ENGINEERING ASPECTS OF MANAGING DAIRY LAGOON WATER

Eric Swenson, P.E.[1]

In the summer of 2001 I co-authored with Marsha Campbell Mathews, Thomas Harter, and Roland Meyer a paper entitled *Matching Dairy Lagoon Nutrient Application to Crop Nitrogen Uptake Using a Flow Meter and Control Valve*[i]. This paper is an update regarding the engineering aspects presented in that earlier paper and contains new insights and lessons learned in the field designing and reviewing operations of metered dairy lagoon water application systems. I would like to take this opportunity to thank all of the dairy operators who have allowed me to work with them to create application systems that more closely match nutrient application to crop uptake.

OVERALL LAGOON WATER DISTRIBUTION SYSTEM DESIGN CRITERIA:

New approaches have been established to improve upon past practices of approximating the application rates of lagoon water to field crops. These new approaches allow accurate measurement and control of nutrients applied. Experience in the field has shown that the following are key components to such an upgraded application system:

- Equipment must be simple to construct and operate.
- All components must be reliable and require minimum maintenance.
- System construction and operating cost must be low.
- All components must be simple and quick to repair when broken.
- Accurate measurement of lagoon water flowrate and totalized flow.
- Easy sampling for typical lagoon water composition.

Systems containing these elements have been constructed and successfully operated by dairymen for the past 5 years. These systems have only been applied at dairies that utilize lagoon water for lane flushing and manure transport. The following sections describe each of the elements of these systems.

LAGOON WATER STORAGE SYSTEMS:

SOLIDS SEPARATION: A range of approaches have been utilized to reduce the solids content of storage lagoon liquids by intercepting and removing a portion of these solids prior to the storage lagoon. The term *primary solids separation* can be applied to the removal of oversized solids prior to the storage lagoons. Reductions in total suspended solids, without the addition of chemical flocculating agents, appear to be in the range of 20 to 50 percent depending on the

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[1] Consultant to University of California Cooperative Extension, 3800 Cornucopia Way, Suite A, Modesto, CA 95358 (employed by Merced County, Department of Public Health, Division of Environmental Health, 777 West 22nd Street, Merced, CA 95340, Email: eswenson@co.merced.ca.us). In: Proceedings, National Alfalfa Symposium, 13-5 December, 2004, San Diego, CA, UC Cooperative Extension, University of California, Davis 95616. (See http://alfalfa.ucdavis.edu for this and other proceedings).

approach employed. Failure to implement *primary solids separation* can result in excessive solids loading of storage lagoons reducing liquid storage capacity, significant solids settling and collecting at the head of fields (with significant local over application of salt and nutrients), and much higher potential for blockage of transfer pipelines. Two common approaches to removing oversize solids from flush water utilized by dairymen are (1) settling basins and (2) screen separators.

(1) ***Settling Basins***: One approach that has been successfully used for solids removal is settling basins. Settling basins allow the removal of significant quantities of suspended solids in the lagoon water. A variety of designs have been employed. From observation of the operation of these basins in conjunction with discussions with dairy operators and the contractors who maintain these facilities it is becoming clear that 3 distinct physical phenomena are probably accounting for the successful operation of these basins: physical settling of solids due to low velocities, impingement of suspended material on the mats of floating solids, and mechanical filtering through the cakes of solids filling the settling basins. It is not unusual to have the top of the floating solids elevation exceed the top of the bank elevation of these settling basins prior to maintenance to remove collected solids. Significantly more research is needed to establish the optimum design and cleaning procedures for these basins to minimize operating cost and maximize performance.

(2) ***Screen Separators***: Stainless steel inclined wedge wire screen separators have also been successfully used. These screens come in a variety of configurations and slot opening sizes. Slot opening sizes vary from approximately 0.010 to 0.060 inches. Systems include single screen configurations, parallel screen operations, and series operation. Screens, especially finer slot sizes, are susceptible to mechanical blockage, bio-fouling, and precipitation of salts. Finer screens may require cleaning with a pressure washer every one or two days to remove fine solids that tend to wedge between the slots. To reduce bio-fouling screens are typically not oriented to the south to reduce solar exposure and in some instances chlorine is added to spray water as a biocide. Solids on sloped screen separators should be removed prior to these solids drying on the screen surface. Periodic applications of weak acid to screen surfaces have also been reported at locations with high dissolved salts to resolution precipitates that have formed. Screened solids can be an excellent source of bedding material for dairies using manure for bedding.

