Project Title: Understanding impacts of climate change on ecology and habitats of waterfowl, shorebirds, and other waterbirds: Guidance for the California LCC and other wetland habitat conservation programs in the Pacific Flyway

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Project Description: This funding request is to support continuation of the multi-partner CA-LCC project to model impacts of climate change on habitats and ecology of waterfowl, shorebirds, and other waterbirds in the Central Valley of California.

Waterbird habitats in the Central Valley of California critical to waterfowl and other wetland birds are highly dependent on snow pack and other precipitation for water supplies. Hydrology of most waterbird habitats in the Central Valley, which include wetlands, flooded rice fields, and other flooded agricultural lands, has been greatly modified. Natural overflow flooding from snow-melt and rain has mostly been replaced by managed flooding with controlled diversions and pumped water delivery from ditches, rivers, sloughs, and wells. Thus, the amount of water stored in reservoirs is crucial to determining the amount of waterbird habitat in the Central Valley. During years with average or above-average reservoir levels, water is available to allow summer irrigations and normal fall flooding and winter maintenance of managed habitats; winter rains provide additional winter habitat. Dry-to-extreme drought conditions can restrict summer irrigations, reducing wetland production of seeds, and reduce or delay fall and winter flooding. Dry winters also produce little or no lowland or bypass flooding.

Food availability is a key factor limiting waterbirds (waterfowl, shorebirds, waders) during migration and winter, and habitat conditions during the non-breeding period may influence reproductive success. Like most Joint Ventures working in waterbird wintering regions, the Central Valley Joint Venture (CVJV) uses a food energy (i.e., bioenergetics) modeling approach to establish habitat objectives for waterfowl and other waterbirds. First, waterbird population objectives, based upon historic bird use patterns and plan population goals (e.g., North American Waterfowl Management Plan) are set. Next, using daily energy requirement for individuals of each species, the amount of required energy for sustaining those goal "use-days" is determined. Finally, using data on food density produced by each type of waterbird habitat (e.g., wetland and flooded agriculture), the model compares population food energy needs and food energy supplied by the mix of available habitats. Timing and amounts of necessary water supplies can then be estimated based on required area of habitats.

Global climate models indicate substantial changes in temperature and timing and amounts of precipitation in watersheds of the Central Valley, translating into temporal and spatial variations in many of the driving forces that define the availability and productivity of waterbird habitats. Changes in timing, amounts, and distribution of precipitation can have major impacts on waterbirds and their habitats. For instance, lack of adequate water supplies in the Central Valley could reduce productivity of wetland habitats and area of wetlands and post-harvest flooded crop fields, changing waterbird distribution in the valley. Increases in climatic water deficits that impact vegetation and associated fauna and insects surrounding wetlands may reduce the ecosystem diversity and impact wetland habitats. Thus, climate change could alter when and where critical resources are available and needed for migratory birds.

The goal of this project is to develop landscape change scenarios based upon downscaled climate models and projected urbanization and investigate impacts of these changes on habitats and ecology of waterfowl, shorebirds, and other waterbirds in the Central Valley. Specific project objectives are to:

- Develop scenarios of Central Valley landscape change based upon changes in water availability, local precipitation, temperature patterns, potential evapotranspiration, and climatic water deficits simulated using downscaled global climate projections for the next century.

- Use bioenergetics modeling and ecological relationships of waterfowl, shorebirds, and other waterbirds and their habitats to investigate scenario impacts on key bird metrics (i.e., abundance, distribution, body condition, and survival) under different management scenarios in the Central Valley.
- Identify timing and locations of critical waterfowl, shorebird, and other waterbird resources that are most at risk due to climate change in the Central Valley.
- Develop adaptive management strategies to account for climate change in waterbird habitat conservation planning in the Central Valley.

