impacts on groundwater quality, as follows:

- **Obtain Water quality data from perimeter drain tile discharge at manure storage basins** - Provide professional evaluation follow-up on testing results of drain tile discharge water for drain systems that MPCA has required of permittees around manure storage basins. There are a large number, perhaps thousands, of perimeter tile drainage systems around concrete or earthen manure storage basins. However, there are only around a dozen feedlot sites statewide that have permit conditions outlining the sampling of drain tile discharge on a routine basis. One challenge to obtain regular samples comes from the seasonal fluctuations in perimeter drain tile flow. At many times the groundwater is not saturated enough to allow the drain tile to flow readily enough to obtain a sample. The drain systems are set around the base of the storage basins to lower the water table beneath the basin and maintain a separation distance of four feet between the bottom of the basin and the underlying water table. The drain tiles typically discharge to county ditches, which flow to surface waters of the state. The quality of water from the drain tiles is representative of the groundwater beneath the manure storage basins and would indicate if there is contaminant leakage from the basins to the groundwater.
- **Evaluate manure storage basins in southeast Minnesota karst region** – In southeastern Minnesota, a number of manure storage basins were built in the mid-1990s, prior to when manure storage basins were required to have double liners. Basins or lagoons built without double liners have a greater potential for catastrophic failure in karst settings. Feedlot staff have conducted some visual inspections of these facilities; however, it would be good to evaluate the condition of the older storage basins (>15 years old) more rigorously. This evaluation could

determine the locations of older basins, depth to bedrock, proximity to springs, sinkholes, streams, and include any soil data or construction information available on these structures from the NRCS, Soil and Water Conservation District, Joint Powers Boards, etc. A pilot study could be conducted for a county where good geologic information is available from county geologic atlases, along with groundwater data and hydrogeologic studies, and where cooperation from local government units is likely. Such counties could include Wabasha, Fillmore, or Olmsted Counties. MPCA groundwater studies from 2001 for these types of structures could supplement this type of analysis, and MPCA could review old-field log books from sample collection efforts.

- **Investigate groundwater quality at larger manure storage basins** – Conduct focused investigations at manure storage basins that pose a greater risk to groundwater quality. Newly constructed basin capacities continue to grow in size each year, with some basin volumes in the 20-30 million-gallon range, per cell. Use information from MPCA Groundwater Monitoring and Assessment Program studies, a comprehensive literature review, and experiences from other states to prioritize site investigations. Collect samples of soil and groundwater with a geoprobe at basins with the following characteristics: unlined basins and or earthen basins; liquid storage greater than 5 million gallons; locations in hydrogeologically sensitive areas of the state with either sand/gravel or fractured bedrock beneath the basin; locations in areas that supply drinking water to wells or springs; and where the uppermost water bearing unit is an aquifer, located in a vulnerable drinking water supply management area, and with liner design seepage rates of 1/56”/day vs. 1/560”/day).

Preventive antibiotics and hormones – The use of antibiotics as a preventive measure in the treatment of livestock must be considered a likely source of the contamination of groundwater.

D. Land Application Sites for Industrial Wastewater and Industrial by-products

This program review identifies program practices implemented by the MPCA Water Quality Permits Program to prevent the contamination of groundwater from the land application of industrial wastewaters and industrial by-products (IBP). It also identifies whether additional data is needed to better evaluate the effectiveness of program practices to protect groundwater resources and discusses other areas of potential concern.

Overview

The Water Quality Permits Program oversees the permitting and regulation of the land application of industrial wastewaters and industrial by-products, primarily generated by the food, beverage and agricultural processing industry. The land application of industrial wastewaters is regulated primarily through National Pollutant Discharge Elimination System (NPDES) and State Disposal System (SDS) permits. These permits set limits on the land application of nutrient-rich process wastewaters for its beneficial use as a fertilizer on agricultural fields. There are currently 25 facilities with NPDES/SDS permits that land apply industrial wastewaters, located mainly in southern and central Minnesota. At most, of these facilities industrial wastewaters are applied by spray irrigation to fields planted to a forage crop during the growing season. These facilities have annual application rates that range between several million gallons up to 100 million gallons for larger facilities. The regulations in the

NPDES/SDS permits emphasize groundwater protection through good crop and irrigation management and set requirements for land application activities with the goal to protect both groundwater and surface water.

The land application of industrial by-products is most often regulated by the MPCA SDS general permit (MNG960000) for wastes generated from the food and beverage processing industry. Under the general permit, industrial byproducts may be land applied for their beneficial use as a fertilizer and soil amendment to agricultural lands. Industrial by-products include materials such as: liquid or dewatered wastewater treatment sludges, wash water from small food preparation, whey from cheese processing, sweet corn silage, ethanol by-products, and materials with similar characteristics. Approximately 80 industrial facilities are covered under this general permit. A gross estimate of land applied industrial by-products in 2012 indicates 65 million gallons and an additional 77 wet tons of industrial by-products were land applied, which is typical of most years.

A majority of industrial by-product management requirements were adopted from the biosolids rules (Minn. R. ch. 7041) into the general industrial by-product permit. The permit requirements for both industrial wastewater and industrial by-products have stated goals to protect water quality in accordance with Minn. Stat. chs. 115 and 116, and Minn. R. chs. 7001, 7050, 7060, and the U.S. Clean Water Act.

Nature of concern related to groundwater quality

Industrial wastewaters and industrial by-products are considered to be high strength organic wastes that may contain nutrients, salts, organic matter, and, to a lesser degree, pathogens. Potential impacts to groundwater quality can occur from their over-application or improperly timed applications, which can exceed the capacity of the soil/crop treatment zone to assimilate the nitrogen they contain, leading to nitrate contamination of the groundwater. In addition, salts in these materials can build up in soils and shallow groundwater leading to contamination of groundwater with chlorides.

Industrial wastewaters are applied through spray irrigation to the same fields continuously for many years. These types of applications have shown impacts to shallow groundwater in the form of nitrate-nitrogen and chlorides at some application sites. Most land application sites receiving high strength industrial wastewaters are required to monitor the condition of the wastewater received, along with the groundwater, tile line discharge, and soils and crops as a part of their permit requirements.

A number of industrial spray sites show elevated nitrate and chloride concentrations in the shallow water table adjacent to the application fields. Concentrations of nitrates or chlorides in excess of permit limits requires actions on the part of the facility to remedy these conditions that include increased monitoring, reductions in applications, or entirely eliminating applications to a field. In general, groundwater contamination at most facilities has shown decreasing trends in recent years and continues to be monitored. There are currently no known cases of groundwater contamination, in excess of drinking water standards, in private or public water supply wells that are directly linked to industrial spray activities in Minnesota.

In contrast to industrial wastewaters, most industrial by-products are surface applied or injected into soils and are routinely applied to different fields or different areas of a field from year to year. Conducting groundwater monitoring at industrial by-product application sites was considered in the development of the industrial byproduct general permit; however, because of the characteristics of food, beverage, and agricultural industrial by-products and the numerous conservative management practices required in the general permit, they are considered to pose a limited environment risk to groundwater if managed properly. For these reasons, industrial by-product land application sites are not required to have groundwater monitoring systems in place.

Contaminants of concern

As noted above, the contaminants of concern in industrial wastewaters and industrial by-products include: nutrients (nitrogen and phosphorus primarily), salts, organic matter, and may contain pathogens. The risk from pathogen contamination in these materials is considered minimal because these materials are generated from food grade by-products. Overall, nutrients, organic matter, and pathogens are considered to be adequately treated where land application is conducted properly and should not create groundwater contaminant problems.

However, the Water Quality Permits Program is routinely faced with permitting decisions regarding the land application of “unusual industrial by-products” that do not fit the definition or characteristics of food and beverage industrial by-products. The industrial by-product general permit is designed to address by-products from the food and beverage industry and may not have appropriate requirements that are protective of human health and the environment for “unusual industrial by-products”. Individual permits are required when the by-product falls outside the agriculture and food and beverage universe and monitoring and management requirements need more specificity than provided in the general permit. The program currently has a need to better understand the fate and transport of constituents contained in “unusual industrial by-products” to avoid contamination of groundwater resources and determine levels where these contaminant pose a risk to human health and the environment. Examples of unusual industrial by-products include petroleum compounds in wash waters, constituents of personal care products discharged by beauty shops, and wastes generated from various manufacturing facilities located outside of sewer service areas.

Program practices used to protect groundwater

As noted above, the Water Quality Permits Program regulates the land application of both industrial wastewaters and industrial by-products through NPDES and SDS permits. The permits set limits and conditions on the locations, quantities and characteristics of land applied industrial wastewaters and industrial by-products that are designed to prevent groundwater contamination.

Historically, program policy has required that land applied industrial wastewaters and industrial by-products must provide a beneficial use as a fertilizer or soil amendment and not be land applied solely for the purpose of waste disposal. However, if land application of some of the unusual wastes is approved, the policy on beneficial use may need to be changed. A number of the permit requirements provide specific protection of groundwater and several provide indirect protection of groundwater resources through management practices that prevent releases of pollutants to the environment, as follows:

- Industrial wastewater facilities that spray irrigate high strength effluent, which receives limited treatment, are required to conduct groundwater monitoring around their spray fields. In addition, these facilities are required to conduct rigorous environmental monitoring throughout the irrigation season that includes monitoring of: tile line discharges, the received wastewater effluent, cooling water, county ditches, soils, crops, and occasionally offsite private wells.
- The permits for industrial wastewater application sites include intervention limits in groundwater for nitrate-nitrogen that are one-quarter of the drinking water standard for nitrate of 10 mg/l. In addition, the industrial wastewater permit sets a total chloride intervention limit

at the secondary drinking water standard of 250 mg/l. An exceedance of either of these limits requires actions by the permittee to prevent these exceedances.

- Industrial wastewater facilities must have a Type V certified operator responsible for the day-to-day operations of the wastewater treatment disposal system.
- Industrial wastewater facilities must prepare a Sprayfield Management Plan that includes details of monitoring, irrigation scheduling, loading rates, soil moisture monitoring, runoff collection, drain tile discharge or collection, and crop management practices.
- Tile drainage systems beneath land application sites are also monitored and have limits set for ammonia-nitrogen and biological oxygen demand. Monitoring data from the tile line discharge is representative of the water quality that may be infiltrating to groundwater.
- Industrial by-products must be completely characterized before a permit can be issued for industrial by-product land application. Industrial by-products must not exceed specific concentration limits for metals, dioxin, and PCBs, and cannot be a hazardous waste.
- The industrial by-product general permit requires that a Type IV certified operator oversee the land application of industrial by-products and ensure they are properly applied. Industrial by-product application sites must also be reviewed by the Type IV operator and their soils tested.
- Land-applied industrial by-products are subject to a number of limitations and restrictions that protect groundwater resources that include:
  - Hydraulic loading limits based on soil texture.
  - Separation distances from drinking water wells, and sinkholes.
  - No industrial by-product applications on fallow ground for the cropping year.
  - Limits on nitrogen applications.
  - Additional restrictions on Industrial by-products that contain pathogens.

The industrial by-product program has implemented an Unusual Waste Review that includes a multi-program task group to determine the proper management of unusual wastes, such as vehicle carwash wastewaters. These wastes may contain constituents such as PFAS that are not typically found in industrial by-products that could impact groundwater quality and must be addressed accordingly. The State of New Jersey is currently investigating the threat posed by PFAS compounds used in carwashes due to the connection of many of the facilities to large septic systems, and the resulting discharge of this contamination to groundwater.

Program data needs

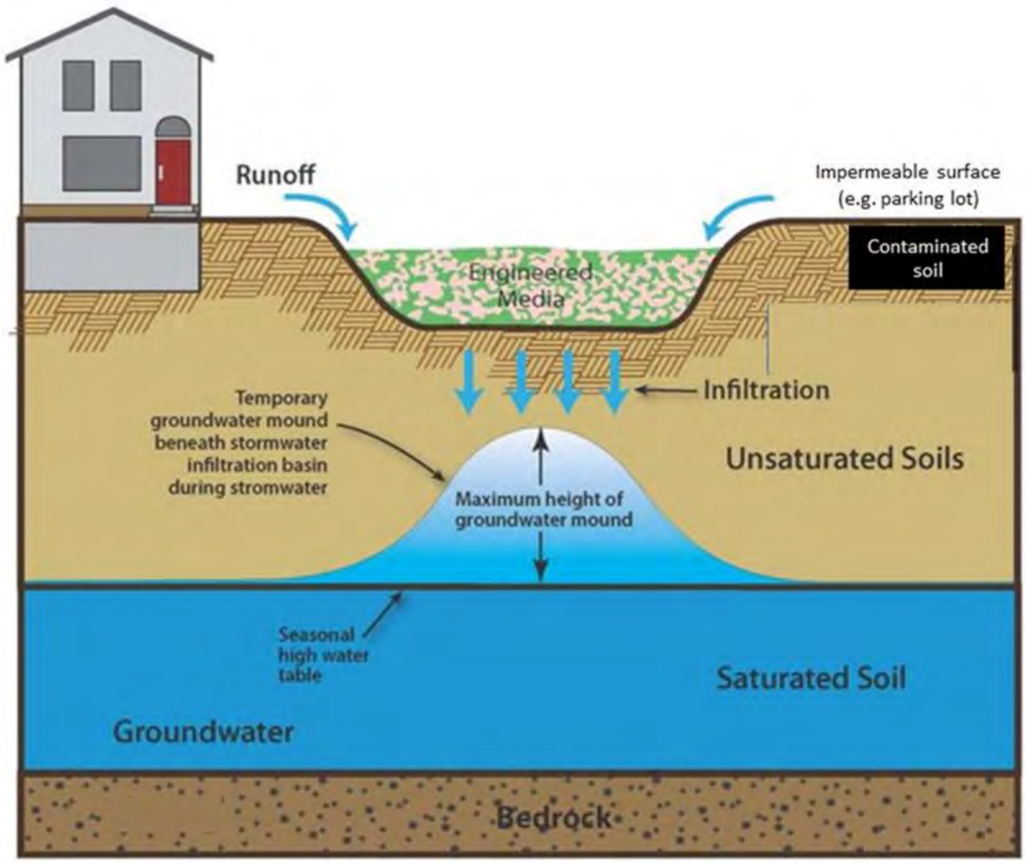
- **Groundwater evaluations -** As risk data becomes available on emerging chemicals of concern, MPCA staff may need to review chemical additives used in land application activities and it may be necessary to review the decision to land apply certain waste types. The Agency is still determining how to proceed with possible groundwater contamination with arsenic, iron, and manganese at high biological chemical demand (BOD) irrigation sites. Preliminary review shows that loading rates are much less in Minnesota than problem sites in other states such as Michigan. If the Agency does decide to review the application of waste for arsenic, iron, and manganese at industrial wastewaters and industrial by-products sites, then it should also consider expanding the review to the animal feedlot and biosolids programs, as similar contamination opportunities apply to all three programs.
- **Unusual wastes** - the Water Quality Permits Program is routinely faced with permitting decisions regarding the land application of unusual wastes that do not fit the definition or characteristics of typical food and beverage industrial by-products or fit neatly into any other land application program at the MPCA. Program staff from water quality, solid waste, and

hazardous waste meet when these types of waste management issues require new approaches. Both carwash wastewater and wastewaters and solids from holding tanks and trap wastes have been addressed in guidance documents. The program requires information on the fate and transport and toxic effects of contaminant compounds contained in unusual wastes in order to develop scientifically based application requirements.

Examples of unusual wastes include constituents of personal care products discharged by beauty shops (personal care products), and wash water wastes generated from various manufacturing facilities located outside sewer service areas. The issue of unusual wastes and their environmental fate for land application scenarios is currently (2018) being investigated by the US Geological Survey's Toxic Substances Hydrology Program. The group has a current study looking at wastewater discharges from food, beverage, and feedstock processing plants. The project team has sampled wastewater discharges from the plants to characterize the chemical signatures. They will likely look at effects from land application in a future, as yet unfunded study.

- **Data review and reporting** - data related to industrial by-product land application activities were once entered into the MPCA's now-retired Delta permit database; however, with the implementation of Tempo, that no longer occurs. The goal is to have facilities enter data, currently required to be reported in the Annual Report, directly into e-Services similar to what facilities are doing for wastewater Discharge Monitoring Reports (DMRs). It is anticipated that this will not occur for a few years. Data for spray irrigation facilities are entered into Tempo through DMRs.

