APPENDIX A:

Ag Water System Assessments and Remediation Guidelines

Prepared by Western Growers Science & Technology

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Special thanks to the following individuals who reviewed and/or contributed to the development of this document:

Hank Giclas, Western Growers

Scott Horsfall, California Leafy Green Handler Marketing Agreement

Greg Komar, California Leafy Green Handler Marketing Agreement

Sharan Lanini, Pacific International Marketing

Teressa Lopez, Arizona Leafy Green Marketing Agreement

Colby Pereira, Costa Farms, Inc.

Channah Rock, University of Arizona

Vicki Scott, Scott Resources/ Consultant

Trevor Suslow, Produce Marketing Association

This document was developed under the leadership of:

Susan Leaman, iDecisionSciences, LLC

Sonia Salas, Western Growers

Disclaimer

This document is intended only to cover key considerations to conduct Ag Water System Assessments and implement Remediation Guidelines for Water Resources. The authors, contributors and reviewers make not claims or warranties about any specific actions contained herein. The providers of this document do not certify compliance with local, state and federal laws, rules and regulations. This document is designed to facilitate inquires and information regarding Ag Water System Assessment and Remediation Guidelines for Water Resources.

Executive Summary

This document outlines Agricultural (Ag) Water Systems Assessments and Remediation Guidelines as guidance in using the tables of qualifying metrics and related decision trees establishing ag water quality expectations and management found in the water section (Issue 6) of the *Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens* (hereby referred to as the *Leafy Greens Guidelines*). This document provides assessment and mitigation activities for preventing microbial contamination from occurring and for when a water sample has generic *E. coli* levels and/or, in the case of treated water, total coliform bacteria above the acceptance criteria.

For purposes of this document:

- An Ag Water System Assessment is an inspection of the entire water system, including water source, storage, conveyance, distribution system, and all water-system-related equipment, for the purpose of identifying conditions (hazards) that may result in microbial contamination.
- Remediation guidelines describe corrective actions and / or mitigation strategies corresponding to the conditions observed in or measured during the Ag Water System Assessment.

An Ag Water System Assessment:

- When conducted periodically, helps to reduce microbial contamination.
- Provides the necessary foundation to develop or enhance your knowledge of your water system.
- Identifies and documents system deficiencies.
- Provides the priority areas for correction of inherent of periodic sources of risk.

Introduction

The Ag Water System Assessment and Remediation Guidelines described herein are to be used as guidance when following agricultural water management best practices and mitigating situations encountered while using the ag water metric tables and decision trees found in the *Leafy Greens Guidelines*. These guidelines require growers to perform an Ag Water System Assessment prior to the start of the growing season on water supplies and distribution systems used in the production of lettuce and leafy greens. In addition to performing an assessment at the start of the season, there are remediation approaches in the *Leafy Greens Guidelines* that require an Ag Water System Assessment to be performed to address microbial test results that do not meet acceptance criteria as well as treatment parameters that do not meet established values/limits.

Ag Water Systems Assessments & Remediation Guidelines

Agricultural water systems are a function of the source, storage, conveyance, distribution system, and all water-system-related equipment. Each component of an agricultural water system that is within your control must be evaluated to ensure that the quality of agricultural water used in leafy green operations is known (i.e., the required parameters are measured and conform to the prescribed standards) and adequate for its intended use.

In general, the purpose of conducting an Ag Water System Assessment is to investigate and assess the consistency and vulnerability of your ag water system. Ag water system assessments are required both: 1) as a preventive measure to be conducted on a routine basis, and 2) as a remedial action as part of troubleshooting activities such as when microbial water quality test results exceed the acceptance criteria.

Initiate an Ag Water System Assessment of your water system:

- It is best to begin assessing your ag water system at the water source. The *Leafy Greens Guidelines* defines water source as "the location from which water originates" (e.g., municipal, well, or surface waters such as rivers, lakes, or streams). Research conducted in the Arizona canal system recommended testing irrigation water 950 meters upstream from the point-of-use (Lothrop, 2015). Continue the ag water system assessment by evaluating the water storage, conveyance system, distribution system, and all water-system-related equipment from the source to the point-of-use. This same strategy should be applied during troubleshooting activities.
- For specific types of ag water sources, follow the Ag Water Systems Assessments and corresponding remediation guidelines outlined below.

It is also highly recommended that you have your entire water system checked annually by a licensed contractor with water system engineering / plumbing expertise. If your ag water system is managed by a water district/municipality, it is crucial that you maintain communications and records associated with those entities concerning potential contamination issues.

How do I know which type of ag water system I have?

Determining Your Ag Water System Type

It's important to note that the ag water metrics are focused on the **entire system** and not just the water source, nor a particular ranch. When determining whether you have a Type A or B ag water system, you must consider your entire system from the source to water storage to where water contacts the crop. If you have a complex ag water system, you may have both Type A and Type B water within your system as a whole. For example, you may have one source that splits, from the source, into multiple branched conveyance/distribution systems. If that source is an on-ranch well containing no detectable generic *E. coli* per 100 mL of irrigation water, continuous branches extending from the well that are not open to the environment may qualify as Type A water (it is in your best interest to confirm water quality at the point of use prior to application) while water pumped from the well into a reservoir would then be considered Type B water. If at any point in a system from source to crop contact, the water is open to the environment, that water is classified as Type B as defined in the metrics. *However*, Type B water can be treated to qualify as Type A water before it is applied to crops (see Table 1 for an overview of ag water system types). Also, if you blend water from Type A and B system types, the water defaults to Type B water.

Ag water system assessments, microbial testing, and when applicable, treatment verification are all used to determine your ag water system type.

Type A

Type A water is ag water that is unlikely to contain indicators of fecal contamination either due to natural hydrogeologic filtration or through controlled USEPA and state regulated treatment.

Type B

All other ag water systems including surface water sources and open conveyance systems, are Type B Ag Water Systems

TABLE 1. Overview of Ag Water System Types

Source	Conveyance, Storage, etc.	Type A	Type B	Type B → A
Municipal water source	Conveyed through a closed delivery system	X		
	Conveyed through an open delivery system without treatment		X	
	Conveyed through an open delivery system and treated prior to application			X
Private water supplier	Conveyed through a closed delivery system	X		
	Conveyed through an open delivery system without treatment		X	
	Conveyed through an open delivery system and treated before being applied			X
On-farm well	Conveyed through a closed delivery system, may include tank storage	X		
	Conveyed through an open delivery system without treatment or subject to contamination (e.g., does not meet Type A microbial standards)		X	
	Conveyed through an open delivery system and treated before being applied			X
	Pumped into a reservoir and treated prior to application through a closed system			X

Surface water	Conveyed through a closed delivery system		X	
	Conveyed through an open delivery system without treatment		X	
	Pumped into a reservoir and treated prior to application through a closed system			X
Irrigation canal water	Conveyed through a closed delivery system		X	
	Conveyed through an open delivery system without treatment		X	
	Pumped into a reservoir and treated prior to application through a closed system			X

Hazard Analysis: When I assess my ag water system, what should I be looking for?

