GOOD AGRICULTURAL PRACTICES TASK FORCE

GAP GUIDELINES & RECOMMENDATIONS

GAP TASK FORCE MEMBERS June 2014

Introduction

With the upcoming adoption of the Federal Regulations for the Food Safety Modernization Act (FSMA), the Hawaii Legislature passed Act 106, Session Laws of Hawaii (SLH) 2013, to create a Good Agricultural Practices (GAPs) Task Force in order to develop Hawaii specific GAPs and preventive measure guidelines that are in consonance to the proposed FSMA rules.

In reviewing GAP guidelines schemes, the Task Force focused on guidelines specific to Hawaii agriculture. The Task Force also focused on strategies for the implementation, support, outreach, and training of said guidelines. Hawaii agriculture sustainability and Hawaii Farmer's foremost concerns regarding the complexity of adapting the guidelines in current farming practices were also addressed. Quoting one such farmer, the below summarizes the gist of concerns of the Hawaiian Farmer regarding GAP guidelines.

FARMER CONCERNS REGARDING HAWAII GAP GUIDELINES – Kenneth Kamiya

"*We realize in our complex system of food production and consumption, no simple answers will prevail. However, as a member of the GAP Task Force, I would like to reiterate important farm assumptions in operation in the system.*

First, farmers are not farming because of "lifestyles", but for the personal satisfaction of filling an important need of society – food. But, we are also business people and unless we can show profits, we will not farm. We are constantly under extreme pressure to balance input costs in relation to sales and any effort to increase costs will not guarantee an increase in profits or sales. It is a dire dilemma for all farmers and any farmer who cannot cope are doomed to failure.

Therefore, it is incumbent for this GAP Task Force to seek ways to assist the farmer in producing wholesome and uncontaminated produce for consumers. To initiate regulations to satisfy "legal protection" on marketing efforts is anti-farming. To the contrary, this Task Force should promote system wide education, based on sound science, for the production, handling, transporting, marketing and consumption of all foods.

Secondly, the complexity of farming is no small matter and the average farmer is a master juggler or jack of all trades person who can never master every facet of farming. To single out GAP will put enormous strain on a small farmer's resources. Incorporation of a standardized GAP will require educational outreach, changes to cultural practices, and perhaps direct government subsidies or incentives.

Further, GAP/food handling should be broad based for all who deal with fresh produce".

NOTE: The GAP guidelines as put forth by the Hawaii GAP Task Force has been developed to the best of the TASK Force Member's knowledge based on current and reviewed information, excluding any information regarding Sprout Risk Assessments.

Task Force Members

Scott Enright – Hawaii DOA, Chairperson (Jeri Kahana, alternate)
Colehour Bondera – Organic farmer
Kenneth Kamiya – Papaya farmer
Shin Xong (Neil) Ho – Vegetable farmer
Fred Lau – Aquaponics famer
Mike Irish – Processor
Derek Kurisu – Retail
Conrad Nonaka – Food service (restaurant)
James Weisiger – Food service (hotel)
Brian Miyamoto - Hawaii Farm Bureau Federation (Myrone Murakami, alternate)
Vincent Mina – Hawaii Farmers Union United (Simon Russell, alternate)
Kacey Robello – Farmers Market
Maria Gallo – CTAHR (Lynn Nakamura-Tengan , alternate)
Clarence Nishihara – State Senator
Peter Oshiro – Hawaii DOH (Lori Nagatoshi, alternate)
Jessica Wooley – State Representative

Facilitator

Sri Pfuntner – Hartono and Company, LLC

Meetings Held

Meeting Date, Place

1. January 31, 2014 – Oahu, Honolulu
2. February 19, 2014 – Oahu, Honolulu
3. March 31, 2014 – Hawaii Island, Hilo
4. April 21, 2014 – Molokai, Kaunakakai
5. April 23, 2014 – Maui, Kahului
6. May 28, 2014 – Kauai, Lihue
7. May 30, 2014 – Hawaii Island, Kona
8. June 9, 2014 – Oahu, Honolulu
9. June 30, 2014 – Oahu, Honolulu

Information Collection

At each Task Force meeting, food safety criteria from the Food and Drug Administration (FDA) Proposed Produce Rule, the FDA Proposed Preventive Control Rule, various other industry standards and data about the many crops grown in Hawaii were discussed in detail. The Task Force subsequently identified priority items inherent to an effective food safety program for farming and related activities. Based upon the analysis, multiple recommendations were formulated which are presented herein.

Agenda topics, objectives, reviews and evaluations addressed at each meeting are as follows *(meeting minutes, presentations, reference material are listed in the appendix – printed & linked to electronic files)*:

1. January 31, 2014 – Oahu, Honolulu
    a. Initiate the Task Force meeting; introduce the general scope and purpose of the task force as outlined in Act 106 SLH 2013, including goal setting and time-lines.

2. February 19, 2014 – Oahu, Honolulu
    b. List the general food safety concerns and issues within the sectors identified in Act 106 SLH 2013; initiate the risk assessment evaluation process within these sectors.
        i. Polled the general food safety concerns, issues and potential solutions within each of the sectors as identified in Act 106 SLH 2013.
        ii. Identified the inter-departmental food safety collaboration roles as they pertain to Hawaii produce production.
        iii. An understanding how to conduct, evaluate and list the major food safety risks associated with each part of the supply chain as it pertains to the individual sectors identified in Act 106 SLH 2013.
        iv. Introduced the fundamental training needs and potential food safety accreditation strategy.

3. March 31, 2014 – Hawaii Island, Hilo
    a. Initiate the first steps towards developing Hawaii specific GAP guidelines.
        i. Review a synopsis of the current FDA proposed Produce Safety Rule as they pertain to Hawaii specific farming operations.
        ii. Review the FDA guidelines regarding the minimization of microbial contamination in produce.
        iii. Initiate an on-farm risk assessment template.
        iv. Initiate GAP principles addressing the on-farm risks.

4. April 21, 2014 – Molokai, Kaunakakai
    a. Develop the Risk Assessment Process for Hawaii specific GAP guidelines.
        i. Completed an on-farm risk assessment template

ii. Developed GAP principles addressing the on-farm risks:
A. General operations
B. Agriculture Water

5. April 23, 2014 – Maui, Kahului
   a. Continuation from item # 4 above.
      i. Completed an on-farm risk Agricultural Water assessment guidelines
      ii. Developed GAP principles addressing the on-farm risks:
         A. Bio-Solids Risk Assessment Guideline
         B. Worker Hygiene – Risk Assessment Guideline
      iii. Equipment – Risk Assessment Guideline

6. May 28, 2014 – Kauai, Lihue
   a. Complete the Farm Risk Assessment Overview & start the GAP guideline process.
      i. Completed the Farm Risk Assessment Overview
      ii. Reviewed Sustainable and Co-management practices
      iii. Initiated the GAP guidelines addressing the on-farm risks

7. May 30, 2014 – Hawaii Island, Kona
   a. Address Traceability & continue the GAP guideline process.
      i. Reviewed Traceability requirements, i.e., trace-back & trace-forward
      ii. Completed the GAP guidelines outline addressing the on-farm risks

8. June 9, 2014 – Oahu, Honolulu
   a. Complete the HI GAP guidelines recommendations including the Traceability Process.
      i. Completed the GAP guidelines outline addressing the on-farm risks, including the Traceability Process

9. June 30, 2014 – Oahu, Honolulu
   a. Finalize the HI GAP guidelines recommendations and validate the priorities identified by the task force; two focus group sessions were conducted. The first session was comprised of three individual focus groups. Each person in the group assumed the role of a regulator, a buyer, a farmer and an industry support position to address key questions and develop recommendations addressing key priorities and on-going concerns. The key questions were:
      i. What do we know?
      ii. In my sector what are my three key priorities?
      iii. How would I propose to address these three key priorities?

   The results of the first session were consolidated and utilized as the foundation for the second session focus groups. The individuals in the first three focus groups were scrambled and another three focus groups were formed. The second session concentrated on finalizing the recommendations for the implementation of the HI GAP guidelines as listed below.

Executive Summary

After due consideration, the GAP Task Force is in accord with the FDA general strategy regarding the Best Practices in sustaining Food Safe Practices in the State of Hawaii, by actively addressing Microbiological Food Risk Prevention, implementing Supply Chain Accountability, and Collaboration between public agencies, academia and industry organizations. Further consideration is emphasized to achieve harmonized GAP practices, harmonized certification or validation schemes, interactive training plans and farmer-to-consumer outreach programs.

A. The key GAP priority risk factors are summarized as follows and outlined in detail subsequently:
   1. GAP Risk Assessment
      a. Crop Selection
      b. Pre-planting
      c. Production
      d. Harvest Event
      e. Post-harvest handling, including packaging and shipping
   2. Crisis Management
      a. Emergency Response
      b. Recall & Traceability

B. The key GAP Task Force Recommendations focused on two key topics:
   1. Comments for FSMA PROPOSED RULES as they specifically impact Hawaiian Agriculture
   2. Recommendations for the Implementation and Sustainability of GAP for the Hawaiian Farmers

It is the GAP Task Force consensus that the foundation for Hawaii specific GAP guidelines and for maintaining sustainable practices and procedures for the prevention of foodborne illnesses that could result from Hawaiian farming practices can be achieved by addressing four key factors within the food safety supply chain, from farm to fork:

1. Consumer education and outreach programs
2. Farmer education and outreach programs
3. Consolidated buyer's approach regarding supplier approval programs
4. Addressing the need for HI specific changes within the propose FDA produce rule, i.e., a HI variance program as enabled by the FDA proposed produce rule.

Striving for harmonized Risked Based GAP practices, harmonized certification or validation schemes, interactive training plans and farmer-to-consumer outreach programs are the essential items necessary for an effective, achievable, practical and economical Hawaii specific sustainable GAP program.

Hawaii Good Agricultural Practices – Key Considerations:

A. GAP Task Force Priority Risk Factors - Detail

The below is a listing of the most important topics discussed by the GAP Task Force.

1. **Risk Assessment** – documented risk assessment recommended per annum and/or when new crops are introduced and/or any major changes in the sub-points below; records may be required depending upon operation status.
   - 1.1. Crops - documented assessment recommended
     - 1.1.1. Risk Matrix Components
       - 1.1.1.1. Consumption parameters – determine who consumes the product and in what form.
       - 1.1.1.2. Recall history – research whether the product type has been involved in a recall.
       - 1.1.1.3. Presence of a 5-log microbial reduction procedure ("kill step") – determine if a "kill step" is needed or mandated; such a step requires a HACCP plan.
       - 1.1.1.4. Growing method (tree, field, green house, hydroponic, aquaponic, shade house)
       - 1.1.1.5. Risk determination - evaluate the risks involved in growing/handling the product.
   - 1.2. Pre-planting
     - 1.2.1. Land topography – the "lay of the land" can impact food safety.
     - 1.2.2. Land history – historical data may show risks.
     - 1.2.3. Land use – current or previous land use may present risks.
     - 1.2.4. Adjacent lands – nearby land uses may have risks.
     - 1.2.5. Animal intrusion – the presence or influx of animals can lead to product contamination.
     - 1.2.6. Irrigation sources – water quality can be a source of product contamination.
     - 1.2.7. Land preparation – preparation techniques may promote risks.
     - 1.2.8. Fertilization – fertilizers can be a source of contamination.
     - 1.2.9. Facilities – buildings and storage areas may be sources of contamination.
     - 1.2.10. Equipment – contaminated equipment may pose a risk.
     - 1.2.11. Labor – improper hygiene habits may promote contamination.
   - 1.3. Production
     - 1.3.1. Fertilizer
       - 1.3.1.1. Type – raw and improperly composted animal based manure can present a risk.
       - 1.3.1.2. Application parameters – how and when applications are made may be a problem.
       - 1.3.1.3. Run-off and drift – undesired movement of fertilizers can present a risk.
     - 1.3.2. Water Use
       - 1.3.2.1. Source type – water from above ground or shallow sources can be of greater risk than deep wells.
       - 1.3.2.2. Irrigation method – subsurface methods are less likely to pose a risk.

- 1.3.2.3. Quality - water quality must be appropriate for the intended use; the proposed FDA Rules stipulate certain parameters.
- 1.3.2.4. Application parameters – the methods and times of application may promote contamination.

1.3.3. Pesticides
- 1.3.3.1. Not directly addressed by proposed FDA rules
- 1.3.3.2. Topic is regulated by local agency
- 1.3.3.3. Topic is included in third party certifications

1.3.4. Equipment and facilities
- 1.3.4.1. Sanitation – equipment and tools must be cleaned and sanitized so that they are not sources of food contamination.
- 1.3.4.2. Sanitary facilities – properly constructed and maintained toilets and hand washing facilities must be present.

1.3.5. Personal hygiene
- 1.3.5.1. Training – employees must receive training at hire and periodically thereafter.
- 1.3.5.2. Hygiene policy and standards – a policy and requirements must be present.
- 1.3.5.3. Visitor policy – a policy and requirements must be present.
- 1.3.5.4. Worker sick policy, employee training, monitoring – a policy and requirements must be present.

1.3.6. Animal intrusion
- 1.3.6.1. Wild life monitoring and mitigation - the presence or influx of animals can lead to product contamination.
- 1.3.6.2. Access control of domesticated animals - the presence or influx of animals can lead to product contamination.

1.4. Harvesting activities

1.4.1. Pre-harvest
- 1.4.1.1. Identify potential crop risks – assessment of risks must be performed to ensure food safety.
- 1.4.1.2. Mitigate risks – defined risks must be addressed to prevent food contamination.

1.4.2. Harvest event
- 1.4.2.1. Worker hygiene – parameters must exist to ensure food safety.
- 1.4.2.2. Equipment hygiene – items must be clean and sanitary.
- 1.4.2.3. Crop specific harvesting techniques – specific procedures may be needed to ensure food safety.
- 1.4.2.4. Field packing – procedures are needed to ensure food safety depending upon the crop.

1.5. Post-harvest activities

1.5.1. Crop transport
- 1.5.1.1. Vehicle cleaning and sanitation – transport vehicles of all types must be clean and sanitary.
- 1.5.1.2. Vehicle inspection – vehicles are to be inspected for food safety issues prior to use.

1.5.2. Crop cooling

1.5.2.1. Method and equipment – methods and equipment used must be listed.
1.5.2.2. Potential risks – food contamination from improper procedures and poor equipment maintenance may occur.
1.5.2.3. Risk mitigation
1.5.2.3.1. Water quality – water used on any food contact surfaces must meet the specified regulatory standard.
1.5.2.3.2. Equipment – items must be clean, sanitary and pass inspection.
1.5.3. Crop washing
1.5.3.1. Method and equipment - methods and equipment used must be listed.
1.5.3.2. Potential risks - food contamination from improper procedures and poor equipment maintenance may occur.
1.5.3.3. Risk mitigation
1.5.3.3.1. Water quality – water used on any food contact surfaces must meet the specified regulatory standard.
1.5.3.3.2. Equipment – items must be clean, sanitary and pass inspection.
1.5.3.3.3. Approved washing products – products employed in the washing procedure must be approved for use on the target crop.
1.5.4. Sanitizing
1.5.4.1. Crop
1.5.4.1.1. Accepted methods (SSOPs) – proper methods must be utilized to ensure food safety.
1.5.4.1.2. Approved sanitizing products – products employed in the sanitizing procedure must be approved for use on the target crop.
1.5.4.2. Equipment cleaning, sanitizing and maintenance
1.5.4.2.1. Water quality - water used on any food contact surfaces must meet the specified regulatory standard.
1.5.4.2.2. Accepted methods (SSOPs) – proper methods must be utilized to ensure food safety.
1.5.4.2.3. Approved sanitizing products – products employed in the sanitizing procedure must be approved for use on the equipment and target crop.
1.5.4.2.4. Maintenance – proper maintenance must be performed to avoid food contamination.
1.5.5. Other inputs-not covered in discussions but needs to be listed for completeness; items must be approved, and be used per label specifications and directions.
1.5.5.1. Pesticides – improper use of pesticides can contaminate the product.
1.5.5.2. Coatings – improper use of coatings can contaminate the product.
1.5.6. Packing House Activities
1.5.6.1. Packaging materials
1.5.6.1.1. Approved for intended use – materials must be constructed from materials approved for food contact; shipping containers where direct food contact does not occur must also be approved for use.

1.5.6.1.2. Proper labeling – labels must meet the stipulations of state & federal regulations, including but not limited to COOL and proposed FDA Rules.

1.5.6.2. Packing procedures – improper procedures can compromise food safety.

1.5.6.3. Packing house sanitation – proper cleaning and sanitation are required, including pest control.

1.5.6.4. Food security (defense) – regulations stipulate that proper security measures must be in place at all times.

1.5.6.5. Operation classification

1.5.6.5.1. Farm - the proposed FDA Rules define farms and farm related activities; farms (as defined) are not required to register with the FDA.

1.5.6.5.2. Mixed-use facility – certain mixed-use facilities are required to register with the FDA under the proposed FDA Rules.

1.5.6.6. Traceability codes – traceability (trace back & trace forward) activities are mandated by regulation.

1.5.7. Worker hygiene-current and proposed regulations mandate that proper worker hygiene, including illness awareness, be practiced to preclude food contamination.

1.5.8. Records – written records are required, depending upon the classification of the operation (some entities may not need to document certain activities).

2. Crisis Management

2.1. Emergency response

2.1.1. Dedicated team – team members and their contact information must be available.

2.1.2. 24/7 response - specific procedures describing activities and responsibilities must be present.

2.1.3. Emergencies – may stem from various occurrences such as natural or man-made disasters, including terrorist activities.

2.1.4. Specific procedures – documents must be in place to describe the procedures to be used in the event of an emergency.

2.2. Crop stock recovery, market withdrawal, recall

2.2.1. Traceability – in the event of a crisis, the operation must be able to provide adequate traceability information in a timely manner.

2.2.2. Specific procedures – documents must be in place to describe the procedures to be used in the event of a stock recovery, market withdrawal or recall.

2.3. Records - written records are required, depending upon the classification of the operation (some entities may not need to document certain activities).

B. GAP Task Force Recommendations

1. Task Force Recommendations regarding comments for FSMA PROPOSED RULES -- DIRECT IMPACT TO HI AGRICULTURE

1.1. Baseline for GAP/GMP will be FDA regulations (Proposed Produce Rule, Proposed Preventive Controls Rule)

1.2. Hawaii needs variances

1.2.1. FDA Proposed Produce Rule allows variances (Subpart P)

1.2.2. Designated authority for the State of Hawaii must request variance in writing

1.2.3. The above entity must provide valid supporting documentation for each request

1.2.4. Variances are to be submitted after the final rule is adopted or sooner if permitted

1.2.5. Variance requests must occur during the compliance period stated in the FDA rule

1.2.6. Possible Hawaii-specific variances to request (depending upon text in the 2nd draft and or the Final Rule)

1.2.6.1. Raise the exemption limit from $25,000 in sales to $100,000 (economic hardship, based upon the 2007 USDA census data) [Section 112.4]

1.2.6.2. Allow farmers to integrate like crops from various farm sources while retaining their status as a "farm" instead of being classed as a "mixed-type facility". [Section 112.3]

1.2.6.3. Allow the use of current industry standards and guidelines for drying, roasting and processing tree nuts. [Section 112.2(b)(1)] NOTE: this process is currently allowed by the proposed rule.

1.2.6.4. Reduce the water testing frequency as it presents an economic burden to very small and small farmers. [Section 112.45] Contest the proposed frequency – the proposed frequency should not be imposed until scientific research has established testing frequencies for different water sources.

1.2.6.5. Address aquaponic water use separately from conventional agricultural water use. Aquaponics is a unique crop production technique. [Section 112.45]

1.2.6.6. Allow the use of manure and compost to follow the current National Organic Program standards. [Section 112.56]

1.2.6.7. Clarification is required regarding aquaponic fertilization procedures based upon the verbiage present in Section 112.56.

1.2.6.8. Clarification is required regarding other natural farming fertilization & soil amendments methods/protocols not discussed in Section 112.56.

1.2.6.9. Stipulate that the natural deposition of grazing animal excreta is not classified as a manure application [Sections 112.82, 112.56].

1.2.6.10. Extend the exemption list for Rarely Consumed Raw items to include the following items. NOTE: The present list in the proposed FDA Rule is exhaustive. The FDA may desire to retain an exhaustive list, thus an exhaustive list for Hawaii is probably needed in the event the FDA does not define another process.

1.2.6.10.1.1. Cassava (*Ipomea batatas*
1.2.6.10.1.2. Breadfruit (*Artocarpus altillus)*
1.2.6.10.1.3. Fern Shoots *(Athyrium esculentum)*
1.2.6.10.1.4. Bamboo Shoots (*Poaceae sp. shoots)*
1.2.6.10.1.5. Swamp Cabbage (*Ipomea sp.* shoots)
1.2.6.10.1.6. Bittermelon (*Momordica charantia*)
1.2.6.10.1.7. Macadamia Nuts Raw mac nuts are readily available.
1.2.6.10.1.8. Green beans; Long beans; Edamame; Pole beans; Bush beans;
1.2.6.10.1.9. Moringa (*Moringa sp.)*
1.2.6.10.1.10. Noni (*Morinda citrifolia)*

1.2.6.11. Request that the FDA propose a process to more easily add or delete items from the list referenced above.

2. Task Force Recommendations for the Implementation and Sustainability of GAP

To finalize the HI GAP guidelines recommendations and to validate the priorities identified by the task force, two focus group sessions were conducted. The first session was comprised of three individual focus groups. Each person in the group assumed the role of a regulator, a buyer, a farmer and an industry support position to address key questions and develop recommendations addressing key priorities and on-going concerns.

The key questions were:

i. What do we know?
ii. In my sector what are my three key priorities?
iii. How would I propose to address these three key priorities?

The results of the first session were consolidated and utilized as the foundation for the second session focus groups. The individuals in the first three focus groups were scrambled and another three focus groups were formed. The second session concentrated on finalizing the recommendations for the implementation of the HI GAP guidelines as listed below.

The following key factors reflect the collaborative consensus of the six focus groups which became the foundation of the GAP Task Force recommendations:

1. The focus groups deduced that a common awareness of food safety is generally recognized by Hawaiian farmers at large, but that the depth of understanding and knowledge base regarding the prevention of foodborne illness risk factors varied widely.
    a. Farmer to farmer training programs would be most beneficial to raise the level of comprehension within the farming communities.

2. It is also realized that food safety awareness is lacking at the consumer level. It is recognized that a consumer outreach program will be extremely beneficial in raising consumer food safety awareness.
   a. The consumer is the concluding risk prevention step within the food safety chain, and the consumer must take an active role in foodborne illness prevention.

Focus Group Findings:

FARMER Concerns – GAP Training and why is this important?

1. Incentive to GAP certification program - recommendation: a program similar to that of pesticide education
   a. How does one incentivize the farmers to follow a program?
      i. A certificate approach can be considered.
   b. What are the benefits of having a program?
      i. Demand for local product based on GAP implemented programs
2. Why would farmers stay in business?
   a. Tax breaks?
   b. Government needs to understand the farmer – outreach?
   c. "Keep me on my farm rather than having to be away from the farm to have to do something else."
3. Who do I turn to for help?
   a. Farmer will contact Farmer
   b. Buyers
   c. Industry support group
   d. Having a support system for help – University extension
   e. Regulators - State & Federal Departments (consultative branch)
   f. Legislators
4. What Tools are available to assist in compliance?
   a. Coaching tools
   b. Funding (grants/subsidize)
   c. Resource teams
      i. Pro-active vs. reactive (prevent contamination)
      ii. Diagnostics – Root Cause analysis – having the ability to find out what the agent is and the source of the outbreak
5. Burden of recordkeeping
   a. Simple methods for recordkeeping – technological solutions
6. Traceability
   a. Understanding liability (burden of proof)

BUYER Concerns – Confidence in the Supply Chain

1. Currently, different buyers have different requirements for their supplier approval programs.
2. Buying from vendors meeting GAP guidelines – confidence will be lacking if/when a vendor cannot verify compliance with a GAP program.
    a. Currently, procurement understands when to accept or reject product but such is based on the quality specifications of a specific product, not a food safety criteria.
3. Supply Chain Traceability is minimal or non-existent.
4. Education needed for employees and consumers
5. Confidence building:
    a. Building relationships – buyer visits farmer
    b. Confidence & trust in the supplier/producer (farm) – confidence building (tour farms)
    c. Open communication between buyer/farmer – trust & confidence building
6. Record keeping requirements are still unclear to the buyer

REGULATOR Concerns – Resources needed & not all illnesses are reported

1. Not all foodborne illnesses are reported
2. Resources (staffing/equipment/other) – to be able to perform the tasks associated with a recall incident including root cause analysis
3. Traceability & additional information from the implicated party
    a. In a recall event, open communication is necessary-contact DOH
    b. Identify the responsible person
    c. How to track it back to the Farmer
    d. Record keeping and smartphone-based Apps across the supply chain aiding in traceability
4. Corrective Actions and root cause analysis

INDUSTRY SUPPORT GROUP Concerns – Bridging the knowledge base

Respecting the diverse differences in Hawaii's varied farms, and the complete food chain systems (from farm to fork) vs. the mainland farming systems and consumer market – there is a need for additional educational programs to bridge the knowledge base. The current knowledge base is built upon mainland farming/consumer models. Hawaii specific programs are needed.

1. Industry Support Group Role:
    a. Can be the core resource for the farmer
    b. Advocacy

    c. Experience & networking

2. Funding will be needed to build the educational and outreach programs.

3. Educational & Outreach program focus:
    a. Buying Program-if farmers grow it, consumers will buy it
    b. Market expansion
        i. Locally grown food
    c. Education
        i. Consumer education "Wash your Fresh Vegetables"
        ii. Education of farmers regarding why and how compliance is important – promote behavior shift
        iii. Buyer education
        iv. Regulator education
            1. Government understanding of the farmer. Farmers need to be heard!

4. Technology development to simplify recordkeeping

5. RESEARCH:
    a. Regionally different issues
    b. Different microclimates within the islands – research to address risk based approaches based upon the regional differences and how the GAP implications thereof

APPENDIX:

Food Safety Landscape 033114

GAP CTHAR safe produce

http://manoa.hawaii.edu/ctahr/farmfoodsafety/

http://manoa.hawaii.edu/ctahr/farmfoodsafety/tools-pubs/log-sheets-farm-signs/

http://www2.ctahr.hawaii.edu/hnfas/publications/foodSafety/farmPractices.pdf

Onfarmfoodsafety.org– Create an Customized Food Safety Plan

Cornell 00 – Gap Decision Tree

Cornell 0 – GAP Decision Tree – Overview
Cornell 1 – GAP Decision Tree – How to use
Cornell 2 – GAP Decision Tree – Checklist
Cornell 3 – GAP Decision Tree – Glossary
Cornell 4 – GAP Decision Tree – Adjacent Land Use
Cornell 5 – GAP Decision Tree – Ag Water
Cornell 6 – GAP Decision Tree – Soil Amendments
Cornell 7 – GAP Decision Tree – Worker Training
Cornell 8 – GAP Decision Tree – Animal Management
Cornell 9 – GAP Decision Tree – Sanitation & Postharvest Handling
Cornell 10 – GAP Decision Tree – Transportation
Cornell 12 – GAP Decision Tree – Postharvest Water

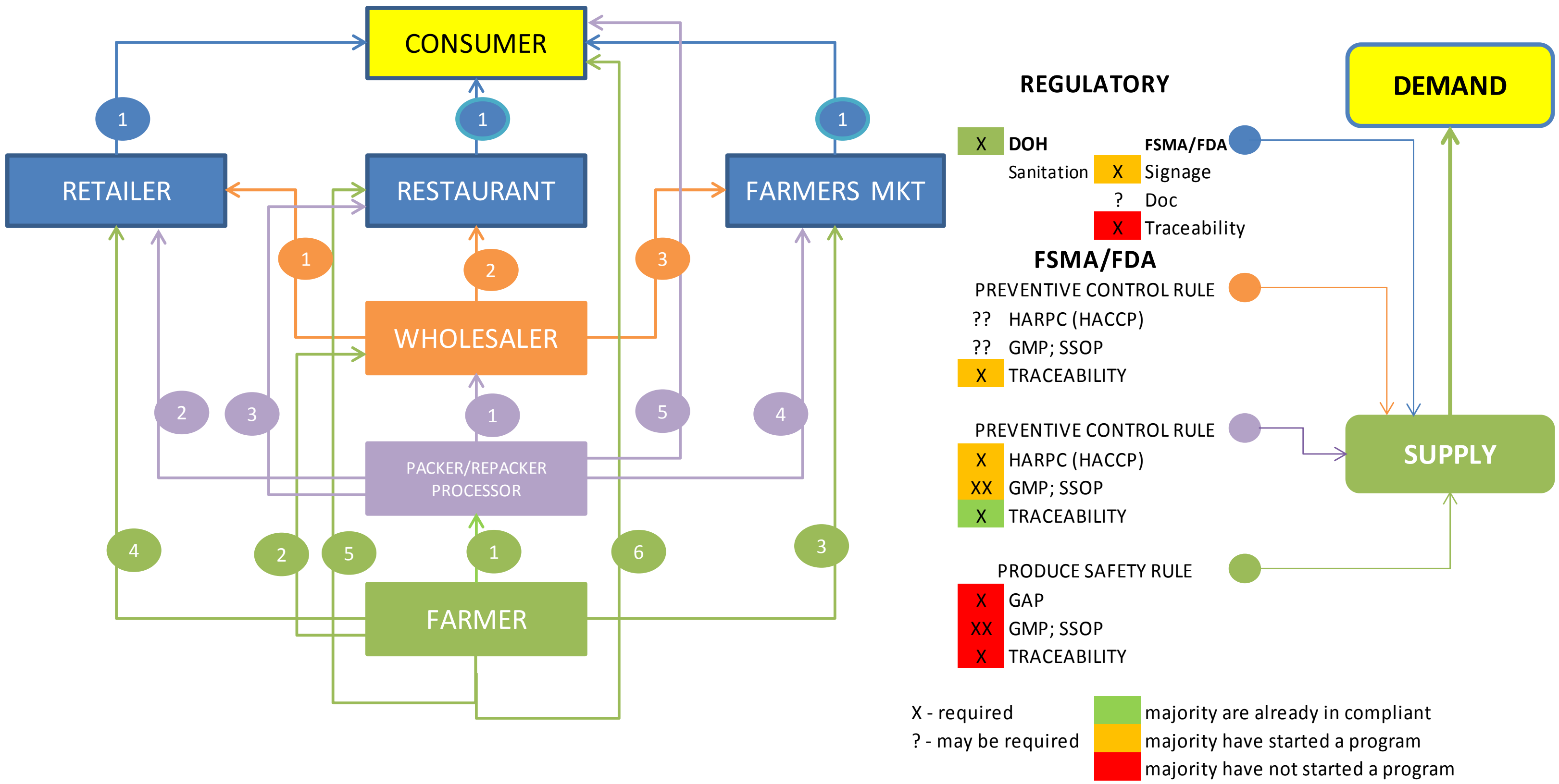
Wild Farm Alliance Food Safety Doc Oct 203

Wild Farm Alliance Food Safety Facts & Tips – FAQs 2013

Center for Produce Safety

CPS Key Learnings May 2014
CPS Ag Water Research Report 2014

FOOD SAFETY LANDSCAPE



National Good Agricultural Practices Program

Department of Food Science—*Farm Food Safety Decision Tree Project*

Home Page: http://www.gaps.cornell.edu/index.html

Decision Tree: http://www.gaps.cornell.edu/tree.html

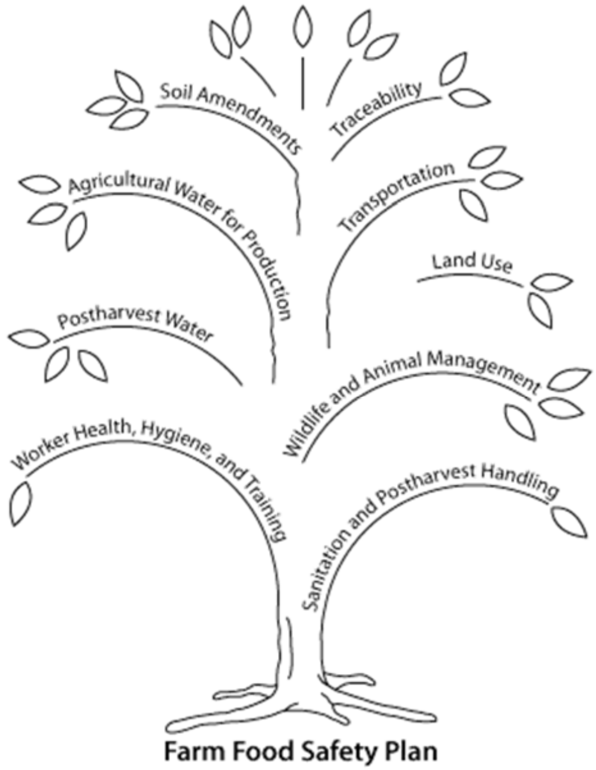
On-Farm Decision Trees:
Farm Food Safety Decision Making Made Easy!

