**Key Uncertainties and Applied Studies Summary** **March 2015**

During the Project's planning phase from 2003-2007, the Science Team with participation of the other Project participants determined the most important gaps in our knowledge about South Bay ecosystem functioning or restoration that may hinder our ability to achieve the Project Objectives. The key Project uncertainties identified were:

• Sediment dynamics, especially the extent to which tidal habitat restoration might result in the loss of slough and Bay tidal mudflat habitat (links to Project Objective 1A and 1C).

• Bird use of changing habitats, especially the extent to which tidal habitat species can be recovered while maintaining the diversity and abundance of nesting and migratory waterbirds observed during pre-ISP conditions (links to Project Objective 1B).

• Effects on non-avian species, especially the extent to which restoration and management will affect fish and other critical species in the South Bay ecosystem (links to Project Objective 1C).

• Mercury, especially the extent to which Project restoration and management actions might result in an increase in bioavailable mercury in the food chain above pre-ISP levels (links to Project Objective 4).

• Water quality, especially the effects of pond management regimes on slough and Bay water quality and important species (links to Project Objective 4).

• Invasive and nuisance species, especially the invasive Spartina hybrids, red foxes, California gulls, and mosquitoes (links to Project Objective 5).

• Public access and wildlife, especially the extent to which various forms of public access and recreation can be integrated into the Project without significantly affecting wildlife (links to Project Objective 3).

• Social dynamics, especially the extent to which the local population in the South Bay will actively support the Restoration Project over time (links to all Project Objectives, but especially Project Objectives 2 and 3).

The Project's Science Syntheses (available from the managing agencies or on the Project website) provide more information on the connection between these uncertainties and the Project Objectives.

The Science Team then developed a list of the highest priority applied studies, to be researched through hypothesis testing and modeling, in order to reduce the eight key uncertainties. The table below lists the applied studies questions, the principal investigator, and when and where research occurred. Each of these questions will require multiple studies in order to develop adequate information for management. In addition, numerical modeling is essential to address questions and develop predictive power. Specifically, sediment dynamics questions, water quality, mercury transport, bird carrying capacity, and effects of human population dynamics all require modeling. Results from many of the applied studies and models have already informed management decisions and Phase 2 actions.

| | **Key Uncertainties, in italics, are followed by specific, high-priority Applied Study Questions (in bold) with a brief explanation of the importance of each question.** | **Where Studies Were Conducted (Year)** | **RFP Study or other Directed Study** | **Notes and Funding Source(s)** |
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| ***Sediment Dynamics*** | *Is there sufficient sediment available in the South Bay to support marsh development without causing unacceptable impacts to existing habitats?* | | | |
| 1 | **Will sediment accretion in restored tidal areas be adequate to create and to support emergent tidal habitat ecosystems within the 50-yr projected time frame?** Sediment deposition has varied greatly over the last 150 years. Large-scale restoration occurring over decades will also affect sediment dynamics throughout the South Bay and regional study will be required to understand these changes. | Island Ponds A21 (2006-9) and Pond A6 (2011-2012); Project-wide satellite imagery pre and post restoration (2009 – 2011) | Callaway Topic 1 RFP proposal<br><br>Fullfrost Topic 1 RFP study | Final Callaway Report on Island Pond A21 completed<br><br>Funding by SCC |
| 2 | **Will sediment movement into restored tidal areas significantly reduce habitat area and/or ecological functioning (such as plankton, benthic, fish or bird diversity or abundance in the South Bay?** Sediment accretion into the restored ponds is expected to reduce the amount of mudflat in the South Bay, but it is not known whether mudflat loss will be significant in terms of acreage or its effect on South Bay ecology. Such changes are expected to occur over decades. | Shoals area off SF2 (2008/10); and Pond A6 Shoals (2010) | Takekawa, Jaffe, Schoellhamer Directed Study | USGS Science funding. Funding for this project ended in FY2010, needs additional study/funding |
| 3 | **Will restoration activities always result in a net decrease in flood hazard?** Increased tidal prism will scour slough channels within a relative short time frame (months to years) and reduce flood hazard. Changes in tidal elevations and prism in sloughs occurring over months to years may potentially increase flood hazard. | Alviso Slough bathymetry (2010 - 2013);<br><br>Alviso Slough Cross sections | Jaffe Directed Study | USGS Science funding, EPA, SCC<br><br>Santa Clara Valley Water District |
| ***Bird Use of Changing Habitats*** | *Can the existing number and diversity of migratory and breeding shorebirds and waterfowl be supported in a changing (reduced salt pond) habitat area?* | | | |
| 4 | **Will the habitat value and carrying capacity of South Bay for nesting and foraging migratory and resident birds be maintained or improved relative to current conditions?** Overall ecosystem changes and effects must be measured and compiled over decades to | Pond islands-nesting, roosting, foraging | Ackerman Topic 3 RFP Study | PRBO Topic 6 RFP study will provide |

