B.C. IRRIGATION MANAGEMENT GUIDE

Chapter 4

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Prepared by

B.C. Ministry of Agriculture, Food and Fisheries
Resource Management Branch

Published by

Irrigation Industry Association of British Columbia

2005 ISSUE

LIMITATION OF LIABILITY AND USER'S RESPONSIBILITY

The primary purpose of this B.C. Irrigation Management Guide is to provide irrigation professionals and consultants with a methodology to assess the irrigation system performance and manage the system effectively.

While every effort has been made to ensure the accuracy and completeness of these materials, additional materials may be required to complete more advanced assessments. Advice of appropriate professionals and experts may assist in completing assessments that are not covered in this Guide.

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4 BASIC ENVIRONMENTAL FARM ASSESSMENT FOR IRRIGATION

The Irrigation System Assessment process incorporates soil, climate and crop requirements. The basic components of an Irrigation System Assessment covered in this chapter are:

- **4.1** Preparation of an Irrigation Farm Plan – Worksheets 1(a) and 1(b)
- **4.2** Irrigation System Audit – Worksheet 2(a) and 2(b)
- **4.3** Total Irrigated Area and Irrigation System Peak Flow Rate Check – Worksheets 3(a), 3(b), 4(a) and 4(b)
- **4.4** Annual Water Use Check – Worksheets 5(a) and 5(b)
- **4.5** Water Diversion and Conveyance Loss Checks – Worksheet 6
- **4.6** Screen Area Check – Worksheet 7
- **4.7** Irrigation Water Quality Check – Worksheet 8
- **4.8** Irrigation System Uniformity Check – Worksheet 9

Note: *Worksheets 1(a), 2(a), 3(a), 4(a) and 5(a) are for sprinkler systems while 1(b), 2(b), 3(b), 4(b) and 5(b) are for trickle systems. Worksheet 6 through 9 can be used for both systems.*

All worksheets are provided in blank versions as well, and can be found in Appendix C.

4.1 Preparation of an Irrigation Farm Plan

An Irrigation System Assessment should be based on a good site plan showing the location of farm buildings, manure and chemical storages, field shapes, and irrigation system intake. This information is important for plan development in terms of managing water quality and quantity on the farm.

Two sample farm plans are prepared for sprinkler and trickle systems as shown in Figures 4.1 and 4.2. Refer to Assessment 4.1 for obtaining a list of information from the plans to be used in irrigation worksheets throughout this chapter.

Assessment 4.1 Farm Plan

Worksheet 1(a) – Sprinkler
Worksheet 1(b) – Trickle

Information

The basic information required to complete an irrigation assessment can be determined from:

- Farm site information.
- Farm plan that includes the irrigation design information and layout. An irrigation plan may be a separate plan from the farm site plan.
- Irrigation system supplier.
- Water licences pertaining to the farm.
- Water purveyor information if water is obtained from a purveyor.
- Pump name and pump curve if a pump is used.
- B.C. Hydro bill if a pump is used.

Follow Examples 4.1 (sprinkler system in Armstrong) and 4.2 (trickle system in Kelowna) to identify the information necessary to complete the rest of the worksheets in this chapter. Some of the information will be obtained from the farm plan while others from field or equipment measurements. Not all of the information will be used in the worksheets but they will help in performing a better assessment of your farm.

GENERAL FARM INFORMATION

• CROP	ALFALFA
• IRRIGATED AREAS (acres)	170
• IRRIGATION INTERVAL (days)	15
• No. OF IRRIGATIONS PER YEAR	4

PUMP SPECIFICATIONS

• MODEL NUMBER	ST007
• HORSEPOWER (hp)	125
• IMPELLOR SIZE (in. diameter)	15-7/32
• REVOLUTIONS PER MINUTE (rpm)	3,600
• FLOW RATE (US gpm)	850

NOZZLE SPECIFICATIONS

	for 1, 2, and 3	for 4
• No. OF NOZZLES	30 EACH	17
• NOZZLE SIZE (in. x in.)	11/64 x 3/32	11/64 x 3/32
• NOZZLE OPERATING PRESSURE (psi)	50	50
• NOZZLE FLOW RATE (US gpm)	8.0	8.0

TOTAL No. OF NOZZLES	107
TOTAL FLOW RATE (US gpm)	856

LEGEND

M/L	MAINLINE
W/M	WHEELMOVE
	DIRECTION OF WHEELLINE MOVEMENT
	M/L with HYDRANTS
	LATERAL
	CHANNELIZED STREAM
	ROAD
	BUSH
	DITCH
	SOIL PIT
	BUILDINGS

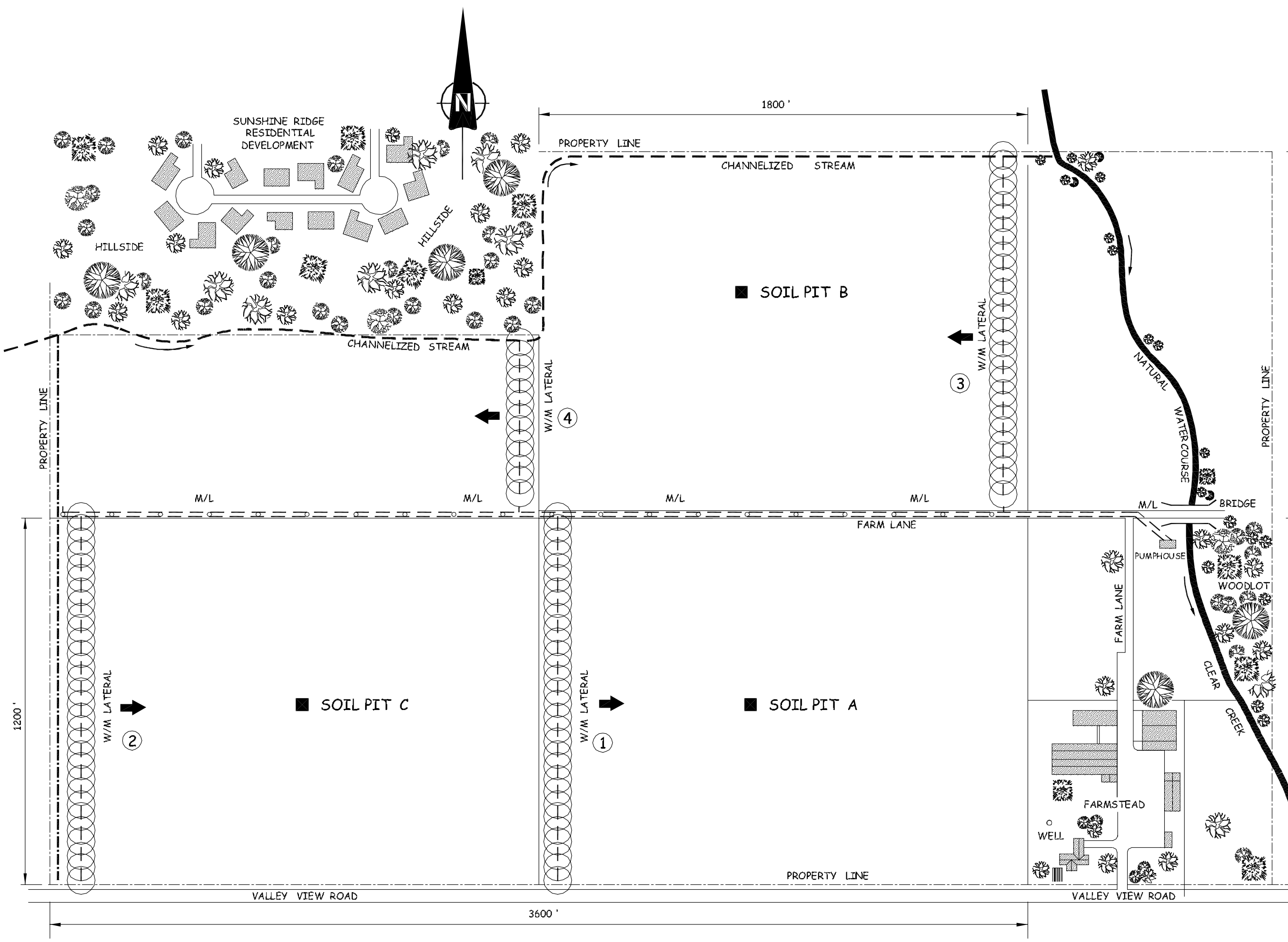


FIGURE 4.1
SAMPLE SPRINKLER IRRIGATION PLAN - WHEELMOVE SYSTEM 1

Example 4.1 Farm Plan for a Sprinkler Irrigation System in Armstrong
Worksheet 1(a) Information from Farm Plan – *SPRINKLER*

INFORMATION	Value	Box No.	Unit	Source
Worksheet 3(a) Total Irrigated Area Using System Information				
Irrigation interval per pass	*15*	1	days/pass	Farm info
Irrigation sets per day	*2*	2	sets	Farm info
Sprinkler spacing	*40*	3	ft	Farm info
Number of sprinklers	*30*	4	sprinklers	Farm info
Distance moved per set	*60*	5	ft	Farm info
Worksheet 3(b) Total Irrigated Area Using Field Dimension				
Field width	*–*	1	ft	Farm info
Field length	*–*	2	ft	Farm info
Worksheet 4(a) Irrigation System Peak Flow Rate Check				
Calculated Irrigation System Peak Flow Rate				
Peak flow rate on water licence or provided by irrigation district or water purveyor	*–*	2	US gpm	Water licence or purveyor
Peak evapotranspiration (ET) in *Armstrong*	*0.21*	–	in/d	Table 3.1
Estimated peak flow rate requirement per acre	*5.0*	3	US gpm/acre	Table 3.2 or 3.3
Actual Irrigation System Flow Rate				
Flow rate metered or provided by district	*–*	5	US gpm	Meter or district
Pump Specifications:				
Model number	*ST007*	–		Field check
Impellor size	*15 – 7/32*	–	in Dia.	Pump name plate
Revolution per minute (rpm)	*2,200*	–	rpm	
Flow rate	*850*	6	US gpm	Pump curve
Nozzle Specifications:				
Size	*11/64 x 3/32*	–	in x in	Field check
Operating pressure	*50*	–	psi	Field check
Flow rate	*8.0*	7	US gpm	Farm plan
Number of nozzles	*107*	8	nozzles	Farm plan
Worksheet 5(a) Annual Water Use Check				
Calculated Annual Water Use Requirement				
Annual water withdrawal stated on water licence	*262*	2	ac-ft	Water licence
Estimated annual crop water requirement	*12*	3	in	Table 3.4
Application efficiency of irrigation system	*72*	4	%	Table 6.1
Meter Information				
Meter reading at start of year	*–*	6	US gal	Water purveyor
Meter reading at end of year	*–*	7	US gal	

Pump Specifications

Pump horsepower	*125*	**9**	hp	Pump name plate
Energy consumption for entire year	*140,337*	**10**	KWh	Hydro bill

Refer to Worksheet 4(a) for the rest of the information regarding pump

Irrigation Specifications

Irrigation interval	*15*	**16**	days	Farm plan
Number of irrigations per year	*4*	**17**		Farm plan

Worksheet 6 Water Diversion and Conveyance Loss Checks

Conveyance channel flow rate at/near diversion	*1,000*	**1**	US gpm	Site
Overflow in channel	*50*	**2**	US gpm	Site
Number of operating days per season	*80*	**3**	days	Site
Amount of water licensed	*300*	**4**	ac-ft	Water licence
Conveyance channel flow rate at/near intake	*820*	**5**	US gpm	Site

Worksheet 7 Intake Screen Area Check

Screen mesh size	*8 x 8*	**2**	mesh	Site
Percent open area of mesh size	*60*	**3**	%	Table 4.3

For flat screen,

Number of screened surfaces	*4*	**5**	ft	Site
Length of screen	*5*	**6**	ft	Site
Width of screen	*2*	**7**	ft	Site