E. Stormwater Program



Stormwater Program

This program review identifies program practices implemented by the MPCA's Stormwater Program (SWP) that reduce and prevent the degradation of groundwater from stormwater runoff. This review identifies data needs for better evaluating the effectiveness of SWP practices to protect groundwater resources and provides recommendations for addressing these data needs.

Overview

The MPCA's SWP regulates the discharge of stormwater and snowmelt runoff from municipal separate storm sewer systems (MS4), construction activities, and industrial facilities, mainly through the administration of NPDES/SDS permits. The SWP program oversees the permitting of approximately 250 municipal systems, 2,000 construction stormwater sites, and 2,500 industrial facilities, in any given year. The SWP administers general permits (and in some cases, individual permits) that incorporate state (Minn. R. ch. 7090) and federal Clean Water Act requirements to reduce the amount of sediment and pollution in stormwater runoff that enters surface and groundwater.

Management of urban stormwater runoff utilizes volume control practices (e.g., infiltrate, evaporate or reuse), filtration practices (e.g., rain gardens, sand filters), rate control and sedimentation practices (e.g., stormwater ponds), and new pollutant removal technologies (e.g., chemically enhanced treatments such as iron enriched sand filters). On a national scale, the EPA has strongly encouraged federal facilities and states to adopt low impact development (LID) practices, primarily for infiltration-based BMPs, and Better Site Design practices that protect forest and stream corridors.

In 2009, the Legislature directed the MPCA to develop performance and design standards or other tools to enable and promote the implementation of low-impact development and other stormwater management techniques. (Minn. Stat. 115.03, subd. 5c). That language defines low impact development as “an approach to stormwater management that mimics a site’s natural hydrology as the landscape is developed. Using low-impact development approach, stormwater is managed on-site and the rate and volume of predevelopment stormwater reaching receiving waters is unchanged. The calculation of predevelopment hydrology is based on native soil and vegetation.”

Working off the principles of low impact development, a diverse group of stakeholders from the public and private sectors and the Minnesota Stormwater Steering Committee worked with the MPCA to develop a Minimal Impact Design Standards (MIDS) package. This included: 1) volume performance goals, 2) a method to determine credits for those goals, 3) a user-friendly calculator to input site conditions and credits, 4) design specifications for a variety of LID practices, and 5) an ordinance package to help developers and communities implement MIDS.

Nature of concern related to groundwater

Several BMPs infiltrate treated stormwater into the soil, where it can recharge groundwater aquifers. The management of stormwater runoff is increasingly relying upon these infiltration practices.

Several field and laboratory studies conducted over the past 10 years provide information on the fate of pollutants in water as the water goes through infiltration practices. Trojan et al. (2018) provide an extensive review of groundwater impacts from stormwater infiltration practices. While recent studies provide considerable information to better guide the use of infiltration practices, several information gaps remain, including the following:

- Because soils have finite retention capacities, we need a greater understanding of the processes and timing of pollutant breakthrough.
- Pollutant transport and retention in underground infiltration systems is poorly understood.
- We need a greater understanding of chloride dynamics in urban runoff and resulting fate and transport of chloride in infiltration systems.
- We need additional monitoring for organic pollutants (e.g., hydrocarbons, pesticides) and pathogens in the region beneath infiltration systems.

We have a poor understanding of the hydrology of infiltration practices, specifically understanding and quantifying the fate of infiltrated water.

Contaminants of concern

Stormwater runoff, including snowmelt, contains pollutants such as nutrients, pathogens, heavy metals, solids, organic compounds such as oil and pesticides, and chlorides. Properly constructed and maintained BMPs are effective at attenuating most pollutants. The following conditions or pollutants represent a potential risk to groundwater from infiltrated stormwater runoff.

- Chloride is mobile and will not be retained by stormwater BMPs.
- Pathogens are also mobile in infiltration systems constructed in highly permeable soils with low organic matter content.

- Stormwater hotspots are locations where activities have the potential to produce high levels of pollutants in runoff.

Program practices used to protect groundwater

The SWP incorporates required stormwater practices into permits; provides guidance, tools, and outreach on stormwater management; and conducts and supports stormwater research efforts. Examples of these include the following:

- Stormwater permits regulate the discharge of stormwater and snowmelt runoff through administration of a general permit, and in some cases, individual permits, for MS4, construction activities, and industrial facilities. Permit requirements include performance goals (e.g., infiltrating 1 inch of runoff from new impervious surfaces for post-construction), BMPs (e.g., the 6 Minimum Control Measures), development of stormwater pollution prevention plans and programs (SWPPPs), and annually reporting progress toward meeting Total Maximum Daily Load requirements.
- The Minnesota Stormwater Manual is an innovative, online, interactive and user-friendly tool that provides guidance on BMP design, construction, operation, maintenance, and assessment. Specifically, the manual contains two sections addressing stormwater infiltration and infiltration practices. The manual includes information and guidance on tools, such as model ordinances and water quality models, and was developed using a wiki application to allow for easy editing and powerful search abilities. Included in the manual is information on MIDS, including a link to the calculator, guidance and examples for using the calculator, and a MIDS ordinance package. Information on stormwater infiltration and infiltration practices can be found in the stormwater manual wiki, available at: https://stormwater.pca.state.mn.us/index.php?title=Main_Page.
- The SWP is currently conducting research on pollutant fate in infiltration systems and infiltration characteristics of swales. The SWP regularly collaborates with the University of Minnesota and others conducting stormwater research.
- The SWP regularly provides outreach through webinars, newsletters, presentations, and meetings with stakeholders.

Table 3. Summary of typical risk of groundwater (GW) contamination by pollutant, increasing groundwater risk, and management strategies for reducing risk

Pollutant	Risk of GW contamination from infiltration practices	Conditions when pollutant may represent a risk to GW or surface water receiving groundwater inputs	Management strategies for sites where conditions may represent a risk
Nitrate	Low-moderate	Nitrogen fertilizer used historically, and where turf is being established; use of media with organic nitrogen that can convert to nitrate	Pretreatment to remove organic Nitrogen; reducing infiltration rates by using finer texture material; relocating high Nitrogen practices away from drinking water receptors
Chloride	High	Areas receiving applications of chloride-based deicers	Reducing chloride deicer application. Encouraging infiltration may reduce peak concentrations in surface waters, but overall loading remains unchanged
Phosphorus	Low	Infiltration practices having a high concentration of organic matter discharging to shallow GW near surface receiving waters	Ensure concentration does not exceed 30 mg-P/kg-soil; construct layer at bottom of the practice to attenuate phosphorus using elemental iron
Toxic metals	Low	Practices with low adsorption capacity; low pH media; large inputs of chloride; receiving high concentration of metals in runoff	Replace top few inches of soil or media in the infiltration practice; test soil to ensure proper pH; limit chloride loads to the practice
Pathogens	Low-moderate	Practices with low adsorption capacity (e.g. low organic content) & rapid infiltration rates; areas with high concentration of bacteria (like Enteroviruses)	Utilize infiltration practices having greater concentrations of organic matter; avoid underground infiltration in very coarse soils if bacteria concentrations are high
Organic chemicals	Low-medium (varies by chemical)	Practices having low adsorption capacity (often low organic content) & rapid infiltration rates; nearby large terrestrial sources of soluble contaminants	Add organic matter to soil or media
Temperature	Low-moderate	Infiltration practices with very rapid infiltration rates and located adjacent to temperature-sensitive receiving waters	Locate practices representing a risk away from temperature-sensitive waters or slow infiltration rates by adding organic matter or fine-textured material

Program data needs

- Promote the creation of statewide GIS data layers to evaluate options to infiltrate stormwater in new development and redevelopment areas in relation to wellhead protection zones, extremely vulnerable aquifers (e.g. sand/gravel outwashes over bedrock), depth to shallow groundwater, and hydrologic soil groups (A, B, C, and D).
- Incorporate research and case studies of groundwater impacts from stormwater infiltration practices into guidance (e.g., the Minnesota Stormwater Manual). This involves collaboration with outside partners, such as municipalities, watershed districts, and other state agencies. Specific focus areas include:
  - Obtaining a better understanding of the fate of chloride and pathogens in infiltration systems.
  - Obtaining a better understanding of infiltration volumes and fate of infiltrated water.
  - Assessing changes in shallow groundwater that relate to potential issues for buried utilities and structure basement flooding (e.g. groundwater mounding potential).
  - Identifying locations of BMPs relative to wellhead protection areas and their emergency response areas for source water protection.
  - Evaluating failed infiltration projects to determine causes.
  - Obtaining a better understanding of infiltration at Brownfield sites.
- Improve data collection and management for stormwater infiltration projects. Components of this effort could include:
  - Advancement of standardized data collection protocols through development of recommendations and guidelines for sample collection and analysis.
  - Collection of monitoring data for input to a common database that allows for access by outside stakeholders.
  - Data interpretation and reporting.

F. Biosolids Program

This program review identifies program practices implemented by the MPCA Biosolids Program (MBP) to prevent the contamination of groundwater. It also identifies whether additional data are needed to better evaluate the effectiveness of biosolids program practices to protect groundwater resources and notes other areas of potential concern related to the land application of biosolids and groundwater quality.

Overview

The MBP oversees the land application and storage of municipal sewage sludge or biosolids for beneficial use as a soil amendment in accordance with Minn. R. ch. 7041. Biosolids are a nutrient-rich solid, semisolid, or liquid organic material that results from the treatment of domestic wastewater (sewage sludge) by municipal treatment plants. Biosolids are land applied to improve the fertility of cropland and forestland, as well as to restore and revegetate land impacted by the mining of iron and taconite (Western Lakes Superior Sanitary District and other facilities).

In Minnesota, there are approximately 280 facilities generating biosolids on a regular basis; this number has not changed substantially over the last 10 years. The total biosolids produced in 2016 was approximately 148,825 dry tons; 21% was land applied, 61% was incinerated, and 18% was landfilled.

Table 4. Biosolids in Minnesota in 2016

Method	Amount	Percent	# of Facilities
Incinerated	90,873 Dry tons	61%	3
Land Applied	30,951 Dry tons	21%	137
Land filled	27,001 Dry tons	18%	18

On a tonnage basis, the majority of Minnesota biosolids are incinerated in St. Paul and Eagan, while a larger number of municipal wastewater treatment facilities land apply their biosolids. There are a few facilities like Grand Rapids that landfill their biosolids on a continual basis. In 2016, biosolids (class B) were land applied on 16,733 acres, approximately 1,800 fewer acres than in 2009. A majority of biosolids are applied to agricultural fields planted to field corn and soybeans. The total acreage of land where biosolids are applied in the state represents less than 0.001% of the approximately 23,000,000 acres used as cropland in Minnesota, in any given year.

Nature of concern related to groundwater

Biosolids contain nutrients (nitrogen and phosphorus), pathogens, trace metals and trace amounts of persistent organic compounds. They are routinely applied to agricultural lands as a soil amendment. If biosolids are improperly applied, some pollutants such as nitrogen could potentially leach past the soil/crop treatment zone and negatively impact groundwater quality.

The primary concern with the improper land application of biosolids to groundwater quality is from nitrate/nitrogen impacts, and to a lesser degree, pathogens. However, the conservative management requirements for land-applied biosolids make the likelihood of impacting groundwater quality negligible. The MPCA requires that all land-applied biosolids be processed and tested before use and be low in potential contaminants and treated to reduce the levels of pathogens and odor.

The conservative management of land-applied biosolids, and the relatively small acreage they are applied to, suggests a limited risk to groundwater quality, as long as they are managed in accordance with the BMPs set forth in Minn. R. ch. 7041.

Contaminants of concern

The contaminants of concern in biosolids include: nutrients (nitrogen and phosphorus primarily), trace metals, pathogens, and trace amounts of persistent organic compounds. The nitrogen content of the biosolids typically drives their application rates which are set to meet the agronomic needs of crops grown on the land they are applied. Setting the biosolids application rates to meet agronomic cropping needs helps avoid over application that could lead to nitrate impacts to groundwater quality. The phosphorus content of biosolids is usually not considered to be a threat to groundwater quality because phosphorus adsorbs to soil and typically will not leach to groundwater in appreciable quantities. Pathogens are treated in biosolids prior to land application and receive further treatment in the soil when land applied, and trace metals are tracked and regulated to prevent their excess accumulation at biosolid application sites. Nutrients, pathogens, and trace metals are regulated by MBP requirements and should not create groundwater contaminant problems if BMPs are followed.

Persistent organic compounds that include pharmaceuticals, personal care products, steroids, and hormones show high affinities for organic carbon in biosolids and preferentially accumulate in them (Kumar et al., 2017), as can be seen in the results of the Environmental Protection Agency's (EPA) Targeted National Sewage Sludge Survey of 2009. In addition, PFAS has also been detected in biosolids, biosolids amended soils, and in the environment adjacent to biosolids, application sites (Lindstrom et al., 2011; Blaine et al., 2013; Sepulvado et al., 2011; Higgins, 2017).

In general, organic contaminants tend to accumulate in biosolids in the part per billion to part per million-concentration range (Kumar et al., 2017). The relative risk of organic contaminants in land-applied biosolids is currently being debated by the water quality professionals who treat the wastewater and manage biosolids, toxicologists who set contaminant limits for food and water, and research scientists who are studying the presence of these contaminants in food crops, soils receiving biosolids applications and nearby surface water and groundwater. Ultimately, the EPA will be need to provide some regulatory direction or guidance for biosolids management, considering these contaminants, which has been provided for nutrients, metals and pathogens, under the current biosolids regulations in 40 CFR part 503 (see https://www.epa.gov/biosolids/select-biosolids-regulatory-processes).

Persistent organic chemicals are not specifically addressed within the scope of the MBP and the MBP relies on the EPA to provide regulatory guidance for biosolids management as set forth under 40 CFR part 503. The current MPCA biosolids rules (Minn. R. ch. 7041) incorporate all of the 40 CFR Part 503 requirements for land applying public and private biosolids. In the event the EPA promulgates new requirements for biosolids related to persistent organic compounds, it is reasonable to assume these requirements will be incorporated into MBP BMPs.

Program practices used to protect groundwater

The MBP applies Minn. R. ch. 7041 to biosolids land application operations in Minnesota. Minn. R. ch. 7041 includes all of EPA's 40 CFR Part 503 requirements for land applying public and private biosolids. Together these rules:

- Regulate the pathogen and vector attraction treatment standards and chemical monitoring of biosolids that are land applied.
- Establish criteria for the permitting, land application site approval, storage, pollutant limits, management practices and limitations, recordkeeping and reporting of biosolids that are land applied in Minnesota.

Biosolids land application must follow minimum design requirements. A number of these requirements provide specific protection of groundwater and several provide indirect protection of groundwater resources through management practices that prevent releases of pollutants to the environment, as follows:

- Stricter management practices are required for highly permeable soils that receive biosolids. Nitrogen application rates must comply with agronomic application rate requirements set in federal rule. The agronomic rate is the sludge application rate, which is designed to 1) provide the amount of nitrogen needed by the food crop, feed crop, fiber crop, or vegetation grown on the land, and 2) to minimize the amount of nitrogen in the biosolids that passes below the root zone to the groundwater.
- Biosolids rules require a minimum separation distance to bedrock and the seasonal high water table of three to five feet to allow for soil conditions, which are necessary to treat the biosolids, as well as provide a good growing environment for crops.
- Biosolids may not be applied within 1000 feet of a public water supply well or within 200 feet of private wells to avoid possible direct contamination of a well or water supply.
- Biosolids applications are prohibited on fallow land because there is no crop growing which will remove the nitrogen supplied by the biosolids.
- A crop must be growing on the site if biosolids are applied in June, July, and August so that any nitrogen applied is taken up by the crop rather than potentially lost to groundwater.
- Biosolids application is not allowed on cropland when the soil phosphorus test is greater than 200 part per million unless a federal Natural Resources Conservation Service conservation plan is in place.

Program data needs and recommendations

The MBP deals with data from about 280 facilities and thousands of land application sites associated with these facilities. Since June of 2015, site approval information and annual report data has not been entered into an official MPCA database. As of early 2019, all Biosolids annual reports have been scanned into Tempo; however, the data is not currently entered in a manner that facilitates use of the data. In addition, in approximately 2013, MPCA staff discontinued entering in metal loading rates into the now-retired Delta database. Site approval information and annual report data exists since the program started in 1982; while all of the information is in paper form, only some information is in electronic form, making it challenging to easily access data when needed.

