Appendix A. Qualitative Assessment of Climate Change Vulnerability of National Fish Hatcheries in the Columbia-Pacific Northwest Region: Warm Springs National Fish Hatchery

I. INITIAL QUALITATIVE ASSESSMENT, 2011

The U.S. Fish and Wildlife Service (USFWS) qualitatively assessed climate change vulnerabilities of all National Fish Hatcheries (NFHs) during calendar year 2011. These assessments were based on a MS-Excel spreadsheet template that was developed in the Headquarters Office (HQ) of the USFWS and distributed to all NFHs. Appendix A presented here summarizes the methods, results, and conclusions of those vulnerability assessments for Warm Springs NFH (Figure A1).

II. METHODS

The initial vulnerability assessment for Columbia-Pacific Northwest Region hatcheries consisted of two Excel Spreadsheets, *Spreadsheet 1* and *Spreadsheet 2* (Tables A1 and A2, respectively).

A. Spreadsheet 1

The purpose of *Spreadsheet 1* was to identify climate change stressors that are likely to occur by the year 2050 ("40 years out") and then assign a risk level for each stressor. Possible risk levels ranged from 1 ("negligible risk") to 5 ("extreme risk") and were based on the projected severity and likelihood of the stressor (Table A1).

The original Excel template for *Spreadsheet 1* was focused on the NFH and local watershed and did not account for areas where fish are released or migrate. The ability of NFHs in the Columbia-Pacific Northwest Region to meet their goals for Pacific salmon and Steelhead (*Oncorynchus* spp.) requires that a portion of released fish successfully migrate to the ocean and return back to the NFH where they can be recaptured as adults for broodstock. Consequently, the USFWS's initial climate change evaluations for NFHs in the Columbia-Pacific Northwest Region were subdivided into two categories: (a) the "NFH and local watershed", and (b) the "migration corridor". This latter category included all stream and river areas between the NFH and the ocean (Table A1).

B. Spreadsheet 2

The purpose of *Spreadsheet 2* (Table A2) was to identify and prioritize – for each NFH – management actions that could potentially be implemented to adapt or mitigate for the impacts of each climate change stressor identifed in *Spreadsheet 1* based on their relative risks. A template for this Spreadsheet was not provided by HQ. Rather, *Spreadsheet 2* was developed specifically for Columbia-Pacific Northwest Region NFHs to facilitate the recording of the requested information.

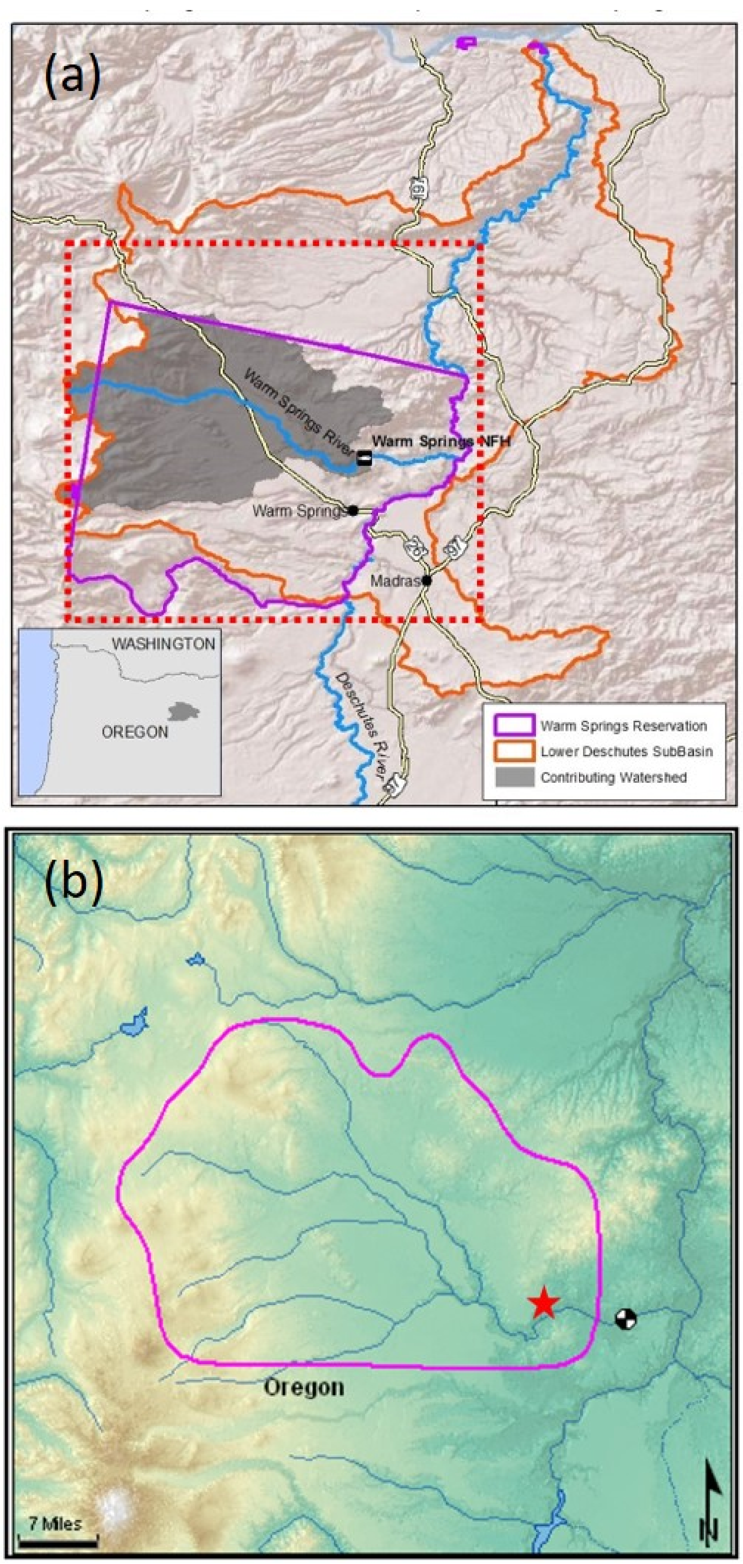

Figure A1. (a) Warm Springs River watershed in Central Oregon. The red dotted line demarcates border of part b. **(b)** Downscaled, climate projection graphs were obtained for the Warm Springs River watershed (lavender encirclement) from the Climate Impacts Group (CIG) at the University of Washington (Figure A2). The location of Warm Springs NFH is indicated by the red star. The USGS reference gaging station is shown by the black and white quartered circle (at Kahneeta, Oregon).