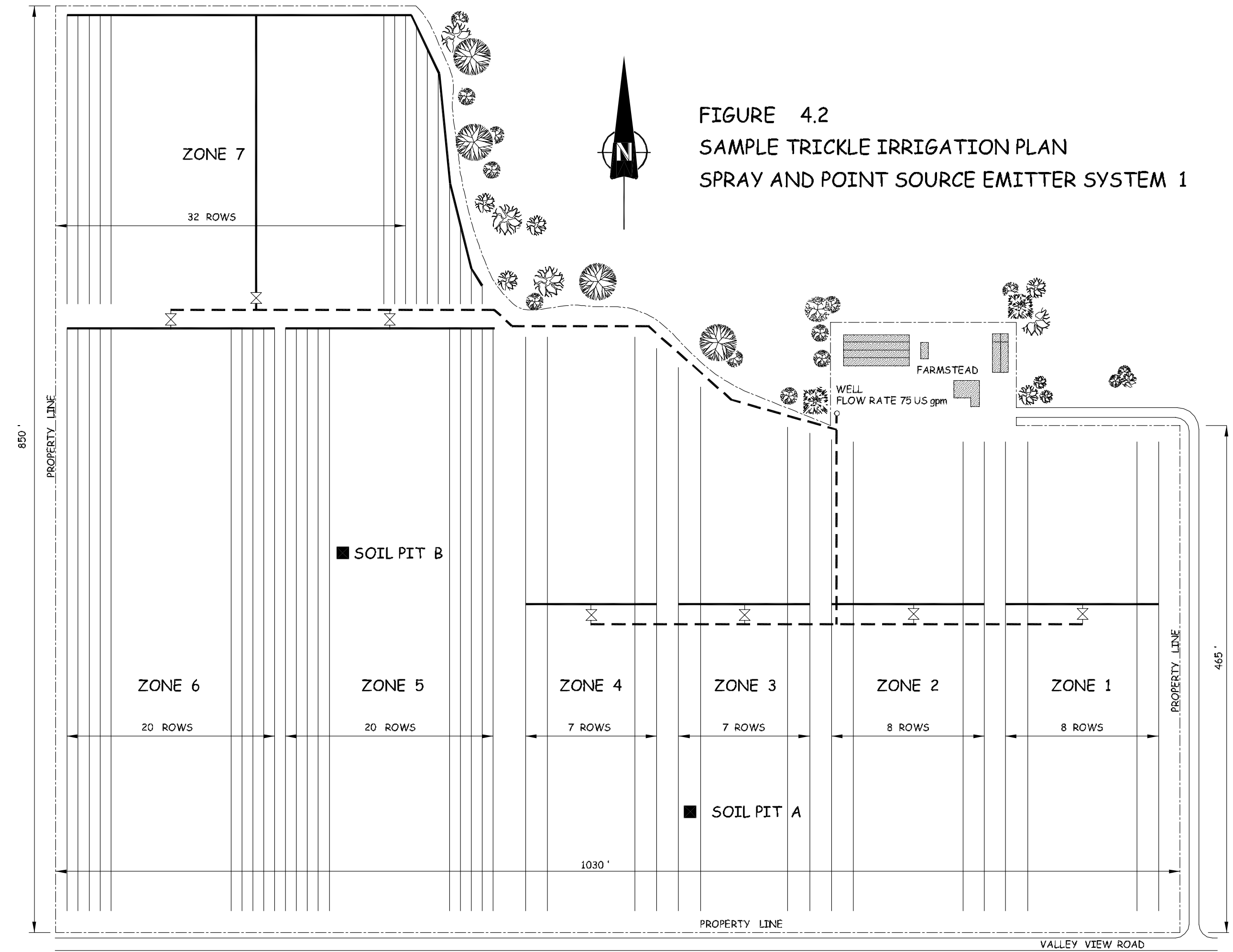
For cylindrical screen,

Diameter of screen	*–*	**9**	ft	Site
Length of screen	*–*	**10**	ft	Site

Worksheet 8 Irrigation Water Quality Check

Sodium adsorption ratio (SAR)	*6.0*	**1**		Laboratory
Electrical conductivity (EC) of water	*1.2*	**3**	dS/m	Table 4.4
E. coli count	*300*	**5**	cfu/100 ml	Laboratory
Fecal coliform count	*–*	**6**	cfu/100 ml	Laboratory

FIGURE 4.2
SAMPLE TRICKLE IRRIGATION PLAN
SPRAY AND POINT SOURCE EMITTER SYSTEM 1



GENERAL FARM INFORMATION

• IRRIGATED AREAS (acres)	14
• NUMBER OF ZONES	7
• TOTAL SYSTEM OPERATING TIME (hr/d)	23.5

EMITTER SPECIFICATIONS

	ZONES 1, 2 3 AND 4	ZONES 5, 6 AND 7
• EMITTER TYPE	SPRAY	POINT SOURCE
• EMITTER OPERATING PRESSURE (psi)	20	15
• EMITTER FLOW RATE (gph)	5.7	1.0
• EMITTER SPACING (ft)	2 @ 10	4
• EMITTERS PER PLANT	2	1.25
• ZONE OPERATING TIME PER DAY (hr/d)	2.5	4.5
• ZONE FLOW RATE (US gpm)	72	49

LEGEND

- PROPERTY LINE
- MAINLINE
- SUBMAIN
- DRIP LINES
- ROAD
- BUSH
- SOIL PIT
- BUILDINGS

ZONE INFORMATION

ZONE No.	AREA (acres)	CROP	PLANT SPACING (ft. x ft.)	No. of PLANTS per ROW	No. of PLANTS	No. of EMITTERS	FLOW RATE per EMITTER (gph/emitter)	No. of EMITTERS per TREE	TOTAL FLOW RATE (US gpm)	PRESSURE SETTING (psi)
1	2	APPLES	10 x 20	54	352	704	5.7	2	67	21.5
2	2	APPLES	10 x 20	54	352	704	5.7	2	67	21.5
3	2	APPLES	10 x 20	54	333	666	5.7	2	63	21.5
4	2	APPLES	10 x 20	54	378	756	5.7	2	72	21.5
5	2.2	GRAPES	5 x 10	107	2014	2812	1.0	1.25	47	17
6	2.2	GRAPES	5 x 10	107	2120	2960	1.0	1.25	49	17
7	1.6	GRAPES	5 x 10	54	1817	2478	1.0	1.25	41	31

Example 4.2 Farm Plan for a Trickle Irrigation System in Kelowna
Worksheet 1(b) Information from Farm Plan – *TRICKLE*

INFORMATION	Value	Box No.	Unit	Source
Worksheet 3(b) Total Irrigated Area				
Field width	*465*	1	ft	Farm info.
Field length	*1,030*	2	ft	Farm info.
Worksheet 4(b) Irrigation System Peak Flow Rate Check				
Calculated Irrigation System Peak Flow Rate				
Peak flow rate on water licence or provided by irrigation district or water purveyor	*–*	2	US gpm	Water licence or purveyor
Peak evapotranspiration (ET) in *Kelowna*	*0.24*	–	in/d	Table 3.1
Estimated peak flow rate requirement per acre	*6.0*	3	US gpm/acre	Table 3.2 or 3.3
Actual Irrigation System Flow Rate				
Flow rate metered or provided by district	*–*	5	US gpm	Meter or district
Pump Specifications:				
Model number	*–*	–		Field check
Impellor size	*–*	–		Pump name plate
Revolution per minute (rpm)	*–*	–	rpm	
Flow rate	*–*	6	US gpm	Pump curve
Emitter Specifications:				
Size	*5/8*	–	in I.D.	Field check
Operating pressure	*8*	–	psi	Field check
Flow rate (zone 4)	*5.7*	7	gph	Farm plan
Number of emitters (zone 4)	*756*	8	emitters	Farm plan
Worksheet 5(b) Annual Water Use Check				
Calculated Annual Water Use Requirement				
Water withdrawal amount on water licence	*–*	2	ac-ft	Water licence
Estimated annual crop water requirement	*12*	3	in	Table 3.4
Crop adjustment factor	*1.0*	4		Table 4.2
Application efficiency of irrigation system	*92*	5	%	Table 6.1
Meter Information				
Meter reading at start of year	*5,290,500*	6	US gal	Water purveyor
Meter reading at end of year	*12,116,400*	7	US gal	
Pump Specifications				
Pump horsepower	*–*	10	hp	Pump name plate
Energy consumption for entire year	*–*	11	KWh	Hydro bill

Refer to Worksheet 4(b) for the rest of the information regarding pump

Irrigation Specifications (based on emitter specifications)

Number of zones	7	17	zones	Farm plan
Operating hours per zone per day	2.5	18	hr/zone/d	Farm plan
Number of operating days per year	100	19	days	Farm plan

Worksheet 6 Water Diversion and Conveyance Loss Checks

Conveyance channel flow rate at/near diversion	–	1	US gpm	Site
Overflow in channel	–	2	US gpm	Site
Number of operating days per season	–	3	days	Site
Amount of water licensed	–	4	ac-ft	Water licence
Conveyance channel flow rate at/near intake	–	5	US gpm	Site

Worksheet 7 Intake Screen Area Check

Screen mesh size	–	2	mesh	Site
Percent open area of mesh size	–	3	%	Table 4.3

For flat screen,

Number of screened surfaces	–	5	ft	Site
Length of screen	–	6	ft	Site
Width of screen	–	7	ft	Site

For cylindrical screen,

Diameter of screen	–	9	ft	Site
Length of screen	–	10	ft	Site

Worksheet 8 Irrigation Water Quality Check

Adjusted sodium adsorption ratio (SAR_{adj})	–	2		Laboratory
Electrical conductivity (EC) of water	–	3	dS/m	Table 4.4
E. coli count	–	5	cfu/100 ml	Laboratory
Fecal coliform count	–	6	cfu/100 ml	Laboratory

4.2 Irrigation System Audit

An irrigation system assessment includes an evaluation of the irrigation system performance by conducting a simple audit of the irrigation system. An irrigation system audit should be done and all possible corrective actions identified taken prior to the peak flow and annual water use checks in this Guide are done. The intent is to make the system work as efficiently as possible so that the checks can identify whether additional corrective actions are required.

In some case, the audit will identify areas of improvement that may not be easy to rectify. These should be noted and revisited if the checks indicate that the system performance is not acceptable. Expertise such as a Certified Irrigation Designer (CID) may be required to correct some of the problems. The B.C. Irrigation Management Guide can be used to determine what actions may need to be taken. In some cases, a redesign of the system may be necessary.

Guidance on how to conduct a system audit for a sprinkler and a trickle/drip irrigation systems are outlined in Table 4.1 below.

Table 4.1 Irrigation System Audit Checklist

Sprinkler System Audit	Trickle/Drip System Audit
For each zone, 1. Check that all sprinklers are of the same model. Ensure that all sprinklers rotate uniformly and at least twice per minute. 2. Check that all nozzles have the same size. 3. Check that all sprinkler and lateral spacing is uniform. Check sprinkler head and lateral line spacing to make sure they do not exceed 60% of the sprinkler wetted diameter. Preferable sprinkler spacing is 50% of the wetted diameter. 4. Operating pressure at the beginning of the zone should be within the best operating range for the nozzles being used. 5. Check the operating pressure at the first and last sprinklers on the lateral with a pressure gauge. The pressure differential between the first and last sprinkler within a zone should be as minimal as possible, but should not exceed 20%.	For each zone, 1. Check that all emitters are of the same model throughout the entire zone. 2. Check that all emitter have the same size throughout the zone. 3. Check that emitter spacing is uniform throughout the zone. 4. Check the operating pressure at the beginning and end of the zone with a pressure gauge. The pressure differential between the beginning and end within a zone should be as minimal as possible, but should not exceed 10% unless pressure compensating emitters are used. 5. If possible each zone should be irrigating the same crop and the same plant size. 6. Ensure that each zone has a uniform soil type.

Example 4.3 Sprinkler Irrigation System Checklist in Armstrong (I)

Worksheet 2(a) Irrigation System Audit – *SPRINKLER*

Question: Do the system conditions meet all the minimum standards?

Checklist:

	Yes	No
1. Are all sprinklers of the same model?	✓	
2. Are all nozzles of the same size?		✓
3. Are all sprinkler and lateral spacing uniform (50 – 60% wetted diameter)?	✓	
4. Is the operating pressure in the best range?	✓	
5. Is pressure differential minimal?	✓	

Answer:

Do the system conditions meet all the minimum standards?

	Yes	- OK
✓	**No**	- See action items.

Example 4.4 Trickle Irrigation System Checklist in Kelowna (I)

Worksheet 2(b) Irrigation System Audit – *TRICKLE*

Question: Do the system conditions meet all the minimum standards?

Checklist:

For each zone,

	Yes	No
1. Are all emitters of the same model throughout the zone?	✓	
2. Are all emitters of the same size throughout the zone?	✓	
3. Are all emitter spacing uniform throughout the zone?	✓	
4. Is pressure differential minimal?	✓	
5. Is the same crop or same plant size grown in the zone?	✓	
6. Is the soil type uniform throughout the zone?	✓	

Answer:

Do the system conditions meet all the minimum standards?

✓	**Yes**	- OK
	No	- See action items.

Actions for Worksheets 2(a) and 2(b) – Irrigation System Audit

Nozzle/Emitter:

- ✓ Replace nozzles that are worn out.
- ✓ Replace nozzles if they are not of the same size as the original system design.
- ✓ Install flow control nozzles if the lateral has a significant elevation difference between the first and last sprinkler.

Spacing:

- ✓ Although difficult in some instances, consider adjusting sprinkler spacing if the spacing is too big or not uniform.
- ✓ For wheelline and hand line systems, spacing can be adjusted by offsetting lateral settings every other irrigation.

