DRAFT REPORT

Yolo Bypass Flood Date and Flow Volume Agricultural Impact Analysis

PREPARED FOR:	Yolo County
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Executive Summary

The state and federal government propose to increase the frequency and duration of flooding in the Yolo Bypass for fish habitat, both as a major component of the Bay Delta Conservation Plan (BDCP) and also as a Reasonable and Prudent Alternative (RPA) in the federal National Marine Fisheries Service's Biological Opinion for winter run salmon, spring run salmon, and Central Valley steelhead. Under both alternatives the project will have broader support and cost less if effects on items such as flood protection, migratory waterfowl and other terrestrial species habitat, and agriculture are minimized. This report provides a quantitative framework for assessment of agricultural impacts from proposed flooding scenarios in the Yolo Bypass and evaluates both the Biological Opinion RPA and BDCP Conservation Measure 2 (CM2).

Yolo Bypass Fisheries Enhancement Conservation Measure #2 (CM2), as stated in the February 2012 BDCP draft, would lower a portion of the Fremont Weir to an elevation of 17.5 feet, from its current elevation of 32.8 feet, and construct an operable gate to allow Sacramento River water to flow into the Yolo Bypass (BDCP 2012). CM2 also includes a number of other actions within the Yolo Bypass including construction of fish passage improvements at the Fremont Weir. CM2 actions are designed to reduce migratory delays and loss of adult salmon, steelhead, and sturgeon, enhance rearing habitat for Sacramento River Basin salmonids, enhance spawning and rearing habitat for Sacramento splittail, and improve food sources for delta smelt downstream of the Bypass. The operations pattern[4] for the proposed Fremont Weir gate suggests supplemental flooding up to 6,000 cubic feet per second (cfs) for 30 to 45 days in years when flooding occurs naturally in the Yolo Bypass.

The Biological Opinion Reasonable and Prudent Alternatives (RPA), Actions I.6 and I.7, would also lower a portion of the Fremont Weir and construct an operable gate to allow Sacramento River water to flow into the Yolo Bypass. The RPA scope is to provide habitat for winter run salmon, spring run salmon, and central valley steelhead. The RPA requires flooding for juvenile winter run, spring run, and Central Valley steelhead from "December through April" in the "lower Sacramento River basin." The RPA further identifies "an initial performance measure" of 17,000 to 20,000 acres with "appropriate frequency and duration." The RPA recommends flows through an operable gate at the Fremont Weir for inundation of up to 20,000 acres in the Yolo Bypass. This study provides a data-driven assessment of the effect of proposed RPA and CM2 implementation on agricultural productivity and Yolo County's overall economy, and provides a framework for evaluating BDCP proposals once they are further developed.

The 57,000-acre Yolo Bypass is first and foremost one of the primary means of providing flood protection to the Sacramento region. In addition, Yolo Bypass agriculture provides significant benefits to the local economy, migratory waterfowl, and the flood protection system. The Bypass can carry, on average, four times the flow of the Sacramento River or approximately 420,000 cfs. Yolo Bypass agriculture helps to maintain this flood capacity by controlling vegetation, thereby reducing the state's responsibility for vegetation removal. Yolo Bypass rice fields also provide habitat and food for migratory waterfowl when flooded for straw decomposition during the winter months.

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[4] See Table 3.4-3 of the February 2012 BDCP Draft Report.

"Natural" flooding in the Yolo Bypass can occur at any time from the Sacramento River overtopping the Fremont Weir and/or from tributary flows entering the Bypass from the west during storm events. Farmers have adapted to these conditions and landowners have lowered their lease rates to some extent to reflect the risk. Natural flooding delays planting times and reduces crop yields in the Bypass – or even prevents planting. Late season flood events may reduce crop yields through short-duration flooding, even if farmers prepare fields early in the season. As such, increased frequency and duration of inundation within the Bypass for fish habitat may translate into financial losses for farmers and the regional economy.

Current proposals recommend flows between 3,000 and 6,000 cfs through an operable gate in the Fremont Weir. Flooding at the proposed volumes would inundate[5] between 12,200 and 25,000 total[6] acres, assuming no flooding from creeks on the west side of the Yolo Bypass. An increase in flooding could result in economic losses to farmers and the local economy, dependent on timing, frequency, volume, and duration. In addition, flooding may increase the costs of late season rains which potentially affects land values, lending institutions, and farming in the Yolo Bypass.

This study evaluates the expected losses of total agriculture revenue, total Yolo County revenue (value added), tax revenue, and jobs for the twelve policy scenarios listed in Table 1. These scenarios evaluate the Biological Opinion RPA under five proposed end dates for Fremont Weir flows through an operable gate, and the CM2 scenario in the February 2012 BDCP draft, for two flow rates.

Table 1. Inundation End Dates / Scenarios

3,000 cfs	**6,000 cfs**
Feb 15	Feb 15
Mar 24	Mar 24
Apr 10	Apr 10
Apr 30	Apr 30
May 15	May 15
CM2 Scenario	CM2 Scenario

The fundamental driving factors in the analysis are total acres inundated, reduced crop yields, and increased land fallowing. As the last day of flooding through the proposed gate in the Fremont Weir increases, farmers must delay field preparation and planting, resulting in reduced crop yields and increased land fallowing. Agricultural revenues fall, which translates into losses in the Yolo County economy and employment in the region. Table 2 identifies the expected total annual losses to the Yolo County economy (also known as value added losses) associated with

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[5] This study is an agricultural impact analysis and, as such, areas of inundation include the literal flooding "footprint" plus fields that are partially inundated, discussed in Section 2.2.

[6] 12,200 total acres includes 4,500 acres of wetlands and Liberty Island, and 25,000 total acres includes 9,200 acres of wetlands and Liberty Island. Thus, flooding will affect between 7,700 and 15,800 acres of land used for agricultural production. This footprint does not include any land in Solano County.

the inundation scenarios evaluated in the study. Under the RPA proposal, the effect of increased flooding early in the season is small, less than $0.25 million with 6,000 cfs flow. Flooding through May 15 significantly increases effects, with total losses to Yolo County economy of $3.8 million and $8.9 million under 3,000 cfs and 6,000 cfs, respectively. Under the CM2 proposal, where flooding only occurs as an extension to natural flooding, expected annual losses range from $0.63 to $1.5 million under 3,000 and 6,000 cfs, respectively.

Table 2. Expected Total Annual Loss to Yolo County Economy (Value Added) (Thousands of 2008 dollars)

Inundation End Date / Scenario	3,000 cfs	6,000 cfs
February 15	148	241
March 24	931	1,744
April 10	2,337	5,015
April 30	3,371	7,735
May 15	3,886	8,889
CM2 Scenario	625	1,468

This analysis does not explicitly consider changes in late season rains and management or operation difficulties which may affect drainage and field preparation times. Consequently, the estimates in this study are a conservative measure of the expected annual losses to the economy from increased frequency and duration of inundation in the Yolo Bypass. We also would like to stress the model results are sensitive to several assumptions. In particular, the areas of inundation under different flooding scenarios may change with different hydrologic models and consideration of tributary flows. We also use an expected crop price that is representative of an average over the past 25 years and neither relies on recent boom price levels or earlier depressed agricultural conditions.

In addition to expanded inundation scenarios as more information becomes available, we also recommend the following actions:

- Create inundation scenarios that include the west side tributaries to the Bypass once existing models are adequately reviewed.
- Create inundation scenarios that reflect potential constrained project footprints of 7,000 to 10,000 acres, since the current analysis only models unconstrained flooding and therefore includes acres that do not directly benefit fish.
- Analyze the effect of crop insurance on farmer responses to inundation proposals.
- Analyze the response of agricultural lending institutions to inundation proposals.
- Evaluate proposed flood policies under a range of expected future crop prices.
- Compare the predicted area of inundation under the MIKE21 and HEC-RAS models.

We thank Yolo County, the State and Federal Contractors Water Agency (SFCWA), and the Conaway Preservation Group for the funding and support necessary to prepare this study.

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1 Introduction

The state and federal government propose to increase the frequency and duration of flooding in the Yolo Bypass for fish habitat, both as a major component of the Bay Delta Conservation Plan (BDCP) and also as a Reasonable and Prudent Alternative (RPA) in the federal National Marine Fisheries Service's Biological Opinion for winter run salmon, spring run salmon, and Central Valley steelhead. Under both alternatives, the project will have broader support and cost less if impacts – such as flood protection, migratory waterfowl and other terrestrial species, and agriculture – are minimized.

In this study, we estimate the extent of inundation, crop yield loss, and effects on the agricultural economy from increasing the frequency and duration of flooding in the Yolo Bypass. All estimates include the direct economic effects associated with reduced agricultural production, as well as multiplier (direct and induced) effects associated with upstream and downstream changes to the regional economy. We developed the framework in this study as an analytic tool which may be used to evaluate alternative policy scenarios in the future. For example, the BDCP proposal for the Yolo Bypass and the salmon RPA were not fully developed at the time of this study. The analysis uses twelve specific policy scenarios to demonstrate the framework, but can be used in the future to analyze any Bypass proposal.

Yolo Bypass Fisheries Enhancement Conservation Measure #2 (CM2), as stated in the February 2012 BDCP draft, would lower a portion of the Fremont Weir to an elevation of 17.5 feet, from its current elevation of 32.8 feet, and construct an operable gate to allow Sacramento River water to flow into the Yolo Bypass (BDCP 2012). CM2 also includes a number of other actions within the Yolo Bypass including construction of fish passage improvements at the Fremont Weir. CM2 actions are designed to reduce migratory delays and loss of adult salmon, steelhead, and sturgeon, enhance rearing habitat for Sacramento River Basin salmonids, enhance spawning and rearing habitat for Sacramento splittail, and improve food sources for delta smelt downstream of the Bypass. The operations pattern[7] for the proposed Fremont Weir gate suggests supplemental flooding up to 6,000 cubic feet per second (cfs) for 30 to 45 days in years when flooding occurs naturally in the Yolo Bypass.

The Biological Opinion RPA, Actions I.6 and I.7, would also lower a portion of the Fremont Weir and construct an operable gate to allow Sacramento River water to flow into the Yolo Bypass. The RPA scope is to provide habitat for winter run salmon, spring run salmon, and central valley steelhead. The RPA requires flooding for juvenile winter run, spring run, and Central Valley steelhead from "December through April" in the "lower Sacramento River basin." The RPA further identifies "an initial performance measure" of 17,000 to 20,000 acres with "appropriate frequency and duration." The RPA recommends flows up to 8,000 cfs through an operable gate at the Fremont Weir for inundation of up to 20,000 acres in the Yolo Bypass. This study provides a data-driven assessment of the effect of proposed RPA under five end dates to water flows through an operable gate at Fremont Weir under two flow volumes.

We use the HEC-RAS hydrologic model and the DAYCENT agronomic model to estimate the extent of inundation and change in crop yield, respectively, under a series of proposed policies.

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[7] See Table 3.4-3 of the February 2012 BDCP Draft Report.

We estimate the effect on agricultural production using the Bypass Production Model (BPM), developed specifically for the Yolo Bypass. The BPM estimates the change in crop mix, agricultural revenues, and other factors due to crop yield loss (DAYCENT model) and the number of acres affected (HEC-RAS and MIKE-21 models) in the Yolo Bypass. Results from the BPM are linked to the IMPLAN regional input-output model to estimate total output, value-added, and employment losses within the Yolo Bypass and the Yolo County economy.

1.1 Scope of Analysis and Caveats

In this report we model the effects of increased flooding on Yolo Bypass agriculture and the county economy. Thus the geographic scope of the analysis is Yolo County and, in particular, the Yolo Bypass. We do not consider crop production shifts out of the region. This would require, in part, an analysis of the rice mills in West Sacramento and Woodland to determine proportion of business from Bypass production in addition to other regional economic effects. Additionally, a shift in rice production out of the Bypass is an agronomic question since specific soil and climate is required.

The modeling approach we adopt is sensitive to several parameters which we have made every attempt to clearly state and, where possible, report sensitivity analysis. We preview the important parameters in this section and review them throughout the text. Section 5 provides sensitivity analysis.

Subbing: Increased flooding in the Bypass may raise the groundwater table in regions out of the Bypass. This may restrict farming and/or reduce yields in affected areas, thereby increasing economic losses.

Late Rains: We provide expected annual loss estimates by using a time series of hydrologic conditions in the Bypass. However, late season rains may have additional costs which we have not captured. For example, if farmers begin field preparation late due to flooding for fish habitat and late rains occur, this may delay planting further and increase economic losses.

Prices: Expected future crop prices are uncertain. We use a conservative estimate of 2009-2010 average prices which does not reflect recent booms or historic depressed levels. We provide sensitivity analysis in Section 5.

Lending and Insurance: We do not evaluate the effect of increased flooding on lending and insurance for farmers in the Bypass. This is related to late season rains and other management difficulties Bypass farmers may face with extended policy flooding.

Drought: For the RPA scenarios we have implicitly assumed water will be available for policy flooding in every year. Extended drought may lower the river level below the range of the operable gate at Fremont Weir, which may decrease expected losses since flooding will not occur in these years.

1.2 Inundation Scenarios

We consider five inundation dates and two different flow rates associated with RPA implementation. Additionally, we consider the CM2 proposal under the same flow rates, for a total of twelve policy scenarios (see Table 1). The inundation dates correspond to the last day of Sacramento River water releases through operable gates in the Fremont Weir: February 15th, March 24th, April 10th, April 30th, and May 15th. The two flow rates are 3,000 cfs and 6,000 cfs, which correspond to the flows recommended for fish in *Technical Study #2: Evaluation of North Delta Migration Corridors: Yolo Bypass* prepared for the BDCP Integration Team in April 2009.

We identified the five end dates to represent a range of outcomes from RPA alternatives to flooding for fish habitat in the Yolo Bypass. The RPA only include flooding through April, however we include a May 15th date to inform discussions related to potential flooding for splittail. The BDCP currently proposes flooding for splittail every 7 years if flooding does not occur naturally, although the acres of splittail flooding are not specified. Once acreage targets are more fully refined, the model framework can be used to develop loss estimates specific to proposed flooding scenarios.

The CM2 scenario, as described in the introduction, corresponds to supplemental flooding in years with natural overtopping at Fremont Weir. As such, the end date in this scenario is variable and depends on the specific water year. In Section 3.3 we describe the time series of hydrologic conditions used to generate annual expected losses in the CM2 scenario.

Fields in the Bypass must drain before farmers can begin preparation for planting. Agricultural fields located along the east side of the Bypass adjacent to the Tule Canal/Toe Drain tend to drain slower than higher elevation fields to the west. Slower drainage time on the east side delays planting date and tends to lower crop yields. On average, it takes two weeks for fields to drain on the west side of the Bypass and four weeks on the east side of the Bypass. Field preparation takes an additional four weeks. Thus, there is a delay of six to eight weeks between the last day water is released through a Fremont Weir gate and planting, depending on the location of the field.

February 15th. February 15th represents an end date to Fremont Weir flooding when agriculture is largely unaffected. Farmers have an adequate buffer for unforeseen circumstances, such as rain or cool conditions that lengthen the time needed for field drainage. Farmers state they prefer to start ground preparation by March 15th to allow adequate time for field work and planting. It takes approximately 4 weeks from the date a farmer can start field work to the date of planting, so an end date of February 15th would typically result in early April planting on the west side of the Bypass and mid-April planting on the east side.

March 24th. March 24th represents an end date to Fremont Weir flooding when growers are expected to experience yield losses (see Section 3). Consequently, we anticipate some land fallowing and shift in crop mix but, in general, crop yields are high enough to cover variable costs.

April 10th. The April 10th end date translates into planting in early June. According to farmers interviewed, in an average year, June 10th is the last possible date to plant. With an April 10th end date to water releases, farmers would plant in late May on the west side and by June 10th on the east side. As such, significant yield losses and land fallowing are expected in this scenario. If any unforeseen circumstances occur in this scenario, there is a high risk that planting will not occur.

April 30th. The April 30th end date translates into planting in late June and corresponds to the latest flood date under the RPA. According to farmers interviewed, in an average year, June 10th is the last possible date to plant. As such, significant yield losses and land fallowing are expected in this scenario. In this scenario, planting may not occur at all on the east side of the Bypass and there is a high risk that planting will not occur on the west side.

May 15th. The May 15th end date for water releases represents a date when farmers state they will not plant crops. However, this date is frequently referred to in public forums as important for splittail habitat. Yield response functions from the DAYCENT model confirm that crop yields are not high enough to cover variable operation costs if flooding ends May 15th. Consequently, significant land fallowing would occur. However, contracts and other fixed costs may induce farmers to plant late in the season.

CM2. The CM2 scenario corresponds to a verbal interpretation of the proposal in the BDCP February 2012 draft. This proposal may change in the future. In this scenario, flooding is extended by 30 days in years with natural flooding in the Bypass to augment habitat and there is no flooding in dry years. We use a 26 year hydrologic time series, described in Section 3.3, to simulate this proposal. For example, with natural flooding until February 1 the CM2 proposal extends flooding by 30 days, through March 1.

2 Data Overview

We collected extensive data for the Yolo Bypass to facilitate an empirical analysis of the proposed inundation scenarios. These include the following: (i) field-level geo-referenced crop data and agricultural region definitions, (ii) crop yields and yield change based on planting date, (iii) crop prices, (iv) costs of production, and (v) area inundated under proposed flow volumes. We review these data in the following section.

