

**Title:**

**Utilizing NASA and ESA Earth Observations within the BayDeltaLive Constituent Tracker Decision Support Tool to Monitor Turbidity, Water Temperature, and Chlorophyll-a Conditions for Real-time Water Operations in the San Francisco-Bay Delta**

**Project Overview:**

In collaboration with 34 North, USGS, NASA/JPL and DWR, this research and development project will advance the Bay-Delta Live (BDL) technology platform to provide data and decision support tools that implement novel methods needed to view and analyze continuous water quality conditions at a finer spatial scale within the Sacramento-San Joaquin Bay Delta. By synthesizing data from in-situ stations, boat transects, remote sensing and field samples, these tools and data analysis methods will provide key water operations workgroups and managers with the ~~tools and~~ information needed to understand how the Delta aquatic ecosystem will respond to Sacramento Regional Waste Water Treatment Upgraded Facility, WaterFix and EcoRestore.

Water quality and quantity are critical elements of ecosystem health and developed freshwater supplies. While there are measures in place to protect human and environmental health from poor water quality conditions, implementation of these measures is often reliant on physical water samples and fixed station data. Both of these data collection methods have gaps in their spatial and temporal coverage, which presents management difficulties, especially in complex and heavily managed systems such as the Sacramento-San Joaquin Bay Delta. Field data that is supplemented by remotely sensed information can be used to obtain a more complete understanding of water conditions and help inform water management decisions. In this project 34 North, USGS and NASA/JPL will develop methods that synthesize key datasets to produce data models and visualization tools that can be used to inform water management decisions and practices. This will include a turbidity estimate derived from remotely sensed data captured by three Earth observing satellites. The application will also provide a platform to compare satellite, boat transect and *in situ* turbidity data from USGS and CDEC water quality stations at critical water quality locations and timeframes. Ultimately, 34 North will work with USGS and DWR to help refine the Semi-Empirical Single Band Turbidity Algorithm to adapt with real time management methods and instrumentation in the field. Ideally the project will help to incorporate site-specific constants into the algorithm to make remote sensing data a key component of real time operations by implementing these data as part of the BDL constituent tracker.

The constituent tracker project currently underway aims use advanced data modeling algorithms, implement precise error handling techniques, introduce new data constituents (including remote sensing data), improve regional granularity, develop data visualization techniques, and add data dashboards to view and report these data. The proposed prototype project area will focus on the Suisun Marsh, up the Sacramento River into Liberty Island (ARC). This region was selected because of the extensive real-time station network available (The real-

time stations within the project area are positioned to allow for tidal overlap), proximity the Sac Regional Sanitation Discharge Site, and its importance to the native fish communities in the Delta. The intent of this project is to extend the usefulness of the data presently collected at current monitoring stations for management decisions by providing a regional-scale perspective on how the system is functioning that obviates the need to examine dozens of time series plots. The basic concept is to combine key hydrology data with constituent (conductivity, turbidity, temperature) data collected at the same station in order to depict a more accurate picture of environmental conditions at a constant point in tide. Tidal fluctuations within the Delta create data accuracy issues for real time water operators. Project goals and deliverables include:

- Spatial maps to managers visualizing constituent fields that include the best possible representation of gradients (e.g. compensate for the "smearing" of the gradients when using linear interpolation methods to estimate the constituent fields as is shown in [www.baydeltalive.com/turbidity](http://www.baydeltalive.com/turbidity) and [www.baydeltalive.com/salinity](http://www.baydeltalive.com/salinity)).
- Spatial maps registered to a constant point in tide (at slack water) when strung together over days (e.g. 14-day spring/neap cycle), will provide estimates of the tidally averaged (net) movement of constituent fields.
- Implement numerical analytical frameworks provided by USGS. The proposed approach leverages existing conductivity and turbidity data along with water velocity time series to estimate spatial distributions with tide. This work is intended as a proof-of-concept /feasibility study.
- Display and reporting of relevant field data from special studies (remote sensing) and data from ongoing monitoring programs.
- Set up use cases to showcase important environmental or operations events data to display and report via dashboards to reflect key historical water operations. (see appendix B) These data views will give water operators and study participants collaborative workspaces to view and analyze all data in order to tune algorithms and or collection methodology.
- Implement product dashboards and refined techniques Delta wide. Beginning with Old and Middle River.

#### Keywords:

Turbidity, electrical conductivity, water temperature, smelt, Sacramento San Joaquin Bay-Delta, water quality, Landsat 8, Sentinel-2, Sentinel-3. salmon, operations, exports, Old and Middle River, ARC, Liberty Island, Tide, BiOps, RPAs

#### Partner Organizations:

| Organization                                             | POC (Name, Position/Title)                                                                                                     | Partner Type  |
|----------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|---------------|
| Metropolitan Water District of Southern California (MWD) | Dr. David Fullerton, Principal Resource Specialist,<br>Dr. Shawn Acuna, Environmental Scientist, Russell Ryan, Senior Engineer | End User      |
| NASA/JPL                                                 | Christine M. Lee                                                                                                               | Data Provider |
| USGS                                                     | Jon Bureau<br>Brian Bergamaschi                                                                                                | Data Provider |

|          |                                                                                                               |                        |
|----------|---------------------------------------------------------------------------------------------------------------|------------------------|
|          | Bryan Downing                                                                                                 |                        |
| 34 North | Amye Osti, Engineer<br>Nathan Hemenway, Engineer<br>David Osti, Project Management<br>Karly Wagner, Scientist | Software Developer     |
| DWR      | Karen Gehrts, Division Manager<br>Bryant Giorgi, Operations                                                   | End User/Data Provider |
| OSU      | Nick Tufillaro, Researcher                                                                                    | Data Provider          |