Solids removed through any of the several approaches are often dewatered on concrete slabs with controlled drainage being directed back into the storage lagoon(s). Some dairy operators are composting separator solids prior to land application.

LAGOON STORAGE CAPACITY:

In at least one central California county[ii], 120 days of liquid storage is currently required for storage lagoons. A limited number of dairy operators are constructing lagoons with up to 180 days of storage. An existing facility may currently have only 30 days of operational storage making agronomic application of lagoon water difficult or impossible. A dairy storage lagoon may have floating pumps or pumping systems that do not allow for the full use of all the lagoon storage capacity. Storage capacity must be calculated from the maximum allowed operating level (usually 2 feet of freeboard to top of berm for constructed lagoons above grade and 1 foot for lagoons constructed below grade[iii]) to the minimum operating level (often dictated by operation of floating flush lane pumps – see figure 1). Storage lagoons should have adequate capacity to store all required liquids based upon anticipated storm water and dairy operation inflows minus anticipated farming scheduling dictated outflows, in addition to meeting other legally required minimum storage capacities. Some soil types may significantly restrict the amount of liquid material that can be applied during the winter months leading to the need for additional storage.

Recent work in the area of nutrient management associated with dairy operations has placed an increasing emphasis on management of organic nitrogen. Significant quantities of organic nitrogen may be stored in fine solids that typically accumulate in the bottom of storage lagoons. In past years this material would be allowed to accumulate for multiple years prior to removal. The storage capacities of these lagoons are significantly impacted by the accumulation of these solids. It now appears that in order to make the nutrient management plan work at many dairies, these fine solids need to be removed from the storage lagoon(s) on an annual basis and land applied.

One approach that has been taken to minimize the buildup of fine solids in storage lagoons is to construct and operate 2 storage lagoons in series. The first storage lagoon is sized to allow for the storage of approximately a third of the total storage requirement and the remaining lagoon is sized for the balance of the required storage. These lagoons are operated in such a way that during the bulk of the year only the smaller lagoon is needed for storage. In this manner, the bulk of the fine solids collect in the smaller lagoon. These smaller lagoons can be equipped with floating pumps and agitators to allow fine solids removal during irrigation events. Care must be taken to prevent bottom scour of lagoons during pumping and agitation (particularly where clay lagoon liners are installed).

In larger lagoons it can be effective to have multiple connection locations for pump discharge hoses and electrical connections. Some operators have found it advantageous to locate connections along a common bank between both lagoons allowing the equipment to move between lagoons.

LAGOON WATER TRANSFER SYSTEMS:

