AN ASSESSMENT OF FUTURE MARKETS FOR CROPS GROWN ALONG THE COLUMBIA RIVER:

Economic Implications of Increases in Production Resulting from New Agricultural Water Rights Under the Columbia River Initiative

Gary W. Williams
Oral Capps, Jr.*

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* Williams is Professor of Agricultural Economics and Director, Texas Agricultural Market Research Center, and Capps is Southwest Dairy Marketing Endowed Chair and Professor of Agricultural Economics, Department of Agricultural Economics, Texas A&M University, College Station, Texas 77843-2124.

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ABSTRACT

This report examines the likely effects of additional agricultural water rights under the Columbia River Initiative (CRI) on net crop revenues (hay, orchards, vegetables, potatoes, wheat, and other crops) in the state of Washington over the next 20 years. This study corrects for four potentially serious methodological flaws made in two previous studies associated with the CRI and concludes that those studies substantially overestimated the net revenues accruing to producers in the Columbia River area from new irrigated acreage under the CRI. In fact, the net revenues are more likely to be negative than positive. Methodological errors made in the two previous studies lead to results that support a policy prescription that is just the *opposite* of what would be in the best economic interest of the state of Washington and the Columbia River region.

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AN ASSESSMENT OF FUTURE MARKETS FOR CROPS GROWN ALONG THE COLUMBIA RIVER: The Economic Implications of Increases in Production Resulting from New Agricultural Water Rights Under the Columbia River Initiative

EXECUTIVE SUMMARY

The State of Washington commenced the Columbia River Initiative (CRI) to establish a new water management program for the main stem Columbia and lower Snake rivers to provide water for consumptive use while protecting the environment. Two economic studies were conducted by the State of Washington to inform decisions about such a program. The first study by Huppert et al. (2004) was an analysis of the economic consequences of the CRI for the State of Washington. The second study by Zhang (2004) used the results of Huppert et al. to conduct a cost-benefit analysis of the CRI for the State of Washington.

This study is an independent analysis of the likely effects of additional agricultural water rights under the Columbia River Initiative on net agricultural revenues in the state of Washington over the next 20 years. The study was designed to follow the Huppert et al. and Zhang methodology in principle but correct for four methodological errors in their work that could have a substantial impact on the net agricultural revenue calculations and, therefore, on the cost-benefit analysis: (1) the assumed elasticities of supply and demand; (2) the choice of crop mix on the new irrigated acreage; (3) the potential intra-state tradeoffs in production; and (4) confusing before/after measurement of changes and with/without measurement of changes.

The first methodological error was the assumption that the demand for the crops produced along the Columbia River is perfectly price elastic which guarantees the highest gross revenue calculations possible. We correct for that error in this study by using estimates of the elasticities of supply and demand to calculate the price and quantity implications of increased water available for agricultural production in the Columbia River area.

The second error in the Huppert et al. and Zhang methodology is their assumption that any new water is applied to crops on new acreage in proportion to their shares of total existing acreage and that the crop mix does not change over time. In this analysis, we allow the crop mix to change over time and conduct two scenarios using different water allocation assumptions. In the first, new water is applied proportionally to all crops as done by Huppert et al. In the second, new water is applied only to marginal crops defined as wheat, hay, and an "other crops" group.

The third error in the Huppert et al. calculations is their exclusive focus on the Columbia River region. The problem arises in using the Huppert et al. revenue calculations to infer benefits from the CRI to the state of Washington since any production increase in the Columbia River region could well be offset by a reduction in production elsewhere in the state. We address this problem by working from the state level down to the Columbia River region in our baseline forecasts and by allowing for supply induced declines in price that discourage production outside the Columbia River region as well.

Finally, the Huppert et al. methodology confuses the levels of production and revenues that would have existed even without new water rights with those that result solely as a consequence of the new water rights. To address this problem, we first established a forecast baseline of acreage, yields, prices, production, and demand in the Columbia River area over a 20-year forecast period and then simulated the impact of new water as changes in prices, quantities, and revenues from their forecast baseline levels. This process insures that the calculated changes in revenues result only from a CRI change in water availability rather than from any other source.