C. Temperature, precipitation and hydrology projections, 2020s – 2080s

Climate change projections for mean air temperature, precipitation, and several stream/hydrology parameters were obtained in the form of summary graphs from the Climate Impacts Group at the University of Washington (CIG-UW; http://www.hydro.washington.edu/2860/). The summary graphs were generated for the 2020s, 2040s, and 2080s from the outputs of 10 general circulation models (GCMs) representing downscaled projections for monthly mean air temperature and precipitation at nearly 300 specific streamflow locations and representative watersheds throughout the Pacific Northwest. Those projections are based on the A1B greenhouse-gas emissions scenario from the Fourth IPCC Report (IPCC 2007). The A1B scenario assumes some future actions will be taken to reduce the emission of carbon dioxide and other greenhouse gases relative to historic and recent trends. CIG-UW has coupled those downscaled temperature and precipitation projections to historic and future streamflow patterns within watersheds via the *Variable Infiltration Capacity* (VIC) hydrologic model (Liang et al. 1994; http://www.hydro.washington.edu/2860/new_users/).

D. Temperature, precipitation and hydrology projections for Warm Springs NFH

Hydrology projection graphs for the Warm Springs River watershed (Figure A1), the water source for Warm Springs NFH, were used to assess future temperature, precipitation, and hydrology conditions at Warm Springs NFH in the 2020s, 2040s, and 2060s relative to baseline historic conditions (Figure A2). Hatchery staff used those projection graphs to complete *Spreadsheet 1* based on their best professional judgment, experiences, and institutional knowledge (Table A1). Hatchery staff then completed *Spreadsheet 2* to propose specific adaptation and mitigation actions for each of the climate stressors identified in *Spreadsheet 1*.

E. Figure A2: Temperature, precipitation, hydrology projections

Figure A2 on the following page shows the climate-hydrology projections for the Warm Springs River basin used by staff at Warm Springs NFH to complete *Spreadsheet 1*. Figure A2 has six graphs labeled (a) through (f). Each graph shows climate and hydrology projections for three time periods: the 2020s, 2040s, and 2080s. Brief descriptions of those graphs follow.

1. **Graph (a): Combined flow** is the average monthly total runoff and surface water base flow over the entire basin expressed as an average depth (inches). This variable is a primary component of the simulated water balance, and is one of the primary determinants of raw total stream flow as measured at the mainstem gaging station (Figure A1). The blue line shows the simulated historic mean value for the years 1971 – 1999; the red line shows the ensemble average of the outputs for 10 downscaled GCMs; and the red shaded area shows the range of outputs for the 10 GCMs for each of three future time periods.
2. **Graph (b): Simulated low streamflow** at the gaging-station (Figure A1) in cubic feet per second (cfs), quantified by 7Q10 statistics. "7Q10 low flow" is the estimated minimum flow that occurs over seven consecutive days in 10% of the years (i.e., the estimated 7-day lowest flows that occur, on average, once every10 years). The blue circle shows the simulated historic mean value; red circles show the values for the 10 downscaled GCMs; the horizontal black line shows the ensemble average of the 10 downscaled GCMs; and the orange circle shows the values for the composite delta downscale method.
3. **Graph (c): Monthly average air temperature (°F)** over the entire watershed upstream from the gaging station. Colored markings (dots, lines, shading) are the same as described

for Graph (a).

4. **Graph (d): Monthly average total precipitation** (rain + snow) over the entire watershed upstream of the gaging station expressed as an average water depth (units = inches). Colored markings (dots, lines, shading) are the same as described for Graph (a).
5. **Graph (e): Simulated peak streamflow** at the gaging station for 20, 50 and 100-year peak flows (units = cfs). These graphs show simulated projected peak flows expected in 5%, 2% and 1% of the years, respectively over a 100-year period for each of three time periods. Colored markings (dots, lines, shading) are the same as described for Graph (b).
6. **Graph (f): Snow water equivalent (SWE) of projected snow pack** on first day of month averaged over the entire watershed upstream of the gaging station, expressed as an average water depth (units = inches). This variable is a primary component of the simulated water balance, and quantifies natural water storage of snowpack. Colored markings (dots, lines, shading) are the same as described for Graph (a).