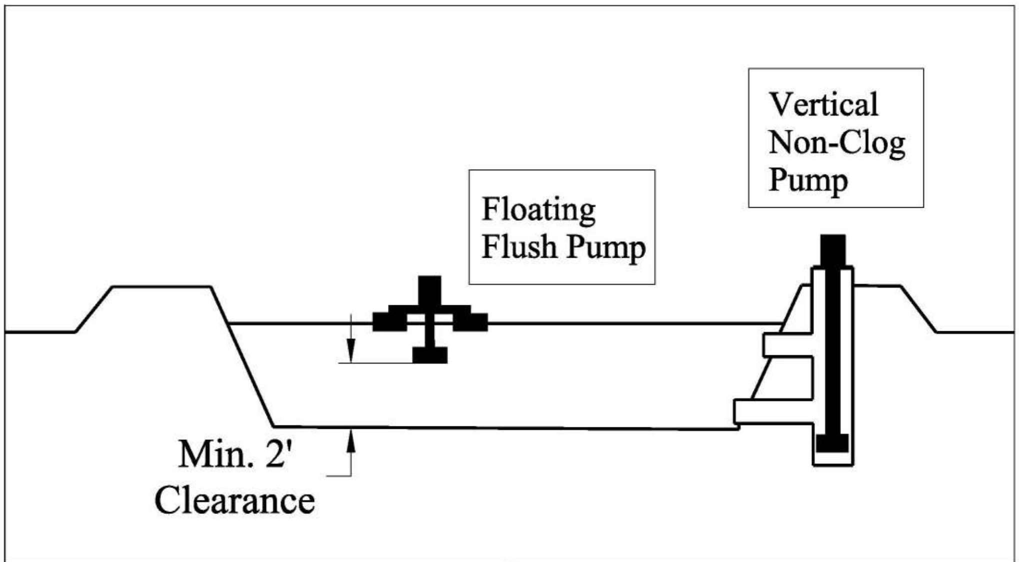
IRRIGATION WATER SUPPLIES: One of the first steps in designing a lagoon water irrigation system is establishing the capabilities of the existing fresh water irrigation supplies and how these supplies impact irrigation rates. Water may be available from surface facilities (such as canals or rivers), private wells, or treated effluent from processing facilities. The quality, quantity, and time availability of the water sources is important. Successful irrigation systems often include a supply of fresh water for dilution of lagoon water in the winter as well as summer irrigation seasons. At some facilities it may be necessary to increase the quantity of fresh water irrigation supplies to ensure high irrigation distribution uniformity can be obtained.

DETERMINING TRANSFER RATE: Once a knowledge of the known fresh water irrigation supplies is determined, cropping patterns are established, and the range of irrigation rates are established (acre/hour irrigated), then one must estimate what the maximum desired application rate and timing of nutrients from lagoon water would be for optimal plant uptake. Typical ranges of nitrogen applied for irrigation from lagoon water sources are typically in the range of 30 to 130 pounds per acre assuming that 50% of the organic nitrogen is plant available. The range of anticipated nitrogen available from the lagoon water also needs to be estimated (this might be something like 200-350 ppm available nitrogen). This information taken together will allow the irrigation designer to establish a maximum and minimum rate for lagoon water application.

TRANSFER OF LAGOON WATER: Lagoon water can be transferred by pumping or gravity flow. Pumps are utilized to transfer lagoon water when gravity head is not adequate. An irrigation designer should establish required flow and pressure characteristics of the pump. Pumps designed for “trash” type services have been used with a good success rate. These pumps are often called “Non-clog” pumps. The best service has been experienced with pumps having submerged impellers such as submersible or vertical turbine style pumps. Calculated flowrates for agronomic application of lagoon water delivered to the field have been decreasing in recent years in response to increased accounting of organic nitrogen in lagoon water. These decreasing flowrates have led to the need for pumps with higher discharge heads at lower flowrates than have commonly been used in the past for similar applications. Self-priming, end suction, non-clog pumps are not recommended for lagoon pumping due to the foaming nature of some lagoon water which can negatively impact pump priming and operation.

It is desirable to have a lagoon pumping or gravity draining system that will allow the lagoon to be fully drained. Many lagoon flush pumps are mounted on floating platforms (see figure 1). These pumps often require several feet of water depth to avoid bottom scour. One approach that has been employed successfully is to construct a small lagoon after the settling basins (or adjacent to the screen separator) and before the storage lagoon that is always maintained at a full level.