Operating Pressure:

- ✓ Where excessive pressure losses are due to elevation, flow control nozzles should be used for sprinkler systems and pressure-compensating emitters for trickle systems.
- ✓ If excessive pressure losses occur due to friction, consider using larger lateral pipe sizes in critical sections or decrease sprinkler/emitter flow to reduce pressure losses for both sprinkler and trickle systems.

Others:

- ✓ If more than one crop or more than one plant size is grown in a zone, consider dividing the zone into smaller areas.
- ✓ If there is more than one predominant soil type within a zone, consider dividing the zone into smaller areas to accommodate soil changes.

Case Study 4.1 Irrigation System Audit in Armstrong – *SPRINKLER*

Scenario:

Using Example 4.3, the farmer in Armstrong noticed that some parts of his field puddle and some spots were dry under the same irrigation schedule. All lines of the wheelline system were checked but no leaks were found. All sprinklers were checked and were found to be of the same model. The system design indicated that all nozzles should be 3/8 inch. A visual observation of the system operation found that some of the nozzles were partially or fully clogged causing lower or no flow. With a 3/8-inch drill bit, the nozzle openings were checked and 30% of the nozzles were found to have worn out causing a higher flow than what the system was designed for in the first place. Some of the nozzles had also been replaced with a different size over the years.

Action:

Purchase new nozzles and replace all nozzles on the system with the correct size as stated on the original irrigation plan.

4.3 System Peak Flow Rate Check

The irrigation system should be designed and operated so that the peak flow rate meets the climate, crop and soil requirements. Some irrigation licences may state a peak flow or withdrawal rate. A basic irrigation system assessment should check the actual irrigation system flow rate against the calculated peak flow rate required for the region.

Example 4.7 for sprinkler systems
Example 4.8 for trickle systems

If the check indicates that the system peak flow rate exceeds the calculated peak flow rate, the system operating conditions need to be reviewed. If the issue is not easily resolved, consult a Certified Irrigation Designer (CID). A list of CIDs can be obtained from the Irrigation Industry Association of B.C. (IIABC) at www.irrigationbc.com.

www.irrigationbc.com

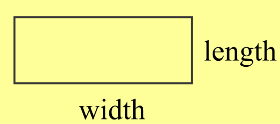
Pre-Assessment – Total Irrigated Area

The total irrigated area needs to be known before assessing the system peak flow rate. Use Equation 4.1 to determine the total irrigated area in acres. For an irregular shaped field, divide the field into rectangular and/or triangular blocks and add all field areas to obtain the total irrigated area.

Equation 4.1 Total Irrigated Area *Worksheet 3*

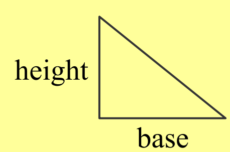
(a) For square or rectangular field,

$$Total\ Irrigated\ \ Area = \frac{Field\ Width \times Field\ Length}{43{,}560}$$



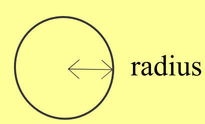
(b) For triangular field,

$$Total\ Irrigated\ \ Area = \frac{Field\ Base \times Field\ Height}{21{,}780}$$



(c) For circular field,

$$Total\ Irrigated\ \ Area = \frac{3.14 \times (Field\ Radius)^2}{43{,}560}$$



Units:

Total Irrigated Area [acres]
Field Width [ft]
Field Length [ft]
Field Base [ft]
Field Height [ft]
Field Radius [ft]

Assessment 4.2 Total Irrigated Area

Worksheet 3(a) – can be used for handmove and wheelmove systems only
Worksheet 3(b) – can be used for both sprinkler and trickle systems

The area that is irrigated by a handmove or wheelmove irrigation system can be determined by using system information as described in **Worksheet 3(a)**.

Information

The information required for determining the irrigated area is:

- sprinkler spacing
- number of sprinklers per line
- lateral line spacing or distance moved per set
- number of irrigation sets in the field

The irrigated area can also be obtained by determining the field dimensions using **Worksheet 3(b)**.

Information

For square or rectangular field,

- measure field width
- measure field length

For triangular field,

- measure field base
- measure field height

For circular field,

- measure field radius

Determine the total irrigated area

- Multiply the field width by the field length to obtain the total irrigated area (Equation 4.1).
- For irregular-shaped fields, divide it into rectangular and triangular fields, and add all field areas to obtain the total irrigated area.

Example 4.5 Total Irrigated Area in Armstrong (II)

Worksheet 3(a) Total Irrigated Area Using System Information

Question: For the wheelmove system in Figure 4.1, there are 30 sprinklers which are spaced 40 ft apart. The wheelline is moved 60 ft per set. The system runs two irrigation sets per day. The irrigation interval is 15 days per pass. What is the total irrigated area of the farm that is irrigated at one time?

Information:

Irrigation interval per pass	15	1	days/pass
Irrigation sets per day	2	2	sets
Sprinkler spacing	40	3	ft
Number of sprinklers	30	4	sprinklers
Distance moved per set	60	5	ft

Calculation:

Step 1. Calculate the number of sets per pass

No. of Sets per Pass = Irrigation Interval per pass x Irrigation Sets per Day

= 15 [1] days x 2 [2]

= 30 [6] sets

Step 2. Calculate the field width

Field Width = Sprinkler Spacing x No. of Sprinklers

= 40 [3] ft x 30 [6]

= 1,200 [7] ft

Step 3. Calculate the field length

Field Length = Distance Moved per Set x No. of Sets

= 60 [5] ft x 30 [6]

= 1,800 [8] ft

Step 4. Determine the field area

Equation 4.1(a)

$$\text{Total Irrigated Area} = \frac{\text{Field Width x Field Length}}{43{,}560}$$

$$= \frac{1{,}200\ [7]\ \text{ft x } 1{,}800\ [8]\ \text{ft}}{43{,}560}$$

= 49.6 [9] acres

Repeat the same step for irregular shaped field.

Answer:

Total Irrigated Area = Sum of All Field Areas

= (49.6 [9] + 99.2 [9] + 21.2 [9]) acres

= 170 [10] acres

Example 4.6 Total Irrigated Area in Kelowna (II)
Worksheet 3(b) Total Irrigated Area Using Field Dimension – *TRICKLE*

Question: What is the total irrigated area of the farm in Figure 4.2 that is irrigated at one time?

Information:

Field width	*465*	**1**	ft
Field length	*1,030*	**2**	ft

Calculation:

Determine the field area

Equation 4.1(a)

$$\text{Total Irrigated Area} = \frac{\text{Field Width x Field Length}}{43{,}560}$$

$$= \frac{465\ [1]\ \text{ft x } 1{,}030\ [2]\ \text{ft}}{43{,}560}$$

$= 11$ **[3]** acres

Repeat the same step for irregular shaped field

Answer:

Total Irrigated Area = **Sum of All Field Areas**

= (*11* **[3]** + *3* **[3]** + *–* **[3]**) acres

= *14* **[4]** acres

Step 1. Calculated Peak Flow Rate

Peak flow rate is determined by using Equation 4.2 and the estimated peak flow rate requirement per acre obtained from Table 3.3.

Equation 4.2 Calculated Peak Flow Rate ***Worksheets 4(a) and 4(b)***

$$Calculated\ Peak\ Flow\ Rate$$
$$= Estimated\ Peak\ Flow\ Rate\ Requirement\ per\ Acre \times Irrigated\ Area$$

where

Calculated Peak Flow Rate = peak flow rate [US gpm]
Estimated Peak Flow Rate Requirement per Acre = values from Table 3.3
Irrigated Area = entire area covered by irrigation system [acres]

Step 2. Actual System Flow Rate

The actual system flow rate can be determined using meters, water purveyor restrictions, pump information, or sprinkler nozzle output. Worksheets 4(a) and 4(b) illustrate more than one method that can be used to determine an accurate actual system flow rate.

➔ **Examples 4.7 and 4.8**

Water Meter

A water meter installed on the irrigation system can be used to determine the system flow rate by measuring the amount of water that passes through the meter during a given time period.

Water Purveyor

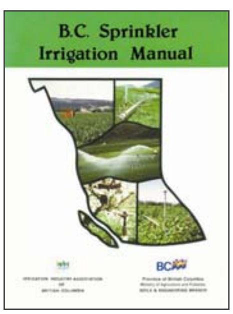
Water purveyors supplying irrigation water often allocate a flow rate to the farm based on acreage. Most often, these flow rates are regulated using flow control valves. Contact your water purveyor to find out how much water you are allowed to take if you are on a municipal system or an irrigation district.

Pump Curve

The pump curve can be used to estimate the irrigation system flow rate by using the impellor diameter, the number of revolutions per minute (rpm) of the pump, and the system operating pressure. This method is most reliable for pumps that have a steeper pump curve. Contact your pump supplier for pump curve information. It is a good idea to confirm the pump flow rate determined from a pump curve with one of the other methodologies whenever possible.

Sprinkler System Output Flow Rate

For sprinkler irrigation systems, the output flow rate can be determined by:



1. measuring the sprinkler flow rate using a pail and stop watch;
2. averaging the flow; and
3. multiplying this number by the number of sprinklers operating.

Alternately, the sprinkler flow rate can be estimated using the tables in Appendix B. The operating pressure and nozzle size must be known to use these tables. Both sprinkler and gun system flow rates can be estimated using this method. Flow rates can also be obtained from the manufacturer's product information.

B.C. Sprinkler Irrigation Manual

The flow rates of sprinkler nozzles should be checked at three locations: the beginning, the middle and the end of the lateral. It is important that all nozzles on the system are of the same type and have the same operating pressure; otherwise, this system peak flow rate check will be inaccurate. Pressure variances occur due to friction and elevation differences, and are evident if the sprinklers at the end of the lateral do not have the same flow rate as those at the start of the lateral. Sprinkler system lateral lines should be operated on the contour whenever possible. If the laterals run up or down a steep slope, each nozzle will be operating at different pressures. More nozzles along the lateral should then be checked to determine an average nozzle flow rate. Pressure losses along lateral lines should not be excessive. For more information on pressure distribution assessment, refer to Chapter 6.

Assessment of Sprinkler Systems, Chapter 6

To determine sprinkler system output flow rate using nozzle flow, refer to Equation 4.3.

Equation 4.3 Sprinkler System Output Flow Rate *Worksheet 4(a)*

$$Sprinkler\ System\ Output\ Flow\ Rate = Nozzle\ Flow\ Rate \times No.\ of\ Nozzles$$

where
Sprinkler System Output Flow Rate = flow rate at the outlet [US gpm]
Nozzle Flow Rate = value from supplier's tables [US gpm]
No. of Nozzles = number of nozzles operating at one time

Trickle System Output Flow Rate

Trickle and drip systems are much more efficient than sprinkler systems, and may therefore be able to irrigate an equivalent size field at lower flow rates. However, to conduct a system peak flow rate check, the same calculated peak flow rate obtained for the sprinkler system should be used. The reasons for this are:

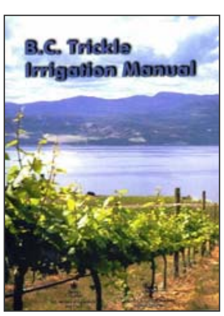
- The farm may convert to an alternate crop requiring that a different irrigation system be used. The flow rate must be capable of supplying the required flow rate.
- Water licence flow rates do not take into consideration system types when establishing flow rates. The allowable water withdrawal rates are based on sprinkler system flow rates.
- Irrigation districts establish flow rates based on the requirements of sprinkler systems.

Drip systems do not need to operate 24 hours per day if the sprinkler system peak flow rate is used. To determine trickle system output flow rate using the emitter flow rate, refer to Equation 4.4. For farms using more than one type of emitter for different crops or zones, use the zone with the highest flow rate.

Equation 4.4 Trickle System Output Flow Rate *Worksheet 4(b)*

$$Trickle\ System\ Output\ Flow\ Rate = Emitter\ Flow\ Rate \times No.\ of\ Emitters \times 0.0167$$

where
Trickle System Output Flow Rate = flow rate at outlet [US gpm]
Emitter Flow Rate = value from supplier's tables or determined on the farm [L/hr]
No. of Emitters = number of emitters operating in one zone



What if my peak flow rate is below the calculated one?

Farms that have a limited water supply may use drip systems to stretch the water supply further. In these cases, the peak flow rate may be lower than the calculated required peak flow rate, and the operating hours per day will be higher.

B.C. Trickle Irrigation Manual

Step 3. Calculated Versus Actual Irrigated System Flow Rates

To complete the system peak flow rate check, compare the calculated peak flow rate to the actual system flow rate. It is recommended that the actual flow rate does not exceed the calculated flow rate. Equation 4.5 determines the percent difference between the two values for both the system peak flow rate check and the annual water use check.