The purpose of an Ag Water System Assessment is to identify, assess, and mitigate the microbial hazards that could potentially contaminate ag water. When assessing the hazards to a system, focus on scenarios that could potentially lead to contamination. Just because a hazard is present does not necessarily mean it will result in contamination; identifying the hazards allows you to evaluate the potential risk related to the hazard and, when appropriate, apply or establish measures to reduce the risk.

STEP 1: Assess Hazards Related to Water Sources

Start by completing a detailed water system description and provide a unique ID for each water system that will be used to produce lettuce and leafy greens. Whenever possible you should begin your ag water system assessment at the water system source as this is the first opportunity for controlling microbial contaminants. The *Leafy Greens Guidelines* defines water source as "the location from which water originates" (e.g., municipal, well, or surface waters such as rivers, lakes, or streams). Research conducted in the Arizona canal system recommended testing irrigation water 950 meters upstream from the point-of-use (Lothrop, 2015). When investigating your ag water system source, you should identify the characteristics, conditions, and activities that may lead to microbial contamination. In addition to assessing water system components currently in use, you should also assess all components such as abandoned wells and ancillary equipment that are not in use as these unused components can potentially serve as conduits for surface and subsurface waters during flooding or heavy rain.

Wells

When you assess your irrigation wells, you should focus on the integrity (meaning the state of repair) of the well components (see Table 2) and the condition of the area surrounding the well (see Table 3). You should check your well(s) on a regular basis and have licensed contractor with water system engineering/plumbing expertise inspect it annually. Keep records of the inspection dates and any repairs that were made. Many issues associated with component parts of a well are not visible to the naked eye. When addressing issues that threaten the integrity of the well or its components, it is highly recommended to consult with an experienced professional (e.g., an engineer, hydrogeologist, etc.).

TABLE 2. Assessing Well Components

Well component	Assessment Guidelines	Remediation Guidelines
What to inspect	What to look for	What to do about it
Well casing	Listen for water running down into the well. If you can hear water, there could be a crack or hole in the casing. If you can move the casing by pushing against it, you may also have a problem with the integrity of the casing. The well casing should extend at least 18 inches above the ground.	Contact a well contractor or other trained individual for well casing repair or construction of a new well.*
Annular space – the space between two well casings or between the casing and the wall of the drilled hole.	The annular space of the well should have a minimum of 25 feet of sealing material.	Contact a contractor or other trained individual for correction of a deficient **annular** space seal or construction of a new well.*
Well cap or seal	The well should be completely sealed against surface water, insects, or other foreign matter. Look for holes, missing plugs, leaking water (artesian flow). If water is coming out, then contaminants can seep in.	Replace any missing plugs and seal any openings, gaps or cracks. *Contact a well contractor or other trained individual to install a new cap and/or wellhead gasket.*
Well vent	Check the cleanliness & integrity of the well vent screen. Look for tears or holes.	Vents must be covered with a screen. Replaced damaged vent screen.
Concrete well pad	Look for cracks that would allow water to enter well casing.	Seal cracks or re-pour a new concrete pad. Ground should slope away from well so that surface water cannot collect near the well.
Well pump	Make sure pump is operating properly; check for corrosion.	Clean, repair or replace pump

*Many CA and AZ counties' Departments of Environmental Health have listings of licensed contractors.

Information taken from A Guide for The Private Well Owner, Santa Clara Valley Water District, County of Santa Clara, Department of Environmental Health and Preparing for a Sanitary Survey: Information to Help Small Water Systems, WA State Dept of Health, DOH Pub.#331-238.

TABLE 3. Assessing the Area Surrounding the Well

Issue	Assessment Guidelines		Remediation Guidelines
Cleanliness	Look for potential contaminants, animal feces, or debris.		Manually remove anything that could pose a contaminant risk. Consider creating a buffer or fencing to protect well head from contaminants.
Gradient	There is standing water of unknown quality around the well or water draining toward the well. Well is downstream from a potential contaminant source.		Re-grade ground around the well so it slopes away from the well but does not contaminate production area. Move the potential contamination source.
Potential contaminant source	Recommended minimum horizontal distance from:		
	Any sewer	50 ft.	Do one or more of the following: Remove potential contaminant source if possible Treat the water Decommission the well and establish a new well at another location.
	Watertight septic tank or subsurface sewage leaching field	100 ft.	
	Cesspool, seepage, manure	200 ft.	
	Animal enclosure	100 ft.	

Information taken from DWR – Southern District Water Well Standards, Part II, Section 8 and A Guide for The Private Well Owner, Santa Clara Valley Water District, County of Santa Clara, Department of Environmental Health

Surface Water in Canals, Laterals, and Ditches

Per Table 4, when you do an Ag Water System Assessment of canals, laterals, and ditches, you should focus on the integrity of surrounding banks (i.e. levees, sides, dikes, etc.) including potential point source and non-point source contributions or discharges (e.g. drainage into these systems). Inspect these water sources on a regular basis and keep records of the date of inspection and any observations and corrections you made.

TABLE 4. Guidelines for Assessing Surface Water

Issues	Assessment Guidelines	Remediation Guidelines
Animal hazards	Look for evidence of animal hazards (observed animal in canal, fecal deposits, burrowing, or animal carcasses).	Remove animal debris; if animal intrusion is a regular occurrence, investigate the potential cause for intrusion, implement buffers or fencing (restriction) of wild or domestic animals from up-stream water sources including areas where birds may roost overhead (e.g., overpass, underpass, powerlines, turnout headers).
Contaminating waters	Look for water that may be draining into the canal.	Redirect water of unknown quality with diversion dikes, gradients, inlet/outlet control structures, etc. If water system is managed by a water district/municipality, notify appropriate authorities that waters of unknown quality is entering the system.
Cleanliness	Look for trash and debris accumulation.	Remove and dispose of items away from water.
Canal integrity	Look for evidence that the structure of the canal has been compromised.	Report leaking or damaged canals to the appropriate authority (e.g., water district).
Canal maintenance	Be aware of canal maintenance (e.g. dredging) activities	Establish communications with irrigation districts to confirm canal maintenance schedule. Do not irrigate with canal water immediately following a canal maintenance activity.
Adjacent property	Look for potential contamination sources adjacent to the canal such as roads, compost / manure piles or spreading, human sewage, etc.	Remove hazards or address hazards with property owner.

Irrigation Water Reservoirs

When conducting an Ag Water System Assessment of a reservoir, focus the inspection on the condition of the source water, the integrity of the reservoir's surrounding bank system, and potential for contamination from both point source (e.g. animal hazards) and non-point sources (e.g. drainage into the reservoir, influent). Inspect reservoirs on a routine basis and keep records of the date of inspection and any observations made.

