Manure Storage Sealing

Final Report - Project #01/37

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Introduction

There is a lack of knowledge on the ability of standard concrete floors to adequately prevent leaking of livestock manure. Previous assumptions suggested that the dry matter in the manure would adequately seal any normal cracking (caused by temperature changes or other stress) that form in a non-reinforced floor. A literature search done by Fleming et al. (1999) found that very little work had been done in this area, and there was insufficient data to ensure that these assumptions are valid. With the popularity of slatted floor barns (with storage under the barn), this issue is very important. There have been recent cases of barn systems that have been found to leak, resulting in contamination of drainage tiles below the barns. In these situations, it is currently believed that connections of under-barn drains are the culprit. A recent screening study funded by Ontario Pork raised questions about the integrity of the seal in existing concrete manure storages. Follow-up investigations are ongoing.

The current concrete construction standard includes non-reinforced concrete floors and non-lined liquid manure tanks. Cracks in concrete are quite common, but the size is generally so small that no leaks occur. Cracks may be caused by a few factors, including stresses related to temperature differentials during the curing process. However, the main cause of cracks is shrinkage caused as excess moisture is lost from fresh concrete. The size of cracks varies and most hairline cracks have no influence on the structural integrity of the wall or floor, especially in reinforced concrete. Although not typically used in manure storage construction, standards exist for average design crack widths in reinforced concrete. For example, the American Concrete Institute committee on concrete cracking (ACI Committee 224) refers to these as “tolerable crack widths”, and for water-retaining structures (the most stringent standard), the allowable width is 0.10 mm (0.004 inches) (Concretenetwork.com 2000).

A few producers in Ontario have invested in under-floor liners, to reduce risks of possible leaks. An alternate method to reduce risks of leaking might be to use reinforced concrete. Of course, both alternatives would involve extra capital cost to the livestock operation.

Objectives

The project was designed to test the assumption that small cracks in concrete tanks, if they do develop, will self-seal. The project consisted of two parts - one carried out at the “lab” scale and the other carried out at a farm. We started into the project with the fear that if this work was not completed, then it would not likely be possible to use this sealing assumption to allow non-reinforced floors to be used in unlined liquid manure storage systems. Specific objectives that were originally set :

1. To investigate the potential for a newly-installed concrete tank floor to leak.
2. To measure the ability of manure (under pressure) to self-seal small openings.

Project Description

This study was carried out in two parts - Part A was a field investigation involving a commercial barn; Part B was a laboratory study.

Part A - Field Study

The farm-based study was initiated in November of 2001 on a farm in southwestern Ontario. The study was located at a new barn constructed in the fall and winter of 2001-2002, built to house 2400 nursery (aka "weaner") pigs and 2100 finishing pigs. The barn had an impervious liner beneath the concrete storages to prevent any potential leakage from leaching into the surrounding soil and ground water. The general layout of the barn is shown in Figure 1.

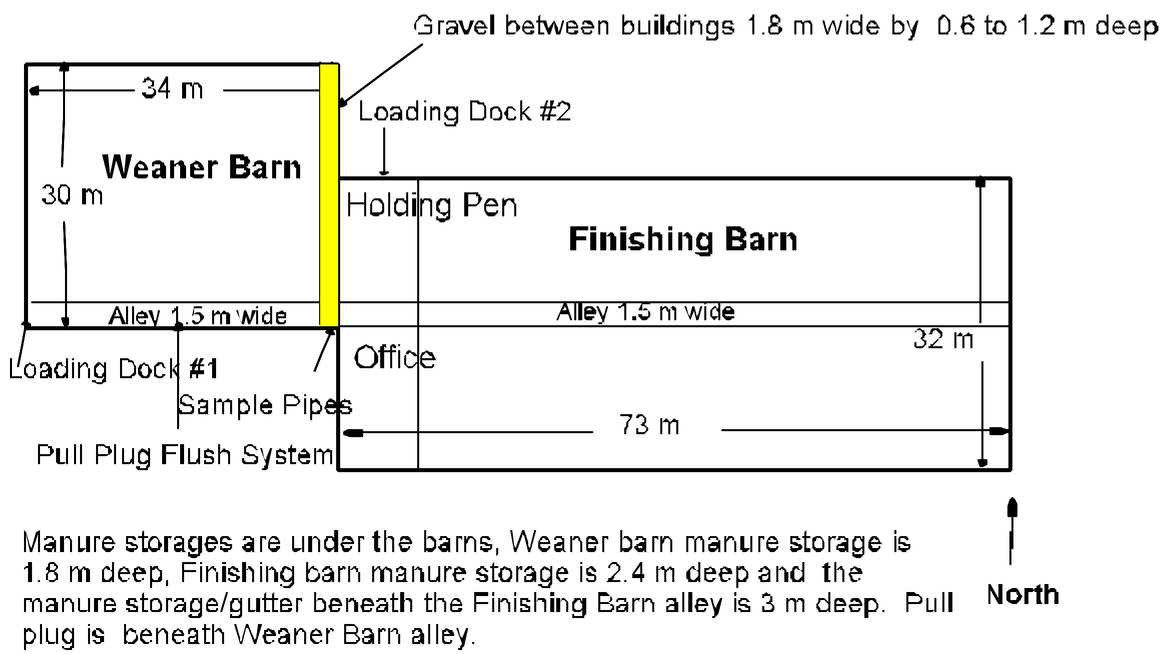

Figure 1 Top view of barn, showing manure storages

A monitoring system was installed on November 15, 2001, to capture leachate. This was installed in conjunction with the “pull plug” manure transfer system beneath the nursery barn but would also capture any leaks in the concrete beneath the nursery barn and finishing barn manure storages. The monitoring system was located beneath the pull plug system and the concrete manure storage floor, and on top of the impervious liner. The pull plug system flushed into a large gutter under the finishing barn, adjacent to the nursery barn. The difference in floor elevation between the weaner barn and finishing barn is shown in Figures 2 and 3.