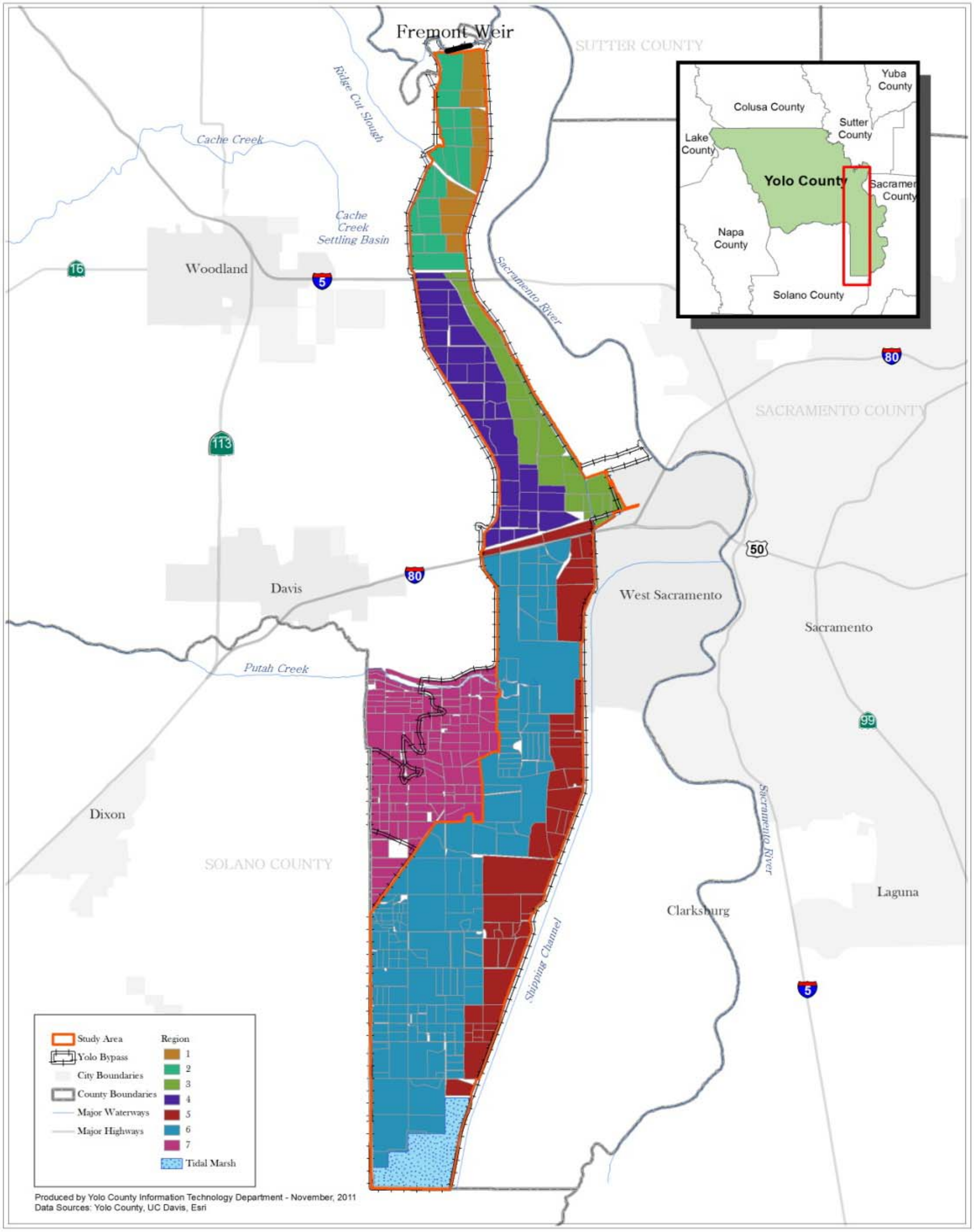
2.1 Agricultural Sub-regions

The Yolo Bypass slopes gradually downward from west to east and north to south. Temperatures are generally lower in the southern end of the Bypass. Consequently, there are heterogeneous production conditions across the region and natural differences in both yield and drainage times. We identified 7 homogenous agricultural sub-regions in the Yolo Bypass which represent these production conditions and, as such, form the basis of the BPM. We used soil and climate data, in addition to interviews with Bypass farmers, to develop homogenous agricultural sub-regions. The regions are illustrated in Figure 1.

Note that the BPM, as with the majority of agricultural production models, is a regional economic model, defined over the 7 regions illustrated in Figure 1. Field-level yield and production data are available for a subset of fields in the Bypass (discussed below), and these data are used in the DAYCENT agronomic model. We discuss this point again in Section 2.3 and again in Section 3, but want to raise the point here so the reader is not confused about the use of field-level data versus agricultural sub-regions in the model.

As shown in Figure 1, Regions 1 and 2 are located north of Interstate 5, Regions 3 and 4 are located between Interstate 5 and Interstate 80, and Regions 5, 6 and 7 are located south of Interstate 80. The area south of Interstate 80 is divided into three regions due to its relatively large width and the distinct row crop region located in its western portion, which distinguishes it from the managed wetlands and grazing lands located to the east. Region 7 is located outside of the flood inundation footprint and is not anticipated to be affected by the implementation of CM2 of the RPA, so it is not discussed in further detail in this report or considered in the analysis.

Figure 1. Yolo Bypass Sub-regions



Produced by Yolo County Information Technology Department - November, 2011
Data Sources: Yolo County, UC Davis, Esri

2.2 Field Level Crop Data and Flood Footprint

We compiled detailed land use data for 2005-2009 from Pesticide Use Reports, the Yolo Natural Heritage Program, the Sacramento-Yolo Mosquito and Vector Control District, the Yolo Basin Foundation, and individual farmers. As a result of the extent of data collected, and verification with key stakeholders, the database for this study is the most comprehensive and detailed information on Yolo Bypass land use available.

Table 3 identifies major land uses in the area of the Bypass affected by each of the respective flow volumes (identified by the HEC-RAS hydrologic model, discussed in Section 2.6) over the five years of data collected for the study. Agricultural land constitutes the majority of the area within the Bypass, followed by wetland and fallow land. The main crops in the affected area of the Yolo Bypass are rice, irrigated pasture, processing tomato, vine seed, safflower, wild rice, corn, and sunflowers.

We model 3,000 cfs and 6,000 cfs scenarios in this report which correspond to different total affected acres, as estimated by the HEC-RAS model. An important consideration for the agricultural impacts analysis is that the geography of land use in the Bypass means that a sub-set of fields will be partially innundated. In other words, the HEC-RAS model estimates a "literal" footprint of affected acres dependent on the flow volume, but this does not account for existing agricultural fields. Cultivation of proportions of fields is costly and, in many cases, impossible. Partial innundation makes it difficult or impossible to use machinery to begin field preparation and, as such, the field is effectively entirely inundated. It is essential to account for the difference between the literal footprint from hydrologic modeling and the effective footprint, the latter is relevant for agricultural impact analysis.

In order to incorporate the effective flood footprint, we conducted a series of interviews with Bypass farmers and extension specailists to determine the proportion of a field flooded at which farmers cannot begin preparation. Farmers interviewed report the decision to prepare a partially inundated field is different between rice and other field crops and depends on a number of factors including relative prices, weather, and costs. We determined when 20 percent of a rice field is flooded farmers will not begin preparation. For all other crops, 30 percent is the relevant proportion. Fields partially inundated according to the above proportions are modeled as effectively flooded and consequently included in the affected acres estimates.

Note that preparation of a partially innundated field includes installation of checks to control existing flooding and other potentially costly management alternatives. We do not include these production costs in the analysis, thus our estimates are conservative.

Table 3. Major Land Uses in areas affected by flooding in the Yolo Bypass (acres)

Crop and Flow Volume	2005	2006	2007	2008	2009
Fallow					
3,000 cfs	3,220	3,606	1,702	1,514	984
6,000 cfs	6,640	6,860	2,858	3,526	2,297
Liberty Island					
3,000 cfs	2,071	2,071	2,071	2,071	2,071
6,000 cfs	2,071	2,071	2,071	2,071	2,071
Vine					
3,000 cfs	245	0	0	0	72
6,000 cfs	245	104	0	0	238
Pasture					
3,000 cfs	2,026	2,026	2,026	2,026	2,284
6,000 cfs	3,890	3,890	3,987	3,890	5,166
Rice					
3,000 cfs	765	173	931	968	1,531
6,000 cfs	2,358	1,254	2,920	2,409	4,263
Safflower					
3,000 cfs	606	657	519	770	499
6,000 cfs	1,450	1,545	1,616	1,840	1,273
Sunflower					
3,000 cfs	138	0	0	0	0
6,000 cfs	138	0	0	0	0
Processing Tomatoes					
3,000 cfs	662	867	721	930	1,047
6,000 cfs	1,285	1,285	1,370	1,829	1,779
Wetland					
3,000 cfs	2,501	2,502	2,503	2,504	2,505
6,000 cfs	7,076	7,076	7,076	7,076	7,076
Wild Rice					
3,000 cfs	0	195	427	494	494
6,000 cfs	0	928	2,292	2,303	2,393
Corn					
3,000 cfs	0	138	584	208	0
6,000 cfs	0	138	925	208	0

We identified 9 major crop groups in areas affected by flooding in the Bypass, which we use for the subsequent analysis. The 9 crops include corn, irrigated pasture, non-irrigated pasture, rice, wild rice, safflower, sunflower, processing tomatoes, vines (melons). Fallow land is an implicit tenth group. Approximately 100 acres of crops did not fit into these categories directly, including dry beans and organic rice. We determined that the number of acres was not sufficient to require an additional crop group and these acres were included in the crop group with the most similar cost, return, and production characteristics. Specifically, organic rice acres were added to the rice crop group and dry bean acres were added to the corn crop group.

Figures 2-6 illustrate the distribution of land use across the entire Yolo Bypass, by field, for the years 2005 through 2009. These data show typical crop rotations across the sub-regions. In the southern end of the Bypass, the crops are predominately pasture and in the northern sub-regions the crops are predominately rice. The eastern sub-regions include a mix of pasture, rice, corn, and processing tomatoes.

Crop acreage increased during the dry years of 2007 through 2009 and fallow land decreased. Note that 2008 and 2009 were characterized by high agricultural commodity prices potentially driving larger acreages into production, in particular for corn and wheat. Rice prices spiked in 2008, which partially explains the increase in rice acreage in the Yolo Bypass. Water year type also affects production. The California Department of Water Resources classified 2005 as an above normal hydrologic year type, 2006 as wet, and 2007 through 2009 as dry years. The Fremont Weir overtopped through May 3rd in 2006, overtopped for three days in May of 2005 (resulting in a couple of weeks of inundation), and did not overtop in 2007 through 2009.

Figure 2. Agricultural Land Use, Yolo Bypass 2005

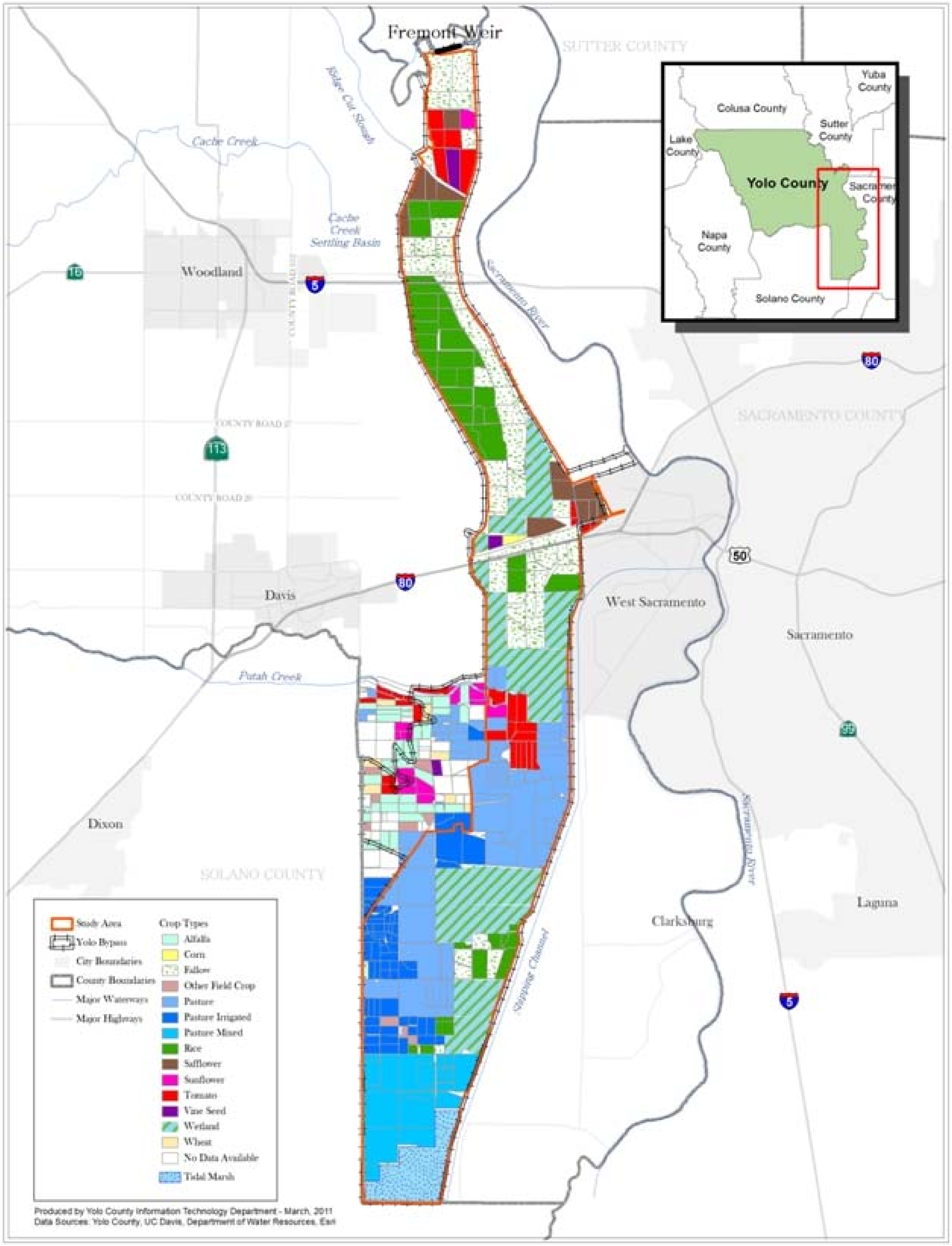


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Figure 3. Agricultural Land Use, Yolo Bypass 2006

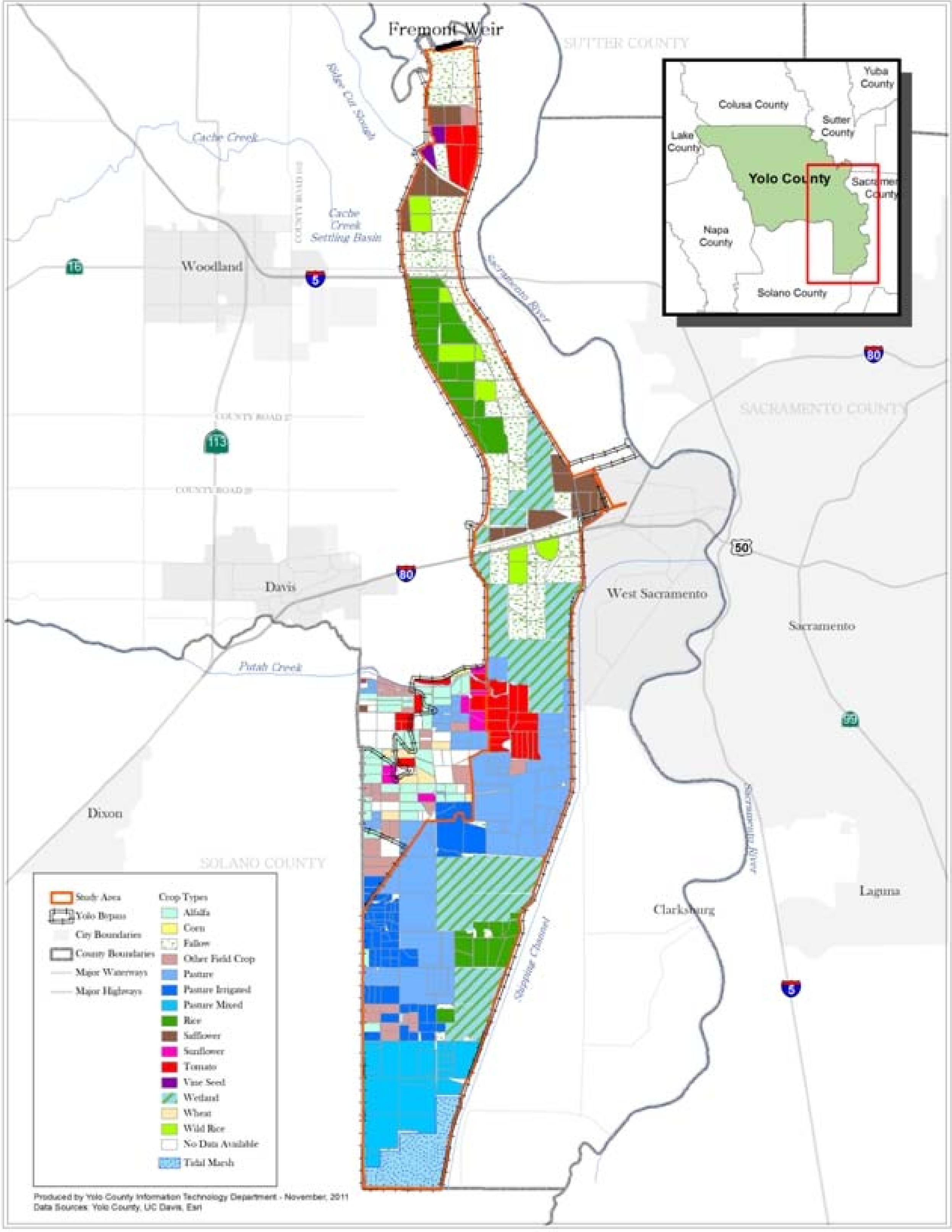

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Figure 4. Agricultural Land Use, Yolo Bypass 2007

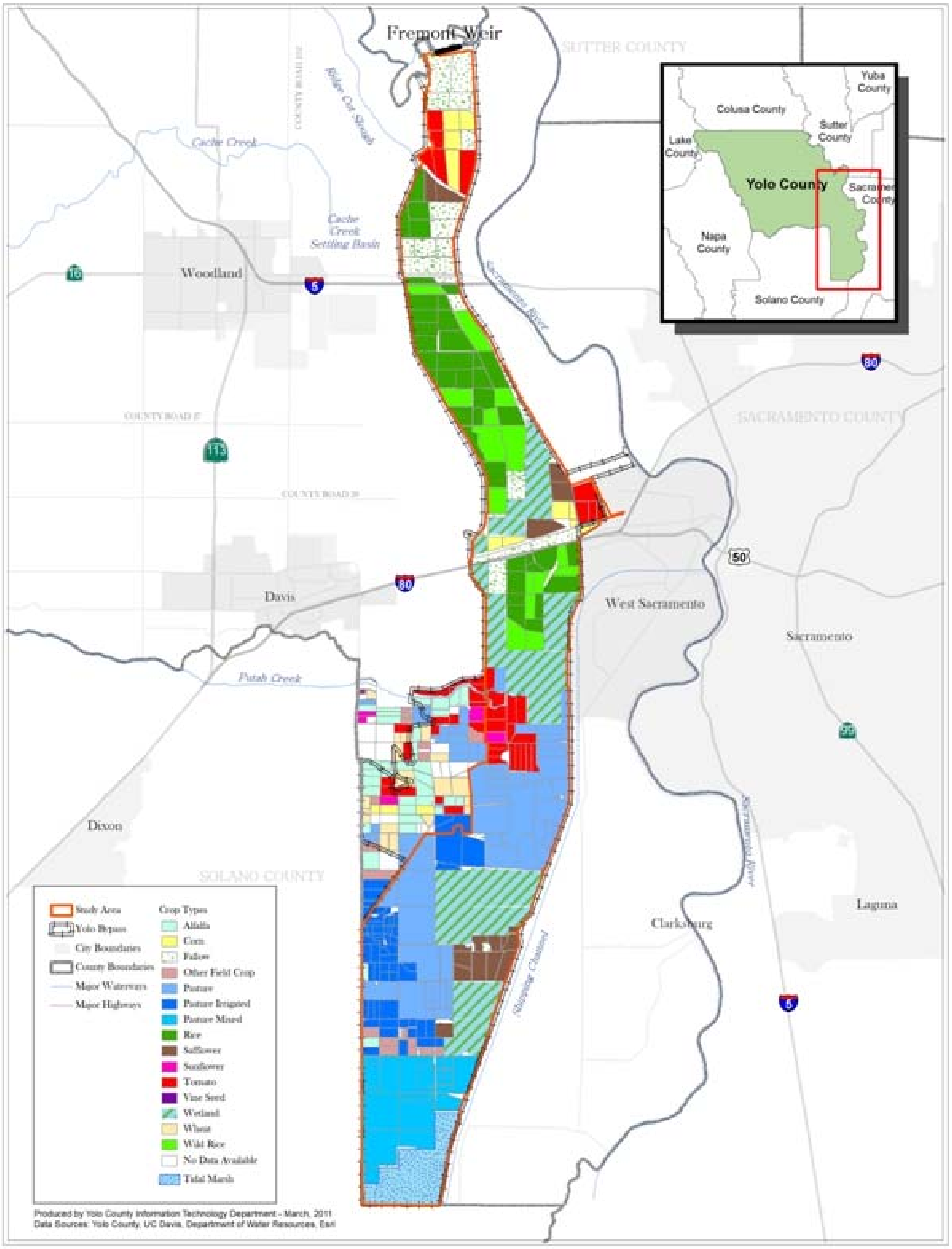

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Figure 5. Agricultural Land Use, Yolo Bypass 2008