Where the peak flow rate is established by a water licence or a water purveyor, the calculated peak flow rate must not be exceeded.

Equation 4.5 Percentage Difference in Flow Rate

Worksheets 2(a) and 2(b)

$$Percent\ Difference = \frac{Actual\ Value}{Calculated\ Value} \times 100\%$$

where
Percent Difference = percent difference between actual and calculated values [%]
Actual Value = irrigation system flow rate [US gpm] or farm annual water use [in]
Calculated Value = calculated peak flow rate [US gpm] or calculated annual water requirement [in]

Assessment 4.3 System Peak Flow Rate Check

Worksheet 4(a) – Sprinkler
Worksheet 4(b) – Trickle

Information

- Irrigated area is the entire area irrigated by the irrigation system.
- Determine the peak flow rate requirement per acre (Table 3.3).

Step 1. Determine calculated peak flow rate

- Use the total irrigated area and estimated peak flow rate requirement per acre to determine the calculated peak flow rate (Equation 4.2).

Step 2. Determine actual irrigation system flow rate

- Determine the system flow rate using one of the methods outlined in this section (Equation 4.3).

Step 3. Compare the values

- Calculate the percent difference between the actual and calculated values (Equation 4.5).
- The actual irrigation system flow rate should not exceed the calculated required peak flow rate. If the peak flow has been established by a water licence or a water purveyor, the calculated peak flow rate cannot be exceeded.

Example 4.7 Sprinkler Irrigation in Armstrong (III)
Worksheet 4(a) System Peak Flow Rate Check - *SPRINKLER*

Question: The total irrigated area in this example is 170 acres. The irrigation pump curve indicates a flow rate of 850 US gpm. The irrigation system has 107 sprinklers with 11/64" x 3/32" nozzles operating at 50 psi. Does the system flow rate meet either the licensed water withdrawal rate (if stated) or the calculated peak flow rate for Armstrong?

Information:

Irrigated area (Box 10 of Worksheet 3(a))	*170*	1	acres
EITHER peak flow rate on water licence (if stated)	*–*	2	US gpm
OR peak flow rate requirement per acre (Table 3.3)	*5.0*	3	US gpm/acre

Calculation:

Step 1. Determine calculated peak flow rate.

Equation 4.2

Calculated Peak Flow Rate = Estimated Peak Flow Rate Requirement per Acre x Irrigated Area

= *5.0* [3] US gpm/acre x *170* [1] acres

= *850* [4] US gpm

Step 2. Determine actual irrigation system flow rate using one or more of the following methods:

Method 1. Water purveyor restriction or measured flow rate using a meter

Flow rate measured using a meter or provided by district *–* [5] US gpm

Method 2. Pump peak flow rate

Irrigation pump peak flow from pump curve *850* [6] US gpm

Method 3. Determine flow rate using sprinkler nozzles

Nozzle flow rate from supplier's tables *8.0* [7] US gpm

No. of nozzles *107* [8] nozzles

Equation 4.3

Sprinkler System Output Flow Rate = Nozzle Flow Rate x No. of Nozzles

= *8.0* [7] US gpm x *107* [8] nozzles

= *856* [9] US gpm

Note: *Either one of the two values (850 US gpm pump flow rate or 856 US gpm sprinkler flow rate) can be used. In this case, the higher one is used.*

Answer:

Step 3. Calculate percent difference of peak flow rate.

Equation 4.5

$$\textbf{Percent Difference} = \frac{\textbf{Irrigation System Flow Rate}}{\textbf{Calculated Peak Flow Rate}} \times 100\%$$

$$= \frac{856 \text{ [Maximum of 5, 6 or 9] US gpm}}{850 \text{ [2 or 4] US gpm}} \times 100\%$$

= *100* [10] %

Is *100* [10] % less than or equal to 100%

- ✓ **Yes** Flow rate is not exceeded
- **No** Refer to action items

Example 4.8 Trickle Irrigation in Kelowna (III)

Worksheet 4(b) System Peak Flow Rate Check - *TRICKLE*

Question: An orchard in Kelowna has a trickle irrigation system irrigating 14 acres. The largest zone with the most emitters and highest emitter flow rate is Zone 4. It has 756 emitters with emitter flow rate of 5.7 gph. Does the trickle system flow rate meet either the licensed water withdrawal rate (if stated) or the calculated peak flow rate for Kelowna?

Information:

Irrigated area (Box 10 of Worksheet 3(b))	*14*	1	acres
EITHER peak flow rate on water licence (if stated)	*–*	2	US gpm
OR peak flow rate requirement per acre (Table 3.3)	*6.0*	3	US gpm/acre

Calculation:

Step 1. Determine calculated peak flow rate.

Equation 4.2

Calculated Peak Flow Rate = **Estimated Peak Flow Rate Requirement per Acre** x **Irrigated Area**

= *6.0* [3] US gpm/acre x *14* [1] acres

= *84* [4] US gpm

Step 2. Determine actual irrigation system flow rate using one or more of the following methods:

Method 1. Water purveyor restriction or measured flow rate using a meter

Flow rate measured using a meter or provided by district *–* [5] US gpm

Method 2. Pump peak flow rate

Irrigation pump peak flow from pump curve *–* [6] US gpm

Method 3. Determine flow rate using trickle emitters

Emitter flow rate from supplier's tables	*5.7*	7	gph
Number of emitters operating at one time	*756*	8	emitters

Equation 4.4

Trickle System Output Flow Rate = **Emitter Flow Rate** x **No. of Emitters** x **0.0167**

= *5.7* [7] gph x *756* [8] emitters x 0.0167

= *72* [9] US gpm

Answer:

Step 3. Calculate percent difference of peak flow rate.

Equation 4.5

$$\textbf{Percent Difference} = \frac{\textbf{Irrigation System Flow Rate}}{\textbf{Calculated Peak Flow Rate}} \times 100\%$$

$$= \frac{72 \text{ [Maximum of 5, 6 or 9] US gpm}}{84 \text{ [2 or 4] US gpm}} \times 100\%$$

= *86* [10] %

Is *86* [10] % less than or equal to 100%

✓ **Yes** Flow rate is not exceeded

No Refer to action items

Actions for Worksheets 4(a) and 4(b) – System Peak Flow Rate Check

If the system flow rate is greater than the withdrawal rate shown on the water licence or the calculated peak flow rate for the region, reduce the peak flow rate by one of the following methods:

- ✓ Operate less sprinklers at one time.
- ✓ Change the nozzle size to reduce water requirement.
- ✓ Continue with the assessment process outlined in this publication to further assess water requirements and irrigation system performance to make adjustments where necessary.
- ✓ If the problem cannot be solved, refer to Chapter 6 for a more detailed assessment.

➔ **Assessment of Sprinkler Systems, Chapter 6**

4.4 Annual Water Use Check

This check compares the annual water use of an existing irrigation system against the calculated annual water requirement for the farm location. Use Worksheet 5(a) for sprinkler systems and 5(b) for trickle systems. If the check indicates that the annual water use exceeds the calculated annual requirement by 10%, review the system design and/or the system operation.

Farmers irrigating from wells or municipal supplies should use this check to determine if the annual amount applied is within acceptable limits.

For farmers who have a water licence, Worksheets 5(a) and 5(b) can also be used to determine if the annual licensed amount is being exceeded. Worksheet 6 provides additional information to check the actual licensed amount for situations where conveyance losses from diversions may also occur.

➔ **Water Diversion and Conveyance Loss Checks, Section 4.5**

Step 1. Calculated Annual Water Requirement

The calculated annual water requirement is determined using an estimated value of crop water requirements and irrigation system efficiency factors.

The estimated annual crop water requirement values in Table 3.4 are based on data collected over the last 40 years. It is accepted that some years are wetter or drier than others and therefore annual water use varies. Regardless, farmers using a well or other water source should adhere to the calculated annual water requirement figures determined in this chapter. Annual withdrawal amounts stated on a water licence cannot be exceeded.

Sprinkler Systems

The estimated annual crop water requirement is obtained from Table 3.4. Refer to "Annual Crop Water Requirement" in Chapter 3 for details.

➔ **Annual Crop Water Requirement, Chapter 3**

The calculated annual water requirement is determined using Equation 4.6 for a sprinkler system. An application efficiency factor must be applied to the values in Table 3.4 to determine the calculated annual water requirement for the specific irrigation system being used. Table 6.1 provides a guide to irrigation system efficiencies. For the calculations in the worksheets, use the typical application efficiency column.

Equation 4.6 gives the calculated annual water requirement for sprinkler systems taking into consideration the estimated annual crop water requirement and the system application efficiency.

Equation 4.6 Calculated Annual Water Requirement for Sprinkler Systems

Worksheet 5(a)

$$\begin{matrix} Calculated\ Sprinkler\ Annual \\ Water\ Requirement \end{matrix} = \frac{Estimated\ Annual\ Crop\ Water\ Requirement}{Application\ Efficiency} \times 100\%$$

where Calculated Sprinkler Annual Water Requirement = annual water required by sprinkler system [in]
Estimated Annual Crop Water Requirement = value from Table 2.4 [in]
Application Efficiency = typical application efficiency from Table 6.1 [%]

Trickle Systems

A trickle system irrigates less crop area than a sprinkler system because emitters apply water directly to the root zone. The efficiency of a trickle system is also much higher than that of a sprinkler system which adds to water savings. Table 4.2 provides factors that can be used to adjust the annual crop water requirement values in Table 3.4. Equation 4.7 can be used to calculate the annual water requirement for a trickle system taking into account application efficiency and the crop adjustment factor.

Equation 4.7 Calculated Annual Water Requirement for Trickle Systems

Worksheet 5(b)

$$Calculated\ Trickle\ Annual\ Water\ Requirement$$
$$= \frac{Estimated\ Annual\ Crop\ Water\ Requirement \times Crop\ Adjustment\ Factor}{Application\ Efficiency} \times 100\%$$

where Calculated Trickle Annual Water Requirement = annual water required by trickle system [in]
Estimated Annual Crop Water Requirement = value from Table 3.4 [in]
Crop adjustment factor = value for Table 4.2
Application Efficiency = typical application efficiency from Table 6.1 [%]

Table 4.2 Crop Adjustment Factors for Trickle Systems	
Crop Type	**Adjustment Factor**
Apples, Cherries – Medium Density	0.90
Apricots, Peaches, Pears – Medium Density	0.80
Tree Fruits – High Density	1.00
Grapes	0.70
Blueberries	0.80
Raspberries	0.70
Strawberries	0.75
Tomatoes	0.90
Vegetables	0.80

Step 2. Actual Annual Water Use

The annual water use by an irrigation system can be determined using meter data, pumping information or irrigation system operation information. Any of the following methods can be used to estimate the annual water use.

Water Meter

A water meter provides accurate information on annual water use. Metered systems are usually on municipal or irrigation district water supplies. Trickle irrigation systems often have flow meters to monitor system performance, but these meters do not provide annual data. The meter reading can be converted into annual water use using Equation 4.8.

Equation 4.8 Annual Water Use – Metered Water Use *Worksheets 5(a) and 5(b)*

$$Annual\ Water\ Use = \frac{Meter\ Reading\ at\ End\ of\ Year - Meter\ Reading\ at\ Start\ of\ Year}{27027 \times Irrigated\ Area}$$

where
Annual Water Use = water used in a year [in]
Meter Reading at End of Year = value from meter at end of year[US gal]
Meter Reading at Start of Year = value from meter at start of year [US gal]
Irrigated Area = entire area covered by irrigation system [acres]

Pump Operation

The operating hours of an electric irrigation pump may be determined from information on the hydro bill. The amount of energy used can be converted into operating hours and annual water use using Equation 4.9.

Equation 4.9 Annual Water Use – Pump Water Use *Worksheets 5(a) and 5(b)*

(a) $$Pump\ Power = Pump\ Horsepower \times 0.746$$

(b) $$Pump\ Operating\ Hours = \frac{KW\ Hours\ for\ Entire\ Year}{Pump\ Power}$$

(c) $$Annual\ Water\ Use = \frac{Pump\ Operating\ Hours \times Pump\ Flow\ Rate \times 0.0022}{Irrigated\ Area}$$

Units:

Pump Power	[KW]
Pump Horsepower	[hp]
Pump Operating Hours	[hr]
KW Hours for Entire Year	[KWh]
Annual Water Use	[in]
Pump Flow Rate	[US gpm]
Irrigated Area	[acres]

Note: The pump flow rate is determined in Worksheet 4(a) or 4(b). All other information is from the pump curve or an electric bill.

Irrigation System Operation

Sprinkler Systems

Annual water use for a sprinkler system can be estimated by using Equation 4.10. The system flow rate was determined in Worksheet 4(a). Irrigation interval is the number of days between the start of an irrigation at any one setting and the start of the next irrigation at the same setting. It can be determined by dividing the length of the field by the distance the lateral is moved each day. The number of irrigations per year is the number of times the irrigation system has covered the field over the irrigation season.