Products from this project will include: 1) realistic set of scenarios of changes in habitat quantity, quality, distribution, and timing based on projected regional water supplies, urbanization, and water management options; 2) an evaluation of the impacts on key waterbird habitat under each scenario; 3) an evaluation of the impacts on waterbird bioenergetics and other key ecological metrics (e.g., condition, survival) under each scenario; 4) a website describing project goals, partners, results, and management implications; and 5) consultations with JVs and LCCs to apply project results and meet the project's ultimate goal of developing adaptive strategies that account for impacts of climate change in waterfowl, shorebird, and other waterbird habitat conservation planning.

2011 CA-LCC Priorities Addressed by the Project:

- Developing models at scales relevant to resource managers that clearly address specific manager needs and characterize habitat/organism responses to projected change under alternative climate/economic/planning scenarios
- Better understanding of demographic responses to climate change, including dispersal, survival, and productivity (e.g. why hotspots are hot)
- Modeling the frequency, intensity, and impacts of extreme climate-driven events (e.g. sea level rise, floods, wildfires, and droughts)
- Future scenario planning at landscape and ecoregional scales
- Identifying ecosystem impacts of adaptive land-use change – avoiding conflicts between human infrastructure changes and biodiversity/conservation

How the Project Meets the LCC Evaluation Criteria:

The project will provide critical information and support to improve planning and delivery of the CVJV and other habitat and avian population conservation programs in the Central Valley by modeling alternative scenarios of climate change, management of water and habitats, and urban growth to better understand impacts of climatic change on habitats and ecology of waterfowl, shorebirds, and other waterbirds. This information need is clearly stated in the North American Waterfowl Management Plan "*…changes in climate may have profound effects on wetland ecosystems, particularly those already stressed by degradation. Adaptive conservation strategies are needed to anticipate and address changes.***"** and is especially timely given the numerous proposals under consideration for management of water supplies in the Central Valley. This project is endorsed by the USFWS Pacific Region, California Waterfowl Association, and the CVJV consortium of 22 federal, state, and non-governmental organizations. This project is a multi-organizational partnership comprised of wildlife research and habitat management biologists, hydrologists, climate scientists, and water management modelers. Due to promising early results and improved clarity regarding the complexity of the project topic revealed by initial work, the project has attracted a new partner (Delta Waterfowl Foundation) who will provide approximately $80,000 per yr to support an expanded collaboration with the Stockholm Environment Institute (SEI) and the University of California-Davis. These new partners will enhance both the hydrologic and bioenergetic modeling capabilities of the project team and further ensure project success. This new funding along with the significant value of in-kind contributions from project partners will

provide approximately a 1.7x match of LCC funds. Although this work will focus on waterfowl, shorebirds, and other waterbirds during the non-breeding period, because of the analysis of wetland and agricultural habitats, it will also inform, and could be expanded to specifically address other periods and wetland-dependent species, such as endangered giant garter snakes. Further, this work will provide a basis for similar evaluations in other regions. A proposal to expand this project into the Great Basin was endorsed by the Intermountain West Joint Venture and others demonstrating the applicability of this approach for other LCCs. Results of this project will include reports summarizing development and analysis of realistic scenarios of changes in habitat quantity, quality (including food availability), distribution, and timing and predicted impacts on ecology of waterfowl, shorebirds, and other waterbirds. Insights produced by this project are critical to help the CVJV understand how their goals of restoring 120,000 acres of wetlands, enhancing 443,000 acres of agricultural lands, and protecting 200,000 acres of wetlands may might need be adjusted to adapt to impacts of climate change, urbanization, and other factors.