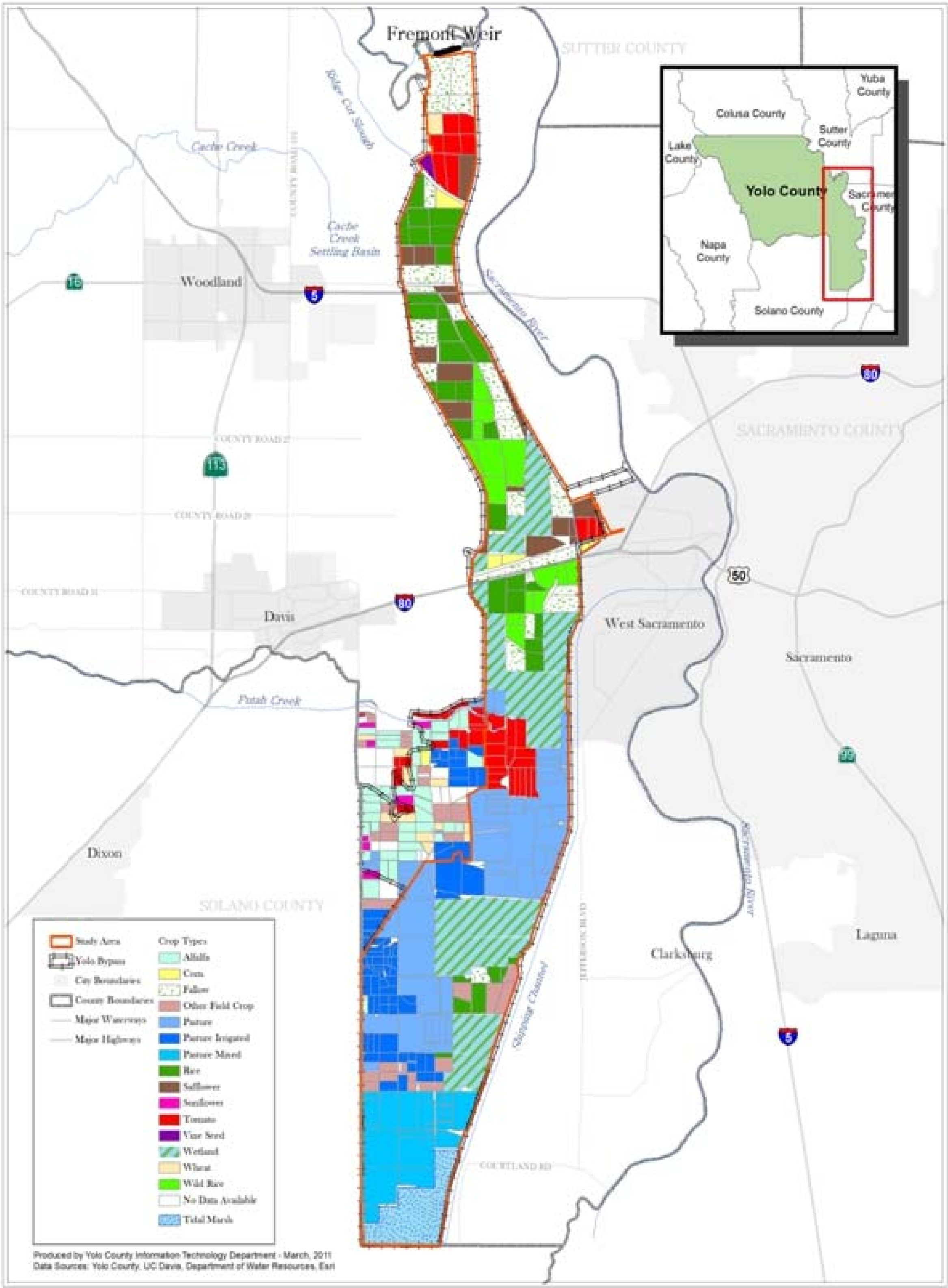

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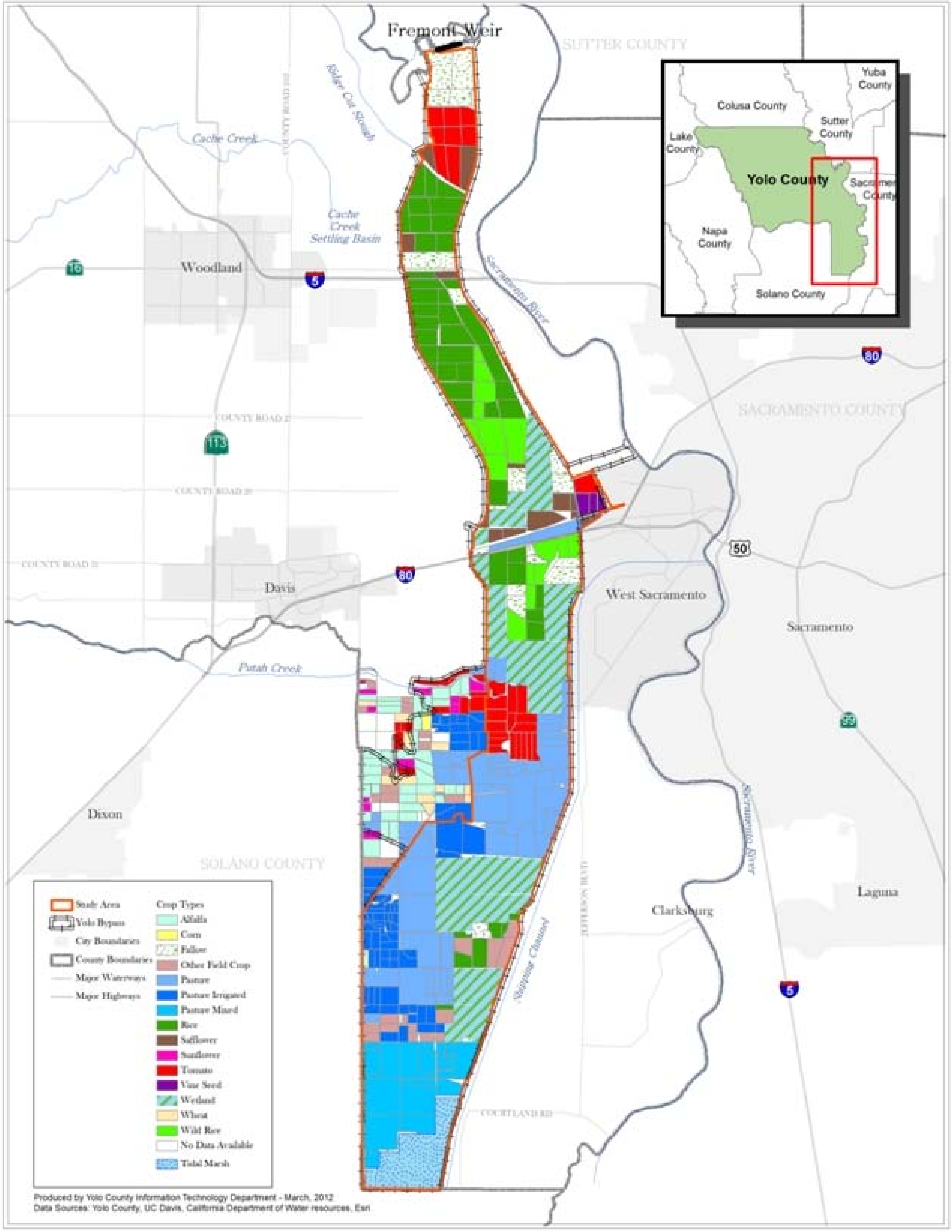
Figure 6. Agricultural Land Use, Yolo Bypass 2009



Produced by Yolo County Information Technology Department - March, 2012
Data Sources: Yolo County, UC Davis, California Department of Water resources, Esri

2.3 Crop Yields

Holding total area inundated constant, crop yields are the fundamental driving factor for agricultural revenue losses due to flooding in the Yolo Bypass. We use two sources of information on crop yields in this analysis. This procedure is outlined here, explained again in Section 3, and all the technical details and equations are contained in Appendix A.

We observe field-level yield data and other micro-production characteristics (soil, climate, etc.) for a subset of fields in the Bypass. These fields are used to calibrate the DAYCENT agronomic model. The DAYCENT model estimates the yield on any given field taking into account all production conditions, including climate and date the crop was planted. We then use the calibrated DAYCENT model to estimate crop yields on a subset of fields in each of the 6 regions of the BPM. We control for all other factors and allow the planting date to vary, thus the DAYCENT model generates a series of data points, for each crop and region, which tells us the expected yield conditional on the crop planting date.

We use the data points from the DAYCENT results to estimate a single yield function, for each crop and region. We fit this function using non-linear regression analysis (discussed in Section 3 and Appendix A). The result is a single function, for each crop and region in the Bypass, which relates crop yield to the planting date. These functions are included in the BPM, discussed in Section 3.

In summary, we use field-level production observations to calibrate a field-level agronomic model. We use the model to simulate the yield on a subset of fields for each crop and region as a function of planting date. Finally, we fit a non-linear function to these data, for each crop and region. Thus, we are able to determine crop yields, for each region, as a function of the planting date.

Note that consistent data on the yields, prices and costs of growing melons for vine seed were unavailable. Instead, we use economic information for melons grown for fruit, accordingly crop yields and budgets are expressed in terms of melons grown for fruit. This is not a critical assumption since melon acreage in the affected area averages less than 200 acres per year (between 2005 and 2009).

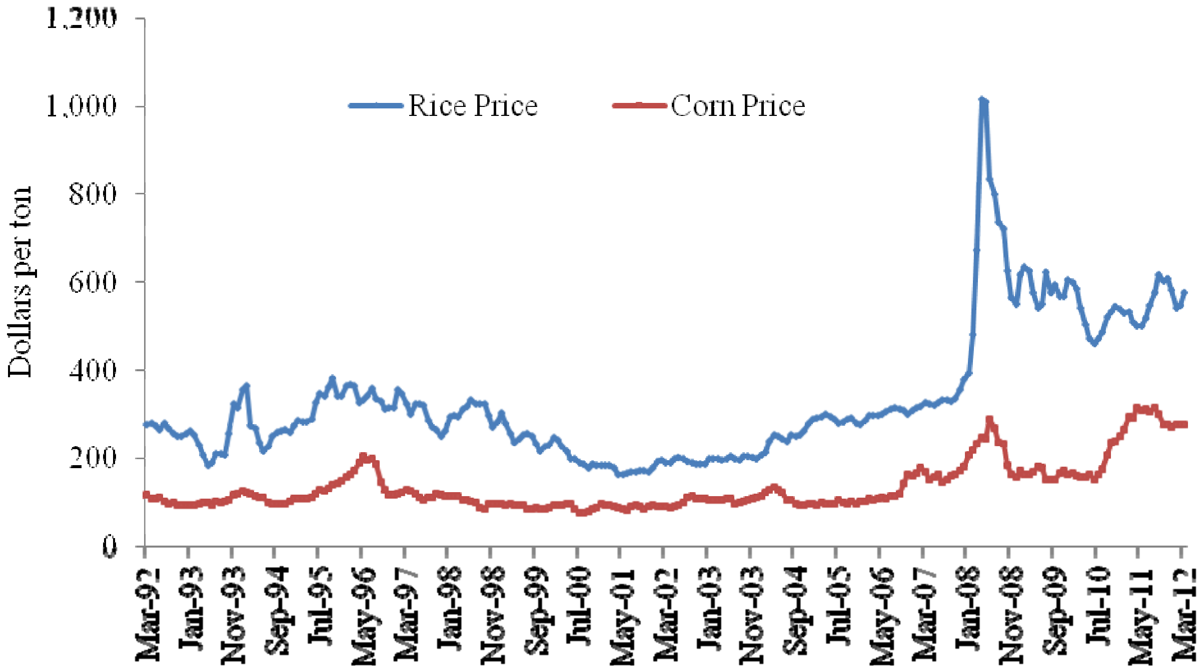
2.4 Crop Prices

We obtained crop prices for the 9 crops considered in the analysis from the Yolo County Agricultural Commissioner reports (Agricultural Commissioners Reports, 2012). No price data per animal unit month (AUM) or hay production was available for pasture, thus we used the price estimate per AUM per acre provided in the Cost and Returns study for flood irrigated pasture grown in the Sacramento Valley (UC Cooperative Extension, 2003). Additionally, sunflower prices are only available for 2007 and 2008 in the Agricultural Commissioner’s data. Therefore, we used data reported by the National Agricultural Statistics Service (NASS). We also use NASS data for wild rice because no price data are available prior to 2006.

One of the key components of this analysis is expected crop prices. Higher crop prices translate into larger losses per acre and induce farmers to plant later in the season, thereby reducing fallow land. The results of this study are sensitive to the choice of expected future crop prices.

Unfortunately, there is no general consensus for future expected crop prices. The commodity price spike of 2007/2008 was unprecedented and followed decades of declining real commodity prices. Prices have since declined but remain higher than pre-spike levels and appear to have stabilized on a higher trend. Figure 7 illustrates the 20 year trend in corn and rice prices and highlights the difficulty of selecting representative prices to use in this analysis.

Figure 7. Commodity Price Trends, Monthly Prices from 1992 - 2012[8]



All of the impact analysis in this report uses a two year average (2009-2010) of crop prices for each of the crop groups. There are two main reasons for this which include, (i) these years are representative of historical average prices in Yolo County and, (ii) 2009 and 2010 crop prices exclude the price spikes in 2008 and again in 2011. The 2009 and 2010 average prices represent a conservative and defensible estimate for crop prices in this analysis.

Table 4 summarizes the average crop price[9] (dollars per ton) for each of the crop groups included in the analysis. Column two shows the prices used (2009-2010 average) and column three shows the 10 year average crop price. Related to point (i), above, Table 4 shows that 2009-2010 average crop prices are representative of the recent history (2000 - 2009 average). Namely, rice and corn prices are slightly higher than the 10 year average but other crops are generally lower. Column four reports 2008 prices for each of the crops. With the exception of corn and safflower, all crop prices were significantly inflated in 2008. In summary, 2009 and 2010 average prices are

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[8] Data compiled from http://www.indexmundi.com/

[9] Rice prices do not include direct payments, counter-cyclical program payments, or marketing loan payments. Where applicable, these are included in the data used for the analysis.

representative of recent prices in Yolo County and, more importantly, omit the recent price spikes.

Table 4. Crop Prices, 2009-2010 average and 2000-2009 average (2008 dollars per ton)

Crop Group	2009-2010 Average	2000-2009 Average	2008
Corn	172.69	124.31	152.20
Irrigated Pasture	49.20 (based on $35 per AUM)	49.20 (based on $35 per AUM)	49.20 (based on $35 per AUM)
Non-Irrigated Pasture	49.20 (based on $35 per AUM)	49.20 (based on $35 per AUM)	49.20 (based on $35 per AUM)
Rice	397.89	251.36	513.10
Wild Rice	961.85	1,275.30	1,684.20
Safflower	351.18	319.79	432.62
Sunflower	1,196.15	1,781.47	1,092.32
Processing Tomatoes	78.81	59.15	68.81
Vine Seed (Melon Proxy)	303.00	292.9	296.10

2.5 Costs of Production

In this report, we use Cost and Return studies developed by the UC Cooperative Extension (UCCE) to determine crop costs of production. These studies provide production costs for representative farmers in the Sacramento Valley and, as such, are representative of Bypass farming. Crop budgets are prepared for various years, thus we use the NASS prices paid indices for specific item categories to express each item cost in constant 2008 dollars.

Land prices are excluded from the input data in the model, thus the BPM represents returns to land and management. This is common in PMP models, technical discussion is left in Appendix A. However, note that PMP captures implicit land costs through the calibration routine, thus these costs are not “omitted” from the model. Table 5 summarizes the variable costs of production for each crop.