Several years ago, concerns were raised that biosolids may have been a source of groundwater contamination in Lynden Township south of St. Cloud. Several area wells in close proximity to the City of St. Cloud's biosolids land application sites were found to have elevated concentrations of metals. A follow-up analysis of biosolids loading data and additional well analysis was needed to reach the conclusion that biosolids were not the source of any groundwater contamination and the original testing of these wells was in question.

- The MBP needs to have all of its biosolids land application locational information and metals loading data entered into the MPCA's Tempo database or another database, to allow for ready access and data analysis. This is necessary to address data request concerns related to groundwater quality concerns, as identified in Lynden Township, and from a program management standpoint to better track nutrient and metals concerns related to biosolids land application activities.
- There is a program interest to better understand the fate of and human health risks associated with persistent organic compounds likely to be present in biosolids (pharmaceuticals, personal care products, steroids, and hormones). However, the financial and staff resources necessary to conduct this type of work are beyond the scope of the program's resources. Currently, the testing of persistent organics in biosolids is being conducted by the EPA. It is reasonable to expect the Biosolids Program will stay current with EPA's research in this area and look for results from any risk analysis or development of pollutant limitations resulting from EPA's work.

Blaine, A.C., Rich, C.D., Hundal, L.S., Lau, C., Mills, M.M., Harris K.M., Higgins, C. 2013. Uptake of Perfluoroalkyl acids into Edible Crops via Land Applied Biosolids: Field and Greenhouse Studies. Environ. Sci. Technol., 47: 14062-14069.

Higgins, C.P. Accumulation of Perfluoroalkyl Acids in Food Crops. Colorado School of Mines. April 19th, 2017 presentation.

Kumar, K., Lakhwinder, S. H., Bastian, R.K., and Davis, B. Land Application of Biosolids: Human Health Risk Assessment Related to Micro-constituents. Water Environment Federation, 2017.

Lindstrom B.A., Strynar, M.J., Delinsky, A.S., Nakayama, S. F., McMillan, L., Libelo, E.L., Neill, M., Thomas, L. Application of WWTP Biosolids and Resulting Perfluorinated Compound Contamination of Surface and Well Water in Decatur, Alabama, USA. 2011. Environ. Sci. Technol., 2011, 45, 8015-8021.

Sepulvado, J.G.; Blaine, A.C., Hundal, L.S.; Higgins, C.P. Occurrence and fate of perfluorochemicals in soil following the land application of municipal biosolids. Environ. Sci. Technol. 2011, 45 (19), 8106-8112.

G. Inflow and Infiltration

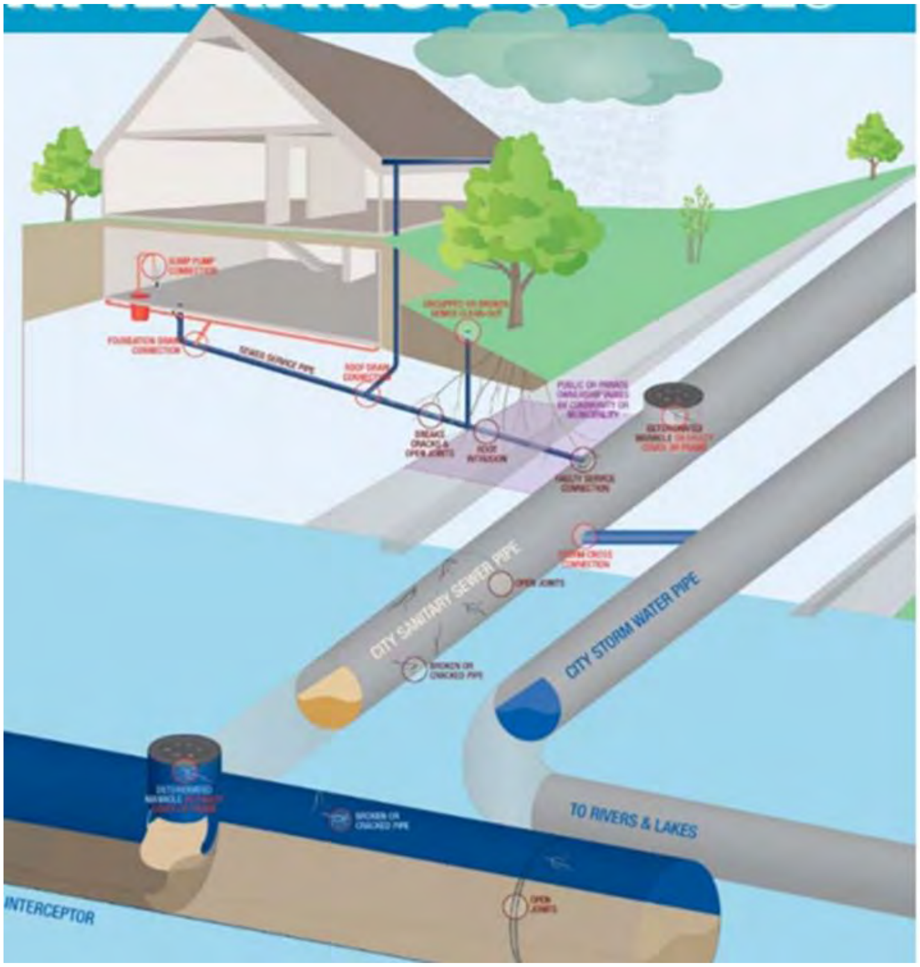


Figure credit: Metropolitan Council

Nature of concern related to groundwater

The concern has been raised that leakage from municipal wastewater piping systems or city sewers may be contributing to groundwater pollution and should be addressed within the scope of a review of MPCA groundwater protection practices. Basic definitions of inflow and infiltration (I&I): inflow is a plumbing choice (e.g. a storm drain or gutter connected to a sewage system); while infiltration is a leakage due to wear or breakage, where water is forced into pipe by external positive pressure. City sewers are known to have problems with I&I, or excess water entering sewer systems from groundwater and stormwater through holes, cracks, joints and faulty connections. However, the reverse process of wastewater leaking out of sewer pipes or exfiltration may also affect groundwater quality. The following comments were gathered from conversations with MPCA staff in the Municipal Wastewater Section.

There are thousands of miles of city sewer piping and infrastructure in various conditions throughout the state; however, there are no known volumes of wastes that can realistically be estimated as impacting groundwater from systems that do leak. Inflow and infiltration could be occurring anywhere there are city sewer systems, so it is probable this would be occurring within wellhead protection areas and vulnerable aquifers. There is no list of sites where I&I impacts to groundwater are being investigated or targeted for investigation.

I&I is recognized as a concern from the wastewater engineering perspective when groundwater leaking into old or broken sewer pipes increases the volume of water going to the publicly owned treatment works (POTW). There is a wastewater infrastructure-funding program that funds sewer rehabilitation projects where I&I may be a problem. These projects are ranked on the Clean Water Project Priority List and are overseen by the Minnesota Public Facilities Authority and other state agencies, including the MPCA. Rehabilitation projects fix leaky sewer problems, and new sewer systems are tested for sewers for leakage when they are installed. Sewer rehabilitations use materials that are less likely to leak than materials used in the past and sanitary sewer piping is separated from stormwater piping systems.

The main contaminants in sewage include bacteria measured as fecal coliform, biological oxygen demand (BOD), nitrogen, phosphorus, and numerous other parameters from improper disposal of household wastes and industrial wastes that could contain contaminants of emerging concern (CECs).

The MPCA staff noted the biggest potential impacts to groundwater from city sewers would likely be from a complete pipe failure; however, that would likely result in a sewer back up or overflow and would be identified. In addition, dry weather flow into the POTW can also be used to determine if significant leakage is occurring. If there is less flow volume than predicted by user inputs, the piping system probably leaks into the surrounding soils and groundwater.

Overall, the ability to locate and assess the impacts of leaking sewer pipes to groundwater would be very difficult to assess and monitor without exact locations of leakage. Leakage can flow along the pipe trench within the gravel sub base most pipes are laid in and enter soils or groundwater in a different area from that of the leakage. Methods such as dye tracing or video logs of piping could be used to locate leakage that may affect groundwater; however, as stated previously there is no list of sites that are being monitored or investigated for leakage impacts to groundwater.

Summary and next steps

A review of MPCA program documents and interviews with program staff indicate that several MPCA programs require groundwater quality monitoring data to verify whether their groundwater BMPs are protective of groundwater resources. More specifically, this includes groundwater monitoring of mid-sized septic systems (MSTS sites), select animal feedlot manure storage basins, stormwater infiltration sites, and enhanced monitoring at specific industrial wastewater land application sites.

In addition, analysis of existing groundwater quality data sets was also identified as a need to assess the impacts of program BMPs. The Demolition Landfill Program has a pressing need to conduct a statistical data analysis of groundwater monitoring data collected over the last eight to ten years from demolition landfills to assess the impacts of program BMPs contained in their Demolition Landfill Guidelines. The Animal Feedlot Program would also benefit from an analysis of a water quality database collected from larger permitted facilities collected from monitoring wells and tile drainage discharge stations.

Furthermore, program staff has identified a need to collect and store data in a database that allows for meaningful analysis and data sharing. Formerly, the bulk of data generated by the Solid Waste Demolition Landfill program and for the land application of industrial wastewaters and industrial by-products was stored in the now-retired Delta database. Once a decision is made concerning the restarting of the loading of this information into a MPCA database, data generated from the monitoring of stormwater infiltration sites should also be collected, assessed and made available to outside parties.

Summaries of the MPCA program data needs are provided in Appendix A in table form and more detailed descriptions are found at the end of each program write-up under the "Program BMPs and Data Needs Findings" section of the report.

Work plans

The next step in this process is to develop work plans to address program data needs that will enhance program groundwater BMPs. Developing work plans must be conducted with program staff, and management and will need to consider a number of factors. Some of these factors include available funding, staff resources, program readiness, scope or length of project, material costs, and whether the BMP evaluation should be conducted solely by the MPCA staff or jointly with outside stakeholders, consultants, responsible parties, other government entities, or contracted out entirely.

Several programs are moving forward with their priority data needs collection; however, these are limited by staffing resources. Both the Demolition Landfill and Stormwater Programs have taken initial steps to collect data for their priority needs, and the SSTS program and Industrial Waste land application programs have set their priority data needs and are looking for resources and outside partners to initiate data collection.

Appendix A

Table 1. Program data needs and recommendations

MPCA Programs	Program data needs and recommendations
Solid Waste Demolition Landfill	• Encourage reuse of demolition materials to reduce reliance on unlined facilities • Provide incentives to owners of unlined landfills to move to facilities that are more protective of degradation through using liners and leachate collection systems • Seek funding for these changes in the State of Minnesota 2018-19 Biennial Budget
Subsurface Sewage Treatment Systems (SSTS)	• Groundwater monitoring at MSTS sites • Assess impacts of smaller ISTS to groundwater monitoring for CECs • Reduce the intentional flushing of unused pharmaceuticals from home and farm
Animal Feedlot	• Follow-up testing and analysis of the drain tile discharge water sampling performed at feedlots, whose permits require testing • Evaluate older manure storage basins lacking double liners in SE Minnesota karst region • Investigate groundwater quality at larger manure storage basins
Land Application of Industrial Wastewaters and IBPs	• Unusual wastes and their environmental fate for land application scenarios are currently (2018) being investigated by the USGS Toxic Substances program • Loading rates at high BOD irrigation sites in Minnesota are much less than similar sites in other states such as MI, which may lead to further study • Site information related to application that used to be entered in the now-retired Delta database is not currently entered in its replacement, Tempo, as of 2018. There will be an attempt to once again capture this information in the future.
Stormwater	• Promote creation of statewide GIS layers to evaluate options to infiltrate stormwater in new development & redevelopment areas in context of vulnerable aquifers • Develop case studies to assess groundwater impacts for stormwater infiltration BMPs (e.g. the Minnesota Stormwater Manual; consider Cl, pathogens, infiltration at brownfields, etc.) • Data collection for stormwater infiltration projects
Biosolids	• No specific recommendations for groundwater monitoring • Biosolids annual reports have been scanned into Tempo, but the data is not in a readily accessible format. New biosolids site approvals and cumulative metals loading data have not been stored electronically since the switch to Tempo. There is a recognized program need to store this data within Tempo. • There is a recognition that the fate of persistent organic compounds (i.e. pharmaceuticals, personal care products, steroids, PFAS, and hormones) in biosolids is important; however, the financial and staff resources necessary to conduct this type of work are beyond the scope of the program's current resources.
Inflow and Infiltration (I&I)	• Limited groundwater impact concerns. Concerns relate to groundwater leaking into wastewater infrastructure. • Investigating leakage to groundwater would be difficult and has not been done in the Municipal Program.

'Manure is complicated': 5 reasons you need a manure management plan

blog-crop-news.extension.umn.edu/2023/06/manure-is-complicated-5-reasons-you.html

By: Chryseis Modderman, Extension manure management educator

When applying manure, the main goals are to apply at an accurate rate and to avoid nutrient pollution. But this isn't always easy because manure, in general, is complicated. There are five main factors that make manure complicated; often, more complicated than commercial fertilizer. Following a manure management plan will help combat these challenges. Read on for the five challenging factors.

Overall nutrient content is low

Total nutrient content of manure is low – rarely above 10 percent – whereas commercial fertilizers have a much higher nutrient concentration by weight. The low nutrient content of manure is a potential problem because you need a lot more volume of manure than commercial fertilizer to achieve the same nutrient application rates. This increases time and transportation cost, making it more economical to apply to the field nearest the barn. Over time, repeated over-application to the same field can lead to nutrient build up and subsequent pollution. It is quite common to see fields nearest a livestock operation with very high soil test phosphorus levels.

Nutrient ratio is fixed

Unlike commercial fertilizers that can be mixed and adjusted to reach desired nutrient balance, manure nutrients are fixed. It is what it is. Let's do some quick math to illustrate this. Let's say you have turkey manure with 30 pounds of plant-available nitrogen and 40 pounds of plant-available phosphorus per ton, and your agronomist says to apply 180 pounds of nitrogen per acre for your corn crop. You'd need to apply manure at six tons per acre (180 / 30 = 6).

Does this application rate pose a risk for nutrient pollution? Yes. At 6 tons/acre, you will apply 240 lbs P/acre (40*6=240). Corn only uses 0.29 lbs P per yield unit. So, even a really high yield of 250 bu/ac corn would only require 72.5 lbs P/acre; and that's including what is already in the soil. Adding 240 lbs of P is way too much! Over-application of phosphorus can lead to phosphorus buildup, which can lead to pollution.

Nutrient availability is difficult to estimate

Nutrient availability, especially the availability of nitrogen, can be challenging to accurately estimate. Manure supplies two forms of nitrogen: inorganic and organic nitrogen. The inorganic nitrogen is immediately available to the plant; while the organic nitrogen is not. Organic nitrogen can become inorganic nitrogen over time through a process called mineralization. The challenge is estimating how much organic nitrogen will become inorganic nitrogen, and how fast. This can be tricky because mineralization is a microbial process, meaning that how fast or slow it processes organic nitrogen depends heavily on the environment. And we know how fickle the environment can be!

Nutrient content is not uniform

Unlike commercial fertilizers that are fairly uniform throughout, manure uniformity varies spatially and over time. This can make accurate rate calculations tricky. To meet this challenge, it is very important to take a good representative manure sample for testing. But even then, it is likely that slight over- or under-application can occur.

Nutrient timing may not be ideal

In a perfect world, manure would only be applied when the nutrients are necessary and when it poses the least risk to the environment. Unfortunately, we don't live in a perfect world. Often, manure application timing is driven by storage limitations and working around wet weather, harvest, or planting rather than when it is best for the crop and environment. Nutrient loss from manure is higher when application occurs in late winter, around the time of snowmelt.

How to meet these challenges

While we may never be 100 percent perfect with manure management, there are ways to minimize these challenges. The most significant is to have a manure management plan which encompasses best management practices such as accurate rate calculations, sampling, setbacks and buffers, spreader calibration and more!

This post was originally published by Manure Manager and has been republished here with permission.