The purpose of the Decision Trees is to:

1. Help you identify risks and practices that reduce risks;
2. Prioritize the implementation of practices to use limited resources wisely;
3. Familiarize you with the terms and methods necessary to understand and follow requirements and expectations for food safety from buyers, farm markets, schools, and federal regulations.

Begin with How to Use the Decision Trees and reviewing the Checklist to identify which Decision Tree you should complete first. There is a Glossary in case any terms are unfamiliar.

All of the Decision Trees follow simple
'YES or NO' pathways to aid you in assessing your current practices.



- Worker Health, Hygiene, and Training
- Agricultural Water for Production
- Soil Amendments
- Wildlife and Animal Management
- Land Use
- Postharvest Water
- Sanitation and Postharvest Handling
- Traceability
- Transportation

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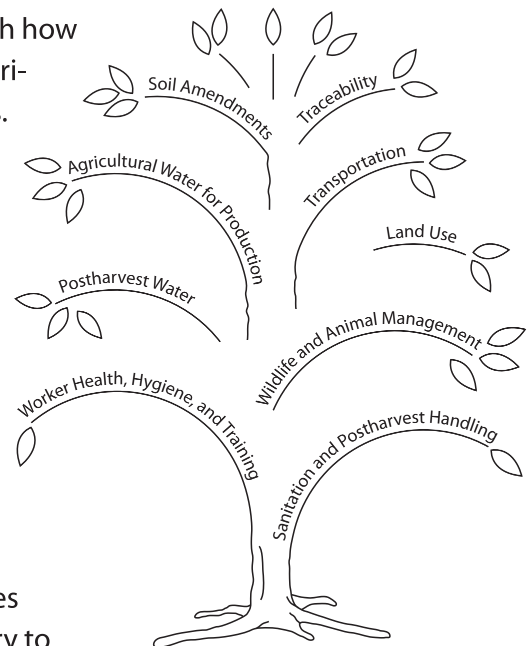
How to Use These Decision Trees

Decision making can be overwhelming. At our disposal, we have infinite sources of advice and information—credible and not—from the internet, friends, colleagues, grower organizations, and federal agencies. Information can be confusing and contradictory no matter what the topic.

Food safety is in the news daily. Many growers are overwhelmed with how to implement food safety practices on their farms including how to prioritize practices and how to do get it all done with limited resources. These On-Farm Food Safety Decision trees were designed to make it easy for you to get started on your farm food safety plan.

Think of your farm food safety plan as the trunk of a tree with many branches. Each branch represents a specific area of food safety. The branches and trunk are not pieces that get stuck together, but grow together as a whole tree. You cannot sustain the tree without the trunk and branches just as you cannot make your entire farm safe by doing some food safety practices and not others.



Farm Food Safety Plan

The purpose of the Decision Trees is three fold—first, to help you begin to identify risks and practices that reduce risks; second, help you prioritize the implementation of practices to use limited resources wisely; third, to familiarize you with the terms and methods necessary to understand and follow requirements and expectations for food safety from buyers, farm markets, schools, and federal regulations.

All of the Decision Trees follow simple 'YES or NO' pathways to aid you in assessing your current practices.

Each Decision Tree is composed of a number of sections:

1. Overview
2. Decision Tree
3. Sample Standard Operating Procedures (SOPs)
4. Sample Recordkeeping Logs
5. Template Food Safety Plan Language

Overview

The overview describes the key issues for each branch of the tree including key risk areas, other documents you may need to aid in your assessment, and actions you can take to reduce foodborne illness risks.

Decision Trees

There are nine decision trees as part of this tool. We suggest following them in order but they can also be used individually. The nine trees are:

1. Worker Health, Hygiene, and Training
2. Agricultural Water for Production
3. Soil Amendments

4. Wildlife and Animal Management
5. Land Use
6. Postharvest Water
7. Sanitation and Postharvest Handling
8. Traceability
9. Transportation

Each decision tree is a series of graphical branches with a series of questions followed by YES or NO and directional arrows to lead you to an eventual endpoint. Each YES question is typically the best practice. If your answer is YES, follow the arrow and move to the next question. If your answer is NO, follow the directional arrow to the corrective action or actions that should be taken as well as the rationale for making those changes to get you to where you can answer YES to the best practice. There are exceptions to this flow, so be sure to read carefully. Continue down the tree, reviewing each corrective action or best practice as determined by your YES or NO answers.

Sample Standard Operating Procedures (SOPs)

Most trees include samples of one or two SOPs relevant to that section. Also included in the appendix is "How to Write an SOP" to guide you through development of any additional SOPs you may need.

Sample Record Keeping Logs

Record keeping is important so sample logs have been provided. Record keeping methods are personal and varied; use the method and format that makes the most sense for you and your workers. There is no right or wrong method of record keeping. The important point is to do the record keeping.

Template Food Safety Plan Language

Having a farm food safety plan is a good idea for all growers. Even if you only sell at a farmers market once a week, having a food safety plan is your instruction manual to implementing practices on your farm and a guide for all your workers. For each decision tree, we have included words you can edit and adapt for your own farm food safety plan.

The information in the template food safety plan, SOPs, and record keeping logs are examples you can use. They are not intended to be used directly. Tailor them to fit your farm operation and practices.

On-Farm Food Safety Decision Tree

Checklist to Prioritize Practices

Highest Priority GAPs			
If your answer is in a shaded box, please refer to the decision trees listed on the right to address produce safety risks that may exist. **Do you...**	**Yes**	**No**	**Decision Trees**
Provide food safety training to all workers?			Worker Health, Hygiene, and Training
Train all workers about produce safety in a language they understand?			Worker Health, Hygiene, and Training
Prohibit workers who are sick from handling fresh produce?			Worker Health, Hygiene, and Training
Provide clean toilets and handwashing facilities within 1/4 mile walk from fields?			Worker Health, Hygiene, and Training
Monitor toilet and hand washing sinks and clean and restock when needed?			Worker Health, Hygiene, and Training
Use water to irrigate, frost protect, cool, or apply sprays during the production of fresh produce?			Agricultural Water for Production
Allow any water (besides rain) to contact the edible portion of the crop?			Agricultural Water for Production
Test your agricultural water for quantified generic E.coli?			Agricultural Water for Production
Use raw untreated manure on the farm?			Soil Amendments
Incorporate raw, untreated manure into the soil less than 1 year before harvest?			Soil Amendments
Conduct field assessments before harvest to look for fecal contamination?			Wildlife and Animal Management
Train workers to follow company policies regarding proper harvest procedures if fecal material is found in the field and to wash their hands and change clothing if contaminated?			Wildlife and Animal Management
Establish buffers zones around fecal contamination and signs of significant animal activity (such as damaged product or extensive tracks) found in the field?			Wildlife and Animal Management
Clean and sanitize any tools or equipment used to handle feces or contaminated produce?			Wildlife and Animal Management
Keep farm animals and livestock near produce production areas?			Wildlife and Animal Management; Land Use
Grow crops on land that had previous use that may present a food safety risk to the crop?			Land Use
Grow crops on land that was used as a feedlot in the last 2 years?			Land Use
Have produce fields near a Confined Animal Feeding Operation (CAFO)?			Land Use

On-Farm Food Safety Decision Tree

Checklist to Prioritize Practices

Highest Priority GAPs			
If your answer is in a shaded box, please refer to the decision trees listed on the right to address produce safety risks that may exist. **Do you...**	**Yes**	**No**	**Decision Trees**
Use water that is the microbial equivalent of drinking water to begin all postharvest practices involving water such as rinsing and cooling?			Postharvest Water
Add sanitizer to your postharvest wash water?			Postharvest Water
Monitor sanitizer levels in postharvest water on an established schedule?			Postharvest Water
Change your postharvest water based on turbidity or on a standardized schedule?			Postharvest Water
Reduce or eliminate standing water in your packing area?			Postharvest Water; Sanitation and Postharvest Handling
Pack fresh produce into new single-use containers or reused containers that have been cleaned and sanitized?			Sanitation and Postharvest Handling
Clean (and sanitize, when possible) all produce contact surfaces including harvest bins, conveyor belts, and grading tables at the end of each day?			Sanitation and Postharvest Handling
Monitor and control for pests?			Sanitation and Postharvest Handling
Remove cull piles from the packing area everyday?			Sanitation and Postharvest Handling
Label each container sold by your farm with your farm name, city, and state?			Traceability

On-Farm Food Safety Decision Tree

Checklist to Prioritize Practices

Lower Priority GAPs			
If your answer is in a shaded box, please refer to the decision trees listed on the right to address produce safety risks that may exist. **Do you...**	**Yes**	**No**	**Decision Trees**
Post food safety signs/posters in a language workers understand?			Worker Health, Hygiene, and Training
Inspect your water sources at the beginning of production and throughout the year?			Agricultural Water for Production
Inspect your water distribution/delivery system and equipment at the beginning of the growing season?			Agricultural Water for Production
Cover or physically contain raw untreated manure that you store on your farm?			Soil Amendments
Store raw or incompletely composted manure close to produce fields, packing areas surface water sources, or well heads?			Soil Amendments; Land Use
Compost manure according to industry standards?			Soil Amendments
Conduct a pre-plant assessment to determine produce safety risks presented by wild and domestic animals?			Wildlife and Animal Management
Monitor fields for animal activity and intrusion?			Wildlife and Animal Management
Implement methods to prevent and minimize animal entry through the use of fences, noise cannons, or other deterrents?			Wildlife and Animal Management
Grow crops on land that has a history of flooding or has recently experienced a flood?			Land Use
Grow produce in fields that recieve runoff from neighboring fields, pastures, or barnyards?			Land Use
Drain your main irrigation lines after irrigating?			Land Use
Monitor postharvest water to minimize infiltration into susceptible produce commodities?			Postharvest Water
Clean and sanitize postharvest water tanks, bins, and washers at the end of everyday?			Postharvest Water
Train all workers to change or clean aprons and gloves (if worn) when dirty?			Sanitation and Postharvest Handling
Develop SOPs for cleaning and sanitation tasks?			Sanitation and Postharvest Handling
Train all workers to follow farm SOPs to clean and sanitize surfaces, tools, and equipment?			Sanitation and Postharvest Handling

On-Farm Food Safety Decision Tree

Checklist to Prioritize Practices

Lower Priority GAPs			
If your answer is in a shaded box, please refer to the decision trees listed on the right to address produce safety risks that may exist. **Do you...**	**Yes**	**No**	**Decision Trees**
Remove as much dirt, mud, and debris as possible from fresh produce and fresh produce bins before entering the packing area?			Sanitation and Postharvest Handling
Store produce in an area that is regularly cleaned and inspected for pest activity?			Sanitation and Postharvest Handling
Establish lot numbers for all commodities grown on your farm?			Traceability
Inspect and clean trucks and vans before transporting fresh produce?			Transportation
Maintain a specified temperature in your produce transportation vehicle?			Transportation

On-Farm Food Safety Decision Tree

Checklist to Prioritize Practices

Lowest Priority GAPs			
If your answer is in a shaded box, please refer to the decision trees listed on the right to address produce safety risks that may exist. **Do you...**	**Yes**	**No**	**Decision Trees**
Keep records of worker and visitor training?			Worker Health, Hygiene, and Training
Keep records of toilet and handwashing facility monitoring, cleaning, and servicing?			Worker Health, Hygiene, and Training
Keep a first aid kit in a known and convienient location?			Worker Health, Hygiene, and Training
Instruct workers to take breaks only in designated areas?			Worker Health, Hygiene, and Training
Have a water source and distribution map for your farm?			Agricultural Water for Production
Keep records of all water test results and water management actions?			Agricultural Water for Production
Store compost near fields or water sources?			Soil Amendments
Keep finished compost under covered storage?			Soil Amendments
Keep records of soil amendment applications?			Soil Amendments
Check soil amendment storage facilities weekly and clean when necessary?			Soil amendments
Document animal activity monitoring and actions taken to reduce risks?			Wildlife and Animal Management
Have a written history of previous land use?			Land Use
Keep records of all your postharvest water management and sanitation activities?			Postharvest Water
Diagram the flow of produce through the packing area to identify produce contact surfaces?			Sanitation and Postharvest Handling
Store packing containers and packaging materials in a covered area to reduce the potential for contamination?			Sanitation and Postharvest Handling
Use refrigerated or cold storage rooms properly?			Sanitation and Postharvest Handling
Link all lot numbers to type of commodity, production field, harvest date, packing date, and crew through record keeping?			Traceability
Conduct mock recalls to test your traceability practices?			Traceability
Make sure vehicles are precooled, if using refrigeration, before loading produce?			Transportation
Cover produce during transport from the field to the packinghouse?			Transportation
Keep records of transportation practices such as vehicle inspections prior to loading?			Transportation

Decision Tree Glossary

Animal Intrusion
Significant evidence of wildlife or other animal activity in or near produce growing and handling areas. This may include animal feces, urine, tracks, or crop damage that may indicate that the crop is at high risk for being contaminated with foodborne illness causing pathogens.

Biofilm
Bacterial layers that are a mixture of different microorganisms held together and protected by glue-like carbohydrates secreted by the microorganisms. These secretions help the microorganisms attach to surfaces and make the microorganisms difficult to remove.

Buffer zone
A defined distance from which product will not be harvested if it is contaminated with animal feces or other sources of contamination that may pose a food safety risk.

Cleaning
Physically removing soil and residues from a surface.

Colony Forming Unit (CFU)
A cell or cluster of cells capable of multiplying to form a colony of cells. It is used to express the concentration of microorganisms in a sample assuming that each colony originates from an individual cell.

Co-management
Practices that minimize the risk of fecal contamination and resulting microbiological hazards associated with food production while simultaneously conserving soil, water, air, wildlife, and other natural resources.

Cross-contamination
Contamination of one food item with microbial pathogens from another food item, water, surface, or other object. Cross-contamination occurs when fruits and vegetables become contaminated with bacteria such as *Salmonella* or *E.coli* from contact with manure. Other sources of cross-contamination may include harmful pathogens transferred to produce surfaces through contaminated wash water, packing lines, worker hands, harvest bins, or trucks.

Cull pile
A pile of discarded plant material or rejected produce that may become an attractant to pests or a source of nutrients for the growth of bacterial pathogens.

Detergent
A cleaning agent that contains surfactants to reduce surface tension between food surfaces and the soil that is removed during cleaning. Detergents penetrate quickly and aid in lifting soil off of surfaces. Detergents are used in the cleaning process to remove soil before a sanitizer is used.

Food Contact Surfaces
Surfaces that come into contact with food. Food contact surfaces are considered Zone 1 and should be prioritized for cleaning and sanitation practices in the packing area.

Good Agricultural Practices (GAPs)
Any agricultural management practice or operational procedure that reduces microbial risks or prevents contamination of fruits and vegetables on the farm or in the packinghouse.

Good Manufacturing Practices (GMPs)

Standards published in the Code of Federal Regulations (Title 21, Section 110) to ensure the safety of foods by outlining sanitary standards and practices for production and handling.

Hazard Analysis Critical Control Point (HACCP)

A process that identifies where potential contamination can occur (the critical control points or CCPs) and strictly manages and monitors these points as a way of ensuring the safety of the products being produced. HACCP requires a level of control within a facility so that processes can be monitored at all times and be corrected if the process exceeds the established critical control points. HACCP is used in processing plants but is not appropriate in fresh produce fields because the necessary level of control is not achievable.

Infiltration

The passage of water from the dump tank into fresh produce, caused when the dump tank water is cooler than the produce.

Inorganic Fertilizer

A chemical fertilizer of synthetic or mineral origin.

Microbial equivalent to drinking water

Absence of total coliforms.

Microorganisms

Bacteria, molds, viruses and other organisms so small that they can not be seen without the aid of a microscope. Another word for microorganism is microbe. In the case of foods, some microorganisms are beneficial and create desirable food products, while some cause foods to spoil. Some are harmful to humans and can cause sickness and even death.

Mock Recall

A test of a farm's traceability system.

Most Probable Number (MPN)

A statistical value representing the viable bacterial population in a sample.

Nephelometric Turbidity Units (NTU)

A unit of measurement that defines the level of cloudiness or haziness (turbidity) of solution such as water. An NTU level can be used to establish a threshold for when postharvest water should be changed to reduce food safety risks and ensure the effectiveness of postharvest sanitizers.

Foodborne Illness Outbreak

The occurrence of two or more cases of illness resulting from eating or drinking a common food.

Parts Per Million (PPM)

A way of expressing very dilute concentrations of substances; in this document it refers to sanitizers. One ppm is equivalent to 1 milligram of something per liter of water (mg/l).

Pathogen

A disease causing microorganism.

Personal Protective Equipment (PPE)

Equipment worn to minimize exposure to a variety of hazards. Examples of PPE include items such as gloves, eye protection, hearing protection (earplugs, muffs), hard hats, respirators and full body suits.

Policy

A statement that explains practices aimed at achieving a specific food safety outcome. Policies are specific to each farm. Policies are valuable to both management and workers because they clarify the farm's food safety goals.

Postharvest Handling

Any practices that occur after harvest including cooling, culling, and packing.

Potable

Meets EPA drinking water standards including an absence of total coliforms.

Recall
A voluntary or mandatory action taken by growers, packers, or produce distributors to remove potentially contaminated and, therefore, injurious produce from the marketplace including consumer homes.

Riparian Areas
Interface between land and a river or stream, or between produce production areas and wildlife habitat.

Run-off
Rainwater, leachate, or other liquid that drains over land, leaves the land surface, and enters unintended areas such as streams, fields, or packing areas.

Sanitize
The treatment of a surface that has been previously washed and rinsed to reduce or eliminate any remaining microorganisms. Various chemical compounds or sometimes very hot water can be used to sanitize surfaces. A surface must be cleaned before it can be sanitized because a dirty surface cannot be sanitized.

Sanitizer
A substance for killing microorganisms, designed for use in water or on food contact surfaces.

Scope
To who or what the Standard Operation Procedure (SOP) applies.

Side-dressing
Application of a soil amendment to the side of the planted crop row so the nutrients are available in the root zone without damaging the plant.

Standard Operating Procedure (SOP)
Describes an activity and how to properly complete the activity. An SOP should specify all the materials needed, the frequency with which each activity is conducted, and identify the employee(s) responsible for the implementation and documentation of the activity.

Template
Pre-developed language and suggestions to aid in the development of a farm food safety plan. Templates must be edited to reflect activities on your farm.

Traceability
The ability to track a food product through the food production and distribution system. In the case of fruits and vegetables, this includes back to the field where it was grown and any subsequent handling, storage, and sale.

Turbidity
The cloudy appearance of water when suspended sediments such as soil are present. The level of turbidity is measured in Nephelometric Turbidity Units (NTU).

Worker
Any person, paid or unpaid, working on a farm producing or handling fresh fruits and vegetables. This includes growers, farm managers, family members, migrant labor, summer help, and packing house employees.

Land Use Overview

When assessing food safety risks on your farm, it is important to understand past uses of produce fields. Consider biological, chemical, and physical risks that may result from previous uses such as animal feed lots or if the land was previously a building site or dumping ground. In addition, adjacent land use needs to be considered. Whether the surrounding land is occupied by private homes, animal production farms, wooded areas, or a bustling city, there is potential for food safety risks to be present. Contamination of crops, soil, and water has resulted from leaking septic tanks, run-off from animal production farms, and fecal deposits from wildlife that enter fields. Being aware of past field uses and adjacent land use will help you develop practices that reduce any food safety risks that exist.

To begin evaluating your farm's land use risks, draw a map of your field areas and land features. Be sure to include man-made structures such as irrigation systems, ditches, and roads. The map should include key pieces such as:

- Crop specific production and packing areas. Make note if these areas were previously used in ways that would introduce biological, chemical, or physical hazards.
- Field sanitation units (Porta-Potties)
- Location of active wells and septic systems
- Surface water sources
- Areas that are prone to flooding
- Raw and composted manure storage sites/ composting areas
- Animal pasture areas and /or barns where they are kept on your farm
- Chemical storage areas on your farm
- Adjacent land uses such as animal operations on neighboring farms, including distances from fields and impact on any water sources used by your farm.

It may also be helpful to include these things on the map so that it can be incorporated into your overall farm food safety plan to support production logs, traceability, and other produce safety related practices:

- Soil map
- Drainage map
- Copy of field records and growing history
- Physical address or GPS location of the farm
- Road names that form farm borders
- Name or number you assign to each field for traceability practices

To minimize food safety risks, crop production areas and water sources should be a sufficient distance from any raw manure sources, which include animal production farms, manure containment areas, and manure storage and composting facilities. While there is no conclusive research that validates exact distances needed between fields and potential sources of contamination, this decision tree uses recommendations from the California Leafy Green Marketing Agreement[1].

Recommended distances can be adjusted depending on characteristics of your farm related to topography including land slope, physical barriers such as trees or grass-covered land, and other attributes such as the number of animals present. For example, if the field is located on top of a hill and a dairy operation is downwind and at the bottom of the hill, the risk is minimal and the recommended distance may be decreased. Physical barriers such as berms, vegetative buffer strips, containment structures, ditches, and mounds can prevent run-off from contaminating crops. If physical barriers are in place, the recommended distances may be decreased. High concentrations of wildlife (e.g. deer, waterfowl) or domestic animals (e.g. cows, sheep, horses) increase the potential contamination risk because they can harbor harmful pathogens in their feces[2]. If wildlife activity is high and fecal material is present, actions should be taken to reduce or eliminate their activity in or around fresh produce fields and packinghouses (see Domestic Animal and Wildlife Decision Tree). Keep in mind that with more animals present, there may need to be more distance between the animals and the produce fields. When assessing the risk of manure sources near surface water, consider the distance from the manure source to the water and any ditches, canals, or land slope issues that feed the water source.

If your land is prone to flooding, consider the risks present to the crop and water sources. There are two types of flooding. The first occurs after a heavy downpour when fields become saturated and water pools on the soil surface. This type of flooding can reduce yields and even kill plants, but does not introduce water from surface water sources. The second type of flooding is more severe and occurs when water or runoff from surface waters such as rivers, lakes, or steams overflow and run into fields. Flood waters, as described in the second definition, are more likely to contain chemical and biological contaminants that may be harmful to the health of humans and animals[3]. According to the FDA, edible portions of crops that are contacted by this type of flood water are considered adulterated and cannot be sold.

Awareness of previous and adjacent land use will help you to assess risks on your farm. There are many actions that can be taken to reduce identified risks such as planting agronomic crops in higher risk fields or extending buffer areas between adjacent lands and produce fields. Remember, the focus should be on risk reduction since you can never completely remove all risks.

References

1. Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens. 2013. California Leafy Green Products Handler Marketing Agreement (LGMA). Available at: http://www.caleafygreens.ca.gov/food-safety-practices#downloads

2. Beuchat, L.R. (2006). Vectors and conditions for preharvest contamination of fruits and vegetables with pathogens capable of causing enteric diseases. British Food Journal, 108(1), 38–53.

3. FDA Guidance for Industry: Evaluating the Safety of Flood-affected Food Crops for Human Consumption. http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/EmergencyResponse/ucm287808.htm

The information in the template food safety plan, SOPs, and record keeping logs are examples you can use. They are not intended to be used directly. Tailor each to fit your farm operation and practices.

Land Use

1

Do you have a written history of previous land use?

No

Collect and document information about how the land was previously used. In some cases, it may be necessary to consult county land documents or neighbors. Determine if any of the previous land uses pose any risk to your crop production areas or water sources. Previous land use risks include biological (e.g. feed lot, ground for spreading municipal biosolids), chemical (e.g. industrial landfill, mine), and physical (e.g. junk yard, construction waste landfill). If crop land was previously used in a way that could have resulted in contamination, soil should be tested to further define the risks so corrective actions can be taken, if necessary. If there is no previous use of the land that gives any indication of food safety risks, state so in the food safety plan. If there is a concern, explain what has been done to correct the problem and prevent crop contamination. *See the Land Use Risk Assessment Log and Land Use Risk Assessment SOPs.*

Yes

2

Are crops grown on land that has a history of flooding or recently experienced a flood?

Yes

Flood waters can carry potential contaminants from adjacent areas and spread it over a wide area. If you farm on land with a recent history of flooding, soil should be tested before crops are grown. Consider testing soil for coliforms and heavy metals before crops are grown. If the edible portion of a crop is exposed to flood waters, the produce is considered adulterated under section 402(a)(4) (21 U.S.C. 342(a)(4)) of the Federal Food, Drug, and Cosmetic Act and should not enter human food channels[5].

When assessing the level of risk posed by flooding, some factors to consider are:

- Whether the crop is an annual or perennial (annual crops are at a greater risk)
- If the edible portion comes into contact with the soil
- What risk areas are a part of the flood plain (raw manure, septic system, waste site, etc)
- Timing of the flood - if the flood happens in the spring before planting or a flood that occurs when the commodity is in the field

To reduce risks when planting after a flood: allow soil to dry out, till thoroughly, allow time for microbial pathogens to decline (the longer the better), add organic matter to promote decomposition of biological contaminants, or sow a cover crop.

No

Land Use

3

Is produce grown in fields that might receive runoff from neighboring fields, pastures, or barnyards?

Yes

Runoff or wind spread from animal pens and grazing pastures or fields receiving manure applications can contaminate your produce field. Pathogens and contaminants can persist in soil for a prolonged period of time. For example, *E. coli* O157:H7 can survive in soil for up to 21 months[2]. Pathogen populations in raw manure tend to rapidly die off, but can survive in the soil at low populations for a prolonged amount of time[3]. Factors such as exposure to the sun (solarization) and wind (desiccation) may help reduce pathogen populations[6]. Monitor the field for any signs of runoff from adjacent land. If there is a risk present, reassess field use or create physical barriers such as windbreaks, buffer strips, or diversion ditches to protect produce fields.

No

4

Are produce fields located near municipal/commercial sewage treatment facilities or waste material landfills?

Yes

Chemicals and pathogens may leach from landfill and sewage areas and contaminate crops, soil, and ground water used for production. Landfills and sewage treatment facilities can also attract unwanted wildlife and pests such as birds, rats, and raccoons. If fields are close to treatment facilities or landfills, assess the likelihood of contamination from leaching, wind, and pests.

No

5

Are produce fields located within 30 feet[1] of a septic system leach field or tank?

Yes

Underground septic systems can leach chemicals and pathogens into soil and water. Septic systems should be inspected yearly to make sure they are working properly and produce fields should not be located within 30 feet of septic tanks and septic leach fields. The safe distance may be increased or decreased depending on risk factors such as age of the septic tank, whether the septic leach field is inactive or active, whether it is located uphill or downhill of crop, and what physical barriers are present in the event that a back-up or spill occurs. Refer to the **Septic System Inspection Log**.

No

Land Use

6

Are produce fields located within 1 mile of Animal Feeding Operations (AFO)[4] or Concentrated Animal Feeding Operation (CAFO) or feedlot?

Yes

Large scale animal feeding operations are a significant food safety risk because of the high concentration of animals that may shed pathogens in their manure. These types of operations are often surrounded by bare ground which increases the likelihood of run-off and windborne movement of pathogens.

When assessing your farm's risk, factors to consider are:

- The number of animals present
- Whether the crop is downhill and/or downwind from source
- Whether the ground is bare or has vegetation
- Evidence of run-off into water sources or near production areas
- Whether physical barriers are present
- If manure management programs are used by the operation

No

7

Are grazing lands and domestic animals (including hobby farms and non-commercial livestock) located within 30 feet[1,7] of produce fields?

Yes

Domestic animals on adjacent land present a food safety risk if there is a chance of wind or run-off spreading fecal matter to produce fields. When assessing risks to your farm, some factors to consider are if physical barriers are present (fencing, ditches, berms), location of crop field (uphill, downhill) from animal grazing area, number of animals present, and the likelihood of run-off and wind spread. Some research suggests a 30 foot buffer[7] is sufficient to protect produce crops from animals grazing on vegetated land. Remember, if you farm with horses or use other animals during production, there must be a plan for their presence in the field, especially close to harvest. See the **Wildlife and Animal Management** tree for more specific recommendations.

No

Land Use

8

Is raw untreated manure from livestock, manure containment structures, storage piles, and composting facilities located within 400 feet[1] of produce fields?

Yes

If manure is close to production areas, there is a risk that it will contaminate produce by run-off or wind spread. When assessing your farm's risk, factors to consider are the amount of manure present, crop location (downhill and/or downwind) from source, likelihood of run off or leaching, physical barriers present, and how storage piles/facilities are protected.

No

9

Is raw untreated manure located within 200 feet[1] of well heads?

Yes

Manure storage areas can leach pathogens into the soil, wells, and other water sources. Wells are particularly susceptible to contamination if they are not capped or properly constructed. When assessing your farm's risk, factors to consider are well construction, presence of risks in well-recharge areas, presence of back-flow devices on all lines fed by the well, location of wells (uphill or downhill) from manure areas, likelihood of leaching, and presence of physical barriers that prevent cross-contamination.

No

10

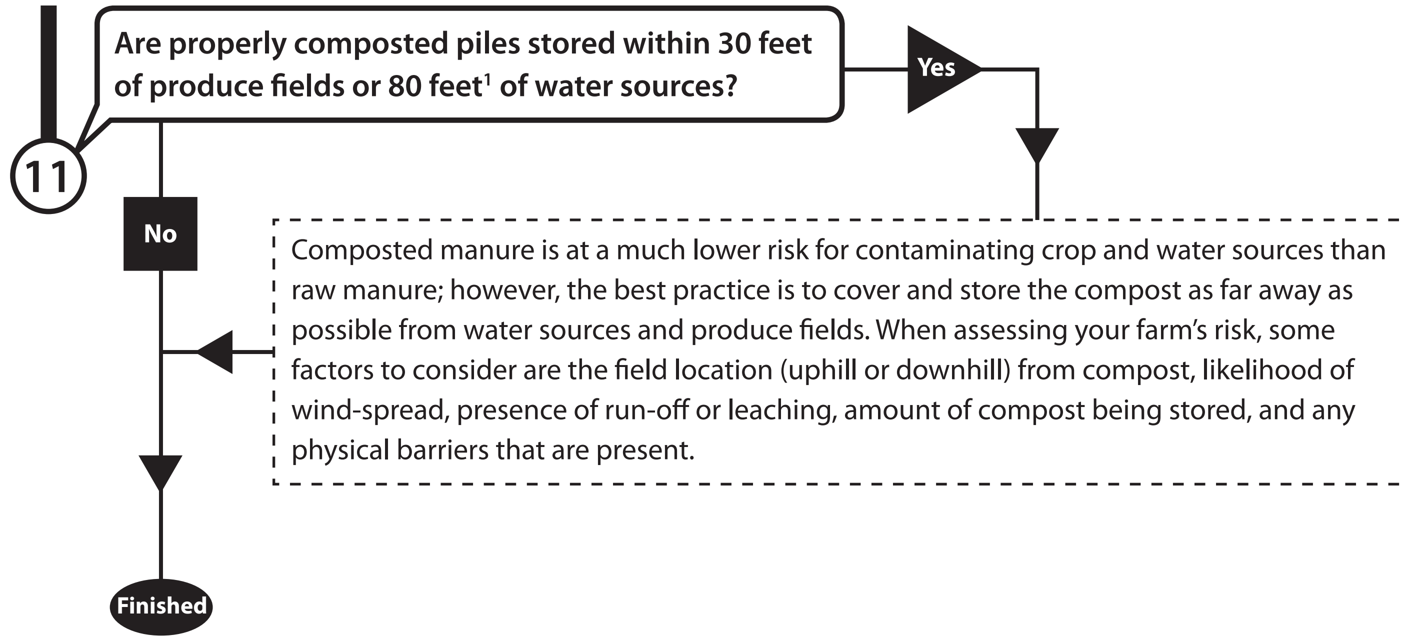
Is raw untreated manure located near surface water sources used during the production of fresh fruits and vegetables?

Yes

Raw manure storage areas near surface water can result in water contamination, either by run-off or through leaching. Safe distance recommendations from the surface water source depend on soil type and slope of land. The Leafy Greens Marketing Agreement (LGMA)[1] recommends at least 100 feet if soil is sandy, 200 feet if soil is clay or loam, and 300 feet if slope is greater than 6%.

No

Land Use



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Sample SOP: Land Use Risk Assessment

Revision: 2.0
Date: 11/18/2013

1—Purpose

Describes how to assess previous and adjacent land use for risks to make sure that they are not a source of contamination to fresh fruit and vegetables.

2—Scope

Applies to people involved in deciding where crops are to be planted or those responsible for assessing produce fields prior to planting.

3—Responsibility

Prior to planting, farm owners/managers must evaluate previous and adjacent land uses for possible sources of contamination and document the assessment. When necessary, actions should be taken to correct, or reduce contamination risks that are identified to prevent contamination of the future produce crop.