#### Community Concerns:

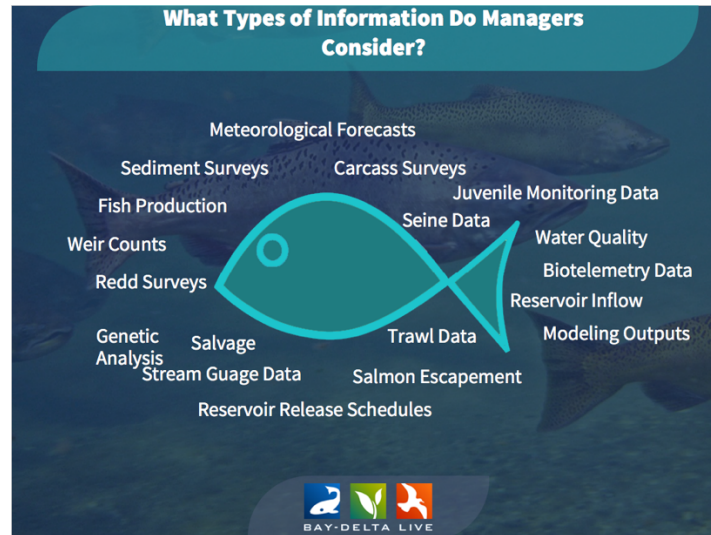
- There is a need for remotely-sensed tools to monitor turbidity in areas not covered by *in situ* monitoring stations and to assist with turbidity model calibrations.
- Prolonged drought conditions in California have necessitated an increased use of water resources from the Bay-Delta for both agricultural and municipal usage. Tools are needed to optimize water use and improve water quality.
- Diverting water from this region must be done in consideration of the Delta smelt, an endemic and federally protected endangered fish species that spawns within the Bay.
- The Bay-Delta region is heavily studied and monitored, and the stakeholders in this community would like increased data availability in one centralized location.
- In situ sensors are generally on channel margins, there is variability in the margins and mid channel turbidity that may give incorrect pictures of current turbidity conditions.
- Data exists from fixed sampling locations; assumptions are made about conditions between fixed sampling locations.
- Ability to adapt global algorithms to the Delta to increase resolution and accuracy.

**Project Need:** The State has an ~~compelling~~ interest in understanding how the Delta aquatic ecosystem will respond to upcoming changes to Sacramento's Regional WWTP, Eco Restore and California water fix. The impacts of all programs and changes will extend throughout the estuary, with potential consequences to water quality, ecosystem services, and water supply reliability. A program of research and enhanced monitoring is urgently needed to provide early warning about unexpected effects, and as a component of adaptive management. The proposed work will document current conditions and develop novel monitoring approaches that can help scientists and managers predict how the ecosystem will respond to these changes.

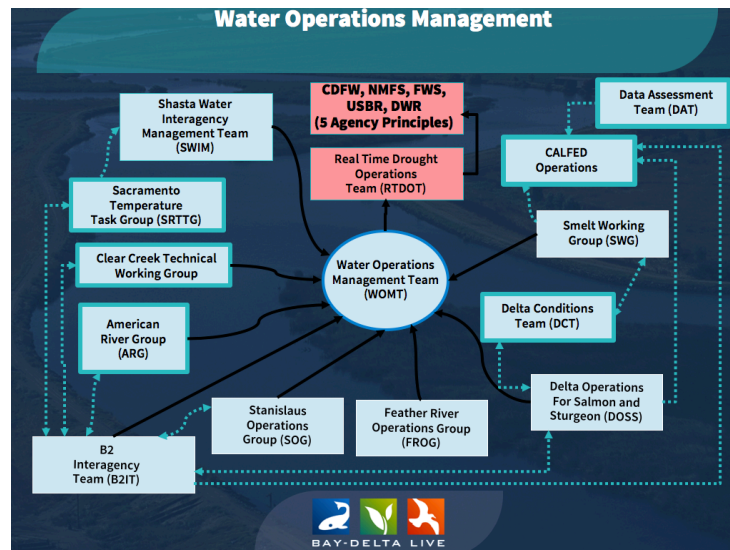
**Current Decision-Making Practices & Policies:** Currently, Bay-Delta water quality assessments and management policies are primarily informed via field observations from *in situ* monitoring stations and sediment transport models that interpolate turbidity values between these fixed station sites. While Bay-Delta variations in salinity are well-understood, turbidity is less so. Data from these snapshots and models is currently necessary to balance water resource needs with proper ecosystem functioning. Turbidity distributions are an important component of the overall water management decision-making process (including MWD), which includes determining the timing of pumping station operations to avoid accidental entrainment of endangered species like the Delta smelt. In addition, continued research efforts into the link between turbidity values

and preferred smelt habitat utilizing all available technologies, will help to ensure compliance with local and federal wildlife protections.

### Current Water Operations Data Overview



### Current Water Operations Decision Management



Detailed description of Workgroups included in Appendix

Decision Support, Visualization and Analytical Tools and Benefits:

| Product             | Earth Observations Used                | In-situ Data | Partner Benefits and Use                                                                                                                                                                                                                    | Software Release |
|---------------------|----------------------------------------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Turbidity Maps      | Landsat 8 OLI, Sentinel-2, Sentinel-3A | All          | This product will be used for improved monitoring and management strategies for pumping facilities, such as pumping restrictions, periodic closure, or Delta smelt salvage at pumping facilities in the southern Bay-Delta.                 | N/A              |
| Constituent Tracker | Landsat 8 OLI, Sentinel-2, Sentinel-3A | All          | This product will advance the Bay-Delta Live technology platform to provide the data and decision support tools to use new methods needed to view and analyze continuous water quality conditions at a finer spatial scale within the Delta | January 2018     |