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June 18, 2024

VIA EMAIL

Stephen M. Jann, Manager
Permits Branch, Water Division
U.S. EPA Region 5
77 W Jackson BLVD
Chicago, IL 60604

RE: U.S. Environmental Protection Agency Review of Pre-Public Notice Draft Feedlot NPDES General Permit (MNG440000)

Dear Stephen M. Jann:

The Minnesota Pollution Control Agency (MPCA) reviewed the U.S. Environmental Protection Agency's (EPA) comments and recommendations of Minnesota's Pre-Public Notice Draft Feedlot National Pollutant Discharge Elimination System (NPDES) General Permit (Permit), fact sheet, and supporting documents submitted to the MPCA on May 9, 2024. After thoughtful consideration, the MPCA offers the following response.

Comment 1
EPA has direct implementation for the NPDES program in Indian Country. The Permit should contain language excluding concentrated animal feeding operations (CAFOs) located within Indian Country from coverage under the Permit.

Response 1
The *Permit Eligibility* section of the Permit will be modified to exclude facilities in Indian Country from coverage under the Permit.

Comment 2
The Permit needs to specify the required contents of the notice of intent for coverage under the Permit. 40 C.F.R. § 122.28(b)(2)(ii).

Response 2
The MPCA's permit application for coverage under the Permit is Minnesota's equivalent to the notice of intent for coverage (NOC). The permit application includes all the required contents of the specified federal regulation and applicants for NPDES permit coverage must use this application. The definition of *permit application* will be modified in the Permit to clarify the permit application includes all the information required by the specified federal regulation.

Comment 3
The Permit needs to specify the deadlines for submitting notices of intent for coverage under the Permit. 40 C.F.R. § 122.28(b)(2)(iii).

Response 3
Minnesota's equivalent to the specified federal regulation is found in Minn. R. 7020.0505. This rule part specifies a deadline of at least 180 days for submitting a permit application for new or expanding facilities. A requirement will be added to the Permit that is consistent with Minn. R. 7020.0505 and the specified federal regulation. Additionally, the *Permit Coverage* section of the Permit specifies a deadline of at least 180 days for submitting a permit application to maintain continuous permit coverage and for modifications.

Comment 4
Permit Part 1.4 allows for suspension of the Permit in accordance with Minn. R. 7001.0170 through 7001.0190; however, the referenced state rules do not include suspension of permits. Federal regulations do not recognize suspension of permits; federal regulations recognize modification, revocation and reissuance, or termination of permits. The word "suspended" needs to be removed. 40 C.F.R. §§ 122.62 and 124.5.

Response 4
The word suspended will be removed from the specified part of the Permit.

Comment 5
Permit Part 2.5 contains requirements regarding the change of ownership or control of the facility. Minn. R. 7020.0405 only allows a change of ownership or control of an animal feeding operation or manure storage area through a permit modification. Therefore, Part 2.5 needs to be revised to conform with 40 C.F.R. § 122.63, by requiring that a permit modification request include a written agreement with a specific date for transfer of permit responsibility, coverage, and liability between the current and new permittees.

Response 5
As noted in the comment, the transfer of permit responsibility, coverage, and liability is managed through the MPCA's permit modification process. Through this process, the specific date for transfer of permit responsibility, coverage, and liability are transferred from the current and new permittee at the time coverage under the Permit is issued to the new owner/operator of the facility. Additionally, the Permit stipulates in the *General Conditions* section, "The permit is not transferable to any person without the express written approval of the agency …," and in the *Facility Modifications* section, "if ownership or control changes without an assignment of coverage under this Permit, the original Permittee may still be held liable for violations and the new owner/operator may be held liable for operating without a permit." To ensure the specified federal regulation is satisfied, the MPCA's application for a permit modification will be revised to clarify the specific date for transfer of permit responsibility, coverage, and liability occurs at the time coverage under the Permit is issued to the new owner/operator of the facility.

Comment 6
When manure is transferred, Permit Part 9.4 requires that the permittee provide to the manure recipient, at the time of transfer of ownership, a "Manure Transfer Tracking" form that is generated by the Nutrient Management Tool. This form does not include the date of manure transfer but should. 40 C.F.R. § 122.42(e)(3).

Response 6
The Nutrient Management Tool will be modified to include the date of manure transfer.

Comment 7

Permit Part 10.2 requires the CAFO to use Minnesota's Nutrient Management Tool to develop and maintain the Manure Management Plan (MMP). The Minnesota Nutrient Management Tool does not conform with the following requirements of 40 C.F.R. § 122.42(e)(1) nor does the Permit include specific conditions that conform with these federal requirements. Conditions addressing these federal requirements need to be included in the Permit or the Minnesota Nutrient Management Tool could be updated to include these federal requirements.

Response 7

The Permit will be modified to address the specified federal regulation in the following ways.

Comment 7a

The Permit does not specifically prohibit the disposal of mortalities in storm water storage systems. 40 C.F.R. § 122.42(e)(1)(ii).

Response 7a

The *Requirements for Operation and Maintenance of the Facility* section of the Permit will be modified to prohibit disposal of mortalities in stormwater storage systems.

Comment 7b

The Permit does not specifically require that clean water be diverted, as appropriate, from the production area., 40 C.F.R. § 122.42(e)(1)(iii).

Response 7b

The *Requirements for Operation and Maintenance of the Facility* section of the Permit will be modified to ensure clean water is diverted, as appropriate, from the production area.

Comment 7c

The Permit does not specifically prohibit the disposal of chemicals and other contaminants handled on-site into storm water storage systems. 40 C.F.R. § 122.42(e)(1)(iv).

Response 7c

A requirement will be added to the *Requirements for Operation and Maintenance of the Facility* section of the Permit to prohibit the disposal of chemicals and other contaminants handled on-site into storm water storage systems.

Comment 8

Permit Part 15.1 contains land application setback requirements. Federal regulations require that manure, litter, and process wastewater not be applied closer than 100-foot to any down-gradient surface waters, open tile intake structures, sinkholes, agricultural well heads, or other conduits to surface waters unless a compliance alternative is exercised. Part 15.1 includes setbacks for several land features; however, Part 15.1 does not include a setback for the broader term "other conduits to surface waters" which would ensure setback requirements apply to all conduits to surface waters rather than just those identified in the Permit. 40 C.F.R. § 412.4(c)(5).

Response 8

A requirement will be added to the *Land Application of Manure - Setbacks* section of the Permit to include a 100 ft setback for other conduits to surface waters.

Comment 9

Permit Parts 16.2 and 16.3 require "that the production area is designed, constructed, operated, and maintained to contain all manure, manure-contaminated runoff, or process wastewater, and all direct precipitation" (Emphasis added). To conform with federal regulations, the word "or" needs to be removed from Parts 16.2 and 16.3. Federal regulations require that production areas are designed, constructed, operated and maintained to contain all manure, litter, and process wastewater (Emphasis added). 40 C.F.R. Part 412.

Response 9

The word *or* will be removed from the specified part in the *Requirements for Operation and Maintenance of the Facility* section of the Permit.

Comment 10

Permit Part 26.5 does not conform to the federal requirements because it does not identify an overflow as a discharge. In order to conform with federal regulations, Part 26.5 needs to be revised to read "... unless the discharge is an overflow of manure or process wastewater that is caused by a precipitation event ..." (Emphasis added). 40 C.F.R. Part 412.

Response 10

The specified part in the *Effluent Limitation* section of the Permit will be modified to read "... unless the discharge is an overflow of manure or process wastewater that is caused by a precipitation event ...".

Comment 11

Federal regulations require that each NPDES permit (1) include monitoring requirements to ensure compliance with permit limitations and (2) specify required monitoring including type, intervals, and frequency sufficient to yield data which are representative of the monitored activity. 40 C.F.R. §§ 122.44(i) and 122.48. Permit Part 27.5 requires the permittee to ensure that all discharges, spills, or overflows associated with the facility do not cause or contribute to non-attainment of water quality standards. The Permit needs to require monitoring of discharges, spills, or overflows to ensure compliance with Part 27.5. In order to assess compliance with the reference to water quality standards in Part 27.5, monitoring of discharges to surface waters from a production area for volume, duration, pH, phosphorus, NH3-N, BOD, TSS, dissolved oxygen, and E.coli should be required.

Response 11

A part will be added to the *Discharge, Spills, and Overflows* section of the Permit to require monitoring of discharges to surface waters. The requirement will include actions to obtain grab samples of the discharge within a specified time of discovery, and one sample per day thereafter until the discharge is stopped. The requirement will also include actions to obtain analysis for pH, total nitrogen, ammonia nitrogen, total phosphorus, E. coli, five-day biochemical oxygen demand (BOD5), and total suspended solids. This section of the Permit already includes a requirement to monitor discharge volumes.

Though the MPCA values monitoring and its importance for assessing water quality and determining compliance, the MPCA understands the challenges this requirement presents due to the acute and overland nature of discharges from permitted CAFO in Minnesota. To assist Minnesota and other delegated states, the MPCA requests USEPA to provide guidance documents and training videos on monitoring and sample collection for discharges from CAFOs.

Comment 12

The federal definition of "production area" includes bedding material in the raw materials description, while the definition of "Production Area" in Permit Part 30.47 does not include "bedding materials" in the raw materials description. Part 30.47 definition of "Production Area" needs to be revised to conform with the federal definition. 40 C.F.R. § 122.23(b)(8) and 40 C.F.R. § 412.2(h).

Response 12

The definition of production area will be modified to include "bedding materials" in the raw materials description.

Comment 13

The Standard Conditions of 40 C.F.R. § 122.41 are not incorporated by reference into the Permit. The Permit does not contain the following standard conditions or words used to describe particular conditions do not adequately conform with the following federal standard conditions:

a. Duty to Comply § 122.41(a);
b. Permit Actions § 122.41(f);
c. Duty to Provide Information § 122.41(h);
d. Monitoring and Records § 122.41(j);
e. Signatory Requirement § 122.41(k);
f. Reporting Requirement - Permit Transfers § 122.41(l)(3);
g. Reporting Requirement - Compliance Schedules § 122.41(l)(5);
h. Reporting Requirement - Twenty-Four Hour Reporting § 122.41(l)(6);
i. Reporting Requirement - Other Information § 122.41(l)(8);
j. Reporting Requirement - Identification of the initial recipient for NPDES electronic reporting data § 122.41(l)(9);
k. Bypass § 122.41(m); and
l. Upset § 122.41(n).

Response 13

The Permit will incorporate by reference the specified federal regulations in the *General Conditions* section of the Permit. Additionally, Minnesota's equivalent to the specified federal regulations is found in Minn Rule 7001.0150, subp. 3. These conditions are included in the *General Conditions* section of the Permit.

In addition to the comments included above, EPA included comments identified in Enclosure A of the letter in order to improve the overall Permit .

Enclosure A, Comment 1
It is recommended that the Permit include a requirement to identify, in the MMP, subsurface drain tiles on all fields where manure or process wastewater is land applied, and to require observation of subsurface drain tile outlets prior to, during and following land application of manure or process wastewater for volume/rate of flow and color, turbidity, foam, and odor to identify any discharges that may violate effluent limitations.

Response Enclosure A, Comment 1
The MPCA's Nutrient Management Tool, that will be used by permittees to develop manure management plans, requires the permittee to identify the presence of subsurface drain tile inlets on fields where manure and process wastewater will be applied. This indication will automatically generate, and alert the permittee to, the applicable drain tile inlet requirements from the *Land Application of Manure – Setback* section of the Permit. Additionally, a requirement to monitor field tile inlets at or near land application sites during and after land application events was added to *the Land Application of Manure – Inspections* section of the Permit. Though the MPCA values monitoring and its importance for assessing water quality and determining compliance, requiring observations of subsurface drain tile outlets to identify any discharges that may violate effluent limitations presents challenges in Minnesota. Many tile systems in Minnesota are complex networks that connect to other systems before daylighting, miles downstream of the original system. Due to this complexity, discerning the source of effluent volume/rate of flow and color, turbidity, foam, and odor is very difficult. Minnesota will continue to focus on preventing manure and manure contaminated runoff from entering drain tile intakes through measures such as planning, setbacks, buffers, incorporation of manure, and inspections.

Enclosure A, Comment 2
Permit Part 1.2 authorizes the Permittee to operate the facility in compliance with the requirements of Minn. R. 7020, and Minn R. 7020.2015 prohibits animals from entering waters of the State. The Permit could be improved by including a requirement that specifically prohibits the direct contact of confined animals with waters of the United States. 40 C.F.R. § 122.42(e)(1)(iii).

Response Enclosure A, Comment 2
Minnesota's equivalent to the specified federal regulation is found in Minn. R. 7020.2015. This rule part prohibits animals of a CAFO from entering waters of the state. A requirement will be added to the *Requirements for Operation and Maintenance of the Facility* section of the permit that is consistent with Minn. R. 7020.2015 and the specified federal regulation.

Enclosure A, Comment 3

Federal regulations require that manure, litter, and process wastewater not be applied closer than 100-foot to any down-gradient surface waters, open tile intake structures, sinkholes, agricultural well heads, or other conduits to surface waters unless a compliance alternative is exercised. 40 C.F.R. § 412.4(c)(5)(ii) provides that a CAFO may demonstrate that an alternative conservation practice or field-specific conditions will provide pollutant reductions equivalent or better than the reductions achieved by a 100-foot setback. Permit Parts 15.4 through 15.7 include alternative conservation practices. Permit Part 10.2 requires that the manure management plan developed by a Permittee contain requirements of land application of manure sections of the Permit, this would include Parts 15.4 through 15.7. EPA recommends that the State require Permittees selecting to use one of the alternative conservation practices included in Parts 15.4 through 15.7 include a demonstration in the MMP that the alternative conservation practice implemented on a specific land application area will provide pollutant reductions equivalent or better than the reductions achieved by a 100-foot setback.

Response Enclosure A, Comment 3

During the development of the MPCA's 2006 NPDES general permit, the MPCA conducted a literature review to demonstrate the alternative setbacks listed in the *Land Application of Manure – Setbacks* section of the Permit are equivalent to the reductions achieved by the 100 ft setback of the specified federal regulation for all land application areas in Minnesota. The literature review is recorded in the MPCA's summary document, *Runoff Reductions with Incorporated Manure*. The alternative setbacks have been included in subsequent MPCA NPDES CAFO general permits with the implication the specified federal regulation is satisfied for permittees. To clarify this, the *Land Application of Manure – Setbacks* section of the Permit will be modified to explain the listed setbacks are equivalent to the 100 ft setback of the specified federal regulation.

Enclosure A, Comment 4

If a production area is designed, constructed, operated and maintained consistent with federal regulations, the need for emergency manure application should be rare, if at all. It seems a need should only arise, if at all, at the end of the design storage period of the collection of storage devices (i.e., just before crop harvest in the fall and just before the lifting of winter land application restrictions). Permit Part 30.20 defines Emergency Manure Application, and Permit Parts 13.2 and 13.6 authorize emergency land application. Weather is inherently variable. EPA recommends that the definition of emergency manure application provide further clarification on what constitutes "unusual weather conditions" and expand the definition to include opportunities to manage manure other than storage, i.e., treatment, before emergency manure application is allowed.

Response Enclosure A, Comment 4

Instances of emergency manure application under the specified parts of the Permit are rare. The *Additional Requirements for Operation and Maintenance of Liquid Manure Storage Areas (LMSA)* section of the Permit requires permittees to notify the MPCA within 24 hours of encroachment into the freeboard of liquid manure storage areas. This requirement provides the opportunity for MPCA staff and the permittee to explore alternatives to emergency land application of manure such as transporting manure to a different storage area. The MPCA will continue to rely on communication with permittees to manage instances of emergency manure application in the most protective way possible.

Thank you for the thorough review of Minnesota's Pre-Public Notice Draft Feedlot NPDES General Permit (Permit), fact sheet, and supporting documents. The numerous meetings and frequent communication with your staff were appreciated. The MPCA will provide a copy of the final permit and Minnesota's response to any significant comments received during any public notice period as specified in your May 9, 2024 letter.

Sincerely,

Glenn Skuta

This document has been electronically signed.

