Statewide ET Project and Remotely Sensed ET Data: Applications for the Oregon Water Resources Department

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Executive Summary

Purpose. This document describes datasets and applications of the Statewide Evapotranspiration (ET) Project and how those data will be applied to the work of the Oregon Water Resources Department (OWRD).

Applications. Appropriate applications of Statewide ET Project data are identified based on the Oregon Water Resources Department's (OWRD) current needs and understanding of data accuracy (Table ES-1).

Final Deliverables. As directed in HB 2018 (2021), OWRD worked with researchers from Desert Research Institute and OpenET to develop a peer-reviewed report and dataset for the Statewide ET Project. Estimates were produced for statewide irrigation consumptive use and open water evaporation at major reservoirs from 1985 to 2022.

Data Accuracy. Statewide ET Project data were produced using satellite imagery, models, gridded weather data, and Oregon water rights. Uncertainty varies by location depending on several factors, including: (1) the number of fields or area covered, (2) vegetation type, (3) season, (4) year, which determines the number of satellites available, and (5) Oregon water rights information. Uncertainty for monthly ET estimates is 10-20%, approaching field-based in situ methods. Uncertainty for irrigation consumptive use estimates is not fully quantified but is thought to be within 10-30%, while uncertainty for applied irrigation may be larger.

OWRD Applications. Applications of Statewide ET Project data were evaluated using four criteria: (1) the historical use of aerial and satellite imagery at OWRD, (2) data availability and parameters, (3) data accuracy, and (4) purpose of use (e.g., scientific or regulatory; sole, primary, or supporting evidence). The data can reasonably support basin studies, storage distribution estimates, water budgets, and field work planning, and OWRD is exploring use for transfers, planning, Harney Groundwater CREP, pond evaporation, and the surface water availability model update .

Applications OWRD is Not Pursuing at This Time. At this time, OWRD will not use these data as the sole source of information for: in-season regulatory actions, establishing use or non-use, quantifying applied water for one or a few fields requiring highly accurate accounting, or meeting water use reporting requirements (i.e., pumped or diverted).

Ongoing Review. As new information becomes available, OWRD will periodically reevaluate applications based on an improved understanding of these data.

Table ES-1. Summary of applications of remotely sensed and Statewide ET Project data for OWRD.

Currently Supported Applications	Potentially Supported Applications	Not Supported Applications at This Time
Groundwater basin studies	Update to Oregon's Water Availability Reporting System*	Direct regulatory evaluation of duty
Reservoir evaporation	Water rights transfers (i.e., change in character of use)*	Near real-time or in-season evaluation of changes in irrigation application
Water budgets for scientific inquiries	Evidence of use*	Primary/sole evidence for evidence of non-use
Field work planning	Harney CREP, other conservation programs*	Applications where applied water estimates for one or only a few fields are required with high accuracy
Identifying regions with agricultural activity	Pond evaporation*	Water use reporting
Large-scale analyses of ET, consumptive use of irrigation, applied water	Evidence of non-use; forfeiture†	
Place-based planning and water development projects	Identifying irrigation that occurs outside a place of use designated by a water right†	
	Certain conditions specified by a water right§	

* Under consideration † May be appropriate in conjunction with other data § Depends on data accuracy needs and availability

Purpose

This technical memorandum describes datasets and applications of the Statewide Evapotranspiration (ET) Project for the Oregon Water Resources Department (OWRD). Statewide ET Project data include ET, consumptive use of irrigation, and applied water from irrigation. However, appropriate application requires understanding of OWRD's historical use of remote sensing products, data accuracy, and the purpose of the use. As new data and information become available, OWRD will periodically review new data and reevaluate applications based on improved understanding.