TABLE 5. Guidelines for Assessing Reservoirs

Issues	Assessment Guidelines	Remediation Guidelines
Contaminated source water	Biannual or pre-production testing of source water (e.g. well water as described in *Decision Tree for Well Head*)	Options: Drain reservoir and allow to dry; disinfect connection system before refilling reservoir with treated source water. Remove sediments if lined. Treat water as it is taken from the reservoir.
Animal hazards	Look for evidence of animal hazards (observed animal in reservoir, fecal deposits, carcasses).	Remove animal debris; if animal intrusion is a regular occurrence consider installing fencing around the reservoir and/or, in the case of domesticated animals, around the animals
Contaminating influent	Look for potentially contaminated water that may be draining into the reservoir. Exercise caution when back-flushing filtration systems so that this water does not return directly to the source.	Redirect water with diversion dikes, gradients, drainage pipes, inlet control structures, etc. A managed grassed buffer zone around reservoir (but not on banks) helps prevent contamination.
Reservoir integrity (including linings)	Look for evidence that the reservoir structure or lining has been compromised.	Repair damaged linings or any leaking reservoir under your control.
Connected reservoirs	Confirm there is an air-gap separation at the supply side	Establish an air gap connection if one does not exist
Overflow pipe/intake/ aeration systems	Observe whether they are clean and free of weeds and debris.	Cover opening with a mesh screen. Remove debris and weeds.

STEP 2: Assess Hazards Related to Irrigation Systems

Contamination of irrigation systems can be prevented with proper maintenance and storage. You should inspect your irrigation water conveyance equipment on a routine basis to ensure the equipment is not compromising water quality. Document your routine inspections as well as inspections when microbial levels of irrigation water are above acceptable levels.

For mechanical components:

- Check primary and secondary filtration equipment for cleanliness and proper function.
- Check for leaks on seals, gaskets, and fittings.
- Check for overall cleanliness of components (especially at the beginning of the season).

For water lines:

- Check for visual evidence of microbial growth including, but not limited to white stringy slime and red filamentous, thread-like sludge.[1]
- For drip irrigation systems, use of a water treatment (approved by the USEPA for agricultural use) is advised if water source is not treated (see footnote for a chlorine treatment formula[2] and an example of its use[3]).
  - o Since bacteria can grow in filters, inject chlorine upstream from filter units.
  - o Chlorine may be injected continuously (at concentration of 1-2 ppm) or as a shock treatment (at concentrations of 10-30 ppm). If system is shock treated, the treated water must be disposed of according to regulations and not applied to crops.

For all components:

- Inspect for visual evidence that storage areas for equipment and components have not been contaminated through animal roosting or nesting.
- Sanitary unit/toilets maintenance and use have not impacted irrigation system components.
- Composts or other farm inputs have not contributed to contamination of irrigation system components.
- Establish a documented regular maintenance schedule of inspection and flushing.
- Develop SOPs for equipment maintenance and cleaning.

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1 Benham, B., Ross, B., (2002), Filtration, Treatment, and Maintenance Considerations for Micro-Irrigation Systems, Virginia Cooperative Extension, Pub. No. 442-757.

2 A general formula for calculating the amount of chlorine for injection:

$IR = Q \times C \times 0.006/S$

Where: IR = injection rate (gal/hour); Q = irrigation system flow rate (gal/min); C = the desired chlorine concentration (ppm); and S = strength of chlorine solution used (percent).

Chlorine materials commonly used and their corresponding strength (S)

- Sodium hypochlorite: 5.25 - 15
- Calcium hypochlorite (dry): 65 - 70
- Chlorine gas: 100

It may be necessary to lower the pH during chlorination to increase the effectiveness of the microbial action.

- pH should be ≤ 7.0.
- Acid and chlorine should be added to the system 2 to 3 feet apart.
- NEVER combine chlorine and acid in the same container.

3 Example: A grower wishes to use household food-grade chlorine products bleach (NaOC at 5.25% active chlorine) to achieve a 3-ppm chlorine level at the injection point. The flow rate of his irrigation system is 90 gal/min. IR = 90 gal/min x 3 ppm x 0.006/5.25 = 0.31 gallon per hour. At an irrigation flow rate of 90 gal/min, the grower is pumping: 90 gal/min x 60 min = 5400 gal/hr. The goal is to inject 0.31 gallon of chlorine solution into 5400 gallons of water each hour that injection occurs. If the injector is set for a 300:1 ratio, it will inject 5400/300 or 18 gal/hr. Then, 0.31 gallon of chlorine solution should be added to 18 gallons of water in the stock solution. Note: be careful to use the same time units (hours) when calculating the injection rate.

TABLE 6. Risk factors related to the presence of microbial hazards in ag water sources

Risk Factor	Result	Source
Rain events	Increased total coliform bacteria levels	Steele *et al*, 2005 Topalcengiz *et al*, 2017 Ellis *et al*, 2015
	Increased *Salmonella* and *E. coli* concentration in Georgia ponds	Harris *et al*, 2018 Gu *et al*, 2013 Luo *et al*, 2015
	Positive association with *Salmonella* spp., *Campylobacter* spp., and *E. coli* O157:H7 detection in water	Jokinen *et al*, 2012
Livestock presence and density	Increased nutrients in water	Nash *et al*, 2009
	Increased concentration of *L. monocytogenes* and pathogenic *E. coli*	Falardeau *et al*, 2017 Benjamin *et al*, 2014
	Positive association with *Salmonella* spp., *Campylobacter* spp., and *E. coli* O157:H7 detection in water	Jokinen *et al*, 2012
Wildlife presence and density	Increased *E coli* detection	Somarelli *et al*, 2007 Cox *et al*, 2005
Wind speed, direction	Higher *E. coli* levels	Benjamin *et al*, 2013 Francy *et al*, 2013
Season	Higher prevalence, lower survival in summer months in Arizona canals	Fonseca *et al*, 2011
	Increased O157 detections in irrigation ponds during summer and fall in Georgia	Gu *et al*, 2013
	Positive association with *Salmonella* spp., *Campylobacter* spp., and *E. coli* O157:H7 detection in Alberta ag watershed	Jokinen *et al*, 2012

Corrective Actions and Remediation

Remediation: Well Disinfection

If generic *E. coli* level in a well water sample is above corresponding acceptance criteria, wells must be disinfected in order to reduce or eliminate the contamination. Follow the disinfection steps outlined in Table A in Appendix 1.1 and keep records of when, why and how disinfection was done as well as corresponding microbiological tests to confirm successful treatment.

TABLE 7. Instructions for Well Disinfection Using Chlorine:

Any USEPA approved treatment can be utilized. Chlorine is a widely used chemical water treatment, but other chemical, physical, and biological treatments are also available.