Glenn Skuta
Division Director
Watershed Division

GS/LS:rjp

cc: Michael Kuss, EPA R5-WD-Permits (electronic)
Lisa Scheirer, MPCA
George Schwint, MPCA
Randy Hukriede, MPCA
Steve Schmidt, MPCA

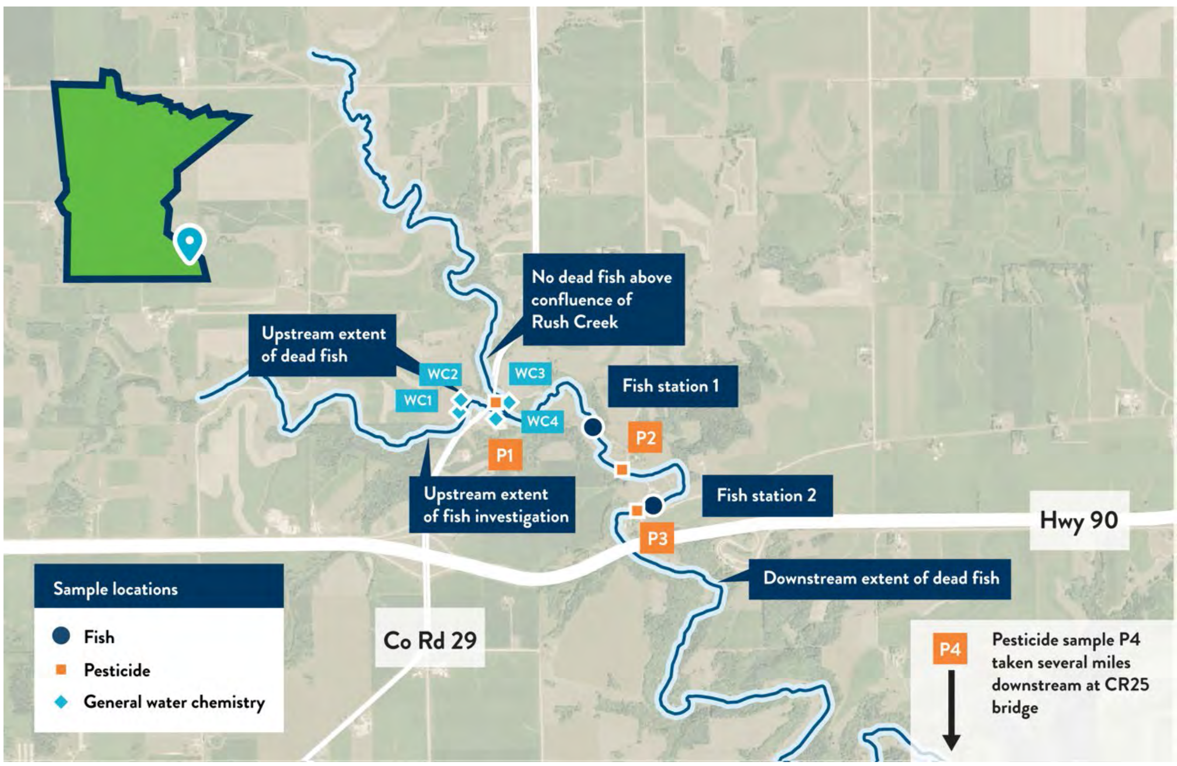
MINNESOTA

Pollution Control Agency | Department of Natural Resources | Department of Agriculture

Rush Creek fish kill response — Winona County

Summary

Rush Creek is a cold-water trout stream that begins just south of the city of Lewiston in Winona County. It flows in a southerly direction into Fillmore County and eventually joins the Root River at the city of Rushford. Rush Creek is highly valued by trout anglers.



Rush Creek investigation map

On the evening of July 25, 2022, the Minnesota Duty Officer (MDO) received a report of several dead fish in Rush Creek. Local staff from the Minnesota Department of Natural Resources (MDNR) and Minnesota Pollution Control Agency (MPCA) began coordinating a response immediately. The field response began the following morning, July 26, and included staff from Winona County, the Minnesota Department of Agriculture (MDA), MDNR, and MPCA.

Fisheries staff from the MDNR estimated that more than 2,500 fish were killed, including at least 1,900 brown trout. The remaining species included white sucker and mottled sculpin. The responding agencies concluded that the fish kill likely happened after a significant runoff-producing local rainfall event on July 23, 2022 (1.5 inches to 2 inches that fell in a short period of time). Several factors may have contributed to the fish kill including warm temperatures, recent upstream applications of manure and pesticides, and low-flow conditions in the creek prior to the rainfall, resulting in limited dilution of the contaminated runoff.

Two branches of Rush Creek converge in the area of the fish kill; one from the north in the direction of Lewiston, the other from the west. Because no dead fish were observed in the branch from the north, it was concluded that the contaminated runoff came from the 10 square-mile area that drains to the western branch. This eliminated from consideration a wastewater discharge from the City of Lewiston.

First report, response, extent, and size of fish kill

Following the report to the Minnesota Duty Officer, local staff from DNR and MPCA began coordinating a response on the evening of July 25, 2022.

On July 26, MDNR Fisheries staff, MPCA feedlot staff and water monitoring staff, MDA pesticide monitoring staff, and Winona County feedlot staff were all on site. MDNR Fisheries staff walked the stream to determine the geographic extent of the fish kill and to document the type, size, and number of fish lost. MPCA and Winona County feedlot staff evaluated livestock facilities and a manure application field in the vicinity of the fish kill and began a broader survey of livestock facilities in the larger upstream drainage area. MPCA and MDA monitoring staff made visual observations, took field measurements, and collected water chemistry samples as well as macroinvertebrates at multiple locations on Rush Creek.

White sucker fish found in Rush Creek

MDNR Fisheries staff determined that the fish kill occurred over two miles of Rush Creek from just upstream of Winona County Road 29 to downstream of Interstate Highway 90. Their survey of 1,050 feet of Rush Creek collected 162 brown trout, 27 white sucker, and 23 mottled sculpin. The estimated total number of fish killed were 2,523 including 1,921 brown trout, 325 white sucker, and 277 mottled sculpin. *For information about fish by location, type, size, and quantity, see Tables 1-3 in the Appendices.*

On the morning of July 27, DNR Fisheries staff noticed after a second, smaller rainfall event, that the western branch of Rush Creek was cloudy and discolored as compared to the branch from the north. Fisheries staff collected water samples for analysis by MPCA and MDA.

In subsequent days, additional investigatory visits were made to the area, including a visit on August 4 that included a stream ecologist from Winona State University accompanying MDNR Fisheries staff surveying aquatic macroinvertebrates in Rush Creek.

Water sample results

MPCA and MDA staff coordinated water quality sampling on July 26 at multiple locations on Rush Creek. The samples were analyzed for 182 different pesticide analytes (including fungicides and insecticides) and 13 different general water chemistry analytes (*see Table 4 in Appendices*) typically measured during fish kills. None of the analytes were detected at elevated levels.

Additional samples were also taken on July 27, after a small rain event. This rain event produced observed runoff and stream response, so a sample was collected to gain information about potential sources that may have still been present in the watershed. Elevated levels of E. coli bacteria (an indicator of manure or sewage) and phosphorus were present in this sample, but the remaining general water quality parameters were not found at elevated levels. Compared to the July 26 sample, some additional pesticides were detected, but not at elevated levels. The results showed organic pollution, which is common for a runoff event in this region. *See Table 5 for pesticide sample results.*

Organic pollution results from the decomposition of living organisms and their by-products. This includes decaying plant material, manure and human sewage, livestock feed, and waste products from the food processing industry. Organic pollution can be directly or indirectly toxic to fish and other aquatic life.

Typically, water quality impacts from fish kill events are difficult to capture unless samples are collected within a short period of time (i.e., ideally within 24 hours). Streams will often fall back to "normal" water chemistry levels very quickly after storms due to constant inflows of new groundwater. By the time water samples were taken on Rush Creek (two to three days after the storm event), the contamination that killed the fish had already moved downstream and/or was significantly diluted, making it difficult to detect in water quality samples.

Aquatic macroinvertebrate sample results

There were two primary purposes for the macroinvertebrate sampling conducted by a stream ecologist from Winona State University and MDNR Fisheries staff. The first purpose was to help understand whether there would be broader or lingering ecological impacts to Rush Creek beyond the fish that died at the end of July. Macroinvertebrates play a key role in a stream's food chain. In simple terms, they eat algae and other organic matter and become food for fish. While fish are highly mobile and can recolonize rapidly, it would take some time for macroinvertebrates to return to an area where they were severely impacted. The second purpose for the sampling was to provide clues to possible causes of the fish kill, as fish and macroinvertebrates have different susceptibilities to pollutants.

The intent of the macroinvertebrate sampling was to assess conditions at multiple locations in the fish kill zone, and to compare these results with a sample from the non-impacted north branch of Rush Creek. There was also a limited opportunity to compare with previous macroinvertebrate sampling on Rush Creek.

The macroinvertebrate sampling results indicate that whatever killed the fish in Rush Creek did not harm the macroinvertebrate community in an appreciable way. A comparison of the macroinvertebrate data collected on Rush Creek above and below the confluence with the South Tributary stream did not show any differences that suggest an impact to the macroinvertebrate community. Similarly, a comparison between the data collected in the South Tributary, to the data collected on the upstream and downstream reaches did not show any discernable differences. There were subtle differences in the data, but not more than would be expected to occur naturally.

Combined with the pesticide water sample results, the lack of impact to the macroinvertebrate community may suggest pesticides were less of a factor in the fish kill as compared to organic pollution.

Feedlot and pesticide use survey results

MPCA and Winona County staff conducted multiple feedlot inspections and in-field land application inspections in the area of the fish kill on July 26, July 27, and Dec 12, as well as a stockpile investigation on Aug 11. These inspections included feedlot facility inspections, review of land-application of manure records, and in-field land-application inspections. Winona County feedlot staff requested land application of manure records from all facilities located within the 10 square-mile watershed in the western branch of Rush Creek. Of the 100 landowners contacted regarding manure application and manure stockpiling activities, Winona County received more than 60 responses. Winona County determined that those who did not respond were not feedlot owners, were small feedlot owners who were not required to maintain land-application records or were small land/feedlot owners whose land did not directly impact the stream (meaning the land was in the watershed, but any run-off from the land would flow overland across others property prior to making it into a Rush Creek).

The inspections and records review showed that two facilities within the watershed had inadequate or incomplete records, as well as setback violations from sinkholes and special protection areas. This resulted in notices of violation issued to these two facilities. However, during the course of the in-field land-application inspections, no evidence of direct discharge to Rush Creek was found. The MDA surveyed property owners in the vicinity of Rush Creek to identify potential pesticide applications in the area. During the MDA's investigation, they identified cropland that had received pesticide applications around the time of the rain event on July 23. After reviewing application records and applicator interviews, the MDA found no label violations associated with these applications.

Fish kill cause: Burst of rain; contaminated runoff; low creek flows

Responding state agencies concluded that contaminated runoff following a significant rainfall event on July 23 likely caused the fish kill. As discussed previously, several factors may have contributed to the fish kill including warm temperatures, recent upstream applications of manure and pesticides, and low-flow conditions in the creek prior to the rainfall, resulting in limited dilution of the contaminated runoff. It is difficult to determine how a mix of contaminants might interact to harm fish. Warm summer temperatures and lower flows may also elevate stream temperatures; this in turn may stress cold-water fish species and make them more susceptible to mortality, although there is no direct evidence that this was the case here.

Infectious disease may also be an important factor associated with fish kills in Minnesota, and opportunistic bacterial pathogens are implicated in multiple freshwater fish mortality events each year. However, infections disease was ruled out as a major contributing factor to the Rush Creek mortality event since standard pathological inspection (including parasite screening, viral and bacterial culture) did not uncover any infectious agents.

Fish community recovery

As we have observed in recent fish kills, fish will continue to return to the section of stream where the kill occurred, but it will take years to replace the larger fish that previously resided in this section of stream. Rush Creek is known for having abundant brown trout, is larger than most area streams, and is over 22 miles long. These are all factors that increase resiliency, but brown trout are a sensitive fish species. A fish kill of this magnitude will certainly disrupt the size structure, species diversity, and numbers of catchable size trout. If pollution events continue, there could be detrimental effects to the entire stream long-term.

Also, despite the apparent resiliency observed in Minnesota driftless-region trout streams so far, large scale mortality events are evidence of severe stressors that are concerning, including the possibility of increased frequency of extreme weather events. Minnesota waters are expected to continue their warming trends and be impacted by increased frequency of severe precipitation events. Thus, it is imperative to identify and work to mitigate stressors associated with large scale mortality events in these vulnerable fisheries.

Next steps

This is the fourth significant trout stream fish kill in this part of southeastern Minnesota since 2015. The other fish kills occurred on the South Fork of the Whitewater River, Garvin Brook, and Trout Valley Creek. Certain common conditions and risk factors have emerged. These include low stream flow, warm air temperature, elevated water temperatures, thunderstorms, and the presence of certain types of pollutants that are susceptible to runoff.

Unauthorized releases and permit violations that lead to fish kills are preventable and unacceptable. To mitigate the fish kill risk, the MPCA, MDNR, and MDA are working to summarize and proactively communicate these risk factors as part of an interagency effort. An emphasis of this communication effort will be on the use of weather and runoff forecasting tools to help plan the timing of manure and pesticide applications. Additional strategies include inspections of livestock facilities, including land application of manure records and field reviews, in areas where fish kills have occurred, and the precise identification of high-risk runoff pathways on agricultural fields in a part of Minnesota characterized by steep slopes and karst topography.

For more information

It is critical for anyone that observes a fish kill to report it immediately to increase the chances of identifying the cause or source for a fish kill. If you see something, contact the MDO at 800-422-0798. If there is an immediate threat to life or property, call 911 first.

There is more information on fish kills in Minnesota on the MPCA website. You can also learn more on the DNR website.

Appendices — Rush Creek fish kill

Table 1. Universal Transverse Mercator (UTMs) of stations on Rush Creek, July 26, 2022. Station 1 and 2 were counting dead fish and fish kill extent is the entire reach dead fish were observed (12,437 ft).

Station	Station length (feet)	Downstream UTMs (easting, northing)	Upstream UTMs (easting, northing)
Fish station 1	536	591071, 4865976	591017, 4866125
Fish station 2	514	591528, 4865304	591670, 4865369
Fish kill extent	12,437	592004, 4864755	590280, 4866074

Table 2. Species and length of dead fish collected in Station 1 and 2 (1,050 ft) on July 26, 2022.

Species	Length category	Number
Brown trout	3-5 inches	33
Brown trout	6-10 inches	112
Brown trout	11-15 inches	15
Brown trout	16-20 inches	2
White sucker	ALL	27
Mottled sculpin	ALL	23
	TOTAL	**212**

Table 3. Estimated numbers of dead fish in Rush Creek (12,437 ft).