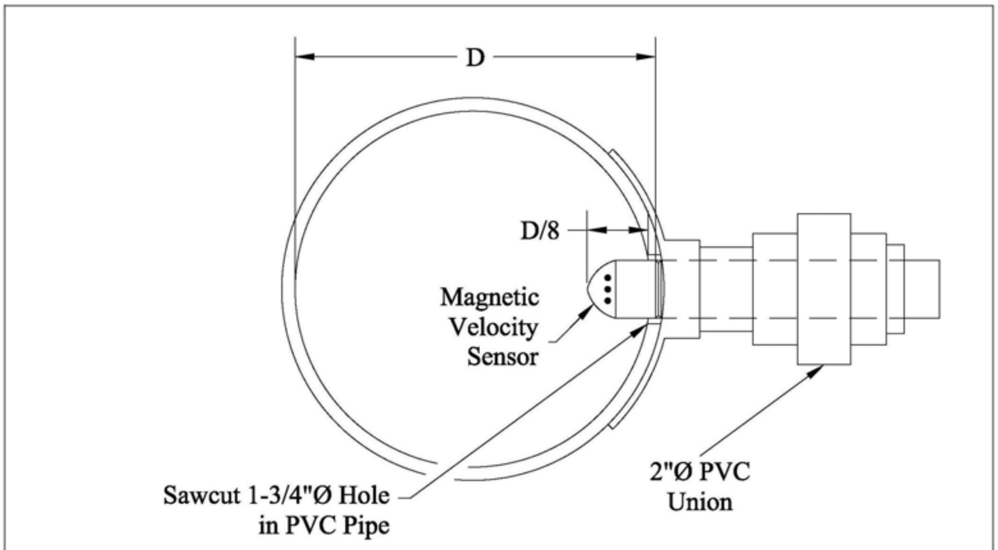
The floating flush pump is then moored in this small lagoon. The lagoon water irrigation pump(s) can be installed in the larger storage lagoon as a floating pump or a stand mounted pump. Stand mounted pumps can be constructed with inverts 2 to 3 feet below the bottom of the lagoon to maintain required pump submergence. Stand mounted lagoon water pumps work well with lagoons less than 20 feet deep.



Pump Style Impacts on Lagoon Capacity — Figure 1

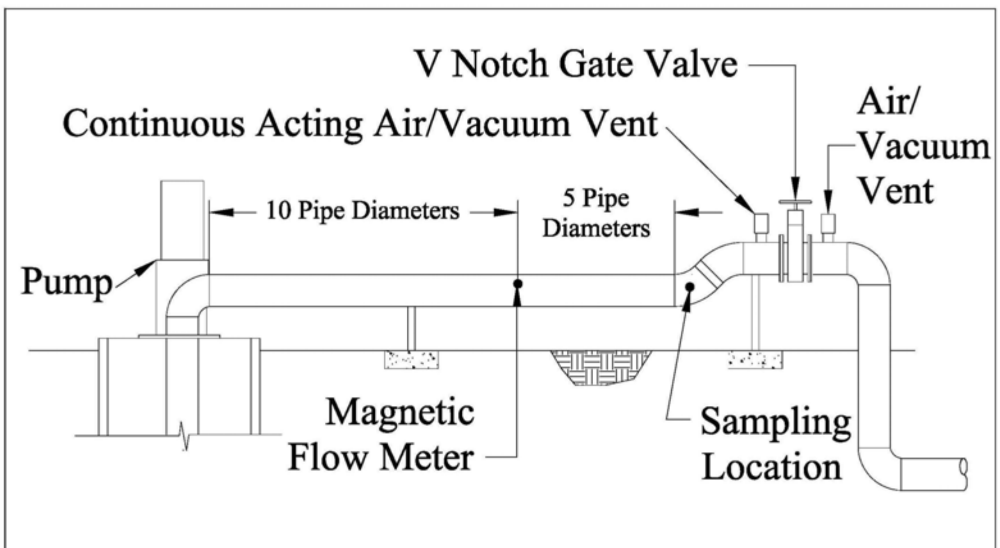
FLOW MEASUREMENT OF LAGOON WATER: In order to accurately apply a known amount of nutrients from lagoon water to cropped acreage the concentration of these nutrients in lagoon water must be established and the volume of application of these materials must be measured. Experience and testing has shown that a real-time, continuous measurement of the flowrate and totalized flow of lagoon water can be reliably made using magnetic flow meters such as have been employed for many years in the municipal waste water industry. Anticipated accuracy's of these metering installations in the field can be within 5 percent of actual. Probe style magnetic flowmeters have been used successfully with insertion depths of 1/8th of the pipe diameter without excessive problems with debris collecting on the probe tip (see figure 2).