Project Benefit to End User:

- Enhanced accuracy of constituent (turbidity) models will better inform water management strategies in the Bay-Delta. Models may help to decrease delta smelt entrainment and improve continuity of pumping operations to provide ample water-flow for municipal and agricultural purposes.
- Using multiple data inputs in addition to in-situ data will increase certainty of environmental conditions in the Delta.
- Decreased variability in conditions when recommendation is made to change operations

### Data Collection & Parameters:

| Platform & Sensor                        | Parameter(s)                                                      | Date range            | Frequency of Data Collection | Use                                                            |
|------------------------------------------|-------------------------------------------------------------------|-----------------------|------------------------------|----------------------------------------------------------------|
| Landsat 8, Operational Land Imager (OLI) | Turbidity (FNU)                                                   | April 2013-Current    | 16 day                       | Generating time-series turbidity maps and Comparison snapshots |
| Sentinel-2 MSI                           | Turbidity (FNU)                                                   | January 2016-Current  | 10 day                       | Generating time-series turbidity maps and comparison snapshots |
| Sentinel-3 OLCI                          | Remote sensing reflectance ( $R_{rs} sr^{-1}$ ); turbidity (FNU)  | December 2016-Present | 2-4 day                      | Generating time-series turbidity maps                          |
| CDEC                                     | Turbidity (FNU/NTU), Water Temperature (C/F), Chlorophyll-a, Flow |                       | 15 min                       | Time series                                                    |
| NWIS                                     | Turbidity (FNU/NTU), Water Temperature (C/F), Chlorophyll-a, Flow |                       | 15 min                       | Time series                                                    |
| DWR Turbidity Transects                  | Turbidity                                                         |                       | as requested                 | Comparison snapshots                                           |
| USGS Boat Transects                      | First Flush                                                       |                       | Daily                        | Comparison snapshots                                           |
| OSU Boat transects                       | TBD                                                               |                       | TBD                          | Comparison snapshots                                           |
| Wind Speed and Direction                 | As needed                                                         |                       | 15 Min                       | Generating time-series turbidity maps                          |
| NOAA Forecast                            | River, Tide, National Weather Service                             |                       |                              | Generating time-series turbidity maps                          |

### Ancillary Data Utilized:

- USFWS DJFMP and EDSM Fisheries Monitoring Data
- CDFW Salvage Data, Trawl Data (20 MM, SKT, FMWT, SLS, Townet), RST Data (Knights Landing, Tisdale)
- Delta Operations (NDOI, X2, Delta Inflow, Exports, Percent Inflow Diverted, Controlling Factors)
- NOAA Tide and River Forecasts

- UC Davis Arc Data
- DWR Yolo Bypass Fisheries Monitoring Data

#### **Models and Algorithms Utilized:**

- Anchor QEA Turbidity Model
- USGS Slack Water Algorithms
- 34 North Data Interpolation Algorithms
- Nick Tufillaro OSU Algorithms
- 34 North Visualization Model

Brief Description in this section, detailed methods in Appendix

#### **Software Utilized:**

- OpenNRM- Collaborative natural resource Management Application
- Esri ArcGIS – raster manipulation and analysis, image enhancement and map creation
- QGIS, open source mapping application
- R – data processing, statistical analysis, and figure generation
- Python – data processing and analysis
- MATLAB – data analysis and figure generation
- ACOLITE – atmospheric correction and processing for Landsat 8 OLI and Sentinel 2
- SeaDAS – corrections and processing for Sentinel 3
- SNAP – Sentinel visualization and analysis
- Adobe Creative Suite – graphics, time-series turbidity animations

#### **Data Use and Product Applications:**

34 North will focus on key operations, fisheries and storm events during the 2015-2016 drought conditions. See Appendix B (excel spreadsheet for corresponding satellite dates)

#### **1. Support Adaptive Management Decision Making and Monitoring of the Incidental Taker Permit for Water Fix**

**Description:** CDFW Issued an Incidental Take permit for the construction and operation of the Water Fix Project. This permit allows for the take of state and federally listed species through construction and operation.

**Regulatory Mandate:** Incidental Take Permit, Biological Opinions for the Water Fix

#### **Supporting Data:**

- Retrospective Analysis: remote sensing (dates provided below)
- Fish monitoring results
- Hatchery releases
- Construction implementation and status
- CDEC/NWIS Sensor Network

| Retrospective Dates for Events                                                                                                                                                                                                                                                                  | Date Source | Corresponding Satellite Imagery |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|---------------------------------|
| There are known salmonid and smelt cues for migration in and through this area. Collaboration with fisheries agencies (NMFS, USFWS, and CDFW) will help to identify key conditions, time periods, parameters, and locations for retrospective analysis and future indications for this project. |             | See attached excel appendix B   |

**Need:** During construction and operation of the "Water Fix" there is a ~~great~~ need for Adaptive Management practices to minimize adverse effects of construction and operations to listed species. It will be necessary to track and closely monitor catch as part of the issued incidental take permits. This will help to prevent exceedance of the limit through communication of status, as well as provide information on coming trends in environmental conditions that may cue salmonid and smelt species to migrate in and through the area of concern.

## 2. Delta Cross Channel Gate Operations

**Description:** In the months of October and November conditions upstream of the Delta are monitored through NMFS RPA Action Suite IV.1. There are specific triggers that indicate outmigration cues for salmonid species coming from the Sacramento River and tributaries. Changes in these environmental conditions and increased catch of salmonids upstream of the Delta trigger closure of the Delta Cross Channel Gates to prevent entrainment of fish into the South Delta and increase survival chances.