Steps	Detailed Disinfection Instructions	Step Summary
1.	Using food-grade chlorine, create a solution containing at least 50 mg/l (or ppm - parts per million) available chlorine and add it to the well. Tables A-F in Appendices 1.1-1.3 lists quantities of various chloride compounds required to dose 100 feet of water-filled casing at 50 mg/l for diameters ranging from 2 to 24 inches. If bringing the well back into service quickly is desired (such as when wells have been repaired or when a pump has been repaired or replaced), the solution should contain at least 100 mg/l available chlorine. To obtain this concentration, double the amounts shown in corresponding table.	Use the appropriate table in Appendices 1.1-1.3 to make a 50 ppm (mg/L) chlorine solution and add it to the well.
2.	To prevent contamination of the well during disinfection, first clean the work area around the top of the well. Remove grease and mineral deposits from accessible parts of the well head and flush the outside surfaces with chlorine solution (1/2 cup of food-grade sodium or calcium hypochlorite in 5 gal of water). Turn off the pump. Remove the cap or the well plug on the rubber seal. There are many types of well caps and plugs. If you have questions, you should contact a licensed well driller. If you have a submersible pump, you may also want to contact a licensed well driller for advice on disinfection procedures. Wash the pump column, drop pipe, or anything inserted into the well with chlorine solution. Try to coat the sides of the casing as you pour. NOTE: To prevent later corrosion, thoroughly flush sensitive pump parts such as wiring with fresh water after disinfection process is completed.	Clean surrounding area & disinfect well head. Turn off the pump. Remove well cap. Wash sides of well casing, pump column, and anything inserted into the well with chlorine solution.

3.	After it has been placed into position, turn the pump on and off several times so as to thoroughly mix the disinfectant with the water in the well. Repeat this procedure 3-5x at 1-hour intervals. Test for the presence of chlorine in well discharge with a residual chlorine test[4]; if chlorine is not detected, the disinfection process should be repeated.	Mix well water by turning pump on and off several times until discharge tests positive for residual chlorine. Repeat 3 - 5x at 1-hour intervals.
4.	The well shall be allowed to stand without pumping for 24 hours.	Let pump/well rest for 24 hours.
5.	The waste water shall then be pumped to land and contained. Avoid all water conveyance features such as swales, ditches, canals, creeks or streams. Do not allow overland flow to reach surface waters. Pump until presence of chlorine is not detectable. The absence of chlorine is best determined by testing for available chlorine residual.[5] NOTE: Heavily chlorinated water should not be discharged into any plumbing system that utilizes individual sewage disposal systems (septic tanks). Such strong disinfectants could neutralize the bacteria needed to stabilize the sewage and may also damage the soil adsorption system.	Pump water to a safe waste location until chlorine is no longer detected.
6.	A water sample shall be taken and submitted to a certified laboratory for examination. For individual wells, technical advice regarding the water sample collection may be obtained from your local health departments or from the laboratories that will examine the sample. If no technical assistance is available, use the following procedure: Use a sterile sample bottle, preferably one provided by the laboratory, and before sampling ensure that the sample bottle is properly labeled with location, date, and time of sampling. It is extremely important that nothing except the water to be analyzed comes in contact with the inside of the bottle or the cap; the water must not be allowed to flow over an object (such as the hands) and into the bottle while it is being filled. If the water is collected from a sample tap, turn on the tap and allow the water to flow for 2 or 3 minutes before collecting the sample. Do not rinse the sample bottle. The sample should be delivered to the laboratory as soon as possible and in no case more than 6 hours after its collection. During delivery, the sample should be kept as cool as possible (but not frozen).	Take a water sample using sanitary techniques and submit it to a lab for testing.

4 Clark, G., Lamont, W., Marr, C., Rogers, D., (1996) Maintaining Drip Irrigation Systems, Kansas State University, Commercial Vegetable Production. https://www.bookstore.ksre.ksu.edu/pubs/mf2178.pdf

5 Inexpensive color comparator residual chlorine test kits can be purchased from most large department stores and swimming pool supply companies.

7.	If the laboratory analysis shows the water is not free of generic *E. coli* contamination, the disinfection procedure should be repeated. Depending on the level of contamination, it may be necessary to use a higher concentration chlorine solution (several times that shown in Table **A-F in Appendices 1.1-1.3**). The water should then be retested. If repeated attempts to disinfect the well are unsuccessful, a detailed investigation to determine the cause of the contamination should be undertaken.	If testing shows microbial levels are still above acceptable action levels, repeat the disinfection process.

See Tables A-F in Appendices 1.1 – 1.3 for the amount of chlorine compound required to dose specific volumes of water-filled well casing at 50 milligrams per liter[6]

- Appendix 1.1 – 70% calcium hypochlorite[7] (dry weight)[8]
- Appendix 1.2 – 25% chloride of lime[8]
- Appendix 1.3 – 5.25% sodium hypochlorite[9]

6 Some authorities recommend a minimum concentration of 100 mg/L. See instructions given in Appendices to calculate higher concentrations.

7 HTH, Perchloron, Pittchlor, etc.

8 Where dry chlorine is used, it should be mixed with water to form a chlorine solution prior to placing it into the well. Note that dry chlorine should always be added to water, not vice versa. Further, the chemical should be added slowly. These precautions are necessary to lessen the possibility of a violent chemical reaction.

9 Food-grade chlorine, etc.

Remediation for Distribution Systems

TABLE 8. Ag Water System Assessment of Distribution System

Issues	Remediation Guidelines
There are cross-connections in the plumbing system.	Make sure that your plumbing is not connected to another source of water that may be contaminated (e.g. a defunct community water system).
There is not adequate back-flow protection.	Install a back-flow prevention device on every outdoor faucet (available at most hardware and plumbing supply stores).
There are dead-end or unused water lines connected to your distribution system.	Flush lines regularly or remove any used lines or sections of the water system.
There are abandoned or inactive wells on my property.	When no longer in use, wells must be decommissioned to prevent them from functioning as a vertical conduit for contaminants that could impact the entire water supply. The process of decommissioning, capping or sealing an abandoned or inactive well must be done by carefully filling the interior of the well casing with a sealing agent. This procedure should be conducted by personnel with expertise in this type of activity.

Remediation for Tank Storage: Clean and Sanitize

If water in storage tank tests positive for generic *E. coli* (or total coliform bacteria if the water is treated), contact a water system contractor or other trained individual to clean and disinfect the tank. Document all cleaning and sanitizing events.

Remediation by Water Treatment

Agricultural Water Treatment Systems

There are typically three types of water treatment systems that a grower would employ to meet current LGMA metrics for Agricultural Water Type B to Type A. Category I – Liquid Chemical Injection, Category II – Tablet System, or Category III – Physical Treatment with Pesticide Device.

Liquid Chemical Injection

- Liquid hypochlorite
- Peroxyacetic acid
- Chlorine dioxide
- Hydrogen peroxide
- Liquid Calcium hypochlorite

Tablet Systems

- Calcium hypochlorite

Physical Treatment with Pesticide Device as referenced by EPA

- Ultraviolet light
- Ozone generator
- Physical filtration (membrane or other media)

Critical Components of an Agricultural Water Treatment System

Important to all agriculture water treatment systems are the components that are put together to create a successful system capable of reducing microbiological indictor organisms to acceptable levels. For each of the three identified above, critical components have been listed below in an effort to advise selection of a treatment system as well as a reminder of the components necessary.

Liquid Chemical Injection

Any liquid that is recognized by EPA as a registered pesticide product for agricultural use can be injected.