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| | understand the overall implication of South Bay restoration on migratory birds. Some factors that could affect bird numbers are changes in disease and predation rates, food availability, and nest competition | waterbirds – SF2, A12, A16? (2011-2012);<br><br>Shoals- foraging – SF2 (2008-10);<br>Foraging – A6 (2010)<br><br>SBSP Ponds 2002-2013);<br>Carghill Ponds (2002-present);<br><br>Model of shoals carrying capacity | <br><br><br><br><br>Takekawa<br><br><br>SFBBO/PRBO<br><br><br>Rowan Topic 9 RFP study | baseline bird abundance, salt pond carrying capacity model. SCC funded.<br><br>USGS Science funding;<br><br>USFWS funding<br><br>Bird Data Synthesis report is in process |

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| 5 | **Will shallowly flooded ponds or ponds constructed with islands or furrows provide breeding habitat to support sustainable densities of snowy plovers while providing foraging and roosting habitat for migratory shorebirds?** Simple changes to existing pond management or simple habitat alteration may significantly benefit nesting snowy plovers while still providing nesting and foraging habitat for other species, but the extent of potential benefits is not known. | Plovers – Baywide and nesting (2003 – present);<br><br>Nesting ,roosting, foraging waterbirds – SF2, A12, A16? (2011-2012)<br><br>Plover Social Attraction Study – SF2, A16 (2015)<br><br>Plover Habitat Enhancement study on Pond E14 (2014-5). | SFBBO/FWS (ongoing);<br><br>Ackerman Topic 3 RFP study.<br><br>Ackerman<br><br>SFBBO | USFWS funded.<br><br>SCC funded<br><br>Plover SA study, USACE funded<br><br>SCC funded |
| 6 | **Will ponds reconfigured and managed to provide target water and salinity levels significantly increase the prey base for, and pond use by waterfowl, shorebirds and phalaropes/grebes compared to existing ponds not managed in this manner?** Ponds managed as small-scale salt pond systems may provide enhanced benefits for wide range of birds. But, the extent to which they can improve the prey base and increase foraging shorebird densities in the short and long-term is not known. | Baywide: Model of bird abundance and salt pond habitat;<br><br>E12/E13 bird and invert studies (2012-2014)<br><br>E6A/B invert and duck study (2013-2014) | Athearn Topic 9 study<br><br>DeLaCruz<br><br>DeLaCruz | SCC funded<br><br>WCB/DU funded<br><br>Cosco Busan NRDA funded |