**Regulatory Mandate:** NMFS RPA Action Suite IV.1,

**Supporting Data:**

- Catch indices (Knights Landing, Sacramento Trawl, Sacramento Seine)
- Mill Creek, Deer Creek, Wilkins Slough Flow Data and flow change
- Knights Landing Temperature

| Retrospective Dates for Events                                           | Date Source |
|--------------------------------------------------------------------------|-------------|
| First Alert Triggered: 10/3/17, 10/14/17-12/5/16                         | DOSS        |
| 11/4/16 KNCI was 16.1, KLCI on 11/5/16 was 10.2, KLCI on 11/6/16 was 5.3 | DOSS        |
| Second Alert Triggered 11/21/16, 11/23/16-11/27/16, 11/29/16-12/3/16     | DOSS        |



|                                                                                |      |
|--------------------------------------------------------------------------------|------|
| Gates Closed on 11/6/16 and opened on 11/15/16 (Catch Index Trigger)           | DOSS |
| Gates Closed on 11/25/16 and opened on 11/29/16 (Catch Index Trigger on 11/23) | DOSS |
| Gates Closed 12/1/16 to 1/31/17 and from 2/1/17 to 5/20/17                     | DOSS |
| From May 21-June 15 gates will be closed for up to 14 days                     | DOSS |

**Need:** Increased certainty of environmental conditions upstream of the Delta, to aid managers in correct assessment of juvenile salmonid migration conditions.

### 3. Factors Controlling Exports and Diversions

**Description:** Various RPA's (NMFS and USFWS) are designed to limit entrainment of salmon and smelt into the South Delta.

**Possible Factors:**

- Seasonal Salinity Management
- D-1641 E:I Ratio
- -5000 cfs OMR limit
- operational capacity

**Regulatory Mandate(s):**

- RPA IV.2.1
- RPA IV.2.3
- D-1641

**Supporting Data:**

- OMR Flow
- Turbidity and Flow Data
- Salvage

| Retrospective Dates for Events                                                                                       | Date Source |
|----------------------------------------------------------------------------------------------------------------------|-------------|
| Seasonal Salinity Management: 10/18/16-10/29/16, 11/15/16-11/26/16,12/6-12/12                                        | DOSS        |
| D-1641 E:I ratio of 65% 10/30/16-11/8/16                                                                             | DOSS        |
| 11/27/16-12/6/17, 1/31-2/7 Exports at Capacity                                                                       | DOSS        |
| 12/15/16-12/16/16 Exports reduced by 1000 cfs for LFS protection                                                     | DOSS        |
| 12/17-27 Voluntary export reductions to 7000 cfs combined for OMR and turbidity management for the protection of DSM | DOSS        |
| 1/17-18, 1/21-22 -5000 cfs OMR limit                                                                                 | DOSS        |

|                                                                                                           |      |
|-----------------------------------------------------------------------------------------------------------|------|
| 4/1/17-5/15/17 I:E Ratio controls exports (because flow on Vernalis >21,750 cfs ratio is not controlling) | DOSS |
| 5/15/17 I:E Ratio Controls Exports                                                                        | DOSS |

**Need:** The volume of water exported via the pumps in the Delta is controlled by regulatory actions for Beneficial Uses, water quality management, and endangered species preservation.

#### 4. Old and Middle River Flow Management

**Description:** To decrease the risk of entrainment of sensitive fish species into the South Delta the net negative flows of Old and Middle River are controlled when fish migration conditions or large numbers of fish are detected.

**Supporting Data:**

- Salvage of Threatened and Endangered Fish
- Turbidity and Flow Data
- Exports/Pumping
- Fish catch USFWS and CDFW Monitoring Programs

**Regulatory Mandate:** NMFS RPA IV.2.3, NMFS RPA IV.2.1

| Retrospective Dates for Events                                    | Date Source |
|-------------------------------------------------------------------|-------------|
| 1/1 OMR no more negative than -5000 (IV.2.3)                      | DOSS        |
| Positive OMR values coinciding with max pumping/demand: 2/18-5/29 | DOSS        |

**Need:** Limits to the maximum net negative flow of Old and Middle River is a primary method for reducing the risk of entrainment of listed and endangered fish species into the South Delta.

#### 5. DWR Boat Operations for Turbidity Transects

**Description:** (from fact sheet) The DWR Turbidity Transects will obtain a finer resolution of turbidity concentration in the South Delta. Turbidity is a key environmental trigger in the USFWS and NMFS Biological Opinions for anadromous fish and Delta Smelt, this mid-channel turbidity monitoring will be an important supplement to the existing continuous water quality station network in the Central and South Delta. Daily turbidity transects will create a necessary 'early warning' system for improved efficiency between State Water Project operations and Delta Smelt and salmonid trawl efforts.

**Supporting Data:**

- Boat Transect Data
- CDEC Turbidity Monitoring Data
- Salvage

**Regulatory Mandate:** Drought Operations Contingency Plan

| Retrospective Dates for Events | Date Source |
|--------------------------------|-------------|
|--------------------------------|-------------|

|          |     |
|----------|-----|
| 1/3/17   | DWR |
| 12/19/16 | DWR |
| 12/27/16 | DWR |
| 1/6/17   | DWR |
| 1/13/17  | DWR |
| 1/19/17  | DWR |
| 2/7/17   | DWR |
| 12/22/16 | DWR |
| 12/29/26 | DWR |

**Need:** Turbidity Boat Transects are frequently used by the Smelt Working Group (SWG) in assessing Turbidity conditions and evaluating risk to Delta Smelt. The transects are often needed in adverse weather conditions, this tool would minimize operational cost and increase frequency of data collection (through models and satellite) for the SWG.