- Operator
- Source water
- Power source (electric or fuel generator)
- Water inlet
- Electric pump (e.g. peristaltic) or Hydraulic powered system (e.g. venturi)
- Chemical inlet
- Liquid disinfectant/tote
- Treated water outlet
- Agricultural water distribution system

Tablet Systems

- Operator
- Source water
- Power source (electric or fuel generator)
- Water inlet
- Electric or fuel pump (e.g. peristaltic)
- Chemical reservoir/barrel
- Chemical tablets
- Treated water outlet
- Agricultural water distribution system

Physical Treatment with Pesticide Device

Any USEPA Pesticide device can be used which is effective for in-line treatment of agricultural water.

Note: Because some of these devices commonly used by industry currently do not hold USEPA approval, supporting scientific studies which validate the activity of the system as a grower would intend to operate it will be needed.

- Operator
- Source water
- Power source (electric or fuel generator)

- Water inlet
- Electric or fuel pump (e.g. peristaltic)
- Filter, light or generator
- Treatment reservoir (can be within the distribution system)
- Treated water outlet
- Agricultural water distribution system

Start-up, Commissioning and Standard Operating Procedures for Agricultural Water Treatment systems

With start-up and commissioning of any new equipment or practice on-farm, it is important to evaluate environmental conditions that may affect irrigation water treatment efficacy and performance.

- Parameters that provide valuable information about treatment efficacy in relationship to water quality are:
    - Turbidity
    - Total suspended solids
    - pH*
    - Flow rates*
    - Antimicrobial dose*
    - Historical microbial monitoring data

*These items are required per the *Leafy Greens Guidelines*.

Develop an individualized, written Standard Operating Procedure (SOP). SOPs outline what tasks need to be done, how to perform them, and can generally be followed by anyone. Written SOPs help ensure proper compliance and implementation of critical tasks such as irrigation water treatment. Many equipment manufacturers will likely have a SOP that they can provide to you at installation that can be modified to your individual farm practices.

A water treatment SOP may include:

- Step-by-step instructions to ensure the water treatment is correctly implemented by following the SOP
- Location, name, and suggested supplies needed
- When and how often practices should be completed
- Required records
- Critical limits and operational limits
- Description of what is being monitored and when it is to take place
- Corrective actions if critical limits are not met

Monitoring, Verification and Validation

Monitoring can largely fit into two overarching categories — **verification** and **validation**. **Verification** asks whether the system is being implemented according to the SOP. It is the process of confirming the truth, accuracy, or validity of your agricultural water treatment system. While monitoring of operational parameters, mentioned below, are part of the agricultural water treatment system **verification**, the act of monitoring itself does not satisfy the **verification** requirement.

Verification may include a records review of monitoring activities have been performed as specified, if corrective actions have been performed whenever monitoring indicated non-compliance from critical limits, if equipment has been calibrated at the frequencies specified in the SOP, etc. Records must also be reviewed, dated, and signed by the supervisor or responsible party within a reasonable time after the records are made and are included as part of the system **verification**.

Alternatively, the goal of conducting a **validation** is to demonstrate that a process, when operated within established limits, produces a product of consistent and specified quality with a high degree of assurance. **Validation** of agricultural water treatment systems is necessary to obtain water with all desired quality attributes. **Validation** establishes the process control **verification** parameters.

Typically, a **validation** is conducted by the manufacturer/supplier or other third party that is certified to conduct the scientific study and not conducted on-farm by individual users. Individual users should be able to reference an appropriate validation study to their ag water system. It may include scientific evaluations of log reductions in concentration of foodborne pathogens or indicators important to the fresh produce industry. Log reductions are the calculation of the number of bacteria, total coliform bacteria for example, that has died-off or been inactivated as a result of a treatment such as chemical addition (e.g. PAA, chlorine) to water. Log reductions are calculated by collecting water samples both before and after treatment at predetermined time points and then comparing the concentrations of bacteria in both sets of samples. A log value is then calculated to represent that reduction in concentration of bacteria as a result of treatment.

$$\text{Log Reduction } E.\ coli = \log 10 \left(\frac{\text{No. of } E.\ coli \text{ in water before treatment}}{\text{No. of } E.\ coli \text{ in water after treatment}} \right)$$

And percent reduction is calculated with the following formula:

$$Percent\ Reduction = \frac{(A - B) \times 100}{A}$$

Where:

A is the number of viable microorganisms before treatment,

B is the number of viable microorganisms after treatment

In additional to bacterial reduction/inactivation, **validation** studies typically also include evaluation of the impact of environmental parameters such as pH, temperature, turbidity on the efficacy of an agricultural water treatment chemical or process, as well as industry recommended critical limits.

Critical limits are a maximum and/or minimum value to which a parameter must be controlled to prevent, eliminate, or reduce to an acceptable level the occurrence of the identified hazard or indicator. Alternatively; an **operational limit** can be used to inform the operator of the agricultural water treatment system that something may be wrong with the system operation and may trigger them to implement a **process adjustment**.

> **Example:** The agricultural water treatment operator for Sunshine Ranch sets an ***operational limit*** of 5 ppm of free chlorine to ensure that they are well above the ranches ***critical limit*** of 2 ppm. Upon measuring free chlorine residual at the last sprinkler head, the operator notices the ppm starting to fall below the ***operational limit*** of 5 ppm over the last hour of sampling. The

operator decides to conduct a ***process adjustment*** of increasing the dosing rate at the pump to bring the free chlorine residual back up to the farms ***operational limit***. If the residual ppm of chlorine had dropped below the ranches ***critical limit*** of 2 ppm, a ***corrective action*** would have been warranted.

Managing Validation and Verification of Irrigation Water Treatment Systems within the Leafy Green Guidance

Initial Irrigation Water Treatment Assessment

Prior to 21 days-to-scheduled harvest conduct an initial irrigation water treatment assessment to establish treatment process parameters that will be monitored to ensure consistent treatment delivery and to demonstrate effectiveness. Repeat this assessment if a material change (e.g., change in equipment or type of water treatment) to your system occurs. Incorporate this assessment's findings into your water treatment SOP.

Before using treated water to irrigate crops within the ≤ 21 days-to-scheduled harvest timeframe growers must first establish SOPs outlining irrigation treatment and process parameters for all irrigation treatment systems unless duplicated systems are in use.

Table 9. Initial Irrigation Water Treatment Assessment (taken directly from the *Leafy Greens Guidelines)*