Warm Springs River Basin

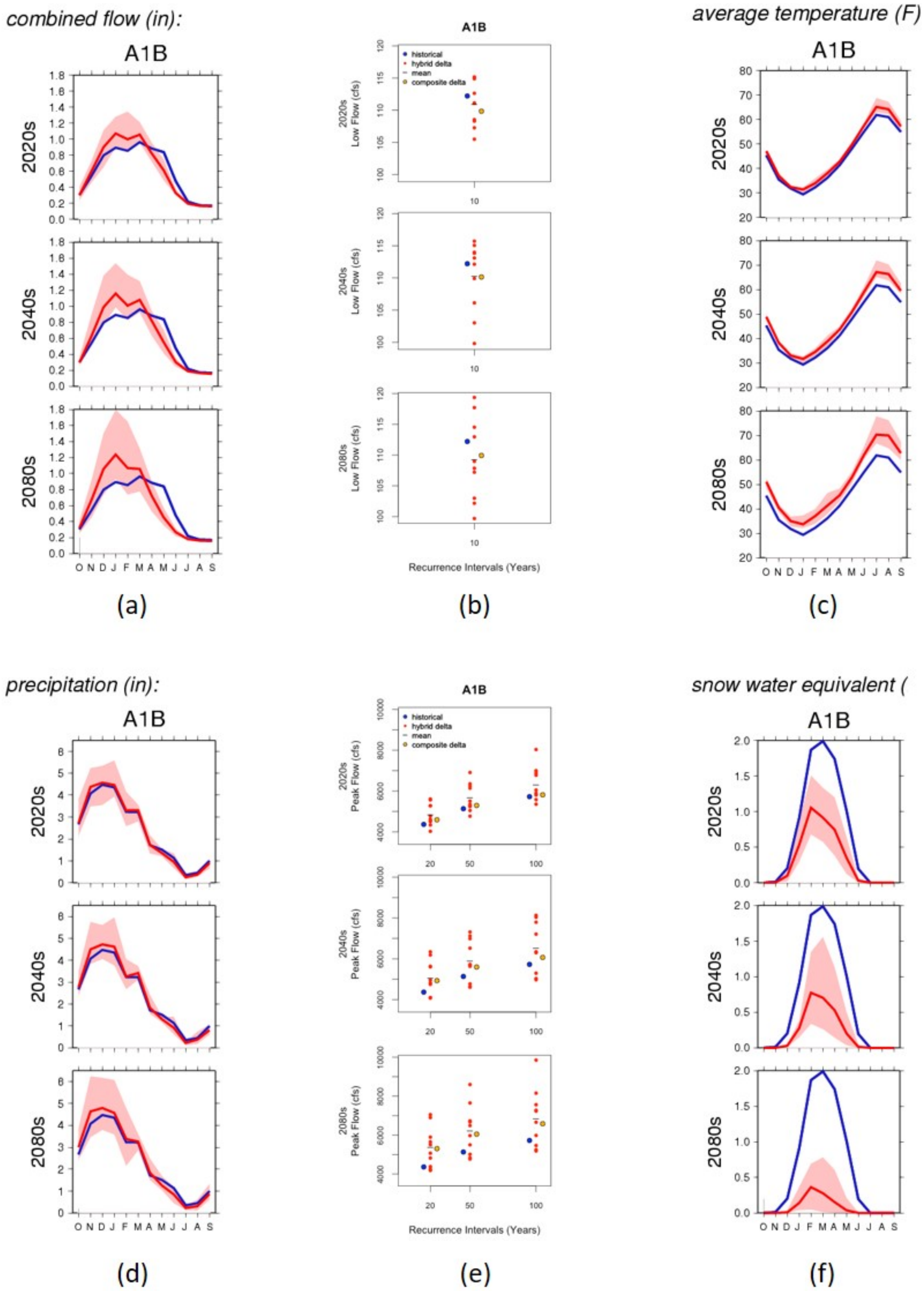

Figure A2. Climate and hydrology projections for the Warm Springs River Basin, Oregon (CIG 2011). The blue lines (a, c, d, and f) and dots (b, e) are the1971 – 1999 simulated historic means. The red line and red shading in (a), (c), (d), and (f) are the mean and range, respectively of outputs from 10 GCMs. For low and peak flows (b and e), the red dots are the projections from the 10 GCMs, the horizontal line is the average of the 10 GCM projections, and the orange dot is the composite model output.

III. RESULTS

A. Climate change risks identified by hatchery staff at Warm Springs NFH (see Table A1)

1. **Stressors with the highest identified risks**[1]
   - Increase in surface water temperature at the hatchery and local watershed
   - Increase in surface water temperature in the migration corridor
   - Increase in pathogens and disease at the hatchery
2. **Stressors with the next highest identified risks**[2]**:**
   - Decrease in water quantity in the migration corridor
   - Increase in annual average ambient temperature at the hatchery
   - Increase in number of warm days (heat waves) at the hatchery
   - Increase in summer average air temperature at the hatchery
   - Decrease in summer average precipitation at the hatchery
   - Increase in frequency and duration of extreme thunderstorms at the hatchery
   - Increase in frequency of extreme snow storms
   - Increase in prevalence of fish parasites at the hatchery
   - Increase in frequency of fire events at the hatchery
   - Skill sets: need for additional fish health specialists and biological training of fish culture staff to address increased fish health risks

B. Management actions to adapt/mitigate for extreme and high risk climate-change stressors identified in Table A1 (see Table A2)

The manager and staff at Warm Springs NFH suggested the following management actions as first and second priorities (Priority Rank 1 or 2) for potentially adapting or mitigating for the projected effects of climate change based on time/effort, dollar cost, and feasibility of implementation (Table A2):

1. **Priority 1:**
   - Use Cornell tanks with degassing tower and oxygen supplementation to compensate for decrease in dissolved oxygen and water quality
   - Increase energy (electricity) budget to address increased water chilling requirements and reduction in groundwater domestic water availability
   - Extend use of chillers during holding of broodstock and egg incubation
   - Change smolt release strategies to compensate for reduced downstream smolt survival in the migration corridor
   - Adjust broodstock collection and spawn dates in response to life history adaptations to altered hydrologies and thermal regimes
   - Modify fish culture protocols and goals to address increased fish health risks
   - Expand fire safety precautions, increase contingency planning for emergency fire events, and increase water pumping capabilities to adapt to increased fire risks during the summer
   - Enhance cyclic maintenance timing (e.g., exercising back-up electricity generators) in

[1] Risk level = 5: *extreme risk, immediate action required* (Table A1).
[2] Risk level = 4: *high risk; high priority for action* (Table A1).

response to increase in duration and intensity of thunderstorms.