## 6. Delta Smelt Life Cycle Model and Habitat

### Description:

- Predict migration based on environmental conditions/ time of year, refine conceptual model.
- Conduct retrospective analysis of DSM Catch and environmental conditions and location in the Delta to support the Life Cycle Model.
- Determine if fish are being caught where the life Cycle model (spatially, temporally, in the right habitat, and right Water Quality conditions) would predict.

### Supporting Data:

- USFWS CDFW Smelt Catch
- LSZ and X2

### Regulatory Mandate:

| Retrospective Dates for Events | Date Source | Corresponding Satellite Imagery |
|--------------------------------|-------------|---------------------------------|
| SKT 1: 1/9/17-1/13/17          | CDFW        |                                 |
| SKT 2: 2/3/17-2/9/17           |             |                                 |
| SKT 3: 3/6/17-3/9/17           |             |                                 |
| SKT 4: 4/3/17-4/6/17           |             |                                 |
| SKT 5: Need Dates              |             |                                 |
|                                |             |                                 |
|                                |             |                                 |

Delta Smelt Risk Assessment Matrix:

| Life Stage                                                                                               | Adults                          | Adults                          | Adults                                        | Adults and larvae                                                   | Adults and larvae                                                                        | Larvae and juveniles                                                                                                          | Larvae and juveniles                                                  | Juveniles                                                             |
|----------------------------------------------------------------------------------------------------------|---------------------------------|---------------------------------|-----------------------------------------------|---------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------|
| Previous Year's Fall Midwater Trawl Recovery Index (1)                                                   | Index below 74                  | Index below 74                  | Index below 74                                | Index below 74                                                      | Index below 74                                                                           | Index below 74                                                                                                                | Index below 74                                                        | Index below 74                                                        |
| Risk of Entrainment (2)                                                                                  |                                 |                                 |                                               | X2 upstream of Chipps Island and temps are $\geq 12^{\circ}$        | X2 upstream of Chipps Island and temps are between $12^{\circ}$ and $18^{\circ}\text{C}$ | X2 upstream of Chipps Island and mean delta-wide temps $<18^{\circ}\text{C}$ and south delta temps below $25^{\circ}\text{C}$ | X2 upstream of Chipps Island and temps are below $25^{\circ}\text{C}$ | X2 upstream of Chipps Island and temps are below $25^{\circ}\text{C}$ |
| Duration of Spawning period (number of days temperatures are between $12$ and $18^{\circ}\text{C}$ ) (3) |                                 |                                 |                                               |                                                                     | 39 days or less by April 15                                                              | 50 days or less by May 1                                                                                                      |                                                                       |                                                                       |
| Spawning Stage as determined by spring Kodiak trawl and/or salvage (4)                                   |                                 |                                 | Presence of Adults at spawning stage $\geq 4$ | Adult spawning stage $\geq 4$                                       | Adult spawning stage $\geq 4$                                                            |                                                                                                                               |                                                                       |                                                                       |
| smelt distribution (5)                                                                                   | See footnote #5                 | See footnote #5                 | See footnote #5                               | See footnote #5 or negative 20mm centroid or low juvenile abundance | Negative 20mm centroid or low juvenile abundance                                         | Negative 20mm centroid or low juvenile abundance                                                                              | Negative 20mm centroid or low juvenile abundance                      | Negative 20mm centroid or low juvenile abundance                      |
| Salvage Trigger (6)                                                                                      | Adult concern level calculation | Adult concern level calculation | Adult concern level calculation               | Adult concern level calculation                                     |                                                                                          | If salvage is above zero                                                                                                      | If salvage is above zero                                              |                                                                       |

| Tools for Change (7)                       | December | January | February | March | April | May | June | July |
|--------------------------------------------|----------|---------|----------|-------|-------|-----|------|------|
| Export reduction at one or both facilities | X        | X       | X        | X     | X     | X   | X    | X    |
| Change in barrier operations               |          |         |          |       |       | X   | X    | X    |
| Change in San Joaquin River flows          |          |         |          | X     | X     | X   | X    | X    |
| Change position of cross channel gates     |          |         |          |       |       | X   | X    |      |

<https://www.fws.gov/sfbaydelta/CVP-SWP/Documents/SmeltWorkingGroup/dsram.pdf>

**Need:** To better preserve the endangered Delta Smelt, it is crucial to understand the most suitable conditions and locations for delta smelt. This includes: environmental conditions, locations, time of year, habitat type, etc.

## 7. Managing/Minimizing Salvage and Entrainment Risks

**Description:** Incidental Take Permits are issued each year for salvage of Delta Smelt at the Export (CVP and SWP) facilities. The Incidental take permit is issued each year based on the previous year's FMWT index. Incidental take is closely monitored and exports are adjusted based on ITL. Operations of the export facilities are controlled by the ITL. Possible management questions include: Is there a link to increased salvage of Delta or Longfin Smelt and Water Quality conditions? If there is a link can Water Quality trends accurately predict uptakes in salvage. If this has already been done, how long ago? Are conditions in today's Delta the same as when the algorithm was developed? How does the constituent tracker become another tool for predicting uptakes in DSM Salvage? Constituent tracker to predict uptake in incidental take?