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| | | | | |
| 7 | **To what extent will the creation of large isolated islands in reconfigured ponds maintain numbers (and reproductive success) of terns and other nesting birds in the South Bay, while increasing densities of foraging birds over the long term compared to ponds not managed in this manner?** Changing salt pond island configurations may result in significant increases in nesting and foraging bird densities but to what extent is not known. | Nesting, roosting, foraging waterbirds – SF2, and other locations (2011-2012) | Ackerman Topic 3 RFP | No long term studies yet planned |
| 8 | **Will pond and panne habitats in restoring tidal habitats provide habitat for significant numbers of foraging and roosting shorebirds and waterfowl over the long term?** Naturally-maintained pond and panne habitat within marshes could potentially provide significant habitat for many species that currently use ponds. But, little is known about the extent of potential benefits to waterbird species on short or long timescales. | | | Tidal pond and panne habitats not yet formed, will need to assess later. |
| 9 | **How do Ridgway's rails (aka California clapper rail) and/or other key tidal habitat species respond to variations in tidal marsh habitat quality and what are the habitat factors contributing to that response?** Increased tidal habitat is expected to boost populations of California clapper rails and other key species, but the data on the conditions that produce high quality habitat for survival and reproduction are needed. | Clapper rail population dynamics and habitat requirements<br>Hg effect on rail | Overton Topic 9 RFP study<br><br>Ackerman et al. 2012, Environmental Pollution 162:439-448 | First clapper rail detected at Pond A21 in July 2014.<br><br>USFWS/USGS Science Support Program. |
| ***Effects on Non-Avian Species*** | *Can restoration actions be configured to maximize benefits to non-avian species both onsite and in adjacent waterways?* | | | |

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| 10 | **To what extent will increased tidal habitats increase survival, growth and reproduction of native species, especially fish and harbor seals?** The extent to which restoring tidal habitats will affect native species, including steelhead, harbor seals, native fish and oysters, is unknown. This question requires long-term study on local and regional scales relevant to the species examined. | Island Ponds A19, A20, A21; Ponds A8, A6,& Alviso Slough/Coyote Creek; Ponds E9, E8X , E8, & Old Alameda Creek (2010 -2011); Pond SF2 Bair Island | Hobbs Topic 7 RFP Study (2010 – 2011) funded by NMFS. Continued study in 2012 and 2013, funded by SCC, Leopard Shark Mitigation fund. 2013 work redirected to support Hg fish collections and steelhead smolt study. | |
| ***Mercury*** | *Will mercury be mobilized into the food web of the South Bay and beyond at a greater rate than prior to restoration?* | | | |

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| 11 | **Will tidal habitat restoration and associated channel scour increase MeHg levels in marsh and bay-associated sentinel species?** Restoration actions could increase the bioavailability of mercury in sediment and water. Bioavailable mercury becomes a problem when it leads to deleterious accumulation in wildlife and people. Sentinel species, such as some invertebrates, fish and birds, are a cost effective way to monitor this toxic pollutant. | Alviso Ponds and Alviso Slough fish/waterbird biosentinels; Hg Remobilization; Hg in Water; Sediment Flux/Diel Study (2010 – 2015)<br><br>Alviso area, SF2 and Ponds A6 and shoals<br>Fish and waterbird eggs (2010) | Ackerman Topic 2 RFP study (2010-2011); Jaffe and Marvin-DiPasquale Hg remobilization studies (2010 – 2015); Pond A6 Hg deposition study (2013); Slough Water Hg studies (2010, 2011, 2014, 2015); Slotton Slough Fish Studies (2010, 2011, 2013-2015); Shellenbarger Alviso Slough sediment flux station (2010 – 2015); Marvin-DiPasquale/Shellenbarger Hg Diel study (2013):<br><br>Ackerman Directed Study | Jaffe and VanDerWeggen developing an Alviso Slough Scour model in 2014 to increase understanding of what effect opening notch gates have on scour/Hg remobilization. Funding from SCC, EPA, SCVWD.<br><br>USGS Science Funding |
| 12 | **Will pond management increase MeHg levels in ponds and pond-associated sentinel species?** Pond management could increase the bioavailability of mercury in sediment and water over pre-ISP conditions. Sentinel species, such as some invertebrates, fish and birds, are a cost effective way to monitor this pollutant. | Alviso Ponds and Alviso Slough fish/waterbird biosentinels (2010-2015); | Ackerman Topic 2 RFP study (2020 – 2011); Ackerman, Slotton fish and bird egg studies 2013 – 2015. Marvin | Funding from SCC, EPA, SCVWD |