Equation 4.10 Annual Water Use for Sprinkler Systems *Worksheet 5(a)*

$$Annual\ Water\ Use = \frac{System\ Flow\ Rate \times Irrigation\ Interval \times No.\ of\ Irrigations\ per\ Year \times 0.053}{Irrigated\ Area}$$

where

Annual Water Use =	water used per year [in]
System Flow Rate =	system flow rate from Worksheet 4(a) [US gpm]
Irrigation Interval =	number of days between two consecutive irrigations [days]
Irrigated Area =	entire area covered by irrigation system [acres]

Trickle Systems

Trickle irrigation systems are more efficient than most other irrigation systems. They also operated more frequently than other systems, usually every day or numerous times every week. Use Equation 4.11 to obtain annual water use for trickle systems. The annual water use for each zone should be calculated separately, and then added together to determine the total annual use for the irrigation system.

Equation 4.11 Annual Water Use for Trickle Systems ***Worksheet 5(b)***

(a) For zones with the same flow rate:

$$Annual\ Water\ Use = \frac{Zone\ Flow\ Rate \times No.\,of\ \ Zones \times hr\,/\,zone\,/\,day \times No.\,of\ \ Days \times 0.0022}{Irrigated\ \ Area}$$

(b) For zones with different flow rates:

$$Annual\ Water\ Use\ \ per\ Zone = Zone\ Flow\ Rate \times hr\,/\,zone\,/\,day \times No.\,of\ \ Days$$

$$Annual\ Water\ Use = \frac{\left(\sum Annual\ Water\ Use\ \ per\ Zone\right) \times 0.0022}{Irrigated\ \ Area}$$

where
Annual Water Use = water used per year [in]
Zone Flow Rate = system flow rate from Worksheet 4(b) [US gpm] (***Note:*** *The flow rate of each zone must be the same or the annual water use must be calculated separately for each zone.)*
Irrigated Area = entire area covered by irrigation system [acres]
Annual Water Use per Zone = water used per zone per year [US gpm]

Conversion of Inches of Water to Acre-Feet

To conduct a water licence check, the annual water use calculated in inches must be converted to acre-feet in order to be compared to the licensed volumes. Equation 4.12 performs this conversion. System flow rates and estimated number of days are used in Worksheet 6. The annual water use in acre-feet should not exceed the amount stated on the water licence.

Equation 4.12 Annual Acre-Feet of Irrigation Water Use ***Worksheets 5(a) and 5(b)***

$$Annual\ Water\ Use\,[ac-ft] = \frac{Annual\ Water\ Use\,[in] \times Irrigated\ \ Area\,[acres]}{12\,[in\,/\,ft]}$$

Follow Assessment 4.4 to perform annual water use checks for sprinkler and trickle irrigation systems.

Assessment 4.4 Annual Water Use Check

Worksheet 5(a) – Sprinkler
Worksheet 5(b) – Trickle

Information

- Determine the entire area irrigated by the irrigation system
- Determine the application efficiency of the irrigation system from Table 6.1.
- For trickle systems, determine the crop adjustment factor from Table 4.2.

Step 1. Determine calculated peak flow rate

- Determine the calculated annual water requirement using Equation 4.6 for sprinkler systems or Equation 4.7 for trickle systems.

Step 2. Determine actual irrigation system flow rate

- Determine the irrigation system annual water use by using one of the methods outlined in this section.

Step 3. Compare the values

- Calculate the percent difference between the actual and calculated values (Equation 4.5).
- The actual irrigation system annual water use should not exceed the calculated required peak flow rate by 10%. If the farm obtains water from a surface water source under a water licence, the annual use allowed by the licence cannot be exceeded.

Example 4.9 Sprinkler Irrigation in Armstrong (IV)

Worksheet 5(a) Annual Water Use Check - *SPRINKLER*

Question: Continuation of Example 4.7.
The total irrigated area is 170 acres. The 125-hp irrigation pump operates at a flow rate of 850 US gpm. The electric bill indicates a hydro use of 140,337 KWh. It takes 15 days to cover the field. The field is irrigated four times during the year. Water withdrawal rate on the water licence is 262 acre-feet. Does the annual water use meet the licensed amount (if applicable) and/or the calculated annual irrigation water requirement for Armstrong?

Information:

Irrigated area (Box 10 of Worksheet 3(a))	*170*	1	acres
Water withdrawal amount on water licence (if applicable)	*262*	2	ac-ft
Estimated annual crop water requirement from Table 3.4	*12*	3	in
Application efficiency from Table 6.1	*72*	4	%

Calculation:

Step 1. Determine calculated annual water requirement.

Equation 4.6

$$\text{Calculated Annual Water Requirement} = \frac{\text{Estimated Annual Crop Water Requirement}}{\text{Application Efficiency}} \times 100\%$$

$$= \frac{12\ [3]\ \text{in}}{72\ [4]\ \%} \times 100\%$$

$$= 17\ [5]\ \text{in}$$

Step 2. Determine actual annual water use using one or more of the following methods:

Method 1. Metered water use

Meter reading at start of year	–	6	US gal
Meter reading at end of year	–	7	US gal

Equation 4.8

$$\text{Annual Water Use} = \frac{\text{Meter Reading at End of Year} - \text{Meter Reading at Start of Year}}{27027 \times \text{Irrigated Area}}$$

$$= \frac{-\ [7]\ \text{US gal} - -\ [6]\ \text{US gal}}{27027 \times -\ [1]\ \text{acres}}$$

$$= -\ [8]\ \text{in}$$

Method 2. Pump water use

Pump horsepower from supplier's table	*125*	9	hp
Energy consumption for entire year from hydro bill	*140,337*	10	KWh
Pump flow rate from pump curve	*850*	11	US gpm

Equation 4.9(a)

$$\text{Pump Power} = \text{Pump Horsepower} \times 0.746\ \text{KW/hp}$$

$$= 125\ [9]\ \text{hp} \times 0.746\ \text{KW/hp}$$

$$= 93\ [12]\ \text{KW}$$

Equation 4.9(b)

$$\text{Pump Operating Hours} = \frac{\text{KWh for Entire Year}}{\text{Pump Power}}$$

$$= \frac{140{,}337\ [10]\ \text{KWh}}{93\ [12]\ \text{KW}}$$

$$= 1{,}509\ [13]\ \text{hr}$$

Equation 4.9(c)

$$\text{Annual Water Use} = \frac{\text{Pump Operating Hours} \times \text{Pump Flow Rate} \times 0.0022}{\text{Irrigated Area}}$$

$$= \frac{\boxed{1{,}509}\ \boxed{13}\ \text{hr} \times \boxed{850}\ \boxed{11}\ \text{US gpm} \times 0.0022}{\boxed{170}\ \boxed{1}\ \text{acres}}$$

$$= \boxed{16.6}\ \boxed{14}\ \text{in}$$

Method 3. Sprinkler system annual water use

Sprinkler system output flow rate from Box 5, 6 or 9 of Worksheet 4(a)	856	15	US gpm
Irrigation interval	15	16	days
Number of irrigations per year	4	17	

Equation 4.10

Annual Water Use

$$= \frac{\text{System Flow Rate} \times \text{Irrigation Interval} \times \text{No. of Irrigations} \times 0.053}{\text{Irrigated Area}}$$

$$= \frac{\boxed{856}\ \boxed{15}\ \text{US gpm} \times \boxed{15}\ \boxed{16}\ \text{days} \times \boxed{4}\ \boxed{17} \times 0.053}{\boxed{170}\ \boxed{1}\ \text{acres}}$$

$$= \boxed{16}\ \boxed{18}\ \text{in}$$

Answer:

If there is a water licence, go to Step 3(a), and do Step 3(b) to double-check.
If groundwater is used or water is supplied by a purveyor (no water licence), follow Step 3(b) only.

Step 3(a). Calculate the annual water use and compare it with the water licence withdrawal.

Equation 4.12

$$\text{Annual Water Use [ac-ft]} = \frac{\text{Annual Water Use [in]} \times \text{Irrigated Area [acres]}}{12\ \text{[in/ft]}}$$

$$= \frac{\boxed{16.6}\ \boxed{8,\ 14\ \text{or}\ 18}\ \text{in} \times \boxed{170}\ \boxed{1}\ \text{acres}}{12\ \text{in/ft}}$$

$$= \boxed{235}\ \boxed{19}\ \text{ac-ft}$$

Is 235 | 19 ac-ft less than 262 | 2 ac-ft?

- ✓ **Yes** — Water withdrawal not exceeded
- **No** — Refer to Section 4.5

Step 3(b). Calculate percent difference of annual water use. Use the metered water use if available because it is the most accurate method.

Equation 4.5

$$\text{Percent Difference} = \frac{\text{Actual Annual Water Use}}{\text{Calculated Annual Water Requirement}} \times 100\%$$

$$= \frac{\boxed{16.6}\ \boxed{8,14\ \text{or}\ 18}\ \text{in}}{\boxed{17}\ \boxed{5}\ \text{in}} \times 100\%$$

$$= \boxed{98}\ \boxed{10}\ \%$$

Is 98 | 10 % less than 110%

- ✓ **Yes** — annual water use not exceeded by more than 10%
- **No** — Refer to action items

Example 4.10 Trickle Irrigation in Kelowna (IV)

Worksheet 5(b) Annual Water Use Check - *TRICKLE*

Question: Continuation of Example 4.8.

A high density 14-acre apple orchard in Kelowna has a trickle irrigation system with a flow rate of 58 US gpm (Box 9 in Worksheet 4(b)). The irrigation system consists of seven zones that have similar flow rates. Each zone operates for 2.5 hours per day. The system operates 100 days during the irrigation season. A meter on the system indicates readings of 4,510,900 US gallons at the start of the year, and 12,116,400 US gallons at the end of the year. The water licence states a water withdrawal rate of 20 acre-feet. Does the annual water use meet the licensed amount (if applicable) and/or the calculated annual irrigation water requirement for Kelowna?

Information:

Irrigated area (Box 10 of Worksheet 3(b)	*14*	1	acres
Water withdrawal amount on water licence (if applicable)	*20*	2	ac-ft
Estimated annual crop water requirement from Table 3.4	*19*	3	in
Crop adjustment factor from Table 4.2	*1.0*	4	
Application efficiency from Table 6.1	*92*	5	%

Calculation:

Step 1. Determine calculated annual water requirement.

Equation 4.7

$$\textbf{Calculated Annual Water Requirement} = \frac{\textbf{Estimated Annual Crop Water Requirement} \times \textbf{Crop Adjustment Factor}}{\textbf{Application Efficiency}} \times 100\%$$

$$= \frac{19\ [3]\ \text{in} \times 1.0\ [4]}{92\ [5]\ \%} \times 100\%$$

$$= \boxed{20.7\ [6]}\ \text{in}$$

Step 2. Determine actual annual water use using one or more of the following methods:

<u>Method 1. Metered water use</u>

Meter reading at start of year	*6,089,400*	7	US gal
Meter reading at end of year	*12,116,400*	8	US gal

Equation 4.8

$$\textbf{Annual Water Use} = \frac{\textbf{Meter Reading at End of Year – Meter Reading at Start of Year}}{\textbf{27027 x Irrigated Area}}$$

$$= \frac{12{,}116{,}400\ [8]\ \text{US gal} - 4{,}510{,}900\ [7]\ \text{US gal}}{27027 \times 14\ [1]\ \text{acres}}$$

$$= \boxed{20.1\ [9]}\ \text{in}$$

<u>Method 2. Pump water use</u>

Pump horsepower from supplier's table	–	10	hp
Energy consumption for entire year from hydro bill	–	11	KWh
Pump flow rate from pump curve	–	12	US gpm

Equation 4.9(a)

Pump Power = Pump Horsepower x 0.746 KW/hp

$$= –\ [10]\ \text{hp} \times 0.746\ \text{KW/hp}$$

$$= \boxed{–\ [13]}\ \text{KW}$$

Equation 4.9(b)

Pump Operating Hours = **KWh for Entire Year** / **Pump Power**

–	11	KWh
–	13	KW

= – [14] hr

Equation 4.9(c)

Annual Water Use = **Pump Operating Hours x Pump Flow Rate x 0.0022** / **Irrigated Area**

= (– [14] hr x – [12] US gpm x 0.0022) / (– [1] acres)

= – [14] in

Method 3. Sprinkler system annual water use

Trickle system output flow rate from Box 5, 6 or 9 of Worksheet 4(b)	72	16	US gpm
Number of zones	7	17	zones
Operating hours per zone per day	2.5	18	hr/zone/d
Number of operating days per year	100	19	d

Equation 4.11(a)

Annual Water Use

= **Zone Flow Rate x No. of Zones x Operating Hours x No. of Days x 0.0022** / **Irrigated Area**

= (72 [16] US gpm x 7 [17] zones x 2.5 [18] hr/zone/d x 100 [19] d x 0.0022) / (14 [1] acres)

= 19.8 [20] in

Answer:

If there is a water licence, go to Step 3(a), and do Step 3(b) to double-check.
If groundwater is used or water is supplied by a purveyor (no water licence), follow Step 3(b) only.