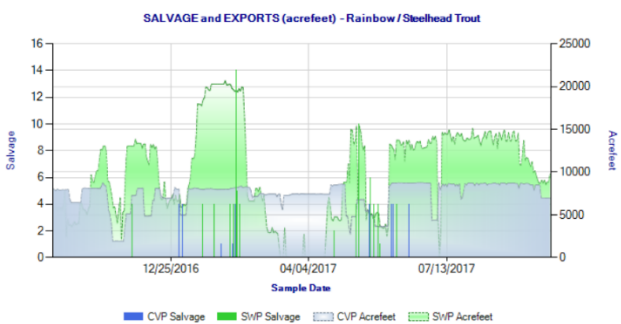
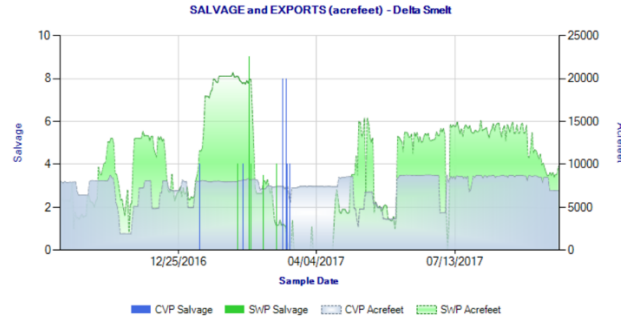
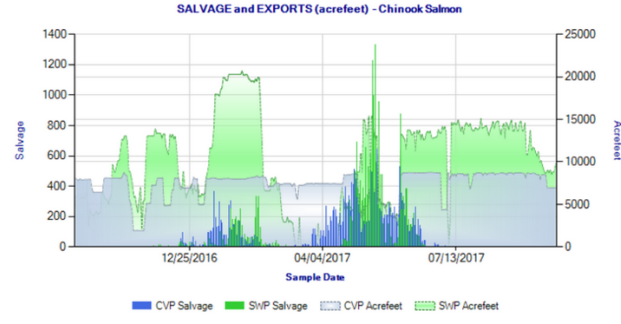
### Supporting Data:

- CDEC/NWIS Turbidity, Electrical Conductivity, Flow, Water Temperature
- Tide stage

## Regulatory Mandate:

Salvage Concern for Delta Smelt

- Adult: Dec-March
- Juv. May-June

| Retrospective Dates for Events                                                                                                                                          | Date Source |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| 2016- days of high salvage (smelt and salmon)                                                                                                                           | CDFW        |
| 12/18 salvage of Chinook spiked to 30 at each facility (clipped)                                                                                                        | CDFW        |
| 12/19-12/20 wild chinook salvaged                                                                                                                                       | CDFW        |
| 1/30/17 unclipped fall run chinook salvaged                                                                                                                             | CDFW        |
| 3/27/27 unclipped spring-run chinook salmon salvaged                                                                                                                    | CDFW        |
|  <p>Please note these results may be preliminary and are thus subject to change.</p>  | CDFW        |
|  <p>Please note these results may be preliminary and are thus subject to change.</p> | CDFW        |
|  <p>Please note these results may be preliminary and are thus subject to change.</p> | CDFW        |

**Need:** Can environmental conditions in and upstream of the Delta be used to predict high salvage events. Using this knowledge can we further maximize pumping/export operations minimize risk to species for entrainment and salvage. Need to match salvage spikes (graphs below) with Satellite Imagery, create a visual with salvage spikes and satellite dates.

## 8. First Flush Tracking

**Description:** Action 1 of the Delta Smelt RPA's uses turbidity to control exports at the pumping facilities. Changes in turbidity, deemed the "First flush" are a known indication of delta smelt migration for spawning. By monitoring turbidity conditions in the Delta, the goal is to reduce exports to limit the entrainment/salvage of Delta Smelt.

### Supporting Data:

- Turbidity at: Prisoner's Point (PPT), Holland Tract (HOL), Victoria Canal (VCU)
- Salvage
- X2
- CDFW Trawls, EDSM Trawls

**Regulatory Mandate:** USFWS RPA Action 1 Part A- Dec 1-20 based on environmental conditions SWG can recommend changes, After Dec 20- Part B goes into effect if 3-day average Turbidity exceeds 12 NTU

| Retrospective Dates for Events                                                   |
|----------------------------------------------------------------------------------|
| 2016 First Flush event (or series of high flow events)                           |
| Could use date range of atmospheric rivers from 2016-2017                        |
| Part A is limited to Dec 1-Dec 20                                                |
| December 13 SWG Recommended a start date to action part A (Recommended to USFWS) |

**Need:** The migration of Delta Smelt is linked to the "First Flush" event. It is critical to understand the timing of this first lush event and corresponding environmental conditions to predict movement of Delta smelt and make changes to operations accordingly.

## 9. Water Temperature Monitoring (For Smelt Working Group)

### Description:

- For RPA Action 1 and 2: 3 station average water temperature, stations: Antioch, Rio Vista Bridge, Mossdale 12 C 3 station daily average
  - Daily Average temperature between 12 and 18 indicates "spawning day"
  - because of high flow conditions on Sac and Vernalis Action Offramp was initiated
- RPA Action 1 Offramp monitoring: 3 day >25C at Clifton Court Forebay (CCF)

### Supporting Data:

- CDEC Water temperature Insitu data (3 station average: Antioch, Rio Vista Bridge, Mossdale)

**Regulatory Mandate:** USFWS RPA Action 1

**Need:** Temperature is monitored as a cue to end delta smelt migration and begin spawning. Temperature at Antioch, Rio Vista Bridge, and Mossdale having a combined daily average of 12 C, is an indication that spawning has or will begin for delta smelt. Satellite imagery would increase the spatial resolution of temperature in this key area.