This document contains the following sections:

- Executive Summary
- Introduction to the Statewide ET Project
  - Definitions
- Overview of Remote Sensing Data
  - OWRD's Use of Aerial and Satellite Imagery
  - Data from the Statewide ET Project
- Data Accuracy
- Applications of Statewide ET Data
  - Current Applications and Considerations
  - Applications that Inform Regulatory Activities
  - Applications that OWRD is Not Pursuing at this Time

Introduction to the Statewide ET Project

Oregon House Bill 2018 directed OWRD to develop a statewide dataset for evapotranspiration (ET), consumptive use of irrigation, and applied water from irrigation. This effort, called the Statewide ET Project, was a collaborative project between Desert Research Institute (DRI), OpenET, and OWRD scientists and involved satellite imagery, geospatial data, and hydrologic modeling (Huntington et al. 2025).

This document describes Statewide ET Project products and discusses applications and best uses of these data. This document also reviews OWRD's use of aerial and remote sensing satellite imagery to provide context for the Statewide ET Project and where these new datasets provide additional information and potential expanded applications for OWRD.

OWRD is committed to using best available science for decision-making and, as this dataset matures, may adapt new applications based on new information, new data products, and improved understanding of appropriate applications. The data and applications described below are based on OWRD's current needs and understanding of data accuracy, which will be periodically reevaluated.

Definitions

Applied water from irrigation is the amount of irrigation water applied to a field, and what is measured at the field with a flowmeter. For the Statewide ET Project, applied water from irrigation is determined by scaling the consumptive use of Irrigation by the irrigation efficiency of the field's irrigation system (i.e. some irrigation water may run off, infiltrate past the root zone, drifts, etc).

Consumptive use of irrigation is irrigation water that is removed from and can no longer be used by the source hydrological system. This is the fraction of total ET that is derived from irrigation water. In practice, this is determined by subtracting the contribution of precipitation, often called effective precipitation, from total ET.

Evapotranspiration (ET) is the combination of evaporation from the land surface and transpiration from plant tissues. Evaporated water may be from precipitation, irrigation, and other water sources.

Net Irrigation Water Requirement (NIWR) is the amount of additional water that needs to be supplied through irrigation to ensure optimal crop growth. NIWR is determined by subtracting the contribution of precipitation from modeled crop ET.

Normalized Difference Vegetation Index (NDVI) is a vegetation index that uses properties of light, namely the ration between near-infrared light and visible red light, to understand land surface properties. NDVI responds to vegetation growth and vigor. OWRD has used NDVI from satellite data to understand if irrigation likely occurred on a property. NDVI was a supporting dataset for the Statewide ET Project.

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft).[1]

Overview of Remote Sensing Data

OWRD's Use of Aerial and Satellite Imagery

The State of Oregon has used aerial- and satellite-based imagery and data to inform natural resources management since data first became widely available through federal sources[2] including imagery-based assessments of land cover and land use since the mid-1990s. OWRD has also used this imagery for several purposes, such as evaluating whether irrigation may have occurred using NDVI. These images can show relative vegetation vigor—an indirect measure of applied irrigation via vegetation growth—but not quantify the rate or volume of water use. As satellite technology and methods have advanced, remote sensing approaches to estimate consumptive use through ET have improved. Thus, remotely sensed estimates of vegetation vigor, relative water use, and ET are increasingly used at OWRD.

[1] https://www.usgs.gov/faqs/what-remote-sensing-and-what-it-used
[2] U.S. Department of Agriculture National Agricultural Imagery (NAIP), NASA, and U.S. Geological Survey Landsat programs (https://landsat.gsfc.nasa.gov/)

Aerial Imagery

Aerial images are acquired by cameras onboard aircraft, which collect each image at a specific date and time. OWRD routinely uses imagery from the U.S. Department of Agricultural National Agriculture Imagery Program (NAIP), Oregon Statewide Imagery Program (OSIP), and Google Earth (Table 1). Image resolution can be high, ranging from centimeters to meters. However, images are not available for every year and do not contain enough spectral and temporal information to accurately compute growing season or annual ET. OWRD uses aerial images for a variety of purposes including: (1) understanding agricultural activities, (2) identifying agricultural fields, (3) assessing irrigation patterns, (4) field work and planning, (5) understanding hydrology infrastructure, such as diversions and canals, and (6) providing evidence of use for regulatory activities.