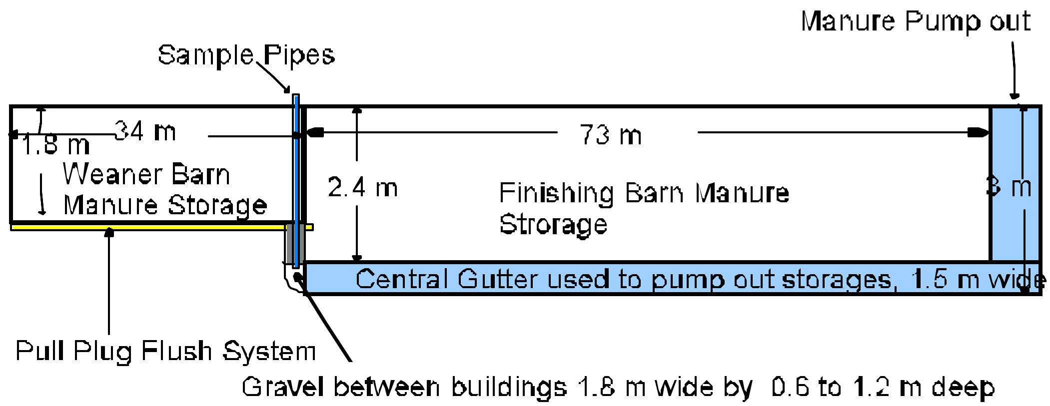

Figure 2 Side view of manure storages, facing North

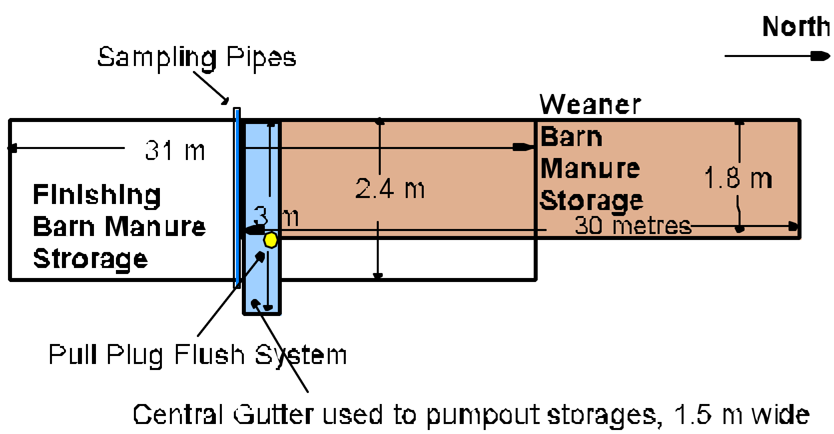

Figure 3 End view of manure storages, facing West, showing storage depths and sample pipe location

The monitoring system consisted of a series of three sampling tubes. One tube made of perforated PVC conduit (51 mm diameter), had a nylon filter sock pulled over the entire perforated tube and was placed directly beside the pull plug system (6.1 m of perforated pipe). The pipes were laid in a sand bed, on top of the liner but about 305 mm below the rest of the manure storage grade and the concrete floor.

Figure 4 Floor of weaner barn manure storage, showing liner, before installation of pull plug transfer system.

Figures 4, 5, 6 and 7 show the construction of the “pull plug” manure transfer system used for the weaner barn and the installation of the sample pipes. Sample pipe P1 was routed down into a gravel bed between the nursery barn and the finishing barn, about 625 mm below the manure storage grade. This gravel bed was on top of the liner, that dipped from the grade beneath the nursery barn to beneath the finishing barn manure storage, a drop of about 625 mm. It was expected this sampling pipe would pick up any liquid that leaked from the pull plug system.

The other two sampling tubes were 38 mm PVC pipe, 3.7 metres long, with a 305 mm long slotted screen at the bottom of the pipe. They were placed into the gravel bed about 625 mm below the concrete floor of the nursery barn manure storage, and 320 mm below the level of the pull plug system. These two sampling pipes were expected to pick up any liquid leaking from the pull plug system that was missed by the perforated pipe, and also pick up any liquid from any cracks that may form in the concrete of either the weaner barn or finishing barn manure storages.

Figure 5 Sampling pipe in trench next to pull plug transfer pipe

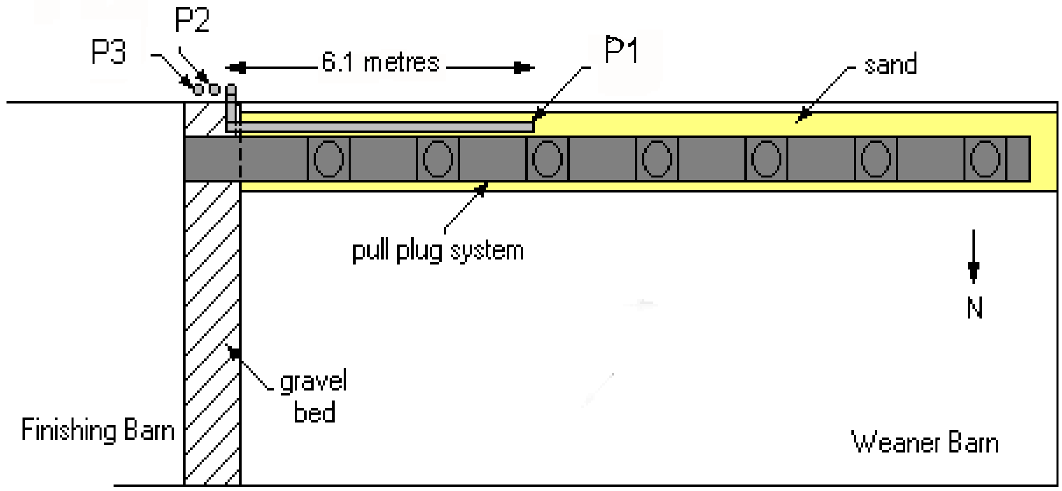

Figure 6 Top view showing locations of sample pipes P1 (in the sand along the transfer pipe), P2 and P3 (in the gravel between the finisher and weaner barns.