- Increase use of water filters to address a decrease in water quality associated with higher river flows in winter (more precipitation falling as rain than snow)
- Modify fish production protocols and goals in response to increase risk from invasive species
- Increase fish health monitoring, diagnostics and treatment in response to increase in pathogen prevalence and fish health risks
- Increase prophylactic treatments of adult fish in broodstock holding ponds to reduce pre-spawning mortality and increase smolt-to-adult survival
- Increase number of fish health specialists for monitoring, diagnosis and treatment of disease.

2. **Priority 2:**
   - Rear juvenile fish at another hatchery and/or close hatchery to mitigate for water temperatures that could reach lethal temperatures during the summer
   - Capture adult fish for broodstock at a downstream location in the Warm Springs and Deschutes River systems and transport to the hatchery to adapt to anticipated decrease in the number of adult fish returning to the hatchery
   - Rear alternative species to mitigate for thermal migration barriers in the mainstem Columbia River during the late spring and summer.
   - Increase budget for pharmaceuticals to adapt to increased likelihood of disease outbreaks
   - Do not spawn adult fish during heat waves in summer
   - Modify work schedules of hatchery staff during heat waves
   - Release smolts at earlier dates as an adaptation measure in response to increased growth rates and earlier peak flows of the Warm Springs River due to warmer temperatures and earlier snow melt
   - Reduce rearing densities and number of fish reared as an adaptation measure for increased fish health risks
   - Increase biological training of fish culture staff in response to increased workload and challenges associated with increased physiological stress and disease risks of cultured fish.

IV. DISCUSSION AND CONCLUSIONS

A primary concern at Warm Springs NFH, based on this initial qualitative assessment in 2011 of climate change vulnerabilities, was the projected increase in surface water temperatures, both at the hatchery and in the migration corridor of the Columbia River. An increase in pathogen prevalence and disease at the hatchery, due to higher water temperatures, was also considered the highest risk due to climate change. Disease issues and concerns related to high water temperatures have become increasing problems at Warm Springs NFH since 2015 (see main report).

A common concern at all NFHs in the Columbia-Pacific Northwest Region was the effects of climate change stressors on disease and increased prevalence of pathogenic organisms, both at the hatcheries and in the migration corridors. In general, disease risks for Pacific salmon and Steelhead increase with increases in water temperature, fish density indexes and water flow indexes. Climate models project increased air temperatures and decreased surface water quantities during the summer months throughout the Pacific Northwest, due in large part to more precipitation falling as rain and less as snow (i.e., higher snow level elevations) during the winter. One overall effect of these projected changes are region-wide increases in surface water temperatures during the summer months.

Overall, the manager and staff at Warm Springs NFH used their expert opinions and professional experiences to conclude that some major management and facility adaptations would most likely be necessary to adapt and/or mitigate for the projected effects of climate change. Facility adaptations include (a) increased use of water chillers for holding broodstock and incubating eggs, (b) oxygenation of culture water, and (c) an increase in the electrical power budget. Management adaptations include (a) modification of smolt-release strategies and (b) increase in fish health monitoring and prophylactic treatments to reduce disease risks. Some extreme measures, identified as 2nd priority adaptations, include the rearing of juvenile fish at another facility or rearing a species other than Spring Chinook Salmon (*Oncorhynchus tshawytscha*) at Warm Springs NFH.

V. LITERATURE CITED

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007, Fourth Assessment Report of the IPCC. Available at: https://www.ipcc.ch/report/ar4/syr/.

Liang, X., D. P. Lettenmaier, E. F. Wood, and S. J. Burges. 1994. A simple hydrologically based model of land-surface water and energy fluxes for general-circulation models. Journal of Geophysical Research 99(D7):14,415-14,428.

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VI. SPREADSHEET 1 INSTRUCTIONS (see Table A1)

The following steps were used to complete Spreadsheet 1 of the initial climate change vulnerability assessments of National Fish Hatcheries in the Columbia-Pacific Northwest Region. The completed Spreadsheet for Warm Springs NFH is presented as Table A1.

1. **Step 1: Stressors. Identify climate change stressors (columns 1 and 2).** The climate and hydrology projection graphs (Figure A2) were used to identify climate change stressors for Warm Springs NFH: 0 = not likely to be a stressor; 1= likely to be a stressor.

2. **Step 2: Severity. Determine the severity of each stressor on NFH operations and programs (column 3).** The following table was used to classify the severity of each stressor on a scale of 1 to 5:

Designation	Impact	Examples
5	Catastrophic	Permanent loss of facility function, loss of all aquatic species, safety concerns
4	Major	Long term loss of function (> six months), loss of all or most of aquatic species
3	Moderate	Disruption and alteration of normal operations related to fish culture for up to six months, loss of aquatic species due to poor water quality or quantity
2	Minor	Disruption of normal operations for a week, no loss of organisms
1	Insignificant	Short-term inconvenience

3. **Step 3: Likelihood. Determine the likelihood that each stressor will occur (column 4).** The following table was used to classify the likelihood of each stressor on a scale of 1 to 5.

Designation	Percent (%) Likelihood	Description of Likelihood Level
5	>90%	Very likely, almost certain, is expected to happen
4	66 – 90%	Likely, will probably happen
3	33 – 66%	Possible, might occur, 50/50 chance of occurring
2	10 – 33%	Unlikely, but possible
1	<10%	Very or highly unlikely, but conceivable

4. **Step 4: Risk. Determine the risk level of each stressor to NFH operations and programs (column 5).** The following table was used to assign a risk level for each stressor as a function of its severity and likelihood. By definition, risk is the product of severity of impact (Step 2) and the probability of the stressor occurring (Step 3).

Likelihood of Stressor	Impact = 5 Catastrophic	Impact = 4 Major	Impact = 3 Moderate	Impact = 2 Minor	Impact =1 Insignificant
5 (> 90%)	5	5	5	4	3
4 (66 – 90%)	5	5	4	4	3
3 (33 – 66%)	5	5	4	3	2
2 (10 – 33%)	5	4	3	2	2
1 (<10%)	4	4	3	2	1

Risk Level Score	Risk Level
5	Extreme risk; immediate action required
4	High risk; high priority for action, begin planning as soon as practicable
3	Moderate risk; include in response planning, but lower priority
2	Low risk; minimal action likely to be required
1	Negligible risk, no response required

Table A1. Spreadsheet 1 for assessing the climate change vulnerability of Warm Springs NFH. The goal of this Spreadsheet was to identify climate change stressors, and then assess their potential severity and likelihood to assign a "risk level" for that stressor.