Satellite Imagery

Satellite data, for which large public repositories are available, are often collected more frequently (e.g., days-weeks) than aerial imagery. Satellite data contain spectral (i.e. light within the electromagnetic spectrum) information that can be used to quantify vegetation vigor, irrigation status, and ET through time. This document focuses on two Landsat-derived datasets currently used by OWRD: NDVI and ET (Table 1).

OWRD has used NDVI to map vegetation and its "greenness." During the growing season, an agricultural area with higher NDVI values than nearby non-irrigated areas can indicate the "greener" field has been irrigated. NDVI data have been used to (1) support technical staff in scientific studies, (2) show evidence of irrigation for water right transactions, and (3) provide supporting evidence of use for regulatory activities.

OWRD and others have used ET based on remote sensing to quantify water fluxes in the state (Beamer and Hoskinson, 2021, Bromley et al., 2024, Snyder et al., 2012, Velpuri et al., 2020). More recently, OpenET provides Landsat-based ET data from multiple commonly used models and calculates a single ensemble value from those models (Melton et al., 2022; https://etdata.org). These data were used for Oregon's Statewide ET Project. OWRD staff have used these data in combination with other imagery and information to: (1) identify areas where irrigation may have occurred, (2) assist staff with field work planning, and (3) prompt further investigation.

Table 1. Aerial and satellite data routinely used by OWRD.

Data	Resource	Spatial Resolution	Repeat Cycle	Period of Record
Aerial Imagery	NAIP, OSIP, Google Earth, others	centimeter to meter	~1 per year or less; varies by source	OWRD maintains NAIP images from 1995
NDVI	Landsat, other satellites	30 meter; depends on satellite/sensor	8-16 days; has varied over time	1984-present
ET	OpenET (satellite data, gridded weather data, and models)	field-scale	daily-monthly	past 5 years + current year (through public user interface)

Data from the Statewide ET Project

Data from the Statewide ET Project were produced at a statewide scale using remote sensing imagery, models, gridded weather data, and OWRD water rights (Huntington et al., 2025). OpenET model runs were combined with crop demand modeling and gridded weather data to remove the contribution of precipitation from ET, allowing for estimates for consumptive use of irrigation and applied water. Collectively, this has refined and potentially expanded applications for remotely sensed data at OWRD.

Data available from the Statewide ET Project include consistently processed, documented, and spatially and temporally complete records of ET, consumptive use of irrigation, applied water from irrigation, and NIWR for Oregon from 1985 to 2022 (Table 2). ET and consumptive use of irrigation can be obtained for agricultural fields within Oregon's hydrological domain, but applied water is not provided for other states. Data also include modeled reservoir evaporation for key reservoirs and shallow pond evaporation. Also included are gridded raster data for gridMET reference evaporation and precipitation (Abatzoglou, 2013).

Table 2. Data generated from the Statewide ET Project.

Dataset	Purpose	Spatial and Temporal Scale
Agricultural field boundary dataset	Agricultural fields from aerial and satellite imagery (~259,000)	Field scale; does not change with time
Field attributes – irrigation data (status, system, source water)	Assess if a field was irrigated, how, and source water type according to the field's water right (ground or surface)	Field scale; some parameters are statics across time and others vary annually
DRI geodatabase (weather-based ET modeling)	Determine consumptive use of irrigation and applied water from irrigation by partitioning total ET into precipitation and applied irrigation fractions. ET and NIWR are also available.	Field, HUC-12, and HUC-8 scale; monthly or annual, 1985-2022 (Nov. and Dec. in 1984)
Open water evaporation modeling	Evaporation from major lakes and reservoirs	Reservoir scale; 1980-2021
Satellite-based ET	Statewide coverage of gridded ET data for Oregon	30-m raster grids; monthly, 1985-2022
ET station network expansion	Identify gaps in agricultural weather and support ET work	Point; 15-minute data is available at AgriMet