The farm was visited during construction to confirm that the manure storages were construction to reduce the risk of leaking. Proper joints were used between the floor and the walls and steel reinforcement was used in the walls. The impervious liner was inspected prior to the installation of the concrete floor. The pull plug system was also inspected during construction to confirm that suitable materials were used, all seals were in place and joints were tight. The site was again visited following the completion of construction, starting January 24, 2002 when some leachate was discovered in the gravel bed where the sample pipes were installed. This was likely from the wet weather experienced during construction in the fall, with some water trapped in the gravel bed, above the liner. Background levels of nutrients and bacteria were measured then to give values before pigs were put in the barn. The sample pipes were pumped dry February 19, 2002 with 33 litres of leachate removed.

The site was visited bi-weekly starting February 19, 2002 with visits March 6, March 20, April 4, April 15, May 8 and May 29. Initially the manure storages had 30 cm of water pumped into them to make it easier to flush solids from the barn.

Farm visits were made throughout the rest of 2002 on June 26, July 25, September 9, October 11, when spreading the manure from the barn was started, and November 27 with the last of the manure spread. Visits were completed in 2003, as discussed later.

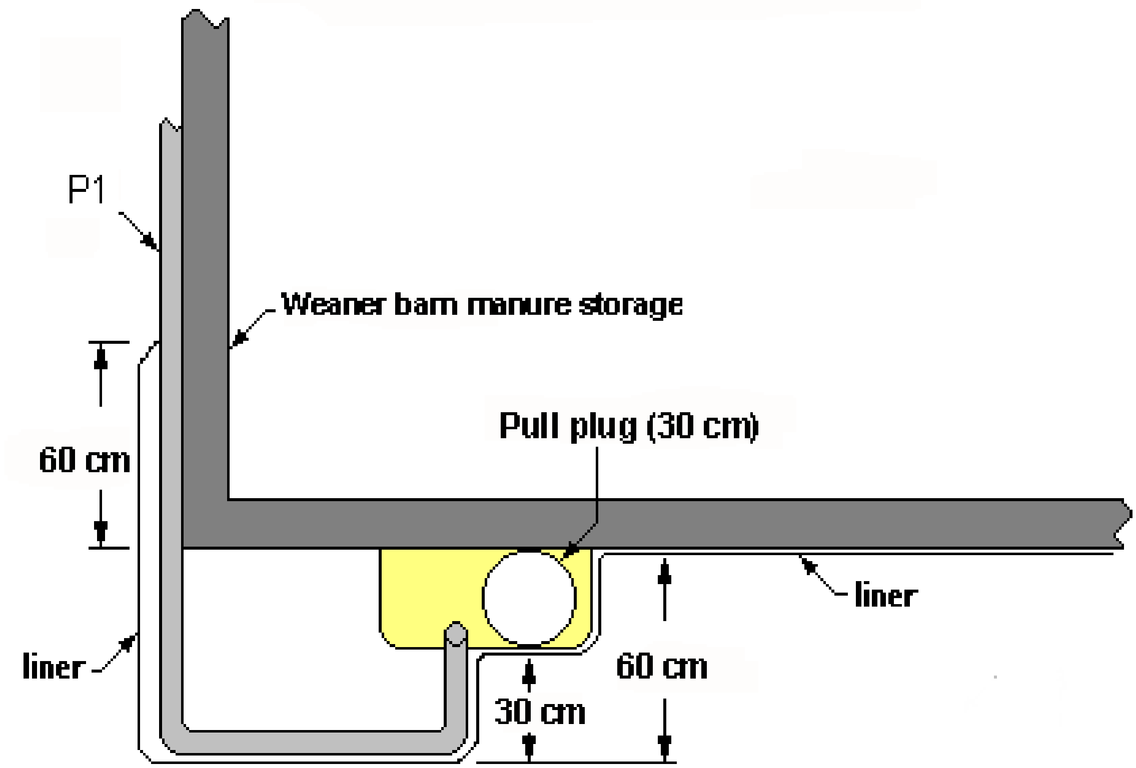

Figure 7 Cross-section showing details of sample pipe P1 installation

Part B - Lab Study

To test the sealing ability of manure under pressure (i.e. under conditions similar to a manure storage where there is a hydraulic head), a system was designed to run several tests. It was set up at Ridgetown College in the summer of 2001. The setup consisted of 18 pipes - nine 102 mm diameter PVC pipes, 1.2 metres long, and nine 102 mm PVC pipes 2.4 metres long. Each pipe had a slotted screen installed on the bottom. The slotted screen was fused to the bottom of the pipes using solvent and a coupler joint. An end cap was fused to the bottom of the screened section. The length of the screened section depended on the size of slotted screen opening. There were three different slotted screen sizes tested: 0.254 mm, 0.508 mm and 0.762 mm. These were based on Imperial dimensions of 0.01 inches, 0.02 inches and 0.03 inches - referred to by the industry as 10, 20 and 30 mil slots. Information on the length of slotted sections and area of slots is found in Table 1.

Table 1 Slot sizes and lengths for the pipes used in the test setup

slot size (mil)	slot size (mm)	pipe length (m)	length of slotted section (mm)	area of slotted opening (mm^2)
10	0.254	1.2	240	3658
10	0.254	2.4	240	2341
20	0.508	1.2	120	4389
20	0.508	2.4	120	4389
30	0.762	1.2	80	3487
30	0.762	2.4	80	3487

The slot sizes were not selected to correspond to typical concrete crack widths. They were instead selected to correspond to commercially available pipes (slot sizes are available in the range from 10 to 125 mil) and to ensure that they were larger than concrete cracks.

The setup is shown in Figure 8, and a close-up of one of the slotted pipe sections is shown in Figure 9.