Warm Springs NFH (Oregon) **Potential Stressors from Climate Change**	**Step 1: Identify *Hazards* likely to occur on hatchery**	**Step 2: Determine the severity of the *Stressor***	**Step 3: Determine the Likelihood of *Hazard***	**Step 4: Determine *Risk Level***
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
SURFACE WATER QUANTITY (Hatchery and local watershed)				
decrease in water quantity (hatchery)	1	2	3	3
increase in water quantity (hatchery)	0			
SURFACE WATER QUANTITY (Migration Corridor)				
decrease in water quantity (migration corridor)	1	3	3	4
increase in water quantity (migration corridor)	0			
GROUND WATER QUANTITY (Hatchery and local watershed)				
decrease in water quantity (hatchery)	1	1	3	2
increase in water quantity (hatchery)	0			
SURFACE WATER QUALITY (Hatchery and local watershed)				
decrease in water quality (hatchery)	1	2	3	3
increase in water quality (hatchery)	0			
SURFACE WATER QUALITY (Migration Corridor)				
decrease in water quality (migration corridor)	0			
increase in water quality (migration corridor)	0			
GROUND WATER QUALITY (Hatchery and local watershed)				
degradation of water quality (hatchery)	0			
improvement of water quality (hatchery)	0			
SURFACE WATER TEMPERATURE (Hatchery and local watershed)				
temperature increase (hatchery)	1	4	5	5
temperature decrease (hatchery)	0			
SURFACE WATER TEMPERATURE (Migration Corridor)				
temperature increase (migration corridor)	1	3	5	5
temperature decrease (migration corridor)	0			
GROUND WATER TEMPERATURE (Hatchery and local watershed)				
temperature increase (hatchery)	0			
temperature decrease (hatchery)	0			

Table A1. Continued, page 2 of 6.

Warm Springs NFH (Oregon) **Potential Stressors from Climate Change**	**Step 1: Identify *Hazards* likely to occur on hatchery**	**Step 2: Determine the severity of the *Stressor***	**Step 3: Determine the Likelihood of *Hazard***	**Step 4: Determine *Risk Level***
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
AMBIENT TEMPERATURE CHANGES (Hatchery and local watershed)				
increase in annual average temperature (hatchery)	1	3	4	4
decrease in annual average temperature (hatchery)	0			
increase in number of warm days (aka heat waves1) (hatchery)	1	3	4	4
decrease in number of warm days (hatchery)	0			
increase in number of frost days2 (hatchery)	0			
decrease in number of frost days (hatchery)	0			
increase in spring average air temperatures (hatchery)	0			
increase in summer average air temperatures (hatchery)	1	2	4	4
increase in fall average air temperatures (hatchery)	1	1	4	3
increase in winter average air temperatures (hatchery)	0			
decrease in spring average air temperatures (hatchery)	0			
decrease in summer average air temperatures (hatchery)	0			
decrease in fall average air temperatures (hatchery)	0			
decrease in winter average air temperatures (hatchery)	0			
PRECIPITATION CHANGES (Hatchery and local watershed)				
increase in annual average precipitation (hatchery)	0			
decrease in annual average precipitation (hatchery)	0			
increase in spring average precipitation (hatchery)	0			
increase in summer average precipitation (hatchery)	0			
increase in fall average precipitation (hatchery)	0			
increase in winter average precipitation (hatchery)	0			
decrease in spring average precipitation (hatchery)	0			
decrease in summer average precipitation (hatchery)	1	2	4	4
decrease in fall average precipitation (hatchery)	0			
decrease in winter average precipitation (hatchery)	0			
increase in frequency of extreme thunderstorms (hatchery)	1	3	3	4
decrease in frequency of extreme thunderstorms (hatchery)	0			

Table A1. Continued, page 3 of 6.

Warm Springs NFH (Oregon) **Potential Stressors from Climate Change**	**Step 1:** **Identify *Hazards* likely to occur on hatchery**	**Step 2:** **Determine the severity of the *Stressor***	**Step 3:** **Determine the Likelihood of *Hazard***	**Step 4:** **Determine *Risk Level***
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
PRECIPITATION CHANGES (Hatchery and local watershed): Continued.				
increase in frequency of extreme snow storms (hatchery)	1	3	3	4
decrease in frequency of extreme snow storms (hatchery)	0			
increase in duration of extreme thunderstorms (hatchery)	1	3	3	4
decrease in duration of extreme thunderstorms (hatchery)	0			
increase in duration of extreme snow storms (hatchery)	1	2	3	3
decrease in duration of extreme snow storms (hatchery)	0			
increase in amount of snow pack (hatchery)	0			
decrease in amount of snow pack (hatchery)	1	1	3	2
ealier snow melt date (hatchery)	1	2	3	3
later snow melt date (hatchery)	0			
lower snow line (hatchery)	0			
higher snow line (hatchery)	0			
EXTREME WEATHER EVENTS (Hatchery and local watershed)				
increased average wind speed annually (hatchery)	0			
decreased average wind speed annually (hatchery)	0			
increased average wind duration annually (hatchery)	0			
decreased average wind duration annually (hatchery)	0			
change in wind patterns (hatchery)	0			
increased speed and duration of westerly wind flow (hatchery)	0			
decreased speed and duration of westerly wind flow (hatchery)	0			
increased speed and duration of southernly wind flow (hatchery)	0			
decreased speed and duration of southernly wind flow (hatchery)	0			
increase in number of flood events annually (hatchery)	1	2	3	3
decrease in number of flood events annually (hatchery)	0			
increase in the average duration of flood events annually (hatchery)	1	2	3	3
decrease in the average duration of flood events annually (hatchery)	0			
increase in the severity of flood events annually (hatchery)	1	2	3	3
decrease in the severity of flood events annually (hatchery)	0			

Table A1. Continued, page 4 of 6.