Step 3(a). Calculate the annual water use and compare it with the water licence withdrawal.

Equation 4.12

Annual Water Use [ac-ft] = **Annual Water Use [in] x Irrigated Area [acres]** / **12 [in/ft]**

= (20.1 [9, 15 or 20] in x 14 [1] acres) / 12 in/ft

= 23.5 [19] ac-ft

Is 23.5 [19] ac-ft less than 20 [2] ac-ft?

	Yes	Water withdrawal not exceeded
✓	No	Refer to Section 4.5

Step 3(b). Calculate percent difference of annual water use. Use the metered water use if available because it is the most accurate method.

Equation 4.5

$$\text{Percent Difference} = \frac{\text{Actual Annual Water Use}}{\text{Calculated Annual Water Requirement}} \times 100\%$$

= (*20.1* | **9, 15 or 20** in) / (*20.7* | **6** in) x 100%

= *97* | **21** %

Is *97* | **21** % less than 110%

✓ **Yes** annual water use not exceeded by more than 10%

No Refer to action items

Actions for Worksheets 5(a) and 5(b) – Annual Water Use Check

If the on-farm actual annual water use is greater than the maximum calculated annual requirement:

- ✓ Continue with the assessment and initiate irrigation scheduling techniques that can be used to reduce water consumption through the B.C. Irrigation Management Guide.
- ✓ If the problem cannot be solved, refer to Chapter 6 for a more detailed assessment.

➔ **Irrigation System Assessment, Chapter 6**

4.5 Water Diversion and Conveyance Loss Checks

A water licence is required prior to installing an intake and withdrawing water from a surface water source. The water licence is a legal document; therefore, the conditions stated on the licence must be met. Water licences usually provide the annual withdrawal amount in acre-feet.

Water Diversion

It is possible that the water licence allows more water to be diverted than the calculated annual water requirement would indicate because:

- water licences are not issued for the exact amount of water required, but are increased to the next one-half acre-foot of water
- a historic water licence may have been issued for flood irrigation, allowing for additional water due to the inefficiencies of flood and other older irrigation system types
- the water licence may include conveyance losses in the diversion channel

📖 **Understanding an Irrigation Water Licence**

Conveyance Losses

Conveyance losses occur where an irrigation diversion channel is used to deliver water from a creek, river or reservoir to the irrigation system. The water diversion check is done by estimating the amount of water diverted at the water source, and comparing it to the amount of water that reaches the irrigation system intake. The amount of water authorized to be diverted by a licence where diversion channels are used includes the conveyance losses and the calculated annual water use. The flow rate in the channel at the head of the beginning of the diversion channel should be used to check if the diverted flow is within the licensed amount, and is calculated using Equation 4.13.

Equation 4.13 Annual Water Diverted – Water Diversion Check

$$Annual\ Water\ Diverted = \frac{(Channel\ Flow\ Rate - Overflow) \times No.\ of\ Operating\ Days}{226.3}$$

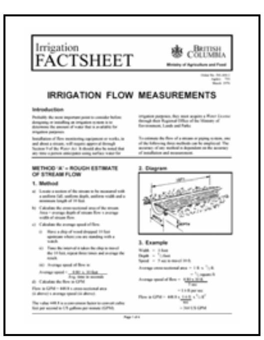
where

Annual Water Diverted = amount of water taken from stream that is not returned [ac-ft]
Channel Flow Rate = flow rate measured at the diversion point [US gpm]
Overflow = water returned to the stream [US gpm]
No. of Operating Days = number of days of operation [days]

Historic water licences often include an allowance for conveyance losses which is the water lost in the channels from the point of diversion to the farm. Losses can be very high for long ditches that traverse rocky ground. Even if the water diversion check in Assessment 4.5 is acceptable, conveyance losses should be calculated to determine if improvements to the diversion channel are warranted.

Conveyance losses can be determined by checking the diversion channel flow rates. Equation 4.14 provides a comparison of the flow rate in the diversion channel at the diversion with the flow rate close to the irrigation system intake, and thereby estimates the conveyance losses.

In some instances, the conveyance channel may have an overflow that returns water to the stream after the irrigation system intake. Since the overflow returns to the stream, it should not be counted in the conveyance loss calculation.


Irrigation FACTSHEET

IRRIGATION FLOW MEASUREMENTS

Figure 4.3 illustrates a typical diversion scenario. A water licence allows for storage of water in a reservoir behind a dam. Flow is released from the dam into the stream where at some point the water is diverted into a diversion channel and delivered to the farm. Water is lost in the diversion channel from the creek to the farm because of seepage, evaporation and transpiration by plants growing in or near the channel. In the scenario shown in Figure 4.3, the excess water that is not used by the farm returns to the river. The factsheet on Irrigation Flow Measurements contains information on how to determine channel flow rates.

Irrigation Flow Measurements

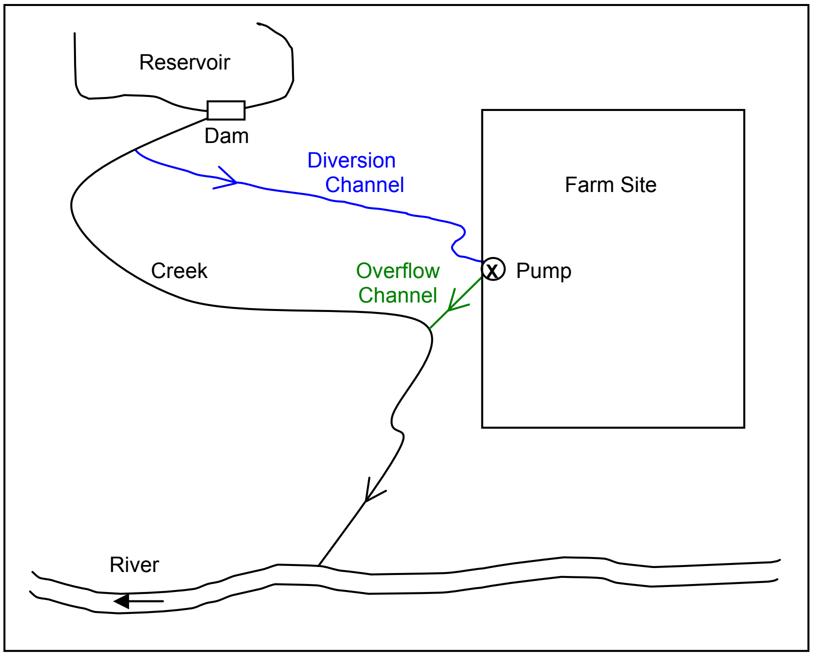


Figure 4.3 Conveyance Loss Example

Equation 4.14 Conveyance Losses *Worksheet 6*

(a) $$Reduction\ in\ Channel\ Flow\ Rate$$
$$= Flow\ Rate\ at\ Diversion - Flow\ Rate\ at\ Irrigation\ Intake$$

(b) $$Conveyance\ Losses = \frac{Reduction\ in\ Channel\ Flow\ Rate \times No.\ of\ Operating\ Days}{226.3}$$

where Operating Days = time between the diversion is opened and closed [days]

Units: Reduction in Channel Flow Rate [US gpm]
Flow Rate at Diversion [US gpm]
Flow Rate at Irrigation Intake [US gpm]
Conveyance Losses [ac-ft]

Assessment 4.5 Water Diversion and Conveyance Loss Checks

Worksheet 6

Information

- Record the annual water use allowed from the water licence.
- Determine the flow rate in the channel close to the point of diversion and at the irrigation system intake.
- Record the irrigation system flow rate as determined in Worksheet 4(a) or 4(b).
- Estimate the number of days that the diversion or irrigation system is operating each season. This was also done in Worksheet 4(a) or 4(b).

Water Diversion Check

Step 1. Determine the flow rates in the diversion channel

The flow rate in the diversion channel should be measured at the diversion point and at the irrigation intake. If it is evident that the conveyance losses are significant, additional measurements should be taken at various stages to pinpoint where the highest losses are occurring. Improvements to the channel can then be made at these locations.

- Calculate the annual amount of water diverted in acre-feet at the diversion point.
- Determine the amount of water that returns to the stream if there is an overflow channel in the place.

Step 2. Compare the diverted amount with water licensed amount

- Compare the annual amount of water diverted at the intake to the diversion channel with the amount authorized by the water licence. The amount diverted cannot exceed the licensed amount. If water is returned to the stream via an overflow, this amount can be deducted from the diverted amount. However, there may still be concerns regarding the reduced flow in the original stream from the intake location to the point where the overflow is returned to the stream.

Conveyance Loss Check

Step 3. Calculate conveyance losses

- Calculate the water losses in the conveyance channel using Equation 4.14(a) and (b).

Step 4. Assess conveyance losses

- If the conveyance loss in the diversion channel exceeds 25% of the licensed amount, then action should be considered to improve the channel or replace portions of the channel with piping.

Example 4.11 Sprinkler Irrigation System in Williams Lake
Worksheet 6 Water Diversion and Conveyance Loss Checks
(can be used for both sprinkler and trickle systems)

Question: A farmer in Williams Lake has a water licence which allows a water withdrawal of 300 acre-feet from a stream. A two-km diversion channel delivers water from the creek to the irrigation system intake. The channel flow rate at the diversion is 1,000 US gpm, and near the intake is 820 US gpm. The overflow channel flow rate is 50 US gpm. The irrigation system operates for 80 days per season. Is the amount of water diverted within the licensed water amount? Are the conveyance losses acceptable?

Information:

Conveyance channel flow rate at point of stream diversion	1,000	1	US gpm
Overflow in channel	50	2	US gpm
Number of operating days per season	80	3	days
Amount of water licensed	300	4	ac-ft
Conveyance channel flow rate near irrigation system intake	820	5	US gpm

Water Diversion Check

Calculation:

Step 1. Determine Annual Water Diverted.

Equation 4.12

$$\text{Annual Water Diverted} = \frac{(\text{Channel Flow Rate} - \text{Overflow}) \times \text{No. of Operating Days}}{226.3}$$

$$= \frac{(\boxed{1,000}\;\mathbf{1} - \boxed{50}\;\mathbf{2})\ \text{US gpm} \times \boxed{80}\;\mathbf{3}\ \text{days}}{226.3}$$

$$= \boxed{336}\;\mathbf{6}\ \text{ac-ft}$$

Answer:

Step 2. Water Diversion Check

Is 336 **6** ac-ft less than 300 **1** ac-ft?

	Yes	- OK
✓	**No**	- The licensed amount of water is exceeded. - Reduce conveyance losses

Conveyance Loss Check

Calculation:

Step 3. Calculate conveyance losses

Equation 4.14(a)

$$\text{Reduction in Channel Flow Rate} = \text{Flow Rate at Diversion} - \text{Flow Rate at Irrigation}$$

$$= \boxed{1,000}\;\mathbf{1}\ \text{US gpm} - \boxed{820}\;\mathbf{5}\ \text{US gpm}$$

$$= \boxed{180}\;\mathbf{7}\ \text{US gpm}$$

Equation 4.14(b)

$$\text{Conveyance Losses} = \frac{\text{Reduction in Channel Flow Rate} \times \text{No. of Operating Days}}{226.3}$$

$$= \frac{\boxed{180}\;\mathbf{7}\ \text{US gpm} \times \boxed{80}\;\mathbf{3}\ \text{days}}{226.3}$$

$$= \boxed{64}\;\mathbf{8}\ \text{ac-ft}$$

Answer:

Step 4. Assess Conveyance Losses

Recommended Maximum Conveyance Losses	**=**	**Water Licensed Amount x 25%**
	=	*300* [1] ac-ft x 25%
	=	*75* [9] ac-ft

Is *64* [8] ac-ft equal to or less than *75* [9] ac-ft?

- ✓ **Yes** - OK
- **No** - see action items.

Large licences can still have significant quantities of water lost due to conveyance without exceeding the 25% trigger used to take action. Conveyance losses that are significant or exceed 25 ac-ft may still require that an assessment of the conveyance channel be done. There may be portions of the channel that have very high losses. These areas should then be identified and improvements considered. See Case Study 4.2.

Actions for Worksheet 6 – Water Diversion and Conveyance Loss Checks

Water Diversion Check

If the annual water use exceeds the licensed amount:

- ✓ Check the irrigation system annual water use to ensure that use and schedule are appropriate to minimize operating days.
- ✓ Check diversion channel conveyance losses.

  ➔ **Assessment 4.5**

- ✓ Conduct a detailed irrigation system assessment and initiate irrigation scheduling techniques.