<table>
<tr><th colspan="2">Initial Irrigation Water Treatment Assessment</th></tr>
<tr><td colspan="2">Target Variable: Antimicrobial treatment parameters (e.g., chlorine or other antimicrobial treatment concentration, other per manufacturer's recommendations).</td></tr>
<tr><td>Antimicrobial treatments: USEPA-approved for use in agricultural water.
Initial Assessment Sampling Procedure:
To conduct the assessment, begin sampling after your irrigation system has stabilized (i.e., all lines are pressurized, and the calculated feed-rate is verified). Test the water at least three (3) times producers at the manufacturer's recommended sampling location in the delivery system (e.g., first or last sprinkler head).
Initial Assessment Sampling Frequency:
This is a one-time seasonal testing event for each treatment system conducted during one irrigation event occurring before the 21-day-to-scheduled-harvest-period begins. Sample the water at least three (3) times at least 20 minutes apart.
Initial Assessment Acceptable Performance Criteria:
Per label instructions on parameters indicating treatment (e.g., sanitizer) effectiveness (e.g., chemical break point).</td><td>This one-time initial assessment must be completed on each irrigation system delivering treated water to crops before entering the 21-days-to-scheduled-harvest timeframe. Before using treated water to irrigate crops within the (≤) 21 days-to-scheduled-harvest timeframe, producers must first establish SOPs outlining the following about their irrigation system and treatment process:
• The irrigation system parameters, such as water flow rate, distance from the treatment to the first sprinkler, the pipe diameter, etc. that are required to set up and run the treatment system.
• The treatment process parameters such as antimicrobial dosing unit settings, pH, residual antimicrobial level at discharge point (first sprinkler), and any other parameter as needed that will be monitored to ensure consistent treatment delivery and to demonstrate its effectiveness in meeting the microbial requirements.</td></tr>
<tr><td colspan="2">Records: Document treatment-related parameter values such as antimicrobial levels, pH, dose settings, etc. to demonstrate the system is working as intended. Each water sample and analysis shall record the type of water source, date, time, and location of the sample, the method of analysis, and, if quantitative, the detection limit. All test results and remedial actions shall be documented and available for verification from the producer/shipper who is the responsible party for a period of two years.</td></tr>
</table>

Initial Microbial Water Treatment Assessment

Confirm that water microbial quality is not being degraded as it passes through each of your water treatment systems (i.e., due to equipment conditions) by performing a microbial water quality assessment during an irrigation event before entering the less than 21 days to scheduled harvest timeframe.

Table 10. Initial Microbial Water Quality Assessment (taken directly from the *Leafy Greens Guidelines*)

Initial Microbial Water Quality Assessment
Target Organisms: • Total coliforms (TC) • Generic *E. coli*

Sampling Procedure:

Collect at least three (3)-100 mL samples at the end of the delivery system (e.g., last sprinkler head).

Sampling Frequency:

This is a one-time seasonal sampling event conducted for each irrigation system during one irrigation event occurring before the 21-day-to-scheduled-harvest-period begins. Collect the three (3)-100 mL samples no closer than 20 minutes apart. (Also conduct this assessment after any material modifications to Type A overhead irrigation systems.)

Acceptance Criteria – Initial Assessment

In three (3) consecutive samples:

Total coliform: A maximum level of ≤ 99 MPN in 100 mL or an adequate log reduction based on the untreated water's baseline total coliform levels*

Generic *E. coli*: No detection in two (2) of three (3) samples with a maximum level of ≤ 10 MPN allowed in one (1) sample

Acceptance Criteria - Follow-up Testing

Non-detectable in four (4) of five (5)-100 mL samples and ≤ 10 MPN as the single sample maximum for one (1) sample.

Note: For the purposes of water testing, MPN and CFU are considered equivalent.

The purpose of this assessment is to confirm that the water's microbial quality is not being degraded as it passes through your system (i.e., due to equipment conditions). The assessment is performed to verify that your irrigation water delivery system is able to maintain and deliver water of the same microbial quality (e.g., Type A) as the source water. Unless there is a material change to your system (e.g., change in equipment or type of water treatment), this is a one-time assessment for each irrigation system, and it is not necessary to repeat system evaluations for each irrigation event.

To test your water delivery systems, sample and test irrigation water during an irrigation event. All discrete systems are to be tested before entering the 21-days-to-scheduled-harvest timeframe. To assess the water delivery system, water samples are taken at the end of the line where water contacts the crop.

Initial Assessment Testing

- After activating and stabilizing your treatment system (i.e., all lines are pressurized and the performance-established feed-rate is verified), sample and test the treated water source for total coliform and generic *E. coli* in three (3)-100 mL samples. To maintain its Type A status, water samples must have: no detectable generic *E. coli* in at least two (2) of the three (3) samples with a maximum level no greater than (≤) 10 MPN in the remaining sample, and
- data monitoring and total coliform at a level no greater than (≤) 99 MPN in 100 mL

* As an alternative to the threshold approach for total coliform (TC) (≤ 99 MPN / 100 mL), operators can verify their treatment system by conducting paired pre- and post-treatment microbial testing of source water (A log reduction assessment is typically used to verify a treatment system based on TC concentration – see section below related to water testing and monitoring activity related to historical pre-treatment TC counts).
If two (2) or more of the three (3) water samples do not meet the acceptance criterion for total coliform or generic *E. coli* or the generic *E. coli* level in at least one sample is greater than (>) 10 MPN, then conduct the following follow-up tests:

Follow-up Testing

1. Pause irrigation and perform a root cause analysis and an ag water system assessment as described in Appendix A to determine why the treatment was not effective and correct the failure.
2. After assessing the system, retest the system for total coliform and generic *E. coli* in five (5)-100 mL samples collected during the next irrigation event using the sampling procedure and frequency (described in the left column). Water samples can be pulled from the end of any system nodes/branches in the irrigation system of concern. If test results meet the acceptance criteria for total coliform and generic *E. coli*, the water system can be used as a Type A treated system.

Testing Failure

If test results exceed the acceptance criteria for TC or generic *E. coli*, then the system is not considered acceptable for a treated Type B→A ag water system. Perform a root cause analysis to identify why the treatment was not effective and correct the failure. In the interim, the water can be used as a source for a Type B ag water system.

Test Method: Any FDA-allowed method

Records: Each water sample and analysis shall record the type of water source, date, time, and location of the sample, the method of analysis, and, if quantitative, the detection limit. All test results and remedial actions shall be documented and available for verification from the producer/shipper who is the responsible party for a period of two years.

Monitoring of Agricultural Water Treatment Systems

You must monitor any treatment of agricultural water with **each irrigation event** for the process parameters determined in the initial irrigation water treatment assessment and established by SOP at a frequency adequate to ensure that the treated water is consistently safe and of adequate sanitary quality for its intended use and/or consistently meets the relevant microbial quality as required in the *Leafy Greens Guidelines*' table describing the "Routine Verification of Microbial Water Quality". The following section outlines both non-microbiological and microbiological monitoring activities that support successful implementation of agricultural irrigation water treatment.

Non-Microbiological Water Testing as a Monitoring Activity

The text below outlines treatment parameters that are generally suggested for each of the three categories of agricultural water treatment system. It is important to align your SOP and manufacturer or chemical supplier recommendations to ensure that the monitoring parameters you choose are sufficient to meet your treatment objectives.

Special attention should also be payed regarding any operational changes or process adjustment as to how long to wait after a modification has been made to re-verify the parameter of interest (e.g. purging and re-stabilization of the disinfectant in the distribution system).

Failure to bring the system back into critical limit(s) performance, results in a trigger for microbial testing per the *Leafy Greens Guidelines*' table containing the "Routine Verification of Microbial Water Quality" if water quality falls outside the acceptable monitoring parameters established within the company SOP.

Liquid chemical injection

- Verification setting for chemical injection systems
- Verification pumps are on and operating at recommended flow rate
- Verifying Concentration of residual disinfectant
- pH

Tablet systems

- Verifying Concentration of residual disinfectant
- pH
- Oxidation Reduction Potential (ORP)

Physical Treatment with Pesticide Device

- Unit power is ON
- Sensor is operating
- % UV transmittance (UV dose)
- Preventative Maintenance (tube cleaning records, etc.)