Species	Estimated number	% of total
Brown trout	1,921	76%
White sucker	325	13%
Mottled sculpin	277	11%
TOTAL	**2,523**	

Table 4. General Water Chemistry Sample Results

	Water Sample Station			
	WC1	WC2	WC3	WC4
Date	7/26	7/26	7/26	7/27
	all values in mg/l			
Ammonia-N	0.10	<	<	0.06
Unionized ammonia	0.011*	na	na	na
Chloride	25.3	25.7	34.9	23.4
NO2/NO3	<	12.0	8.7	7.9
TSS	490	5.2	10	28
TSVS	100	<	3.2	9.0
TP	2.06	0.068	0.102	0.491
Ortho-P	1.42	0.059	0.089	0.301
TKN	9.07	<	<	1.04
CBOD (5-day)	25.7	0.78	0.99	na
Comments	Standing water near stream; 1L given to MDH for pesticides; some analyses not available	South (west) trib.	North trib.	South (west) trib.; repeat sample by DNR next day after 0.5 inches rain; preserved late.; E. coli out of hold - 24000 MPN/100ml

< = below reporting limit, non-detect
All field parameters (temperature, pH, dissolved oxygen, conductivity) taken were normal on 7/26
*Chronic WQ standard for unionized ammonia for cold-water streams (0.016 mg/L; 16 ug/L)

Table 5. Rush Creek Fish Kill Pesticide Samples

Analyte	P1 - CR 29 South Tributary		P2 - CR 5 North	P3 - CR 5 South	P4 - CR 25	Lowest available aquatic life fish benchmark or MN state standard
All results and reference values are in ng/L						
2022 Dates sampled	**7/26**	**7/27**	**7/26**	**7/26**	**7/26**	
2,4-D	< 8.3	9.15	22.6	16	18.4	79,200
Acetochlor ESA	31.8	162	98.3	96.6	99.5	> 90,000,000
Acetochlor OXA	< 33.3	296	98.6	96.6	< 33.3	No benchmark available
Alachlor ESA	< 41.6	< 41.6	178	165	595	> 52,000,000
Atrazine	32.2	60.7	33.9	< 30	46.4	3,400[†]
Azoxystrobin	< 10	36.7	< 10	< 10	< 10	147,000
Deethylcyanazine Acid	< 25	< 25	< 25	< 25	28.8	No benchmark available
Desethylatrazine	92.9	72.4	97.1	98.9	84.6	1,000,000*
Didealkylatrazine	155	151	206	199	151	> 50,000,000
Hydroxyatrazine	13.7	58.8	29.1	28.1	18.6	> 1,500,000
Metolachlor ESA	455	258	546	504	425	24,000,000
Metolachlor OXA	< 10	36.1	28.4	26.6	16.1	> 46,550,000
Propiconazole	< 10	25.6	< 10	< 10	< 10	15,000
Pydiflumetofen	< 10	49.0	< 10	< 10	< 10	42,000[‡]

† Class 1B, 2A and 2Bd waters; protected for cold water aquatic life and drinking water
* No fish benchmark available; used the non-vascular plant benchmark value for reference
‡ No fish benchmark available; MDA calculated an insect-based value based on toxicity data from the EPA Environmental Fate and Effects Division (EFED)

Frontier: Eating the Metaphorical Elephant: Meeting Nitrogen Reduction Goals in Upper Mississippi River Basin States

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Highlights

- Meeting nutrient reduction goals will be a massive effort with many challenges.
- No one practice or group of practices will meet the goals; a mix of multiple practices is needed.
- Edge-of-field practices become increasingly important as implementation level increases.
- Understanding the scale of the challenge is a necessary step toward meeting the challenge.

Keywords. *Gulf of Mexico, Hypoxia, Nitrate, Nutrient reduction, Subsurface tile drainage.*

The hypoxic zone (dissolved oxygen concentration <2 mg L^{-1}) in the Gulf of Mexico is the world's second largest (Altieri and Diaz, 2019) and is a persistent ecological concern. The Hypoxia Task Force (HTF) plan to reduce the zone's size directed states in the Mississippi River basin (MRB) to develop nutrient reduction strategies (NRS) to reduce nitrogen (N) and phosphorus (P) loads to the gulf by 45% from a baseline period (1980 to 1996). The goal of the reductions is to shrink the five-year average area of the zone to ≤5,000 km^2 (USEPA, 2008). State-level NRS recommend a suite of approaches to reduce N loads from agriculture, including in-field management, land-use change, and edge-of-field practices. However, the scale of implementation needed, along with economic and other barriers, make this a "grand challenge," and progress toward meeting the N reduction goal has been minimal (IDALS, 2020; IEPA, 2021; MPCA, 2020).

To better understand the scale of the challenge, we looked at levels of nutrient-reduction conservation practice (simplified to "conservation practice" or "practice" henceforth) implementation needed to meet the N reduction goal. Iowa, Illinois, and Minnesota are the three upper MRB states that included science assessments as part of their NRS and are estimated to contribute 36% of the delivered N load to the Gulf of Mexico from the MRB (IDALS, 2013; IEPA, 2015; MPCA, 2014; Robertson and Saad, 2021). The states' science assessments and NRS documents were used to quantify the performance of conservation practices and implementation needs to meet the N reduction goal. Nitrogen reductions were estimated for different levels of implementation for: (1) individual in-field management (nutrient management and cover crops), changes in land use, and edge-of-field conservation practices and (2) the stacking or combining of these practices.

Approach

We selected practices consistent across states (fig. 1), grouping them as: (1) in-field management (nutrient management and cover crops), (2) changes in land use (CRP/perennialization and conversion of unprofitable land), and (3) edge-of-field (buffers, saturated buffers, [denitrification] bioreactors, and wetlands). For each conservation practice, we categorized implementation in each state into four increasingly challenging levels: benchmark, low, medium, and high. Benchmark estimates were based on implementation data available from the time the states' NRS were written (2012 or 2013). We used estimates from this timeframe rather than the baseline period (1980 to 1996) because of uniformity of the available information. The high implementation level was set as an estimate of maximum achievable adoption. First, values were taken from NRS documents when possible. If the NRS did not report a maximum value, literature was used to set an upper limit (cover crops and unprofitable land conversion). Finally, professional judgement was used when literature was not available. The low and medium implementation levels were chosen as described in the

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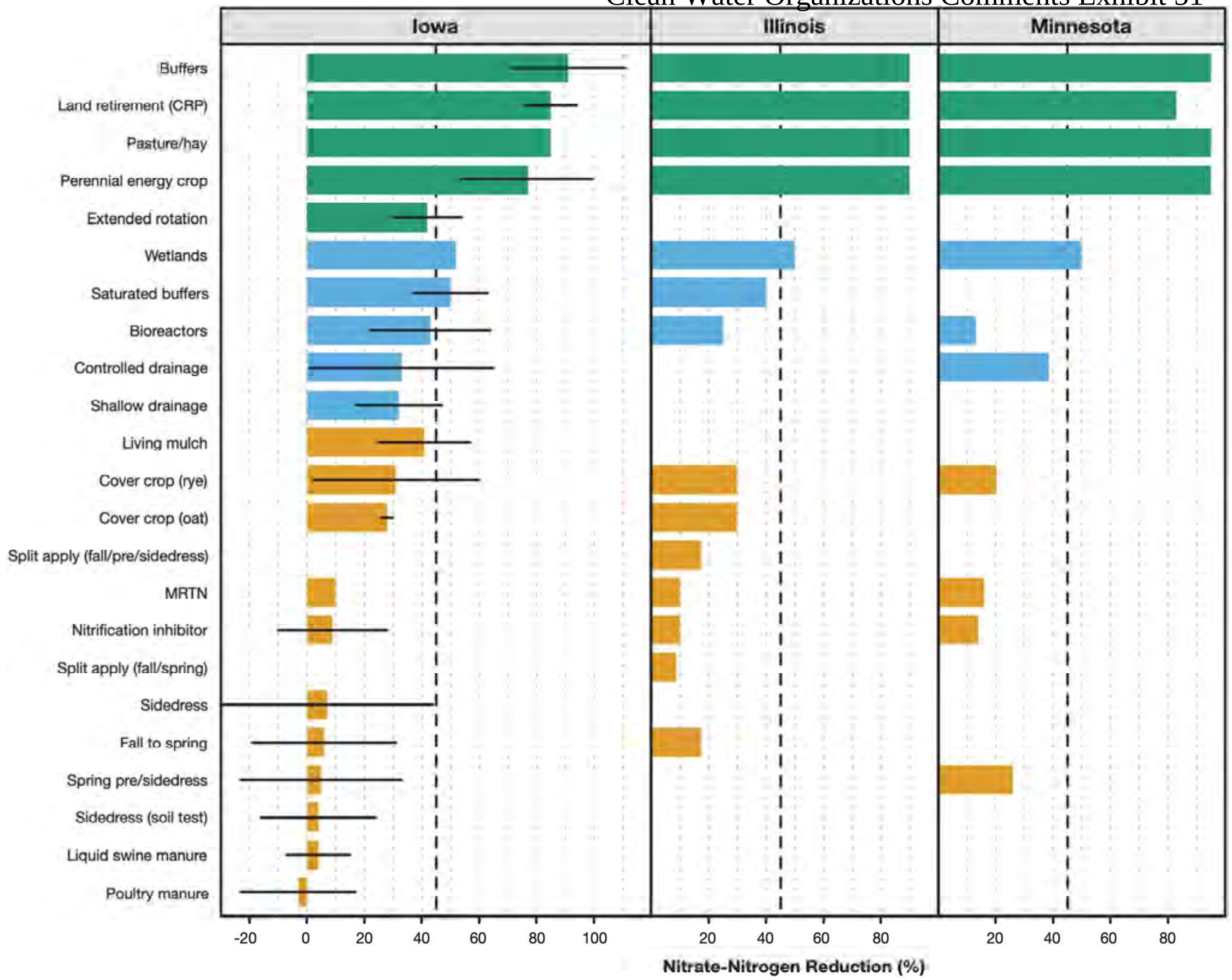

Figure 1. Estimated mean nitrate-N reductions for various in-field management (orange), edge-of-field (blue), and land-use change (green) practices included in the Iowa, Illinois, and Minnesota nutrient reduction strategies (MRTN = maximum return to N rate of fertilization). Error bars for Iowa represent ±1 standard deviation from the mean. Error bars were not available from the Illinois and Minnesota documents.

subsequent discussion of individual practices and are shown in table 1.

Iowa and Illinois developed example scenarios to attain 45% N reductions, whereas Minnesota determined that 45% could be approached but not achieved. The HTF plan goal focuses on total N reduction; however, because nitrate-N is the predominant form of N in water, we refer to nitrate-N reduction henceforth.

Each state used a unique accounting system to determine loads leaving state boundaries. The accounting system may have included distinguishing between source areas (e.g., areas with vs. without tile drainage). Because no effort was made here to recreate the accounting system for each state, relative reductions with respect to the baseline period were used. For example, if a state listed a conservation practice as having a 30% nitrate-N reduction and our analysis called for the practice to be implemented on 50% of the row crop area (defined henceforth as the corn and soybean area), nitrate-N reduction was calculated as 30% × 50% = 15% (fig. 2). Total nitrate-N reductions, as percentages, for each strategy and for each level of implementation were calculated on a state-area-weighted basis. In Minnesota and Illinois, this included only the portion of the state draining to the MRB.

Conservation practice implementation data during the benchmark period were acquired from state-specific reports developed to support HTF efforts (IDALS, 2013; IEPA, 2015; MPCA, 2014). In most cases, benchmark implementation estimates were negligible compared to scenarios outlined by each state necessary to meet HTF goals.

The areas affected by each of the eight individual practices assessed for the low-, medium-, and high-level implementation scenarios are shown in figure 3. Note that the row crop area, the maximum area available for conservation practice implementation, was greatest for Iowa, followed by Illinois and Minnesota, with 9.03, 8.29, and 6.31 million ha, respectively (fig. 3a, "High" column).

In-Field Management

Nitrogen Management

The primary N management practice examined across the three states' NRS was N application rate. Because other fertilizer/manure N management practices provide inconsistent

Table 1. Nitrate-N reduction by conservation practice and state, and area impacted [and nitrate-N reduction] at four levels of implementation (benchmark, low, medium, and high) for individual conservation practices. The bottom segment of the table shows the total nitrate-N reduction, after adjusting for conservation practice stacking, by state and level of implementation, and the area-weighted averages across all three states.

Nitrate-N Reduction by Practice and State[a]	Area Impacted (ha) [and Nitrate-N Reduction] for Each Level of Conservation Practice Implementation			
	Benchmark	Low Level	Medium Level	High Level
In-Field Management				
Nitrogen management		75% of row crop area is at maximum return to N (MRTN)	90% of row crop area is at MRTN	100% of row crop area is at MRTN
Iowa: 10%	2,709,000 [3%]	6,771,000 [8%]	8,126,000 [9%]	9,028,000 [10%]
Illinois: 10%	2,489,000 [3%]	6,223,000 [8%]	7,468,000 [9%]	8,298,000 [10%]
Minnesota: 16%	1,892,000 [5%]	4,729,000 [12%]	5,675,000 [14%]	6,306,000 [16%]
Total	7,090,000 [3%]	17,724,000 [9%]	21,269,000 [10%]	23,632,000 [12%]
Cover crops[b]		No-till area	All area rotating from corn to soybeans	Estimated maximum[c]
Iowa: 31%	154,000 [1%]	2,814,000 [10%]	3,596,000 [12%]	6,862,000 [24%]
Illinois: 30%	129,000 [0%]	2,450,000 [9%]	3,333,000 [12%]	5,062,000 [18%]
Minnesota: 10%	165,000 [0%]	331,000 [1%]	2,772,000 [4%]	2,838,000 [5%]
Total	448,000 [0%]	5,595,000 [7%]	9,701,000 [10%]	14,761,000 [17%]
Land Use				
Perennial conversion (CRP)[d]		Historic high	Increase by 25% over historic high	Increase by 50% over historic high
Iowa: 85%	665,000 [6%]	892,000 [8%]	1,115,000 [11%]	1,338,000 [13%]
Illinois: 90%	417,000 [5%]	440,000 [5%]	550,000 [6%]	660,000 [7%]
Minnesota: 83%	630,000 [8%]	744,000 [10%]	930,000 [12%]	1,115,000 [15%]
Total	1,712,000 [6%]	2,076,000 [7%]	2,595,000 [9%]	3,114,000 [11%]
Conversion of unprofitable land[e]		Convert 30% of unprofitable land	Convert 60% of unprofitable land	Convert 90% of unprofitable land
Iowa: 85%	5,000 [0%]	135,000 [1%]	271,000 [3%]	406,000 [4%]
Illinois: 90%	4,000 [0%]	124,000 [1%]	249,000 [3%]	373,000 [4%]
Minnesota: 83%	3,000 [0%]	95,000 [1%]	189,000 [2%]	284,000 [4%]
Total	12,000 [0%]	354,000 [1%]	709,000 [3%]	1,063,000 [4%]
Edge-of-Field				
Buffers		10% increase over benchmark from NRS maximum minus benchmark	10% increase over benchmark from NRS maximum minus benchmark	NRS maximum[a]
Iowa: 91%	1,000 [0%]	17,000 [0%]	81,000 [1%]	162,000 [2%]
Illinois: 90%	253,000 [3%]	300,000 [3%]	487,000 [5%]	722,000 [8%]
Minnesota: 95%	125,000 [2%]	131,000 [2%]	152,000 [2%]	179,000 [3%]
Total	379,000 [1%]	447,000 [2%]	721,000 [3%]	1,063,000 [4%]
Saturated buffers		10% of estimated maximum	50% of estimated maximum	Estimated maximum[f]
Iowa: 50%[g]	[0%]	109,000 [1%]	547,000 [3%]	1,093,000 [6%]
Illinois: 40%[h]	[0%]	108,000 [1%]	540,000 [3%]	1,080,000 [5%]
Minnesota: 44%[f]	[0%]	30,000 [0%]	151,000 [1%]	303,000 [2%]
Total	[0%]	248,000 [0%]	1,238,000 [2%]	2,476,000 [5%]
Denitrifying bioreactors		10% of NRS maximum	50% of NRS maximum	NRS maximum[a]
Iowa: 43%	[0%]	402,000 [2%]	2,010,000 [10%]	4,020,000 [19%]
Illinois 25%	[0%]	180,000 [1%]	901,000 [3%]	1,802,000 [5%]
Minnesota: 13%	[0%]	16,000 [0%]	79,000 [0%]	158,000 [0%]
Total	[0%]	598,000 [1%]	2,990,000 [5%]	5,980,000 [9%]
Wetlands		10% of NRS maximum	50% of NRS maximum	NRS maximum[a]
Iowa: 52%	0 [0%]	518,000 [3%]	2,590,000 [15%]	5,180,000 [23%]
Illinois: 50%	0 [0%]	126,000 [1%]	631,000 [4%]	1,261,000 [8%]
Minnesota: 50%	0 [0%]	63,000 [1%]	316,000 [3%]	631,000 [5%]
Total	0 [0%]	707,000 [2%]	3,536,000 [8%]	7,072,000 [14%]
Stacked Practices				
Total nitrate-N reduction by state (adjusted for stacking)				
Iowa	[10%]	[31%]	[50%]	[72%]
Illinois	[11%]	[25%]	[36%]	[49%]
Minnesota	[15%]	[22%]	[31%]	[37%]
Total nitrate-N reduction (adjusted for stacking)				
	[12%]	[26%]	[40%]	[55%]

[a] IDALS (2013), IEPA (2015), and MPCA (2014).
[b] USDA-NASS (2012).
[c] Kladivko et al. (2014).
[d] USDA-FSA (2020).
[e] Brandes et al. (2016).
[f] Chandrasoma et al. (2019).
[g] IDALS (2017).
[h] IEPA (2021).