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| | | Alviso area, SF2 and Ponds A6 and shoals<br>Fish and waterbird eggs | DiPasquale pond water studies (2010, 2011, 2014, 2015) | USGS Science Funding |
| ***Water Quality*** | *Will restoration adversely affect water quality and productivity?* | | | |
| 13 | **What is the effect of a) pond management, including increased pond flows and associated managed pond effects, and b) increased tidal prism from tidal habitat restoration on water quality, phytoplankton and fish diversity and abundance, and food web dynamics in South Bay?** Pond management and resulting water discharges to the Bay have the potential to decrease slough and Bay water quality and affect Bay species, but little is known of the short or long-term effects of pond management on the South Bay ecosystem. Restoring tidal action to ponds will increase the tidal prism and tidal currents in South Bay. South Bay phytoplankton dynamics at the base of the food web are dependent on hydrodynamics and mixing. | Water quality monitoring of ponds and discharges required by RWQCB<br><br>Baywide: Benthic communities pre (1993 -95) and post ISP (2006 – 08) | USGS water quality monitoring, taken over by USFWS in 2013.<br><br>Thompson Topic 5 and 6 RFP study | USFWS funded<br><br>SCC funded |
| ***Invasive and Nuisance Species.*** | *Can invasive and nuisance species such as Spartina alterniflora (or the invasive Spartina hybrid), corvids and the California gull and, if warranted, raptors such as the northern harrier, be controlled. I f not, how can the impacts of these species be reduced in future phases of the project?* | | | |
| 14 | **Where not adequately eradicated, does invasive *Spartina* and hybrids significantly reduce aquatic species and shorebird uses?** The Invasive Spartina Project is a comprehensive | Invasive Algerian sea lavender study | Archbald Topic 9 RFP study | SCC funded |

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| | program to control *Spartina alterniflora* hybrids to a level at which native species are not threatened. If this Project is not successful, this applied studies question would need investigation. | | | Depends on Invasive Spartina Project results |
| 15 | **Will California gulls, ravens, and crows adversely affect (through predation and encroachment on nesting areas) nesting birds in managed ponds?** Data indicate that a number of native predatory species are increasing in population and are negatively affecting native breeding birds, but the extent of the impacts are not known. | CAGU nest surveys A1, A5, A6, A9/10, Coyote Hills and Mowry colonies; gull color-marking (2010 – 2012) | Ackerman Topic 8 RFP study | SCC funded |
| ***Public Access and Wildlife*** | *Will trails and other public access features / activities have significant negative effects on wildlife species?* | | | |
| 16 | **Will increases in boating access significantly affect birds, harbor seals or other target species on short or long timescales?** While there is a strong constituency for increased boating access, there is almost no information in the San Francisco Bay on the immediate or long-term effects of recreational boating on birds or other target species in different habitat types. | | | No studies planned for birds or harbor seals |
| 17 | **Will landside public access significantly affect birds or other target species on short or long timescales?** Information on the short and long-term effects of general and specific trail uses, such as dog walking, on birds and other key species in different habitat types (ponds, sloughs, tidal habitat) is mostly lacking, as is information on effective mitigation measures. | Plovers – Eden Landing or Warm Springs; Foraging ( 2003-present)<br>Waterbirds – E12/13, SF2, other locations (2010-2012) | SFBBO/FWS (ongoing)<br>Trulio Topic 4 RFP study | USFWS funded<br>SCC funded |
| 18 | **Will public access features provide the recreation and access experiences visitors and the public want over short or long timescales?** The public's desire for recreational uses changes over time. Understanding and providing the opportunities people value, to the extent feasible, is essential for the Project engender stewardship and public support in the short and long-term. | Trail user surveys (2010 – 2012) | Trulio Topic 4 RFP study | SCC funded |