4—Materials

- Land Use Risk Assessment Log
- Pen or pencil

5—Procedure

To be completed before planting produce fields then reviewed and updated annually or as changes are made.

1. Choose fields for production based on where there is the least likelihood of contamination. (This could mean not planting in a field or planting a low risk crop in a field of concern)
2. Review and assess field risks including previous and adjacent land uses.
    a. Check sewage treatment or septic systems on site (if present) to make sure they are properly maintained to prevent contamination to fields and water sources.
    b. Review locations of sanitation units in the field to make sure they have not leaked or spilled.
    c. Assess wildlife activity by reviewing the Wildlife Activity logs. Determine whether actions need to be taken to minimize animal activity in produce fields.
    d. Gather information related to application of chemicals to land that may pose a food safety hazard.
    e. Review your water sources including wells, open water sources, and municipal systems to ensure they are in good condition.
    f. Assess impact from adjacent land. Be sure to evaluate animal operations that are adjacent to your land, talk with neighbors about their current land uses, and gather information about previous land uses.

3. Record any risks in the Land Use Risk Assessment Log.
4. If you identify any risks, make the necessary changes to correct or reduce the risks. Depending on the risk, this might include actions such as testing the water or soil for chemical and biological contaminants, creating buffer zones, building berms to contain manure/compost, or constructing fences to keep domestic animals away from produce growing areas.

Record all corrective actions taken in the **Land Use Risk Assessment Log**.

Keep records ***[enter location here]*** and review before planting each season.

Sample Land Use Risk Assessment Log

Name of farm:____

This evaluation should be completed yearly or as changes are made to the farm or production practices.

Task	Yes or No	Observations	Corrective Actions	Date	Initials
Are there any previous land uses or adjacent land uses that represent contamination risks to fruit and vegetable production?					
Have there been any significant changes to land use this year (i.e. addition of grazing animals, field location changes, etc.)?					
Have neighboring properties changed or added activities that might affect fields and water sources (animals, manure or compost storage)?					
Has there been any run-off from compost and manure storage areas or animal pens or grazing areas?					
Were there any flooding events this year?					
Have you inspected your well head to make sure it is in good condition and not in need of any repair?					

Sample Land Use Risk Assessment Log (cont.)

Name of farm:____

This evaluation should be completed yearly or as changes are made to the farm or production practices.

Task	Yes or No	Observations	Corrective Actions	Date	Initials
Have you inspected your septic tank and leach field to make sure they do not lead to contamination of produce fields?					
Are portable toilets and handwashing stations used in the field functioning properly (i.e. no leaks or spills) and located away from produce growing and handling areas?					
Have there been any treatments or chemical applications to the land that may pose a risk to food safety?					
Has fecal contamination or damage to crops by wildlife been an issue in the past year? (Check Animal Activity Logs)					

Reviewed by: ______________________________ **Title:** ____________________ **Date:**________________

Septic System Inspection Log

Name of farm:____

Type of system: ____ **Age of system:** ________________

Date:	Observations of Drainfield:	Tank Condition	Lid Condition	Identified by (Initials):	Corrective Actions:	Date Corrective Action Completed:	Completed by (Initials):
2-26-13	*Smelly odor, soggy ground*	*intact*	*intact*	*ABC*	*Had it pumped, receipt on file. No risk to crops, located well away from growing area.*	*3-5-13*	*ALW*

Reviewed by: ______________________________ **Title:** ____________________ **Date:**________________

Template Language for Land Use Section of a Farm Food Safety Plan

Risk Assessment

Previous uses of production fields and current adjacent land use can introduce biological, chemical, and physical risks to fresh produce fields, soil, and water sources. To reduce the risk of contamination during production of fresh produce, we have assessed previous uses of all fields intended to grow fruit and vegetable crops as well as current adjacent land uses that may represent produce safety risks. Our farm conducted an assessment of risk on ***[enter date]*** to determine whether the land was safe to use prior to planting fruit and vegetable crops for human consumption.

Our assessment included:

- Reviewing the lands' history and previous uses
- Susceptibility to flooding and flood events
- Identification and inspection of well heads and well pads to ensure they are in good condition
- Identification and inspection of septic tanks and sewer systems on the farm to ensure they are functioning properly
- Assessment of water sources; both the source (e.g. pond, stream) and the distribution system
- Identification of all manure/compost storage areas and assessment of the risk of run-off or windborne contamination of produce fields
- Identification of all lands used for animal production on our farm and assessment of risks of manure run-off or windborne contamination of produce fields
- Evaluation of activities on neighboring properties and land that may be a potential source of contamination
    - Domestic animal operations such as AFOs/CAFOs
    - Manure and compost storage areas that may run off into water sources or fields
    - Areas of high wildlife activity
    - Any other changes in building structures or activities that may affect land or water sources

The map used for this assessment is included in this farm food safety plan. The farm map identifies septic tanks and sewer access, portable toilets and handwashing stations, wells, irrigation water sources, water distribution lines, animal holding pens and grazing areas, areas prone to flooding, compost and manure storage areas, and other relevant food safety risk factors to our land and crop production areas including adjacent land uses. The map also identifies general land topography to evaluate the potential for run-off or windblown contamination.

Actions

After completing our assessment, risks are evaluated to determine whether our farm needs to take action. Our farm documents any actions taken to minimize or eliminate the identified food safety risks.

Examples include:

- Talking to neighboring land owners about mitigating a risk on their land that may affect our land, water sources, or crops
- Avoiding planting produce crops in specific locations that have been identified as having food safety hazards such as areas that are prone to flooding, fields that are contaminated with pathogens or chemicals (if identified), or areas that have been used as prior waste or industrial sites
- Testing soil and water sources to determine the level of risk that is present and keeping these tests on file for at least 2 years
- Installing barriers to prevent run-off from compost and manure storage areas or animal grazing and holding pens
- Establishing buffer distances between produce growing and handling areas and compost and manure storage, animal grazing and holding pens, septic leach fields and tanks, or other food safety risks present on the land
- Developing a co-management approach to minimizing risks from wildlife while keeping environmental conservation in mind

The assessment of risk is reviewed each year, including supporting documentation such as corrective actions taken or problems that may have occurred in the previous year.

Agricultural Water for Production Overview

Agricultural water used to grow fresh produce can carry and distribute human pathogens. Surface water is more likely to be contaminated by human and animal fecal material than ground water because it is open to the environment. Therefore, it poses a much greater risk to human health when surface water used for irrigation or protective sprays directly contacts the edible portion of the crop. Surface water available for fresh fruit and vegetable production has been found to be contaminated with human pathogens such as *Salmonella, Escherichia coli* O157:H7, *Giardia*, and *Cryptosporidium*[1, 2, 3, 4]. Water distribution systems are also of concern, because these systems distribute water throughout the farm and can become contaminated if pipes, backflow devices, or other pieces of the distribution system are not in good condition and functioning properly.

Actions can be taken on the farm to reduce the risks of contamination from agricultural water used during the production of fresh produce.

1. Map and inspect all water sources and distribution systems
2. Select water application methods that reduce risks
3. Test all agricultural water for quantified generic *E. coli*
    a. Identify a water testing laboratory
    b. Sample collection
    c. Delivering samples to the laboratory
4. Keep records of all water management actions and test results

Map and Inspect All Water Sources and Distribution Systems

Create a map of all water sources and distribution systems to identify how water moves throughout the farm. All water sources, such as surface water and wells, should be inspected at the beginning of the growing season and periodically throughout the season. Surface water sources, such as ponds, lakes, rivers, or canals, should be inspected for the presence of wildlife and adjacent land uses that could lead to contamination of the water source. Well casings should be inspected to make sure they are intact and well recharge areas should be free of grazing animals or other risks. Any identified risks should be taken care of before the water is used for fresh produce production (e.g. repairing broken equipment, treating the water or using filtration to assure water is sufficiently clean for its intended use).

All distribution systems, as well as equipment used to move water, should be inspected at the beginning and throughout the growing season to ensure the lines are clear and not likely to introduce microbial risks to the crop receiving the water. This includes repairing broken lines and emitters as well as removing any debris in the lines, such as nesting wildlife, which could lead to contamination. Repairing damaged equipment is very important because broken water emitters can turn a drip system into an overhead system, thereby bringing water in direct contact with the edible portion of the crop. Furthermore, if pathogens are present in the irrigation water and the water sits stagnant in the pipe between irrigation applications in warm weather, the pathogens can quickly multiply in the pipe and potentially form a biofilm. Therefore, water should be drained from the pipe between irrigation applications.

Select Water Application Methods that Reduce Risks

Drip irrigation is the least risky method of water distribution because the water normally does not contact the edible portion of the crop, unless you are growing root vegetables or the drip line develops a leak. Overhead irrigation and the application of topical protective sprays result in direct water contact with the edible portion of the crop, so the safety is determined by the quality of water that is applied. If you are using a surface water source for overhead irrigation or for mixing topical protective sprays, you must test this water before using it and throughout the production season.

If you have concerns about the quality of your water that comes in direct contact with the crop, there are other things that can be done to reduce microbial risks. It is still important to test your water so you understand the quality, but you can also:

1. Apply any water that contacts the edible portion of the crop at least two weeks prior to harvest to allow time for drying, and UV light to reduce potential pathogens on the crop.
2. Use water application methods that do not result in direct contact with the edible portion of the crop, such as drip or trickle irrigation.

Test all Agricultural Water for Quantified Generic *E. coli*

Water that directly contacts the edible portion of the plant is most important to food safety because water can carry pathogens and contaminate the crop. The source of any water that directly contacts the edible portion of the crop must be tested for quantified generic *E. coli*. Testing for generic *E. coli* is not the same as testing for total coliforms, so be sure to ask specifically for a **quantified generic *E. coli* test**. The Food Safety Modernization Act (FSMA) proposed produce safety rule specifies these water-testing schedules. If the source is surface water, such as a river, lake, pond, or stream, it must be tested once every week throughout its use. If the source is a well, it must be tested at the beginning of the growing season and every three months during the growing season. If the source is a municipal water source, a copy of the municipality's tests or certification of the quality (water bill) is acceptable as verification of water quality. These are proposed water testing schedules, but they provide an idea of what may be appropriate or required in the future.

The proposed produce safety rule's water standards state that any agricultural water that directly contacts the edible portion of the crop must have less than 235 colony forming units (CFU) or most probable number (MPN) of generic *E. coli* per 100 mls of water sampled for any single sample. The five most recent water samples must have a rolling geometric mean of less than 126 CFU or MPN per 100 mls of water sampled. These standards are derived from the EPA water quality standards and have been modified for the produce industry by the California Leafy Greens Marketing Agreement as well as in the proposed produce safety rule[5, 6, 7].

The easiest way to compare your water tests to these standards is to look at the quantified *E. coli* number on your test results. Is it higher than 235 CFU (or MPN) per 100 mls? If so, you must discontinue use of the water immediately. If the sample is below 235 CFU (or MPN) per 100 mls, then you will need to calculate the rolling geometric mean (n=5) by taking the last 5 test results you have.

The easiest way to calculate this is to put the numbers into a Microsoft Excel spreadsheet (one number per cell), then click on the Formulas tab and select the GEOMEAN calculation under the Statistical Formulas. Alternatively, you can calculate the geometric mean by multiplying all the numbers together, then take the 5th root of this number. This will give you the rolling geometric mean in CFU (or MPN) per 100 mls. **If the rolling geometric mean is less than 126 CFU (or MPN) per 100 mls, you can use the water**. If not, you should not use this water in any way if it will directly contact the edible portion of the crop unless it is treated (e.g. filtration, UV, chemically) and confirmed through re-testing to meet these standards. Chemically treating water has its own risks so all treatment options should be evaluated for their effectiveness and appropriateness for the farm and the crops grown.

The only way to know the water quality is to test the water. It is recommended to test all agricultural water, but if the water is delivered through drip, it does not have to meet the same standards as water that directly contacts the edible portion of the crop. Some buyers and audit companies have established water standards even for water that does not directly contact the edible portion of the crop. Understanding water quality allows growers to make informed water management decisions, especially once a normal baseline has been established from season to season[8, 9].

Identify a Water Testing Laboratory

Find a laboratory that is capable of providing the analysis you need. Currently, testing for quantified generic *E. coli* is the industry standard and included in the proposed FSMA produce rule. Tests that can achieve this type of analysis with an upper limit that exceeds 235 CFU/100 ml include Colilert Quantitray 2000 and modified mTec (EPA 1603). There may be other types of tests that can be used, but be certain to specify the type of water source since many labs are not prepared to handle surface water sources.

Sample Collection

Follow the sampling guidelines recommended by the laboratory doing the water analysis. This includes using designated sampling containers. Please review the sample SOP in this portfolio for specific sampling instructions.

Delivering Sample to the Laboratory

All samples should be delivered to the selected lab on the day of collection or shipped overnight early delivery. Some tests have a 6-hour hold time limit. If this is the case, you will need to deliver the sample that day within 6 hours of taking the sample. If you are shipping bottles, you may want to place the water sample bottle in a Ziploc® bag and pack it snugly in the box with ice and packing peanuts. If you are shipping more than one sample to the lab in one day, and in the same box, be extra careful that all samples are properly labeled so that there is no confusion about the origin of the sample. Ship samples with plenty of ice or ice packs.

Keep Records of All Water Management Actions and Test Results

Records should be kept for all water tests as well as any water management actions that are taken to identify and reduce risks that may be present in the water or the water delivery system. Template logs are provided to assist you with this record keeping process.

References

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The information in the template food safety plan, SOPs, and record keeping logs are examples you can use. They are not intended to be used directly. Tailor each to fit your farm operation and practices.

Agricultural Water for Production

1

In the field, do you irrigate, frost protect, cool, apply protective sprays, or use any agricultural water during the production of fresh produce?

Yes → continue to question 2.

No →

If you do not use any water in the field while growing fresh produce, there is no applied water risk. Note in your food safety plan, "We do not apply any water including protective sprays during production, so we do not have a water management or testing plan."

2

Do you have a water source and distribution map for you farm?

Yes → continue to question 3.

No →

Create a map (can be hand drawn) that shows the location of your water sources and how water is distributed throughout your farm from those sources. Note the irrigation method and other distribution details on the map. This will help you assess risks related to water distribution.

3

Do you inspect your water sources at the beginning of production and throughout the growing season?

Yes → continue.

No →

All water sources should be inspected at the beginning and periodically throughout the growing season. Surface water sources, such as ponds, rivers, and streams, should be inspected for the presence of wildlife and adjacent land issues that could lead to contamination of the water source. Well casings should be inspected to make sure they are intact and well recharge areas should be free of grazing animals or other risks. Any identified risks should be fixed before the water source is used for fresh produce production.

Agricultural Water for Production

4

Do you inspect your water distribution or delivery system, including equipment, at the beginning of the growing season?

No

All water distribution and delivery systems, as well as equipment used to move water, should be inspected at the beginning and throughout the growing season. This will ensure that the lines are clear and not likely to introduce microbial risks to the fresh produce crop receiving the water. Preventative maintenance, such as repairing broken lines and emitters, and removing any debris in the lines (e.g. nesting wildlife), will help prevent the spread of contamination.

Yes

5

Does any agricultural water used during production have direct contact with the edible portion of the crop? This includes water used to mix protective sprays.

No

Water that never comes in direct contact with the edible portion of the crop represents the lowest risk. Some buyers and audit companies require all water used during production, regardless of how it is applied, be tested and meet specific water quality standards. It is recommended that you test this water for quantified generic *E.coli* to establish a baseline of water quality for the water source.

Yes

6

Is all agricultural water tested for quantified generic *E.coli*?

No

The source of any water that has come in direct contact with the edible portion of the crop must be tested for quantified generic *E. coli*. The FSMA proposed produce rule states that if the source is a surface water source, such as a river, pond, or stream, it must be tested once per week throughout its use. If the source is a well, it must be tested at the beginning of the growing season and every three months thereafter during the growing season. If the source is a municipal water source, a copy of the municipality tests or certification of the quality is acceptable as verification of water quality.

Yes

Agricultural Water for Production

7

Is *E.coli* present at less than 235 CFU or MPN per 100 mls water sampled for a single sample and a rolling geometric mean (n=5) of less than 126 CFU or MPN per 100 mls of water?

Yes

No

Do not use this water to mix sprays or apply irrigation that will come in direct with the edible portion of the crop. Inspect the water source and delivery system to see if there is any obvious source of contamination. Retest the water source if you need to use the water. If the water still does not meet the standard, the water will need to be treated to meet the standard or an alternative water source that meets this microbial standard should be used. See the EPA reference for specifics on water quality and the Agricultural Water for Production Overview for how to calculate a rolling geometric mean.

8

Do you keep records of all water test results and water management actions, such as inspecting water sources and water delivery systems?

Yes

No

Records should be kept for all water tests as well as any water management actions taken to identify and reduce risks that may be present in the water or the water delivery system. Template logs are provided to assist you with this record keeping process.

Finished

Sample SOP:
Agricultural Water for Production Testing

Revision: 1.0
Date: 2/22/2013

1—Purpose

Describes how to sample surface water for generic *E.coli* analysis. It can also be used when sampling well or municipal water.

2—Scope

Applies to any farm personnel responsible for sampling water and submitting it to a laboratory for analysis.

3—Responsibility

Anyone responsible for sampling water or submitting the samples to a laboratory should understand this SOP. Anyone responsible for keeping records of water tests results should also be familiar with the SOP in case there are unusual test results so they might be able to identify a problem with the sampling, shipping, or analysis.

4—Materials

- Marker for labeling bottles
- Water sampling stick (not required but helpful for sampling surface water)
- Disposable gloves
- Sealed, sterile sampling container (1 Liter bottle or lab provided container)
- Cooler
- Ice packs
- Tape
- Ziplock® bags
- Garbage/disposal bag for waste
- Shipping labels (if mailing to lab)

5—Procedure

Water Sampling Protocol for Surface Water

Collection of Water Sample

**Always follow instructions provided by selected lab regarding container and sampling protocol.*

1. Label bottle with name, water source type, date, and time of collection.
2. Identify good sampling area, sampling nearest use area as possible.
3. If using a sampling stick, assemble bottle on sampling stick.

4. Put on gloves.
5. Uncap bottle as close to the water source or irrigation equipment as possible. Do not place fingers on bottle lip or inside bottle.
6. Dip bottle into source and collect water. If sampling from irrigation equipment, it may be necessary to let the water run for a while to ensure you are getting water that has not been sitting in the pipes. Do not let bottle lip contact irrigation equipment. Collect at least 100 mls of water from each location. Be sure to sample the water after it flows through the irrigation filter (if applicable).
7. When bottle is full, tightly cap. Be sure not to touch the inside of the bottle and the lip.
8. Double check bottle labeling to be sure it is correct.
9. Place the water bottle in 1 gallon Ziplock® bag and seal (only critical if shipping samples).
10. Place in cooler with ice packs.
11. If shipping, label cooler and seal.
12. Deliver to selected lab or drop off at shipping company for shipment. Be sure delivery meets the hold-time standard set by the laboratory; otherwise, the test results will not be certified.

Water Sampling Protocol for Well Water

1. Label bottle with name, water source type, date, and time of collection.
2. Sample nearest point of use as possible.
3. Turn faucet on. Let the water run long enough so that you are testing water from the well and not just the water that has been sitting in the pipes or hose. Depending on your water system, this could be as long as 5 minutes or as short as 1 minute.
4. Put on gloves.
5. Uncap bottle as close to the water source as possible. Do not place fingers on bottle lip or inside bottle.
6. Place bottle into running water and collect at least 100 mls of water.
7. When bottle is full, tightly cap. Be sure not to touch the inside of the bottle and the lip.
8. Double check bottle labeling to be sure it is correct.
9. Place the water bottle in 1 gallon Ziplock® bag and seal (only critical if shipping samples).
10. Place in cooler with ice packs.
11. If shipping, label cooler and seal.
12. Deliver to selected lab or drop off at shipping company for shipment. Be sure delivery meets the hold-time standard set by the laboratory; otherwise, the test results will not be certified.

Sample Water Testing Log

Name of farm: *Pleasant Valley Farm*

See farm policy and SOP for specific water sampling procedures.

Date/Time sampled	Name of sampler	Water Source/ Sample location	Date/Time S = Shipped D = Dropped off	Laboratory name	Quantified Generic *E. coli* results and method	Date results received	Exceed 126 CFU per 100ml (yes/no)	Corrective actions taken (yes/no)	Initials
5/22/13 13:15	*Jack Smith*	*Pond/off the dock*	*5/22/12 15:00 D*	*Wedo Poo*	*10 CFU/100 mls Quantitray 2000*	*5/25/12*	*No*	*No*	*EAB*
Notes:									
Notes:									
Notes:									
Notes:									
Notes:									

Reviewed by: ______________________________ **Title:** ____________________ **Date:**________________

Sample Water Source Inspection Log

Name of farm: *Pleasant Valley Farm*

See farm policy for specific water source inspection procedures.

Date	Water Source	Observations	Corrective Actions Taken	Initials
4/22/13	*Well*	*Well casing in good shape, recharge area clear.*	*None*	*EAB*
4/22/13	*Pond*	*Significant geese presence.*	*Introduced swan decoys. Will monitor.*	*EAB*

Reviewed by: ______________________ **Title:** ______________ **Date:**____________

Sample Water Distribution Inspection Log

Name of farm: *Pleasant Valley Farm* ______________________________

See farm policy for specific water distribution inspection procedure.

Date	Water Distribution System	Observations	Corrective Actions Taken	Initials
4/23/13	*Overhead pipes*	*Nothing broken, but some debris in the lines.*	*Blew out lines with high pressure air.*	*EAB*

Reviewed by: ______________________________ **Title:** ______________________ **Date:**____________________

Template Language for Agricultural Water for Production Section of a Farm Food Safety Plan

Risk Assessment

Agricultural water used to produce fresh fruits and vegetables is a concern because water can carry and distribute human pathogens. Surface water is more likely to be contaminated because it is open to the environment. Overhead irrigation or protective spray applications are of most concern because they contact the edible portion of the crop. Our farm uses water from ***[identify sources here]***. We use ***[type of irrigation]*** and apply sprays mixed with ***[source of water]*** water.

Actions to Reduce Risks

We inspect our water sources and distribution system at the beginning of each season and ***[insert frequency]*** per season. Any problems that are identified and corrective actions taken are recorded in the Water Source Inspection or Water Distribution Inspection Logs.

All agricultural water is tested for quantified generic *E. coli*. Surface water sources are tested ***[enter frequency]*** and/or well water sources are tested ***[enter frequency]***. The sampling details and test results are documented on the Water Testing Log. We also request copies of tests done by the municipality and keep copies of these tests on file.

If any single water sample is above 235 CFU per 100 mls of water sampled or if the rolling geometric mean is above 126 CFU per 100 mls, we do not use the water in any way that directly contacts the edible part of the crop. Should water treatment or use of an alternative water source be necessary, we document all actions we take on our Water Testing Log.

All sprays are mixed with potable water. All overhead irrigation applications with surface water are completed at least two weeks prior to harvest.

All water management and water testing logs are kept on file ***[enter location here]*** for at least ***[2 years – or enter duration here]***.

Soil Amendments Decision Tree

1. Do you use inorganic fertilizer?

- **No** → State in plan: “No inorganic fertilizer is used on the farm”. Go to question 4.
- **Yes** → Go to question 2.

2. Are inorganic fertilizers stored in a covered area that is separate from where produce is handled or stored?

- **No** → Fertilizers must be protected from the weather, so they do not chemically react or leach. Produce can be contaminated if handled or stored near fertilizer, or if it comes in contact with chemical leachate.
- **Yes** → Go to question 3.

3. Are inorganic fertilizer storage facilities checked weekly and cleaned when necessary?

- **No** → Storage facilities should be inspected weekly to check for spills to reduce risks of chemical contamination. Use the *Chemical Storage Facility Monitoring Log* to document maintenance checks and cleanings.
- **Yes** → Go to question 4.

4. Do you use raw untreated manure (e.g. teas, leachates, and slurries) on the farm?

- **No** → State in plan “No raw animal manure is used on the farm”. Go to question 1.
- **Yes** → Continue.

Soil Amendments Decision Tree

5 **Do you incorporate raw untreated manure in to the soil at least 1 year before harvest[1]?**

No

Raw manure presents a food safety risk because it contains pathogens that can contaminate fresh produce. When using raw manure, reduce risks by incorporating it into the soil within 72 hours after application, and never apply it during the growing season. Maximize the time between manure application and crop harvest to reduce risks. The LGMA requires a 1 year harvest interval, while the NOP requires 90/120 days[7] and the FSMA proposed produce rule requires 9 months.[13] Refer to the *Soil Amendments Overview* for more information and references.

Yes

6 **Do you avoid spreading raw untreated manure on fields that are water saturated, prone to annual flooding or runoff, or are frozen or snow covered?**

No

Manure applied to fields that are water saturated or prone to flooding can leach and contaminate surrounding production areas and water sources. Be sure to know and follow municipal, state, and federal rules and regulations. Your Natural Resources Conservation Service[8] (NRCS) state offices will have current state standards on water quality protection practices (codes 590 and 633).

Yes

7 **If raw untreated manure is stored on your farm, is it covered and physically contained?**

No

Runoff, leachate, and wind spread from raw manure piles can result in the contamination of produce, soil, and water sources. To reduce risks, manure piles should be physically contained and covered to protect them from rainfall and wind. The minimum containment for storage is on a concrete slab. Raw manure should never be piled in a produce field or on bare soil.

Yes

Soil Amendments Decision Tree

8

Is raw untreated manure from livestock, manure containment structures, storage piles, and composting facilities located at least 400 feet[14] from produce fields and handling sites?

Yes

No

If manure is close to production areas, there is a risk that it will contaminate produce by runoff or wind spread. Safe distances for storage will vary depending on the amount of manure present, crop location (downhill and/or downwind) from source, likelihood of runoff or leaching, physical barriers present, and how storage piles/facilities are protected.

9

Is raw untreated manure located at least 200 feet[14] from well heads?

Yes

No

Manure storage areas can leach pathogens into the soil, wells, and other water sources. Wells are particularly susceptible to contamination if they are not capped or properly constructed. To reduce risks of well contamination, be sure the well is properly constructed and capped, install back-flow devices, keep animals out of the well recharge area, store manure downhill from the well, and make sure water runs away from the well head.

10

Is raw untreated manure separated from surface water sources used during the production of fresh fruits and vegetables?

Yes

No

Raw manure storage areas near surface water can result in water contamination, either by runoff or through leaching. Safe distance recommendations from the surface water source depend on soil type and slope of land. The Leafy Greens Marketing Agreement (LGMA)[1] recommends at least 100 feet if soil is sandy, 200 feet if soil is clay or loam, and 300 feet if slope is greater than 6%.

Soil Amendments Decision Tree

11 **Do you use composted manure or compost manure on your farm?**

No → Go to Question 16.

Yes ↓

12 **Is the composting process done on your farm?**

No → If you get your compost from a supplier, ask for documentation about the composting method and microbial testing to include in your records.

Yes ↓

13 **Do you properly process/compost manure according to industry standards? For compost guidelines refer to the *Soil Amendment Overview*.**

No → Composting manure reduces food safety risks by reducing the likelihood that pathogens are present. Composting requires specific active processing treatments; passive treatments like "aging" do not count as composting. For composting standards, refer to the *Soil Amendment Overview*. If proper composting practices have not been met by you or your provider, then you must follow the application and storage guidelines for raw manure outlined in questions 5–10.

Yes ↓

14 **Do you keep finished compost under covered storage?**

No → If you store finished or curing compost on your farm, it should be covered to prevent recontamination of the pile. It can be covered with a tarp or stored in an enclosed facility. Recontamination of a compost pile can occur by rain[16], wind spread from adjacent manure piles, or bird or other animal intrusion.

Yes ↓

Soil Amendments Decision Tree

15

Is compost stored at least 30 feet[14] from produce fields and 80 feet[10] from water sources?

No

Composted manure is aless likely to contaminate crop and water sources than raw manure; however, the best practice is to cover and store the compost as far away as possible from water sources and produce fields. When assessing your farm's risk, some factors to consider are the field locations (uphill or downhill) from compost, likelihood of wind-spread, presence of runoff or leaching, amount of compost being stored, and any physical barriers that are present.

Yes

16

Do you keep records of the following?

- **Type of fertilizer being applied**
- **Method of application**
- **Field receiving applications**
- **Date of application**
- **Rate (quantity applied per acre)**
- **What crops will be planted**
- **Compost production methods and microbial testing (if applicable)**

No

Recordkeeping is critical to keeping track of soil amendment applications, both for plant and soil fertility as well as safety. Utilize the *Soil Amendment Application Log* for your food safety plan and application recordkeeping.

Yes

Finished

16. Erickson, M., F. Critzer and M. Doyle. 2010. Composting Criteria for Animal Manure. Produce Safety Project Issue Brief on Composting of Animal Manures. 13 p. http://www.pewtrusts.org/en/research-and-analysis/reports/0001/01/01/issue-brief-series-analyses-of-possible-sources-of-produce-contamination

Worker Health, Hygiene, and Training Decision Tree

1

Do you hire any workers (including non-paid family members)?

Yes

No

If you are the only worker on your farm, you must understand the risks associated with your own actions. Please review the practices outlined in this tree to make sure you know which practices you need to follow. In addition to knowing and following proper health and hygiene practices, as the only worker you are responsible for writing your farm food safety plan. Template food safety plan language about worker health, hygiene, and training is provided at the end of the decision tree to help you write your plan. Please continue through this decision tree.

2

Have all workers received training in areas important to produce safety using a language they understand? This training should include:

- **How and when to properly wash their hands**
- **The importance of being clean and wearing clean clothes to work**
- **How to handle illnesses and injuries on the farm**
- **Knowing how to complete all the farm food safety practices they are assigned**

Yes

No

A worker education and training program that explains the microbial risks associated with farm work and emphasizes practices that can reduce these risks is essential to produce safety. Verbal and written training materials should be presented using a language workers understand. Proper hand washing and hygiene instructions are critical to minimizing the risk of contamination from workers. Training should include all farm food safety practices for which workers are responsible for completing.

Worker Health, Hygiene, and Training Decision Tree

3

Have workers been informed not to come to work if they are sick and instructed on how to report illnesses?

No

People who are ill or who have symptoms of nausea, vomiting, or diarrhea can contaminate fruits and vegetables with harmful microorganisms and should not handle produce. Every farm should have an illness reporting policy that workers understand and can follow. Sick workers should stay at home.

Yes

4

Is a first aid kit available in a known and convenient location, and have workers been instructed how to respond to injuries on the farm?

No

A first aid kit should be stocked and available to all workers and visitors. Workers who have cuts or other injuries could contaminate fresh produce with bodily fluids such as blood. All workers need to be trained to respond to injuries including knowing the location of first aid supplies, how to wash and bandage minor cuts, and to wear gloves or other covering to provide a secondary barrier between the injury and produce they handle. All contaminated produce must be thrown away and the injury should be written on the injury reporting log and kept on file.

Yes

5

Are workers instructed to only take breaks in designated areas so that they are not eating, or smoking in the fields or near product in the packinghouse?

No

Eating or smoking should not be allowed in the field, packinghouse, or other production areas to prevent contamination. Workers must wash their hands after eating, drinking, smoking, using the toilet, or taking a break, and before returning to work. Workers must always wash their hands before handling produce.

Yes

Worker Health, Hygiene, and Training Decision Tree

6

Have workers been informed of the farm's food safety policies and any other food safety practices they are responsible for implementing?

Yes

No

Workers who know the farm's food safety policies and who understand food safety risks, will be actively involved in the farm's food safety program. Informing workers is particularly important if they have other food safety responsibilities such as monitoring toilet and hand washing facilities, pest control procedures, or other key steps that require implementation and recordkeeping.

7

Are there signs or posters in a language the workers understand reminding them to properly follow the farm's food safety practices?

Yes

No

An effective worker training program should be reinforced daily through signs posted in a language workers understand or with pictures that describe appropriate actions. These materials will also serve to remind visitors of the farm's food safety policies.

8

Are records kept of worker training?

Yes

No

Worker training is very important for food safety. Records of all training programs should be kept including information about what was covered, who taught the training, workers who attended, date, and the location. Some workers may require additional training, particularly if they are trained for specific tasks beyond basic health and hygiene practices.

Worker Health, Hygiene, and Training Decision Tree

9 **Are visitors asked to sign in and read your visitor policy?**

No → Visitors should be asked to sign in and acknowledge they have read the farm food safety policies that they need to follow while they are on the farm. This may include where they are allowed to visit, areas that are off limits, and your policies regarding hand washing and illness reporting.

Yes ↓

10 **Are there clean toilet and handwashing facilities for workers and visitors within a short (5 minute or 1/4 mile) walk of the fields?**

No → All workers and visitors must have access to clean, conveniently located toilets and hand washing facilities to encourage use.