  ➔ **Irrigation System Assessment, Chapter 6**
  ➔ **Irrigation Scheduling, Chapter 7**

Conveyance Loss Check

If conveyance losses are excessive:

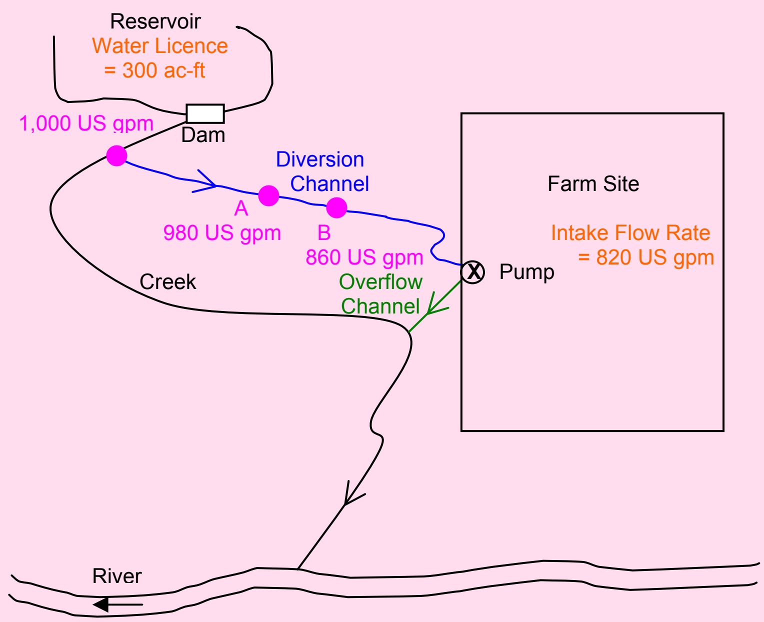
- ✓ Consider lining the channel in areas where losses are high.
- ✓ Reduce channel length by changing the irrigation intake point if possible.
- ✓ Consider conveying the water in a pipe for all or part of the channel.

Case Study 4.2 Water Diversion and Conveyance Loss Checks

Scenario:

According to Example 4.11, the channel flow rate is 1,000 US gpm at the diversion and 820 US gpm near the intake, with a 50-US gpm overflow. The water storage licence allows for 300 ac-ft of water to be collected in storage with the same amount to be diverted for irrigation. It was found that the water diverted (336 ac-ft) exceeds the water licence by 36 ac-ft over 80 operating days per season.

Although it was also found that conveyance losses (64 ac-ft) did not exceed 25% of the licensed amount (75 ac-ft), losses can be reduced. Flow rates were measured at 10 locations along the diversion channel. It was found that conveyance losses were especially high at the rocky area with Point A being 980 US gpm, and Point B 860 US gpm (see figure below). What can be done to reduce the water diverted to meet the annual water licensed amount?



Action:

The action items that can be taken to match the diverted amount with the water licence are:

- An irrigation schedule can be developed that may be able to reduce the number of irrigation days from 80 to 71. The channel diversion may be able to be shut down earlier in the fall by 9 days. This will save 40 ac-ft of water.
  ➔ **Irrigation Scheduling, Chapter 7**

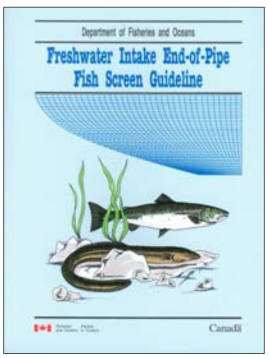
- The conveyance losses can be reduced by piping the section between Points A and B which are identified as having a high water loss. Piping this section will save 120 US gpm which is 42 ac-ft of water.

4.6 Screen Area Check

Many farmers pump water from streams, lakes or ditches. In most cases, these surface water sources also contain valuable fishery resources. The Fisheries Act requires that all pumping systems from water sources containing fish must be appropriately screened. Screening of intakes is also required to keep debris from entering the irrigation system. The screen mesh required for fish will also prevent irrigation nozzles from plugging.

Fish Screening for Water Intakes

Irrigation intakes on fish bearing streams must use a proper screen to protect fish. The following points should be considered to ensure compliance:



- Use Equation 4.15 to ensure the screen area is large enough so that the flow velocities through the screen do not exceed 0.1 ft/sec.
  ➔ **Example 4.12**
- If fish are expected to be present, use screen mesh sizes with clear openings that do not exceed 2.54 mm
- use screen mesh with open areas that are not less than 50% of the total screen area
  ➔ **Table 4.3**

📖 **Freshwater Intake End-of-Pipe Fish Screen Guideline**

Table 4.3 Screen Mesh Open Area

Mesh	Wire Diameter		Width of Opening		Open Area
	[in]	[mm]	[in]	[mm]	[%]
4 x 4*	0.063	1.600	0.188	4.78	56
6 x 6*	0.035	0.889	0.132	3.35	63
8 x 8	0.028	0.711	0.096	2.44	60
10 x 10	0.025	0.635	0.074	1.88	55
12 x 12	0.023	0.584	0.060	1.52	52

* Screen mesh size does not meet the maximum fishery opening size of 2.54 mm (0.1 inches).

It is the responsibility of the owner or operator of the irrigation system to maintain the screen intake in a good state of repair and to ensure that the screen remains in place except for renewal or repair. While the intake screen is being repaired the irrigation diversion or pump should be shut down to prevent the passage of fish into the intake. Follow Assessment 4.6 to determine if the screen area meets fishery requirements.

Equation 4.15 Suggested Screen Surface Area for Fish *Worksheet 7*

$$Suggested\ Screen\ Surface\ Area = \frac{Flow\ Rate}{0.448 \times \%\ Open\ Area}$$

where Suggested Screen Surface Area = screen surface area for proper operation [ft^2]
Flow Rate = value from Worksheet 4(a) or 4(b) [US gpm] value from
% Open Area = Table 4.3 [%]

Note: These screen areas maintain flow velocities throughout the screen at 0.1 ft/s. This screen surface area surpasses the typical requirement of Fisheries and Oceans Canada. However, by having a larger screen area, maintenance is reduced.

Equation 4.16 Actual Screen Surface Area *Worksheet 7*

(a) For box screens:

$$Total\ Surface\ Area = No.\ of\ Screened\ Surfaces \times Length \times Width$$
$$(+\ end\ area\ if\ screened)$$

(b) For cylindrical screens:

$$Total\ Cylindrical\ Surface\ Area$$
$$= 3.14 \times Diameter \times Length\ (+\ end\ area\ if\ screened)$$

where

$$End\ Area = \frac{3.14 \times (Diameter)^2}{4}$$

Note: The circular screen ends may be solid or screened.

Assessment 4.6 Screen Area Check

Worksheet 7

Information

- Determine the flow rate of the irrigation system. Use the flow rate determined in Worksheet 4(a) or 4(b).

➔ **Assessment 4.3**

- Determine the screen mesh size currently in use.

Step 1. Calculate required screen size

- Calculate the screen area that is required to keep flow velocities through the screen at an acceptable level using Equation 4.15.

Step 2. Calculate area of screen currently being used

- Calculate the screen area using Equation 4.16.

Step 3. Compare the values

- Compare the screen mesh size used with the recommended screen mesh in Table 4.3.
- The actual screen size should be at least as large as the required screen size.

Example 4.12 Sprinkler Irrigation in Armstrong (V)
Worksheet 7 Intake Screen Area Check
(can be used for both sprinkler and trickle systems)

Question: An irrigation system in Armstrong with an intake in a fish-bearing stream has a flow rate of 856 US gpm (from Worksheet 4(a)). The intake screen is a four-sided box, each side being 5 ft long and 2 ft wide using 8 x 8 mesh. The ends are solid and not screened. Does the screen surface area meet the fishery requirements for the flow rate?

Information:

Irrigation system flow rate from Worksheet 4(a) or 4(b)	856	1	US gpm
Screen mesh size used	8 x 8	2	mesh
Percent screen open area of mesh size from Table 4.3	60	3	%
Number of screened surface (for flat screens only)	4	4	
Screen length (for both flat and cylindrical screens)	5	5	ft
Screen width (for flat screens only)	2	6	ft
Screen breadth (for flat screens only if end area is screened)	–	7	ft
Screen diameter (for cylindrical screens only)	–	8	ft

Calculation:

Step 1. Calculate required screen surface area.

Equation 4.15

$$\text{Suggested Screen Surface Area} = \frac{\text{Flow Rate}}{0.448 \times \%\ \text{Open Area}}$$

$$= \frac{856\ [1]\ \text{US gpm}}{0.448 \times 60\ [3]\ \%}$$

$$= 31.8\ [9]\ \text{ft}^2$$

Step 2. Calculate actual screen area.

Equation 4.16(a) Flat Screen

Total Flat Surface Area = No. of Flat Screened Surface x Length x Width (+ end area if screened)

$= 4\ [4] \times 5\ [5]\ \text{ft} \times 2\ [6]\ \text{ft}$

$(+\ –\ [6]\ \text{ft} \times –\ [7]\ \text{ft})$

$= 40\ [10]\ \text{ft}^2$

Note: *End area is not screened.*

Equation 4.16(b) Cylindrical Screen

Total Cylindrical Surface Area = 3.14 x Diameter x Length (+ end area if screened)

$$= 3.14 \times \text{Diameter} \times \text{Length} + \left[\frac{3.14 \times (\text{Diameter})^2}{4}\right]$$

$$= 3.14 \times –\ [8]\ \text{ft} \times –\ [5]\ \text{ft} + \left[\frac{3.14 \times (–\ [8]\ \text{ft})^2}{4}\right]$$

$= –\ [11]\ \text{ft}^2$

Answer:

Step 3. Is 31.8 [9] ft² less than 40 [10 or 11] ft²?

✓ **Yes** - OK

No - Screen area is too small. Refer to action items.

Actions for Worksheet 7 – Screen Area Check

If the screen mesh or screen area is not sufficient,

- ✓ Select a screen mesh that coincides with the fishery regulation.
- ✓ Install a screen with a larger surface area as suggested in the calculation. A larger screen area will also plug less frequently and require less maintenance.
- ✓ If possible, reduce the peak irrigation system flow rate.
- ✓ If the problem cannot be solved, refer to Chapter 6 for a more detailed assessment.

➔ **Irrigation System Assessment, Chapter 6**

4.7 Irrigation Water Quality Check

The suitability of water for irrigation will depend on the concentrations of dissolved salts, pathogens and other chemicals. The most common problems associated with poor water quality and irrigation are:

- impact of water quality on soil
- whether to the crop from salts and other chemicals in the water
- crop contamination with pesticides or pathogens that may be a danger to human health

The Canadian Water Quality Guidelines provide standards for irrigation water which are also found in the B.C. Sprinkler and Trickle Irrigation Manuals.

📖 **Canadian Water Quality Guidelines**
📖 **B.C. Sprinkler Irrigation Manual, Chapter 10**
📖 **B.C. Trickle Irrigation Manual, Chapter 12**

Impacts of Irrigation Water Quality

Poor irrigation water quality can impact soil, crops and human health.

Soil

The most common problems with soil resulting from the use of poor quality irrigation water are:

- accumulation of salts in the crop's root zone
- loss of soil permeability due to excess sodium or leaching of calcium

The sodium adsorption ration (SAR) is used to relate the effect of excess sodium to that of calcium and magnesium. To determine if the SAR value is acceptable, use Table 4.4 for sprinkler systems and Table 4.5 for trickle systems.

Table 4.4 relates the SAR to the electrical conductivity (EC) of the water with respect to the impact of irrigation water quality on the ability of water to infiltrate into the soil. SAR and EC must be evaluated together. Water use should be restricted if the conditions in the table indicates a problem.

Table 4.4 Guidelines on SAR and EC for Irrigation Water Infiltration in Sprinkler Systems

SAR	Restrictions on Water Use Electrical Conductivity (EC) [dS/m]		
	Low	**Slight to Moderate**	**Severe**
< 3	> 0.7	0.7 – 0.2	< 0.2
3 – 6	> 1.2	1.2 – 0.3	< 0.3
6 – 12	> 1.9	1.9 – 0.5	< 0.5
12 – 20	> 2.9	2.9 – 1.3	< 1.3
20 – 40	> 5.0	5.0 – 2.9	< 2.9
Source: Water Quality for Agriculture FAO			

For sodic water, an adjusted SAR (SAR_{adj}) may be a better indicator in these situations. SAR_{adj}, determined by laboratory analysis of the water, provides an estimate of the calcium concentration that result in the soil solution when the soil and irrigation water are in equilibrium. The adjusted values in Table 4.5 should be used for trickle irrigation systems.