Data Accuracy

All data, including OpenET data, has uncertainty. Data error is the amount by which a measured value differs from its true value, and uncertainty is the estimation of the likely range of true values as informed by the measured or estimated error. Uncertainty limits appropriate applications for data. OpenET datasets have been extensively reviewed by scientists working with the OpenET consortium (Purdy et al. 2024). Recently, Morton et al. (2024) examined the impact of satellite acquisition frequency on historic modeled ET. Huntington et al. (2025) described the background, processing, and accuracy of consumptive use and applied water, including an assessment of uncertainty associated with these data.

Uncertainty for monthly ET estimates is 10-20%, approaching that of field-based in-situ methods (Huntington et al. 2025). The uncertainty for consumptive use of irrigation estimates is not fully quantified (and possibly cannot be at relevant spatial scales) but is thought to be within 10-30%. The uncertainty for applied water from irrigation is not fully known but may be larger than the uncertainty in consumptive use of irrigation.

It is expected that OWRD staff will subset the statewide ET dataset for a specific region or period for specific applications. For these subsets, it is important to recognize that uncertainty varies with several factors, including: (1) the number of fields or area used in the analysis, (2) agricultural vs. natural vegetation, (3) winter vs. growing season, (4) year, and (5) Oregon water rights information. Specifically:

(1) Uncertainty is larger for individual fields than when aggregated across many fields. Many errors are random and presumably cancel when aggregating across large areas (Huntington et al., 2025).
(2) Uncertainty is larger for natural vegetation than agricultural fields (Volk et al. 2024). There may be an upward bias in ET for drier non-irrigated rangelands (Purdy et al. 2024).
(3) Gaps in satellite imagery increase uncertainty. Therefore, uncertainty is larger during cloudy winters than the growing season (Purdy et al., 2024).
(4) Uncertainty is larger before 2000 and in 2012, when there was only one satellite used for data generation (Morton et. al, 2024). Uncertainty for consumptive use estimates is larger before 2007, associated with modeled effective precipitation and field mapping accuracy.
(5) Estimates of water source (groundwater or and surface water) rely on Oregon water rights mapping. Uncertainty in the location of mapped water rights impacts both field irrigation status and irrigation water source. Huntington et al. (2025) provides a careful discussion of uncertainty associated with these data.

Huntington et al. (2025) and OWRD's discussions with OpenET and DRI scientists indicate that there are ways to better understand—and possibly improve—data accuracy for specific projects that rely on the Statewide ET dataset. Some parameters in this dataset rely on OWRD water rights mapping, and this mapping requires review for some applications. For example, in fields with overlapping surface water and groundwater rights, data accuracy may improve with careful review and refinement of mapping, irrigation system efficiency estimates, and the fraction of water sourced from groundwater. Field methods, such as field surveys and flowmeter monitoring, may

allow for improved accuracy, validation, and understanding of field-level processes. Conversely, a broad understanding of trends and patterns at large spatial scales may need little review.

Applications of Statewide ET Data

Four criteria were used to identify best applications of Statewide ET Project data for OWRD: (1) the historical use of aerial and satellite imagery at OWRD, (2) data availability and parameters, (3) data accuracy, and (4) purpose of use (e.g., scientific or regulatory; sole, primary, or supporting evidence). Specifically, applications of Statewide ET Project data were aligned to OWRD's historical use of publicly available aerial and satellite imagery. Data availability, parameters, and accuracy were considered to evaluate appropriateness for various uses. The purpose of use, particularly implications for determinations made using these data given their accuracy, was also considered.