Figure 8 Test setup, showing racks to hold pipes, pipes of 2 lengths and slotted end sections

Figure 9 Closeup of one of the pipes following partial manure sealing

Racks were built to suspend the pipes upright about 30 cm above the floor. In total, there were 18 pipes used per cycle tested, with three groups of three pipes for each of the two pipe lengths. This gave three reps for each test. The complete test was then run several times, each time using a manure having a different dry matter content.

Variables:

1) Three different screen sizes to represent large cracks in a concrete floor
   - a) #10 - 0.254 mm
   - b) #20 - 0.508 mm
   - c) #30 - 0.762 mm.

2) Manures representing a range of dry matter contents (nine tests were run), including the following target types and dry matters:
   - a) swine manure having a dry matter content of about 1%
   - b) swine manure having a dry matter content of about 3%
   - c) swine manure having a dry matter content of about 5%
   - d) dairy manure having a dry matter content of about 5%

3) Two depths of manure
   - a) 2.4 metres
   - b) 1.2 metres

Pre-testing was first carried out to fine-tune the test procedure and ensure sizes of slots, filling method, sample intervals, etc, were appropriate.. The first pre-test run was made on August 22, 2001, and another was made on August 28, using liquid hog manure. Prior to running the test, pipes were calibrated with water to see how quickly water flowed from each pipe and slot size. The pipes were suspended from the racks inside a building to remove any potential influence of weather. Large garbage pails were placed beneath the pipes to collect manure that leaked from them.

The various types of liquid manure were delivered to a nearby concrete manure storage. The manure came from nearby farms and the sources were the same for 2002 as those used in 2001 (even though the dry matter content varied from fall to spring in some cases). All of the manure came from tanks that were covered to prevent rainwater from entering them.

Manure used for test #1 and test #6 were both from a hog finishing barn located on the college campus. The pens are typically washed down more often than would be the case on a farm. The manure in 2001 was 2.49% DM and in 2002, it was 0.37% DM. In 2002 the barns had just been washed prior to collecting the manure for the test, thus the manure was very dilute.

Manure used for test #2 and test # 7 came from a farm with a slatted floor hog finishing barn, using dry feeders and water nipples. Washing is done when the pens are emptied of pigs and before a new group is brought in. The manure DM levels were 2.59% for 2001 and 4.81% for 2002.

Manure used for tests #3, #5 and #8 were from a farm with a slatted floor hog finishing barn, using dry feeders and water nipples. Washing is done when the pens are emptied of pigs and before a new group is brought in. The manure DM levels were 3.95%, 2.5% and 1.02% for the three tests. The lower DM for test #5 was due to rain water draining into the holding tank at the college. Test #8 had a low dry matter level since the barn had just been emptied of pigs and washed prior to collecting the manure for the test.

Manure used for test #4 and test #9 was from a liquid dairy manure transfer tank. The manure is from a loose housing heifer barn and a dairy barn with tie stalls. Manure is scraped from the gutter in the tie stall area using a gutter cleaner and from the alley in the heifer barn using an automated alley scraper. The cattle are bedded with straw and wood shavings, thus some bedding is included in the liquid manure. The transfer tank agitator/chopper was run before the manure was collected for the test. The manure dry matter levels were 3.74% for 2001 and 2.55% for 2002. The manure used in 2002 contained more flush water. This manure was carried by pails and dumped into the pipes since the pumps could not handle the coarse solids in the manure.

With the exception of tests #4 and #9 (mentioned above), the pipes were initially filled using a submersible sewage pump with a flexible hose and ball valve. This quickly filled the pipes with manure, thus maintaining the desired depth of liquid (not possible using a pail) over the slotted screens. The pipes were filled in sequence starting at the 1.2 m long pipes with the #10 slots followed by the 2.4 m tall pipes. The same sequence was then followed for the pipes with the #20 and then #30 slots. In cases where the slots would not develop a seal, (i.e. the volume of leaked manure exceeded 90 litres during the initial filling), no further testing was done on that slot size and length of pipe. No further testing was done on pipes with larger slots or on the longer pipe size (in cases where the 1.2 m lengths would not seal).

Manure seepage volumes were measured at 5 minutes, 1 hour, 2 hours, 4 hours, 24 and 48 hours after initial pipe filling. At each designated time, the volume of leaked manure was measured and the pipes were topped up with fresh manure (i.e. not with manure than had leaked from the pipe). Samples of raw manure were collected to establish manure characteristics. In addition, composite samples of leaked manure were collected from each slot size and pipe length at 5 minutes and 24 hours from the initial start time for filling the pipes. All samples were tested for % N, % P, % K, (on an as is basis), % Dry Matter, and pH.

Following each set of tests, the pipes and screens were pressure-washed, rinsed and tested to ensure that no material was left in the pipes that might influence the next tests.

Nine tests were subsequently run, starting on the following dates: October 4, December 10, December 12, and December 17, 2001, and June 4, 10, 11, 17, and 19, 2002.

Results and Discussion

Part A - Field Study

Following the addition of 30 cm water to the manure tanks, water was detected in the sample pipes. Presumably, this water leaked into the gravel bed either from the pull plug system, or through cracks in the concrete. On March 6, following the addition of pigs to the barn, manure was noted in the samples collected. This was confirmed by testing the liquid samples for bacteria and nutrient levels. The volume of liquid pumped from the sampling pipes indicated that the manure leak was small. Subsequent sampling again indicated the presence of manure in the leachate, but it was uncertain if it was new or part of the initial flush that had since plugged. The perforated sampling pipe next to the pull plug system (P1) had no liquid in it after March 6. Liquid was pumped from the pipes P2 and P3, March 20, April 4, April 15, and May 8 and by May 29 no leachate was present. In total, 250 L of liquid (containing manure) was removed.