Warm Springs NFH (Oregon) **Potential Stressors from Climate Change**	**Step 1: Identify *Hazards* likely to occur on hatchery**	**Step 2: Determine the severity of the *Stressor***	**Step 3: Determine the Likelihood of *Hazard***	**Step 4: Determine *Risk Level***
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
EXTREME WEATHER EVENTS (Hatchery and local watershed): Cont.				
increase in number of drought events annually (hatchery)	1	2	3	3
decrease in number of drought events annually (hatchery)	0			
increase in the average duration of drought events annually (hatchery)	1	2	3	3
decrease in the average duration of drought events annually (hatchery)	0			
increase in the number of tornadoes (hatchery)	0			
decrease in the number of tornadoes (hatchery)	0			
increase in the severity of tornadoes (hatchery)	0			
decrease in the severity of tornadoes (hatchery)	0			
increase in the number of hurricanes (hatchery)	0			
decrease in the number of hurricanes (hatchery)	0			
increase in the severity of hurricanes (hatchery)	0			
decrease in the severity of hurricanes (hatchery)	0			
increase in the number of ice storms (hatchery)	0			
decrease in the number of ice storms (hatchery)	0			
increase in the severity of ice storms (hatchery)	0			
decrease in the severity of ice storms (hatchery)	0			
increase in the number of monsoons (hatchery)	0			
decrease in the number of monsoons (hatchery)	0			
increase in the severity of monsoons (hatchery)	0			
decrease in the severity of monsoons (hatchery)	0			
increase in the number of hail storms (hatchery)	0			
decrease in the number of hail storms (hatchery)	0			
increase in the severity of hail storms (hatchery)	0			
decrease in the severity of hail storms (hatchery)	0			

Table A1. Continued, page 5 of 6.

Warm Springs NFH (Oregon) **Potential Stressors from Climate Change**	**Step 1: Identify *Hazards* likely to occur on hatchery**	**Step 2: Determine the severity of the *Stressor***	**Step 3: Determine the Likelihood of *Hazard***	**Step 4: Determine *Risk Level***
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
OTHER (Hatchery and local watershed)				
increase in invasive species (hatchery)	1	2	2	2
decrease in invasive species (hatchery)	0			
increase in disease (hatchery)	1	4	4	5
decrese in disease (hatchery)	0			
increase in parasites (hatchery)	1	3	4	4
decrease in parasites (hatchery)	0			
increase in pathogens (hatchery)	1	4	4	5
decrease in pathogens (hatchery)	0			
increase in number of fire events (hatchery)	1	2	5	4
decrease in number of fire events (hatchery)	0			
increase in intensity of fire events (hatchery)	0			
decrease in intensity of fire events (hatchery)	0			
extreme precipitation events-hurricane (hatchery)	0			
extreme precipitation events-tropical storm (hatchery)	0			
extreme precipitation events-cyclones (hatchery)	0			
extreme precipitation events (hatchery)	0			
OTHER (Migration Corridor)				
increase in invasive species (migration corridor)	1	2	2	2
decrease in invasive species (migration corridor)	0			
increase in disease (migration corridor)	1	2	2	2
decrese in disease (migration corridor)	0			
increase in parasites (migration corridor)	1	2	2	2
decrease in parasites (migration corridor)	0			
increase in pathogens (migration corridor)	1	2	2	2
decrease in pathogens (migration corridor)	0			

Table A1. Continued, page 6 of 6.

Warm Springs NFH (Oregon) **Potential Stressors from Climate Change**	**Step 1: Identify *Hazards* likely to occur on hatchery**	**Step 2: Determine the severity of the *Stressor***	**Step 3: Determine the Likelihood of *Hazard***	**Step 4: Determine *Risk Level***
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
COASTAL (Hatchery and local watershed)				
increase in wave size and intensity (hatchery)	0			
decrese in wave size and intensity (hatchery)	0			
increase in marine cloudines (decreasing temperature) (hatchery)	0			
decrease in marine cloudiness (increasing temperature) (hatchery)	0			
increase in sea level (hatchery)	0			
decrease in sea level (hatchery)	0			
change in ocean currents (hatchery)	0			
change in wave patterns (hatchery)	0			
Management				
skill set: additional biological and fish health training of hatchery staff	1	3	4	4

VII. SPREADSHEET 2 INSTRUCTIONS (see Table A2)

The following steps were used to complete Spreadsheet 2 of the initial climate change vulnerability assessments of National Fish Hatcheries in the Columbia-Pacific Northwest Region. The climate change stressors identified in Spreadsheet 1 were listed in the first column of Spreadsheet 2. The following steps were then completed for each of those identified stressors. The completed Spreadsheet for Warm Springs NFH is presented as Table A2.