Most magnetic lagoon water flow metering installations require a straight run of pipe that is full of fluid. A typical installation for downstream of a pump discharge is shown is figure 3. Optimum installation of the meter is at least 10 pipe diameters immediately downstream of the pump discharge. This would be followed by approximately 5 pipe diameters of straight run of pipe. Two 45 degree elbows can be installed after the 5 diameter long straight section to insure that the pipe is always full of water. An air vent is provided after the rise to



Probe Style Magnetic Flow Meter

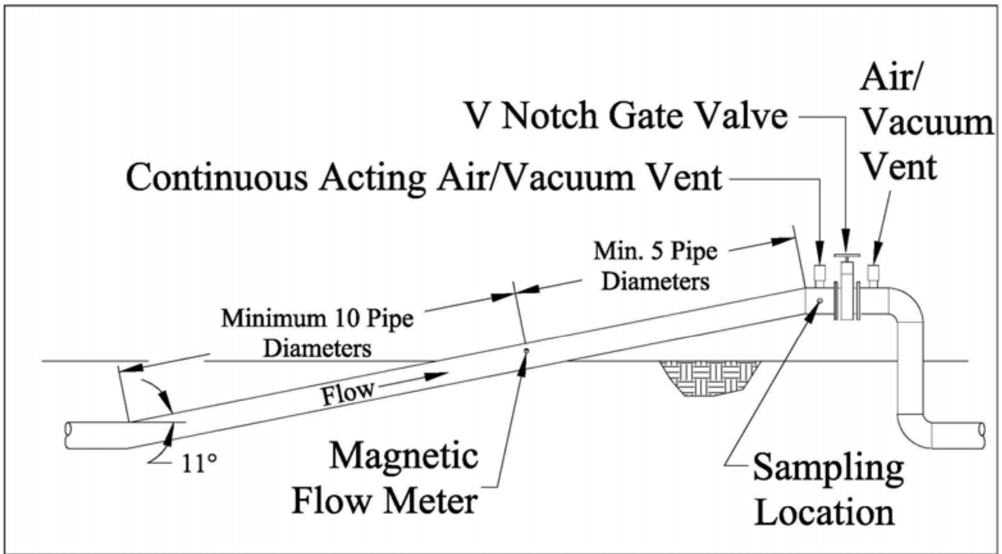
Figure 2



Horizontal Manure Water Metering Run

Figure 3

insure that all air has been vented from the pipe. A new typical installation configuration for installation of magnetic flow meters on pipelines significantly downstream of vertical turbine style pumps or connected to floating pumps has been developed placing the straight section of the metering run on an incline (see figure 4). The cost and simplicity of this sloped approach has proven popular.



Sloped Manure Water Metering Run

Figure 4

Some problems with magnetic flow meters in the field have been experienced. Temperature ratings for the fluid contact portion of some magnetic flow meters are limited to approximately 150 degrees F. The interior of steel flow metering piping exposed to full sun and drained of water probably significantly exceed this temperature and one probe failure has been attributed to this type of occurrence. Constructing a structure to shade steel metering pipe runs from the sun is recommended. Other failures have been attributed to under-voltage on supply power to the unit and resulted in failure of the meter electronics. Mounting of these meters near storage lagoons may also expose them to hydrogen sulfide that may have long-term negative effects.

Gravity flow situations may provide the opportunity for the use of alternative flow metering approaches. Some existing dairies have multiple gravity outlets from one lagoon further complicating the situation. An attempt to apply open channel flow metering approaches to the lagoon water gravity flows is being made through the use of 'V' notch weirs. This approach is under development and results are not available at this time. The use of a canal metergate (similar to a standard canal gate) has been used successfully to meter gravity flows from a dairy lagoon and is a low cost solution to some metering needs.