For the June 26, July 25, September 9, October 11, and November 27 visits, the sampling pipes were dry. This seemed to confirm that any earlier leaks had stopped. Also it confirmed that the pull plug system had not leaked when manure was flushed from the barn, during the emptying operation. With no leachate detected in the pipes, the next visit was delayed until May 1, 2003. Liquid was detected in P2 and P3, the ones installed in the gravel bed between the two barns. P1 was dry. Samples were collected and 126 litres of liquid were pumped from the sample pipes, only partially draining them. The site was visited again on May 7 and P2 and P3 were pumped dry with a total of 1159 litres of liquid removed. The site was again visited May 22 when liquid again was found in P2 and P3. The volumes of leachate were similar to those found on the visit May 7. On subsequent visits June 2, June 16 and October 20, significant volumes of leachate were again found in P2 and P3. This did not appear to be the result of manure leaking from the barn, however. Steps were then needed to determine if the new source of water might be either groundwater or surface water.

In an effort to determine if this leachate was groundwater, a piezometer was installed in the soil near the barn. A 100 mm diameter hole was drilled 5.5 m south of the barn using a Giddings boring machine, to a depth of 6.7 m. Based on an apparent water table depth of 4.8 m, a 6.95 m piezometer was installed in the hole. It consisted of 38 mm PVC pipe with a 250 mm long slotted screen covered with a filter sock at the bottom of the pipe. The hole was backfilled with coarse sand to 1.8 metres below grade and bentonite clay “hole plug” to the surface. This would allow shallow ground water to collect in the piezometer for sampling. The piezometer was monitored after installation, until it was removal on October 20, 2003. During that time, no water was detected in it. It therefor appeared unlikely that groundwater was entering the space between the liner and the concrete floor. The more likely problem appeared to be entry of surface water.

The leachate found in the liner (in May, 2003) appeared to be surface water leaking back into the liner, likely in an area where the liner was not adequately sealed to the concrete walls of the barn. The liner only came partially up the wall of the barn to about 90 cm above the footing of the weaner barn. The water was most likely rainwater draining from the barn roof, flowing down the edge of the foundation and into the liner (such as at inside corners, at loading docks or around the sampling pipes). This would most easily

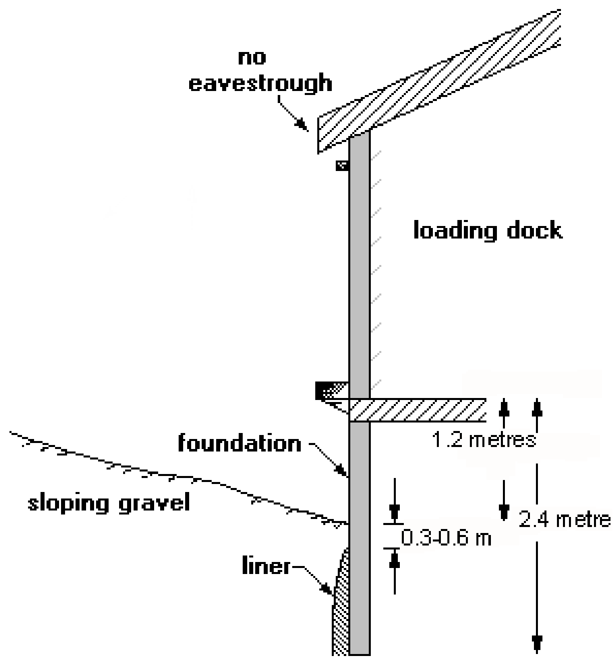

Figure 10 Loading dock used to move pigs into and out of barn. The soil is sloped towards the barn, the liner is attached below the soil grade and the roof does not have an eaves trough.

occur in the loading dock areas where the ground sloped towards the barn (see Figure 10).

Nutrient and bacteria concentrations (see Tables 2 and 3) indicated manure was present in the leachate on March 6 , 2002, with the highest bacteria levels found on that sampling date. Subsequent samples also showed the presence of manure, but bacteria levels continued to decline until the sampling pipes were dry on May 29, 2002. On May 1, 2003, liquid was again found in P2 and P3 and when tested had bacteria and nutrient levels below the background values.

On the final visit, October 20, 2003, no bacteria were detected in the liquid samples collected from P1, P2 and P3. These values seemed to confirm that the water pumped from the sample pipes was surface water that had leaked into the liner.

Table 2 - NH_4-N (mg/L) concentrations in the leachate collected at the various sampling times from each of the three sample pipes

	P1	P2	P3
February 19, 2002	0.2	0.2	1.11
March 6	0.28	71.1	55.9
March 20	NA	NA	NA
April 4	NA	900.3	859.6
April 15	NA	187.3	97.7
May 8	NA	90.2	185.9
May 29	NA	NA	NA
May 1, 2003	NA	0	0
October 20	0	0	0

Note: avg manure NH_4-N concentration during the study (3 samples) was 3960 mg/L

Table 3 - E. coli levels in liquid samples from each of the three sample pipes

	P1	P2	P3
Feb 19, 2002	3	120	239
March 6	<1.0	145000000	45,000,000
March 20	NA	26,900,000	58,500,000
April 4	NA	1,670,000	262,000
April 15	NA	17,000	9500
May 8	NA	1250	5500
May 29	<1.0	NA	NA
May 1,2003	NA	43	11
October 20	<3.0	<3.0	<3.0

The well water for the barn was tested for bacteria and nutrient levels (depth 11 metres). The water was free of bacteria and nutrient levels. It appeared there was no manure or surface water contamination of the well. Three manure samples were collected and analyzed over the duration of the study. The average results were as follows:

NH_4-N	3958 mg/L
total N	0.41%
total P	0.09%
K	0.31%
Dry Matter	3.98%
pH	7.4
Electrical Conductivity	22.4 mS/cm
E. coli from 1 sample	427 mpn.

Part B - Lab Study

1 - General

For the first run, the manure dry matter content was 2.49% (in each case, the manure DM was not known until after the test was over). Although there was significant plugging in the 10 mil slots, complete sealing never occurred. The 20 mil slots did not seal for either pipe length. The 30 mil slots did not seal at all and attempts to fill the pipes had to be abandoned.

For Test #2, the manure DM was 2.6 %. Results were similar to the first run, with significant plugging for the 10 mil slots but never completely sealing. The 20 mil performed similar to the 10 mil. With the 30 mil slots, only partial sealing could be attained on the 1.2 m pipe length, and no sealing on the 2.4 m pipe length.