5. **Step 5: For each stressor listed in column 1, list in column 2 one to five expected effects of that stressor to the hatchery facilities, programs, and/or fish propagated at the hatchery.**
6. **Step 6: In column 3, list management actions that could be implemented to adapt or mitigate for each effect listed in column 2 (Step 5).**
7. **Step 7: On a scale of 1 to 5, determine the time/effort to implement each management action identified in Step 6 based on the criteria in the following table, and enter that time/effort classification number in column 4 of Spreadsheet 2.**

Time/Effort Classification	Difficulty	Duration	Description of Classification
5	extremely difficult	over 1 year	Intensive amount of effort and time is needed to implement
4	very difficult	6 months to 1 year	Large amount of effort and time is needed to implement
3	difficult	2 to 6 months	Moderate amount of effort and time is needed to implement
2	moderate	1 week to 2 months	Some effort and time is needed to implement
1	easy	less than 1 week	Little to no effort or time is needed to implement

8. **Step 8: On a scale of 1 to 5, determine the relative dollar ($$$) cost to implement each management action identified in Step 6 based on the criteria in the following table, and enter that dollar-cost classification number in column 5 of Spreadsheet 2.**

Dollar-Cost Classification	Relative expense	Cost	Description of Classification
5	Extremely expensive	$$$$$	Not able to implement; cost prohibitive
4	Very expensive	$$$$	Intensive amount of funding is needed to implement
3	Expensive	$$$	Large amount of funding is needed to implement
2	Moderately expensive	$$	Moderate amount of funding is needed to implement
1	Not expensive	$	Little to no and funding is needed to implement

9. **Step 9: On a scale of 1 to 5, determine the feasibility to implement each management action identified in Step 6 based on the combination of time/effort (Step 7) and dollar-cost (Step 8) according to the following table, and enter that feasibility number in column 6 of spreadsheet 2.**

Cost to implement	Time/effort = 5: Extremely Difficult	Time/effort = 4: Very Difficult	Time/effort = 3: Difficult	Time/effort = 2: Moderate	Time/effort = 1: Easy
5 = Extremely Expensive	5	5	5	4	3
4 = Very Expensive	5	5	4	4	3
3 = Expensive	5	5	4	3	2
2 = Moderately expensive	5	4	3	2	2
1 = Not Expensive	4	4	3	2	1

Feasibility Level Score	Feasibility
5	Very Low Feasibility
4	Low Feasibility
3	Moderate Feasibility
2	High Feasibility
1	Very High Feasibility

10. <u>Step 10, part 1</u>: **Prioritize or rank the management actions that could be implemented to adapt/mitigate for the identified effects of each climate change stressor and enter that rank priority in column 7.** Each hatchery manager and his/her staff ranked the order, or priority, that they would implement each of the possible management actions based on (a) feasibility of implementation (time/effort + $$$) and (b) professional experience and institutional knowledge.

    <u>Step 10, part 2</u>: **Provide comments regarding feasibility, constraints, priority, or any other information regarding the potential difficulty, benefits, risks, etc. of implementing each management action to adapt/mitigate for the effects of each climate change stressor.**

Table A2. Spreadsheet 2. Qualitative assessment of climate change vulnerability of Warm Springs NFH, page 1 of 2.

Warm Springs NFH (Oregon)							
Potential Stressors from Climate Change (as identified as "1" in Worksheet 1)	Step 5: Expected effects from stressor (list each effect in a new row; max.of 5)	Step 6: Management actions to adapt/mitigate for effects of stressor	Step 7: Time and effort to implement management action (1, 2, 3, 4, or 5)	Step 8: Dollar cost to implement management action (1, 2, 3, 4, or 5)	Step 9: Feasibility to implement management action (1, 2, 3, 4, or 5)	Step 10, part 1: Priority/rank of management actions to adapt/mitigate for effects of stressor (1, 2, 3, …etc.)	Step 10, part 2: Comments on feasibility and priority to implement management action to adapt or mitigate for the effects of stressor.
WATER QUALITY AND QUANTITY CHANGES (Hatchery)							
Decrease in surface water quantity (hatchery)	Increase in water temperature	extend current use of chillers	2	3	3	2	not feasible for summer fingerling life stage, volume of water too great to chill, current extreme is 72°
Decrease in surface water quality (hatchery)	decrease in dissolved oxygen	use Cornell tanks with degassing tower and O2 supplementation	5	3	5	1	feasible, potential to improve current and future production
	increase in fish pathogens	reduce rearing densities and number of fish reared	2	2	2	3	feasible, may violate legal mandate with US v Oregon
	decrease in carrying capacity of hatchery for rearing fish						
Decrease in ground water quantity (hatchery)	increase in the cost of domestic water use	increase energy budget	3	3	4	1	feasible
Increase in surface water temperature (hatchery)	increased need to chill water for incubating eggs and adults held for broodstock	extend current use of chillers	2	3	3	1	feasible, may violate legal mandate with US v Oregon
	water temperatures could exceed lethal limit for juvenile salmon during summer	close hatchery or rear juvenile fish at another location	5	5	5	2	seasonally marginal for rearing juvenile spring Chinook; may need to consider alternative site option.
WATER QUALITY AND QUANTITY CHANGES (Migration corridor)							
Decrease in surface water quantity (migration corridor)	reduced post-release survival of smolts	support changes to impoundment release strategies	2	2	2	1	feasible, requires negotiation with Bonneville Power Adminsitration and Army Corps of Engineers
	decrease in number of adult salmon trapped at hatchery	trap adult fish lower in system and truck to hatchery	5	3	5	2	difficult, expensive, does not resolve issue
Increase in surface water temperature (migration corridor)	Creation of thermal barrier to upstream migration of adult salmon and steelhead	Rear alternative species	4	1	4	2	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
	increased fish health risks	Adjust broodstock collection and spawn dates in response to life history adaptations to altered hydrologies and thermal regimes.	2	2	2	1	The dollar cost could increase if the length of time required to hold adult fish prior to spawning increases and/or fish health risks increase.
	decrease oxygen level	close hatchery or rear juvenile fish at another location	5	5	5	3	seasonally marginal for rearing juvenile spring Chinook; may need to consider alternative site option.
AMBIENT TEMPERATURE CHANGES (Hatchery)							
Increase in annual average temperature (hatchery)	increase energy demand to chill water for fish	increase annual energy budget	2	3	3	1	not feasible for summer fingerling life stage, volume of water too great to chill, current extreme is 72°
	increase fish health risks	increase annual chemical budget	2	2	2	2	feasible, will require additional funds
	temperature exceeds lethal limit for production fish	close hatchery or rear juvenile fish at another location	5	5	5	3	seasonally marginal for rearing juvenile spring Chinook; may need to consider alternative site option.
Increase in number of warm days (aka heat waves1) (hatchery)	increase water temperature	increase energy and chemical budget	2	3	3	1	feasible, expect potential for catastrophic losses
	restrict fish production when temperatures exceed lethal limit	no production during this period	5	1	4	2	feasible, may violate legal mandate with US v Oregon, will require alternate growing site
Increase in number of frost days2 (hatchery)	increase potential for facility damage	increase budget for weather damaged items	2	2	2	1	feasible, will require emergency repair funds
Increase in summer average air temperatures (hatchery)	health risk to staff	modify work schedules and PPE	2	1	2	2	feasible
	increased fish health risks	modify production protocols and goals	4	2	4	1	feasible, may violate legal mandate with US v Oregon, will require alternate growing site
Increase in fall average air temperatures (hatchery)	increase fish health risks	modify production protocols and goals	4	3	5	2	feasible, may violate legal mandate with US v Oregon, will require alternate growing site
	increase use of chiller for incubation	extend current use of chillers	2	3	3	1	feasible, will require additional operational funds