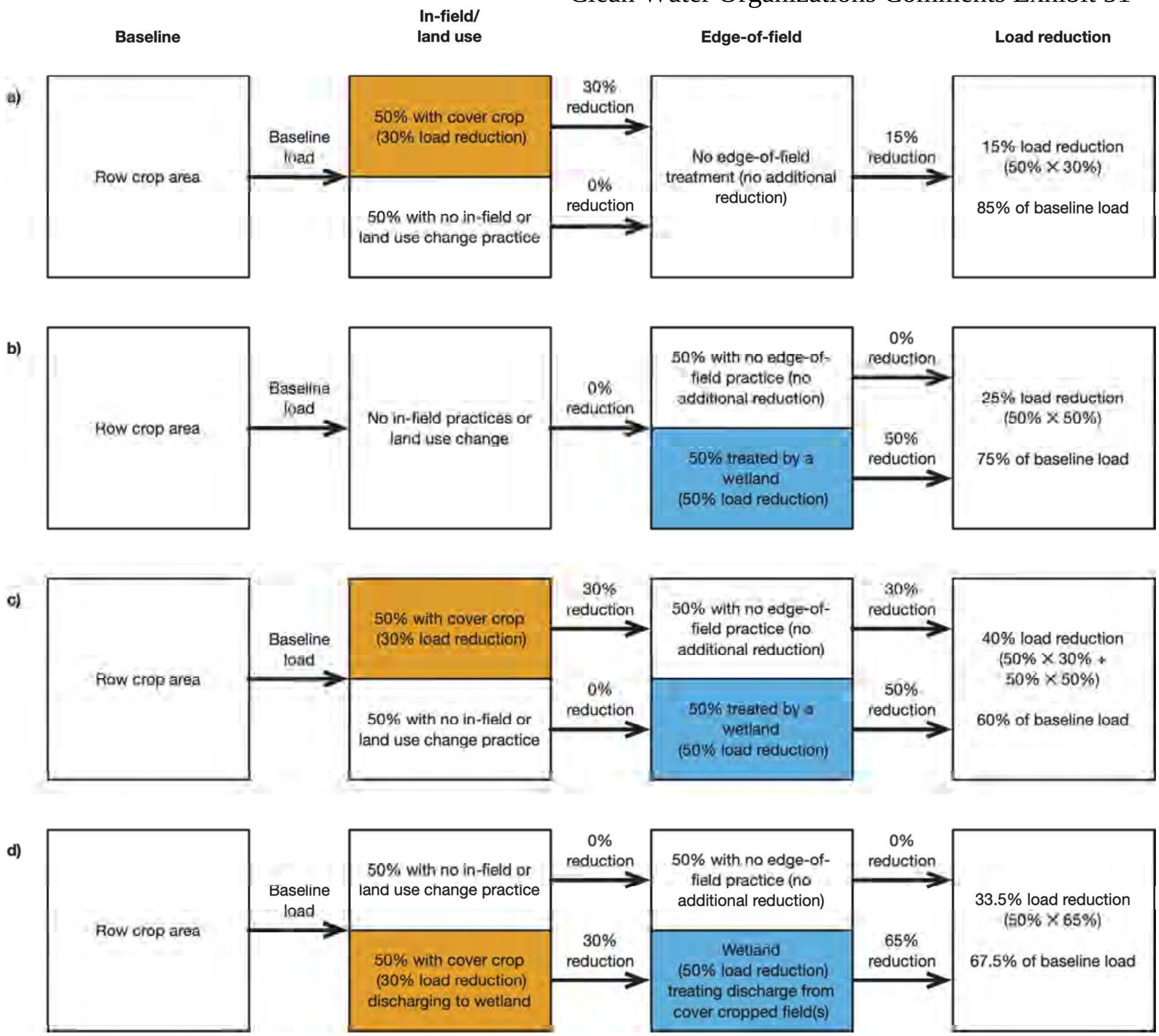

Figure 2. Calculation of N reductions with examples for: (a) individual in-field or land use practices, (b) individual edge-of-field practices, (c) combination of in-field or land-use change and edge-of-field practices on separate land areas, and (d) combination of in-field or land use and edge-of-field practices on the same land area (stacked). For stacked practices (example d), the load reductions are not additive (e.g., not 15% + 25%), and the total load reduction (33.5%) is less than the load reduction from the combined practices with no overlap (example c, 40%) for the same total area because the edge-of-field practice is treating the reduced load from the in-field practice. Example load reductions used (cover crops and wetlands) were from the Illinois NRS.

and low nitrate-N loss reductions (note the error bars in fig. 1 for Iowa) and were not common across the NRS, they were omitted from the analysis. Each state had difficulties assessing benchmark N management implementation due to lack of available data on fertilizer sales and animal units. We assumed that 30% of farmers were applying N at a rate of maximum return to N (MRTN) during the benchmark period (Anderson and Kyveryga, 2016). All states estimated the impact of reducing average N application to the MRTN rate on all areas, which we used as the high implementation level for N management. In Iowa and Illinois, this was estimated to reduce nitrate-N loss by 10%, but the loss reduction was greater in Minnesota (16%), as shown in table 1. Across all states, reducing application rates to MRTN on all areas was estimated to reduce nitrate-N load by 12% (fig. 4a). The low- and medium-level implementation scenarios were estimated to reduce nitrate-N load by 9% and 10%, respectively (fig. 4a).

Cover Crops

Theoretically, cover crops could be implemented on all crop land; however, the added management required to effectively reduce N loss and minimize risk for cash crops, coupled with short growing-season challenges in northern areas, suggest that effective universal implementation is unlikely. To establish the high level of implementation, maximum cover crop area estimates from Kladivko et al. (2014) were extrapolated from the study watersheds to the state level. Based on these assumptions, nearly 14.8 million ha (63% of row crop ha) could host a cover crop in the three-

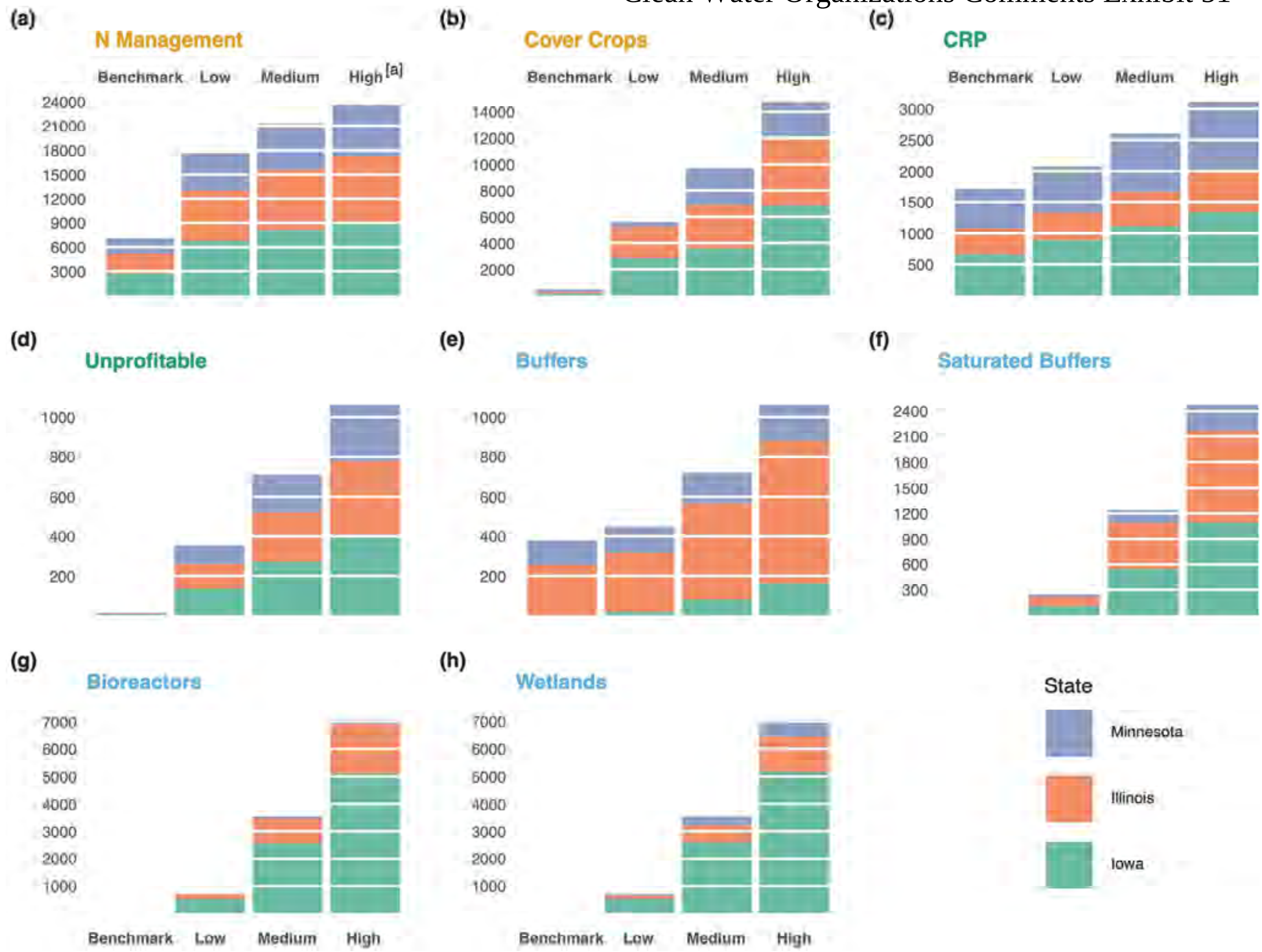

Figure 3. Areas (thousand ha) affected by each of the eight individual practices assessed for benchmark, low-, medium-, and high-level implementation. Practice groupings are denoted by title color: (a-b) in-field, (c-d) land-use change, and (e-h) edge-of-field.
[a] In graph (a), the areas for the "High" column for N management represent the total row crop areas for each state because it was assumed that N management would be implemented on all available row crop areas at the high level.

state region (fig. 3b), with an estimated 17% nitrate-N loss reduction (fig. 4a). The low and medium levels of implementation for cover crops were based on a blend of approaches from the state NRS. The low implementation level was based on no-till farmers adopting cover crops (MCCC, 2021). The medium implementation level was based on planting cover crops after corn harvest transitioning into soybeans (SARE, 2007; Kaspar and Licht, 2019). During the benchmark period, few cover crops were implemented, although accelerated adoption of the practice occurred subsequently (fig. 3b). Because few other in-field practices provided comparably high N reductions, all three states' NRS relied heavily on cover crop implementation to meet water quality goals.

Land Use

Perennial Conversion (CRP)

Land use conversion from row crops to perennial vegetation was consistently among the practices with the greatest nitrate-N loss reductions on a per area basis across the three states' NRS (fig. 1). The year with the greatest Conservation Reserve Program (CRP) enrollment by state (USDA-FSA, 2020) was used as the basis for the low-level implementation, which had origins in two of the states' NRS scenarios. Medium- and high-level implementations for CRP were arbitrarily set as the low implementation level plus 25% and 50%, respectively. The term CRP here includes both land set aside in government programs and land converted to perennial use that would provide similar ecosystem benefits. Starting with historically high CRP acreages (low-level implementation) and expanding beyond that (medium- and high-level implementation) results in potential nitrate-N loss reductions of 7% to 11% (fig. 4b). Implementing the high-level scenario would require substantial increases in CRP funding, new programs and funding mechanisms, or major market shifts to incentivize perennial production.

Conversion of Unprofitable Areas

Our estimate of potential area for the conversion of unprofitable row-cropped land to perennial coverage was based on research in Iowa (Brandes et al., 2016) and the assumption that the relative amount of unprofitable land was similar in each state. Brandes et al. (2016) highlighted that high-risk areas like floodplains tend to be highly unprofitable, losing more than \$250 ha^{-1} $year^{-1}$. At the 2013 peak of the four-year

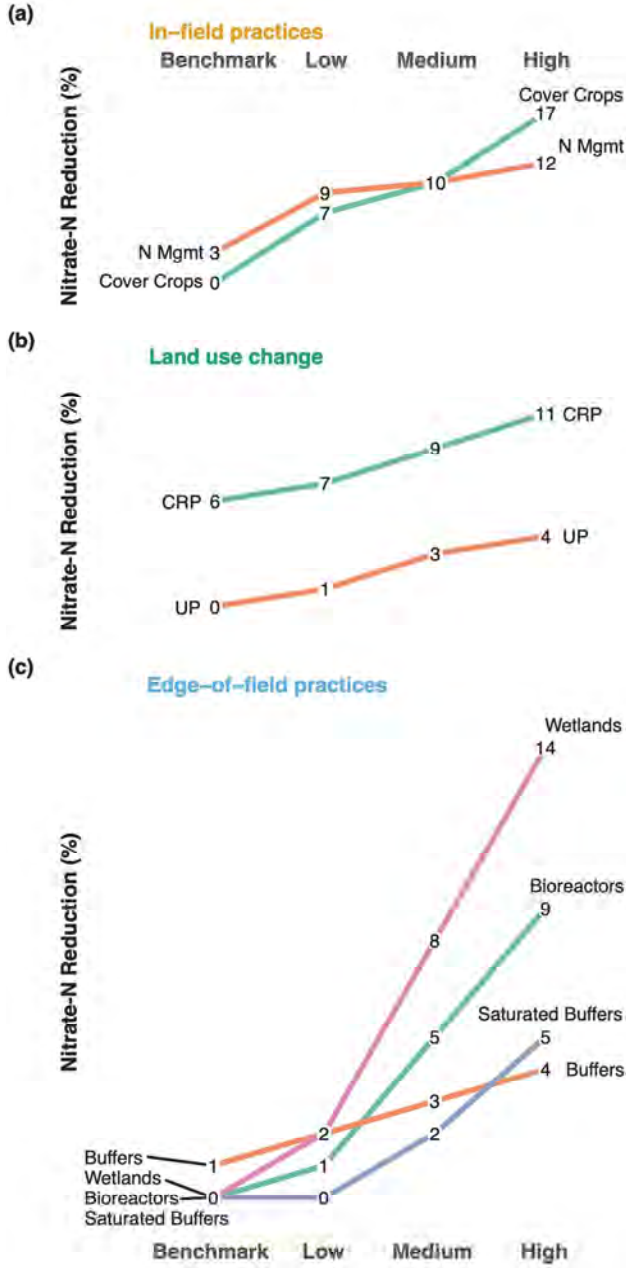

Figure 4. Area-weighted average nitrate-N reductions (%) for Iowa, Illinois, and Minnesota for individual practices, grouped by type, for the benchmark, low, medium, and high levels of implementation.

study, nearly 11% of farmland was considered highly unprofitable in Iowa, with a 2010 to 2013 average of about 3% (range 0.2% to 11%). Due to the dynamic nature of this measure, the authors selected 5% of the row crop area of each state as potentially highly unprofitable. Of that 5%, we assumed that 90% (or 4.5% of row crop area) would be an appropriate high-level implementation target because much of this land could be in small pockets and unsuitable to farm around. Based on high-level implementation of the unprofitable land strategy, we estimated a 4% reduction in nitrate-N losses (fig. 4b). The high-level implementation area represents 1.06 million ha in the three states, which is roughly one-third the area of the high-level implementation of CRP. There are substantial uncertainties associated with the unprofitable land strategy due to the uncontrollable and fluctuating factors of market forces and weather.

Edge-of-Field Practices

For many of the edge-of-field practices, NRS documents listed scenarios highlighting potential statewide implementation, which corresponded to the high-level implementation scenario. These NRS values were used for buffers, bioreactors, and wetlands. Benchmark-level implementation for saturated buffers and bioreactors was set at zero because nearly all installations during this period were research sites. No effort was made here to determine the feasibility of maximums in strategy documentation or state scenarios, although potential overlaps from stacking or combining practices on the same area are addressed below.

Buffers

Buffers (also known as riparian buffers), whether installed or naturally present, are an edge-of-field practice for treating surface runoff, but they also can greatly reduce (~90%) nitrate-N concentrations in water flowing laterally through the root zone (Douglas-Mankin et al., 2021). However, water interacting with the buffer root zone is likely only a small fraction of water generated from the adjacent field, particularly in a tile-drained landscape. Because estimation of the amount of water interacting with the root zone is difficult, each state made some general assumptions to quantify the potential area treated by buffers. Over the three-state region, approximately 1.1 million ha may be influenced by the presence of a buffer, with estimated nitrate-N reductions of approximately 4% for high-level implementation (fig. 4c). After the benchmark period, Minnesota instituted a buffer law that required buffers along all public waters and drainage ditches. Implementation of buffers is estimated at greater than 99% (Tom Gile, MPCA, personal communication) with model-predicted total N reductions of 1.0% to 1.6% (MPCA, 2019).