#### 10. D-1641 Compliance Monitoring

**Description:**

**Supporting Data:**

- CDEC Flow, Turbidity, Electrical Conductivity Data

**Regulatory Mandate:** DWR Water Right Decision 1641

#### 11. Sacramento River Temperature Compliance Monitoring –

**Description:** Monitoring fisheries and water temperature to manage upper reservoirs.

**Supporting Data:**

- CDEC Sacramento River Water Temperature Data (Filtered using BDL 7DADM filter)
- CDFW Fish Survey data

#### 12. Fall X2 Monitoring-

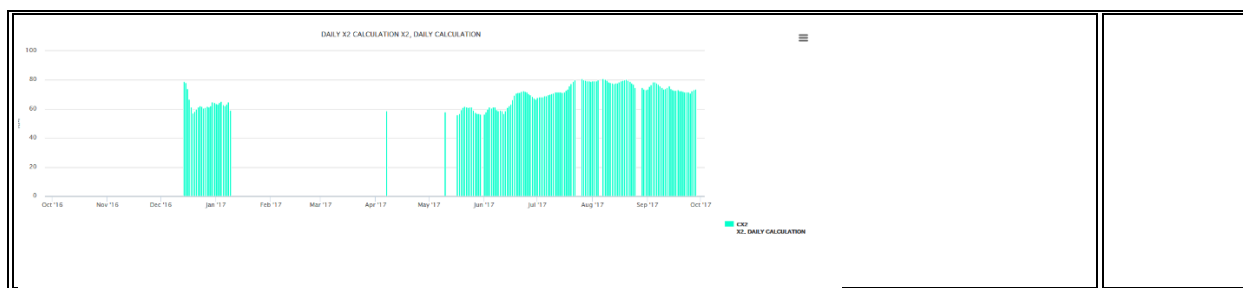
**Description:** RPA to manage Delta Outflow so that X2 averages 74 km or 81 km (based on previous years Water Year Type)

**Supporting Data:**

- Flow Data (Delta Inflow, Net Delta Outflow, Sacramento River Flow, San Joaquin River Flow, QWEST)
- X2 Daily Location (CDEC)
- Water Year Classification
- Water Temperature
- USFWS and CDFW Smelt Catch

**Regulatory Mandate:**

| Retrospective Dates for Events                                                       | Date Source |
|--------------------------------------------------------------------------------------|-------------|
| Imagery from dates where X@ crossed 56 km and 81 km thresholds                       | CDEC        |
| Comparison of environmental conditions on Dates where X2 daily average value matches | CDEC        |



Fall X2 is monitored in September and October- useful data to have is all satellite dates in this date range, then would look at the X2 values for those dates. (see appendix B)

<http://www.baydeltalive.com/maps/14545>. Comparison of satellite images when values are the same but dates are different, detect trend in imagery.

**Need:** X2 and the Low Salinity Zone (LSZ) is the known ideal habitat for Delta Smelt, a federally listed endangered species endemic to the Bay Delta. X2 is currently only reported when it is greater than 56 km and less than 81 km. Tracking of X@ and environmental conditions (Water Temperature, Electrical Conductivity, and Turbidity) in the LSZ in combination with fish catch can give a more robust picture of Delta Smelt population dynamics.

### 13. Hatchery Releases and Fish Survival:

**Description:** Linking hatchery release location, date, and amount with environmental conditions and eventually uptake in salvage following release. Aim to determine if environmental data can be used to predict release survival rate.

#### Supporting Data:

- Hatchery Releases
- CDFW Salvage
- Acoustic Telemetry Network

#### Regulatory Mandate:

| Retrospective Dates for Events                                                | Date Source |
|-------------------------------------------------------------------------------|-------------|
| CNFH release of 2nd Spring Run surrogates on 12/21/16                         | CDFW        |
| CNFH 1/2-7 Steelhead production release                                       | CDFW        |
| CNFH Release 1/9/17 genetic late-fall run                                     | CDFW        |
| LSNFH release of winter-run chinook on 2/2/17 (some were acoustically tagged) | CDFW        |
| CDFW release of winter run steelhead on the American River 2/22-24            | CDFW        |
| 3/20 1,000,000 spring-run Chinook release from Feather River Hatchery         | CDFW        |

Full List of hatchery releases for WY 2016 and 2017 can be found here:

<ftp://ftp.dfg.ca.gov/salvage/SALMON%20AND%20STEELHEAD%20HATCHERY%20RELEASES/SALMON%20AND%20STEELHEAD%20HATCHERY%20RELEASE%20SUMMARY%20TABLE/>

**Need:** Increase the opportunities for hatchery fish survival by releasing them at when environmental conditions are optimal.

#### Constituent Tracker Data Pipeline Key Factors:



- Frequency of data collection
- data duration
- data source
- data owner, along each step of the pipeline
- initial file format
- Corrections calculated
- Water Quality Processing Algorithm
- Post processing/packaging
- color correction
- product format

Data Input Types:

Input- Satellite Imagery Turbidity (OSU)

Input-Satellite Imagery Chlorophyll a (Merced)

Input- Satellite Imagery (Water Temperature)

Input- Insitu Data

Input- DWR Transect Data

Input- OSU Transects

**METADATA requirements with pipeline-** have a naming convention, and chain of command in document

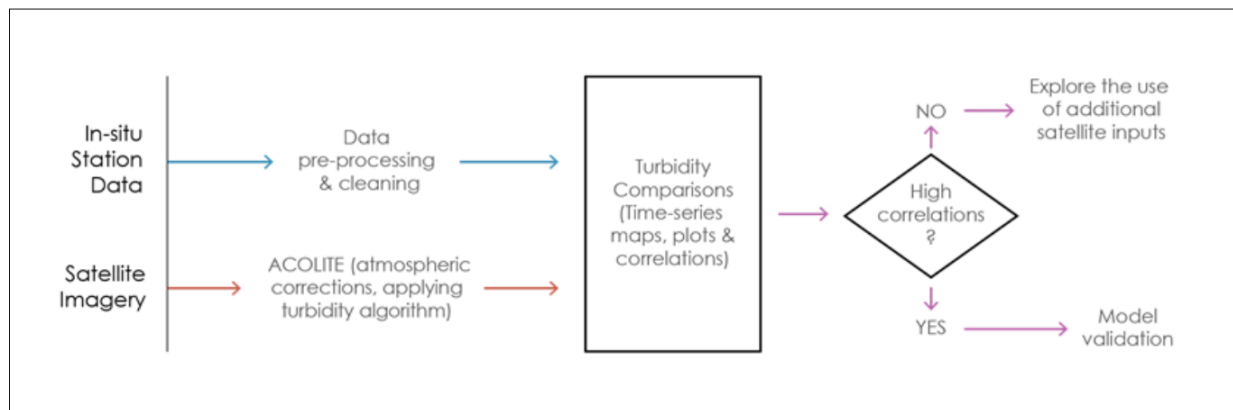
- File Storage
- Naming Convention
- Chain of Command
  - who has handled and edited, what edits, date edited
- Archiving
- Download options and formats (geotiff)