The manure in Test #3 had a DM of 4.0%. The results with this manure were more dramatic. All slotted screens sealed in about 30 seconds, with very little seepage after that. A very small amount leaked in 24 hours (from 20 to 70 mL).

The dairy manure tested in Test #4 had a DM content of 3.74% and yielded results similar to Run #3 for hog manure. Plugging occurred in the first 30 seconds with very little seepage after that. In 24 hours, 10 to 70 mL leaked out of the pipes, regardless of the slot size.

The hog manure in Test #5 was 2.5% DM. The DM content was initially higher than this, but rain running into the test setup holding tank diluted it somewhat. The manure did significantly plug the #10 slotted pipe but there was still manure leaking from the pipes after 48 hours. Similar results were seen with the #20 slot pipes although it took longer for the leaking to drop to levels similar to the #10 slotted pipes. The #30 slotted pipes would not seal when initially filled with manure.

The manure DM in Test #6 was 0.37% . This very dilute manure was largely wash water. The manure partially plugged the #10 slotted pipe, 1.2 m tall, although so much manure leaked out that this was abandoned after four hours.

In Test #7, the manure DM was 4.81%. The results from this run were quite dramatic. Plugging of all slot sizes occurred within seconds with little or no leaking occurring after five minutes, even with the largest slot size. Plugging of the slots was virtually complete. With the more dilute manures, the pipes could be drained when the testing was complete by simply tapping the pipes with a hammer to break the manure seal. This method did not work for this manure and the manure had to be pumped from the pipes.

Test #8 used manure with a DM of 1.02%. As with the other dilute manure, although some partial plugging occurred, the pipes continued to leak and never fully plugged. Results were recorded for the #10 slot, 1.2 m and 2.4 m, and the #20 slot, 1.2 m pipes. The other pipes would not seal and testing of them was abandoned.

The final test was liquid dairy manure with a dry matter level of 2.55% The results from this run were similar to Test #7, with plugging occurring in seconds. Once again, there was very little leaking after five minutes (mainly the #30 slot).

In most tests, typically, manure would seal the slots but when more manure was added to top up the pipes after each measurement, some manure would start leaking again. Every effort was made to avoid tapping the pipes during sampling or measuring of seepage. The renewed leaking was presumably due to the sudden slight increase in hydraulic head as the pipe was topped up.

2 - Effect of Pipe Length and Slot Size

As mentioned, two pipe lengths were used in this study, 1.2 m and 2.4 m. Most liquid manure storages used in Ontario have a total depth of between 2.4 and 3.0 m, though there are many under-barn temporary storages with depths of less than 2.4 m.

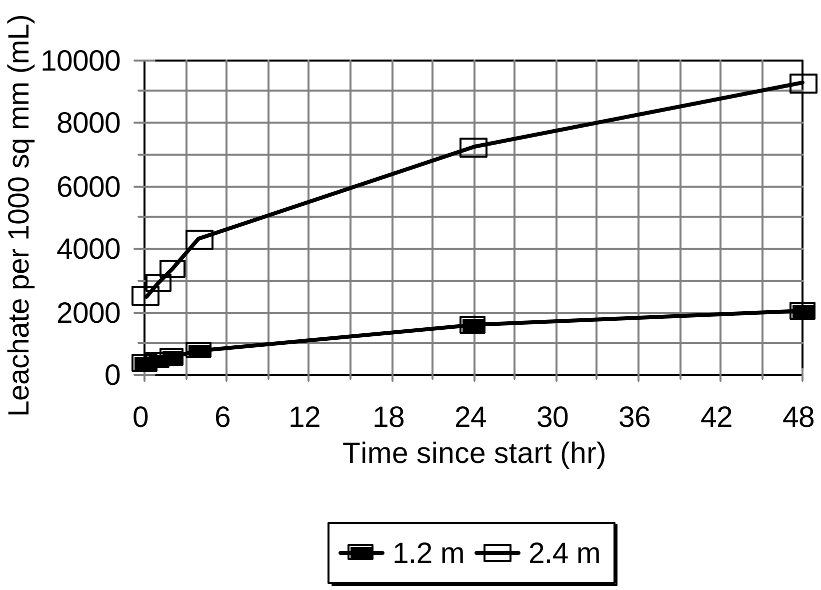

Figure 11 Cumulative average amounts of manure leachate for all #10 slot tests over the 48 hours of the test

The difference in hydraulic head had a significant impact on the total amount of seepage from the various pipes. Figure 11 shows the average total amount of seepage from the pipes having the #10 slots. This graph and the other analysis that follows does not include the small amount of data for Test #6, where the manure was so dilute.

During the 48 hour test, an average total of 2025 mL of manure leaked from the #10 slot pipes per 1000 mm^2 total slot opening. The corresponding value for the 2.4 m length of pipe was 9264 mL, more than 4 times greater. Table 4 gives the quantities of manure that leaked from the various pipes during this 48-hour period. While it may not seem that the relationship is as dramatic for the #20 and #30 slot sizes, consider that not all manures were tested in the longer pipes, since the shorter pipes sometimes did not develop a seal. For this reason, the P-value for the effect of slot size on the amount of manure leaking from the pipes was only 0.089 - further analysis would be expected to yield a significant relationship if only the tests are included where complete testing was done.

Table 4 Average total amounts of manure leaking from the various pipes per 1000 mm^2 total slot opening

	Depth = 1.2 m	No. tests	Depth = 2.4 m	No. tests
#10 slot	2025	21	9264	21
#20 slot	3312	21	4648	18
#30 slot	6839	15	5889	12

When performing the tests, it appeared that the rate of leaking of each of the pipes varied from manure to manure but was highest in the first five minutes, then tapered off drastically. This is shown in Figure 12, which includes the rate of leaking for all tests using the #10 slot. By the time 48 hours had elapsed, the average rate of leaking for the #10 slot pipe (1.2 m long) was down to 0.32 mL per minute (per 1000 mm^2 of opening).