Table 5. Variable Production Costs ($/ton) per acre (in 2008 dollars)

Crop Group	Cost
Corn	$607
Melons	$4,110
Pasture irrigated	$269
Pasture dry	$118
Rice	$898
Safflower	$239
Sunflower	$553
Tomato, processing	$1,838
Wild rice	$502

2.6 Areas of Inundation

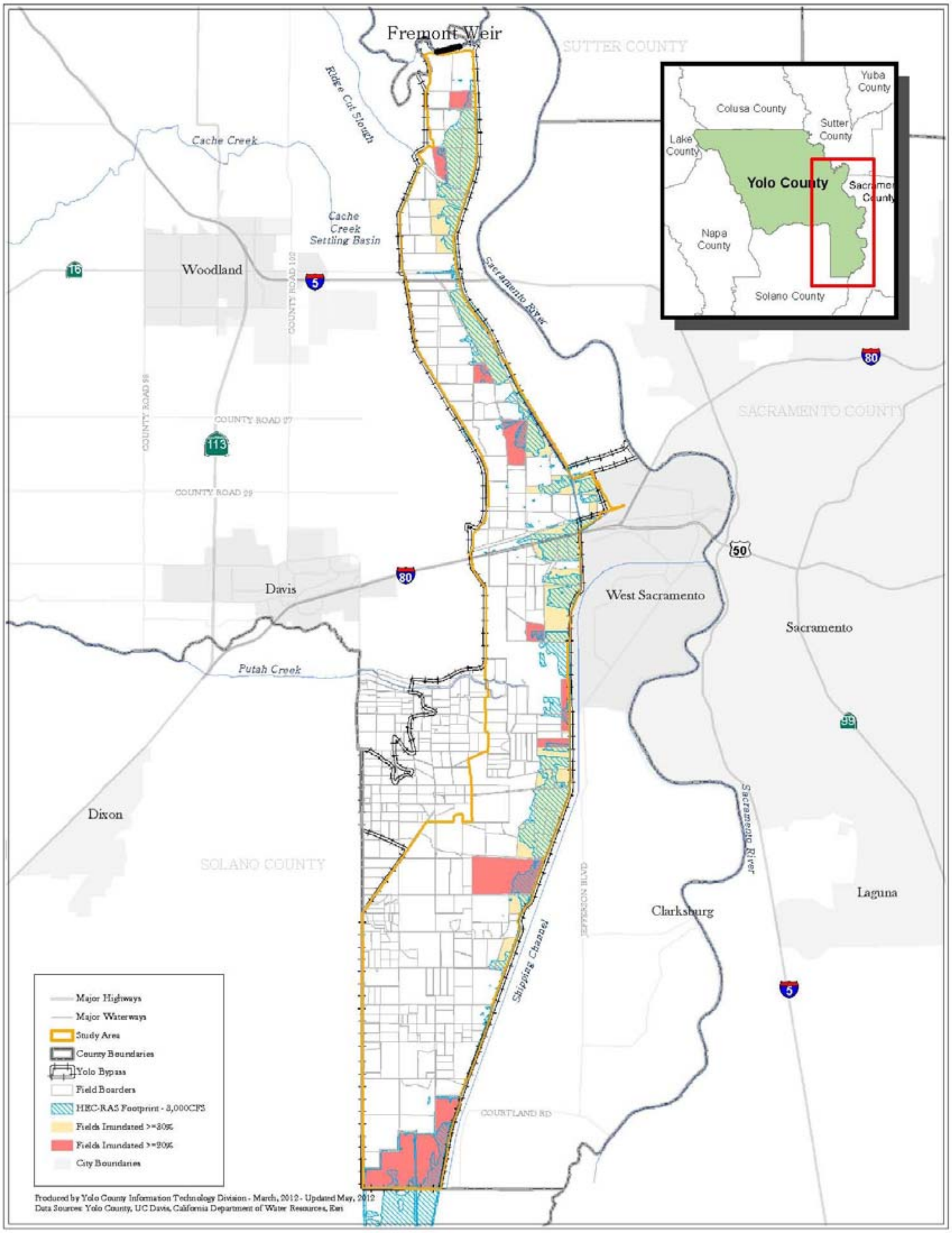
The second key driving factor in this analysis is the total number of affected acres under proposed flow volumes from Fremont Weir water releases through an operable gate. We consider two flow volumes, 3,000 and 6,000 cfs, in this report.

We estimate the number of affected acres using the one-dimensional HEC-RAS hydrologic model hydraulic simulation model. We use the HEC-RAS model for two reasons including, (i) the National Marine Fisheries Service used the HEC-RAS model to estimate acreage for the Biological Opinion, and (ii) Yolo County is still in the process of completing an independent review of the MIKE-21 model. An initial comparison of the MIKE-21 and HEC-RAS footprints for 3,000 cfs and 6,000 cfs indicate the difference is relatively small.

Given the potential interest in this issue, some additional information is necessary to justify the decision to rely on HEC-RAS. Both one-dimensional (1-D) and two-dimensional (2-D) models are useful tools in hydraulic engineering and water resource planning studies. The accuracy of both 1-D and 2-D models is strongly dependent upon the quality of information specified by the user as input into the model and on the boundary conditions (flow, initial water level and channel roughness) the user must also specify. It can therefore be difficult to compare results without understanding how each model was developed, including how bed roughness, inflow and stage boundary conditions were specified, and other how other assumptions and constraints were entered as user-specified inputs to each model. Once Yolo County develops a better understanding of the models' assumptions, the existing framework can be used to estimate effects for different model outputs.

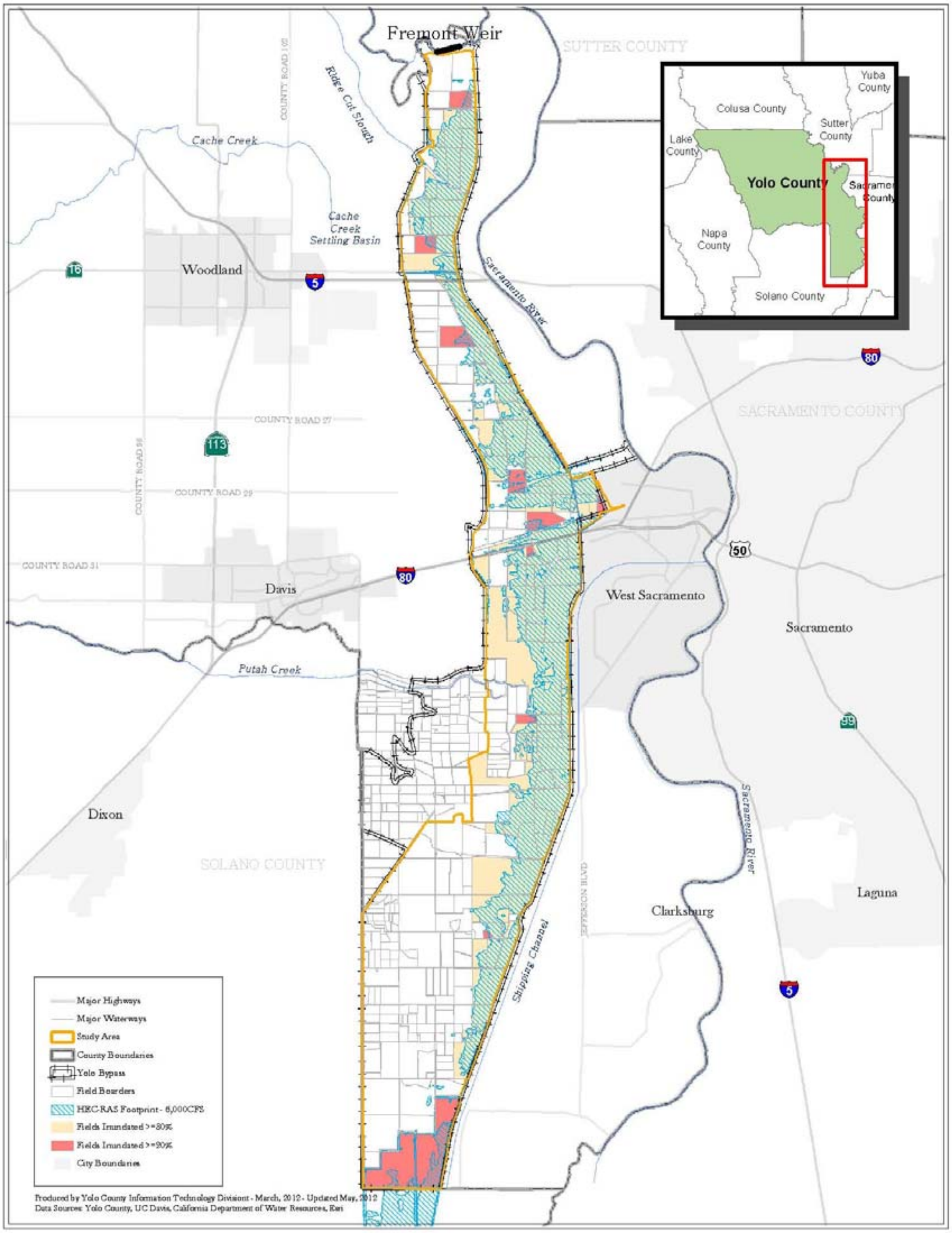
Figures 8 and 9 identify the fields inundated under the 3,000 and 6,000 cfs flow rates. We consider a field, in terms of restricting farm operations, to be effectively inundated if 30 percent or more of the field was inundated for field crops and 20 percent or more for rice crops. As discussed in Section 2.2, this reflects input received from Bypass farmers indicating that they would not typically initiate field preparation efforts if a portion of their field is still partially inundated. The blue areas in these figures identify the predicted flood inundation area. The red and yellow areas identify the contiguous fields that would be affected at 20% and 30%, respectively. Note that as the flow rate increases, the number of affected acres increases. Consequently, planting dates are delayed on more fields and farm revenue losses are expected to increase.

Figure 8. Agricultural Land Flooded under 3,000 cfs flow rates.



Produced by Yolo County Information Technology Division - March, 2012 - Updated May, 2012
Data Sources: Yolo County, UC Davis, California Department of Water Resources, Esri

Figure 9. Agricultural Land Flooded under 6,000 cfs flow rates.



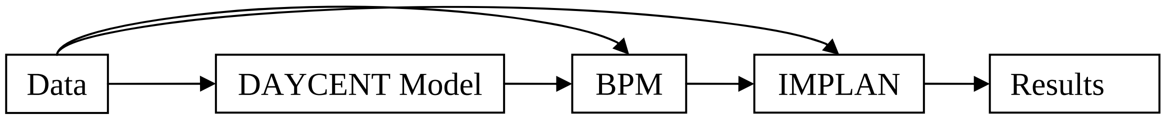
Produced by Yolo County Information Technology Divisiont - March, 2012 - Updated May, 2012
Data Sources: Yolo County, UC Davis, California Department of Water Resources, Esri

3 Overview of the Modeling Approach

We estimate the effect of the twelve proposed policies on Bypass agriculture based on the data summarized in Section 2 and a series of empirical models, summarized in this section. This section briefly reviews the modeling approach and policy scenarios evaluated. A detailed technical overview of the modeling approach is included in Appendix A.

Figure 10 provides a simple illustration of the key steps in our analysis. Starting with input data (including the HEC-RAS and MIKE-21 models) described in the previous section, we use a series of linked models to estimate the effects on agriculture. The DAYCENT model is an agronomic model used to estimate field-level yields, as a function of planting date, for subsets of fields in each region of the Bypass. Regression analysis on the DAYCENT model output and additional input data are used to calibrate the BPM. Output from the BPM and other input data are used as inputs to the IMPLAN model. The fundamental results include direct, indirect, and induced (the sum of which is total) expected effects on total agricultural output (revenues), value added, agricultural employment, and statewide taxes.

Figure 10. Illustration of the Fundamental Modeling Approach



We briefly preview the five steps outlined in Figure 10, and provide more details in the subsequent sections.

Data: Input data were described in Section 2. In summary, we compiled a comprehensive economic, agronomic, and geo-referenced dataset of agricultural production in the Yolo Bypass between 2005 and 2009.

DAYCENT Model: Field-level data were used to calibrate the agronomic DAYCENT model (DeGryze et al 2009). We use the DAYCENT model to estimate crop yields as a function of various agronomic conditions, including planting date. We use non-linear regression analysis to fit a series of crop yield functions, for each crop and region in the Bypass. Technical details are provided in Appendix A.

BPM: We use the crop yield functions estimated from the DAYCENT model, plus additional economic data, to calibrate the BPM. The BPM is the fundamental model of this analysis. The BPM relates changes in crop yield and total affected acres to changes in agricultural production and, fundamentally, changes in agricultural revenues. The BPM is a Positive Mathematical Programming (PMP after Howitt, 1995) model of agriculture in the 6 regions of the Yolo Bypass. PMP models calibrate exactly to an observed, base year, of production conditions and grower decisions and have been used extensively for water and agriculture policy analysis in

California and around the world. Appendix A reviews the technical details of the BPM and PMP calibration procedure.

IMPLAN: The IMPLAN model estimates regional economic losses. Expected revenue losses from the BPM analysis represent direct economic effects. However, upstream and downstream industries will be affected and some agricultural workers will lose their jobs when production in the Bypass decreases. We use the IMPLAN regional Input-Output (IO) model to estimate the direct, indirect, and induced effects of the 12 policy scenarios. The sum of these components represents the total effect of the policies.

The key result from this overview is that all of the analysis in this report is driven by observed data and observed grower decisions in the Bypass. We use a sequence of linked models to estimate the total (direct, indirect, and induced) effects of flood date and flow volume on agriculture in the Yolo Bypass. These effects are defined and described in detail in Section 4 and Appendix A.

3.1 Estimating Crop Yields (DAYCENT Model)

Crop yields are the fundamental driving factor for agricultural revenue losses due to flooding in the Yolo Bypass. As farmers delay planting, crop yields decline which, in turn, leads to lower revenues and land fallowing. We estimate crop yields, and variation based on planting date, using the DAYCENT agronomic model and non-linear regression analysis on output data.

We can summarize the procedure as two steps, (i) estimate field-specific yields using the DAYCENT model and, (ii) use the DAYCENT model output to perform regression analysis and estimate crop and region-specific yield functions. These functions relate crop yield to the planting date and are directly incorporated into the BPM. More information about this process is available in Appendix A.

Table 6 presents the results (after both steps are completed) from the yield data analysis by sub-region. Yields vary across regions and by planting date. Recall that after the last day of water releases through the Fremont Weir gate, there is a 6-8 week delay before planting occurs, this is implicitly built into the yield data summarized in Table 6.

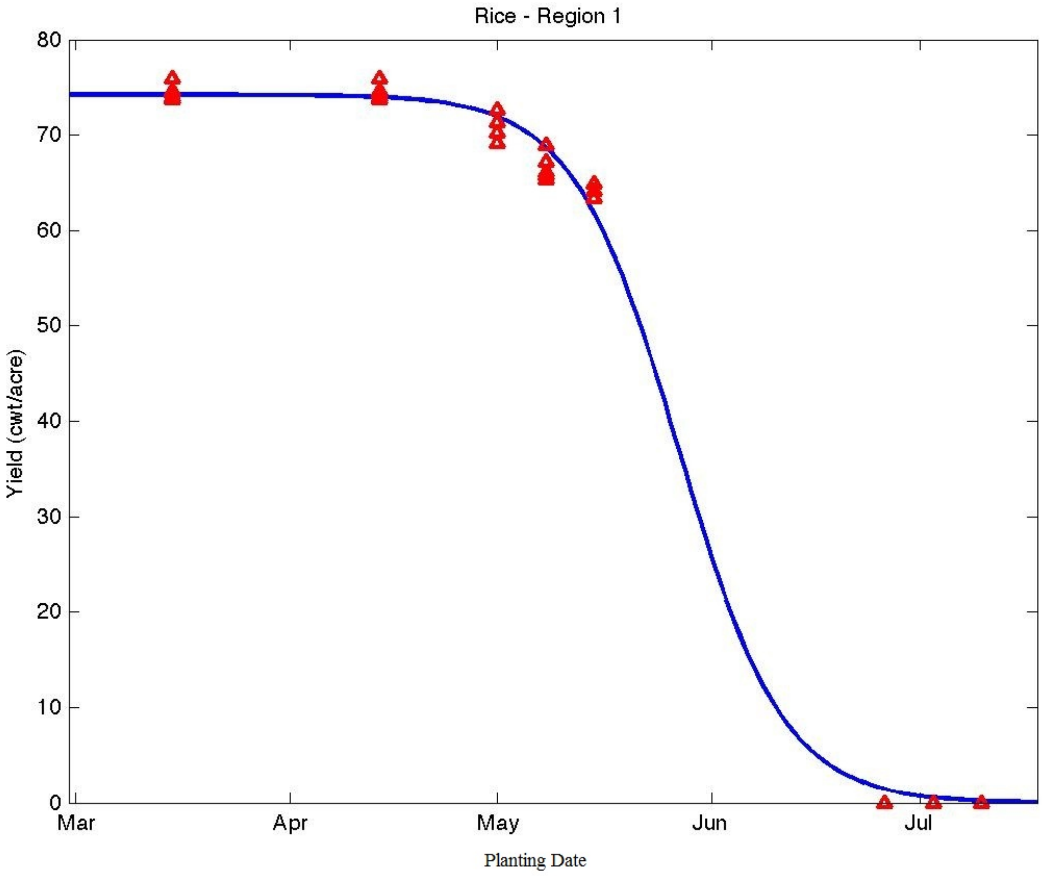
There are crop and region specific functions underlying all of the data summarized in Table 6. Figure 11 summarizes this function for an example crop of Rice in Region 1. Yield functions for all the crops can be found in Appendix A. The vertical axis identifies the expected yield, the horizontal axis identifies the date, red triangles are output data from the DAYCENT field-level model, and the blue line represents the results of the fitted non-linear yield function.

There are several things to note from the example in Figure 11. First, one of these functions (the blue line) exists for every crop in every region. This governs the relationship between crop yield and planting date and, in part, drives the results of the economic (BPM) model. Second, note that the relationship is non-linear, as expected. Over some range early in the season, farmers will realize only a slight yield decline from a small delay in planting date. However, substantial delays cause yields to decline rapidly.

Table 6. Estimated yield by planting date (last day of water releases) (tons/ac)

Yield (ton/acre)	Region	Last day of water releases at Fremont Weir			
		Feb 15th	March 24th	April 10th	May 15th
Corn	1	5.84	4.72	0.51	0.00
Corn	2	5.90	5.84	4.05	0.01
Corn	3	5.88	4.76	0.59	0.00
Corn	4	5.73	5.48	3.09	0.02
Pasture - dry (AUM/acre)	5	0.45	0.29	0.25	0.21
Pasture - dry (AUM/acre)	6	0.55	0.33	0.28	0.22
Pasture - irrigated (AUM/acre)	5	2.23	1.44	1.26	1.05
Pasture - irrigated (AUM/acre)	6	2.77	1.64	1.38	1.10
Rice	1	4.14	3.19	1.08	0.01
Rice	2	4.15	3.98	2.88	0.09
Rice	3	4.15	3.20	1.09	0.01
Rice	4	4.12	3.92	2.76	0.09
Rice	5	3.66	2.50	1.14	0.07
Rice	6	3.74	3.42	2.41	0.21
Safflower	1	1.07	0.51	0.29	0.07
Safflower	2	1.19	1.01	0.76	0.21
Safflower	3	1.09	0.51	0.29	0.08
Safflower	4	1.09	0.74	0.48	0.14
Safflower	5	0.98	0.41	0.21	0.04
Safflower	6	1.10	0.70	0.43	0.12
Sunflower	1	0.64	0.56	0.52	0.45
Sunflower	6	0.63	0.60	0.56	0.46
Processing Tomato	1	38.57	34.60	28.79	10.35
Processing Tomato	2	38.76	37.25	33.98	17.59
Processing Tomato	3	38.99	35.06	29.18	10.29
Processing Tomato	6	38.36	36.23	32.48	17.74
Melons	2	7.52	7.52	6.55	3.55
Melons	3	6.80	6.20	4.84	2.10
Melons	4	6.65	6.65	5.77	2.97
Wild rice	1	0.92	0.71	0.24	0.00
Wild rice	2	0.92	0.88	0.64	0.02
Wild rice	3	0.92	0.71	0.24	0.00
Wild rice	4	0.92	0.87	0.61	0.02
Wild rice	5	0.81	0.56	0.25	0.02
Wild rice	6	0.83	0.76	0.54	0.05

Figure 11. Example Yield Function, Rice in Region 1



3.2 Bypass Production Model

The Bypass Production Model (BPM) combines the HEC-RAS data, DAYCENT yield functions, and other economic data into a Positive Mathematical Programming (PMP) agricultural production model of the Yolo Bypass. The model calibrates exactly to an observed base year of input and output data which, in our analysis, is 2005 - 2009 average land use. In other words, the model exactly replicates observed farmer behavior, in terms of input use and outputs, over this period. Once the model calibrates, and a series of economic and numerical checks are satisfied (see Howitt et al. 2012), we use the BPM to simulate changes in agricultural production under the twelve proposed policy scenarios. We review the basics of the BPM in this section, the interested reader can find technical details in Appendix A.