End product- geotiff

Pipelines for data use snapshot and ops

**Methodology and Data Pipeline:**

Methodology (from DEVELOP Presentation)



## APPENDIX A: Workgroup Detail

1. Workgroups and Technical Teams: Description of each workgroup, agencies/entities involved, laws/guidelines, data used for decision-making

1. Delta Operations for Salmonids and Sturgeon (DOSS)

|                              |                           |
|------------------------------|---------------------------|
| Participating Agencies       |                           |
| Area of Focus                | Salmon and Sturgeon       |
| Data Used                    | CDEC, CDFW, USFWS,        |
| Regulatory Mandates Enforces | NMFS/NOAA BiOps and RPA's |
| Active                       | October-June              |

2. Smelt Working Group (SWG)
  3. Delta Conditions Team (DCT)
  4. Water Operations Management Team (WOMT)
  5. Data Assessment Team (DAT)
  6. Sacramento river Temperature Task Group (SRTTG)
2. Detailed Algorithms for Constituent Tracker and OSU Methods

Bay Delta Live current turbidity/salinity model description:

### BDL Model Background

In 2015 and in collaboration with Metropolitan Water District, USGS, 34 North and Resource Management Associates, Turbidity Tracker version 1 for visualizing and analyzing turbidity and salinity conditions in the Sacramento-San Joaquin Bay-Delta was developed. The project, which is currently used by water operators, is available on BDL as data dashboards and visualization tools (<http://www.baydeltalive.com/turbidity>) and (<http://www.baydeltalive.com/salinity>). These publicly available data products provide a visual interpolation and provide correlating analytics of turbidity and salinity conditions for managers, scientists, and stakeholders who aim to better understand the general hydrodynamic and water quality conditions in the Sacramento Bay Delta. The original version of this model and visualization tool collects real-time constituent data via web services from the Department of Water Resources – California Data Exchange Network (CDEC). The spatial interpolation for the grid uses the Laplace equation which computes the weights at each node. The grid, produced for web delivery, is at a 500-meter resolution and the time frame of the model defaults to a duration of the last 7-days. Time range options are defined by the user who can control duration or specific dates using the advanced timeline tools. The visualization allows users to play through the data at 15-minute, 1-hour, 6-hour, 12-hour or daily time steps. The success of these products as a tool for visualizing important environmental conditions has prompted the need to expand the constituent base (turbidity, nutrients), the implementation of improved data handling, and algorithms, as well as incorporating new methods for visualizing the data. Three techniques will be explored, led by Jon Burau and others at USGS. 34 North will collaborate with USGS after their initial investigation is complete and

experiment with the various methodologies that best define the constituent fields between sampling stations using the web application. The following techniques may vary depending on the findings discovered by the first phase of the USGS investigations.

#### Technique 1: Euler-Lagrange transformation

The measurement of the velocity of a water parcel measured at a fixed site, a Eulerian velocity, does not necessarily represent the velocity that water parcels experience as they travel between sites. The velocity of the water parcel as it travels along its flow path between sites is called the Lagrangian velocity. Consequently, the Eulerian/Lagrangian transformation for each measurement location – essentially a relationship between the fixed site velocity measurements and the velocity a parcel of water experiences – may be used to improve estimates. This is executed by using the timing of a high-gradient front at each station to deduce the tidal excursion integrated Lagrangian velocity for stations within a tidal excursion.

#### Technique 2 – Use of a conservative tracer

Once the Euler-Lagrangian transformation at a station is determined, the continuous time series of conductivity -- a conservative tracer may be used to determine the dispersive term. If the timing of the peak of the front of a conservative tracer measured at one site matches the arrival time of the peak of the same front at a down current site, then a correction based on the second derivative of the spatial distribution may be made to account for differences in the shape of the front because dispersion does not affect arrival timing, only advection does.

#### Technique 3 – Data assimilation or pattern matching

If the tidal excursion is longer than the distance between stations, pattern matching could be used to conform the predicted spatial structure from an up-current site to the actual measurements made at the down-current site. In other words, change the shape and timing of the predicted spatial structure at the downstream site by applying empirical corrections. For example, if the peaks in a front arrive early at the down current site compared to the measured data there, then the Lagrangian current speed needs to be slower between stations. Similarly, if the concentration is lower at the down-current measurement location a dispersive or sink term correction may be appropriate. Conversely, if the concentration at a down-current site is greater, a source term may be appropriate.

Procedure: 34 North will build on previous work done in collaboration with USGS that allows the users to visualize the constituent fields between sampling stations by customizing existing code with techniques established by USGS. One of the challenges of this sub task is to develop techniques to focus on how to adjust constituent values of a particle from one station as it crosses an upstream or downstream station. 34 North will explore techniques and UI elements to adjust the particle values between stations during the tidal cycle from the upstream and downstream stations in real time. Values will reset at the end of each tidal cycle.