Current Applications and Considerations

Data from the Statewide ET Project support water use estimation, water budgets, scientific investigations, management, and planning (Huntington et al., 2025; Table 3). The Statewide ET dataset provides several key parameters that address a range of science and policy needs, so it is important to choose the appropriate parameters when applying these data. For example, ET quantifies total evaporative loss, NIWR provides a measure of irrigation demand and optimal irrigation application, and consumptive use of irrigation quantifies the fraction of total ET that is from irrigation water (see definitions on page 2). These are all important parameters and can collectively inform better understanding hydrology and water management.

Data from the Statewide ET project are a refinement compared to past methods that used NIWR to estimate consumptive use for regional and statewide applications (Cuenca, 1992). As such, these data are particularly well-suited for understanding relative patterns of ET and consumptive use of irrigation at large spatial scales. For work where NIWR was used in the past, data from the Statewide ET Project can often be substituted to meet science and policy objectives. Combining data from the Statewide ET Project with other OWRD datasets can expand its utility, such as in surface water availability assessments for the upcoming update to Oregon's Water Availability and Reporting System.

Table 3 shows examples of applications that are supported by the current availability and accuracy of these data. Table 4 shows applications that are being considered but may require further work to determine appropriateness. Table 5 provides additional applications where these data may inform regulatory activities. Table 6 lists applications that are not currently supported.

Table 3. Current applications of Statewide ET Project data.

Application	Explanation	Existing Methods
Groundwater basin studies	Quantify how much water is used by crops and vegetation within study areas.	AgriMet stations, published ET studies, remotely sensed ET
Bi-weekly updates to Deschutes Storage Report (reservoir evaporation)	Provide updates to reservoir evaporation.	Pan evaporation measurements
Water budgets for scientific inquiries (i.e., canal seepage losses)	ET and consumptive use of irrigation from agricultural fields is a large part of the surface water budget. These data quantify ET losses from the water system.	Oregon crop water use and irrigation requirements (Cuenca, 1992), USGS water use reports
Field work planning and identifying regions with agricultural activity	These data show regions in Oregon where agricultural activities occur and support field work investigations. These uses are typically interested in whether fields are irrigated, not in the ET data itself.	Aerial and remote sensing imagery
Large-scale analyses of ET, consumptive use of irrigation, applied water, and NIWR	These data provide key hydrological information for Oregon to inform a range of science-based questions needed for water management, including rulemaking.	Oregon crop water use and irrigation requirements (Cuenca, 1992), USGS water use reports, no existing method
Place-based planning and water development projects (i.e., 2015 Demand Forecast)	Calculate how much water is used now and in the future as a part of planning	ET Demands model, AgriMet stations

Table 4. Applications under consideration for Statewide ET Project data.

Application	Explanation	Existing Methods
Update to Oregon's Water Availability Reporting System	Estimate water consumptively used within basins and determine how much water to debit from natural flow.	Oregon crop water use and irrigation requirements (Cuenca, 1992), USGS water use reports
Water rights transfers (i.e., change in character of use)	Use as a scientific tool, in conjunction with other information, to estimate the maximum quantity of water that could have been used without waste for a place of use, based on the basin/region, to determine how much water can be transferred without enlargement or injury (ORS 540.610, ORS 540.530).	Oregon crop water use and irrigation requirements (Cuenca, 1992), AgriMet stations
Evidence of use	This data may support claims of use but should not be used without other supporting evidence.	Description of use, flowmeter data, imagery, photographs, receipts showing use
Harney CREP and other conservation programs	Long-term average consumptive use could be used to assist participants in conservation programs (OpenET).	N/A
Pond evaporation	Provide estimate of evaporative losses from shallow ponds.	Oregon crop water use and irrigation requirements (Cuenca, 1992), AgriMet stations, Penman calculation, evaporation atlas (Farnsworth et al., 1982)

Applications that Inform Regulatory Activities

Statewide ET data can be used to inform some regulatory activities, but not others (Table 6). Similar to the use of other publicly available imagery at OWRD, these data can be used to better understand hydrology and irrigation patterns. However, these data should not be used as the sole or primary evidence for regulatory activities. Applying these data for evidence of use or non-use requires interpretation that can be overcome using other information, and therefore should be supported with other data where needed.