Project information and products will be made available on the project website and consultations will be provided to the CVJV on possible adaptive strategies and critical information gaps to account for climate change in habitat conservation planning. Thus, this project will help deliver and coordinate conservation planning to policy-makers, identify information still needed, and promote similar efforts in other regions. To advance LCC goals this project will:

- Assess vulnerability of waterfowl, shorebird, and other waterbirds and their habitats
- Predict changes in waterfowl, shorebird, and other waterbird populations and their habitats
- Conduct bioenergetics modeling to guide conservation planning for waterfowl , shorebird, and other waterbirds and their habitats
- Evaluate effectiveness of management options under changing climate for waterfowl, shorebirds, and other waterbirds and their habitats

Approach and Scope of Work: To accomplish project goals the project team is and will continue to conduct work: ***a)*** downscaling global climate projections of temperature and precipitation, applied to a regional water balance model to provide potential evapotranspiration, climatic water deficit, snowpack, recharge, and runoff to estimate water supply for Central Valley basins for 4 climate change scenarios (2 emission scenarios x 2 climate change models); ***b)*** adapting the WEAP (Water Evaluation And Planning) water management model used by the State of California, which accounts for water distribution system limitations to better predict water supplies available for wetlands and agricultural habitats of importance to waterfowl, shorebirds, and other waterbirds; ***c)*** applying various water management, climatic, and urban growth scenarios in WEAP to estimate amount and temporal availability of water for each habitat of importance to waterbirds; ***d)*** estimating impacts of each scenario on wintering waterfowl food supplies and avian bioenergetics using TRUEMET and agent based modeling; ***e)*** identifying timing and locations of critical waterfowl, shorebird, and other waterbird resources that are most at risk due to climate change in the Central Valley; and ***f)*** developing adaptive management strategies to account for climate change in waterbird habitat conservation planning in the Central Valley.

Climate Downscaling: The downscaling of global climate projections employed a rigorous approach to reducing uncertainty in the process and was applied to fine-scale (270-m spatial scale) hydrologic models. To assess the impacts of climate change, many global socio-economic scenarios are being developed by the Intergovernmental Panel on Climate Change (IPCC) to provide estimates of possible magnitudes of greenhouse gas emissions that are responsible for much of the climate change. The choice of greenhouse gas emissions scenarios which focused on A2 (medium-high) and B1 (low) emissions, was based upon implementation decisions made earlier by IPCC4. The scenarios of CO_2 projections are used as boundary conditions for global circulation models (GCMs) that provide us with insight into how human behavior in the future may influence changes in climate. These GCMs have a

coarse spatial resolution with a grid-cell size on the order of 2.5° × 2.5° (approximately 275 × 275 km2) that is far too coarse for landscape or basin-scale models that investigate hydrologic or ecologic implications of climate change. These simulations of climate change need to be downscaled for ecological scale modeling to a resolution on the order of 1000's or 100's of meters or less. Because the observed western US climate has exhibited considerable natural variability at seasonal to inter-decadal time scales, the historical simulations by the climate models were required to contain variability that resembles that from observations at these short period climatic time scales. Finally, the selection of models was designed to include models with differing levels of sensitivity to greenhouse gas forcing. On the basis of these criteria, two global climate models (GCMs) were identified, the Parallel Climate Model (PCM); with simulations from NCAR and DOE groups and the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) CM2.1 model. Linear regressions of the current weather or climate pattern as the dependent variable and selected historical patterns as independent variables provide high quality analogues that should tend to describe the evolution of weather or climate into the future. These four climate change projections (i.e., PCM-B1, GFDL-B1, PCM-A2, GFDL-A2) were selected for the State of California to produce a realistic simulation of aspects of California's recent historical climate – particularly the distribution of monthly temperatures and the strong seasonal cycle of precipitation that exists in the region and throughout the western states.