Yes ↓

11 **Is the toilet monitored for cleanliness, cleaned when dirty, and restocked when necessary?**

No → Facilities must be cleaned on a regular schedule to make sure they are sanitary and well-stocked with soap, water, toilet paper, and paper towels. Toilets should be checked daily and they should be cleaned and restocked as needed, even if that requires maintenance before the scheduled times.

Soap, water, paper towels, and toilet paper MUST be provided. Lack of supplies makes training ineffective because workers and visitors cannot follow the required practices.

Yes ↓

Worker Health, Hygiene, and Training Decision Tree

12

Are records kept for all toilet and hand washing facility monitoring, cleaning, and restocking as well as any other steps that may be taken to maintain food safety resources such as first aid kits?

No

Records should be kept for all toilet and hand washing facility monitoring, cleaning, and restocking. Some records may be kept daily and others weekly, but all actions need to be recorded. All other health and hygiene facilities maintenance should be recorded as well including monitoring and restocking first aid kits. ***Helpful Tip: Keep a clipboard with a log sheet and pen secured by string close to where recordkeeping needs to happen so it is convenient for workers to complete.***

Yes

Finished

Wildlife and Animal Management Decision Tree

1

Have you assessed animal access (including wildlife, livestock, and pets) to water sources, produce fields, and adjacent lands that may represent a risk of contamination to your crop prior to planting?

Yes / **No**

Animals and animal feces may contaminate produce if they are present in or near produce fields or water sources. Large numbers of animals represent the biggest risks because they can produce large amounts of fecal matter that may be deposited in fields or enter through water runoff, airborne particles, or by contaminating water sources.

Assessment of the food safety risks associated with animals may include:

- Identifying presence and location of grazing and feeding operations
- Identifying the type and approximate number of animals (domestic and wildlife)
- Observing activity patterns or seasonality of domestic animals and wildlife presence
- Evaluating topography of the land to assess for potential runoff

2

Are you monitoring for wildlife and domestic animal presence in your fields and production areas?

Yes / **No**

Monitoring for animal presence is critical because they can carry or spread human pathogens in their feces that may contaminate the crop. Monitor your fields for animal intrusion at least weekly, and more frequently close to harvest to identify problems, and take action to reduce risks.

3

Has there been significant physical evidence of animal intrusion into fields or production areas (e.g. downed fences, animal tracks, animal feces, crop destruction)?

Yes / **No**

Continue to monitor for animal presence and intrusion. Document any activity observed throughout the season, especially close to and during harvest.

Wildlife and Animal Management Decision Tree

4

Have you taken actions to exclude, deter, or limit animal access to fields?

No

Properly dispose of cull piles, and minimize other harborage areas that may attract unwanted animals. Construct fences, or devise methods to exclude, deter, or limit animal entry into the fields. This may also include elimination through nuisance animal permits.*

Note—Co-management: *Be sure to check local, state, and federal laws and regulations that protect endangered species and riparian habitat that may limit removal of vegetation or the construction of deterrent fences for wildlife corridors.*

Yes

5

Have your workers been trained to look for and report animal intrusion or fecal contamination during production, harvest, and packing activities?

No

All workers should be trained to identify the signs of animal intrusion, such as downed fences, crop damage, or presence of fecal material, and report any events to the supervisor while working on the farm. This is important because workers are usually in the field more often and are able to assess more fields than one person (owner or manager) alone.

Training should include:

- How to identify signs of wildlife intrusion (animal tracks, damaged product, downed fences, and the presence of fecal material).
- To whom they should report significant wildlife activity.
- What actions to take (e.g., not harvest product, establish buffer zones, proper removal of affected product, cleaning and sanitation of tools/equipment and hands).
- What should be documented and which recordkeeping logs need to be filled out.

Yes

Wildlife and Animal Management Decision Tree

6

Has a pre-harvest assessment of the crops and fields been completed before each harvest to determine if there has been any significant animal activity that would alter harvest practices?

No

Yes

A pre-harvest assessment of the growing fields focusing on domestic and wild animal intrusion should be completed prior to harvest. This will reduce the likelihood of harvesting a contaminated crop by assessing whether the crop has been contaminated. The presence of fecal material or indicators of animal intrusion, such as extensive tracks or crop destruction, should be assessed to determine the risk of crop contamination and if harvesting should begin.

7

Has significant animal activity or animal fecal material been found in close proximity to or in direct contact with the produce?

No

Yes

Continue to monitor for animal presence and intrusion. Document any activity observed in the future, especially close to and during harvest.

Wildlife and Animal Management Decision Tree

8

Have you modified your harvest practices to reduce risks by not harvesting contaminated areas or by establishing buffer zones that reduce the risks of harvesting contaminated crops?

Yes / **No**

1. Do not harvest produce which is in contact with feces. Depending on the area affected, remove fecal material and affected product, disk the field, or take some other action to limit the risks of contaminating adjacent fields and produce. Be sure anyone involved in the removal process washes their hands and cleans and sanitizes all tools used in the clean-up.
2. If only a portion of the field is impacted, consider establishing a buffer zone* so produce in close proximity to the site(s) of contamination is not harvested. The buffer zone radius should be based on crop type, irrigation or water applications such as rain that may cause splash, and extent of fecal contamination. Buffer zone size varies so consult industry and research publications to determine the buffer that is right for your farm.

**Note—If fecal contamination is identified in the field, several guidance documents may help establish a buffer zone to only harvest product which is at low risk for being contaminated. A minimum no-harvest buffer zone radius of 5 feet from the contaminated produce or feces should be established. This buffer zone may be increased, depending on the crop (ground crop), climate (heavy rainfall increasing splash radius), and contamination event (large wet feces more likely to splash).*[4]

9

Has documentation of animal activity management and monitoring been kept on file, including any corrective actions required to reduce the risk in the future?

Yes / **No**

A written record of animal management, monitoring, activity, or corrective actions should be kept on file. Documentation can help identify trends (such as time of year) that animal activity might be a problem, so practices that reduce risks can be put into place.

Finish

Sanitation and Postharvest Handling Decision Tree

1. Do you sort, package, wash, or grade produce in a packing house, shed, or other structure?

Yes → go to 2.

No → Regardless of where you pack produce, sanitation practices are going to be important to produce safety. Field and open packing areas (e.g. temporary tent, open shelter) may present different challenges than a completely enclosed packing facility. Many of the same principles apply, but open packing areas may have more risks associated with wildlife, birds, and blowing dust. This decision tree highlights the challenges of managing food safety in both closed and open packing areas.

2. Have you diagrammed the flow of produce through the packing area and identified all the food contact surfaces (places where fresh produce touches equipment, brushes, rollers, boxes, etc.)?

Yes → go to 3.

No → To begin developing an effective sanitation program, it is important to understand how fresh produce moves through the packing area and identify all surfaces fresh produce may contact. Once the flow and contact surfaces are identified, an effective sanitation plan can be developed.

3. Can all food contact surfaces in the facility (e.g., grading tables, conveyor belts, tools, bins) be easily cleaned and sanitized?

Yes → continue.

No → Any surface that fresh produce touches after being harvested may serve as a source of contamination. Packing areas, equipment, and surfaces must be constructed to allow easy cleaning and sanitizing. Moving parts such as rollers, brushes, or belts should be easily accessible for cleaning, or able to be removed during the cleaning process. A porous surface, such as wood, cannot be sanitized but it can be cleaned. When repairs or upgrades should be made, replace equipment and tools with materials that can be easily cleaned and sanitized.

Sanitation and Postharvest Handling Decision Tree

4

Have SOPs been developed for cleaning and sanitizing equipment and tools?

No

SOPs* provide a detailed, step-by-step process of how to clean and sanitize equipment and tools. There are four steps involved in cleaning and sanitizing food contact surfaces.

Step 1: Rinse the surface so any obvious dirt and debris are removed.

Step 2: Apply an appropriate detergent and scrub the surface.

Step 3: Rinse the surface with water that is the microbial equivalent of drinking water.

Step 4: Apply an appropriate sanitizer. If the sanitizer requires a final rinse, then this will require an extra step. Let the surface air dry.

*See the supplemental resource: *How to Write an SOP*.

Yes

5

Have workers been trained to follow farm SOPs to properly clean and sanitize surfaces, tools (e.g., knives, blades, and buckets) and equipment?

No

Workers need to understand and follow SOPs if cleaning and sanitizing equipment is part of their job. This may require additional training. See tips for training workers in the W*orker Health, Hygiene, and Training* decision tree.

*See *Tools and Equipment Cleaning and Sanitizing Log*.

Yes

Sanitation and Postharvest Handling Decision Tree

6

Are workers trained to wear clean clothes and follow other personal equipment requirements written in your food safety policy?

Yes / **No**

Workers should be trained so they understand the importance of wearing clean clothes to work and any other practices they need to do. For example, if workers are required to wear gloves or aprons, they should be instructed to change gloves often (if disposable) or clean dirty gloves properly. Aprons and smocks should be kept clean and washed when they are dirty. Gloves and aprons should not be worn outside of the packing facility or in the restroom, and should be stored in a designated place off of the ground in a clean, dry area. Review the *Worker Health, Hygiene, and Training Decision Tree* for more training information and suggestions.

7

Are the packing, sorting, and grading areas cleaned at the end of each day of use?

Yes / **No**

Daily cleaning is important to reduce the risk of microorganisms growing and persisting through the formation of biofilms. Daily cleaning also establishes a culture of cleanliness and prioritizes sanitation practices.

* See *Packinghouse Food Contact Surface Sanitation Log*.

8

Are cull piles properly disposed of at the end of each packing day?

Yes / **No**

Cull piles should be disposed of properly to avoid attracting pests into the packing and storage areas. Cull piles should be removed, composted, or field spread at the end of each packing day.

Sanitation and Postharvest Handling Decision Tree

9

Have you established a pest control program?

Yes

No

For all facilities, a pest control program must be established to exclude or eliminate rodents, birds, and insects from postharvest handling and storage areas. If pest activity is found, methods to reduce or eliminate activity should be developed. This might include installing bird netting under roofs, adding screens to windows, or setting traps. Traps should never be baited inside the packing area, as this may draw more pests into the area. The program should include regular monitoring and corrective actions if pest activity is found. In open air packing facilities, pest control is much more difficult, therefore precautions must be taken to keep produce covered and away from any potential pest contamination.

* See *Pest/Rodent Control Log.*

10

Do you remove as much dirt, mud, and debris as possible from fresh produce and produce bins before entering the packing area?

Yes

No

Any debris and dirt should be removed from fresh produce and produce bins before entering the packing area. This will help keep packing areas clean and prevent cross-contamination of the finished product. Dirt and debris can also decrease the efficacy of chlorine and other water sanitizers, so removing dirt before produce and/or bins enter the wash tank may improve your ability to properly manage postharvest water sanitation practices.

* See *Postharvest Water Decision Tree* for information on postharvest water management.

11

Is produce always packed into new, single-use containers or reused containers that have been cleaned and sanitized?

Yes

No

Fresh produce should always be packed into clean boxes to avoid cross contamination. If boxes are reused, they should be cleaned and when possible, sanitized to keep the produce safe.

Sanitation and Postharvest Handling Decision Tree

12

Are packing containers and packaging materials stored in an area that is covered to reduce the potential for contamination by pests or environmental contamination such as windblown dirt?

No

Packing containers and other packing materials that are not used right away should be stored in a way that protects them from contamination by pests (e.g. rodents and insects), dirt, dust, and water condensing from overhead equipment and structures. If packing supplies are stored outside the packing facility, they should be covered or cleaned and sanitized before use.

Yes

13

Is finished produce stored in an area that is cleaned regularly and inspected for pest activity?

No

Produce storage areas should receive regular cleaning as determined by the farm's SOPs. Your pest control program should include active monitoring of produce storage areas and have corrective actions outlined if the produce has been contaminated by pests. Pallets and boxes of packed produce should be stored 12″ away from storage room walls to facilitate pest control monitoring. Important steps, such as the date cleaning was completed and monitoring of rodent traps, should be documented as part of the recordkeeping.

*See *Produce Storage Area Cleaning and Inspection Log*.

Yes

Sanitation and Postharvest Handling Decision Tree

14

Are refrigerated or cold storage rooms clean and used properly, ensuring the quantity of produce does not exceed the cooling capacity of the refrigerated room?

No

All storage areas, including coolers, should be clean to reduce any risk of cross contamination. The quantity of produce stored in a refrigerated room should not exceed the room's cooling capacity. Improper cooling methods or broken equipment may cause condensation to form and drip onto the produce which can foster the growth of pathogens and spoilage organisms.

Produce that is iced or may drip should not be stored above dry produce. If the cooler is used to store anything besides fresh produce (such as meat or eggs that might represent a contamination risk), be sure that those products are stored in designated areas below and away from fresh produce.

*See *Cooler Temperature Log.*

Yes

Finished

Transportation Decision Tree

1

Do you cover your commodity during transport?

Yes

No

Produce should be covered or otherwise protected as it is moved from the field to the packing area or to the market. Using covered boxes, other covering, or an enclosed vehicle will help protect produce from being contaminated by dirt, dust, bird droppings, and other environmental sources of contamination.

2

Do you have a policy to ensure vehicles that transport produce have not been previously used to haul anything other than fresh produce or that those vehicles have been cleaned and sanitized (if possible) prior to loading and transporting produce?

Yes

No

Fresh produce should not be transported in vehicles that have been used to haul manure, soil, compost, animals (including pets), animal products, or hazardous materials as these present a food safety risk. If vehicles, such as wagons and pick-up trucks, are used for multiple purposes on the farm, then a policy should be put in place to ensure they are cleaned before hauling fresh produce. See the SOP for *Cleaning Produce Transport Vehicles* and document on the logsheet.

Transportation Decision Tree

3

Do you inspect all transportation vehicles prior to loading fresh produce to ensure they are clean and will not serve as a source of contamination to the commodity?

No

All vehicles should be inspected before loading produce to ensure there is no dirt, debris, or other evidence of contamination that may pose a food safety hazard. A written SOP should be developed for cleaning transportation vehicles (if you do this yourself) that includes removing debris, cleaning, and sanitizing (if possible). If the truck is contracted, check it before loading. Look at the outside and inside of the truck. Use your eyes and nose as you inspect the truck. Look for evidence of animals, including pets and pests. Make sure the truck is free of trash, debris and odors. Ask the driver about previous loads that have been carried in the vehicle and when the vehicle was last cleaned.

A designated worker should sign or initial the completed checklist or inspection report, to verify cleanliness and appropriate temperature (if applicable).

Yes

4

Do you have a written policy for precooling produce as needed, maintaining specific temperatures and a plan for monitoring the temperature during transportation?

No

It may be that the fresh produce you are shipping is going a short distance so temperature maintenance is not as important as for longer transit times. However, if you have a contract with a transportation company and you require refrigeration, be sure to include your specified temperature range for the produce that will be transported. Check and record the trailer temperature before loading produce to ensure that the cargo area has been properly pre-cooled. Pre-cooling transportation vehicles is an important step in the cold chain maintenance, because it will help prevent heat build-up and deterioration in quality and safety of the produce.

NOTE: These are best practices. If you do not have a refrigerated vehicle, make every effort to ensure that the vehicle and produce stay as cool as possible. Practical efforts may include keeping the vehicle under shade (but not under trees) or inside a cool building.

Yes

Transportation Decision Tree

5

If produce requires refrigeration, do you regularly inspect and service refrigeration equipment on vehicles to ensure they are working properly and able to cool and hold produce at the desired temperature?

No

Refrigeration equipment must be monitored and repaired as necessary to ensure that proper temperatures can be maintained throughout transportation. Monitor to prevent condensation of refrigeration units from dripping onto produce. Temperatures can be recorded by using handheld thermometers or thermostatic devices on the unit and recorded on a maintenance log. Specify expectations and requirements for refrigeration in contracts if you hire others to transport your produce.

Yes

6

Do you train your workers to load and unload produce to minimize damage, prevent contamination, and maintain quality?

No

Training workers to properly load and unload produce will help minimize damage and prevent contamination of produce. Produce should be handled carefully so as not to bruise or injure it. Aside from significant deterioration in quality and consumer acceptance, bruises and cuts on produce can foster the growth of harmful pathogens if they are present. Containers, pallets, and bins should not be stacked on top of each other unless care has been taken to ensure produce on the bottom will not be injured and is protected from contamination from produce or containers stacked above. If a refrigerated vehicle is needed, workers should be trained to load containers to allow proper airflow and not overload the vehicle beyond its cooling capacity.

Yes

Transportation Decision Tree

7

Do you keep records of transportation practices?

No

Records should be kept of all transportation practices that reduce produce safety risks.

- Inspecting vehicles prior to loading
- Maintaining vehicles
- Pre-cooling and cold chain maintenance practices (if applicable)

See *Transportation Log* and *Refrigerated Truck Loading Log*.

Yes

Finished

E.A. Bihn, M.A. Schermann, A.L. Wszelaki, G.L. Wall, and S.K. Amundson, 2014 www.gaps.cornell.edu

Postharvest Water Decision Tree

1

Is postharvest water the equivalent of drinking water at the beginning of all activities such as rinsing and cooling?

No

Begin all postharvest activities with water that is the equivalent of drinking water. If you are not sure of your water quality, test it to confirm it is free of total coliforms. If you are using municipal water, municipalities treat and test the water so you should be able to get a copy of their test results. Well water should be tested at least twice per year.

If you use surface water from a reservoir, pond, stream, lake, canal, ditch, river, rainwater or cistern for postharvest use, it should be treated to be the equivalent of drinking water and tested to ensure it is safe to use. Document all water treatment practices and keep records of all water tests.

Yes

2

Is all postharvest water use single-pass only (i.e., sprayed over the produce, not recycled)?

No

Single-pass water usually has a lower risk because water contacts produce only once. Pathogen growth and survival can still be a problem, especially if the single-pass water is used inside equipment that is not regularly cleaned and sanitized. Single-pass water should be properly drained and disposed of to prevent field or produce contamination.

Batch or bulk water can be a source of contamination and result in cross contamination of many lots of fresh produce. If a contaminated piece of fresh produce is immersed in the tank or bin, the pathogens can be dispersed by the water. This contaminated water can then cross contaminate clean produce, so a sanitizer must always be added to batch or bulk water.

Note: It is also important to consider water disposal. Follow all local, state, and federal guidelines for releasing or disposing of postharvest water.

Yes

Postharvest Water Decision Tree

3

Do you add sanitizer to your postharvest water?

No

A sanitizer should be added to all postharvest water to reduce cross contamination and minimize potential transfer of pathogens to fresh produce. Sanitizers are critically important when using postharvest water in dump tanks, wash bins, or other batch water systems.

There are many sanitizers that can be used for postharvest water. Pick the sanitizer that is best for your operation and the produce you grow. Make sure to follow the label recommendations and only use sanitizer approved for your specific crop. Monitor sanitizer levels frequently to be sure they are effective at reducing cross contamination risks. If you are certified organic, check with your certifier to make sure you are using an approved sanitizer for your produce.

Yes

4

Do you monitor sanitizer levels in postharvest water on an established schedule?

No

Sanitizer levels must be monitored to make sure the levels are effective at reducing the presence of microorganisms in the water. The primary purpose of the sanitizer is not to clean the produce, but to prevent cross contamination from the water to produce. Always follow the label when using a sanitizer. The build-up of organic material, such as leaves or soil, may bind the sanitizer and reduce its efficacy. Some sanitizers, such as chlorine, are most active at a specific pH, so you should monitor the sanitizer levels and the water pH. Develop an SOP specific to your sanitizer and document all monitoring steps on the *Water Monitoring Log*.

Yes

Postharvest Water Decision Tree

5 **Do you change your filter or bulk/bin/tank water when your water quality monitoring indicates it is dirty?**

No

To reduce risks associated with bulk/bin/tank water, change water or filter when your water quality monitoring system indicates it is dirty. Changing the water may depend on the sanitizer because some sanitizers are more sensitive to the presence of organic material. You should create a policy and SOP describing how and when to change water. Document all water changing activities including water monitoring on a *Water Monitoring Log*.

Yes

6 **Do you monitor the temperature of your postharvest water?**

No

Some fresh produce commodities are susceptible to infiltration when immersed in water that is colder than the pulp temperature. Infiltration is the passage of water from the bulk/bin/tank water into fresh produce, usually caused by a temperature differential larger than 10°F, where the water is cooler than the produce. If that water is contaminated, microorganisms could enter the produce with the water. Tomatoes, cantaloupes, and apples are some crops susceptible to infiltration. Monitor pulp temperature and water temperature to make sure the water temperature is less than 10°F warmer than the pulp temperature, and document on a *Water Monitoring Log*.

Yes

7 **Do you clean and sanitize your postharvest equipment including tanks, bins, and washers on a standardized schedule?**

No

Tanks, bins, and washers should be cleaned and sanitized to reduce the risk of biofilm formation and the risk of cross contamination. Develop a policy that includes an SOP with step-by-step instructions for cleaning and sanitizing, including which detergents, sanitizers, and tools should be used, how often to clean the equipment, and what needs to be cleaned such as hoses, brushes, and conveyor belts. Document all cleaning and sanitation activities on the *Cleaning and Sanitizing Log*. For more information on cleaning, see the *Sanitation and Postharvest Handling Decision Tree*.

Yes

Postharvest Water Decision Tree

8

Do you reduce and eliminate standing water in your packing area?

No

Pathogens, such as *Listeria monocytogenes,* can become established and persist in areas with standing water. At the end of each day, check the equipment, including drip pans, to make sure water has drained properly and is not pooling. Workers should be instructed on how to reduce and eliminate standing water and why it is important.

Yes

9

Do you keep records of all your postharvest water management and sanitation activities?

No

Records should be kept of all postharvest water management and sanitation activities, such as:

- Water tests that document the water is the equivalent of drinking water
- Steps taken to monitor postharvest water such as water temperature, turbidity, and pH
- Actions taken to reduce risks such as changing postharvest water and cleaning tanks, bins and washers

SOPs and logs should be developed to make sure activities are done properly and documented. Your postharvest water management policy should be detailed in your farm food safety plan.

Yes

Finished

A FARMER'S GUIDE TO FOOD SAFETY
AND CONSERVATION:
FACTS, TIPS & FREQUENTLY ASKED QUESTIONS
October 2013

http://wildfarmalliance.org/resources/FS_FactsTipsFAQ.pdf

Co-published by Wild Farm Alliance and Community Alliance with Family Farmers

1. **Sun**: UV radiation from the sun may inactivate recently deposited pathogens on the surfaces of soil and leaves, as well as in clear water. The sun also facilitates the desiccation of pathogens, which leads to pathogen reduction.

2. **Dust from animal activity** is reduced with the application of water by sprinklers and with manure harvesting. Reducing emissions and removing manure proactively are cost-effective means of mitigating pathogen transfer.

3. **Diversions** redirect water running off of confined animal feeding operations to waste treatment and sedimentation lagoons, preventing the movement of waterborne pathogens to nearby farm traffic areas, fields and waterways. Vegetated diversions also intercept organic matter and soil carrying pathogens running off pasture, and divert potentially contaminated water away from specialty crop fields. The diversions slow pathogen dispersal and provide a matrix for beneficial bacteria and protozoa that compete with and consume pathogens. Plants should be selected for low-flow filtering capacity and the ability for high flows to flow through the vegetation. Selection criteria should also consider how well air and sunlight are able to penetrate into the vegetation, as the cool, moist, shaded interior vegetation may provide favorable habitat for pathogen survival. Otherwise additional maintenance will be required that regularly harvests and removes excess vegetation.

4. **Waste storage pond** temporarily stores waste, such as manure runoff from confined animal feeding operations, thereby reducing pollution potential in the landscape. The waste storage pond should be properly designed and maintained so that it does not overflow. Food safety Good Agricultural Practices (GAPs) recommend that the effluent from the ponds not be used on crops typically eaten raw. Monitoring of animal movement around the pond and between waste handling areas and crop fields should be a scheduled activity.

5. **Restored wetlands** can considerably reduce pathogen transport by slowing the water, which increases the interaction time, and providing a matrix for beneficial microbes. The diverse plant and microbial community establishes desirable interactions that serve to

limit pathogen persistence. Use of vegetation and designs that facilitate slow moving water over long periods in the wetland allow the best chance for pathogen reduction in water draining from the wetland. The vegetation in the wetland may decrease the ability of UV light to reach the pathogens, which may increase survival. However, pathogens may be retained on vegetation. As water recedes, the pathogens that are retained on the vegetation may be expose to sunlight and desiccation.

6. **Riparian forest buffers** are vegetated areas along bodies of surface water**,** including streams, wetlands and lakes. They may trap wind-borne pathogens on their vegetation and filter waterborne pathogens attached to suspended organic-soil particulates and other solids. The diverse plant and microbial community in the buffers encourages interactions limiting pathogen persistence.

7. **Flooded field**: Food safety GAPs recommend that crops typically eaten raw are not planted on lands that often flood. If and when a flood occurs, it may take time for pathogens present in the soil to die off. Depending on the frequency of floods, the field could be fallowed for a period, replanted to a cover crop, or possibly, permanently taken out of production with the restoration of riparian habitat.

8. **Windbreaks** can trap dust containing pathogens and prevent it from entering specialty crop fields. Plants should be selected with foliar and structural characteristics to optimize dust/pathogen interception. If interior vegetation is too dense, it may provide a cooler, moister and shadier environment, which may create a favorable conditions for temporary pathogen survival.

9. **Evidence of animal intrusion in a crop field should be monitored.** Food safety GAPs recommend that farmers monitor for animal feces and signs of feeding, and when found, a no-harvest buffer is placed around the contaminated source, or other measures are taken to reduce risk of harvesting the contaminated crop. The following considerations all factor into determining the appropriate risk reduction actions taken: the type and number of animals; whether they are present intermittently or continually; if they are there because of food, a movement corridor, or live next to the crop; and if they are seen initially before planting or right before harvesting.

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11. **Irrigation:** Food safety GAPs recommend using sources of irrigation water that are adequately free of contamination. Management techniques that promote infiltration of the water into the soil can reduce runoff and may aid in reducing the movement of pathogens already present in the field. Techniques that aid in infiltration include soil quality

management that increases porosity and improves structure, and irrigation management that keeps soil from becoming saturated.

12. **Sediment basins** capture and detain sediment-laden runoff that may contain pathogens. Correctly designed, basins allow sufficient time for the sediment to settle out of the water. With moist, cool conditions, the basin may support the survival of pathogens. Having a sediment basin that dries down as rapidly as possible helps to alleviate these moist conditions and helps reduce pathogen survival. Moist sediment that is removed from the basin and put on cropland should be treated as contaminated and a time period similar to non-composted soil amendments between its application and the next cropâ€™s harvest should be established.

13. **Riparian forest root zone:** The roots of the riparian forest promote water infiltration and provide biological activity. This helps divert pathogens from surface water, and encourages interactions with other soil microorganisms that can limit pathogen persistence.

14. **Stream ecosystem**: In a stream ecosystem where diverse microbial communities exist, they are thought to reduce pathogens by competition, parasitism, and predation. Clear water allows light to reach pathogens, which can lead to their reduction. Flowing water dilutes pathogen populations. Some algae and protozoa may serve as an alternate host for pathogens, allowing pathogens to survive even when environmental conditions are unfavorable.

15. **Diverse microbial populations compete with and consume pathogens in water, soil and on plant surfaces.** When diverse microbial populations are present, beneficial microbes compete with pathogens for carbon and nitrogen, while others kill and consume them. Diverse microbial communities in water and on plants also compete for resources and/or consume pathogens. In some instances, biofilms-a matrix of bacteria and carbohydrates-can harbor pathogens.

16. **Cover crops:** Rotating with cover crops increases soil organic matter and supports soil microbial communities that may aid in suppressing pathogens. Cover crops may also reduce the movement of pathogens in water run-off by trapping pathogens in their roots and leaves. They can be used as part of a ‘waiting-period’ between events that might pose contamination risk (e.g. grazing, flooding) and the planting of a crop typically eaten raw. Cover crops also reduce open soil, which helps reduce dust transmission problems.

17. **Integrated pest management (IPM)** of vertebrates such as mice and squirrels can be used as a means of control for pest animals that enter crop fields. Having a few predatory animals, such as hawks or owls, on the farm is less of a risk than numerous prey species. A crop should not be planted directly under a raptor nest box or a roost, so that it is not

contaminated with raptor feces. Farm traffic should not carry fecal droppings into the cropped area or equipment and storage yard.

18. **Harvesting orchard fruit** from the tree, not the ground, is recommended by Food Safety GAPs when it will be consumed fresh. Fallen fruit may have come in contact with animal feces.
19. **Field borders** can intercept and reduce waterborne pathogens moving in overland flow from the field. This planting encourages infiltration and serves as a buffer between the field and the riparian vegetation.
20. **Tree bird roost:** Food safety GAPs recommend that a no-harvest zone is established under branches that hang over the field to ensure bird feces will not touch the crop.
21. **Wildlife corridors** allow wildlife to access resources (water, food, and cover) without having to walk across crop fields or leave their preferred habitat.
22. **Crop placement:** Food safety GAPs recommend that leafy green vegetables or other crops typically eaten raw not be planted near manure stockpiles or composting facilities and windrows, or other areas of contamination, as pathogens may transfer to the field via water or wind.
23. **Compost:** Properly managed compost windrows heat up to a temperature that results in significant pathogen reduction. Compost itself supports beneficial organisms that compete with, inactivate, and consume pathogens. Compost that has been allowed to be re-contaminated, or compost that is unfinished could be a source of pathogens; thus, measures should be taken to prevent these below par composts from moving onto adjacent fields through wind or water. For information on proper compost management practices refer to ‘Chapter 2: Composting’ in Part 637 of the USDA, NRCS National Engineering Handbook.
24. **Conservation cover** is used to establish and maintain perennial vegetative cover to protect soil and water resources on land retired from agricultural production or on other lands needing permanent protective cover that will not be used for forage production. Perennial plants may trap wind borne pathogens on the vegetation and waterborne pathogens in the root system.
25. **Prescribed grazing** uses animals to manage vegetation. It also helps to increase water infiltration, reduce runoff and prevent erosion. This aids in stopping the movement of pathogens in water runoff. Grazing animals are a reasonably foreseeable source of pathogens; thus, measures should be taken to prevent pathogens from the animals’ feces from moving onto adjacent fields through wind or water.

A FARMER'S GUIDE TO FOOD SAFETY AND CONSERVATION:

FACTS, TIPS & FREQUENTLY ASKED QUESTIONS

October 2013

Background

It seems every few months headlines like these make breaking news: "*E. coli* Fears Prompt Romaine Lettuce Recall," "Spinach Recalled in 39 States," "Cantaloupe *Listeria* Outbreak Deadliest in a Decade." These dramatic headlines reflect the attention given to food-borne illness outbreaks associated with contaminated fruits and vegetables. Taking sound, science-based steps to reduce the risk of contaminating produce with pathogens makes sense, but some misguided food-safety standards and interpretation of audit checklists have encouraged or required the removal of on-farm conservation plantings such as hedgerows, windbreaks and grassed-waterways, and the destruction of riparian areas and wetlands. Conservation-minded farmers know that conserving these areas on the farm helps protect water and air quality, supports pollinators, and reduces erosion and greenhouse gases. In a climate of food-safety angst, knowing the basics of managing crops and conservation practices to address food safety can go a long way in maintaining on-farm conservation plantings while reducing the risk of pathogen contamination.

It is highly unlikely that farmers would ever intentionally sell contaminated produce. In the past, it was long held that common sense approaches were sufficient to ensure produce did not have food-borne pathogens. Animals were discouraged from production areas because they damaged crops. The potential for animal manures applied as fertilizers and soil amendments to result in water and crop contamination with human pathogens was well recognized. However, in 2006, everything changed when an outbreak of *E. coli* O157:H7 was traced back to a farm on California's Central coast, the center of the state's fresh-cut salad industry. While it was never unequivocally determined how the spinach became contaminated, non-native feral pigs, contaminated irrigation water, and adjacent cattle operations were all considered as possible sources. All wildlife and the habitat they occupied became scrutinized by public health, academia, and especially the leafy greens industry.

Beneficial natural processes, such as Integrated Pest Management (IPM), help to control rodents.

Periodically monitoring for animal damage or feces in the production field ensures a safe harvest.

Ironically, research conducted in response to this and related leafy greens recall incidents has, so far, indicated that native wildlife in the U.S. have a low relative prevalence of carrying human pathogens. The broad risk appears low; however, the combination of low localized prevalence of wildlife pathogen shedding and changing seasonal conditions remain a concern. Non-native feral pigs were first introduced to California during colonization by Spain and later in the 1920s as a game animal. Particularly where their range intermingles and overlaps with cattle, feral pigs do have a higher prevalence of shedding and now pose a risk to leafy crops. Industry buyers purchasing fresh-cut leafy greens from growers often refuse to buy lettuce or spinach that comes within a certain distance of wildlife habitat because large mechanized harvesters do not exclude picking up hidden fecal matter or even small animals with the crop, as manual harvesting does. To avoid losing production area, many growers are pressured into removing conservation plantings and other non-crop vegetation, such as riparian vegetation, immediately adjacent to their land. In effect, these buyers require 'sterile' or 'scorched-earth' environments; no grass in the drainage ditches, no bushes next to fields—just dirt and lettuce. This aversion to wildlife and its habitat, driven by the uncertainties of risk, has unfortunately transferred to other crops even though their harvests don't accidentally take small animals.