Remotely sensed ET and associated estimates of applied water from the Statewide ET Project should not be used to evaluate compliance with the specified amount/duty on a water right for enforcement actions at this time. This is for two main reasons: (1) OpenET states "it is important to consider data from OpenET as 'rebuttable estimates', especially in any process pertaining to administration of water rights"[3], and (2) OWRD's current understanding of data accuracy (see earlier section) is that estimates of applied water at the field-level are not sufficient for this application at this time.

Table 5. Applications of remotely sensed or Statewide ET data that inform regulatory activities.

Application	Explanation	Appropriate Use
Direct regulatory evaluation of duty	Applied water from the ET data is compared to the duty in a water right for regulatory actions.	Unsupported use
Evidence of non-use; forfeiture	The ET data, in conjunction with other evidence, may provide a better and more accurate understanding of irrigation patterns.	May be appropriate in conjunction with other data
Identifying irrigation that occurs outside a place of use designated by a water right	The ET data, in conjunction with other evidence, may provide a better and more accurate understanding of irrigation patterns.	May be appropriate in conjunction with other data
Other conditions specified by a water right	A water right may have particular specifications that the ET data can inform but are not identified here. The ET data may be appropriate to use, but the analyst should consider the appropriateness, data quality, and data accuracy before use. A supporting memo may be needed.	Varied; depends on data accuracy needs and availability

Applications that OWRD is Not Pursuing at this Time

Applications that OWRD is not pursuing at this time (Table 6) include (1) near real-time or in-season evaluation of changes in irrigation application, (2) primary/sole evidence for evidence of non-use, (3) applications where applied water estimates for one or only a few fields are required with high accuracy, and (4) water use reporting.

[3] etdata.org/how-to-use-data-from-openet/openet-fo Both FSD and TSD will be playing a role, and we might want to reach out to PCI to see if Sue Parrish may be available to help on some of the coordination details. r-policy-makers-and-regulators (accessed 3/4/2025)

OWRD should not accept applied water derived from satellite-based ET for water use reporting requirements at this time. ET data is not a direct measurement of applied irrigation water and can only be used to estimate diverted or pumped water use. Therefore, OWRD should not accept this data in lieu of other methods until critical uncertainties can be addressed across Oregon. Known concerns include: (1) significant conveyance losses that can lead to underestimates of diversion-based values, (2) variation in accuracy across time and region given antecedent and other environmental conditions, leading to mismatch between estimates of use and the actual timing of applied water, and (3) need for further validation of underlying data sets and calculations to ensure estimates of applied water are not over- or underestimated.

Table 6. Applications of remotely sensed or Statewide ET data that OWRD is not pursuing at this time.

Application Not Pursued	Explanation
Assessment of near-real time or in-season changes in irrigation application	Using the OpenET website to assess whether water was shut off to an irrigated field within a short-term time period (days-weeks) could be misleading, as plants use water in the soil.
Primary/sole evidence of non-use	These data are not currently considered sufficient as the primary or only source of evidence for regulatory investigations into evidence of non-use.
Applied water for limited fields where high accuracy is required	Estimating applied water for one or only a few fields is associated with large uncertainty.
Water use reporting requirement	This approach currently does not meet reporting requirements for a water right.

Supporting Documents and Links

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NAIP. National Agricultural Imagery Program. https://www.usgs.gov/centers/eros/science/usgs-eros-archive-aerial-photography-national-agriculture-imagery-program-naip

OpenET. OpenET website. https://etdata.org/how-to-use-data-from-openet/ and https://etdata.org/how-to-use-data-from-openet/openet-for-policy-makers-and-regulators/

OSIP. Oregon Statewide Imagery Program. https://geohub.oregon.gov/pages/osipimagery

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Updates:

Version 3/28/2025 – minor edit to definitions.