***NOTE:** It is important to note that the USEPA and the National Organic Program (NOP) have established regulations and standards for maximum disinfectant/chemical residuals allowed. "Maximum residual disinfectant level" is a term defined by the USEPA in the Code of Federal Regulations, Title 40 §§ 141.2, 141.65 as the highest level of a disinfectant allowed in drinking water. This level is currently established by the USEPA at 4 mg/L for chlorine (as Cl_2) and 0.8 mg/L for chlorine dioxide and should be followed by industry.

Microbiological Water Testing as a Monitoring Activity

Microbial water testing is recommended to both validate and verify treatment efficacy and to demonstrate adequate sanitary quality for use on produce. Using the Type B to Type A water metric values, water treatment systems should be monitored post treatment for the following:

- Target: generic *E. coli* and total coliform bacteria per 100 mL collected at the last sprinkler head.
- Log reduction approach – comparing pre- and post-treatment microbial water quality (testing for total coliform bacteria)

Treatment verification: operators can verify their treatment system by conducting paired pre- and post-treatment source water testing for total coliform bacteria. This method depends on your starting TC concentration, so an adequate reduction is achieved as follows:

- For example, if your peak historical pre-treatment TC counts are log 3 in source water, then your treatment process must perform a 2-log reduction.
- For example, if your peak historical pre-treatment TC counts are log 4 in source water, then your treatment process must perform a 3-log reduction.

Table 11. Log Reduction Chart

Log Reduction	% Reduction of Bacteria
1	90
2	99
3	99.9
4	99.99
5	99.999
6	99.9999

Corrective Actions

Corrective Actions and Troubleshooting:

Your goals are to as quickly as possible correct any issue that may cause a non-compliance if you have a failed water test. You will also need to determine what produce has been exposed to water that was not adequately treated. It is wise to conduct an assessment based on factors such as time until harvest, microbial quality of water when deviation was identified, and determine what do with crops which came into contact with untreated or poorly treated agricultural water. Your recordkeeping of corrective actions is also critical in maintaining compliance and proof for future auditing.

Summary

- Have your entire water system checked annually by a licensed contractor or other trained individual and as required in the decision trees in the current edition of the *Leafy Greens Guidelines*.
- Keep detailed records of every Ag Water System Assessment and corrective / remedial action that you perform. Documentation should include:
    - Date of assessment
    - A description of the condition of the water system and any relevant observations
    - Location and description of problem areas and the corresponding repairs and/or resolutions

References:

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Vogel, MP. 2005. *Septic Tank and Drainfield Operation and Maintenance.* Montana State University Extension Service: MontGuide. August.

Washington State Department of Health. 2005. *Preparing for a Sanitary Survey: Information to Help Small Water Systems*. Washington State Department of Health, Division of Environmental Health, Office of Drinking Water.

Resources

The Center for Irrigation Technology, Fresno State: http://www.fresnostate.edu/jcast/cit/

The Irrigation Training and Research Center, Cal Poly, San Luis Obispo – publications and reports: http://www.itrc.org/reports/index.php

WHO: https://www.who.int/water_sanitation_health/publications/wsp170805chap11.pdf

Appendix 1.1: Conversion table for calculating the amount of (70%) Calcium Hypochlorite required to dose specific well volumes at 50 mg/L.

Table A																			
(70%) Calcium Hypochlorite (Dry Weight in ounces)								Length of Pipe Containing Water (ft)											
Pipe Diameter (inch)	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10
2	0.25	0.24	0.23	0.21	0.20	0.19	0.18	0.16	0.15	0.14	0.125	0.1125	0.1	0.0875	0.075	0.0625	0.05	0.0375	0.025
4	1	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10
6	2	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20
8	3	2.9	2.7	2.6	2.4	2.3	2.1	2.0	1.8	1.7	1.5	1.4	1.2	1.1	0.9	0.75	0.6	0.45	0.3
10	4	3.8	3.6	3.4	3.2	3	2.8	2.6	2.4	2.2	2	1.8	1.6	1.4	1.2	1	0.8	0.6	0.4
12	6	5.7	5.4	5.1	4.8	4.5	4.2	3.9	3.6	3.3	3	2.7	2.4	2.1	1.8	1.5	1.2	0.9	0.6
16	10	9.5	9	8.5	8	7.5	7	6.5	6	5.5	5	4.5	4	3.5	3	2.5	2	1.5	1
20	16	15.2	14.4	13.6	12.8	12	11.2	10.4	9.6	8.8	8	7.2	6.4	5.6	4.8	4	3.2	2.4	1.6

Table B	**This Table uses Metric Units**													**This Table uses Metric Units**					
(70%) Calcium Hypochlorite (Dry Weight in grams)								Length of Pipe Containing Water (ft)											
Pipe Diameter (inch)	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10
2	7	6.7	6.3	6.0	5.6	5.3	4.9	4.6	4.2	3.9	3.5	3.2	2.8	2.5	2.1	1.8	1.4	1.1	0.7
4	28	27	25	24	22	21	20	18	17	15	14	13	11	10	8	7	6	4	3
6	57	54	51	48	46	43	40	37	34	31	29	26	23	20	17	14	11	9	6
8	85	81	77	72	68	64	60	55	51	47	43	38	34	30	26	21	17	13	9
10	113	107	102	96	90	85	79	73	68	62	57	51	45	40	34	28	23	17	11
12	200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20
16	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60	45	30
20	450	428	405	382.5	360	337.5	315	292.5	270	247.5	225	202.5	180	157.5	135	112.5	90	67.5	45
**1000 g = 1 Kg				**This Table uses Metric Units**								**This Table uses Metric Units**					**1000 g = 1 Kg		

How to use these tables:

Step 1: Determine the pipe diameter of your well in inches.

Step 2: Determine the well depth (or pipe length) of your well in feet (The company that constructed the well should be able to provide you with the well depth if you do not have it in your records).

Step 3: Determine the water level in your well (in feet).

Step 4: Subtract the well depth from the water level and this will give you the length of pipe containing water (ft).

Step 5: Using the tables above, match up your pipe diameter with your calculated length of pipe containing water to determine the amount of (70%) Calcium Hypochlorite required (Example – If you have a well that has a pipe diameter of 6 inches and a length of pipe containing water that is 60 ft, you would use 1.2 oz or 29 g of (70%) Calcium Hypochlorite).

Step 6: Decide what concentration of chlorine is required for the well disinfection. If you want to use a 50 mg/L chlorine solution, use the number that you derived in the table. If you want a **100 mg/L chlorine solution,** use the number that you derived in the table **multiplied by 2**. If you want a **200 mg/L chlorine solution,** use the number that you derived in the table **multiplied by 4**.

Step 7: **NOTE** – If you are going to weigh out your (70%) Calcium Hypochlorite in **grams – USE TABLE B – These numbers are metric**.