Government agencies are becoming more involved in the produce safety area as well. In 2011 the Food Safety Modernization Act (FSMA) was passed by Congress. When it goes into effect, it will require the implementation of certain on-farm food safety measures. While the legislation has yet to be fully enacted, things are moving forward. In January 2013 the Food and Drug Administration (FDA) published the first draft of the rules that translate the act into on-the-ground regulation. Before the rules officially go into effect, they must be reviewed and commented on by the public and then revised and published in their final form by the FDA. Forward thinking farmers will be learning about the food-safety and conservation issue before FSMA becomes implemented, taking steps to ensure that they are reducing food safety risks while still maintaining the conservation areas important to their operations. Understanding how pathogens move onto crops and having management tools to reduce the risk of this movement are essential knowledge for every produce grower.

How Pathogens Get on the Farm

To put it bluntly, poop contains pathogens. That said, not all poop contains pathogens that make humans sick, but caution should be used to reduce the risk of contaminating crops with feces and the pathogens it may contain. Understanding the pathways in which feces/pathogens come to contaminate crops can aid farmers in preventing contamination from happening, and in identifying potentially contaminated produce before it goes to market.


USDA NRCS

Animal feces can contain pathogens that make humans sick.

Livestock, Wildlife and Human Pathways

Animals intruding onto fields may contaminate a water source or the crops with their feces. Such intruders include wildlife, free-range animals (such as chickens), escaped livestock and companion animals (e.g. dogs, cats). Farmers who use animal traction may also run the risk of having their work animals defecate on crops in the field.

Improper management of raw manure from livestock may increase the risk of pathogen contamination. When used as a soil amendment, raw manure may contaminate crops with pathogens if an appropriate waiting period is not practiced between the application of the raw manure and the harvesting of the crop. Similarly, livestock grazing (and defecating) in harvested fields may potentially contaminate future crops, if an appropriate waiting period is not allowed between grazing and planting/

Washing boots after working with animals, properly composting manure, and keeping livestock out of produce fields can help reduce the risk of contaminating produce with pathogens.

harvesting of crops. Composting or heat-treating manure greatly reduces the number of pathogens in the manure, thus reducing the risk of crop contamination when it is applied as a soil amendment.

Humans may contaminate produce if appropriate sanitary measures such as properly washing hands after using the restroom, changing or washing boots after working with animals, or cleaning farm equipment between non-crop and crop uses, are not taken before harvesting or handling produce. All produce handling surfaces and equipment, including pickup truck beds for local transport, should be managed to prevent cross-contamination from prior uses of the same equipment.

Airborne Pathways

Pathogens that cause human illness can be transported in the air attached to soil and organic particulates and to water droplets. Manure-laden dust blowing off of small or large livestock operations may contaminate surface water sources or produce growing down wind. The pathogen prevalence in the livestock, and the presence of vegetation or the use of other measures that reduce the spread of the dust, determine the extent of the risk.

Waterborne Pathways

Water can become contaminated with pathogens in a number of ways. When water runs off feedlots, pastures, animal loafing areas, manure stockpiles or composting yards, it may pick up feces and pathogens along the way, eventually contaminating the streams, rivers, ponds, and canals to which it flows. Animals may also contaminate water bodies by defecating into the water directly or on banks and levees, leading to pathogen increases during rain events. Poorly managed sewers, septic systems, or portable toilets can contaminate surface water with human feces. Ground water may be contaminated by improperly managed septic systems or by poorly sealed well-heads that allow contaminated surface water to flow into the well. In times of heavy rainfall, very porous sandy soil, soil with macropores from former root penetration, or soil with cracks in its profile may direct pathogens into shallow groundwater and eventually back to surface water.

If contaminated surface or groundwater is used for irrigation, it may lead to persistent crop contamination. Pathogen-laden water during a storm or flood event can also contaminate crops.

As water runs off areas where livestock congregate, it may pick up feces and pathogens along the way.

Sunlight helps kill pathogens through its destructive UV radiation.

Factors that Affect Survival of Human Pathogens

Temperature, Moisture and Diversity

Pathogen survival in soil, water and on plants depends on the temperature, moisture, the nature of the plant surface characteristics, and diversity of the microbial populations present. The sun and desiccation help to kill pathogens. In the summer, when the days are warm and long, direct sunlight, with its destructive UV radiation and its ability to dehydrate pathogens, can help to decrease the survival of pathogens on plant and soil surfaces.

Pathogens tend to persist longest in cooler times of the year when cloud cover and moist conditions are more constant and pathogens, such as *E. coli* and *Salmonella,* are less active. Another bacterial pathogen of concern in minimally processed foods, *Listeria monocytogenes*, actually does better under cool moist conditions but the primary control point is not on the farm. Freezing by itself does not completely kill pathogens. A caveat to that is when rapid freeze-thaw cycles of weather occur, they can cause rapid death of pathogens in soil.

Microbial diversity helps to reduce pathogen survival. Non-pathogenic beneficial microbes usually prevail if diverse populations are present, by outcompeting the pathogens for food, water, and space; by killing and consuming the pathogens; and/or by generally making conditions unfavorable to the pathogens by tying up critical growth nutrients such as soluble iron.

Fumigation studies reinforce that microbial diversity is important. Soil fumigation can foster human pathogens because conditions become more favorable for the survival and growth of the few pathogens that weren't killed or that are re-introduced. Most fumigation is done on conventional farms. Glucosinolate compounds, found in high concentrations in some of the seeds of the *Brassica* plant family, are being applied as mustard meal to decrease organic strawberry plant pathogens, and separate lab studies show that it kills *E. coli* and *Salmonella*. Whether mustard meal will be useful in the field for human pathogens is yet to be determined — the same principle probably applies that if diversity is eliminated, pathogens can persist.

While some microbes may kill pathogens, others may help them survive. In nature, nothing is absolute, and this is the case with biological control of pathogens. While many types of microbes — bacteria, viruses and protozoa — cause harm to human pathogens, not all do. Some protozoa harbor pathogens by consuming but not killing them. Bacterial communities can also surround themselves with a matrix of complex carbohydrates called biofilms. These biofilms sometimes shield pathogens from predators and harsh environmental conditions, while at other times make them more susceptible. Biofilms can form on soil particles and plant roots, in water on aquatic plants and irrigation systems, and on plant leaves.

Soil

Pathogens, like most plants, prefer soils in the range of a neutral pH, with low salts, and with available nutrients, especially carbon and nitrates. Concentrated nutrients exuded by growing root tips, and by diseased plant parts, are especially attractive to microbes. Unlike most plants that can live in many types of soil, pathogens prefer heavier clay soils that can hold water better than sandy soils.

Manure and Antimicrobial Resistance

Pathogenic *E. coli* populations tend to be lower in cattle when the animals graze on forage, than compared to a grain diet. Similarly, when manure comes from a barnyard it tends to have fewer nutrients readily available for pathogens than when it comes from a slurry. Many confined animal feeding operations administer antibiotics and similar drugs, together called antimicrobial agents. When manure from these confined animal feeding operations is spread on a production field, some of the pathogens, as well as other microbes, typically have genetic traits for antimicrobial resistance. This resistance can be transferred among many types of soil microbes, and can increase the risk of non-pathogenic *E. coli*, *Salmonella*, and other bacteria becoming a health hazard, especially for people with compromised immune systems. Microbes that do not infect healthy people can sicken people with weak immune systems, and the antimicrobial resistance makes it more difficult to treat. Pathogens with antimicrobial resistance are not only found in those carried by livestock and in soils with manure, but have also spread to wildlife.

Algae blooms, like the one in this lake, may increase pathogens in the water.

Sediments and Algae in Water

Sediments have been shown to be a key site for pathogen persistence in water bodies. When sediments are stirred up in water, pathogens are brought back into the water column or flow. The reasons for increased pathogens in sediments are not well understood, but the lack of UV radiation and presence of biofilms may be responsible. UV is not able to penetrate sediments at the bottom of creeks, streams, ponds and lakes. Biofilms may provide protection from environmental stress and from predation by other microbes.

Vegetative buffers, like this grassed waterway, help filter out pathogens in runoff water before they reach a pond or stream.

Nutrient pollution in surface water can cause algae blooms or mats. Some kinds of pathogenic bacteria survive longer when attached to algae. UV penetration in water, important in reducing pathogens, is diminished with the presence of algae. Therefore, reducing nutrient runoff from fields and blending tailwater with ground water in ponds may aid in reducing both algae and pathogens in irrigation surface water.

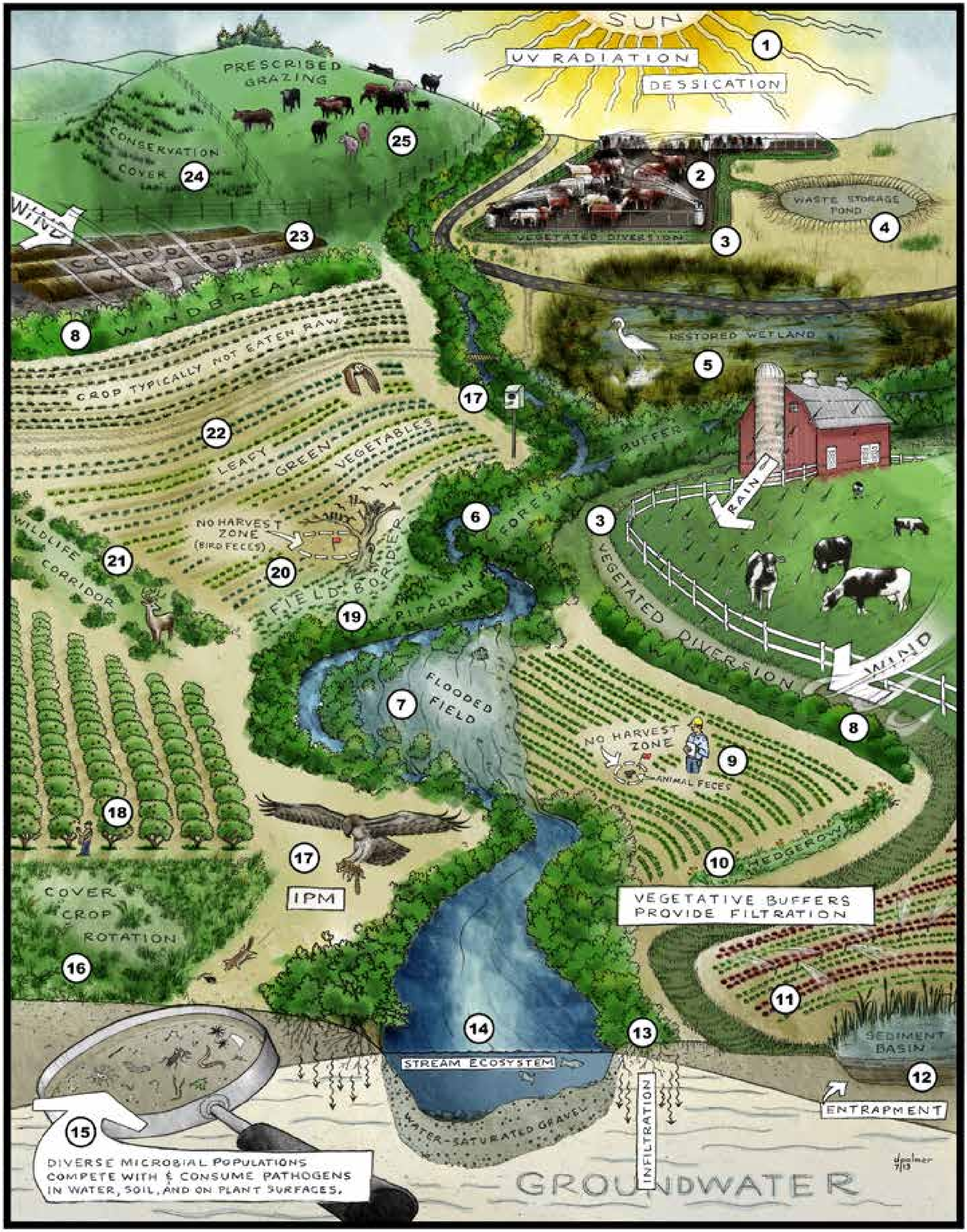
Vegetation

Vegetation can help reduce the movement of pathogens across the farm by filtering pathogens, increasing infiltration of water into the soil, and serving as a structure for biological competition to take place. Grasses and other types of vegetative buffers filter pathogens in runoff before they reach a pond or stream. The vegetation also slows surface water flow which allows for increase infiltration rates.

Wetlands decrease pathogen levels due to increased oxygen levels in the water, antagonistic root exudates, and the fostering of antagonism in biofilms. These processes that act to reduce pathogens in water work best when the water has a long residence time—it moves slowly through the vegetation—a proper hydraulic loading rate—the volume of water flowing through is suited to the size of the planted vegetation, and appropriate settling rates of suspended sediments.

Windbreaks can intercept dust that may be carrying pathogens. When dust trapped on the leaves of a windbreak is exposed to sunlight and other desiccation effects, pathogens can be destroyed.

Healthy Diverse Ecosystems Help to Keep Pathogens in Check



Not to Scale

Illustration Key

Note: The Healthy, Diverse Ecosystems Help Keep Pathogens in Check *illustration* ***is not drawn to scale****; it serves as a visual summary of the conservation practices and food safety actions used to address food safety referenced in this document. These practices and actions do not provide complete and conclusive protection against food-borne pathogens on a given farm/ranch, and some vegetative conservation practices may attract wildlife that can vector pathogens. When implementing in-field practices to address food safety, one should take into account the conditions present on the farm/ranch and use this information to assess the effectiveness of a given practice in* ***reducing the risk of food-borne pathogen contamination of crops.***

1. Sun: UV radiation from the sun may inactivate recently deposited pathogens on the surfaces of soil and leaves, as well as in clear water. The sun also facilitates the desiccation of pathogens, which leads to pathogen reduction.

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Note to User: *Details on the design, dimensions, spacing and maintenance specifications of many of the conservation practices represented here can be found on the NRCS website: http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/?cid=nrcs143_026849.*

Frequently Asked Questions

Questions related to the co-management of food safety and conservation are listed first and followed with general questions that small and mid-sized farmers may have. Answers to these questions are based on common sense, science, and a mix of requirements from third party auditors. While FDA's produce rules are in process, you can visit the WFA website to learn what is being proposed (see www.wildfarmalliance.org).

Co-management Questions

A1. Are there natural processes a farmer can encourage that reduce pathogens on the farm?

Sunlight

Allowing time for sunlight to hit feces left by grazing animals in row crop fields before tilling it in, and managing orchard canopies to let sunlight in on feces will help desiccate and reduce survival of pathogens. The degree of effectiveness depends on how well the pathogens are directly exposed to UV light and how well they dry out. For larger animals, such as cattle grazing un-harvested crops, a light disking to break up partially dried pats may accelerate pathogen die-off. It is important to minimize the potential for manures left on the surface to be carried to surface water during a significant rain or irrigation event, prior to incorporation.

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Clear water allows UV radiation from the sun to enter the water, which helps kill off pathogens.

Clear Water

When UV radiation is allowed to penetrate clear water, pathogens won't survive long. If there is sediment in the water or nutrients causing algal blooms, UV radiation isn't as effective. Proactively protect water quality by ensuring irrigation water infiltrates the soil well, and excess fertilizers and eroded soils are not causing pollution and murky water. UV penetration can then effectively foster pathogen reduction.

Vegetation Intercepts Pathogens

Using nature's vegetative filtering systems by planting or conserving non-crop vegetation in appropriate areas on the farm can help intercept airborne and waterborne pathogens and other pollutants, and keep the water clean (see #s 3, 5, 6, 8, 10, 16, 19, 21, and 24 in illustration).

Proper Composting

Pathogens are reduced by high temperatures and antibacterial compounds found in compost processes that purposely generate alternate cycles of high heat through the correct mix of carbon and nitrogen, moisture, and aeration by turning. Then the curing process at cooler temperatures can allow the growth of suppressant microorganisms that tie-up nutrients and can limit or outcompete pathogen re-growth or growth following accidental re-contamination.

Encouraging Soil Microbe Diversity

Farming practices that increase the native soil microbial community, such as high organic matter inputs of compost, cover crop rotations (see #s 16 and 23 in illustration), and reduced tillage, promote competition, predation and antagonism of pathogens.

B1. Do some animals pose a higher risk of contaminating produce with food borne pathogens than others?

Humans and Livestock Have Pathogens in Common

Livestock and companion animals can carry human pathogens, such as *E. coli*, *Salmonella*, *Campylobacte*r, *Listeria* and *Cryptosporidium*. Some pathogens are more common in some animals than in others. Cattle often host *E. coli* pathogens, while poultry and pigs are common carriers of *Salmonella*. Poultry may also carry *Campylobacte*r. Small ruminants, such as sheep and goats, are infected with *Listeria* more than other animals.

Animals can be carriers of human pathogens, such as *E. coli* O157:H7, that do not make them ill but can cause very severe human diseases. The age of the animal and season of the year may influence the level of pathogens an animal

Young livestock are likely to carry higher levels of pathogens than adults.

Wildlife living near areas with high levels of pathogens, such as these landfill-dwelling seagulls, may pose a greater risk of transferring pathogens than wildlife not associated with such areas.

Vern Wilkins, Indiana University, Bugwood

Seeing rodent-eating raptors, like this Short-Eared Owl, in habitat near a produce field is good for food safety.

carries. Young animals tend to carry higher levels of pathogens than adults. Seasonal stress may also result in higher pathogen levels. Cattle, for example, shed more *E. coli* in their manure during the summer than during the winter. Individual animals can be 'super-shedders' in a herd that has an overall low prevalence of shedding.

Since livestock can be contained, the risk of contaminating crops with livestock manure depends on whether the manure is inadvertently being transported into the produce fields via wind, water, wildlife or people; or whether it has been applied directly on the field as a soil amendment without adequate composting, aging, or time period before planting and harvest.

Native Wildlife Pose a Low Risk of Carrying Human Pathogens
Thus far, studies have shown that native wildlife have a low prevalence of carrying pathogens that cause human illness. The risk of extensive crop contamination from wildlife is small; however, it will never be zero. Within a given population, the number of individual wildlife carrying pathogens, such as *E. coli* O157:H7 or *Salmonella*, is generally less than three percent, based on the fairly limited snapshots of research around the country and the world.

Where wildlife live and what they feed on may influence the level of pathogens they carry. Birds, rodents and feral pigs that live near areas with high levels of pathogens, such as landfills, feedlots, dairies, cattle ranches, or pig farms, may pose a greater risk of transferring pathogens, than wildlife not associated with such areas. Some research shows that non-native feral pigs, which frequently share rangeland with cattle and eat cattle feces, carry food-borne pathogens at a higher rate than native wildlife does.

Unlike livestock, wildlife cannot be contained or completely excluded from produce growing areas, so depending on the circumstances they may pose a risk when in the production field. In writing the 'first draft' of the proposed rules for the Food Safety Modernization Act (FSMA), FDA suggests that the presence of wildlife in a production field is, in and of itself, not a significant food safety risk, though action needs to be taken if evidence of feeding or feces are found in a crop field.

C1. What should I do if I see wildlife in habitat near my produce field?
Seeing wildlife in habitat is usually good, since the habitat is often planted or conserved to support pollinators, migrating predators that eat rodents and other types of wildlife. There is only a potential for a problem when and if wildlife enter a field and damage the crop, and/or leave feces behind that can contaminate the crop. Monitoring the production field next to

the habitat for damage and feces can help determine if the wildlife are coming in, thereby increasing the risk (see #9 in illustration). By monitoring at a scheduled time, preferably in conjunction with other tasks such as during insect pest scouting or before an irrigation, and keeping records of the monitoring, the farmer can both reduce risk and have simple documents that support their farm safety program.

Jason Wade

Predators like bobcats help keep rodent populations down in produce fields.

D1. What steps do I take if I see wildlife or their evidence in the production fields?
Assess the production field for crop damage or animal feces that can contaminate the crop. If found, cordon off a specified area—the damaged/contaminated area plus a small percentage—so the risk of cross contamination is removed from the growing area (see #9 in illustration). The size of the cordoned-off area depends on the amount of feces, splash that could occur from irrigation or rain, and how close the crop is growing to the soil. A five-foot radius for overhead-irrigated crops is typically felt to be sufficient; for drip-irrigated crops in a dry season the contaminated plant and its nearest two neighbors are often cited as sufficient buffering. Dispose of feces and the contaminated product away from the crop, sanitize the shovel or other equipment, and wash hands afterwards. Keep records of all actions taken. Further crop assessments may be required to determine if there are repeat visits by individuals or many wildlife, and if they were feeding or just passing through. The number of wildlife in the crop is important to notice—more intrusion equals higher contamination risk. In writing the 'first draft' of the proposed FSMA rules, FDA's perspective about crop contamination is that if the crop does not come in contact with manure, or in this case with wildlife feces, then it would not be covered in the rule. Hence, deer droppings in an apple orchard would not be covered. Of course, the apples should not be picked up from the ground.

E1. Are predators of rodents okay to have on the farm?
It is better to have a few predators, such as hawks or bobcats, on the farm that help keep the rodent population in check, than numerous rodents that could cause much more contamination (see #17 in illustration). Hawks and owls can be attracted to the farm with hawk perches and owl boxes, but do not plant directly under them. If four-footed predators are present near the production field, monitoring for feces should be conducted periodically.

F1. Can I plant a conservation practice such as a hedgerow, or leave wildlife habitat next to a crop and still be able to pass a food safety audit?
The OnFarmFoodSafety.org self audit, the USDA food safety audit, and several other audit programs allow for non-crop vegetation on the farm without losing certification or audit points. Global GAPs encourages habitat restoration. In writing the 'first draft' of the proposed FSMA rules, FDA's perspective about wildlife habitat is that they do not expect farmers to destroy habitat or otherwise clear farm borders around outdoor growing areas or drainages.

Sam Earnshaw

Many food safety audits allow non-crop vegetation on the farm. Some even encourage habitat restoration.

Jo Ann Baumgartner

As a last resort, fences around fields can discourage wildlife from entering production areas.

G1. What are some ways I can discourage unwanted wildlife?
In some situations, conserving habitat in wildlife corridors along waterways or other established routes may keep wildlife from crossing through the crop (see #21 in illustration). If wildlife, their crop damage or feces are continually found in the produce field, corrective actions are warranted. Removal of animal attractants such as feed (culls or spilled grain) and standing water may reduce intrusion; or use of hazing techniques such as loud noises, raptor or distressed bird sounds, and visual deterrents may also work.

Fencing may be necessary as a last, expensive resort. The type of fencing used depends on the animals that need to be excluded. Short silt fencing can be effective for smaller animals, such as ground squirrels that tend not to climb something they cannot see over. Rabbit fencing is a bit more involved but functions on the same visual barrier principle tied to their natural avoidance behavior. Silt fencing is inconsistent in discouraging movement of frogs into fields and tends to be less effective in irrigated fields when immediately adjacent natural waterways dry up. Short, moveable electric fencing can temporally keep less determined feral pigs out of a field, whereas more permanent short hog wire fencing keeps those more persistent out. Tall permanent fencing, especially when electrified, can keep out deer. By fencing just the production fields, instead of the whole property, room is left for wildlife to move through the farm for food and cover in neighboring lands. In writing the 'first draft' of proposed FSMA rules, FDA's perspective about fencing out wildlife is that they do not expect farmers to fence or otherwise exclude animals from outdoor growing areas.

H1. Is it okay to grow produce next to a compost pile?
When compost includes raw manure as a feedstock, extra steps should be taken to ensure crop contamination does not occur. Taking into account wind direction and speed, locate the compost pile a safe distance away from the production field so that unfinished compost cannot blow onto the crop and contaminate it. Consider planting a windbreak to reduce the distance needed between the compost pile and the production field (see #23 in illustration). The location of the compost should also be chosen so that water running off the site is both contained and diverted away from traffic routes to the crop. When wildlife are attracted to compost feedstock such as produce culls, they may explore or inadvertently step in raw manure and then move through the production field, so keeping culls out of their reach can reduce contamination risk. Ensure that any heavy equipment and hand implements used for making or handling the compost are cleaned and sanitized before being used in the crop. Personnel involved in both compost and crop management should be trained in proper prevention and cross-contamination measures.

I1. Are some fields more suited than others to grow certain types of produce?
Since wind, water, wildlife and people may transport pathogens from contaminated areas such as dairy, livestock, or fowl production facilities, dumps, and compost piles to the crop, it is better to plant low risk crops near these areas, and to install a barrier between them (see #23 in illustration). The Center for Disease Control reports that leafy vegetables, tomatoes, and melons are associated with a high number of food-borne illness outbreaks. FDA has

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Produce contaminated by flood water is considered 'adultered' by the FDA. Converting sections of fields that flood often into permanent field borders reduces the movement of pathogens by intercepting overland water flow.

published guidance's on leafy greens, tomatoes and melon to help growers reduce risk. Depending on the method by which these crops are grown and harvested, they may or may not be higher risk. However, almost every year new commodities not previously recognized as vehicles for food borne outbreaks are identified. Therefore, the prudent approach is to consider all crops as potentially vulnerable to risk although many have naturally risk-minimizing traits of growth habit and cropping practices.

FDA considers the edible portion of produce that has been flooded "adulterated," so fields subject to frequent flooding are better planted to crops not consumed by humans (see #7 in illustration). The best management for areas that often flood may be to covert them to conservation plantings, such as permanent field borders (see # 19 in illustration) or riparian forest buffers (see # 6 in illustration) that intercept pathogens in overland flow and encourage infiltration. The forest root zone along a river, stream, wetland or water body helps reduce the movement of pathogens by slowing subsurface flow of contaminated water and providing for biological activity that can reduce pathogens (see # 13 in illustration). For fields that don't often flood, a waiting period should be instituted to allow pathogen reduction to occur before planting another cash crop. Cover crops can be a temporary solution.

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Funding and technical assistance for on-farm conservation projects can be found through the USDA Natural Resources Conservation Service.

J1. What are the safety precautions I should take when growing produce and raising livestock on the same farm?

In order to reduce the risk of livestock manure unintentionally contaminating the crop, the livestock should be located downhill from the production fields, or runoff should be diverted away from the livestock yards with the use of a berm or diversion ditch (see # 3 in illustration). Depending on the contamination of the diverted water, it may need to be contained in a waste storage pond or sediment basin (see #s 4 and 12 in illustration). Windbreaks and tall hedgerows can be used to reduce dust blowing from livestock areas (see #s 8 and 10 in illustration). If wild birds are eating extra grain, placing the grain in a covered area where the birds don't feel safe entering it can discourage them.

K1. Does prescribed grazing help to reduce pathogens in the environment?

Prescribed grazing helps to disperse animal feces on the grazing lands where healthy stands of grass can help to filter pathogens (see # 25 in illustration). While cattle both in confined operations (fed grain) and out on pasture (eating forage) can test positive for *E. coli* pathogens, a USDA comprehensive review indicates that populations of these pathogens are higher in cattle fed grain diets. Additionally, confined operations concentrate feces and often increase animal vector occurrence, thereby increasing risk.

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Testing your irrigation water for pathogens is a good food safety practice.

L1. Where can I get assistance with installing conservation practices?

The USDA Natural Resources Conservation Service offers technical assistance and Farm Bill cost-share funds for farmers interested in implementing conservation practices. It is important to note that they are not a regulatory body of government. Please visit www.nrcs.usda.gov for further information.

Small- and Mid- Size Farm Questions

A2. Do I need to test my irrigation water?

The Produce GAPs Harmonized Food Safety Standards offered by USDA suggests that testing may not be warranted if past testing showed no high levels of fecal indicators, the crop will be not be eaten fresh, the harvest will not occur soon, and the water will not touch the crop. On the other hand, if any of these conditions do occur, initial baseline testing is recommended, along with the establishment of a routine testing regime. Others recommend testing the water source at the beginning of the growing season for generic *E. coli*. If the water source is found to have high bacterial counts (eg. > 500 *E. coli* /100 ml), advice should be sought from local university extension personnel or farm consultants since recommendations can vary depending on the situation. The quality of the water should conform to prevailing regulations.

B2. Can I still use raw manure?

Pathogens that pose a serious food safety risk may be contained in raw manure. Some standards, such as those in the USDA National Organic Program (NOP), require that raw manure be incorporated into the soil not less than 120 days prior to the harvest of a product whose edible portion has direct contact with the soil, or not less than 90 days prior to the harvest of a product whose edible portion does not have direct contact with the soil. An intermediate recommendation from the USDA GAPs states that when raw manure is applied, it is incorporated at least two weeks prior to planting, and a minimum of 120 days prior to harvest. Some marketing agreements, such as the one for leafy greens, suggest a one-year waiting period between application of soil amendments with raw manure and production of the next crop. It is best to keep records of the composition of the manure and the time and method of application, and to conform with prevailing regulations. If the suggested waiting periods are not feasible, use only properly composted manure.

C2. Is manure-based compost okay to use?

Composting is a treatment process that reduces the microbial hazards of raw manure. When done correctly, the composting process can kill most pathogens in manure. Some standards do not suggest a time period between application and other farming practices, while others recommend it be used only before planting, or only applied at least 45 days before harvest. In all cases, it is a good idea to record the dates that the compost is applied to the field. If not completely composted, it should be treated like raw manure.

Using a waiting period between grazing livestock in orchards or produce fields and the harvest of the subsequent crop helps reduce the risk of pathogens in the livestock manure contaminating produce.

D2. Is it still okay to make my own compost, or should I purchase it?

Manure-based compost can be made safely on the farm when methodical management of the decomposing process is done. *Farming with Food Safety and Conservation in Mind* (see www.wildfarmalliance.org) lists details to be considered when making compost. USDA National Organic Program requires a specified carbon to nitrogen ratio of the compost feedstock, a temperature be reached for a set number of days depending on if it is a static pile or in a windrow, and a specified number of times of turning when in a windrow. Besides recording the compost's composition and the dates and methods of the compost treatment, some standards also recommend that farmers obtain residual fecal indicator and pathogen analyses of the compost. In all cases, care must be taken to ensure composts aren't re-contaminated with pathogens, and the composting process should conform to applicable federal, state, and local regulations.

Compost made solely with vegetative feedstock (i.e. no animal products) has fewer restrictions. The source of the feedstock should not come from situations where hazards such as glass or heavy metals are introduced.

Accepting off-site or purchasing commercial compost should be done only when a letter of guarantee or certificate of pathogen analysis from the compost maker can be obtained. It is also beneficial to find out what the compost was made from (e.g., cattle or horse manure; spent mushroom compost; vegetable culls) and that it was produced under conditions that are not a hazard.

E2. Is aged manure okay to use?
Using aged manure that relies primarily on the passage of time can reduce pathogens. During this aging period, natural temperature and moisture fluctuations and UV radiation from sunlight will decrease the number of pathogens. The time needed to reduce the pathogens will vary depending on the weather and on the type and source of manure. Growers who rely on the passage of time should ensure manure is well aged and decomposed before applying to fields, in order to minimize microbial hazards. Most food safety standards treat aged manure the same as raw manure.

F2. Are there other ways to treat raw manure?
Some standards approve of thermally or chemically processed manure. For instance, steam, ammonia, stabilized lime, and more recently biochars (a by-product of biomass conversion) are used to reduce pathogens in the manure. Care must be taken not to accidentally re-contaminate sterilized manure with pathogens since beneficial microorganisms that are antagonistic to pathogens will be absent.


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Ask U-Pick customers to sign-in at the entrance of the farm and agree to farm hygiene practices.

G2. Can I allow my livestock to graze under a fruit orchard, and in produce fields after the crops have been harvested?
Yes. Grazing should be scheduled so that there is time for pathogens in the feces to be significantly reduced by sunlight and other environmental factors. When ladders are used, harvesters may inadvertently walk in feces or contaminated soil or vegetated cover and then climb up and down their ladders contaminating their gloves, or they may accidentally place harvest containers on contaminated areas of the ground. While some standards do not address this issue, others suggest that a waiting period of 120 days takes place between grazing and harvest. An assessment to determine if any feces are seen should be done between five and seven days before harvest. It is a good policy to never pick fruit up off the ground since the fruit may have come in contact with animal feces (see #18 in illustration).

H2. Can Community Supported Agriculture (CSA) members and U-Pick customers be on the farm?
Yes. Before walking the fields, have members and customers review a food safety Fact Sheet and sign-in on an agreement form to comply with farm hygiene practices that are addressed in the farm's food safety plan.