The BPM estimates the change in crop mix, agricultural revenues, and other factors due to crop yield loss (DAYCENT model) and the number of acres affected (HEC-RAS model) in the Yolo Bypass. The BPM calibrates to an average of 2005-2009 land use input data (summarized in Section 2). All dollars are expressed in 2008 real terms. Crop prices for calibration are an average of 2005-2007 prices in Yolo County. The 2005-2007 average prices were determined to be representative of conditions farmers in the Yolo Bypass faced, on average, when making planting decisions between 2005 and 2009. Input costs are expressed in 2008 dollars, from the UCCE budgets. Policy simulations use 2009-2010 average crop prices, as discussed previously.

Technical details of the PMP calibration procedure and functional forms in the model are left to Appendix A. We briefly review the estimation procedure in this section. The BPM estimation procedure can be summarized as a series of five steps:

Step 1: Calibrate the BPM to base data (2005 - 2009, as discussed previously). Perform a series of checks to ensure economic and numerical conditions are satisfied.

Step 2: Run the BPM for a season with *known* overtopping dates at Fremont Weir, and flooding in the Yolo Bypass. This represents the base condition (e.g. natural flooding) for agriculture in the Bypass in the absence of the proposed policy flooding scenarios (for that year). Repeat Step 2 for a series of known years. There are 26 known overtopping dates in the analysis which are discussed in more detail in the following section.

Step 3: Over the same series of years as step two, run the BPM and impose (sequentially - one at a time) the twelve proposed policy flooding scenarios. This represents what *would have* happened to Bypass agriculture *if* the flooding policy was implemented in that year. Repeat Step 3 for all of the same years as Step 2.

Step 4: For each year simulated in Steps 2 and 3, calculate the difference in agricultural revenues (and other outputs). Record the result for negative changes in revenue. Intuitively, for policy evaluation we are interested in negative changes in revenue because a positive change in revenue implies that the policy was “better” than nature. For example, if natural flooding occurred in the Bypass until April 30th, imposing a policy which stops water releases from a Fremont Weir gate on April 10th would not be possible (i.e. it would increase revenues).

Step 5: Calculate the average loss of revenue (and other changes) across all of the years simulated in Steps 2 - 4. This represents the expected effects due to the proposed flooding scenarios, and is the fundamental output of the BPM.

The fundamental procedure of the BPM is to generate an *expected* effect on agriculture by using the calibrated model to estimate what would have happened under natural flooding, and then asking what would have happened if a specific policy (last day of water releases) was in place. This procedure allows us to generate an expected effect because we control for the expected natural flood events in the Bypass. The following section illustrates this point.

3.3 Adjustments for Natural Flooding

In many years flooding occurs naturally in the Yolo Bypass and, in some years, flooding may occur late in the season. Estimates of agricultural losses need to account for the fact that natural conditions may result in flooding beyond the proposed policy date. We use a 26 year (1984-2009) time-series of hydrologic conditions in the Bypass to estimate expected future revenue losses in the Bypass. The implicit assumption is that the previous 26 years are representative of expectations for natural flooding in the near future. The implications of this assumption and details on the procedure used in the BPM are described in more detail in Appendix A.

Given the 26 year time-series, estimates represent expected annual losses due to flooding for fish habitat in the Bypass. There are two reasons these 26 years of data were identified as reasonable, including (i) detailed flow information over the Fremont Weir was available for these years, and (ii) it is representative of current hydrologic conditions in the Sacramento Valley watershed. Older hydrologic information less accurately represents current conditions because it does not account for changes in urban development and reservoir operations that have altered flows in the Sacramento River over time.

Table 7 summarizes the observed last day of overtopping and provides some notes about the nature of flooding in key years. During the 26 years, there are five years (1989, 1996, 1998, 2003 and 2005) in which flooding events in the Yolo Bypass did not occur consecutively. In these years, except for 2003, an early dry period enabled farmers to proceed with their land preparation, but planting was delayed or significantly affected by late floods. To account for this in the analysis, 28 days (the amount of time needed for field preparation) was credited to the planting date in these years. This assumes that farmers had to wait for the fields to drain in these years, but required minimal field preparation effort since this was completed earlier in the season.

Table 7. Fremont Weir Overtopping End Dates

Year	End Date	Important Notes and Adjustments
1984	11-Jan	
1985	-	
1986	25-Mar	
1987	-	
1988	-	
1989	14-Mar	Early dry year, followed by late flooding, farmers able to prepare fields early reducing the effect of late flooding
1990	-	
1991	-	
1992	-	
1993	6-Apr	
1994	-	
1995	13-May	
1996	24-May	Early dry year, followed by late flooding, farmers able to prepare fields early reducing the effect of late flooding
1997	13-Feb	
1998	8-Jun	Early dry year, followed by late flooding, farmers able to prepare fields early reducing the effect of late flooding
1999	14-Mar	
2000	17-Mar	
2001	-	
2002	10-Jan	
2003	7-May	Flooding confined to the Toe Drain; minimal effect on agriculture
2004	10-Mar	
2005	24-May	Early dry year, followed by late flooding, farmers able to prepare fields early reducing the effect of late flooding
2006	5-May	
2007	-	
2008	-	
2009	-	

3.4 IMPLAN

We use the Impact Analysis for Planning model (IMPLAN) Professional Version 3 and a 2009 database for Yolo County. We link the IMPLAN model to results from the BPM, in order to estimate changes in total output value, value added, employment, and tax revenues as a result of the proposed flood policies. IMPLAN is an input-output model which accounts for relationships between sectors of the economy in order to estimate the effects of a change (e.g. reduced agricultural output) in another sector of the economy. IMPLAN is widely used by State and Federal agencies including the California Department of Water Resources, the California Regional Water Quality Control Boards, the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the U.S. Bureau of Economic Analysis, and the U.S. Bureau of Land Management.

We summarize four key outputs for this analysis: changes in total output value, changes in “value added”, changes in employment, and changes in statewide tax receipts. For each output we report direct, indirect, and induced effects, the sum of which is the total effect. We define these components below, further technical details can be found in Appendix A.

Total Output Value (e.g. Gross Revenues): The gross value of agricultural production in the Yolo Bypass to the “global” economy. For example, this is price multiplied by yield/acre multiplied by the total number of acres.

Total Value Added: The net value of agricultural production in the Yolo Bypass to the Yolo County economy. This measure recognizes that many inputs/outputs are produced or consumed outside of Yolo County and, as such, are not relevant effects for the flood policy analysis. For example, food production is exported out of the county, state, or country for many crops. Similarly, tractors are produced outside of the county, fertilizers are produced in another state, etc. The measure of value added controls for these effects. Total value added includes compensation for employees, income to business and landowners, and other business, specific to Yolo County.

Total Employment: The change in agricultural employment in Yolo County due to changes in agricultural production in the Yolo Bypass. Specifically, this includes NAICS classification system sector 111 - agricultural employment.

Total Statewide Tax Revenue: The change in tax receipts due to reduced output in the Yolo Bypass.

Each of these components has a direct, indirect, and induced effect on the Yolo County economy. The sum of the three is the total effect and sometimes the indirect and induced effects are jointly referred to as “multiplier” effects. We define these terms below.

Direct: Immediate effects on the relevant agricultural economy. For example, gross farm revenue losses due to reduced yields in the Bypass.

Indirect: Changes in related sectors as a result of direct changes to production in the Bypass. For example, reduced production in the Bypass will cause farmers to purchase fewer inputs, this is an indirect effect.

Induced: Changes in all other sectors of the economy as a result of the direct changes to production in the Bypass. For example, reduced production in the Bypass will lead to reduced hours for farm workers who will, in turn, purchase fewer goods and services in the region.

Total: Direct + Indirect + Induced

4 Results

We summarize the results of the analysis in this section. Results correspond to each of the 12 policy scenarios (water release end date and flow volume) for the four measures detailed in Section 3.4. First, we summarize changes in acreage across the Bypass.

Results are annual expected losses, reported in constant 2008 dollars.

4.1 Acreage Change Summary

Figures 12 and 13 summarize the change in total irrigated acres, by year, under the eight policy scenarios (four end dates for water releases through a Fremont Weir gate and two flow rates) corresponding to the RPA scenarios. Farmers may fallow land or shift small amounts of land to alternative crops in response to delayed planting due to flooding. These figures highlight the decision to fallow land. Note the effect of the 26 year simulation on the analysis. Years with late natural flooding reduce (or eliminate) losses to Yolo Bypass agriculture due to the policy scenarios.

There is a base level of average fallow acres in any given year within each of the affected 3,000 and 6,000 cfs flood areas. Specifically, in the 3,000 cfs flood region, the 2005 through 2009 base (calibration) data shows that an average of 2,200 acres are fallow in any given year. Similarly, in the 6,000 cfs flood region, 4,400 acres are fallow in any given year. These additional fallow acres are not included in Figures 12 and 13.

Figure 12 shows the time-series of change in total irrigated acres in the region affected by the 3,000 cfs flow rate. As the last day of water releases from a Fremont Weir gate is delayed, the total number of irrigated acres removed from production increases. An average of 2,580 acres are removed from production per year if the last day of water releases is May 15th.

Figure 13 illustrates the time-series of change in total irrigated acres in the region affected under the 6,000 cfs flow rate. As the last day of water releases is delayed, the total number of irrigated acres removed from production increases. The total number of irrigated acres removed from production is larger than the 3,000 cfs inundation region. On average, 7,400 acres are removed from production under a last day of water releases on May 15th. The maximum number of acres out of production is estimated at over 15,200 with a last day of water releases on May 15th.

Figures 12 and 13 also illustrate the importance of natural flooding in the Bypass. In years where the is natural flooding, the effects of the policy are minimal. For example, February and March flooding have a limited effect in many years. Averaging over these 26 years allows us to generate an expected annual effect of the proposed policies.

Figure 12. Loss of Irrigated Acres in Region Affected by 3,000 cfs Flow Rate, by Year.

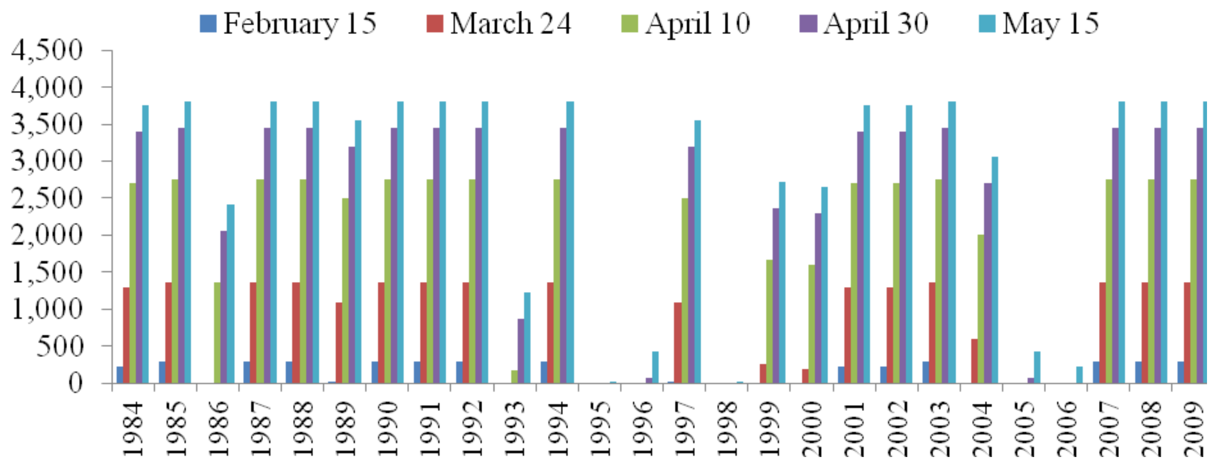
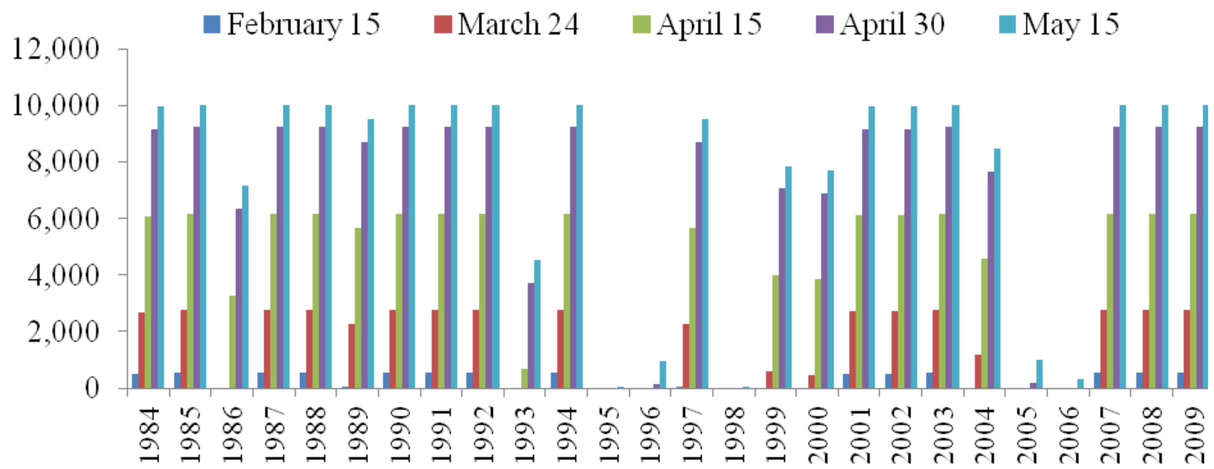


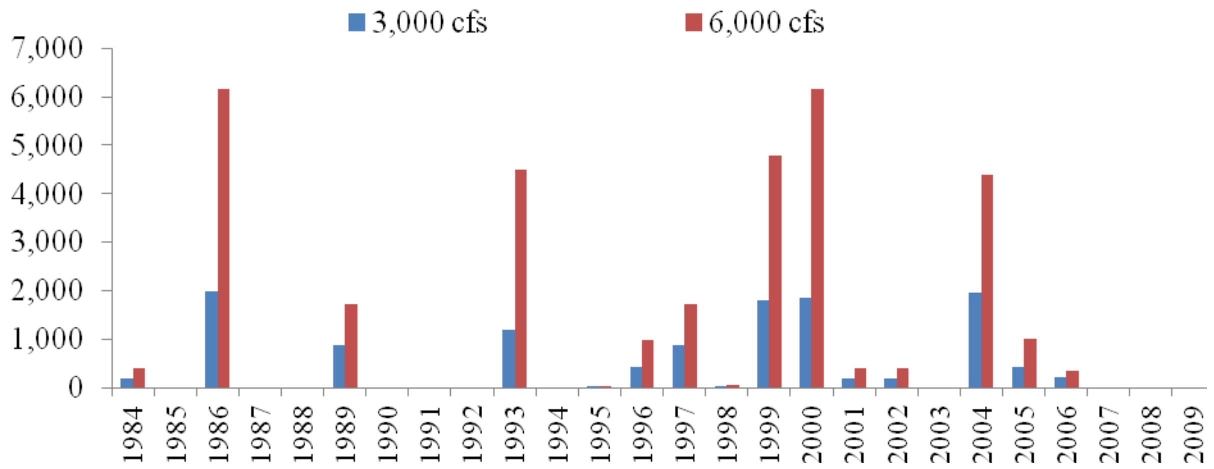
Figure 13. Loss of Irrigated Acres in Region Affected by 6,000 cfs Flow Rate, by Year.



We also evaluated the CM2 scenario where water flows through an operable gate at Fremont Weir are only imposed for an additional 30 days in years when there is natural flooding. As expected, the losses under this proposal are minimal. Figure 14 illustrates the change in total irrigated acres over the 26 years used in our analysis for both 3,000 and 6,000 cfs CM2 scenarios. Note that losses only occur in years when there is natural flooding.

The largest losses occur in years when natural overtopping occured late into the season. For example, in 1999 and 2000 heavy rains caused Fremont Weir overtopping through March 14 and March 17, respectively. The CM2 proposal calls for an additional 30 days of flooding which means flooding through the middle of April. This results in crop yield losses and an increase in fallow acres.

Figure 14. Loss of Irrigated Acres in Regions Affected by CM2 Proposal, by Year and Flow Volume.



4.2 Revenue Losses Summary

We summarize the expected agricultural revenue losses for each flow rate and last day of water releases from the Fremont Weir gate in Table 8. As shown, total output value (gross farm revenue) expected losses range from $0.28 to $17.3 million per year in the RPA scenarios, depending on the last day of water releases from the Fremont Weir gate and the flow rate. As expected, a later water release date delays planting and, consequently, reduces crop yields and increases farm revenue losses. Similarly, higher flow rates affect more fields and increase farm revenue losses.

Losses for the RPA scenarios should be interpreted as annual expected losses from continuous flooding up to the identified end date.

Table 8. Expected Annual Total Revenue Loss (2008 dollars), RPA Scenarios

Expected Total Revenue Loss (Output Value) ($2008)		
	3,000 cfs	6,000 cfs
February 15		
Direct	172,278	280,530
Indirect+Induced	116,463	189,826
Total	**288,741**	**470,356**
March 24		
Direct	1,081,960	2,026,110
Indirect+Induced	731,777	1,370,310
Total	**1,813,737**	**3,396,420**
April 10		
Direct	2,713,780	5,823,400
Indirect+Induced	1,835,472	3,938,499
Total	**4,549,252**	**9,761,899**
April 30		
Direct	3,915,080	8,981,760
Indirect+Induced	2,647,896	6,074,741
Total	**6,562,976**	**15,056,501**
May 15		
Direct	4,512,650	10,333,200
Indirect+Induced	3,052,140	6,988,682
Total	**7,564,790**	**17,321,882**

Expected losses for the CM2 scenario range between $1.2 to $2.8 million per year. The CM2 scenario corresponds to supplemental releases only in years where natural flooding occurs. As such, loss estimates are much lower, between $1.2 and $2.8 million per year. Note that in some years losses are zero (when there is no natural flooding) and in other years losses are substantial (when there is late natural flooding). These loss estimates correspond to expected annual losses, summarized in Table 9.