3 - Effect of Dry Matter Content

There is a range of DM contents of livestock manure on Ontario farms. This may be influenced by many factors, including livestock type, amount of feed or bedding in the manure, added dilution water (i.e. spilled water, washwater, precipitation), genetics, etc. A database of actual manure test results from Ontario farms is found in the NMAN computer software used to create nutrient management plans (OMAFRA 2000). It lists average liquid manure DM's of 3.5% for swine, 6.7% for dairy and 8.3% for poultry, for example. However, for all livestock types, a wide range of DM values is included in the database. For swine, the manure is broken into four groups: "Highly Diluted", at 0 to 2% DM, through "Normal" and "Thick" to "Very Thick" at 10 to 15% DM..

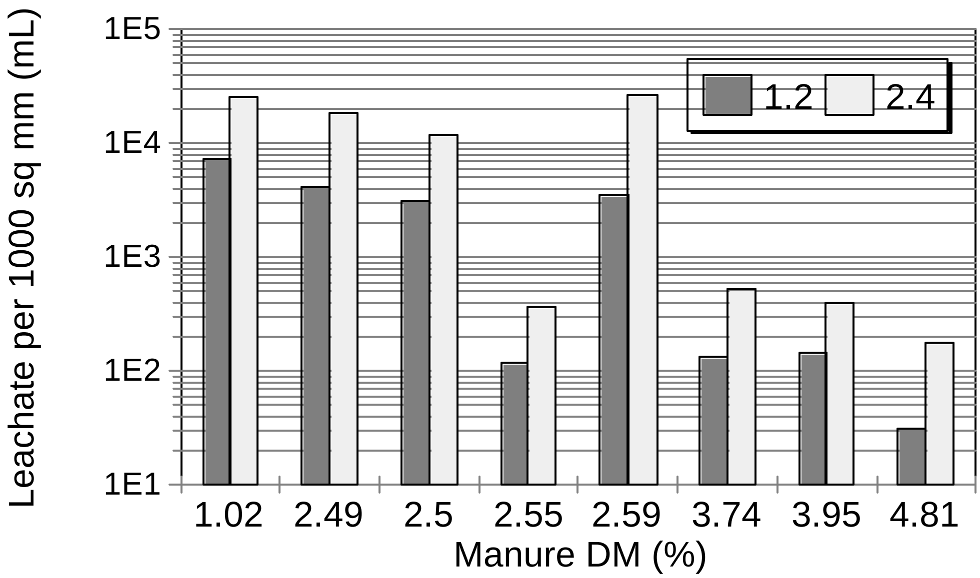

Figure 12 Average total amounts of leachate per 1000 mm^2 of opening for various manure DM contents - for #10 slot pipes of 1.2 m and 2.4 m lengths

In this study the manure DM contents ranged from 0.37% to 4.81%. Since the 0.37% did so poor a job of sealing the openings, it was not used in the analysis - the next lowest DM content was 1.02%. Figure 13 shows the impact of DM content on the total volume of manure leached for the #10 slot pipes. Once again, it is obvious that there was less leachate from the 1.2 m depth than the 2.4 m depth. The decline in average total volume of leachate as the manure DM increases can be seen in Figure 13. The manure having DM = 2.55% had less leachate than expected. This was for Test #9, using dairy manure. The dairy manure samples contained larger fibers than the swine manure - presumably due mainly to the bedding material. These fibers appeared to help establish the seal fairly quickly. The manure with DM = 2.59% had considerably more leachate than expected. It was swine manure, and the reason for the high amounts of leachate are not obvious.

4 - Filtrate Characteristics

The effluent from each of the pipes was collected and was not re-used to fill the pipes. It was felt that the DM content of this manure may be less than that of the raw manure, and that turned out to be the case. This was of course most pronounced for the #10 slot. These openings (0.25 mm) are in the range of sizes used in some mechanical manure separators. As might be expected, any reduction in DM was more pronounced as the DM of the raw manure increased.

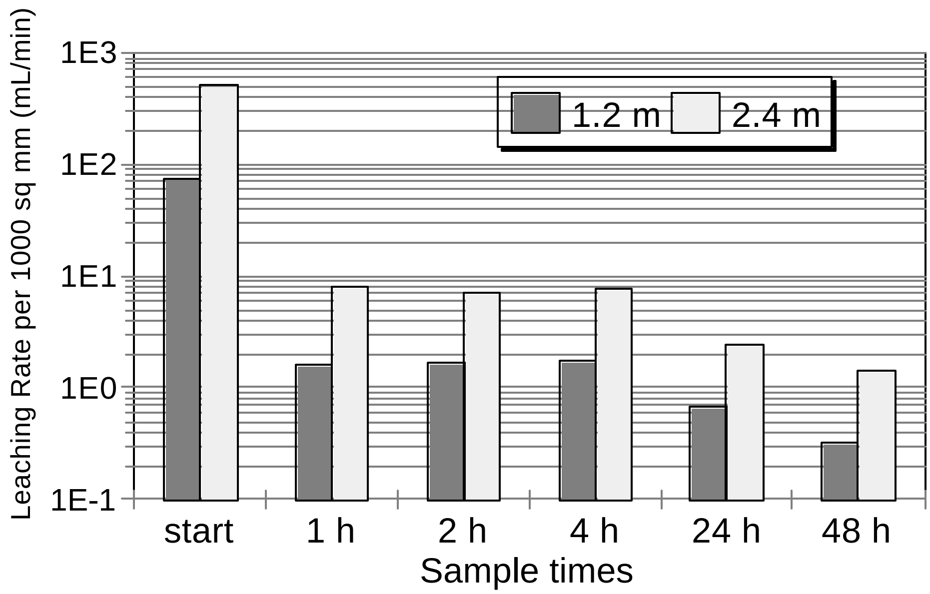

Figure 13 Rate of leaking of manure from the #10 slot pipes over the 48 hours of testing - both 1.2 and 2.4 m depths - per 1000 mm^2 of opening. The rate is expressed in mL/min.