Saturated Buffers

Saturated buffers are a relatively new edge-of-field practice and thus were not discussed in the states' original NRS. Saturated buffers were added to the Iowa NRS in 2014 and were estimated to have similar performance effectiveness as treatment wetlands. Saturated buffers have lower installation costs and less management than other edge-of-field practices and treat subsurface drainage water that bypasses standard buffers. However, the use of saturated buffers is limited by site suitability constraints. Estimates of the maximum potential extent of saturated buffer deployment were obtained from Chandrasoma et al. (2019). Based on these assumptions, the high-level implementation of saturated buffers across the three states will result in a 5% nitrate-N reduction (fig. 4c). The potential impact is less in Minnesota than in Iowa and Illinois based on the criterion of proximity of crop production to perennial streams (table 1; Chandrasoma et al., 2019; USEPA, 2018).

Bioreactors

Estimated nitrate-N loss reductions using bioreactors for the high-level implementation averaged 9% over the three states (fig. 4c). The estimated results of bioreactor deployment varied more among states than for any other practice: 19%, 5%, and <1% for Iowa, Illinois, and Minnesota, respectively (table 1). Variability was attributed to assumptions regarding the row crop area treated by bioreactors and the nitrate-N load removal effectiveness of bioreactors. Minnesota estimated that 80% of tile-drained land considered suitable for bioreactors or wetlands would be treated by wetlands and 20% by bioreactors. Iowa assumed that all tile-drained row crop area could be treated with bioreactors. In practice, many sites have been deemed unsuitable for bioreactors, incorrectly inflating the potential benefit of this practice in Iowa.

Wetlands

Wetlands are an important practice for nitrate-N reduction from tile-drained row crop land and provide several co-benefits over other practices. The practice was included in all three states' NRS. Wetlands included in this study were those that specifically intercept and treat tile drainage. Each state estimated similar nitrate-N removal performance with wetlands (50% to 52%, within the range found by Messer et al., 2021), but their estimates of the area that could be treated by wetlands differed widely (fig. 3h). The high-level implementation scenario was estimated to reduce nitrate-N by 23%, 8%, and 5% for Iowa, Illinois, and Minnesota, respectively (table 1), which is equivalent to a 14% aggregated area-weighted average (fig. 4c). Aggregated nitrate-N load reductions were 2% and 8% for the low and medium implementation levels, respectively.

Stacked or Combined Practices

The above accounting does not consider potential overlaps of combining, or stacking, multiple practices on a given land area. Stacked practices have overall lower combined nitrate-N reductions than the sum of the individual practice reductions due to competition for N from a given land area. For example, if a field has both an in-field practice (fig. 2a) and an edge-of-field practice (fig. 2b), the reduction from the in-field practice will affect the N entering the edge-of-field practice (fig. 2d; Christianson et al., 2018). Effects of practice overlap were appraised using an N load estimate calculator (https://naturalresources.extension.iastate.edu/water-quality/N-load-estimate-calculator).

Estimated impacts for the land use and in-field management strategies were determined using the methods above, and the outcomes were used as inputs to adjust the edge-of-field strategy results. For example, when CRP/perennial area increased, row crop area decreased correspondingly. After the area was calculated, the nitrate-N load reductions for land-use change and in-field management were recalculated. This resulted in lower nitrate-N loads entering edge-of-field practices with subsequent lowering of the overall nitrate-N reduction potential for the edge-of-field practices. The calculator was set up for each state in hypothetical conventionally tile-drained watersheds with areas apportioned per statewide averages for N management, cover crop use, perennial vegetation, tile drainage, bioreactors, wetlands, buffers, and saturated buffers. Specific state percent reduction factors were consistent with figure 1.

Nitrogen reductions across the states, accounting for potential overlaps of practices stacked on the same area, were 26%, 40%, and 55% for the low, medium, and high levels of implementation, respectively (fig. 5, table 1). At the high implementation level, estimated nitrate-N reductions for Iowa, Illinois, and Minnesota were 72%, 49%, and 37%, respectively. The ratios of stacked nitrate-N reductions (fig. 5) to the sum of individual nitrate-N reductions (fig. 4) were 0.91, 0.82, and 0.74 for the low, medium, and high implementation levels, respectively, demonstrating the competition effect of stacking practices on nitrate-N loss reduction. We assumed that there was no overlap of reductions among the practices for the benchmark level.

Implications

Achieving the HTF goal of 45% reduction in N loading to the Gulf of Mexico will require a combination of the medium and high levels of implementation of in-field management, land-use change, and edge-of-field practices. Despite continuing investments in conservation practice adoption, current implementation remains at the benchmark level or between the benchmark and low implementation levels for any of the practices (IDALS, 2020; IEPA, 2021; MPCA, 2020). Additionally, precipitation amount and intensity in this region are increasing (USGCRP, 2018), and legacy effects are long-lasting (MPCA, 2020; Van Meter and Basu, 2017). Thus, potential progress toward the HTF goal will need to be measured in decades, not years, and results here suggest that multiple conservation strategies and many practices will be needed.

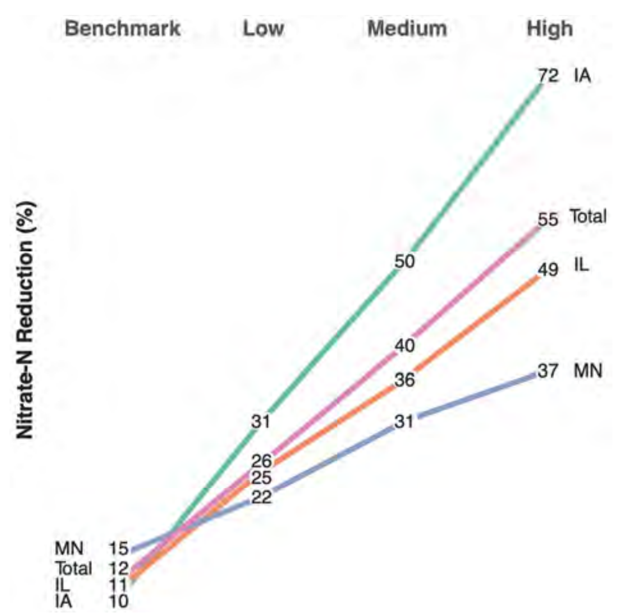

Figure 5. Nitrate-N reductions (%) for Iowa (IA), Illinois (IL), and Minnesota (MN) considering potential overlap of stacking multiple practices on a given land area. Data are shown for each state and the area-weighted average of all states (Total) for the benchmark, low, medium, and high levels of implementation.

Combined N reductions for high-level implementation of in-field management and land-use changes fell short of the 45% goal, even without accounting for overlaps of stacking practices in the same area. The importance of edge-of-field practices was evident as the implementation level increased. The ratio of reductions for the sum of edge-of-field practices to the sum of in-field management plus land-use change practices increased as the level of implementation increased from low to medium to high: 0.18, 0.50, and 0.72, respectively. Our findings that edge-of-field practices need to play a key role in meeting nutrient loss challenges is consistent with the assertion of others that "tackling nutrient loss challenges within the field is not enough" and that "stewardship practices at the edges of farm fields represent a crucial, but underutilized, conservation opportunity" (TNC, 2021).

Each state applied different assumptions when creating its respective NRS. Iowa emphasized cover crops and edge-of-field practices; Illinois emphasized cover crops, nutrient management, and buffers; and Minnesota emphasized land-use change and cover crops (fig. 3). The assumptions were applied with little consideration for overlapping practices. For example, the Iowa NRS does not mutually exclude areas from treatment by both wetlands and bioreactors, creating potential accounting overlap in edge-of-field practices. These scenarios require increased scrutiny and care in accounting. Further north than Iowa and Illinois, Minnesota carries a disadvantage with a shorter growing window for cover crops and lower temperatures for practices that depend on denitrification (e.g., bioreactors and saturated buffers).

Results from this work are consistent with what has been reported by others, i.e., reaching the goal of a 45% N reduction will require numerous combined practices at many locations (Zimmerman et al., 2019; McLellan et al., 2015). In particular, McLellan et al. (2015) found that the use of improved fertilizer management and cover crops would not meet the targeted 45% N load reduction. These researchers (McLellan et al., 2015) highlighted the need to tailor or target conservation practice implementation to local conditions and needs for maximum N load reduction benefit.

Challenges

Increasing precipitation trends will challenge N reduction efforts. Climate shifts have likely countered conservation efforts to mitigate hypoxia (Altieri and Diaz, 2019), and recent modeling has predicted that N loads need to be lowered by 59% to meet the HTF goal (Scavia et al., 2017). Climate projections in the three states indicate increasing precipitation in the winter and spring (USGCRP, 2018). This increase in precipitation immediately prior to or during spring (with its limited vegetative growth) could exacerbate N losses and may require greater practice implementation than noted herein. Additionally, the increase in the number of "mega rains" (storms of >15 cm depth over an area >2,600 km^2; MPCA, 2020) may overshadow gains from conservation practice deployment.

In addition to climate challenges, the impact of time lags on the realization of conservation practice benefits introduces uncertainty in demonstrating results and measuring progress. Time lags are a function of hydrologic travel times and release of accumulated N in the system. Of the former, much has been written, with travel times reported from one to several decades (Schilling and Wolter, 2007; Ilampooranan et al., 2019). Recently, research on biogeochemical time lags has received more focus with an estimated time of a few decades to deplete legacy N to sustainable and acceptable nitrate concentrations after N inputs have ceased (Fenton et al., 2017).

To date, the practices that effect nitrate-N removal also carry inherent risks. In certain years, the MRTN rate will jeopardize yields. Early adopters of cover crops were often highly motivated to ensure the practice was successful. There is a risk that, as a wider audience is incentivized to plant cover crops, the achieved N reductions will be less and primary crop yields will be negatively affected. Setting aside land (CRP and unprofitable land strategy) carries the risk that future events (e.g., market changes) will incentivize producers to convert area back into row crop production. Left unmanaged, edge-of-field practices will lose effectiveness over time. Lack of confidence that a practice will perform as expected can be a barrier to acceptance. Approaches that include development of all three existing reduction strategy categories (i.e., in-field management, land-use change, and edge-of-field) would balance these various risks.

Achieving greater levels of practice implementation challenges the capacity of support systems. For example, seeding and managing 9.7 to 14.8 million ha of cover crops (medium to high implementation scenarios) will require greatly expanded cover crop seed production and handling and custom applicators who can provide seeding and termination services. For edge-of-field practices, meeting the medium and high implementation levels by 2035, the target date for the HTF goal, would require completing from one practice every two days (medium) to one every day (high) of an assumed 150-working-day construction season in each of the 265 counties of the MRB in the three states based on typical treated drainage areas. Each project would require a contractor and crew, a design engineer and support staff, local conservation staff, and administrative staff for programmatic and financial support, as well as the supplies and equipment (e.g., water control structures and woodchips for bioreactors). Our analysis does not account for resource capacities needed to carry out implementation at a regional scale.

We have also not addressed the indisputable economic difficulties in executing even the low level of implementation. The states have proposed costs associated with their NRS (IDALS, 2013; IEPA, 2015; MPCA, 2014). We used these costs, without judgment as to how they were developed or what additional costs would be incurred (e.g., indirect costs for technical assistance, practice design, or program administration) to arrive at the following assessment. Annual cost estimates of implementation scenarios ranged from a low of $51 million in Minnesota to a high of $1.2 billion in Iowa. Summing annual costs for all three states results in estimates ranging from $955 million to $2.2 billion ($40 to $93 ha^{-1} year^{-1}). This range compares to an estimated infinite-life annual land value of $19.2 billion for the three states using average per area land costs (USDA-NASS, 2020) and a 5% discount rate. As presented here, conservation practice implementation would represent between 5% and 12% of land value.

The cost frameworks and trade-offs vary for the different types of practices. Reducing N fertilization rate and taking unprofitable land out of production can potentially be advantageous economically. However, most of the strategies require monetary inputs that are not offset by increased agricultural output. For example, converting row crop land to perennials will often carry an opportunity loss cost. In-field practices require annual renewal with associated annual costs. Edge-of-field practices tend to have higher upfront costs but lower cost per mass of N removed (Christianson et al., 2013, 2018; Jaynes and Isenhart, 2019). The cost of maintaining practices and converted land also needs to be included in economic analyses. Given the magnitude of the need and the unlikelihood that federal and state budgets will expand to provide the financial resources required, it is unlikely that cost-share alone will meet the need. Emerging ecosystem service markets offer another potential approach to incentivize practice implementation.

Research efforts need to increase understanding of the effectiveness and potential of practices, how to optimize them, and how to increase their acceptance and adoption rates. Multi-objective optimization of levels of practice implementation is needed to answer questions about what combinations of practices are most affordable and provide the greatest environmental benefit. Understanding the human dimension of conservation planning and decision making is critical to realizing the potential benefits determined by physical research and modeling, and we encourage additional multi-disciplinary research to further understand how benefits can be achieved. Support for long-term research is critical to evaluating practice performance and maintenance needs under varying environmental conditions over time (Tomer et al., 2014). Additionally, there are large gaps in knowledge regarding the impact of stacking multiple practices on a given area.

Headway is being made on several practices (e.g., Christianson et al., 2021a; Douglas-Mankin et al., 2021; Liu et al., 2021; Messer et al., 2021) and on adjusting the dominant cropping system to support environmentally sustainable agricultural intensification. Beneficial advances continue in precision N management (Jin et al., 2019). Excellent work is progressing in the use of cover crops, although climate limitations exist (Christianson et al., 2021b). Living mulch systems that provide environmental benefits of perennials yet permit corn-soybean row cropping are a promising development (Moore et al., 2019). Drainage water recycling is an emerging practice that provides production benefits as well as downstream N reduction and increases landscape water storage (Hay et al., 2021).

While the current assessment focused on practices implemented primarily within a corn-soybean cropping system, diverse crop rotations in which growing vegetation remains on the land a greater percentage of the year have substantial potential for reducing nitrate-N loss (Koropeckyj-Cox et al., 2021). However, for these systems to be implemented, there needs to be a demand for their various products, whether they be small grains, oilseeds, perennials, and/or forage. Future work should continue to examine how new systems can be implemented and if there are opportunities to reimagine rural landscapes to provide broad environmental services and increased economic sustainability.

Speculation of how future advancements may change the nitrate-N loss situation is highly uncertain. However, history holds examples of advancements that ameliorate problems. Revolutionary changes are difficult to predict, but potential developments include new markets for perennial crops, development of high-production perennial grains or N-fixing maize, more landscape water storage, re-envisioned landscapes with cascading water and nutrient flows, and revolutionary treatment practices. Artificial lighting and plant breeding advancements are revolutionizing indoor production of vegetables and high-value crops (Eigenbrod and Gruda, 2015). It seems unlikely that this revolution could impact land use at the large scale; however, the systems can inform us about water and nutrient recycling and low-environmental-release food production.

Conclusions

Meeting nutrient reduction goals to reduce the hypoxic zone in the Gulf of Mexico will be a massive effort. We have shown that no one practice or strategy will meet the goals and that multiple strategies and practices with widespread adoption are required. Pernicious issues and barriers to implementation demand pressing forward in search of environmental and economic solutions for existing practices as well as revolutionary advancements. The scale of the effort, without other revolutionary changes, includes changes to in-field management for all or nearly all row crop areas, marked increases in perennial land use, and other conservation practices implemented across a majority of row crop acres. Understanding the scale of the N reduction challenge is a necessary step toward meeting it.

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NOMENCLATURE

CRP = Conservation Reserve Program
FSA = Farm Service Agency
HTF = Hypoxia Task Force
IDALS = Iowa Department of Agriculture and Land Stewardship
IEPA = Illinois Department of Environmental Protection
MCCC = Midwest Cover Crop Council
MPCA = Minnesota Pollution Control Agency
MRB = Mississippi River basin
MRTN = Maximum return to nitrogen (rate of nitrogen fertilization)
NRS = Nutrient reduction strategy
SARE = Sustainable Agriculture Research and Education
TNC = The Nature Conservancy
USGCRP = U.S. Global Change Research Program