Table 9. Expected Annual Total Revenue Loss (2008 dollars), CM2 Scenario

Expected Total Revenue Loss (Output Value) ($2008)		
	3,000 cfs	6,000 cfs
CM2 Scenario		
Direct	725,930	1,704,640
Indirect+Induced	490,987	1,152,982
Total	**1,216,917**	**2,857,622**

A proportion of Yolo Bypass production and crop consumption occurs within Yolo County. As such, losses to Yolo County are expected to be less than total revenue losses. The proper measure of the effect on the Yolo County economy is change in "value added" (defined in section 3.4). Table 10 summarizes the change in value added under the proposed flooding policies. In the RPA scenarios expected losses in value added range from $0.14 to $8.9 million per year.

Table 10. Expected Annual Value Added Loss (2008 dollars), RPA scenarios

Expected Total Yolo County Revenue Loss (Value Added) ($2008)		
	3,000 cfs	6,000 cfs
February 15		
Direct	74,648	121,954
Indirect+Induced	73,568	119,914
Total	**148,216**	**241,868**
March 24		
Direct	469,589	879,285
Indirect+Induced	462,261	865,620
Total	**931,850**	**1,744,905**
April 10		
Direct	1,177,877	2,527,185
Indirect+Induced	1,159,463	2,487,936
Total	**2,337,340**	**5,015,121**
April 30		
Direct	1,699,112	3,898,193
Indirect+Induced	1,672,667	3,837,395
Total	**3,371,779**	**7,735,587**
May 15		
Direct	1,958,644	4,484,527
Indirect+Induced	1,928,028	4,414,727
Total	**3,886,672**	**8,899,254**

Comparable to the output value losses, value added losses in the CM2 scenario are lower than many of the RPA scenarios. Table 11 summarizes the CM2 results. Expected annual losses to value added range from $0.63 to $1.5 million per year.

Table 11. Expected Annual Value Added Loss (2008 dollars), CM2 scenario

Expected Total Yolo County Revenue Loss (Value Added) ($2008)		
	3,000 cfs	6,000 cfs
CM2 Scenario		
Direct	315,084	739,971
Indirect+Induced	310,155	728,336
Total	**625,239**	**1,468,307**

4.3 Employment Losses Summary

Table 12 summarizes the corresponding expected annual agricultural job losses under the proposed flooding policies. Employment effects are generally small, ranging from no effect to 130 jobs lost.

Table 12. Expected Annual Agricultural Jobs Loss, RPA scenarios

Expected Total Employment Loss		
	3,000 cfs	6,000 cfs
February 15		
Direct	1	2
Indirect+Induced	1	2
Total	**2**	**4**
March 24		
Direct	7	13
Indirect+Induced	7	12
Total	**13**	**25**
April 10		
Direct	17	37
Indirect+Induced	16	35
Total	**34**	**73**
April 30		
Direct	25	58
Indirect+Induced	24	55
Total	**49**	**112**
May 15		
Direct	29	66
Indirect+Induced	27	63
Total	**56**	**129**

Table 13 summarizes the CM2 scenario employment losses. Direct expected gross revenue losses are less than $1.5 million per year and the corresponding job losses are small.

Table 13. Expected Annual Agricultural Jobs Loss, CM2 Scenario

Expected Total Employment Loss		
	3,000 cfs	6,000 cfs
CM2 Scenario		
Direct	5	11
Indirect+Induced	4	10

Total	**9**	**21**

4.4 Tax Losses Summary

Table 14 summarizes the total expected annual losses in tax revenues to the state under the proposed flooding scenarios in the RPA. Annual tax revenue losses can be as high as $0.82 million under the 6,000 cfs flow scenario that extends flooding as late as May 15. For the 3,000 cfs flow regime scenario, annual tax revenue losses are less than $0.36 million.

Table 14. Expected Annual Total Statewide Tax Revenue Losses (2008 dollars), RPA Scenarios

Expected State and Local Tax Revenue Loss ($2008)		
	3,000 cfs	6,000 cfs
February 15	13,604	22,193
March 24	85,515	160,130
April 10	214,496	460,241
April 30	309,428	709,892
May 15	356,677	816,686

Table 15 summarizes the expected annual tax revenue losses to the state for the CM2 scenario.

Table 15. Expected Annual Total Statewide Tax Revenue Losses (2008 dollars), CM2 Scenario

Expected State and Local Tax Revenue Loss ($2008)		
	3,000 cfs	6,000 cfs
CM2 Scenario	57,377	134,744

5 Sensitivity Analysis

Results of the analysis are sensitive to parameters and assumptions listed in Section 1.1. Some overstate and others understate expected losses however, overall, we feel that our estimates are conservative. Nonetheless, some sensitivity analysis is warranted.

Expected loss estimates are most sensitive to changes in area inundated, yield loss, and crop prices. Area inundated is driven by HEC-RAS model results which are based on RPA and CM2 scenarios. As such, we don't have a basis to vary the number of affected acres. Similarly, yield loss is a function of planting date which is driven by agronomic data and non-linear regression analysis. Thus we do not have a justifiable basis to vary this relationship. Prices, as discussed in Section 2.2 are highly uncertain and we perform sensitivity analysis on these parameters.

We select 2005-2006 average prices to represent a "low" price scenario and 2008 prices to represent a "high" price scenario. Note that some crop prices are actually higher (lower) than the base scenario for the lower (higher) sensitivity analysis scenarios. This is expected since some crop prices are correlated and we typically don't expect to observe all prices trending in the same direction. In other words, a sensitivity analysis where all crop prices are 10 percent higher is not relevant sensitivity analysis. Table 16 summarizes the low and high prices used for sensitivity analysis, in addition to the base (2009-2010) prices used in the analysis. Note that the largest uncertainty occurs with the price of rice, which experienced a large spike in 2008 following years of lower prices.

Table 16. Price Sensitivity Analysis Range (2008 dollars), All Scenarios

Crop Group	2005-2006 Average (LOW)	2009-2010 Average (BASE)	2008 (HIGH)
Corn	141.00	172.69	152.20
Irrigated Pasture	49.20 (based on $35 per AUM)	49.20 (based on $35 per AUM)	49.20 (based on $35 per AUM)
Non-Irrigated Pasture	49.20 (based on $35 per AUM)	49.20 (based on $35 per AUM)	49.20 (based on $35 per AUM)
Rice	274.80	397.89	513.10
Wild Rice	1,469.30	961.85	1,684.20
Safflower	314.80	351.18	432.62
Sunflower	1,056.10	1,196.15	1,092.32
Processing Tomatoes	67.75	78.81	68.81

Vine Seed (Melon Proxy)	349.80	303.00	296.10

Figure 15 summarizes the results of the price sensitivity analysis for the 3,000 cfs scenarios. Sensitivity analysis corresponds to the output of the BPM model, gross agricultural revenues (gross output value), or the direct effects listed in Table 8. The base estimate has been normalized to 1, thus the bars show the percentage deviation due to prices. For example, in the April 10 RPA scenario low prices reduce losses by 24 percent (0.76) and high prices increase losses by 23 percent (1.23).

Figure 15. Price Sensitivity Analysis for Gross output Value under 3,000 cfs, All Scenarios.

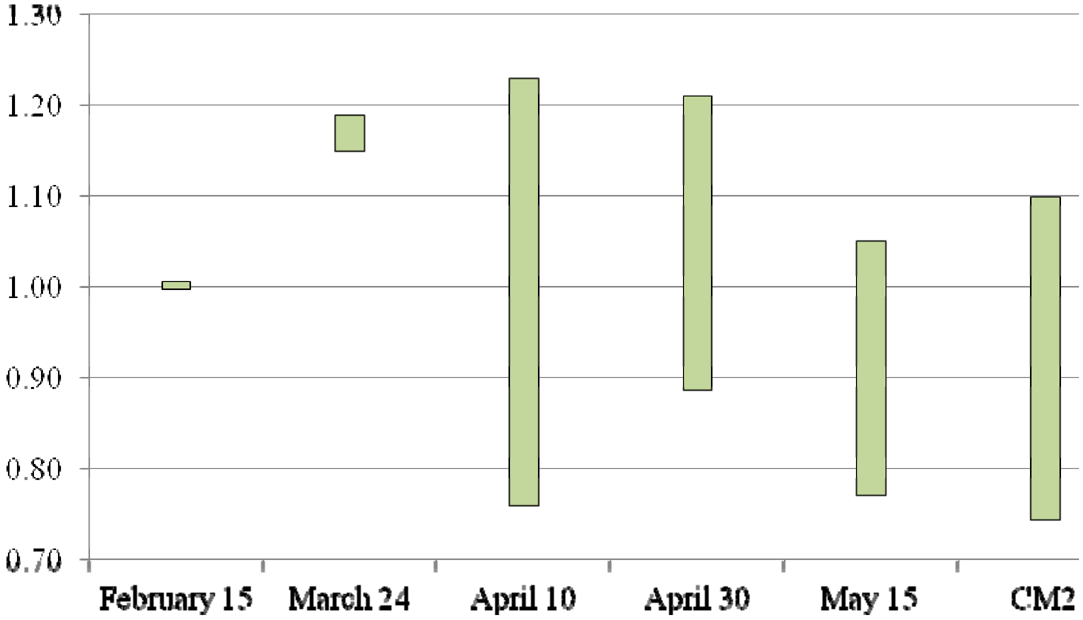
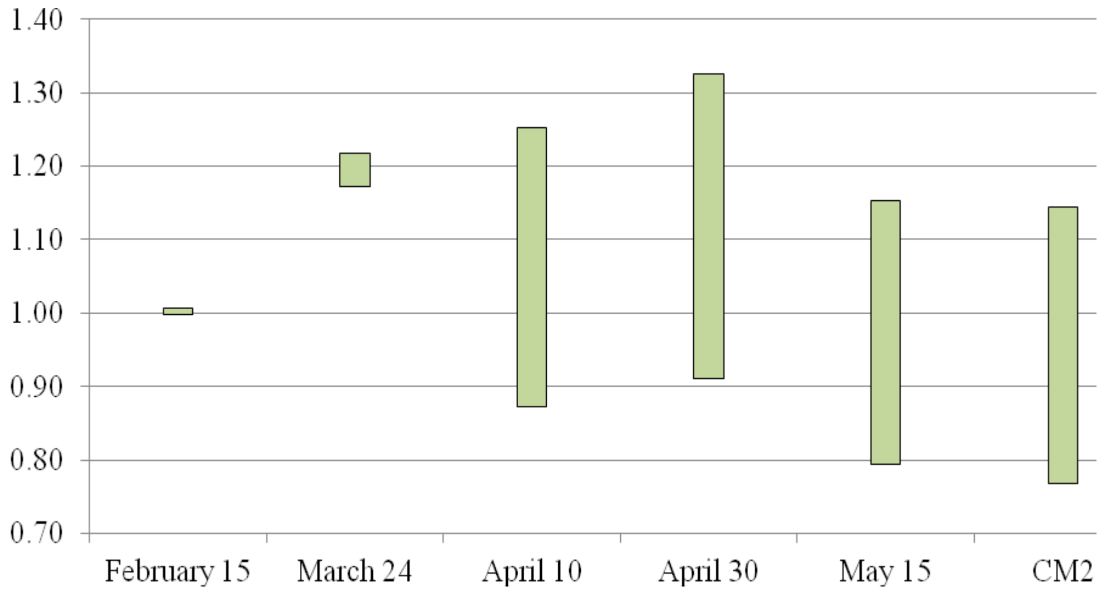


Figure 15 summarizes the results of the price sensitivity analysis for the 6,000 cfs scenarios. Again, sensitivity analysis corresponds to the output of the BPM model, gross agricultural revenues (gross output value), or the direct effects listed in Table 8. The base estimate has been normalized to 1, thus the bars show the percentage deviation due to prices. For example, in the April 10 RPA scenario low prices reduce losses by 13 percent (0.87) and high prices increase losses by 25 percent (1.25). Figures 15 and 16 indicate that results are slightly sensitive to crop prices, as expected. Our estimates based on 2009-2010 average prices are generally conservative since the deviation from the base is generally above 1.

Figure 16. Price Sensitivity Analysis for Gross output Value under 6,000 cfs, All Scenarios.



Other areas where we are unable to perform sensitivity analysis include weather shocks and changes in the cost of production. The latter raises an important point, namely we have implicitly assumed that the costs of production in the Bypass remain constant even with late flooding. However, if production costs go up, for example due to overtime labor or increased preparation costs, loss estimates will increase.

6 Conclusion

This study has assembled extensive data on cropping, water use, and the economics of the agricultural industry in the Yolo Bypass. We then use this data to calibrate and link four models. Namely, an engineering model of field flood inundation (HEC-RAS), an agronomic model of yield loss due to shorter growing seasons (DAYCENT), an economic production model of farm crop decisions in the Yolo bypass (BPM), and finally a regional economic model of the Yolo County economy (IMPLAN). The net economic results from these four models are measured as a set of output values for twelve alternative flood scenarios that cover two different volumes of flooding and five different ending dates for the RPA, plus an evaluation of the CM2 proposal. The five overtopping dates analyzed were selected to span the full range from no effect on cropping, to the cost of flooding that prevents any cropping, and intermediate values.

For each of the twelve scenarios the net dollar effect on the Yolo County economy is measured in terms of value-added. The loss in employment is measured in terms of full-time equivalent jobs, and the effect on the State tax receipts. The expected economic value added losses range widely from $0.15 to $8.9 million per year. The effect on job losses and tax receipts also varies widely, depending on the scenario.

Despite our efforts to assemble the very best data set, we would like to stress that the model results are sensitive to several assumptions. In particular, we would like to note that the areas of inundation under different flooding scenarios may well change with different engineering models and better data. In addition, we have attempted to use a weighted price for future crops that is representative of an average over the past 25 years and neither relies on recent boom price levels or earlier depressed agricultural conditions.

We would also like to emphasize that this study is only able to measure the expected cost to the Yolo County economy, and is not able to account for changes in risk, management difficulties, and other factors facing the county and the agricultural industry in the Bypass. As such, the results of this study should be regarded as a conservative measure of the expected annual economic costs to the county economy of changes in flood policy in the Bypass.

7 References

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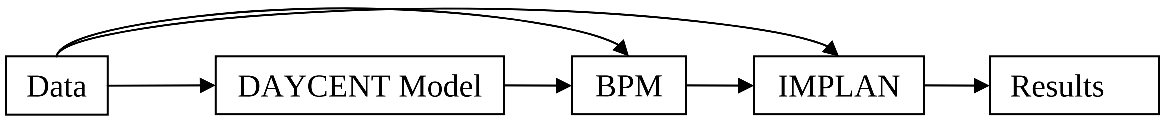
0 Technical Appendix: Overview of the Modeling Approach

Evaluation of agricultural policies requires a modeling framework which can be used to simulate losses and estimate costs. In this report, we adopt a modeling framework driven entirely by a rich, empirical dataset, highlighted by Figure A1. We estimate the effect of 12 proposed policies of flood level and date for fish habitat on Bypass agriculture. The scenarios include flow rates of 3,000 and 6,000 cfs from the Sacramento River passing through an operable gate in the Fremont Weir. The last day of overtopping at Fremont Weir occurs on February 15, March 24, April 10, April 30 or May 15. Additionally, we evaluate the CM2 proposal which does not correspond to a specific end date.

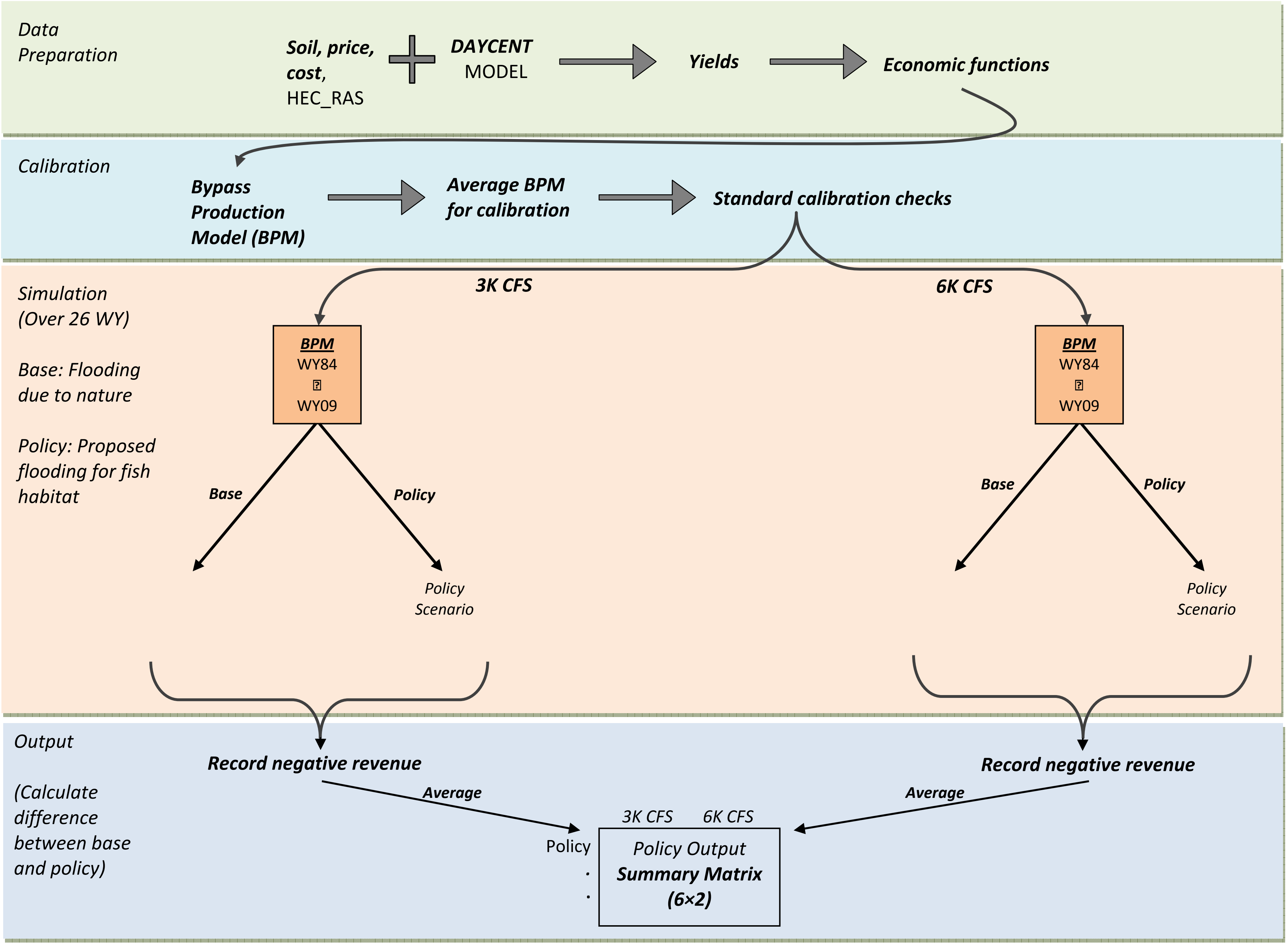
Figure A1 provides a simple illustration of the key steps in the analysis. Starting with input data (including the HEC-RAS model), we use a series of linked models to estimate the impacts to agriculture. The DAYCENT model is an agronomic model used to estimate field-level yields, as a function of planting date, for subsets of fields in each region of the Bypass. Regression analysis on the DAYCENT model output and additional input data are used to calibrate the BPM. Output from the BPM and other input data are used as inputs to the IMPLAN model.