Nutrient values were measured in both raw manure and effluent. There were differences in total N, P, K and in pH, though these likely have very little practical significance in this particular study.

Summary

This project was designed to test the assumption that small cracks in concrete manure storages will self-seal. The project consisted of two parts - one carried out at the "lab" scale and the other carried out at a farm. With any concrete construction, it is assumed that the concrete will develop small cracks as it cures.

Farm Study - Originally, the goal of the farm study was to look only at the potential for the concrete to leak. The cooperator farm, however, also has a pull plug transfer system, and it is unclear whether the small amount of manure that leaked was through floor cracks or through a component of the transfer system - the more likely scenario. The site was monitored for nearly two years, during which time, the storage was filled and emptied, with the pull-plug system being used twice.

- An assumption was made that the impermeable liner captured any liquid that leaked through the floor. There was no reason to suspect otherwise.
- Before pigs were introduced to the barn, clean water leachate was removed from the system. Soon after pigs entered the barn (March, 2002), manure was detected in the leachate water. By May 8, the barn was full and by May 29, no further leachate was detected. It appeared that any leaks had been sealed by that time. No further leaking of manure occurred (testing stopped in October, 2003). Approximately 250 L of contaminated water was removed during this period.
- Assuming that half the leachate consisted of manure (worst case) and that only the weaner pig barn contributed this amount, the amount of manure leaking from the barn before sealing occurred would be equivalent to a depth of 0.12 mm. The actual amount of manure was almost certainly less than this, based on relative NH_4-N concentrations and on the amount of dilution water in the storage.
- This barn was built to high construction standards - high quality concrete, PVC pipe with "T" joints (with seals intact) for all transfer pipe, a leak-stop seal and a concrete key-way at the base of the wall - yet a small amount of manure still was able to leak though the floor.
- The liner for this barn was only drawn partway up the wall of the manure storage. It was felt that any possible leak would be in the floor of the storage or the pull plug system. The possibility of surface water seeping into the system from the top was not anticipated, though it appears to have been the case in 2003.

Lab Study - Slotted pipes were secured to the ends of a series of vertical PVC pipes and the pipes were filled with manure of various moisture contents. Hydraulic heads of 1.2 and 2.4 m were examined. Slot widths of 0.254 (#10), 0.508 (#20), and 0.762 mm (#30) were considered. Also, these slots were straight and smooth and the manure had to travel less than 10 mm before it had leaked through the pipe. In contrast, concrete cracks are generally narrower, are neither straight nor smooth, and the travel distance to penetrate the concrete would almost always be at least 100 mm (for floor, more for walls). The results showed that:

- The greater the hydraulic head, the greater the amount of manure that can leak through. On average, the 2.4 m head resulted in more than four times the effluent than the 1.2 m head, using the #10 slot pipe. Note that all pipes were filled nearly instantaneously, which is not typical in a manure storage.
- The smaller the slot size, the more easily sealed by manure. In several cases, the #20 and #30 slot sizes would not develop a manure seal. In a manure tank, the leaking manure would not likely be able to drain away so quickly if it were able to begin leaking through large cracks.
- The rate of manure leaking from the pipes was highest during the first five minutes and decreased to a fairly low rate (if not a complete seal) by the time 48 hours had elapsed.

- The initial DM content of the manure had a large influence on the total amount of effluent from the pipes. Generally, the higher the manure dry matter content, the faster the sealing occurred (and the lower the total amount of effluent). The manure having a DM of 0.37% did not reliably seal the smallest openings under the lowest head (#10 slot, 1.2 m), though all manures having a DM of >1.0% were capable of sealing at least this condition.
- Manure with a DM of approximately > 3.5% can effectively and quickly seal slot sizes of 0.762 mm.
- The DM and nutrient characteristics of the effluent were different than the raw manure, especially for the #10 slot size, where a physical filtering took place.

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Nutrient and Bacteria Analysis of Leachate Collected From Judge Farm

P1 2002-2003	NH4-N mg/L wet	Total N % wet	pH	Electrical Conductivity mS/cm	E. coli cfu/100 ml
February 19	0.2	<0.01	7.6	0.24	3
March 6	0.28	<0.01	7.4	0.2	<1.0
March 20	NA	NA	NA	NA	NA
April 4	NA	NA	NA	NA	NA
April 15	NA	NA	NA	NA	NA
May 8	NA	NA	NA	NA	NA
May 29	NA	NA	NA	NA	<1.0
May 1 - 2003	NA	NA	NA	NA	NA
October 20-03	0	0	8.0	0.6	<3.0
P2					
February 19	0.2	<0.025	8.2	0.22	120
March 6	71.1	0.035	7.9	3.19	145000000
March 20	NA	0.04	7.7	NA	26900000
April 4	900.3	0.16	7.8	11.1	1670000
April 15	187.3	0.03	7.6	2.8	17000
May 8	90.2	0.01	8.3	1.4	1250
May 29	NA	NA	NA	NA	NA
May 1 - 2003	0	0	7.3	1.2	43
October 20-03	0	0	7.9	0.53	<3.0
P3					
February 19	1.11	0.063	8.6	0.25	239
March 6	55.9	0.015	7.5	1.29	45000000
March 20	NA	0.04	7.5	NA	58500000
April 4	859.6	0.15	7.7	10.75	262000
April 15	97.7	0.02	7.6	1.6	9500
May 8	185.9	0.03	8.3	2.4	5500
May 29	NA	NA	NA	NA	NA
May 1 - 2003	0	0	7.4	1.05	11
October 20-03	0	0	8.0	0.53	<3.0
Well	0.18	0.00	7.7	0.44	<1.0

Note average manure values during study (3 samples) 3958 mg/L (NH4-N), 0.41% (N), 0.09% (P), 0.31% (K), 3.98% (Dry Matter), 7.4 pH, 22.4 mS/cm (Electrical Conductivity) and E. coli from 1 sample, 427 mpn.