FLOW CONTROL OF LAGOON WATER: A flow control device is needed to regulate the flow of lagoon water to the field in most instances. Dairymen to date have primarily been interested in a device that is low in cost, easy to install, and works reliably. The best device that fits this criteria appears to be a gate valve with a 60 degree (see figure 5) or 90 degree'V' shaped orifice (see figure 6). This 'V' shaped valve orifice allows throttling of the flow while still providing a large cross section opening for solids and debris to travel through. The 90 degree

‘V’ shaped orifice has been developed to reduce full flow pressure drop, but still maintain significant plugging resistance. These valves are only somewhat more expensive than a standard gate valve and are available in a wide range of sizes. Valve opening is normally adjusted by turning a handwheel. For convenience the flow meter display is often mounted where it can be read when adjusting the handwheel.

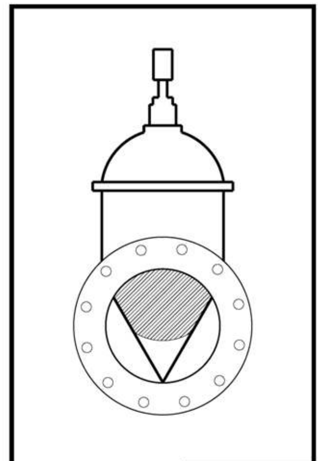


FIGURE 5

Variable frequency drive (VFD) equipped pumps can be used in place of a valve to control lagoon water flow. VFDs control flow by changing the speed of the pump that results in a varying flow output. The electronics that run VFD need to be protected from excessive temperatures and dirt. Pumps that are driven by VFDs must be carefully selected to insure adequate pumping head (pressure) is available at all anticipated pumping rates. An alternative means to variable speed pumping and flow control is through the use of an engine driven pump. Most variable speed pumping systems will result in lower energy usage than a throttling valve. An optimal system configuration if cost were not a significant controlling factor might be to install a VFD with a line power bypass and a gate valve with a 90 degree ‘V’ shaped orifice.

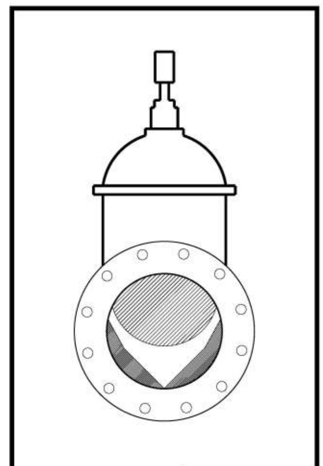


FIGURE 6

LAGOON WATER DISTRIBUTION: A high degree of success has been experienced using PVC pipe for the distribution of lagoon water. High density polyethylene would also make an excellent distribution pipe, but is not easily modified or repaired by staff currently employed at most dairies. Many sites have significant quantities of concrete distribution piping that can require significant maintenance effort to keep operational with minimal leakage. Fluid velocities of 2.5 to 5.0 feet per second (fps) have been shown to be very effective at maintaining most material in suspension and conveying it to the mixing point with fresh water. Pumped systems should utilize combination air/vacuum vents and pressure reliefs that are sized and located as would be required on a clean water irrigation pipe[iv]. Good success has been found using two individual automatic vents with each having 2/3rds of the required total venting capacity. With 2 vents, failure due to plugging of one vent will not lead to complete absence of any automatic venting of the pipeline. When designing PVC constructed pipeline systems a Hazen Williams C value of 140 or lower should be utilized. Caution should be exercised when sizing pumps and piping to transfer very thick slurries found at the bottom of many storage lagoons. The density and viscosity of these slurries is significantly higher than for water.

LAGOON/FRESH WATER MIXING: It is desirable to fully mix lagoon and fresh water prior to application to the crop. This can be done in a number of fashions. One simple approach that has been employed is to discharge the lagoon water into an open standpipe at the beginning of an irrigation system, prior to the first irrigation outlet in the field. Another approach that has been used successfully is to construct round, pressure rated, steel, mixing chambers with automatic air vents where lagoon and fresh water mix prior to field application. Simple pipe tees where the lagoon water is introduced at 90 degrees to the main irrigation flow have also been used effectively.

Dilution of lagoon water with fresh water does several positive things:

- Allows better distribution uniformity of nutrients over the field.
- Decreases the maximum salt loading on the crop.
- Allows reasonable velocities (2-5 ft./sec.) in irrigation distribution piping.