I2. Can school children visit the farm and pick produce?
Because children don't always follow directions, it is best to have a distinct learning area or garden just for them that is separate from the production fields. Instructing kids about food safety, and requiring them to wash their hands before picking and eating produce are good policies.

J2. How can I have cats and dogs on the farm and still grow food safely?
USDA GAP standards suggest that dogs can be in production fields when the harvest is more than 120 days away or the planting is more than two weeks away. As the time becomes closer, the dogs are leashed and any feces are picked up and disposed of properly. Since cats cannot be controlled like dogs, their presence in the production fields is not recommended. In writing the 'first draft' of the proposed FSMA rules, FDA's perspective about crop contamination is that if the crop does not come in contact with manure, or in this case with pet feces, then it would not be covered in the rule. Hence, dog or cat feces in a fruit orchard would not be covered. Again, the fruit should not be picked up from the ground.

K2. Do I need a food safety plan?
There are currently no federal regulations requiring a food safety plan. Several states may create their own food safety requirements. To get ahead of the curve, and to make your customers happy, consider creating your own food safety plan using the step-by-step process on the onfarmfoodsafety.org website, or contact CAFF for individual assistance.


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Food Safety Plans

Most often, a farmer's buyer triggers the need for a food safety plan. This is especially true for anyone looking to sell to government institutional food programs, such as the USDA National School Lunch Program or correctional facilities. That plan typically covers personal hygiene of people on the farm, water testing, use of soil amendments, land use history, neighboring issues, wild and domestic animals, and harvesting. For assistance with creating a food safety plan, contact CAFF.

Food Safety Auditors

Sometimes the buyer requires a third party audit of the farm. If that is the case, they will either request a specific food safety auditor(s) be used, or will let the farmer choose the auditor. A third party audit can be mandatory if the farmer opts to sell to a handler who is part of a USDA recognized commodity group such as the Leafy Green Marketing Agreement. The USDA Agricultural Marketing Service offers food safety audits, as do some states, and there are many private auditing companies. They usually have a very specific checklist and make general observations. The purpose of the auditor's visit is to verify that your written food safety plan "says what you do – and you do what you say."

Food Safety Inspection

The FDA or State health enforcement officer may appear on your farm, but the chances of this occurring are small, unless you are growing a crop considered by them to be risky, or your produce is linked to a food borne illness.

Tips on How to Have a Successful Food Safety Audit or Inspection While Advocating for Farm Conservation Practices

When a food safety visitor comes to inspect a farm operation—be it a third party auditor, the local or state health department, or the Food and Drug Administration (FDA)—it may be helpful to follow the 'Co-management Principles', 'General Rules of Thumb', 'Do's and Don'ts,' and 'Follow-Up' outlined below. The farmer will have a more successful food safety audit or inspection and the food safety visitor will benefit from the farmer being prepared. If at the end of the visit, a recommendation is made to which the farmer does not agree, having a conversation with the inspector's/auditor's supervisor may be helpful in correcting the issue.

Addressing Co-management Principles

Farmers can address food safety without sacrificing responsible on-farm conservation measures. According to the Produce Safety Alliance (run by Cornell University, FDA and USDA), farmers can more effectively advocate for their farming practices with food safety auditors by using risk assessment strategies that help identify risks, and by explaining their rationale for management decisions that address those risks. This risk-assessment approach can be used for conservation measures included in a farming operation, such as maintaining streamside habitat or other non-crop vegetation.

Determine risk reduction protocols that address risk identified for your farm's situation. Assess risk such as pathogens coming from a livestock area; conduct necessary corrective actions that address the problem such as installing a diversion as shown in #3 of the illustration; monitor periodically and write down changes in risk; and implement any other corrective actions if necessary, such as using a cover crop as part of a waiting period between a flooding event and planting the next crop, as shown in #16.

Explain rationale for management decisions. Use descriptions of practices in the key to the illustration above to help craft co-management rationale for decisions made.

General Rules of Thumb

Have a written policy for inspections by food safety auditors and government enforcement officers visiting the farm.

• There should be a clear and concise written policy (program) following the farm's food safety plan while auditors and enforcement officers are on the farm. Everyone in the organization should review this policy in its entirety.

• Official food safety auditors and enforcement officers should be "guided" through your farm operation, but you should not impede them in going where they need to go.

What To Do During the Audit or Inspection

Treat food safety auditors and enforcement officers professionally:
• Consider every visit from them as official.
• Always be courteous to them, such as asking if they would like water, coffee or use of the restroom, but keep a professional distance.
• Recognize that they are not paid to be consultants or to assist you with your food safety management.

Require identification and ask for the reason of the visit:
• Have the auditor or enforcement officer sign in on the visitor's sheet.
• Ask that the auditor or enforcement officer provide appropriate credentials and identification, including their business card.
• Ask for their supervisor's name and contact information.
• Ask the auditor or enforcement officer if the inspection is routine or if there is a specific reason for the inspection.
• Require the auditor or enforcement officer to state his/her specific intentions, and in the case of a FDA inspection, to provide Form FD 482-Notice of Inspection.
• Ask the auditor or enforcement officer what s/he wants to see or do, how long it might take, and what resources s/he might need to assist with the inspection.

Take charge of the visit:
• Provide the auditor or enforcement officer with an overview of your farm, including risk assessment strategies for co-managing food safety with conservation and other issues. These practices can be described in detail as part of your food safety plan.
• Escort the auditor or enforcement officer at all times and proactively explain rationale for co-management and other food safety decisions. If possible have two people from your farm present during the inspection.
• Have all policy, management contacts, and standard information records in organized and clearly labeled binders to facilitate and set a positive tone for the inspection.
• If the auditor or enforcement officer asks for records, provide them with a photocopy while you retain the original.
• If the auditor or enforcement officer asks for a produce sample, ask them to make a duplicate one for you and ask what they intend to specifically test for with the sample. Also ask for the expected time to obtain test results so the physical quarantine of the impacted harvested lot may be anticipated. Send the duplicate to a qualified lab of your choice for the same tests.

Strive for clear communication:
• Listen well and ask lots of questions.
• Answer all questions honestly and take time to fully explain each of your answers.
• Stay focused on questions that are asked and only volunteer information when it is related to specific inspection criteria.
• Ask if any minor infractions can be fixed immediately. Don't necessarily accept any advice or recommendations, orders, directions, or instructions without appropriate justification.

Conditions Under Which an Automatic "Unsatisfactory" Will be Assessed in an Audit or Inspection

• An immediate food safety risk that has or would reasonably cause the produce to become contaminated.
• The presence or evidence of general unsanitary conditions, chemical or allergen hazards, rodents, or excessive pests in the produce.
• Personal hygiene has jeopardized the safety of the produce.
• Falsification of records.
• Not having a written and established food safety plan.
• Not having a designated, qualified person on the far to implement and oversee an established food safety plan.

Training Scenarios for USDA and Third Party Auditors on the Co-management of Food Safety and Conservation as well as Small Farm Concerns

Before a food safety auditor comes to your farm, suggest that they first review training scenarios on co-management and small farm issues posted at www.wildfarmalliance.org. The materials are presented in the accepted food safety industry format of the USDA Harmonized Standards for Field Operations. If the auditor works for, or is accredited by USDA, they can receive continuing education units. By having them learn about co-management and small- and mid-size farm issues, they will be better informed when they arrive at your farm. Farmers may also find value in reviewing these training scenarios, and may want to reference them, if a food safety auditor who has not seen these materials is already on the farm and needs further clarification.

• Ask for references (book, paragraph and line number) to all inspection findings.
• An exit briefing will occur at the end of the audit or inspection, but if one is not done, ask for it, taking good notes. During this debriefing, the auditor or enforcement officer will describe what may be a concern. This will be helpful to know, in case they plan on taking future actions. If the official also asks you to sign a paper with the alleged concern outlined, you may want to defer until you can have your attorney review it.

What Not To Do During the Audit or Inspection (Unless required by proper legal authority)
• Do not admit to any fault or deficiency or sign any forms admitting to fault, without proper legal advice.
• Do not volunteer the following information: recipes, formulas, any item that is strictly proprietary, financial records, research data, customer lists, sales information, pricing information, personnel records, accident data, distribution records, or inventories of products.

Follow-Up Right After the Audit or Inspection
When agreement is not reached:
• If for any reason you do not agree with the auditor or enforcement officer, absolutely have them make complete notes of your objections in their report or provide them (before they leave the farm) with a statement explaining the situation and all facts of the matter.
• At this point it is also recommended that you immediately contact this individual's supervisor and state your concerns. The supervisor wants to talk to you and correct the issues.

Follow-Up Some Time After the Audit or Inspection
Audit results:
• Once the audit is processed, either a final copy of the passing audit, or a letter describing what corrective actions are need to be implemented within a designated period of time will be sent.
Inspection results:
• You should be provided with an inspection report (this can take some months). Respond to any deficiencies noted in the report by making corrective actions in a timely manner (FDA requires 15 days) and telling them you did it. If you do not hear back from the inspecting agency, call them on the phone number they provided to you during the initial visit.
• If you do not agree with the findings, contest them with the advice of an attorney.
• If a warning letter is received, check with your attorney before responding.


Sam Earnshaw


USDA NRCS

By using risk assessment strategies that help identify risk as well as explaining the rationale for management decisions that address that risk, farmers can effectively advocate for their conservation-based farming practices including cover crops and wetlands.

Selected Resources

Co-management Materials

• Farming with Food Safety and Conservation in Mind authored by Jo Ann Baumgartner and Dave Runsten; published by Wild Farm Alliance and Community Alliance with Family Farmers. Updated 2013.
• Co-Management of Food Safety and Sustainability authored by Mary Bianchi and published by UC Davis. 2012.
• Safe and Sustainable: Co-Managing for Food Safety and Ecological Health in California's Central Coast Region authored by Karen Lowell, Jeff Langholz, and Diana Stuart; published by The Nature Conservancy of California and the Georgetown University Produce Safety Project. 2011.

Small and Mid-Size Farm Websites with Food Safety Information

• Community Alliance with Family Farmers (http://caff.org/programs/foodsafety/)
• Wild Farm Alliance (www.wildfarmalliance.org)
• Carolina Farm Stewardship Association (http://www.carolinafarmstewards.org/tag/food-safety/)
• Northeast Organic Farming Association (http://www.nofa.org/advocacy.php)
• National Sustainable Agriculture Coalition (http://sustainableagriculture.net/category/food-safety/)
• Maine Organic Farmers and Gardeners Association (http://www.mofga.org/)

Good Agricultural Practices (GAPs) Websites

• On Farm Food Safety Project has a free online tool, based on a comprehensive risk-based framework, which generates customized on-farm food safety plans based on user input (http://onfarmfoodsafety.org/).
• Produce Safety Alliance is developing a nationwide curriculum to increase understanding of the principles of Good Agricultural Practices (GAPs) and to facilitate the implementation of food safety practices on fresh fruit and vegetable farms and in packinghouses (http://producesafetyalliance.cornell.edu/psa.html).
• Global GAP certifies safe, sustainable production of food, flowers, and ornamentals. They work with more than 140 independent and accredited certification bodies to carry out certification worldwide (http://www.globalgap.org/uk_en/for-producers/crops/).
• USDA GAPs is a voluntary program by USDA Agricultural Marketing Service that provides independent audits of produce suppliers throughout the production and supply chain (http://www.ams.usda.gov/AMSv1.0/HarmonizedGAP).
• Produce GAPs Harmonized Food Safety Standard Field Operation and Harvesting offered by USDA is another independent audit that was created by United Fresh with input from the produce industry (http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5102511).
• California Leafy Green Marketing Agreement (LGMA) membership requires verification of compliance with the accepted food safety practices through mandatory audits conducted by USDA trained auditors (http://www.caleafygreens.ca.gov/).

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A FARMER'S GUIDE TO FOOD SAFETY AND CONSERVATION: FACTS, TIPS & FREQUENTLY ASKED QUESTIONS

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Center for Produce Safety

Key Learnings

Since 2008, the Center for Produce Safety has funded eighty-five research programs with some of the world's leading produce food safety scientists. As articulated in the Center's yearly request for research proposals, we have endeavored to fund applied produce food safety research targeted to the immediate needs of all stakeholders in the produce supply chain. From that body of work, a number of key learnings have emerged that can be used to assist the produce industry in developing hazard and science-based food safety programs. This document lists some of these key findings and offers how the data might be used by those in the produce supply chain to improve their food safety programs.

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INDEX

1. Pathogen survival in commercial production environments can be variable.

Attenuated *E. coli* O157:H7 and *Salmonella* applied directly to the soil or by a spray directly to the surface of spinach or romaine lettuce leaves dies off quickly so that it is very hard to detect after 2 days. However, pathogens may survive for longer periods when associated with organic matter. Spinach inoculated with *E. coli* O157:H7 and turned under the ground was recoverable from the soil for 100 days. When follow up experiments were performed with inoculated spinach under commercial conditions in the Salinas Valley of California (chopping the spinach and permitting it to dry out before incorporation into the soil), no *E. coli* O157:H7 was found on the second crop 27 days after planting and no *Salmonella* was detected 35 days post planting. It is thought that leaving the crop residue on top of the soil to be exposed to the sun and to become dehydrated may prevent pathogen growth and enhance pathogen die off. Similarly, attenuated *E. coli* O157:H7 inoculated into organic fertilizers and disked back into the soils, can survive for extended periods of time.

What does this mean for you?

- These data demonstrate that pathogens can survive in Salinas Valley production environments when associated with organic material, e.g. leaves, organic fertilizers, soils, etc. Therefore, sufficient time (27-35 days) must be scheduled to permit chopping/mowing, dehydration, incorporation and subsequent die off to manage the risk of pathogen survival in the soil and potential cross contamination to the next crop.
- If a pathogen contamination is found on a crop, rotational choices for the next crop should be considered carefully; i.e. a crop that comes to maturity in less than 27 days may not be a wise choice even if the previous contaminated crop residue was permitted to dry out prior to incorporation.
- It is important to establish time intervals for specific environments, crops and soil types as variability in pathogen survival should be expected in different production environments.
- These data clearly point out the importance of performing risk assessments on fields prior to harvest as potential contamination events closer to the time of harvest may be of a higher priority to identify than events further from harvest.

2. Buffer zones can be effective hazard management tools.

Following a natural intrusion of feral pigs into a commercial lettuce field, elevated levels generic *E. coli* were found where the pigs obviously contacted the crop, but not out beyond a 10 foot buffer zone. Wind has also been suspected as a vector for pathogen transfer. A study was conducted where leafy green plantings were situated at various distances down-wind from a cattle feedlot where the herd was known to be contaminated with *E. coli* O157:H7. The data demonstrate that *E. coli* O157:H7 can be transferred via bioaerosols and dust particles to crops at least out to 600 feet (the farthest distance tested). As distance increases away from the cattle feedlot, the frequency and level of contamination diminished. However, bioaerosol and dust particle transference is not a simple matter of distance. The density of the cattle, wind intensity, moisture and activities within the feedlot; i.e. movement of cattle in or out, cleaning, etc., all impact formation of bioaerosols and dust particles containing pathogens.

What does this mean for you?

- Pre-harvest inspection of fields just prior to harvest can be used to identify animal intrusion events and, if found, a harvest buffer zone can be set in place to manage any potential pathogen cross contamination hazards.
- It is important to conduct a comprehensive pre-plant hazard analysis of production locations and to understand the potential for wind-borne contamination from active feed lots prior to planting.
- Where the potential for wind-borne pathogen contamination exists, the use of wind barriers and/or deterrents to dust, e.g. increased moisture may be effective hazard control tools. These factors must be considered in any hazard assessment and the development of management practices.

3. There are no "risky" wild animal species.

A number of studies have been undertaken to examine the potential for animals to harbor human pathogens and transfer them to fruits and vegetables. Field-level experiments and sampling programs have shown that filth flies, several species of birds, reptiles and amphibians, and larger warm-blooded animals like deer, elk, feral pigs and dogs can be carriers of human pathogens like *Salmonella* and *E. coli* O157:H7. Indeed, we have begun to understand that it is not the animal per se, but the potential sources of human pathogen contamination, e.g. concentrated animal feedlots, open sources of raw manure, etc., in the environment in which the animal exists that result in the animal infection and subsequently becoming a transfer vector.

The complex biological interactions between wild animals, the environment and their potential to vector human pathogens to fruit or vegetable crops is an area of intense study. By examining landscape features, land use in adjacent areas, animal movement patterns and prevalence of genetic strains of *E. coli* in soil, animal and water samples, models may be able to be created that might be used to forecast contamination events. While this work is still in the early stages, the prevalence of *E. coli* in environmental samples has been shown to differ between landscapes and different cover types. It also appears that forests that border production fields might be acting as a source of *E. coli* that can be transmitted to the fields since a forest habitat harbors increased genetic diversity and can support higher levels of bacteria than the field environment. This study marks an important departure in industry thinking relative to animal intrusion. It demonstrates how environmental testing data and observation may be used to build predictive models that might assist growers in assessing how pathogens move through production environments and provide insight on how to best manage these potential hazards.

What does this mean for you?

- It is important to understand not only the adjacent land use but also the proximal land use to their production fields and the transitory patterns of wild animals in that environment. This is best accomplished through a thorough hazard analysis prior to planting.
- While human pathogens have been found in a diversity of animal species, the frequency is always fairly low; i.e. simply the presence of an animal is not a guarantee of human pathogen cross contamination to the crop. It is prudent to perform pre-harvest hazard evaluations and to use buffer zones to manage potential risks.
- It is important to put data to work. Environmental testing data, e.g. soil, water, animals, etc., may be combined with observational data on animal movements, weather data and crop data to create predictive models that growers might use to more reliably ascertain real cross contamination hazards moving forward.

4. Keep it simple: practical and cost effective preventive controls can be found.

While many questions around food safety in fruits and vegetables involve complex biological interactions, that is not always the case. For example, it was widely publicized that iceberg lettuce harvest knives used to cut the lettuce plant at the base and then remove the core were a significant point of cross contamination. While this assumption was based on the unlikely presence of high concentrations of pathogens in lettuce fields that would be contacted by the knives, there were no commercial data to disprove this theory. Subsequent research has shown that pathogens are infrequently present in commercial fields and when they are, they are present in very low concentrations. Additionally, simple modifications to lettuce coring knives that extend the distance from the cutting knife to the coring ring can significantly reduce the risk of pathogen contamination. Further, by polishing joint welds, the tools are much easier to sanitize thereby further reducing cross contamination frequencies.

Another example where a relatively simple idea might have a significant impact is the use of zero-valent iron to improve irrigation water quality. The microbial quality of many surface or open sources of irrigation water is largely unknown. However, water testing data collected during the execution of a number of funded research programs indicate that open water sources can undergo periodic fluctuations in indicator generic *E. coli* concentrations and in some regions of the U.S., *Salmonella spp*. are routinely found in surface waters used for irrigation. Zero-valent iron (ZVI) holds promise as a water purification system. Preliminary results describing water purification via the use of scrap iron and sand filters might provide a low cost method to remove contaminants from higher risk irrigation water sources, e.g. surface water sources. When iron fragments are stratified and separated by sand layers, water can be passed through this "filter." It has been shown that *Salmonella* and *E. coli* O157:H7 mixed into the water is bound by the iron, and in some cases, inactivated. While there remains considerable work to be done to translate lab-scale experiments to operationally practical irrigation water purification systems, the technology holds promise as it can be a practical enhancement over sand filters commonly used in production, requires no energy inputs, utilizes scrap iron and represents a renewable method to reduce pathogen contamination in water.

What does this mean for you?

- Equipment surfaces should be designed to eliminate rough edges and cracks that can serve as areas where microorganisms can become established and represent a source of cross contamination to food. Joints should be welded and polished and equipment inspected routinely to insure it is in good repair and easily sanitized. This applies to field, packinghouse and processing equipment.
- Food safety programs should not be rigidly prescribed. Innovation and original thinking are critical tools in addressing food safety questions. Sometimes a relatively simple solution like extending the length of a harvest tool and improving the quality of welds can prove to be an effective preventive control. Low cost, easy to use methods like the use of ZVI to improve irrigation water quality hold the promise of being an effective solution to a worldwide issue.
- It is important that the effectiveness of new preventive controls like ZVI, new equipment designs, etc. are validated under commercial conditions to demonstrate they work as intended and that once incorporated into the operational routine, preventive controls are verified as appropriate.

5. Composting and soil amendment preparation should be viewed as a process with measurable controls.

The use of various composts is a common and necessary practice in the produce industry to improve and restore soil fertility. However, the safe production and application of composts must be viewed as the result of a well- controlled manufacturing process that is monitored and verified. A number of CPS-funded programs have identified key variables that must be understood by compost producers and growers. These include: moisture, heat-up times, time x temperature controls, pH, particle size, C:N ratio, raw material sources, product turns and finished product storage. Even with products like heated chicken pellets where processing temperatures can exceed 300°F, one must be very careful to insure the process is precisely controlled to achieve desired Salmonella population reductions. Failure to properly control any composting or soil amendment preparation process can result in pathogen survival and the development of heat tolerance so that the pathogens are better able to survive and represent a potential cross contamination hazard.

What does this mean for you?

- It is important for growers purchasing composts for use in fields that they know their supplier and that the supplier can demonstrate that the compost was produced according to a validated process and further they can verify that the specific lot(s) being purchased were produced within the parameters of that validated process.
- If a grower is producing composts for use on their farm, they must understand the variables of the composting process and verify that the process they used has effectively reduced human pathogen populations.
- If pathogen or indicator testing is used to verify the efficacy of the composting process, it is important to use sufficient samples sizes and be sure the tests account for the complex organic backgrounds which can affect PCR sensitivity and the presence of non-pathogenic bacterial species.

6. Any wash process must be sufficiently controlled to prevent cross contamination.

Many different products are washed, cooled or transported using water. Therefore it is important that the water is treated and maintained properly so that it does not become a source of cross contamination for human pathogens, should they be present. In other words, understanding your process for water disinfection and validating its efficacy is critical for the safety of the product. It is equally important to remember that simply washing products is not an effective mechanism for removing contamination, i.e. it cannot remove or kill pathogens that have had the opportunity to naturally seek out hidden surfaces on products and adhere to them. CPS-funded research projects have described important variables of your wash water system that must be properly controlled. These include: temperature, pH, turbidity, sanitizer concentration, product load per wash volume, contact time and source water quality. Each type of wash, cooling or product transport system can have different characteristics and physical design so operators must characterize their specific system and validate that their disinfection process or preventive controls are effective and verify that they are operating the system within the validated limits during production runs. Improper control over wash, cooling or water-based transport systems can do harm possibly resulting in large-scale cross contaminations. One CPS-funded program vividly demonstrated this assertion using an inoculated cilantro load and washing it with un-inoculated parsley on a commercial wash system. The improperly controlled wash system permitted cross contamination onto the parsley demonstrating the potential for cross contamination.

More resilient wash water chemistries are emerging. The commercial product, T128 is representative of the "next generation" of chemical wash water sanitation systems. The data generated thus far indicates T128 may act by preserving or "protecting" active chlorine under conditions where increasing organic loads in wash water systems would normally deplete chlorine. In effect, T128 may act as a "safety net" by providing operators protection from cross-contamination. Over time, as organic load builds in wash water using traditional sodium hypochlorite wash water treatment, the amount of active chlorine sanitizer decreases owing to interactions with organic materials. This condition may permit pathogens, if present, to survive in the wash water and cross contaminate the produce as it moves through the system. T128 works by protecting active chlorine as organic loads increase thus diminishing cross contamination risks.

Additionally, reports from CPS-funded scientists revealed that: (1) organic load in tomato wash flumes is a critical factor impacting aqueous chlorine dioxide (ClO_2) concentrations, (2) practical steps to reduce vine and leaf trash in flumes would help minimize the rapid rate of antimicrobial oxidizer loss, (3) while oxidation/reduction potential (ORP) is commonly used as an indirect measure of active chlorine in systems where water contacts raw products, positioning of sensors, water temperature and organic load can impact readings, and (4) two-step combinations in some wash systems (e.g. tomatoes) where physical brushing accompanied by a water/sanitizer spray was shown to result in a >3-log reduction in surface microbes.

What does this mean for you?

- Even properly managed wash systems do not sanitize the surface of fruits and vegetables so the multi-hurdle food safety programs that begin pre-plant and extend through the supply chain are needed. Washing is not a kill step. Improperly managed wash, cooling or transport systems using water can be a significant source of cross contamination if pathogens are present.
- Whenever water contacts the surface of fruits or vegetables, it is important that the microbial quality of that water be properly controlled and monitored. Operational parameters should be developed for the system and the performance of preventive controls should be validated and then verified during use.
- New strategies for washing produce are emerging. Combinations of treatments may offer better and more efficacious control over microorganisms in wash water. Operators needs to monitor and evaluate emerging technologies and test them relative to their unique process requirements.

7. Breeding fruit and vegetable varieties for resistance to human pathogens?

Plant genetics and physiology may play a role in pathogen survival. Two research programs hinted at the role plant genetics may play in pathogen contamination and survival on spinach leaves and tomato fruits. Historically the industry and the research community have focused on a better understanding of the growing environment, pathogen vectors and the genetic and physiological attributes of the pathogen. The data presented on *Salmonella* survival on a broad collection of tomato varieties and *E. coli* interactions with slow and fast-growing spinach leaves may indicate that the genetic and physiological state of the plant may also impact survival of pathogens on plant surfaces. It is unclear whether it may be possible to select for genetic resistance to human pathogens in the future, but a better understanding of plant/human pathogen interactions will help inform future research and risk management strategies.

What does this mean for you?

- Stakeholders in the produce supply chain need to monitor food safety research to have a view to emerging trends and concepts. This base of knowledge will ultimately permit more effective communications with the scientific and seed breeding communities to insure that priority is given to the most promising avenues of research. Certainly unlocking the genetic potential of the plant in combating human pathogen survival is an important avenue to explore in improving food safety.

8. Seek and destroy is a strategy for managing potential *Listeria monocytogenes* hazards.

The 2013 CPS Symposium included a workshop focused on Listeria biology and lessons learned on *L. monocytogenes* control from the meat and produce industries. There are many basic differences between *L. monocytogenes* and other human pathogens like *Salmonella* and *E. coli* O157:H7. One of them is that *L. monocytogenes* can become a resident and persistent problem if it is permitted to establish itself in a produce processing or packing operation. The processed deli meat industry faced similar issues with *L. monocytogenes* ten years ago and adopted a "seek and destroy" strategy, i.e. a robust search for niches where Listeria might become established and implementation of aggressive sanitation programs to prevent Listeria from "moving in" and becoming resident. Key elements of a preventative program are: comprehensive Good Agricultural Practices (GAP) program at the field level to keep the incidence of Listeria introduction into the packing or processing environment low, work flow patterns within the facility that reduce cross-contamination potential, equipment design that reduces potential Listeria harborage areas and facilitates thorough cleaning and sanitation and a risk-based environmental testing program.

What does this mean for you?

- It is critical that operators develop a comprehensive plan for environmental testing and be committed to conducting root cause analysis when positive results are obtained to ensure that the reasons for the positive tests are understood and corrective measures put in place to prevent a reoccurrence.
- Facility and equipment design needs to reflect the potential for *L. monocytogenes* contamination and to permit effective cleaning and sanitation.
- Operators need to have written facility and equipment sanitation programs with verification measures to insure consistent performance.

9. *Salmonella* species can adapt to production environments.

A re-current theme across several research projects has been the hardiness of *Salmonella* in the soil, on soil amendments and on plant tissues. Research on *Salmonella* survival on chicken pellet soil amendments demonstrated that manufacture and production of finished chicken pellets has to be thought of as a manufacturing process with critical measures like moisture level and temperature fastidiously controlled to insure the pathogen is eliminated otherwise it can build a resistance to heat treatments. Similarly, attenuated *Salmonella* was shown to survive much better than attenuated *E. coli* O157:H7 when inoculated onto spinach or romaine leaves, chopped and disked into the soil in the Salinas Valley.   Another project demonstrated that *Salmonella* serovars were much more resistant to the antimicrobial effects of natural isothiocyanates from broccoli versus *E. coli* O157:H7 strains. Lastly, data has been presented that indicated that if *Salmonella* becomes desiccated, its ability to survive can be increased. If *Salmonella* are grown in liquid broth they are much less hardy than *Salmonella* grown on agar plates. This observation has important ramifications for researchers and the design of experiments testing survivability of *Salmonella* in produce environments such as pack houses and fields. It also reminds produce industry operators that the environment in which produce is handled or processed (wet to dry transitions, rapid temperature changes, sanitizer concentrations, etc.) can affect the survivability of *Salmonella* and the potential for cross contamination hazards.

<u>What does this mean for you?</u>

- All operators within the produce supply chain need to consider the potential for *Salmonella* contamination at all levels via a comprehensive hazard analysis and establish preventive controls that effectively diminish the potential hazard.
- Preventive controls need to be validated and their execution must be verified and carried to completion to prevent potential *Salmonella* contaminates from developing tolerances to the treatments.

10. Irrigation water and understanding public health risks.

Large segments of the produce industry currently perform some type of irrigation water testing. Generally, generic *E. coli* is used as an indicator for fecal contamination in irrigation water tests. Detection of generic *E. coli* is not necessarily an indicator for pathogenic *E. coli* strains or *Salmonella spp*. However, data collected over time can be used to establish baseline performance for a water source and any significant deviations from that baseline can be an indicator that the source and/or the delivery system has been compromised and the grower should perform an inspection of the system. One CPS-funded study used over 60,000 California industry irrigation water test results to demonstrate the very low incidence of generic *E. coli* concentrations above the EPA recreational water standard (256 MPN/100 mls for a single test, 126 MPN/100 mls on a five test rolling mean). There were clearly differences in exceedances when comparing closed water sources like deep wells and open water sources such as on-farm ponds and canals. Each irrigation water source should be evaluated for potential contamination risk factors that must be evaluated and managed; e.g. risk of animal intrusion, potential for run-off, water delivery mechanisms, seasonality, etc. A comparative study focused on generic *E. coli* test methodologies pointed out that growers need to be sure that the tests used to measure generic *E. coli* have the proper sensitivity. While several tests are available, it is important that the detection level of the kit is matched to the standard. For example, if the target is the EPA recreational water standard of less than 126 MPN *E. coli*/100 mls, then a test sensitivity of 200 MPN *E. coli*/100 mls would be inappropriate. Data have also been developed that demonstrate the value of using larger water samples to enhance the probability of detecting low levels of contamination.

In one of the first examples where quantitative microbial risk assessment (QMRA) has been applied to produce food safety, irrigation water test data and a series of assumptions around time intervals from final irrigation to product consumption, serving sizes and irrigation practices, relative public health risks were calculated. For example, data has been presented that shows sub-surface drip irrigation with water containing 126 MPN generic *E. coli*/100 mls could result in 9 illness/100,000,000 consumers compared to 1.1 illnesses/1,000,000 consumers if furrow irrigation were used and 1.1 illnesses/1,000 consumers if sprinkler irrigation were used. The data clearly show that public health risk is a function of source water quality and irrigation delivery system used. As in all models, the model is only as useful as the quality of the data and the assumptions made to build it. However, the QMRA model is very useful in helping growers prioritize and manage potential contamination risks.

What does this mean for you?

- Growers, harvesters and processors should include irrigation water sources and delivery systems in any hazard assessment conducted for their operations. Potential sources of contamination should be identified and preventive controls developed to manage hazards.
- Irrigation water testing can be a useful tool to establish baseline performance of irrigation water systems. An irrigation water testing data base may permit growers to identify seasonal hazards and facilitate risk-based testing programs that are more cost effective and more effective in managing contamination hazards.
- Operators that perform irrigation water testing should have written protocols for taking samples and a rationale for the test method used, sample size and what actions are to be taken should the results exceed operating parameters.
- It is time to put our data to work. QMRA represents a useful tool to help the industry quantitate public health risk related to various agricultural inputs or processes. Ultimately this will enable the industry to prioritize risks and expend resources against those areas that can most effectively improve safety.

11. Testing is about sampling strategies.

Product, environmental and water testing have become part of the food safety landscape in the produce industry. A recurrent result among CPS-funded research programs has been that larger sample sizes increase the chance of finding pathogens. Typical commercial product sampling procedures use 25-gram samples of plant tissues and 100-ml samples for water to test for pathogens and/or indicator organisms. Data from a number of projects have shown that increasing the sample size to 150-grams for products and >200 mls for water increases the chance of detecting low level contaminations. Sporadic contamination frequencies and the low concentration of contaminates, make sampling strategies difficult to develop. This reality has been characterized as “finding a needle in a haystack”. One research project provided a stark example of this reality. Raw almonds were collected by handlers over a period of a decade. Of the nearly 15,000 samples collected and tested for *Salmonella*, the frequency of contamination was generally between 1-2 percent and the concentration of *Salmonella* was <1 MPN/100 grams. Over time, the samples that tested negative were held in storage. At the end of the study, the researchers went back and sub-divided the “negative” samples and retested them for *Salmonella*. Approximately 1 percent of the samples were found to be “positive” for *Salmonella*. These results show the limitations of sampling when the frequency and concentration of pathogen contamination are so low. “Positives” can be shown with confidence to be positive, but “negative” samples may not necessarily be negative.