Appendix 1.2: Conversion table for calculating the amount of (25%) Chloride of Lime required to dose specific well volumes at 50 mg/L.

Table C																			
(25%) Chloride of Lime (Dry Weight in ounces)								Length of Pipe Containing Water (ft)											
Pipe Diameter (inch)	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10
2	0.50	0.48	0.45	0.43	0.40	0.38	0.35	0.33	0.30	0.28	0.25	0.23	0.20	0.18	0.15	0.13	0.10	0.08	0.05
4	2	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2
6	4	3.8	3.6	3.4	3.2	3	2.8	2.6	2.4	2.2	2	1.8	1.6	1.4	1.2	1	0.8	0.6	0.4
8	7	7	6	6	6	5	5	5	4	3.9	3.5	3.2	2.8	2.5	2.1	1.8	1.4	1.1	0.7
10	11	10	10	9	9	8	8	7	7	6.1	5.5	5.0	4.4	3.9	3.3	2.8	2.2	1.7	1.1
12	16	15.2	14.4	13.6	12.8	12	11.2	10.4	9.6	8.8	8	7.2	6.4	5.6	4.8	4	3.2	2.4	1.6
16	32	30	29	27	26	24	22	21	19	18	16	14	13	11	10	8	6	5	3
20	48	46	43	41	38	36	34	31	29	26	24	22	19	17	14	12	10	7	5

Table D	**This Table uses Metric Units**													**This Table uses Metric Units**					
(25%) Chloride of Lime (Dry Weight in grams)								Length of Pipe Containing Water (ft)											
Pipe Diameter (inch)	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10
2	14	13.3	12.6	11.9	11.2	10.5	9.8	9.1	8.4	7.7	7	6.3	5.6	4.9	4.2	3.5	2.8	2.1	1.4
4	57	54	51	48	46	43	40	37	34	31	29	26	23	20	17	14	11	9	6
6	113	107	102	96	90	85	79	73	68	62	57	51	45	40	34	28	23	17	11
8	200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20
10	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60	45	30
12	450	428	405	383	360	338	315	293	270	248	225	203	180	158	135	113	90	68	45
16	900	855	810	765	720	675	630	585	540	495	450	405	360	315	270	225	180	135	90
20	1400	1330	1260	1190	1120	1050	980	910	840	770	700	630	560	490	420	350	280	210	140
**1000 g = 1 Kg				**This Table uses Metric Units**								**This Table uses Metric Units**					**1000 g = 1 Kg		

How to use these tables:

Step 1: Determine the pipe diameter of your well in inches.

Step 2: Determine the well depth (or pipe length) of your well in feet (The company that constructed the well should be able to provide you with the well depth if you do not have it in your records).

Step 3: Determine the water level in your well (in feet).

Step 4: Subtract the well depth from the water level and this will give you the length of pipe containing water (ft).

Step 5: Using the tables above, match up your pipe diameter with your calculated length of pipe containing water to determine the amount of (25%) Chloride of Lime required (Example – If you have a well that has a pipe diameter of 6 inches and a length of pipe containing water that is 60 ft, you would use 2.4 oz or 68 g of (25%) Chloride of Lime).

Step 6: Decide what concentration of chlorine is required for the well disinfection. If you want to use a 50 mg/L chlorine solution, use the number that you derived in the table. If you want a **100 mg/L chlorine solution,** use the number that you derived in the table **multiplied by 2**. If you want a **200 mg/L chlorine solution,** use the number that you derived in the table **multiplied by 4**.

Step 7: **NOTE** – If you are going to weigh out your (25%) Chloride of Lime in **grams – USE TABLE D – These numbers are metric**.

Appendix 1.3: Conversion table for calculating the amount of (5.25%) Sodium Hypochlorite required to dose specific well volumes at 50 mg/L.

Table E																			
(5.25%) Sodium Hypochlorite (Liquid Measure in fluid ounces)								Length of Pipe Containing Water (ft)											
Pipe Diameter (inch)	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10
2	2	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2
4	9	8.6	8.1	7.7	7.2	6.8	6.3	5.9	5.4	5	4.5	4.1	3.6	3.2	2.7	2.3	1.8	1.4	0.9
6	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
8	34	32	31	29	27	26	24	22	20	19	17	15	14	12	10	9	7	5	3
10	56	53	50	48	45	42	39	36	34	31	28	25	22	20	17	14	11	8	6
12	80	76	72	68	64	60	56	52	48	44	40	36	32	28	24	20	16	12	8
16	128	122	115	109	102	96	90	83	77	70	64	58	51	45	38	32	26	19	13
20	170	162	153	145	136	128	119	111	102	94	85	77	68	60	51	43	34	26	17

Table F	**This Table uses Metric Units**														**This Table uses Metric Units**				
(5.25%) Sodium Hypochlorite (Liquid Measure in milliliters)								Length of Pipe Containing Water (ft)											
Pipe Diameter (inch)	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10
2	59	56	53	50	47	44	41	38	35	32	30	27	24	21	18	15	12	9	6
4	266	253	239	226	213	200	186	173	160	146	133	120	106	93	80	67	53	40	27
6	600	570	540	510	480	450	420	390	360	330	300	270	240	210	180	150	120	90	60
8	1000	950	900	850	800	750	700	650	600	550	500	450	400	350	300	250	200	150	100
10	1700	1615	1530	1445	1360	1275	1190	1105	1020	935	850	765	680	595	510	425	340	255	170
12	2400	2280	2160	2040	1920	1800	1680	1560	1440	1320	1200	1080	960	840	720	600	480	360	240
16	3800	3610	3420	3230	3040	2850	2660	2470	2280	2090	1900	1710	1520	1330	1140	950	760	570	380
20	6300	5985	5670	5355	5040	4725	4410	4095	3780	3465	3150	2835	2520	2205	1890	1575	1260	945	630
**1000 mL = 1 L			**This Table uses Metric Units**									**This Table uses Metric Units**					**1000 mL = 1 L		

How to use these tables:

Step 1: Determine the pipe diameter of your well in inches.

Step 2: Determine the well depth (or pipe length) of your well in feet (The company that constructed the well should be able to provide you with the well depth if you do not have it in your records).

Step 3: Determine the water level in your well (in feet).

Step 4: Subtract the well depth from the water level and this will give you the length of pipe containing water (ft).

Step 5: Using the tables above, match up your pipe diameter with your calculated length of pipe containing water to determine the amount of (5.25%) Sodium Hypochlorite required (Example – If you have a well that has a pipe diameter of 6 inches and a length of pipe containing water that is 60 ft, you would use 12 oz or 360 mL of (5.25%) Sodium Hypochlorite).

Step 6: Decide what concentration of chlorine is required for the well disinfection. If you want to use a **50 mg/L chlorine solution**, use the number that you derived in the table. If you want a **100 mg/L chlorine solution,** use the number that you derived in the table **multiplied by 2**. If you want a **200 mg/L chlorine solution,** use the number that you derived in the table **multiplied by 4**.

Step 7: **NOTE** – If you are going to weigh out your (5.25%) Sodium Hypochlorite in **milliliters – USE TABLE F – these numbers are metric.**