Dilution ratios of up to 10 parts fresh water to 1 part lagoon water have been noted in the field to achieve agronomic application rates of material. Summer dilution ratios can be in the 5 to 10 parts fresh water to 1 part lagoon water where winter dilutions are often 2 to 3 parts fresh water to 1 part lagoon water. The higher nitrogen application rates in the winter are based on the assumption that colder temperatures will slow the conversion from ammonium to nitrate and that there will be no significant subsequent leaching of nutrients due to irrigation or rainfall events.

Some older lagoon water application systems only have one location for mixing lagoon water with fresh water. For land application areas in excess of approximately 300 acres for a single dairy, that have multiple sources of fresh water, it may be difficult to uniformly apply lagoon water during the peak irrigation season. One approach to increasing the flexibility of lagoon water application is to distribute lagoon water through a dedicated distribution system to multiple fresh water mixing points around a farm. This allows lagoon water to be applied at a distant field while still applying fresh water only at a field close to the lagoon water source.

It is very important to install an effective method of backflow prevention between fresh water sources and lagoon water mixing locations. If a well should shut down or a surface water canal should suffer a failure without backflow prevention, the potential for pumped or gravity transferred lagoon water to flow down a well or into a surface water conveyance facility may exist. For well systems, screened and pumped surface water, or other relatively clean, pressurized water sources, double check anti-siphon (chemigation) check valves have been utilized. Standard swing check valves on unscreened surface water can be subject to jamming by floating debris such as tree limbs of various sizes.

Irrigation districts have a variety of standard required backflow prevention measures and should be consulted prior to equipment installation.

TAIL/STORM WATER COLLECTION AND PUMPING:

It has been suggested that to optimize flood irrigation of land with border check irrigation systems that 15% of supplied irrigation flow be collected at the end of the check.[v] In order to achieve high irrigation distribution uniformities with most flood or furrow irrigation systems, some tail water will collect in the low areas of the field. Rainfall on many manured fields will also result in runoff to low collection areas of fields. At these locations tail water collection and transport systems must be constructed. These systems must be sloped to avoid standing water. Often it is necessary to provide a pumping system that will lift the tail/storm water and convey it through a pipeline. It is often convenient to the operator if this tail water can be applied to the field that is currently being irrigated or returned to an appropriately sized storage lagoon.

Tail/storm water collection and transfer systems must be properly sized to collect and transport the required flows of water. A civil engineer can be utilized to calculate the anticipated runoff from various storm events and make recommendations on rates and volumes of water that can be anticipated. There is additional collection of storm water from corrals and feed storage facilities that should be integrated into this system. Specialists who are familiar with the local soil type and irrigation methods can assist landowners with the design of tail water collection and transport systems for irrigation water.

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[i] *Matching Dairy Lagoon Nutrient Application to Crop Nitrogen Uptake Using a Flow Meter and Control Valve* by Marsha Campbell Mathews, Eric Swenson, et. al. dated July 2001, ASAE Paper No. 01-2105.
[ii] Merced County *Animal Confinement Ordinance* Section 7.13.050.A
[iii] Administrative Draft, CRWQCB, Central Valley Region, *Standard Provisions and Reporting Requirements for NPDES General Permit and Waste Discharge Requirements General Order for Existing CAFOs* dated 2004.
[iv] See *The Surface Water Irrigation Manual* by Dr. Charles Burt published by Waterman Industries, Inc.
[v] Comments by Terry Pritchard, UC Davis, made during Spring 2000 Seminar at UC Extension short course entitled: *Using Dairy Lagoon Water Nutrients for Crop Production***.**

"Funding for this project has been provided in part by the U.S. Environmental Protection Agency (USEPA) pursuant to Assistance Agreement No. C998998901-0 and any amendments thereto which has been awarded to the State Water Resources Control Board (SWRCB) for the implementation of California's Non-Point Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the USEPA or the SWRCB, nor does mention of trade names or commercial products constitute endorsement or recommendation for use."