What does this mean for you?

- It is important to consider the benefits and deficiencies when determining the role of testing to verify food safety programs. If testing is to be used, there should be a written program describing the objectives of the program, the sampling strategy to be employed, the microorganisms to be tested and the protocol to be followed in executing the test, the sensitivity and selectivity of the protocol and how the data will be evaluated and stored.
- When testing is employed, efforts should be taken to use as large a sample as is practical.
- Any operation that employs product, water or environmental testing should develop plans for what actions need to be taken when the test results are “negative” and when they are “positive”. Negative test results generally mean it is acceptable to use that water or product or that the sanitation program was effective. Positive test results can elicit a number of different actions and it is important to plan ahead and have a plan for how the organization should react.

12. Clean and sanitize surfaces that come in contact with products.

Produce handling results in contact between the product and various surfaces that can become contaminated with pathogens. There have been CPS-funded research programs dealing with the potential for transference of pathogens from contaminated gloves, cloths used for wiping fruits, product cartons and plastic harvest buckets. The use of gloves has been debated within the produce industry for several years. Data suggests that hand wash prior to use of any kind of glove is very important and that the gloves need to be sanitized as they are used. Nitrile gloves do not facilitate cross contamination as well as latex gloves, however both types will transfer pathogens if not cleaned and sanitized regularly with a sanitizer. Another frequent point of contention in the industry is the potential for pathogen transference owing to the use of cloths to wipe fruit that is field packed. Again, data have been developed that shows that pathogens can be transferred from fresh tomatoes to cloths and from cloths to subsequently handled tomatoes. While there are many factors at play, moist cloths facilitate transference more readily than dry cloths and dirty cloths seemingly are less efficient at transference than cleaner cloths, although both can facilitate transference if pathogens are present.

The question of pathogen transference from cartons or harvest buckets has also been addressed. Specifically, the re-use of cartons has been examined and it has been demonstrated that cartons that have organic residues and moisture from their initial use can indeed transfer pathogens to fruit re-packed in those cartons. Additionally, pathogen transference has been studied in multiple-use containers like tomato harvest buckets. Variables such as the age and condition of tomato harvest buckets were considered when determining their potential as pathogen transference vehicles. Surprisingly, older, scratched and worn plastic buckets were less effective in transferring inoculated *Salmonella* than newer buckets. Once again, new and old buckets could affect transference if the pathogen was present and the presence of soil on the buckets decreased *Salmonella* die-off. This emphasizes the importance of regularly cleaning and sanitizing harvest containers to prevent transference of pathogens to harvested products.

What does this mean for you?

- If gloves are used to handle raw products, they should be changed frequently and/or cleaned and sanitized periodically while in use. Preference should be given to the use of nitrile gloves. Hand washing should always be a pre-requisite to using gloves.
- The use of cloths to clean or wipe dirt off harvested tomatoes should be avoided. While the contamination frequency would be expected to be very low on the surface of tomato fruits, if a pathogen were there, the cloth could spread that contamination across several fruits.
- It is important to store produce cartons so that they remain dry and clean. If cartons are to be re-used, e.g. re-pack operations, they should be thoroughly inspected and cartons that are wet or have dirt or debris in them should be avoided.
- Re-usable containers like harvest buckets should be periodically cleaned and sanitized. Containers should be visually inspected on a routine basis to be sure dirt and other field debris does not accumulate.

This paper was developed based on data shared by participating scientists at the Center for Produce Safety Research Symposia from 2010 to 2013. The statements made here are interpretations and recommendations.

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Center for Produce Safety
Five Year Research Review

Version 1.1

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CPS CENTER for PRODUCE SAFETY

PMA PRODUCE MARKETING ASSOCIATION

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This report has been prepared to provide a summary of scientific and technical information related to factors that affect the microbial safety of agricultural water and is derived from CPS-funded research reports and other public research sources. The intent of drafting this document is to provide users with currently available information regarding factors that affect the microbial safety of agricultural water, and the information contained within is intended to be used in a manner consistent with existing applicable regulations, standards and guidelines. The information provided herein is offered in good faith and believed to be reliable, but is made without warranty, expressed or implied, as to merchantability, fitness for a particular purpose, or any other matter. The information contained within this report is not designed to apply to any specific operation. It is the responsibility of the user of this document to verify that any information contained within this document is accurate and applicable for its operation. The publishing trade associations, their members and contributors do not assume any responsibility for compliance with applicable laws and regulations, and recommend that users consult with their own legal and technical advisors to be sure that their own procedures meet with applicable requirements.

Table of Contents

1.0 Background

The Center for Produce Safety (CPS) is a leader in the delivery of science-based research for the produce industry. CPS' research has made and continues to make valuable contributions to the industry's food safety knowledge. Recognizing those contributions, the Produce Marketing Association and Western Growers Association, in collaboration with CPS, are in the process of assessing CPS research findings for 2008 through 2013. The review is intended as a produce industry resource to help individuals and companies better understand the state of agricultural water knowledge in regard to food safety. This report, which focuses on agricultural water, is intended as the first in a series.

2.0 Agricultural Water

Agricultural water is a major risk factor in the contamination of fresh produce (Beuchat, 1997; Steele, 2004; Suslow, 2003). Epidemiological evidence that contaminated irrigation water can increase the risk of human disease was demonstrated in a large study in Mexico where higher incidence of disease was reported in households that consumed food irrigated with untreated wastewater than in households that consumed non-irrigated food or food irrigated with water from treated wastewater effluent reservoirs (Cifuentes, 1998). Additionally, an *E. coli* O157:H7 outbreak associated with consumption of shredded lettuce was linked back to the unintentional cross-contamination of well water intended for irrigation with water from a dairy manure lagoon (U.S. Food and Drug Administration and California Food Emergency Response Team, 2008). Irrigation water was also identified as a likely contributing factor in *Cyclospora cayetanensis* infections from raspberries (Herwaldt, 2000). Finally, the same strain of *Salmonella* Saintpaul was identified in irrigation water and on serrano peppers implicated in a salmonellosis outbreak in 2008 (Centers for Disease Control and Prevention, 2008). These incidents are a sampling of reported contamination events providing evidence that water is a risk factor in conjunction with the production and harvesting of fresh produce.

Water use is extensive in produce growing (e.g., irrigation, frost protection, direct application of pesticides), harvesting (e.g., hydration, rinsing) and cooling (e.g., hydrocooling, hydrovac, and ice) operations. Water can be a carrier of many different human pathogens including pathogenic strains of *E. coli, Salmonella, Shigella, Cyclospora cayetanensis, Cryptosporidium parvum* and *Giardia lamblia* and viruses, such as hepatitis A virus. If present, pathogens can potentially enter a water system anywhere from its source through distribution and use (U.S. Food and Drug Administration, 2013a and U.S. Food and Drug Administration, 2013b). Ensuring agricultural water does not become a means of produce contamination and subsequent illness has several challenges. The first relates to the microbial quality of the water itself – which pathogens may be present in agricultural water supplies; how does one determine what microbial quality of water is acceptable for various agricultural water uses and how do agricultural practices and crop type and condition affect the microbial quality of agricultural water needed? Second, how does one know when agricultural water poses a risk to consumers? And when agricultural water microbial quality issues exist, is corrective action necessary based solely on the potential for transference of human pathogens from the agricultural water to the harvestable portion of the crop? If it is necessary, is it even possible (i.e., are there cost-effective technologies available for remediation)? Finally, can tools such as quantitative microbial risk assessment (QMRA) be used to predict potential contamination outcomes, identify prevention strategies and/or prioritize risk management efforts?

Research related to agricultural water microbial quality is limited. Most research regarding water microbial quality (e.g., pathogen prevalence, indicator organisms) has been conducted for objectives related to reclaimed water, drinking and recreational water supplies and the effects of agriculture on the environment. However, much of this research is applicable to and has benefited agriculture.

The microbial quality of and the user's control over source waters as well as both the method and timing of application are key determinants in assessing relative likelihood of produce contamination attributable to agricultural water use practices. To date, agricultural water microbial quality research has focused on pathogen or indicator organism occurrence, transfer of pathogens to crops and management strategies to reduce the likelihood of produce contamination and consumer risk.

This report on the quality of agricultural water reviews and synthesizes much of the existing body of research including past CPS-funded research, and current CPS-funded research that addresses the issues of:

1) Human Pathogen Prevalence, Quantity and Persistence in Agricultural Water,
2) Transfer and Persistence of Human Pathogens from Contaminated Agricultural Water to the Agricultural Environment and Produce,
3) Managing Agricultural Water Safety, and
4) Tools to Assess the Risk Posed by Agricultural Water Use and Practices.

Included in each of this reports' four sections addressing these issues are key findings from completed CPS-funded research and summaries of ongoing research. Final reports for completed CPS-funded research are available on CPS' website: https://cps.ucdavis.edu/grant_opportunities_awards.php. Additionally, select CPS studies that have been published in peer-reviewed journals have been noted along with the study's key findings. In addition to findings from research funded by CPS grant funds, this report includes studies from the scientific body of knowledge that also address the CPS or industry research questions. Relevant studies from the scientific literature were identified in searches using PubMed and Google Internet search engines. The report concludes with a list of data gaps or identifiable agricultural water research needs.

2.1 Human Pathogen Prevalence, Quantity and Persistence in Agricultural Water

The CPS has asked the following research questions related to pathogen prevalence, quantity and persistence in agricultural water in their 2009-2013 requests for proposals:

- What is the frequency of generic *E. coli* detection by water source and production location? Are some water sources more prone to generic *E. coli* contamination? Is there a seasonality component to detection of generic *E. coli* when it is found?
- Irrigation water is a potential source for contamination of tomatoes. What levels of *Salmonella* and indicator organisms are normally found in the water and soils that are used to grow tomatoes in Florida?
- If water used for tree fruit irrigation or overhead cooling is contaminated with microorganisms, what is the transference to the fruit?

2.1.1 What do we know? – Studies from the scientific body of knowledge

Prevalence: Some watersheds that have been extensively sampled demonstrate a consistent pathogen presence, and surveys of waterbodies in various parts of the United States and abroad have reported human pathogen occurrence (Thurston, 2002). A study conducted in south central Georgia reported *Salmonella* prevalence as high as 79% in rural surface water (Haley, 2009). *Campylobacter* was found in 43% and *Salmonella* was found in 62% of samples taken in a rural watershed (Vereen, 2013). Edge et al. (2012) collected 902 water samples from 27 sites in four intensive agricultural watersheds across Canada and found waterborne pathogens in 80% of water samples. These samples also had low generic *E. coli* concentrations (<100 CFU/100 ml).

Weather: Susceptibility to runoff significantly increases the variability of surface water quality. Precipitation relative to fecal deposition is associated with increased levels of microbial populations in runoff from agricultural lands. Lewis et al. (2010) demonstrated that fecal coliform bacteria levels in storm runoff were positively affected by the timing of manure application to a storm event and inversely affected by the presence of vegetative buffers or filter strips. Meals' and Braun's work (2006) also showed a positive association between rainfall and timing of manure application in concentrations of generic *E. coli* in field runoff. In a study analyzing the association between land-use and environmental variables and isolations of *E. coli* O157:H7, *Salmonella* spp., and *Campylobacter* spp. from an agricultural watershed in southern Alberta, an increase in the presence of these three pathogens was predicted by total rainfall in the days prior to sampling, sampling during the summer months, and sampling at sites downstream from high-density livestock operations, respectively. Increased levels of *E. coli* O157:H7 and fecal coliforms in irrigation ponds on produce farms were positively associated with precipitation and runoff (Gu, 2013). The incidence of *E. coli* O157:H7 increased significantly when heavy rain increased the flow rates of the rivers in a major produce production region in California (Cooley, 2007). Elevated temperatures and rainfall have been demonstrated to be associated with increased numbers of fecal coliform and enterococci concentrations, but not generic *E. coli* in a Florida freshwater lake (Staley, 2012a).

Sediments: A number of publications have shown that sediments may act as an *E. coli* reservoir and re-suspension of sediment, rather than runoff from surrounding lands, can create elevated generic *E. coli* concentrations in water (Pachepsky, 2011a). Riverbed sediments have been found to represent a possible reservoir of human pathogens. As sediment compartments (suspended and bed), riverbeds have been found to typically have higher prevalence and levels of human pathogens than water alone (Droppo, 2009). Generic *E. coli* has been demonstrated to survive in sediments much longer than in the overlying water and was inactivated at slower rates when organic carbon contents were elevated (Garzio-Hadzick, 2010). In a study by Czajkowska et al. (2005), *E. coli* O157:H7 survived for extended periods in sediment becoming undetectable only after 60 days at 24°C.

Biofilms: Little has been published about the role if any that biofilms may play as human pathogen reservoirs in irrigation water delivery systems. This may be important as biofilms have been found to play a role in microbiological contamination of drinking water distributing systems (Juhna, 2007). Additionally, elevated generic *E. coli* levels in agricultural water irrigation pipes between irrigation events indicate that *E. coli* growth can occur and most of the increase in *E. coli* numbers was associated with the biofilm on the irrigation pipe walls (Pachepsky, 2012). Pathogenic *Salmonella* have been isolated from aquatic biofilms that persist and keep the *Salmonella* viable, which provides for the potential for release in irrigation systems (Sha, 2013).

Persistence: Human pathogens commonly involved in foodborne illness persist in water for varying lengths of time (Maule, 2000). The presence of fecal material may affect the survival of pathogens (Gu, 2013; McGee, 2002). Most human pathogens can survive in water for varying lengths of time depending on factors such as temperature, salinity, dissolved oxygen, pH, the amount of pathogen present, predation, exposure to ultra-violet (UV) light and nutrient availability (Metge, 2002; Steele, 2004; Wilkes, 2011; Wanjugi, 2013). Though the viability of most pathogenic bacteria in water decreases over time, bacterial endospores survive for an undetermined amount of time while fecal coliforms, *Salmonella* spp., and *Shigella* spp. generally survive less than 30 days at 20-30˚C (Steele, 2004). *Salmonella* spp. has been demonstrated to remain viable for longer than many other enteric bacteria in freshwaters suggesting that the aquatic environment may represent a relatively stable environment for these bacteria (Chao, 1987). *Salmonella* serovars DT104, O78, and ML14 survived for 45 days in autoclaved river water at approximately 105 CFU/ml (from an initial population of approximately 108 CFU/ml) whereas plate counts of untreated or filtered river water supported fewer *Salmonella* (Santo, 2000). Wang and Doyle (1998) measured the survival of *E. coli* O157:H7 in autoclaved municipal water, reservoir water and water from two recreational lakes at 8, 15 or 25°C. The bacterium survived longer in all three water types at 8°C, and the least amount of time at 25°C. At 8°C, populations declined from 10 to 100 CFU/ml in 91 days. At 25°C, populations decreased below the detection limit between day 49 and 84 in all but the autoclaved municipal water. *E. coli* O157:H7 has been demonstrated to survive up to 109 days in water, and *E. coli* O157:H7 collected from inoculated cattle were detected up to 10 weeks longer than the laboratory-prepared cultures suggesting that pathogen survival in low-nutrient conditions may be enhanced by passage through the gastrointestinal tract of cattle (Scott, 2006).

Quantity: Microbial populations may differ depending on the time of year water is sampled (Fonseca, 2011; Gu, 2013; Pahl, 2013; Wilkes, 2011). *E. coli* O157 has been demonstrated to be able to grow in sterile freshwater at low carbon concentrations (Vital, 2008).

Agricultural Water Sources and Distribution Systems: Sources of irrigation water can be generally ranked by the microbial contamination hazard. In order of increasing risk, these are: potable or rain water, groundwater from deep wells, groundwater from shallow wells, surface water, and finally raw or inadequately treated wastewater (Leifert, 2008; Pachepsky, 2011b). A comprehensive survey of human pathogen contamination levels in agricultural water sources has not yet been compiled for the U.S. or for any other country.

Ground Water: Ground water sources that are properly designed, located and constructed generally provide high-quality agricultural water with little variability in microbial quality (Close, 2008; Gerba, 2009). Microbial quality of well water can be affected by the design of wells, nature of the substrata, and the depth to groundwater and rainfall (Gerba, 2009). Long distance transport of pathogens is possible in fractured limestone and clay soils, and gravel sandy soils (Gerba, 2009). A study of well water from 268 households in southeast Nebraska showed 37% of samples contained fecal coliforms as high as 950 cells per 100 ml water. Only 10% of the wells met Nebraska's criteria for private well construction and 30% of these wells contained one or more coliform bacteria per 100 ml. The highest incidence of coliform occurred in dug or augered wells with open-jointed casing (Exner, 1985). Domestic wells at 1,292 farmsteads in Ontario were sampled in 1991 and 1992 and tested for coliform bacteria as well as other contaminants. Thirty-four percent of wells had more than the maximum acceptable number of coliform bacteria. The percentage of wells contaminated by coliform bacteria decreased significantly with increasing separation of the well from the feedlot or exercise yard on livestock farms (Goss, 1998).

Surface Water: Surface water poses the highest potential for contamination and the greatest variability in microbial quality among commonly used agricultural water sources. Water microbial quality can be quickly degraded in storage ponds, due to wildlife and other factors (Higgins, 2009; McLain, 2008). In general surface water presents a higher risk of pathogen contamination than do groundwater sources as demonstrated by numerous studies that have shown there is a significant likelihood that surface waters will contain human pathogens (Betancourt, 2005; Pahl, 2013; Furtula, 2013). Telias et al. (2011) investigated the effect of water on the microbial population of tomatoes and showed that despite the major differences observed in the bacterial composition of ground and surface water used in their study, the season-long use of these very different water sources did not have a significant impact on the bacterial composition of the tomato fruit surface.

Treated Waste Water: In the U.S., the use of treated municipal wastewater as a source of agricultural water for produce crop irrigation occurs only on a very limited scale. Nineteen U.S. states regulate the use of wastewater in crop production with varying degrees of regulation. Some states require very stringent treatment of effluents to reduce the concentration of human pathogens to acceptable levels prior to irrigation, while other states utilize site limitations and restrictions on crop utilization to allow time for pathogen die off (National Research Council, 1996). An extensive review of California's water recycling criteria for irrigation water use and recommendations from a panel of independent advisors was compiled by the National Water Research Institute in 2012 (NWRI, 2012).

Reclaimed Tail Water: The authors are currently unaware of any research that addresses the risk or mitigation strategies for using reclaimed tail water for irrigation.

2.1.2 What have we learned? – CPS-funded ongoing and completed research

Gillor (2009), University of California, Davis & Ben-Gurion University, Science-based monitoring for produce safety: Comparing indicators and pathogens in water, soil and crops.

- There was no statistically significant difference in fecal indicator bacteria levels on tomatoes drip irrigated with treated waste water as compared to tomatoes drip irrigated with potable water. Thus microbial contamination on the surface of tomatoes did not appear to be associated with the irrigation water source when comparing these two agricultural water sources.
- Indicator bacteria testing did not predict the presence of pathogens in any of the matrices (soil, water, crop) tested. High concentrations of fecal indicator bacteria were detected in agricultural water and on tomato surfaces from all irrigation treatment schemes, while human pathogen contamination on tomato surfaces (*Cryptosporidium* and *Salmonella*) was only detected on crops irrigated with treated waste water.
- Publication: Orlofsky et al., 2011.

Marco (2009), University of California, Davis, Contribution of phyllosphere microbiota to the persistence of *Escherichia coli* O157:H7 ATCC 700728 on field-grown lettuce.

- Total bacterial phyllosphere populations on romaine lettuce differed over time during the four-week field trials and season of planting (spring and fall 2009). During the spring 2009, bacterial population amounts also differed significantly depending on method of irrigation and exposure to attenuated *E. coli* O157:H7.
- Zero to seven days after inoculation with attenuated *E. coli* O157:H7, overhead irrigated romaine lettuce plants typically contained two- to five-fold more total bacteria than drip irrigated plants.
- Substantial plant-to-plant variation exists in microbial diversity patterns on lettuce.
- Field grown romaine lettuce has been found to harbor indigenous bacteria that are antagonistic towards the growth of virulent *E. coli* O157:H7 and a total of 28 *E. coli* O157:H7 inhibitory bacterial isolates were identified in this project.
- Publication: Williams et al., 2013.

Koike (2009), University of California Cooperative Extension, Survival of *E. coli* on soil amendments and irrigation water in leafy green field environments.

- Attenuated *E. coli* O157:H7 and generic *E. coli*, when applied to soil, failed to move significantly into irrigation water runoff.

Wright (2010), University of Florida, Science-based evaluation of regional risks for *Salmonella* contamination of irrigation water at mixed produce farms in the Suwannee River watershed.

- *Salmonella* was detected in all irrigation ponds tested in the Upper Suwannee River watershed, but these *Salmonella* populations were very low (at or near the most probable number [MPN] methodology detection limit). *Salmonella* persisted at low population densities in this watershed.
- The highest prevalence and population of *Salmonella* for water samples was found in August-October, while *Salmonella* prevalence and populations in sediment was much more sporadic with peaks occurring in April, June and September.
- Ponds within this watershed that had consistently higher levels of *Salmonella* detected, had no distinguishable pond characteristics or agricultural practices that differentiated these ponds from those with lower levels.

Atwill (2009), University of California, Davis, Epidemiologic analysis and risk management practices for reducing *E. coli* in irrigation source water supplies and distribution systems.

- The majority of water samples tested (79% or 35,093/44,249) contained no detectable generic *E. coli* and 0.86% (380/44,249) exceeded >235 *E. coli* / 100 ml.
- Approximately 8% of well samples had detectable generic *E. coli* compared to 86% of canal and 48% of reservoir samples.
- On-farm reservoir samples have much higher concentrations of generic *E. coli* than well water samples in the central coast of California.
- In California and Arizona, seasonality is a factor in test results with exceedances (>235 generic *E. coli* / 100 ml) more common in summer and fall. There was a positive association between mean air temperature and the probability of an exceedance for canal sources (from mostly California/Arizona desert growing region).
- As the sample volume increases from 100 ml to 1 L or more, the probability of detection of generic *E. coli* increases. Therefore, companies should consider amending current sampling volume practices by increasing the sampling volume to ensure more accurate assessment of generic *E. coli* levels in irrigation water sources.

2.1.3 What is being funded? – CPS-funded new research

Gibson (2013), University of Arkansas, Evaluation of pathogen survival in fresh water sediments and potential impact on irrigation water quality sampling programs.

The objective of this study is to evaluate the relationship between pathogens and fecal indicator bacteria in fresh water sources over time and the role that fresh water sediments may play in the harboring and distributing pathogens in water sources used for irrigation.

2.2 Transfer and Persistence of Human Pathogens from Contaminated Agricultural Water to the Agricultural Environment and Produce.

Although research has shown that pathogens can survive in agricultural water, questions remain as to the risk this poses to the agricultural environment, produce crops and ultimately the consumer. In assessing relative likelihood of contamination from agricultural water use practices, key determinants are microbial quality of source waters, method and timing of application, pathogen species and concentration, commodity characteristics, and climatic conditions. In their Draft Qualitative Assessment of Risk to Public Health from On Farm Contamination of Produce, the U.S. Food and Drug Administration (FDA) composed the following table to present a relative comparison of the likelihood of produce contamination attributable to practices related to agricultural water.

Table 7. Relative Likelihood of Produce Becoming Contaminated with Pathogens of Public Health Concern from Agricultural Water				
	Least			Most
Source	Public Drinking Water	Ground water	Surface water protected from runoff	Surface water unprotected from runoff
And where contamination is known to exist, the likelihood of contamination is a function of the following factors:				
Contact with commodity	Indirect contact		Direct contact	
Commodity effects	Unlikely infiltration		Susceptible to infiltration	
	Surface not conducive to adhesion		Surface conducive to adhesion	
Application timing	Early in crop growth	Late in crop growth	During harvest	Postharvest

From: FDA, 2013 - Draft Qualitative Assessment of Risk to Public Health from On-Farm Contamination of Produce.

In CPS' 2009-2013 request for proposals, research questions addressing transfer and persistence of pathogens to the agricultural environment and produce include the following:

- If contaminated irrigation water is applied to crops, how long will human pathogens (e.g., *Salmonella*, Shiga toxin-producing *E. coli* [STECs] or *Listeria monocytogenes* [*L. monocytogenes*]) persist on the edible portion of the crop? What factors enhance or diminish survival?
- What effects does irrigation delivery method (e.g., drip, flood, sprinkle or furrow irrigation) have on pathogen transference?
- Is water used for irrigation or application of agricultural chemical sprays a risk for contamination in pistachio and walnut crops?
- Drought conditions and seasonal irrigation water shortages can lead to growers using alternative pre-harvest water sources (typically for irrigation and spraying) where the microbial quality of the water may be less than desirable. Therefore, how long do human pathogens (or surrogates/indicators) survive on the surface of leafy greens, tomatoes, peppers, tree fruits or strawberries if transferred via irrigation or spray water? What environmental factors affect survivability? Are there alternative irrigation water delivery systems that minimize transference of pathogens? What water source treatments might be available to minimize transference of pathogens to the crop?

2.2.1 What do we know? – Studies from the scientific body of knowledge

Agricultural Water Practices – Use and Application Methods: While dependent on environmental conditions, research has demonstrated human pathogens persist for various lengths of time in the agricultural environment and on produce when introduced by contaminated irrigation water (Brandl, 2006; Delaquis, 2007; Fan, 2009; Hanning, 2009; Sapers, 2006; Teplitski, 2009). Research has also demonstrated the ability of nonpathogenic *E. coli* to persist for up to 28 days, whereas *E. coli* O157:H7 did not survive for more than 14 days in inoculated spinach plants (Patel, 2010).

Irrigation: Numerous studies have demonstrated that pathogens in contaminated irrigation water may be transferred to irrigated crops (Geldreich, 1971; Hillborn, 1999; Ruiz, 1987; Sadovski, 1978; Wheeler, 2005). In a study investigating *E. coli* contamination risk in lettuce using three different irrigation systems, investigators injected attenuated nonpathogenic *E. coli* into the water stream of overhead, subsurface drip, and surface furrow. Sprinkler irrigated lettuce tested positive for the nonpathogenic *E. coli* for up to seven days, where subsurface drip and furrow methods produced only one positive sample (Fonseca, 2011). Solomon et al. (2002a) investigated transmission of *E. coli* O157:H7 from spray and surface irrigation water to lettuce plants and found that spray irrigation resulted in more plants testing positive.

Overhead Sprinkler: Oliveira et al. (2012) found that after sprinkler irrigating lettuce with water containing *E. coli* O157:H7 three to eight weeks after seedling transplant, initial high levels (103 – 106 CFU/g) on lettuce leaves were reduced to undetectable levels in two to three weeks under field conditions. Markland et al. (2013) inoculated basil, lettuce, and spinach plants with *E. coli* O157:H7, *E. coli* O104:H4, and avian pathogenic *E. coli* (APEC; two strains were used – *stx*+ and *stx*-) via overhead irrigation in a laboratory growth chamber. At 10 days post inoculation, *E. coli* O104:H4, APEC*stx*+ and APEC*stx*- populations were present on basil plants at concentrations of 2.3, 3.1, and 3.6 $\log_{10}$ CFU/g, respectively. *E. coli* O157:H7 was no longer detected on basil four days after inoculation. On spinach and lettuce, *E. coli* O157:H7 populations declined from 105.7 CFU/g, to undetectable three days post-inoculation. At seven days post-inoculation, APEC populations were still measureable at 0.6 to 1.6 log10 CFU/g – reduced 103–105 CFU/g on day 0. The study authors noted that the APEC and *E. coli* O104:H4 strains may be more adapted to environmental conditions than *E. coli* O157:H7. A field study by Islam et al. (2004a) showed transfer of *E. coli* O157:H7 (105 CFU/ml) during spray irrigation to lettuce and parsley with levels reaching non-detection at day 77 and 175 of sampling, respectively. Using the same experimental design, the researchers repeated their experiments with *Salmonella* Typhimurium resulting in non-detectable levels on lettuce and parsley at sampling day 84 and 231, respectively (Islam, 2004b). Following an initial 3-5 log reduction in the first 72 hours, secondary-growth spinach was shown to have culturable *E. coli* for up to six days after spray irrigation with water containing a non-pathogenic strain of *E. coli* O157:H7 at concentrations of 104-107 CFU/100 ml (Wood, 2010). However, Moyne et al. (2011) reported that neither drip nor overhead sprinkler irrigation consistently influenced the survival of *E. coli* O157:H7 on lettuce.

Drip Irrigation: Subsurface drip irrigation has been demonstrated to decrease the risk of produce contamination in some crops (Song, 2006). However, parsley plants drip-irrigated with *Salmonella* contaminated water were found to have *Salmonella* in their stems and leaves (Lapidot, 2009).

Furrow Irrigation: Both 12- and 30-day-old lettuce plants grown in a greenhouse were positive for *E. coli* O157:H7 after application of irrigation water containing low levels (101, 102, 103, 104 CFU/ml) of the pathogen (Mootian, 2009).

Crop Protection / Nutrients / Growth Regulator Sprays: If contaminated water is used in solution preparation, agricultural chemical application may serve as a human pathogen source for fresh produce. Numerous studies have investigated the survival of human pathogens in agricultural chemical solutions. *Salmonella* Newport and Montevideo were able to survive and were not significantly reduced in 11 out of 12 pesticide formulations tested by Mahovic et al. (2013). Guan et al. (2005) tested survival and growth of *Salmonella*, *E. coli* O157:H7, *L. monocytogenes*, and *Shigella* in seven different pesticide solutions and found that most formulations were somewhat inhibitory and, with the exception of *Salmonella*, did not allow growth. Verhaelen et al. (2013) investigated the ability of eight pesticide solutions to reduce virus contamination in water, and found that murine norovirus was found to remain infectious in seven solutions at the highest concentration applied in practice. The pesticides, atrazine, malathion, and chlorothalonil, and inorganic fertilizer, did not affect the survival of generic *E. coli*, *Enterococcus faecalis*, *Salmonella enterica*, human polyomaviruses and adenovirus in water (Staley, 2012b). There is also evidence that pesticides may support the growth of *Salmonella*, if introduced with source water, and may elevate risk during foliar contact application beyond that of the water source alone (Lopez-Velasco, 2013).

Frost Protection: The authors are unaware of any published literature regarding the relative risk posed by use of contaminated irrigation water for either bloom or fruit frost protection.

Root Uptake: Greenhouse studies by Solomon et al. (2002b) and Bernstein et al. (2007) suggested that *E. coli* O157:H7 could be transported into the edible part of lettuce from soil and *Salmonella* Newport could be transported to romaine lettuce seedling leaves through root system. However, other studies, some of which were conducted in outdoor field conditions, have not demonstrated root uptake, internalization and translocation of pathogenic *E. coli* and *Salmonella* from plant root to the edible portions of spinach and other crops (Sharma, 2009; Jablasone, 2004; Miles, 2009; Zhang, 2009; Erickson, 2010a). However Zheng et al. (2013) reported that transplanted tomato plants (within three days) were more susceptible to having bacteria internalized by root uptake as evidenced by increased incidence of internalized bacteria after transplant. These researchers also found that *Salmonella* internalization through the root system was influenced by *Salmonella* serovar as well as plant growth stage.

Other Factors: Further research has shown that numerous factors such as temporality, seasonality and plant characteristics may also play a role in human pathogen transference and persistence on produce.

Pathogen Concentrations: Currently it is inconclusive whether or not the initial concentration of pathogens in agricultural water used for irrigation affects the propensity for produce contamination as the scientific evidence is varied. Human pathogen concentrations in irrigation water may not be the most important factor determining pathogen colonization or internalization in growing produce. This is because human pathogens may not be able to compete well with natural microbiota found in or on the produce item (Pachepsky, 2011b). Some studies have shown a positive relationship with *E. coli* O157:H7 concentrations and spinach contamination while other studies have demonstrated that irrigation water containing 10 to 100 CFU/ml of *E. coli* O157:H7 can lead to contamination for up to 15 days in 30% of the crop (Erickson 2010b; Mootian, 2009).

Serotypes: Spinach irrigated with water containing *Salmonella* strains isolated from either poultry or produce at 6 CFU/100 ml was found to have higher concentrations from produce-isolated *Salmonella* over 35 days (Patel, 2013). Transfer of *Salmonella* to parsley leaves via irrigation water has been demonstrated to be dependent on serotype specific curli-forming abilities of the *Salmonella* strains (Lapidot, 2009). Additionally, significantly higher attachment of *E. coli* O157:H7 occurs on iceberg lettuce and cabbage when attachment strains express curli – a thin fiber on the bacterium's surface that mediates adhesion and entry to the host cell (Patel, 2011).