Water Evaluation And Planning Model (WEAP): We are using the WEAP model and software developed by Stockholm Environment Institute (SEI) to model Central Valley water supplies and area of habitats supported by water supplies that are projected to be available under each climate change and urban growth scenario. We obtained the WEAP Central Valley Planning Area model (WEAP-CV) from the State of California and SEI, and are adapting it as needed. The WEAP-CV model has undergone peer review, its use has been published, and it is currently being used by the State of California for water supply management and planning in the Central Valley. We adapt the WEAP-CV model as needed to better specify factors of particular interest for our evaluation of changes in waterfowl habitats. This includes adapting the Current Trends population growth scenario of the WEAP-CV model to include water demands (including area of wetland and agricultural food habitats), surface water supplies, and climatic water deficit (or net evapotranspiration) specific to each basin. The Current Trends scenario projected agricultural and urban water demands into the future based on recent land use and water demand trajectories. We use the WEAP-CV Adapted Model to compare effects of recent and projected climate on water supplies used for existing waterfowl, shorebird, and other waterbird food habitats. We also examine effects of projected climate on water supplies needed for goal waterfowl food supplies following planned wetland restoration as established by the Central Valley Joint Venture (CVJV) in the CVJV Plan. Modeling provides results for monthly historical (1971-2000) and future (2001-2099) surface runoff for multiple streams and climatic water deficit within basins. Modeling results for each of the four climate change projections is subsequently divided into "projection" periods 2001-2030 (30 years), 2031-2060 (30 years), and 2061-2099 (39 years). To compare impacts of average and dry year conditions on existing and goal waterfowl food supplies we model a time series of six average and six dry years (approx. maximum number of consecutive years that drought has occurred in recent history).

Translating Changes in Water Supplies into Impacts on Ecology: We are utilizing three approaches to assess the impacts of changes in landscape due to urbanization and climate change on ecology of waterfowl and other waterbirds. First, we input estimates of habitat area supported by modeled water supplies (from the adapted WEAP-CV model) into the bioenergetics accounting model "TRUEMET" to compare avian food energy supply vs. energy demand of CVJV-goal wintering populations. TRUEMET is used by the CVJV (and other Joint Ventures) for conservation planning of wintering waterfowl and — although less completely developed — shorebirds. The approach is also possible for other wintering waterbirds but was not applied for conservation planning by the CVJV due to lack of information on existing and goal populations and other data. Secondly, for waterbird guilds for which the TRUEMET approach is not well developed but for which CVJV habitat goals are

established (i.e., breeding waterfowl and shorebirds; other waterbirds), we will compare habitat area supported by water supplies under each scenario vs. CVJV habitat goals. Thirdly, our new partnership with UC Davis will allow us to also investigate the feasibility of agent-based modeling. Our new UC Davis partners have developed a prototype agent-based model to simulate the effect of wetland habitat change on energetics and carrying capacity of foraging waterbirds. This approach offers a significant improvement on our current TRUEMET model in: a) allowing spatially-explicit analysis of the effects of alternative water-management regimes on spatial juxtaposition and distribution of wetland habitats, b) expanding the capacity to generalize across taxa, including waterfowl, shorebirds and other wetland-dependent wildlife, c) incorporating other important determinants of species habitat use and carrying capacity, such as disturbance and dispersion of non-foraging (refuge) habitat, and d) offering the potential to integrate more directly and completely with existing models of water management and in-stream fish habitat.

Integrating Results into Conservation Planning: We will continue to provide periodic project updates to the CA-LCC and CVJV on progress and help adapt results into conservation planning. The website we established describing project goals and methods will be updated with new information on partners, results, and management implications. Once project results are finalized, we will work with the CVJV and their partners to apply results to aid development of management strategies that address critical waterfowl, shorebird, and other waterbird resources that are most at risk due to climate change and other factors.

Products/Data Sharing:

1 Sep 2010 **-** Established project website: http://www.werc.usgs.gov/Project.aspx?ProjectID=204
28 ***Feb 2011*** – *Progress Update* provided to CJVV and CA-LCC summarizing project accomplishments during the first 6 months and results on water supplies, availability of wetland and agricultural habitats, and food supplies for wintering and migrating waterfowl and other waterbirds in the Butte Basin based upon various scenarios of downscaled climate model projections and water management.
1 Oct 2011 – A report summarizing water supplies, availability of wetland and agricultural habitats, and food supplies for wintering and migrating waterfowl and other waterbirds in the Sacramento Valley based upon various scenarios of downscaled climate model projections and water management.
1 Oct 2012 – A report summarizing water supplies, availability of wetland and agricultural habitats, and food supplies for wintering and migrating waterfowl and other waterbirds in the San Joaquin Valley based upon various scenarios of downscaled climate model projections and water management.