Table 4.5 Guidelines on SAR_{adj} Use of Irrigation Water for Trickle Systems

Parameter	Risk to Soil		
	Low	**Medium**	**High**
Ion Toxicity			
SAR_{adj}	< 3.0	3.0 – 9.0	> 9.0
Soil Permeability			
EC [dS/m]	> 0.5	0.2 – 0.5	< 0.2
SAR_{adj}	< 6.0	6.0 – 9.0	> 9.0
Source: B.C. Trickle Irrigation Manual			

Additional irrigation water quality guidelines for ions and heavy metals with respect to soil can be found in:

B.C. Sprinkler Irrigation Manual, Table 10.2

B.C. Trickle Irrigation Manual, Table 12.2

Crops

Crops may be sensitive to dissolved solids and other chemicals that are in the irrigation water. The guidelines for major ions and toxicity to crops can be found in B.C. Sprinkler and Trickle Irrigation Manuals.

B.C. Sprinkler Irrigation Manual, Chapter 10

B.C. Trickle Irrigation Manual, Chapter 12

Plants can be damaged and fruits discoloured or ruined by iron or other chemicals being applied by an irrigation system. There are no guidelines for insecticides as there is no evidence that insecticide residue in irrigation water resulting from registered use are harmful to crops.

If herbicides are applied correctly, no residues should remain in the irrigation water supply. Guidelines of irrigation water quality for some herbicide residues are given in the B.C. Sprinkler Irrigation Manual.

B.C. Sprinkler Irrigation Manual, Table 10.8

Human Health

Many water supplies may contain chemicals or pathogens that could pose a risk to human health. Testing for pesticides and herbicides are expensive and difficult to perform. If the active ingredient is known, specific tests may be done to determine if residues are excessive.

An extensive diversity of microorganisms may be found in aquatic environments, but identifying all species is expensive. Therefore, an indicator organism or surrogate organism that is easily detectable is often used to identify fecal contamination. The two standards used for irrigation water quality with respect to pathogens are E.Coli and fecal coliforms. The normal standard for measurement is colony forming units (cfu) per 100 ml.

Have a water sample tested for E.Coli and fecal coliforms. If the tested values are higher than those in Table 4.6, the water should be treated before use.

Follow Assessment 4.7 and Worksheet 8 in completing the water quality check.

Table 4.6 Irrigation Water Quality Guidelines

Threshold Values for Soil Protection[1]			
Salts		SAR < 3.0 and EC < 0.2 dS/m	
Boron		Concentration < 0.5 mg/L	
Chloride		Concentration < 100 mg/L	
Threshold Values for Food Safety[2]			
Pathogens[3]	**Crop Type**	**E. coli [cfu/100 ml]**	**Fecal Coliform [cfu/100 ml]**
	Crops Eaten Raw	< 77	< 200
	All Other Crops	< 1,000	< 1,000

[1] Source: The Water Encyclopedia 2nd Ed. Van der Leeden, Fritz et al. 1990 Lewis Publishers, Chelsea Michigan, U.S.A.
[2] Source: Ministry of Water, Land and Air Protection (WLAP) and Health Canada
[3] Pathogen levels for crop-washing are 0 cfu/100 mL for both E.coli and fecal coliform

Assessment 4.7 Irrigation Water Quality Check

Worksheet 8

Information

- Have a water sample analyzed at a laboratory for the parameters of concern.

Step 1. SAR Check

- Sprinkler Systems: Compare the EC and SAR values with the restrictions in Table 4.4.
- Trickle Systems: Compare the EC or SARadj value with the standards in Table 4.5.

Step 2. Pathogen Check

- Use the E.Coli or fecal coliform results from laboratory analysis and compare to the values in Table 4.6 to determine if the water is safe for its intended use.

Example 4.13 Sprinkler Irrigation in Armstrong (VI)

Worksheet 8 Irrigation Water Quality Check

(can be used for both sprinkler and trickle systems)

Question: A farm in Armstrong uses surface water for irrigation and crop washing. A laboratory analysis of a water sample from this farm gave the following results:

SAR = 6.1
Electrical conductivity (EC) = 1.2 dS/m
E.Coli = 300 cfu/100 ml

Is the water safe to use for both general irrigation?

Calculation:

Step 1. SAR or SAR_{adj} Check

SAR for sprinkler systems	*6.1*	1	
SAR_{adj} for trickle systems	*–*	2	
Electrical conductivity (EC) (Table 4.4)	*1.2*	3	dS/m
Restriction on water use from Table 4.4 or 4.5	*None*	4	

If the answer in Box 4 is slight to moderate or severe, water use from this source may need to be restricted.

Step 2. Pathogen Check

E.Coli	*300*	5	cfu/100 ml
Fecal coliform	*–*	6	cfu/100 ml

Use Table 4.6 to determine if the values are within acceptable parameters.
In this case, the E.Coli results indicate that the water is suitable for general irrigation (processed crops), but ***not*** for crops that are eaten raw since the E.Coli level is between 77 and 1,000 cfu/100 ml.

Actions for Worksheet 8 – Irrigation Water Quality Check

If any of the checks are not within parameters,

- ✓ If possible, treat the water prior to application to bring it within an acceptable range.
- ✓ Use an alternative source of water.
- ✓ If treatment and alternate sources of water cannot be found, for high pathogen counts do not irrigate crops within two weeks of harvest.
- ✓ Consider using an alternate irrigation system to reduce potential problem. For example, a drip irrigation system can be used to prevent the application of pathogens to a crop eaten raw. Refer to the B.C. Irrigation Management Guide.

B.C. Irrigation Management Guide

4.8 Irrigation System Uniformity Check

An irrigation system uniformity check will provide good information on the performance of the irrigation system. A system that has good uniformity can be operated and scheduled to perform much better than a system with poor uniformity. If an irrigation system is used for chemigation, a system uniformity check should be done as it is important that chemicals be applied as uniform as possible. The irrigation system uniformity is determined by conducting a system audit and a field uniformity tes.

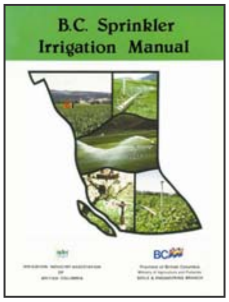
Distribution uniformity (DU) is a measurement of the evenness of water application across a field, and is expressed as a percentage. Although 100% DU is theoretically possible, it is virtually impossible to achieve with an irrigation system in the field. The goal is to obtain the best DU possible. For systems that are chemigating or applying reclaimed water, the minimum acceptable DU is 80% for sprinkler systems and 90% for trickle/drip systems.

Distribution uniformity is especially important when chemigating or irrigating with reclaimed water. Having a system that applies water uniformly over the entire field improves water management on the farm and reduces over-irrigation which may result in runoff and deep percolation. Common causes of poor distribution uniformity are:

- clogged or worn nozzles
- improper nozzle height and angle
- spacing between sprinkler heads or laterals is too far
- high application rates that exceed soil infiltration rates, resulting in runoff and deep percolation
- pressure variations between sprinklers on the system
- irrigating under high-wind conditions
- spread interference by plants
- improper installation

System Uniformity

Sprinkler System



A procedure for conducting an irrigation system distribution uniformity test is outlined in Appendix D of the B.C. Sprinkler Irrigation Manual. The catch cans should be placed between two laterals and two sprinklers on each lateral so that the cans are spaced evenly within an area irrigated by four sprinklers. The B.C. Sprinkler Irrigation Manual provides a diagram of the layout.

A minimum of four areas should be tested. Two areas between the two laterals or sets closest to the water supply and two areas between the two laterals or sets furthest from the water supply. The first area between the laterals should be done near the beginning of the lateral and the second area near the end of the laterals.

B.C. Sprinkler Irrigation Manual

Approximately 24 catch cans should be set out to obtain accurate data. The irrigation system should then be run for 30 minutes during normal operating conditions. The water collected in each can should be accurately measured.

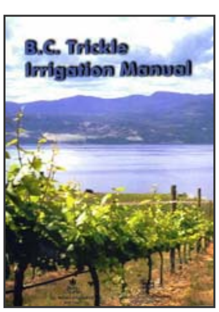
The coefficient of uniformity can be calculated using the procedures outlined in Appendix D of the Sprinkler Irrigation Manual. A simpler coefficient index is to use the lower quarter distribution uniformity (LQDU) as explained in Assessment 4.8. Equation 4.17 is used to calculate the LQDU.

Equation 4.17 Distribution Uniformity *Worksheet 10*

$$DU = \frac{LQ \times 100}{Average\ Catch\ Overall}$$

where DU = distribution uniformity [%]
LQ = average catch can reading for the lowest 25% quartile [mm]
Average Catch Overall = average of all catch can readings

Trickle/Drip System



For drip systems, the system uniformity should be checked by measuring the emitter flow rate at various locations selected throughout the zone. For line source systems with emission orifices spaced closely together, a collection pipe may be required. Section 4.5 of the B.C. Trickle Irrigation Manual provides information on how to collect the emitter flow rates and calculate a trickle/drip irrigation system distribution uniformity. Assessment 4.8 can be used to determine the lower quarter distribution uniformity of a drip irrigation system.

B.C. Trickle Irrigation Manual

Assessment 4.8 Irrigation System Uniformity Check

Worksheet 9

Equipment Requirement

- catch cans of identical size and shape – 16 catch cans are used in our example
- Measuring tape
- Graduated cylinder

Procedure

- **For sprinkler systems, lay the catch cans**:
  - between two lateral lines
  - perpendicular to the direction of the lateral movement
  - space the catch cans uniformly between the sprinklers
  - the number of catch cans used should be in multiples of four so that the lower quartile can be easily determined

  For travelling gun systems, lay the catch cans:
  - between the two travel lanes and perpendicular to the direction of gun movement
  - the cans should be spaced evenly in a pattern that covers the area between the lanes

  For center pivots systems, lay the catch cans:
  - evenly from a point 50 metres from the pivot point to within 10 metres from the wetted perimeter of the pivot
  - at least 24 cans should be used for a quarter mile pivot, 16 cans if the pivot is 200 metres or less

  For drip systems, lay the catch cans:
  - evenly throughout the zone in a manner that collects the emitter discharge
  - measure the flow from emitter at the beginning of laterals near the zone control valve and at the end of laterals furthest from the zone control valve
  - additional measurement can be taken throughout the zone in an orderly fashion so that at least 16 readings have been taken
- Operate the irrigation system for at least 30 minutes
- Record the depth of water in each of the cans with the graduated cylinder
- Rank the volumes collected from the lowest to the highest
- Multiply the total number of cans by 25% to give the number of cans in the lowest 25% quartile.
- Write the depth of the lowest 25% of the catch can readings in the Lowest Quartile column
- Take the average of all the catch can readings
- Take the average of the lowest 25% of the catch can readings
- Calculate the distribution uniformity (Equation 4.17)

Example 4.14 Irrigation System Uniformity of a Centre Pivot System

Worksheet 9 Irrigation System Uniformity Check

(can be used for both sprinkler and trickle systems)

Question: An irrigation system in Penticton has been audited and is in proper working condition. Catch cans are being used to assess the system distribution uniformity. Sixteen catch can readings were taken and ranked as shown in the table below.

Information/ Calculation:

Total number of catch cans = *16* [1]

Number of cans in the lowest 25% = *16* [1] x 25%

= *4* [2]

	Water Depth [mm]	Ranking	Lowest Quartile [mm]
	20	*14*	
	15	*4*	
	14	*1*	*14*
	21	*15*	
	16	*6*	
	17	*8*	
	19	*12*	
	14	*2*	*14*
	20	*13*	
	21	*16*	
	17	*7*	
	18	*10*	
	14	*3*	*14*
	15	*5*	*15*
	18	*9*	
	19	*11*	
Total	*278* [3]		*57* [4]

LQ = *57* [4] mm / *4* [2]

= *14.3* [5] mm

Average Catch Overall = *278* [3] mm / *16* [1]

= *17.4* [6] mm

Equation 4.17

$$\text{DU} = \frac{\text{LQ} \times 100}{\text{Average Catch Overall}}$$

= *14.3* [5] mm x 100 / *17.4* [6] mm

= *82* [7] %

Answer:

Is *82* [7] % more than or equal to 80% (for sprinkler systems) or 90% (for trickle systems)

✓ **Yes** Ok.

No See action items.

Actions for Worksheet 9 – Irrigation System Uniformity Check

If the distribution uniformity is lower than 80% for sprinkler systems or 90% for trickle systems,

- ✓ Conduct a more detailed irrigation system assessment using the B.C. Irrigation Management Guide.
- ✓ Recheck the distribution uniformity once system improvements have been made.
- ✓ Do not operate sprinkler systems under extreme windy conditions.
- ✓ If distribution uniformity is still poor, do not use the system for chemigation.
- ✓ If the problem cannot be solved, refer to Chapter 6 for a more detailed assessment.

➔ **Irrigation System Assessment, Chapter 6**