Figure A1. Illustration of the Fundamental Modeling Approach



Production and geo-referenced land use data, HEC-RAS output, DAYCENT simulations, and regression analysis are used as inputs to the Bypass Production Model (BPM). The BPM is the fundamental economic model in the analysis. The technical details of the analysis can be summarized in four phases including, (i) data preparation, (ii) calibration, (iii) estimation, and (iv) output. The flow chart in Figure A2 illustrates this process, which we review in detail in this technical appendix.

Data preparation involves the compilation and synthesis of model data, including geo-referenced land use data, production data, and HEC-RAS model output. This stage additionally includes field-level simulations with the DAYCENT model and regression analysis. Model calibration includes development of the Bypass Production Model (BPM) and exact calibration, through Positive Mathematical Programming, in inputs and outputs to a known base year. Estimation involves simulation of the calibrated BPM over a series of known water years (nature) and sequentially imposing the 12 proposed policies on the model. The difference between the base and policy simulations is recorded for all years with revenue losses. The output phase estimates losses from the BPM and generates expected annual gross revenue losses. Output from the BPM are input to the IMPLAN model to estimate Yolo County direct, indirect, and induced economic effects.


Data Preparation
Soil, price, cost, HEC_RAS
DAYCENT MODEL
Yields
Economic functions
Calibration
Bypass Production Model (BPM)
Average BPM for calibration
Standard calibration checks
Simulation (Over 26 WY)
Base: Flooding due to nature
Policy: Proposed flooding for fish habitat
3K CFS
6K CFS
BPM
WY84
⍰
WY09
BPM
WY84
⍰
WY09
Base
Policy
Base
Policy
Policy Scenario
Policy Scenario
Output
(Calculate difference between base and policy)
Record negative revenue
Record negative revenue
Average
Average
3K CFS
6K CFS
Policy
.
.
Policy Output
Summary Matrix
(6×2)

1 Data Preparation

We collected extensive data for the Yolo Bypass in order to conduct an empirical analysis of the proposed inundation scenarios. These include the following: (i) field-level geo-referenced crop data and region definitions, (ii) crop yields and yield change based on planting date, (iii) crop prices, (iv) costs of production, and (v) area inundated under 3,000 and 6,000 cfs flow volumes. We review these data in the following section.

1.1 Land Use and Production Data

Production and land use data are summarized in the main text of this report, we provide a brief summary in this section. Land use data are from a series of years, 2005-2009, of land use for major crops, fallow land, and wetland in the Yolo Bypass. We identified 6 agricultural sub-regions in the Yolo Bypass which represent homogeneous production conditions and form the basis of the BPM. We used soil and climate data, in addition to interviews with Bypass farmers, to develop homogenous agricultural sub-regions.

1.2 The DAYCENT Model

The DAYCENT model (DeGryze et al. 2009) is an agronomic model of field-level yields for specific agricultural production regions. Johan Six and Juhwan Lee in the Plant Sciences Department at UC Davis were responsible for model analysis and simulations.

The DAYCENT model calibrates to observed production conditions on a sub-set of fields in the Yolo Bypass. The sub-set of fields is selected to represent heterogeneous production conditions in the Bypass. The model is calibrated against data for corn, rice, safflower, sunflower, processing tomato, alfalfa and mixed melons. The model does not explicitly simulate pasture so we use alfalfa grown on a yearly rotation to proxy for irrigated pasture. Based on interviews with farmers we determined that the yearly yield of dry pasture in AUM/acre is a fifth that of irrigated pasture. The model does not simulate vine seed so we use the yield for mixed melons (honeydew and watermelon) as a proxy for vine seed.

The DAYCENT model estimates the yield on any given field taking into account all production conditions, including climate and date the crop was planted. We use the calibrated DAYCENT model to estimate crop yields on a subset of fields in each of the 6 regions of the BPM. We control for all other factors and allow the planting date to vary, thus the DAYCENT model generates a series of data points, for each crop and region, of the expected yield given the crop planting date.

1.3 Yield Functions Regression Analysis

We use the data points from the DAYCENT model results to estimate a single yield function, for each crop and region. We fit this function using non-linear regression analysis which results in a single function, for each crop and region in the Bypass, which relates crop yield to the planting date. The yield response functions are included in the BPM.

We control for all other factors and specify yield as a function of the planting date. We estimate the yield function by pooling all field observations, from the DAYCENT model, in each region for the years 2005-2009. This is because we want to estimate the average yield response to the planting date over a range of years rather than capturing yearly weather effects. The objective of this study is to estimate the expected effects on agriculture due to increased flooding for fish habitat and, as such, we do not want to capture weather or other effects in the yield response functions.

For each crop i and region g, define $y_{i,g}$ as crop yield and $d_{i,g}$ as the planting date. Note that the planting date is the last day of over-topping plus region-specific drainage and preparation times. Model parameters include $\alpha_{i,g}$, $\beta^{0}_{i,g}$, and $\beta^{1}_{i,g}$. The estimated model for all crops except pasture is defined as

$$y_{i,g} = \frac{\alpha_{i,g}}{1+e^{\beta_{0i,g}+\beta_{1i,g}d_{i,g}}}. \tag{0.0}$$

Pasture exhibits a different response than the other crops due to its resistance to delayed planting date. We define the yield response function for pasture as

$$y_{i,g} = \frac{\alpha_{i,g}}{1+e^{\beta_{1i,g}d_{i,g}}}. \tag{0.0}$$

We experimented with a series of functional forms for the yield response functions and determined that the exponential provided the best fit of the data. Specifically, the AIC (and, AIC-corrected for small sample sizes) indicated that the models in Equations 1.1 and 1.2 were the best fit for the data.

We perform nonlinear regression analysis in Stata to generate parameter estimates. Not all crops are gown in all regions, thus yield functions only apply to regions where crops are grown. Dry and irrigated pasture have the same yield functions. Rice and wild rice have the same yield functions. These simplifications are made because there is limited data availability for these crops. The following tables summarize the parameter estimates and standard errors.

Table A1. Pasture Yield Function Parameter Estimates (standard errors in parentheses)

Pasture in Region	Alpha	Beta-0	Beta-1	Observations
5	0.900	2.784	-0.024	35
	(0.350)	(0.597)	(0.009)	
6	0.886	2.803	-0.025	35
	(0.350)	(0.602)	(0.009)	

Table A2. Corn Yield Function Parameter Estimates (standard errors in parentheses)

Corn in Region	Alpha	Beta-0	Beta-1	Observations
1	5.837	-32.354	0.222	43
	(0.037)	(12.347)	(0.092)	
2	5.905	-31.547	0.217	45
	(0.031)	(9.015)	(0.067)	
3	5.885	-31.247	0.214	45
	(0.038)	(10.278)	(0.076)	
4	5.731	-24.544	0.172	46
	(0.081)	(9.789)	(0.073)	

Table A3. Vine Seed (Melons) Yield Function Parameter Estimates (standard errors in parentheses)

Vine Seed in Region	Alpha	Beta-0	Beta-1	Observations
2	10.907	-5.012	0.032	37
	(1.786)	(1.197)	(0.006)	
3	8.871	-6.218	0.039	37
	(1.811)	(2.107)	(0.010)	
4	9.327	-5.544	0.036	37
	(1.801)	(1.576)	(0.008)	

Table A4. Rice Yield Function Parameter Estimates (standard errors in parentheses)

Rice in Region	Alpha	Beta-0	Beta-1	Observations
1	4.157	-19.492	0.132	54
	(0.014)	(1.065)	(0.007)	
2	4.160	-19.616	0.132	53
	(0.015)	(1.125)	(0.008)	
3	4.162	-19.571	0.132	53
	(0.015)	(1.111)	(0.008)	
4	4.140	-18.971	0.129	54
	(0.016)	(1.139)	(0.008)	
5	3.768	-22.392	0.154	47
	(0.009)	(1.614)	(0.012)	
6	3.821	-21.303	0.145	49
	(0.008)	(1.053)	(0.007)	

Table A5. Safflower Yield Function Parameter Estimates (standard errors in parentheses)

Safflower in Region	Alpha	Beta-0	Beta-1	Observations
1	1.472	-5.498	0.044	51
	(0.244)	(1.364)	(0.008)	
2	1.256	-8.812	0.059	51
	(0.073)	(1.501)	(0.009)	
3	1.531	-5.350	0.044	51
	(0.272)	(1.369)	(0.008)	
4	1.391	-5.830	0.046	51
	(0.200)	(1.360)	(0.008)	
5	1.278	-6.526	0.052	51
	(0.311)	(2.606)	(0.016)	
6	1.521	-5.429	0.045	51
	(0.294)	(1.487)	(0.008)	

Table A6. Sunflower Yield Function Parameter Estimates (standard errors in parentheses)

Sunflower in Region	Alpha	Beta-0	Beta-1	Observations
1	1.816	0.000	0.006	55
	(0.077)	(0)	(0.000)	
6	0.676	-5.104	0.025	55
	(0.054)	(1.968)	(0.010)	

Table A7. Processing Tomatoes Yield Function Parameter Estimates (standard errors in parentheses)

Processing Tomatoes in Region	Alpha	Beta-0	Beta-1	Observations
1	39.29	-10.09	0.06	55
	(0.536)	(0.720)	(0.004)	
2	39.49	-10.09	0.06	55
	(0.568)	(0.756)	(0.004)	
3	39.68	-10.25	0.06	55
	(0.557)	(0.762)	(0.004)	
6	39.76	-8.44	0.05	55
	(0.638)	(0.592)	(0.003)	

Equations (1.1) and (1.2), and the parameter estimates in Tables A1-A7, show that the best fit of the DAYCENT yield data is with a logistic-type functional form. Over a small range of planting delay there is a small effect on yields. Yields decline at an increasing rate over some intermediate range and, at some point, asymptote towards zero. Figures A3-A9 illustrate the yield functions for each crop in an example region. Data points are in red, fitted functions in blue.