Plant Injury: Human pathogens may be internalized into produce via contaminated agricultural water through plant stoma, stem scars or wounds and the conditions may sometimes allow for pathogen growth (Aruscavage, 2008; Gomes, 2009; Kroupitski, 2009; Materon, 2007; Mitra, 2009). Two days following overhead irrigation with water containing 107 CFU/ml nonpathogenic *E. coli*, injured iceberg lettuce was found to sustain significantly higher microbial persistence than uninjured lettuce or lettuce with injuries that occurred greater than two days prior to irrigation (Barker-Reid, 2009). It has also been observed that *E. coli* O157:H7 cells preferentially attached to coarse, porous, or injured surfaces than to uninjured surfaces of green peppers (Han, 2000). Liao and Sapers (2000) observed that *Salmonella* Chester preferentially attaches to injured apple tissue than to unbroken skin. This may be due to the differences in topographical structures and specific physicochemical properties (Liao, 2000).

Temporal/Seasonal Effects: Parsley spray irrigated by water contaminated with *Salmonella* Typhimurium was found to have a higher concentration of the pathogen on leaves when irrigated at night or in the winter (Kisluk, 2012). Nonpathogenic *E. coli* persistence increased from five days during the summer to 17 days during winter months in the soil of furrow irrigated lettuce fields (Fonseca, 2011). Oliveira et al. (2012) found higher levels in the fall than in the spring after sprinkler irrigating lettuce with water containing *E. coli* O157:H7.

Crops: Produce crops may also differ in their propensity to become contaminated with human pathogens via contaminated agricultural water. Song et al. (2006) found that when agricultural water was intentionally contaminated with generic *E. coli* and *Clostridium perfringens* and used to furrow or drip irrigate produce crops the microorganisms of interest were only recoverable on the surfaces of cantaloupe and lettuce, but not on bell peppers. Additionally, crops with harvestable portion that develop on or near the ground (e.g., lettuce and parsley) were more likely to be contaminated with *Salmonella* than produce items grown off the ground (e.g., tomatoes and pimento) (Melloul, 2001). The surface topology of fruits, vegetables and food contact surfaces has been found to influence the bacterial attachment to and removal from a surface (Wang, 2012).

Cultivars: Cultivars may influence the susceptibility of some produce commodities (spinach and tomatoes) to contamination with human pathogen via contaminated irrigation water; however, more research is needed (Barak, 2008; Mitra, 2009).

2.2.2 What have we learned? – CPS-funded ongoing and completed research

Suslow (2011), University of California, Davis, Comparative assessment of field survival of *Salmonella enterica* and *Escherichia coli* O157:H7 on cilantro (*Coriandrum sativum*) in relation to sequential cutting and re-growth.

- Cilantro cultivar had no significant effect on attachment and survival of avirulent *Salmonella* or attenuated *E. coli* O157:H7 on cilantro. However, in general avirulent *Salmonella* persistence was greater than attenuated *E. coli* O157:H7 during the field production and postharvest washing and storage.
- Populations of avirulent *Salmonella* and attenuated *E. coli* O157:H7 declined after inoculation onto cilantro, to below the limit of quantitative detection, but were still detected after 12 days post inoculation by selective enrichment.
- Postharvest washing of cilantro with 50 mg/L sodium hypochlorite did not disinfect the inoculated cilantro (log 6) prior to refrigerated storage.

- Viable attenuated *E. coli* O157:H7 populations were confirmed throughout storage, including the final time point 14 days postharvest and 26 days post inoculation.
- In relation to the potential for re-growth on field cultivated cilantro, no culturable bacteria were detected 22 days after the first cut.
- Avirulent *Salmonella* and attenuated *E. coli* O157:H7 inoculated onto cilantro before cutting, could not be detected after a 22 days re-growth period. Hence commercial field contamination events may be more likely from agricultural inputs, environmental sources or practices that may contaminate cilantro close to harvest.

Suslow (2010), University of California, Davis, Risk assessment of *Salmonella* preharvest internalization in relation to irrigation water quality standards for melons and other cucurbits.

- Root uptake and systemic transfer of *Salmonella enterica* delivered through irrigation water is highly limited and systemic transfer to the edible portion of cucurbits is of low risk concern.
- Optimized irrigation strategies and hardening-off of transplants for young established vines prior to in-season cultivation results in plant-based limitations on vascular mobility of *Salmonella* in the vine.
- Publication: Lopez-Velasco et al., 2012.

Suslow (2009), University of California, Davis, Comparison of surrogate *E. coli* survival and epidemiology in the phyllosphere of diverse leafy green crops.

- Attenuated *E. coli* O157:H7 inoculated onto spring mix could be detected by enrichment eight and 14 days after inoculation.
- Survival of attenuated *E. coli* O157:H7 inoculated onto spring mix varied by variety and greater survival occurred when intermittent rainy weather occurred after inoculation versus when warm, windy weather was observed.
- Uniform contamination of spinach leaves did not result in uniform survival, which indicates that this variability may require consideration of increasing leafy green sample sizes to increase the probability of detection.
- Publication: Tomás-Callejas et al., 2011.

Teplitski (2009), University of Florida, Reducing tomato contamination with *Salmonella* through cultivar selection and maturity at harvest.

- *Salmonella* proliferated less within green tomatoes versus more mature tomatoes.
- Tomato varieties differed by 10- to 1,000-fold in their susceptibility to *Salmonella* proliferation.
- Publication: Noel et al., 2010.

Koike (2008), University of California Cooperative Extension, Examination of the survival and internalization of *E. coli* on spinach under field production environments.

- When attenuated *E. coli* O157:H7 and generic *E. coli* was delivered to spinach roots via sub-surface drip irrigation, it could not be recovered from spinach foliage; however, inoculated bacteria were readily recovered from soil adjacent to the drip lines.
- Attenuated *E. coli* O157:H7 and generic *E. coli* sprayed on soil did not survive for long periods of time under commercial growing conditions in the Salinas Valley. In general a 102 and 105 reduction was observed eight and 15 days post inoculation for attenuated *E. coli* O157:H7 and generic *E. coli*, respectively.
- Spinach plants inoculated with attenuated *E. coli* O157:H7 and generic *E. coli* at various stages of development (first true leaf, first true leaf +7 days and first true leaf +14 day) had no detectable applied bacteria after two weeks.
- Attenuated *E. coli* O157:H7 and generic *E. coli* sprayed on whole plants that were then turned under the soil survived up to 85 days.

Koike (2009), University of California Cooperative Extension, Survival of *E. coli* on soil amendments and irrigation water in leafy green field environments.

- Both generic *E. coli* and attenuated pathogenic *E. coli* persisted in soil six days following drip-irrigation inoculation, but only generic *E. coli* strains were recovered from soil sampled near the root zone 20 days post-inoculation.
- Attenuated *E. coli* O157:H7 and generic *E. coli* did not move significantly into irrigation water runoff or in the soil. Generic and attenuated O157:H7 *E. coli* strains were not detected by iso-grid membrane filtration for all runoff samplings.

Teplitski (2010), University of Florida, Irrigation regime, fruit water congestion and produce safety: parameter optimization to reduce susceptibility of tomatoes and peppers to post-harvest contamination, pathogen transfer and proliferation of *Salmonella*.

- Once contamination occurs, tomato maturity affects the growth of *Salmonella* in tomatoes. Ripe tomatoes (stage 6) are significantly more susceptible to *Salmonella* than younger tomatoes.
- Peppers were generally more susceptible to infections with *Salmonella* than tomatoes.
- Soft rot or lesions on tomatoes caused by *Xanthomonas* and/or *Pseudomonas* spp. significantly promoted growth of *Salmonella* in fruit. Additionally, tomato fruit with no soft rot or lesions but with signs of phytopathology elsewhere on the plant were not susceptible to *Salmonella*.
- Irrigation within two weeks prior to harvest did not significantly affect the ability of *Salmonella* to proliferate in the fruit.
- *Salmonella* growth is promoted by water moving into the tissue in green or pink tomatoes but not red tomatoes.
- Publication: Marvasi et al., 2013.

Rock (2011), University of Arizona, Assessment of *E. coli* as an indicator of microbial quality of irrigation waters use for produce.

- Public health risk is a function of source-water quality and irrigation-delivery system used with drip irrigation presenting the lowest risk of illness followed by furrow and sprinkler irrigation, respectively.

2.2.3 What is being funded? – CPS-funded new research

Critzer (2013), University of Tennessee, Transfer and survival of organisms to produce from surface irrigation water.

- The study purpose is to understand the transfer and survival of foodborne pathogens as well as generic *E. coli* and fecal coliforms from naturally contaminated surface water that will be applied to cantaloupes using drip and spray irrigation methods on bare-ground and plasticulture systems.

Vellidis (2013), University of Georgia, Does *Salmonella* move through the irrigation systems of mixed produce farms of the southeastern United States?

- The expected outcome of the proposed project is information on whether *Salmonella* moves through the irrigation systems of mixed produce farms of the southeastern United States and if so, does it persist on the crop until harvest. The ability of chlorine dioxide treatment to eliminate *Salmonella* from the irrigation water after it is withdrawn from the pond will be explored. Finally, the validity of measuring generic *E. coli* as an indicator for *Salmonella* serovar will be assessed.

Vellidis (2013), University of Georgia, Does splash from overhead sprinkler irrigation systems contaminate produce with *Salmonella* in the southeastern United States?

- The overall goal of this proposal is to develop knowledge that will allow vegetable producers who rely on untreated surface sources of irrigation water coupled with overhead sprinkler irrigation to effectively address recently proposed U.S. Food and Drug Administration rules.

Waite-Cusic (2013), Oregon State University, Survival of generic *E. coli* and *Salmonella* during the growth, curing, and storage of dry bulb onions produced with contaminated irrigation water.

- The primary aim of the proposed research is to quantify the survival of generic *E. coli* and *Salmonella* associated with dry bulb onions through the late stages of growth, water cessation, curing, and storage when inoculated through contaminated irrigation water at realistically high levels (5,000; 10,000 CFU/100 ml).

2.3 Managing Agricultural Water Safety

The following research questions related to managing agricultural water safety to prevent crop contamination were included in the 2009-2013 requests for proposals:

- If generic *E. coli* is detected, why was it found? Were there any structural or operational issues that may have led to contamination (e.g. broken well head, a rain event, etc.)? What mitigation steps were used by growers that had positive test results? How effective were these measures?
- What mitigation step(s) can be applied to various agricultural water sources that would diminish the risk of pathogen contamination to the crop?
- What preventative controls can be applied to agricultural water and how effective are these preventive controls at reducing, controlling or eliminating microbial hazards that may lead to adulteration of produce at the time of harvest?
- How do water-sampling protocols affect the outcome of water-testing programs?
- What are the most common methods used to measure generic *E. coli*?
- Can a sampling model be constructed so that higher risk irrigation water sources are sampled more frequently and lower risk sources less frequently, i.e. can the industry use its water testing resources more efficiently?

2.3.1 What do we know? – Studies from the scientific body of knowledge

Monitoring: Assessing and managing the microbial quality of agricultural water as a farm input is not easy. Agricultural water monitoring is often used to manage agricultural water microbial quality so as to minimize produce contamination; however, it is limited in its ability to monitor risks due to limited sampling frequency, the dynamic nature of agricultural water microbial quality and the time lag between obtaining agricultural water testing results and use of agricultural water (Maki, 2002; Wang, 1998; Winfield, 2003; Gerba 2009; Won, 2013b). Additionally, current agricultural water sampling strategies are based on an assumption that bacteria are floating as single cells in water and do not account for the potentially significant concentration of bacteria associated with suspended and bed sediments (Droppo, 2009).

Indicator Organisms: Because there are many pathogens that can potentially contaminate agricultural water and cause illness if consumed, it is not practical to test for any one pathogen to assess microbial quality. Generic *E. coli*, commonly used as an indicator organism for fecal contamination, is currently used in both recreational water quality standards and drinking water standards as one of several indicators that water is suitable for human contact and consumption. However, despite its use as an indicator of fecal contamination, studies have demonstrated that generic *E. coli* does not consistently correlate with pathogen presence (Benjamin, 2013; Duris, 2009; Edge, 2012; McEgan, 2013; Nieminski, 2010; Vereen, 2013; Wilkes, 2009; Won, 2013a). *L. monocytogenes* was found to have an inverse relationship with fecal indicators (Wilkes, 2009). Benjamin et al. (2013) did not find *Salmonella* or *E. coli* O157:H7 to be correlated with generic *E. coli* concentrations. Studies by Forslund et al. (2012) and Pahl et al. (2013) also found limited association between fecal indicator organisms in irrigation water and the populations on tomatoes. *E. coli* O157:H7 has been found to persist longer in pond water than generic *E. coli* and fecal enterococci most likely due to *E. coli* O157:H7 being less susceptible to environmental stressors like exposure to solar radiation and predation (Jenkins, 2011). *E. coli* has also demonstrated to have the ability to multiply in soil. Hence *E. coli* concentrations can be artificially elevated above that expected from fecal impacts alone and thus challenges the use of generic *E. coli* as a suitable indicator of water quality in tropical and subtropical environments (Solo-Gabriele, 2000). Regrowth of fecal indicator bacteria in river sediments may also lead to a decoupling of the association between fecal indicator bacteria and human pathogens concentrations in water and thus limit the ability of fecal indicator bacteria as indicator for human illnesses (Litton, 2010). The use of bifidobacteria species has been proposed by numerous studies; however, recent research has shown that their use as potential markers to monitor human fecal pollution in natural waters is questionable (Lamendella, 2008).

Biomarkers: Attempts at other methods to identify fecal contamination have been made, though none are as widely accepted as generic *E. coli* (Busta, 2003). Fremaux et al. (2009) used genetic markers to detect the presence of human and ruminant fecal matter, though none of the fecal markers used were able to predict the presence of *Campylobacter* spp. and Shiga toxin producing-*E. coli*. Stelma and Wymer (2012) recommend a number of techniques to increase the likelihood of detection of present pathogens including increasing monitoring frequency, and using a conservative polymerase chain reaction (PCR) method, and a suite of indicators. Litton et al. (2010) found that HF183 *Bacteriodes* may be a good candidate marker for fecal contamination for inland waters. *E. coli eae* and *stx* virulence genes were found not to correlate with generic *E. coli* concentrations when studied in an agricultural watershed (Shelton, 2011).

Agricultural Watershed and Delivery System Management: Protecting surface water from runoff from fecal sources and eliminating or avoiding environmental human pathogen reservoirs at the agricultural water intake have been identified as means to reduce the likelihood of agricultural water contamination (Pachepsky, 2011b). The benefits of vegetative areas have been explored for their ability to protect the microbial quality of agricultural water. In their study investigating runoff from 0.7, 1.7, and 2.7 meter buffer strips, Stout et al. (2005), showed that peak concentrations of fecal coliforms decreased as buffer length increased. Microbial concentrations are also affected by the amount of dry vegetation matter and land slope (Tate, 2006; Atwill, 2006). A study by the U.S. Department of Agriculture (USDA) revealed the importance of the specific soil surface hydrology characteristics (e.g., soil storage capacity and proximity to surface water table) in the vegetative buffer's ability to effectively retain manure-borne bacteria (Cardoso, 2012).

Work by Atwill et al. (2002) and Fox et al. (2011) demonstrated the influence of soil type and flow concentration, respectively, on effective retention of bacteria. Results of a study by Knox et al. (2008), demonstrated the importance of maintaining vegetative areas (e.g., wetlands) surrounding agricultural lands to benefit from contaminant filtration. Cahn et al. (2009) demonstrated that neither vegetated ditches nor the addition of polyacrylamide reduced the concentration of coliforms or generic *E. coli* in run-off from sprinkler irrigated lettuce grown in the Salinas Valley. In addition to protection from runoff – suspended sediments with which fecal indicators and generic *E. coli* are associated, aquatic biota, bank soils, and biofilms in pipe-based irrigation systems have been demonstrated to affect human pathogens in water systems used as agricultural water sources (Pachepsky, 2011a).

Treatments: Various forms of physical and chemical mechanisms have been explored as methods to remove human pathogens from agricultural water sources. Most of these methods have been studied in relation to use of reclaimed wastewater in agricultural applications or for treatment of wastewater effluent before release into the environment.

UV Light: Use of ultra-violet (UV) light, filters containing sand and/or materials with reactive components such as metal ions has been explored as a potential treatment of wastewater with some degree of success in other countries that have a more limited water supply (Khamkure, 2013; Rajala, 2003). The ability of these technologies to disinfect water varies with microbial species. For example, a study on wastewater from municipal wastewater treatment facilities in the U.S. showed that UV irradiation was effective in killing viruses, but the bacterial community, after an initial decline, was able to recover under laboratory conditions that mimicked a receiving stream (Blatchley, 2007). Wastewater treatment plant effluent containing levels of generic *E. coli* greater than 103 CFU/ml was treated by solar disinfection processes and then used to irrigate lettuce; just 26/28 lettuce samples tested positive for the presence of generic *E. coli* versus all lettuce samples irrigated with raw wastewater effluent (Bichai, 2012).

Other: Use of polyacrylamide and biopolymer preparations to protect surface and ground waters from agricultural runoff contaminants including enteric microorganisms has been demonstrated to be a cost-effective method that typically eliminates 70-90% of contaminants from irrigation water (Entry, 2002; Sojka, 2005).

2.3.2 What have we learned? – CPS-funded ongoing and completed research

Wright (2010), University of Florida, Science-based evaluation of regional risks for *Salmonella* contamination of irrigation water at mixed produce farms in the Suwannee River watershed.

- Fecal indicator bacteria (generic *E. coli* and fecal coliforms) testing was of little or no predictive value for *Salmonella*. There was some correlation with fecal coliforms that may have been from a common source.

Kniel (2009), University of Delaware, Mitigation of irrigation water using zero-valent iron (ZVI) treatment.

- ZVI is a useful addition to a sand filtration system to reduce *E. coli* O157:H7 and *Salmonella* contamination in irrigation water. Efficiency of removal was >102 over three months, and ranged from 102-104 removal.

- ZVI looks to be a relatively simple and inexpensive tool that can be added to existing sand filtration units to reduce pathogen contamination risks in agricultural water.

- Publication: Ingram et al., 2012.

2.3.3 What is being funded? – CPS-funded new research

Kniel (2013), University of Delaware, Use of zero valent iron (ZVI) in irrigation of tomatoes with manure-contaminated water at varying *E. coli* levels.

- This study will determine the efficacy of zero-valent iron for use in reducing microbial indicator populations in surface water containing bovine manure with a high organic load and known amount of generic *E. coli*.

Buchanan (2013), University of Tennessee, Evaluation of multiple disinfection methods to mitigate the risk of produce contamination by irrigation water.

- The project deliverables will include inactivation rates of STEC, generic *E. coli*, and fecal coliforms for each irrigation water disinfection system (UV light, peroxyacetic acid, chlorine dioxide) as well as information regarding transfer of these organisms to produce and the effect on produce yield and quality when utilizing indirect and direct irrigation methods and plasticulture and bare-ground cultivation techniques.

Rock (2013), University of Arizona, Evaluation of risk-based water quality sampling strategies for the fresh produce industry.

- The goals of this research are to assess and quantify factors that 1) determine variability of generic *E. coli*, pathogenic *E. coli*, and *Salmonella* occurrence in irrigation water over time, based on historic data and data collected as part of this study, at specific locations in Arizona and Southern California. This data will be used to assess the impact of risk events such as rainfall, water quality factors including temperature and turbidity, canal size, and watershed characteristics (potential sources of fecal contamination), on the occurrence of these organisms; 2) assess the impact of occurrence, duration and intensity of rainfall events on generic and pathogenic *E. coli*/*Salmonella* in irrigation waters with the goal of determining how long after a specific rainfall event the irrigation water quality will be affected; 3) Use an exposure scenario risk-based model for generic and pathogenic *E. coli*/*Salmonella* in irrigation waters to quantify the risks of infection with different sampling frequencies of irrigation waters based on environmental factors (e.g., rainfall), irrigation methods, and type of produce; and 4) develop a cell phone/computer application that can be used for guidance for frequency of sampling after high-risk events.

2.4 Tools to Assess the Risk Posed by Agricultural Water Use and Practices

To investigate tools to assess risk posed by agricultural water use and practices, the CPS has asked the following research questions in their 2009-2013 requests for proposals:

- Growers use a variety of water sources for field operations and irrigation (e.g., wells, on-farm reservoirs supplied by wells, municipal reservoirs, canals, natural ponds, water reclamation projects, lakes, rivers and springs). What are the risk factors associated with each source of water by source and use? What are the transfer coefficients for pathogens by source, concentration and use? Can these transfer coefficients be used to model pathogen risk profiles for each type of water source?
- What factors (source of water, use, and delivery method) affect the risk for contamination of harvested product by agricultural water? Can these risks be quantified?
- Can quantitative risk factors be associated with specific irrigation water sources?
- Research on the survival of foodborne pathogens is usually limited to biosafety level 2 or higher facilities. Selection of appropriate surrogate organisms is complicated by the limited scientific data that validates their use. What phenotypic traits are most important for validating the use of nonpathogenic surrogates that would mimic survival of STECs, *Salmonella* and *L. monocytogenes* on preharvest plants (greenhouse, field trials) contaminated by a water source?
- How does water quality influence the specific risks of contamination of tree fruit and survival of pathogens on fruit surfaces when water is applied preharvest (e.g., overhead irrigation, evaporative cooling, pesticide application) or post-harvest (e.g., hydro cooling)?

2.4.1 What do we know? – Studies from the scientific body of knowledge

Agricultural water contaminated with human pathogens may contaminate produce or by consumption of contaminated agricultural water cause adverse health consequences. Risk assessment characterizes and estimates potential adverse health effects associated with exposure to hazards like human pathogens. Quantitative microbial risk assessment (QMRA), can establish a relationship between the concentrations of pathogenic microorganisms in agricultural water and the probability of illness using statistical exposure and infectivity models. In 2006, the World Health Organization (WHO) narrowly addressed the safe use of wastewater in agriculture in its comprehensive assessment of risk posed by agricultural water use (WHO, 2006). Additionally there are other studies that have used QMRA to assess risk of illness from consuming produce irrigated with contaminated agricultural water. Stine et al. (2005) estimated a 1:10,000 risk of infection when consuming a crop that has been irrigated the day before harvest with water containing 2.5 CFU/100 ml *Salmonella* and 2.5 x 10-5 MPN/100 ml hepatitis A virus. Mota et al. (2009) calculated an annual risk of infection of 9 x 10-6 – 1.04 x 10-4 when consuming bell peppers grown in Mexico irrigated with water contaminated by *Cryptosporidium* at concentrations ranging from 17 – 1,633 oocysts/100 L. Seidu et al. (2013) found that current QMRA models underestimate the number of days between the harvest and irrigation of lettuce, in order to achieve an acceptable annual risk of infection by *E. coli* O157:H7. However, the current state of knowledge does not allow for accurate predictions of microbial reservoirs in agricultural water or the specific pathogens' survival patterns in specific agricultural water used for irrigation, even though factors affecting pathogen survival and patterns of population changes in time are generally known (Pachepsky, 2011b).

2.4.2 What have we learned? – CPS-funded ongoing and completed research

Pleus (2011), Intertox, Inc., Apple growing and packing microbial risk factors and their potential to lead to foodborne disease outbreaks.

- According to the QMRA, if growers apply evaporative cooling water containing 2400 MPN/100 ml generic *E. coli* to the orchard 10 to 12 hours prior to harvest, the probability of gastrointestinal illness for the elderly and adult population consuming contaminated unwaxed Washington fresh-pack apples (worst case scenario) is 1 case in 77 million and 1 case in 67 million, respectively.
- The time interval between evaporative cooling water application and harvest and washing apples with commercial cleaners during packing had the most effect on reducing apple contamination as indicated by the sensitivity analysis.
- The QMRA supports current practices such as those related to evaporative cooling and exclusion of bruised and dropped apples are protective of human health.

Rock (2011), University of Arizona, Assessment of *E. coli* as an indicator of microbial quality of irrigation waters use for produce.

- A QMRA model is only as useful as the quality of the data and the assumptions made to build it.
- According to the QMRA, if irrigation water has a generic *E. coli* density of 126 per 100 ml (or 12.6 generic *E. coli* per 10 ml), and based on Stine et al. (2005), 1.1 x 10-4 of the 126 generic *E. coli* per 100 ml (0.00008%) will be transferred to lettuce for furrow irrigation system and 8.8 x 10-7 of the 126 generic *E. coli* per 100 ml (0.0000007%) will be transferred to lettuce for subsurface drip irrigation system. That corresponds to a risk of

gastrointestinal illness of 1.1 cases in 100,000 for furrows and 9 cases in 100 million for subsurface irrigation system.

- For a sprinkler irrigation system and based on Stine et al. (2011), 0.011 of the 126 generic *E. coli* per 100 ml (0.009%) will be transferred to lettuce resulting in a risk of gastrointestinal illness of 1.1 cases in 1,000.
- Irrigation water containing 126 generic *E. coli* per 100 ml for lettuce would appear to present a minimal risk for furrow and subsurface drip. However, further research on contamination of lettuce by spray irrigation appears warranted to reduce uncertainty in the risk estimate.

2.4.3 What is being funded? – CPS-funded new research

Rock (2013), University of Arizona, Evaluation of risk-based water quality sampling strategies for the fresh produce industry.

- One of the goals of this research is to assess and quantify factors that use an exposure scenario risk-based model for generic and pathogenic *E. coli*/*Salmonella* in irrigation waters to quantify the risks of infection with different sampling frequencies of irrigation waters based on environmental factors (e.g., rainfall), irrigation methods, and type of produce.

2.5 Data gaps: What still needs to be done

In order to provide research that adds value to the fresh produce industry, it is important to identify areas that require more research.

2.5.1 Sampling strategies that provide an estimate of the true underlying distribution of bacteria in a water system

A monitoring protocol is needed that is based on the spatial and temporal variability of human pathogen prevalence, persistence, and concentrations in agricultural water. Most ranch- or farm-level water sampling is conducted at particular locations (i.e., close to the point of use) in the system to meet a food safety requirement and does not capture the bacterial distribution of a water system. Because of these focused sampling plans, it is difficult to assess the true spatial and temporal distribution of human pathogens in the water system. Sampling is typically conducted for the purpose of establishing microbial population occurrence/prevalence levels (i.e., is it present or not?). However, the spatial and temporal distribution and variability of human pathogens in production areas is not fully understood. Questions that remain unanswered include: Where does most growth occur? Are there consistent reservoirs of bacterial communities, and if so, do they correlate with pathogens? How do microbial populations vary temporally? Further exploring the spatial and temporal distribution and variability of human pathogens and indicator organisms will lead to a better understanding of resident and transient bacterial populations, and could lead to a better indicator of pathogen presence as well as technology and practices to mitigate or reduce the risk in these areas.

2.5.2 Correlation of field and water system management practices with pathogen positive/negative agricultural water samples

Many best practices and mitigation measures in use today, though based on known risk factors, have not been evaluated for positive or negative correlation with actual pathogen occurrence. A better understanding of the relationship between pathogen occurrence and field and water management practices would provide growers with practical information to improve the efficiency of their food safety programs. Although management practices may vary across production areas, this type of data collection would be streamlined by the development of a standardized methodology that could be adapted for use by specific commodity groups, a particular growing region, etc.

2.5.3 Development of low-cost, large-scale water treatment for agricultural water disinfection

Surface water sources used for agricultural water in the United States have varying microbial quality. If this water does not meet existing or forthcoming microbial standards for agricultural water, efficient, low-cost, large-scale water treatment is one of the options in maintaining current fresh produce production in these areas. Although water treatment technologies are being used for drinking water systems, these technologies as currently designed may compromise soil and crop quality and may not be practical for use in agriculture. With water quality issues on the forefront in agriculture, adapting existing technologies or designing new technologies is critical for the continuance of production in growing regions with inadequate water quality. Simple and inexpensive methods for improving the microbial quality of marginal agricultural water at the farm level need to be developed, tested, and demonstrated.

2.5.4 A better understanding of risk factors leading to survival and/or growth of pathogens on fresh produce following application of contaminated water used in chemical/nutrient sprays, irrigation, evaporative cooling.

Factors that influence the survival of human pathogens on crops are not completely understood. Some fresh produce crops repeatedly are linked to pathogen occurrence, and in some cases, to foodborne illness. Other crops have never been associated with foodborne illness and may have limited or no data on pathogen occurrence. Are there commodity-specific characteristics associated with pathogen occurrence, survival, and growth? When human pathogens are present, what environmental factors or conditions contribute to pathogen die-off, survival, growth?

2.5.5 Quantitative Microbial Risk Assessment (QMRA)

What level of pathogens in agricultural water applied to fresh produce constitutes a risk to human health? Calculating this risk estimate requires knowledge about a pathogen — e.g., prevalence, survival, growth, infective dose, etc., in addition to commodity-specific information regarding water use during cultivation and handling processes. Most fresh produce commodities lack sufficient data on pathogen occurrence throughout the production and packing process to conduct a QMRA. However, the strategic coordination of research awards from grant authorities such as CPS may assist in standardizing, collecting and assembling the necessary information to conduct a QMRA.

3.0 GLOSSARY

agricultural water – Water used in growing, harvesting, packing, and holding activities on produce where water is intended to, or is likely to, contact produce or food contact surfaces (U.S. Food and Drug Administration, 2013a).

attenuated (bacteria) – To reduce or eliminate the virulence (disease causing ability) of a pathogenic microorganism (U.S. Environmental Protection Agency, 2014).

avirulent – Not virulent; such microorganisms have lost the capacity to infect a host and cause disease (U.S. Environmental Protection Agency, 2014).

Bacteriodes – The most prominent anaerobic bacterial species in the human gut; also bile-resistant, non-spore-forming, Gram-negative rod-shaped.

bifidobacteria – Bacteria that are common inhabitants of the gastrointestinal tracts of mammals, birds, and certain cold-blooded animals (Turroni, 2011).

cell – The smallest unit of living matter capable of functioning independently (National Academy of Sciences, 2014).

coliforms – Gram-negative, non-sporeforming, rod-shaped bacteria that ferment lactose to gas. They are frequently used as indicators of process control, but exist broadly in nature (Western Growers Association, 2013).

colony forming units (CFU) – Viable microorganisms (bacteria, yeasts, and mold) capable of growth under the prescribed conditions (medium, atmosphere, time, and temperature) develop into visible colonies (colony forming units) on agar which are counted (Western Growers Association, 2013).

curli – Thin, aggregative surface fibers on the surface of many pathogenic *E. coli* and *Salmonella* strains that mediate entry into host (e.g., human, animals) cells (Gophna, 2001).

enteric – Of, relating to, or affecting the intestinal tract.

fecal coliforms – Coliform bacteria that grow at elevated temperatures and may or may not be of fecal origin. Useful to monitor effectiveness of composting processes. Also called "thermotolerant coliforms" (Western Growers Association, 2013).

fecal indicator – A microbiological organism (e.g., *E. coli*), or group of organisms (e.g., thermotolerant coliforms), that may be used in certain circumstances to indicate an association with fecal material and hence the potential for illness risk (U.S. Environmental Protection Agency, 2014).

human pathogen – A disease causing agent such as a virus, parasite, or bacteria (Western Growers Association, 2013).

inoculate – The act of introducing microorganism or suspension of microorganisms (e.g., bacteria) into a culture medium (Biology online, 2014).

microbiota – The community of various microorganisms that occur on a given substrate such as on or in plant surfaces, soil, produce, etc.

most probable number (MPN) – A statistical method used to estimate and enumerate microbes in samples, particularly when present in small numbers (Western Growers Association, 2013).

phyllosphere – The above-ground portions of a plant (Lindow, 2003).

phytopathology – The study of plant diseases (American Phytopathological Society, 2014).

potable water – Water that meets quality standards of drinking water such as described in the U.S. Environmental Protection Agency Clean Water Act and World Health Organization's Guidelines for Drinking Water Quality (National Cantaloupe Guidance, 2013).

reclaimed tail water – Water running off the lower end of a field as part of normal irrigation practices that is collected, treated, and reused (Schwankl, 2007).

reservoir (pathogen) – An organism in which a parasite that is a pathogen for some other organism lives and reproduces without harming its host (National Academy of Sciences, 2014).

serotype – Groups within a single species of microorganisms, such as bacteria or viruses, which share distinctive surface structures (Centers for Disease Control and Prevention, 2014).

species – One of the most basic units of biological classification, ranking just below the genus and comprising individuals or populations capable of interbreeding (National Academy of Sciences, 2014).

strain – A genetic variant or specific subtype of microorganism or virus (National Academy of Sciences, 2014).

wastewater effluent – The final product of all earlier treatment processes that can be discharged to a stream, river, bay, lagoon, or wetland (Davis, 2004).

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