(Products in years 3 [2013] and 4 [2014], depending upon future funding levels, will include a report of modeling results for Suisun-Delta, a report summarizing the timing and locations of critical resources for waterfowl and other waterbirds that are most at risk due to climate change in the Central Valley, and a report summarizing and consultations with the CVJV on possible adaptive strategies and critical information gaps to account for climate change in habitat conservation planning for waterfowl and other waterbirds in the Central Valley.)

Measuring results: The project will provide critical information and support to improve planning and delivery of habitat and avian population conservation programs in the Central Valley by modeling alternative scenarios of climate change, management of water and habitats, and urban growth to better understand impacts of climatic change on habitats and ecology of waterfowl, shorebirds, and other waterbirds. Project information and products will be made available on the project website and provided to the CVJV and CA-LCC. In addition, consultations will be provided to the CVJV on possible adaptive strategies and critical information gaps to account for climate change in habitat conservation planning.

Project Duration: 4 yrs; funding request is for year 2

Total Requested Funding: $108,275.

Partners (roles and anticipated contributions to the Project):

USGS-Western Ecological Research Center
Project lead, modeling, coordination, website, provide in-kind salaries & equip

Ducks Unlimited, Inc.
Application of TRUMET bioenergetics modeling, provide in-kind computers

Central Valley Joint Venture
Advise on management goals, provide in-kind salaries

PRBO Conservation Science
Shorebird/other waterbird ecology, provide in-kind computers

Stockholm Environment Institute
Adaptation/application of WEAP model, provide in-kind computers

University of California- Davis
Lead application of agent-based bioenergetics modeling, provide in-kind computers

Delta Waterfowl Foundation
Provide $80K/year to support new partnership with SEI and UCD

Amount of Funding Leveraged for this Project:
Project partners will provide greater than a 1.7 to 1 match [$80,000 from Delta Waterfowl Foundation and in-kind salaries and services valued at approximately $124,000 from other project partners]) for the requested $108,275.

Year 2 Budget

Budget Item	Request from LCC	Approximate value of in-kind Services: PRBO	CVJV	USGS	SEI	UCD	Delta Waterfowl Foundation $$
Permanent Salaries w/benefits							
Project Leader (USGS-WERC)	-	-	-	25,000		5,000	
GIS/IT Specialist (USGS-WERC)	-	-	-	5,000			
Shorebird Ecologist (PRBO)	**5,000**	20,000	-	-			
CVJV Science Coordinator (FWS)	-	-	17,000	-			
WEAP Model Specialist (SEI)	-	-	-	-	-	-	40,000
Agent Based Modeler (UCD)	-	-	-	-	-	-	40,000
Bioenergetics Modeler (DU)	**15,000**	-	-	-	-	-	
Non-Permanent Salaries w/benefits							
Ecological Modeler (USGS-WERC)	**70,000**	-	-	-			
Equipment (Computing, network)	-	10,000	-	15,000	5,000	5,000	
Supplies (Software, miscellaneous)	**500**	-	-	5,000	5,000		
Travel (Partner meetings, conferences)	**250**	-	-	-			
Services							
Statistical support (USGS-WERC)	-	-	-	7,000			
Printing and publication costs	**250**	-	-	-			
Total Direct Costs	**91,000**	10,000	17,000	69,000	10,000	10,000	80,000
Indirect Costs	**17,275**	-	-	-			
Total	***108,275***	*30,000*	*17,000*	*69,000*	*10,000*	*10,000*	*80,000*