Table A2. Continued, page 2 of 2.

Warm Springs NFH (Oregon)							
Potential Stressors from Climate Change (as identified as "1" in Worksheet 1)	Step 5: Expected effects from stressor (list each effect in a new row; max.of 5)	Step 6: Management actions to adapt/mitigate for effects of stressor	Step 7: Time and effort to implement management action (1, 2, 3, 4, or 5)	Step 8: Dollar cost to implement management action (1, 2, 3, 4, or 5)	Step 9: Feasibility to implement management action (1, 2, 3, 4, or 5)	Step 10, part 1: Priority/rank of management actions to adapt/mitigate for effects of stressor (1, 2, 3, …etc.)	Step 10, part 2: Comments on feasibility and priority to implement management action to adapt or mitigate for the effects of stressor.
PRECIPITATION CHANGES (Hatchery and local watershed)							
Decrease in summer average precipitation (hatchery)	increase pumping for fire protection	expand fire safety precautions& well field	5	2	5	1	feasible
Increase in frequency of extreme thunderstorms (hatchery)	increase in power interruptions	enhance back up power features	5	4	5	2	feasible, will require additional reliance on monitoring and backup equipment
Increase in duration of extreme thunderstorms (hatchery)	increase in facility mechanical failure	enhance cyclic maintenance timing	3	3	4	1	feasible, will require additional operational funds
Increase in frequency of extreme snow storms (hatchery)							
Increase in duration of extreme snow storms (hatchery)							
Decrease in amount of snow pack (hatchery)	increase fire potential	expand fire safety precautions	2	2	2	1	feasible
Earlier snow melt date (hatchery)	potential impact with outmigration	adjust release times of smolts relative to optimum flows	5	2	5	2	feasible, data indicates that survival with early release declines
	reduce flows for adult returns	trap adult fish lower in system and truck to hatchery	5	4	5	3	complications
EXTREME WEATHER EVENTS (Hatchery and local watershed)							
Increase in number of flood events annually (hatchery)	decrease is surface water quality	increase use of filters	2	3	3	1	feasible, will require additional operational funds
Increase in the average duration of flood events annually (hatchery)	increased risk of flooding to facility structure and mechanical operations	consider modifying, closing or relocating facility	5	5	5	2	electric-mechanical room (pumps and chillers) is adjacent to river and at risk of flooding
Increase in the severity of flood events annually (hatchery)							
Increase in number of drought events annually (hatchery)	decrease in surface water quality and quantity	increase use of filter & chillers	2	3	3	2	feasible, will require additional operational funds
Increase in the average duration of drought events annually (hatchery)	increase water temperature	increase use of chiller for brood fish and eggs	2	3	3	1	feasible, will require additional operational funds
	decrease in carrying capacity of hatchery for rearing fish	reduce rearing densities and the number of fish reared	3	2	3	3	feasible, may violate legal mandate with US v Oregon, will require alternate growing site
OTHER (Hatchery and local watershed)							
Increase in invasive species (hatchery)	cause modification of current operations	modify production protocols and goals	3	2	3	1	feasible, may violate legal mandate with US v Oregon, will require alternate growing site
Increase in disease (hatchery)	Reduced number of smolts available for release	reduce rearing densities and the number of fish reared	3	3	4	2	feasible, may violate legal mandate with US v Oregon, will require alternate growing site
Increase in parasites (hatchery)	Increased fish health risks	Modify, close or relocate facility	5	5	5	3	seasonally marginal for rearing juvenile spring Chinook; may need to consider alternative site option.
Increase in pathogens (hatchery)	increase in fish mortalities	Increase fish health monitoring, diagnostics, and treatment	2	3	3	1	
Increase in number of fire events (hatchery)	Increased fire and safety risk to facility and staff	enhance fire safety features and contingency planning	2	2	2	1	feasible
OTHER (Migration Corridor)							
Increase in invasive species (migration corridor)	may impact out migrating smolts (predation)	exclusion plans	4	3	5	1	Continue to use HACCP procedures when potential to create pathway exists
Increase in disease (migration corridor)	Reduced smolt-to-adult return rates	increase treatment of adults in holding pond	2	2	2	1	Attempt to block/control pathways to protect hatchery and wild stocks up river
Increase in parasites (migration corridor)	Increased pre-spawning mortality of adult fish retained and held for broodstock						
Increase in pathogens (migration corridor)	Increased fish health risks to adult fish retained fro broodstock						
MANAGEMENT							
Skill set	Reduced ability to adequately monitor, diagnose, and treat fish for disease because of increased work loads.	Increase number of fish health specialists for monitoring, diagnosis, and treatment of fish diseases.	2	3	3	1	
	Increased workload and challenges of hatchery culture staff because of increased physiological stress of fish prior to release.	Increase biological training requirements for fish culture staff.	5	2	5	2	May require reclassification of Position Descriptions.