Figure A3. Fitted Yield Function for Corn in Region 1

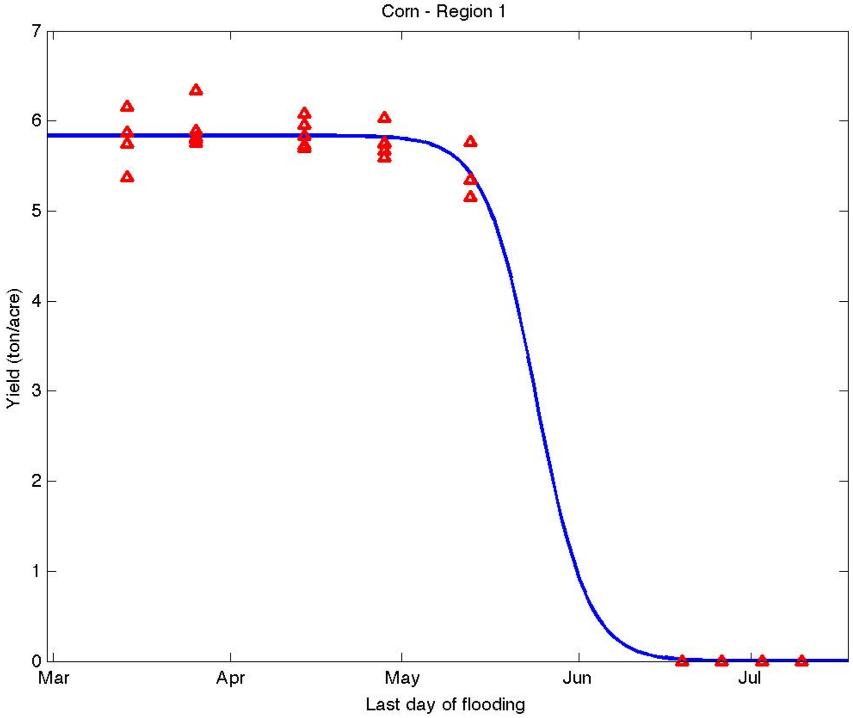


Figure A4. Fitted Yield Function for Pasture in Region 6

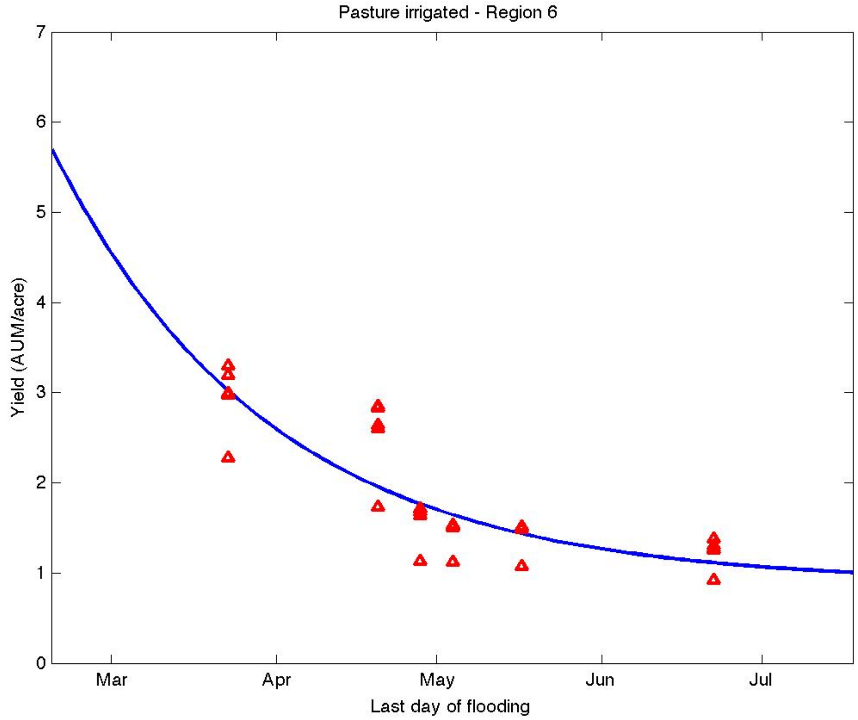


Figure A5. Fitted Yield Function for Rice in Region 2

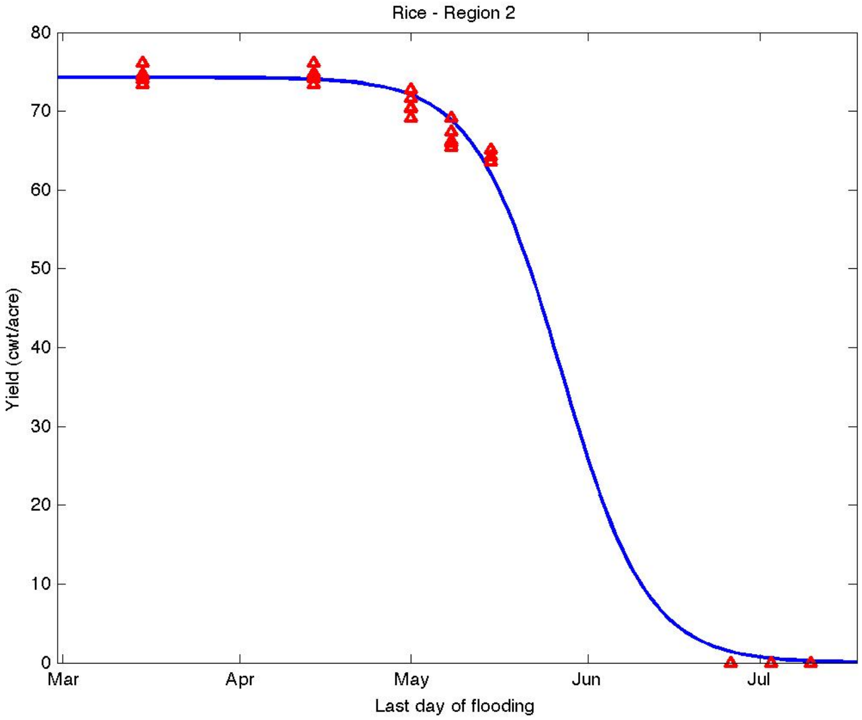


Figure A6. Fitted Yield Function for Safflower in Region 1

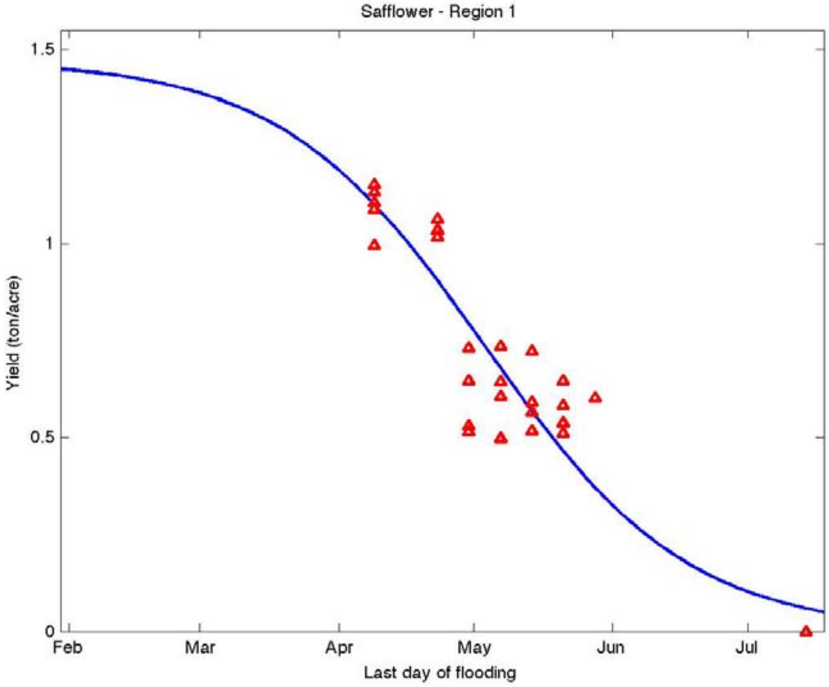


Figure A7. Fitted Yield Function for Sunflower in Region 1

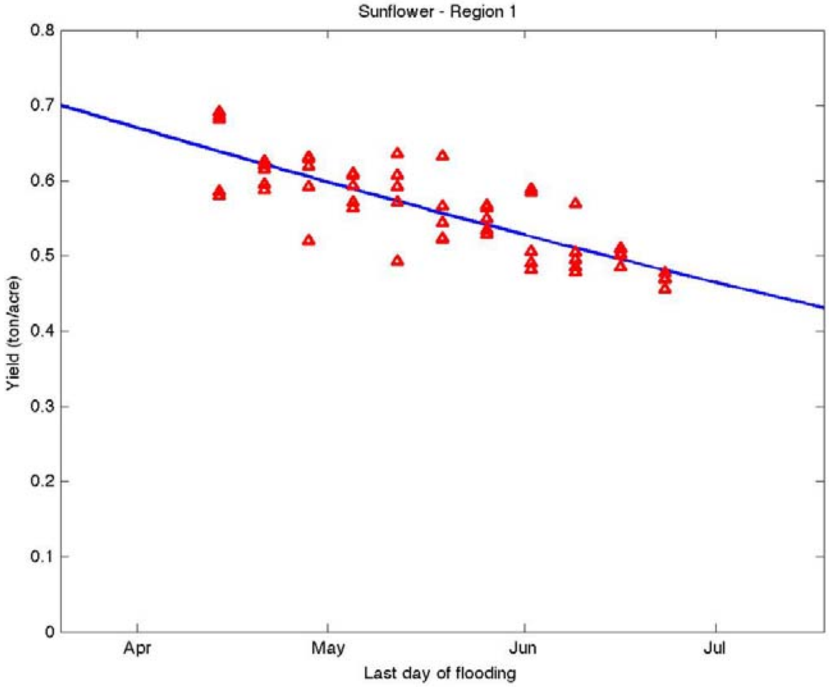


Figure A8. Fitted Yield Function for Processing Tomatoes in Region 3

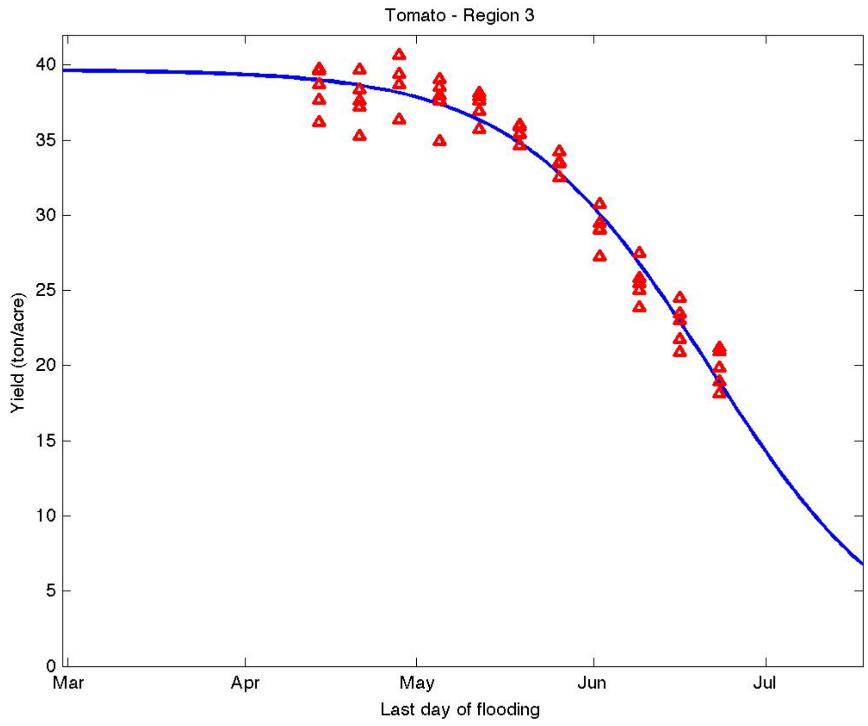
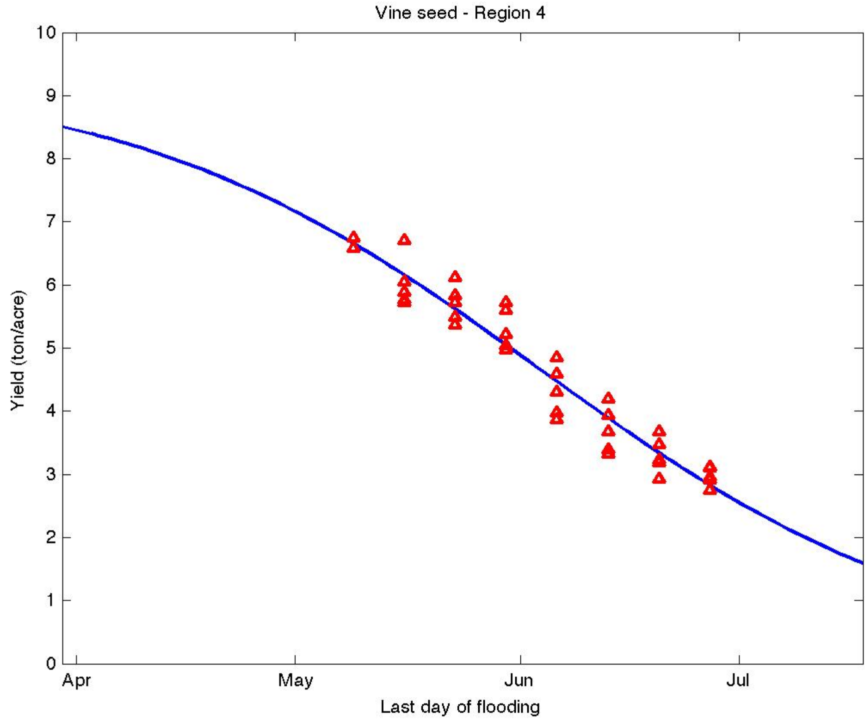


Figure A9. Fitted Yield Function for Melons (Vine Seed) in Region 4



2 The Bypass Production Model (BPM) Calibration

We use the crop yield functions estimated from the DAYCENT model, plus additional economic data, to calibrate the BPM. The BPM is the fundamental model of the analysis. The BPM relates changes in crop yield and total affected acres to changes in agricultural production and, fundamentally, changes in agricultural revenues. The BPM is a Positive Mathematical Programming (PMP after Howitt, 1995) model of agriculture in the 6 regions of the Yolo Bypass.

Note that a model is, by definition, a simplified representation of a real system. In the process of abstracting and simplifying a real system a model loses some information; thus even with theoretically consistent structure it is highly unlikely that a model will calibrate closely to observed (base year) data. The problem is well documented in the agricultural production modelling literature (Hazell and Norton 1986, Kasnakoglu 1990). One solution is to use observed farmer behavior, in the form of observed land use patterns, and additional exogenous information in order to calibrate the parameters of the structural model that exactly reproduce observed base-year conditions. The method of Positive Mathematical Programming is a common calibration method for structural agricultural production models (Howitt 1995), which we use in the BPM.

2.1 Positive mathematical programming (PMP)

The BPM self-calibrates using a three-step procedure based on Positive Mathematical Programming (PMP) (Howitt 1995) and the assumption that farmers behave as profit-maximizing agents. A traditional optimization model would have a tendency for overspecialization in production activities relative to what is observed empirically. PMP incorporates information on the marginal production conditions that farmers face, allowing the model to exactly replicate a base year of observed input use and output. Marginal conditions may include inter-temporal effects of crop rotation, proximity to processing facilities, management skills, farm-level effects such as risk and input smoothing, and heterogeneity in soil and other physical capital. In the BPM, PMP is used to translate these unobservable marginal conditions, in addition to observed average conditions, into region and crop-specific exponential cost functions.

Calibrating production models using PMP has been reviewed extensively in the recent literature. Buyssee et al. (2007) and Heckelei and Wolff (2003) argue that shadow values from calibration and/or resource constraints are an arbitrary source of information for model calibration. Subsequent research suggests using exogenous information such as land rents instead of shadow values (Heckelei and Britz 2005, Kanellopoulos et al. 2010). When multiple years of observations are available Heckelei and Britz (2005) propose a generalized maximum entropy formulation to estimate resource and calibration constraint shadow values. Merel and Bucaram (2010) and Merel et al. (2011) propose calibration against exogenous supply elasticity estimates. The BPM model is calibrated using traditional PMP with exogenous supply (acreage response) elasticity information.

2.2 Model Calibration

PMP is fundamentally a three-step procedure for model calibration that assumes farmers optimize input use for maximization of profits. In the first step a linear profit-maximization program is solved. In addition to basic resource availability and non-negativity constraints, a set of calibration constraints is added to restrict land use to observed values. In the second step, the dual (shadow) values from the calibration and resource constraints are used to derive the parameters for an exponential "PMP" cost function. In the third step, the calibrated model is combined into a full profit maximization program. The exponential PMP cost function captures the marginal decisions of farmers through the increasing cost of bringing additional land into production (e.g. through decreasing quality).

The BPM framework requires that additional land brought into production faces an increasing marginal cost of production. The most fertile land is cultivated first, additional land brought into production is of lower “quality” because of poorer soil quality, drainage or other water quality issues, or other factors that cause it to be more costly to farm. This is captured through an exponential land cost function (PMP cost function) for each crop and region. The exponential function is advantageous because it is always positive and strictly increasing, consistent with the hypothesis of increasing land costs. The PMP cost function is both region and crop specific, reflecting differences in production across crops and heterogeneity across regions. Functions are calibrated using information from acreage response elasticities and shadow values of calibration and resource constraints. The information is incorporated in such a way that the average cost data (known data) are unaffected.

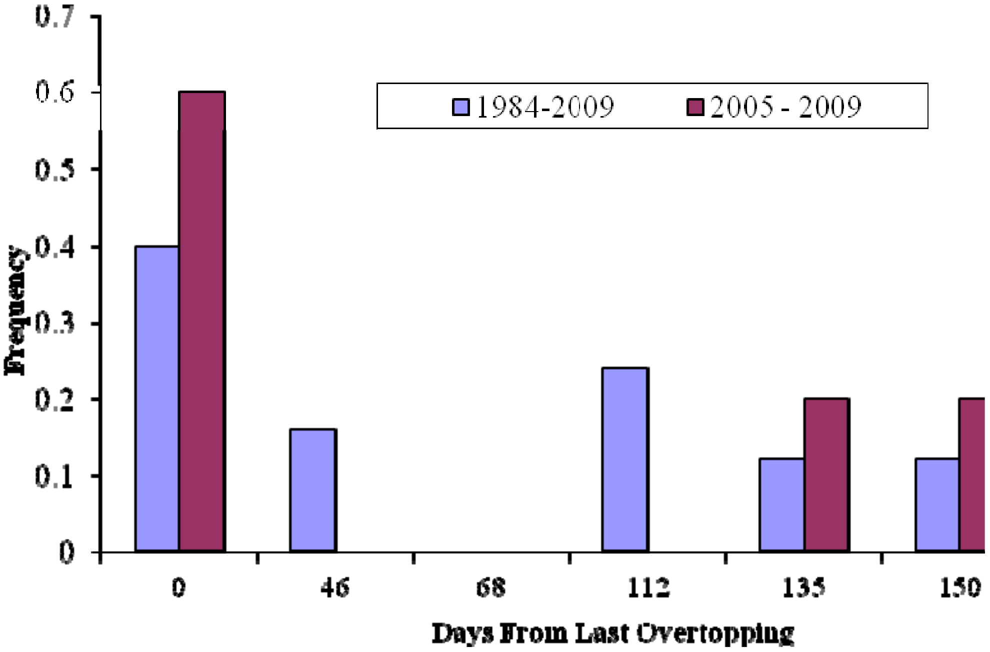
Formally, the exponential PMP cost functions are, for each crop i and region g, defined as

$$C_{gi}(x_{gi}) = \phi_{gi} e^{\gamma_{gi} x_{gi}}, \tag{0.0}$$

where ϕ_{gi} and γ_{gi} are parameters estimated by the PMP calibration routine described above and x_{gi} are total acres observed in production during the calibration base years.

The BPM calibrates to average observed land use between 2005 and 2009. We determined that 2005-2009 are representative of the full dataset (1984-2009) in terms of flood occurrence in the Yolo Bypass and, as such, are representative of land use in 3,000 and 6,000 cfs affected areas of the Bypass. Furthermore, detailed geo-referenced land use data were only available for 2005-2009 in the Yolo Bypass. The histogram in Figure A10 shows that the sub-set of years which we use for calibration (2005-2009) is representative of all years in the data (1984-2009) and, as such, represents a reasonable set of years to use for model calibration. While the data do omit some years of intermediate flood dates, Figure A10 shows that we capture the lower and upper bounds of inundation reasonably well. As such, we feel that calibration to average 2005-2009 land use accurately reflects base conditions in the Bypass.

Figure A10. Histogram of Overtopping Date Frequencies (84-09 and 05-



09)

Standard calibration checks follow model calibration (see Howitt et al. 2012). These checks verify that the base year of observed data is reproduced by the calibrated model and that economic optimization requirements are satisfied.

We use a three year average of prices in the BPM, 2005-2007. These prices were determined to be representative of the average production conditions between 2005 and 2009 and, as such, are representative of the calibration data used in the model.

2.3 Profit Maximization Program Definition

The BPM solves for the cropping pattern that maximizes the agricultural profit across all regions subject to regional land constraints and yield functions estimated from the DAYCENT data. Data are as described previously. We assume the flood agency announces the policy it chooses for that year (or series of years) before farmers make their planting decisions. Therefore, farmers know the last day of overtopping for that year (with the exception of years where nature results in overtopping past the policy date) and the yields associated with that planting date. The objective function for the profit maximization program in the BPM is

$$\max_{x_{ig}} \sum_{g}\sum_{i} p_i \cdot y_{ig} \cdot x_{ig} - \sum_{g}\sum_{i} \phi_{ig} e^{\gamma_{ig} x_{ig}} - \sum_{g}\sum_{i} vc_{ig} x_{ig}, \qquad (0.0)$$

where subscripts and variables are as previously defined, p_i are individual crop prices, and vc_{ig} are region and crop-specific variable costs of production per acre. Yields (y_{ig}) vary by planting date, as defined above, according to the yield functions estimated with DAYCENT model output as,

$$y_{i,g} = \frac{\alpha_{i,g}}{1 + e^{\beta_{0i,g} + \beta_{1i,g} d_{i,g}}}, \quad \forall \mathrm{i} \neq \text{pasture}, \tag{0.0}$$

and

$$y_{ig} = \alpha_{ig} + e^{\beta_{0ig} + \beta_{1ig} d_{ig}}, \text{ for } \mathrm{i} = \text{pasture}, \tag{0.0}$$

where subscripts, variables, and parameters are as previously defined. Finally, land constraints in each region are defined as

$$\sum_i x_{ig} \leq b_g, \ \forall g, \tag{0.0}$$

where b_g is the total number of acres (crop acres plus fallow) observed in each region.

In summary the procedure in the calibrated BPM model is to maximize Equation (1.4) subject to Equations (1.5) - (1.7) by selecting the optimal crop mix, x_{ig}. Simulating the model over the base calibration data reproduces the observed base allocation.

3 BPM Simulation

BPM model simulations proceed for two flow volumes separately: 3k CFS and 6k CFS, given the calibrated model defined in Equations (1.4) - (1.7). we defined the simulation procedure in the main text of the report, and repeat here for completeness.

Step 1: Run the BPM for a season with *known* overtopping dates at Fremont Weir, and flooding in the Yolo Bypass. This represents the base condition (e.g. natural flooding) for agriculture in the Bypass in the absence of the proposed policy flooding scenarios (for that year). Repeat Step 1 for a series of known years, there are 26 total.

Step 2: Over the same series of years as step two, run the BPM and impose (sequentially - one at a time) the 12 proposed policy flooding scenarios. This represents what *would have* happened to Bypass agriculture *if* the flooding policy was implemented in that year. Repeat Step 2 for the all of the same years as Step 1.

Step 3: For each year simulated in Steps 1 and 2, calculate the difference in agricultural revenues (and other outputs). Record the result for negative changes in revenue. Intuitively, we only want negative changes in revenue because a positive change in revenue implies that the policy was “better” than nature. For example, if natural flooding occurred in the Bypass until April 30th then imposing a policy which stops overtopping at Fremont Weir on April 10th would not be possible (i.e. it would increase revenues).

Step 4: Calculate the average loss of revenue (and other changes) across all of the years simulated in Steps 1 - 3. This represents the expected impacts to agriculture due to the proposed flooding scenarios, and is the fundamental output of the BPM.

The fundamental procedure of the BPM is to generate *expected* losses to agriculture by using the calibrated model to estimate what would have happened under natural flooding, and then asking what would have happened if a specific policy (last day of overtopping) was in place. This procedure allows us to generate expected losses because we control for the expected natural flood events in the Bypass. The following section illustrates this point.

4 BPM Output and Expected Losses

The final phase in the analysis is to use the BPM simulations to estimate the change in agricultural gross revenues and acreage as a result of each of the policies (last overtopping date for RPA, or CM2 scenario) under both flow volumes (3k and 6k CFS). We estimate regional economic effects (jobs and income) using the IMPLAN model.

Economic losses are interpreted as expected annual losses in our analysis. The key assumption is that the previous 26 year hydrology in the Yolo Bypass is representative of expected future conditions. Specifically, natural overtopping at Fremont Weir will occur with the same expected frequency, duration, and volume. There are two reasons these 26 years of data were identified as reasonable, including (i) detailed flow information over the Fremont Weir was available for these years, and (ii) it is representative of current hydrologic conditions in the Sacramento Valley watershed. Older hydrologic information less accurately represents current conditions because it does not account for changes in urban development and reservoir operations that have altered flows in the Sacramento River over time. If better data become available we can revisit this assumption.

The policy analysis output in the report is the average, over 26 years, of annual losses as estimated by the individual policy scenarios in the BPM.

4.1 IMPLAN

The IMPLAN model estimates regional economic changes in production, value added, employment, and tax receipts. Expected revenue losses from the BPM analysis represent direct economic effects. However, upstream and downstream industries will be affected and some agricultural workers will lose their jobs when production in the Bypass decreases. We use the IMPLAN regional Input-Output model to estimate the direct, indirect, and induced effects of the 12 policy scenarios. The sum of these components represents the total effect of the policies.

IMPLAN is a multiplier model, which accounts for interrelationships among sectors and institutions in the regional economy. The input-output representation of the economy was first proposed by Leontief (1941). Production in this setting is assumed to occur by using fixed proportions of factors, such that the same amount of a production input.

Coverage if the IMPLAN area for this study is exclusive to Yolo County. We used the NAICS classification system and groped agricultural production into a single sector, NAICS 111. We employed IMPLAN Professional Version 3 and a 2009 database for Yolo County.

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