This report concludes that the errors in the Huppert et al. and Zhang methodology support a policy prescription that is just the opposite of what would be in the best economic interest of the state of Washington and the Columbia River region. Our results demonstrate that the Huppert et al. assumptions and methodology result in a positive net revenue calculation which turns negative when the errors in their methodology are corrected. Thus, rather than supporting the granting of new water rights to agricultural producers in that region, a net revenue analysis that corrects for the errors in the Huppert et al. methodology actually leads to a conclusion that producers in the Columbia area and the state of Washington would be better off economically without new agricultural water rights under the CRI.

Our results simply confirm the well known principle of the "fallacy of composition." This principle warns that even though an individual farm may find it profitable to expand production, if all farms expand production at the same time then the profits for all farms decline. In the context of the CRI, this principal means that any individual producer may well benefit economically by increasing production as a result of new agricultural water rights under the CRI but if all producers in the Columbia River region do the same then prices will decline and the revenues of all producers will also fall. How far the revenues of all producers would fall depends on the price elasticities (responsiveness) of market supply and demand. Using measures of the elasticities of the supply of agricultural commodities in the Columbia River area that we derive using sophisticated statistical procedures and measures of the elasticities of the market demands for those commodities available from other well-known studies, we show that a production increase from new agricultural water rights in the Columbia River area would depress prices for those commodities and result in profit losses (negative net revenue gains) for producers in that area.

More specifically, this report concludes the following:

- The Huppert et al. assumption that demand is sufficient to absorb all the additional supply guarantees the highest gross revenue calculation possible.
- Any assumption on the elasticity of supply and demand other than those made by Huppert et al. will necessarily lead to a lower net revenue calculation than they report.
- Huppert et al. and Zhang substantially overestimated the net revenues to producers in the Columbia River area from an increase in irrigated acreage under the CRI. The overestimate was severe enough that the net revenues are more likely to be negative than positive.
- This same conclusion holds even if water is allocated only to marginal crops rather than to all crops in proportion to their share of total existing acreage as assumed by Huppert et al.
- New water for agricultural irrigation in the Columbia River area would tend to depress prices of all crops but particularly those of orchard crops and vegetables.

- New water would also boost crop production in the region but the increases would be less than the maximum because prices would decline.
- For vegetables and potatoes, the percentage increases in their supplies as a result of new water availability would be outweighed by the percentage decline in their prices on average over time leading to declining gross revenues for those crops.
- For orchard crops, wheat, and the "other crops" group, the production expansion from new water would tend to be greater in percentage terms than the corresponding negative effect on prices leading to increases in gross revenues for those crops.
- The positive gross revenue effects for orchard crops, wheat, and "other crops" would likely be sufficient to offset the negative gross revenue effects for vegetables and potatoes leading to a positive gross revenue result of $1.25 billion over 20 years, an average of $62.4 million per year, some $10.4 billion less than the $11.7 billion estimate of aggregate gross revenues that results from using the flawed Huppert et al. gross revenue calculation methodology.
- After deducting the cost of the additional production, however, the net returns to producers from new agricultural water rights under the CRI would likely be negative, costing the state about $1.4 billion over a 20-year period, an average annual loss of about $70 million, instead of adding a net benefit to the state as concluded by Huppert et al. and Zhang.

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AN ASSESSMENT OF FUTURE MARKETS FOR CROPS GROWN ALONG THE COLUMBIA RIVER: The Economic Implications of Increases in Production Resulting from New Agricultural Water Rights Under the Columbia River Initiative

The State of Washington commenced the Columbia River Initiative (CRI) to establish a new water management program for the main stem Columbia and lower Snake rivers to provide water for consumptive use while protecting the environment. Two economic studies were conducted by the State of Washington to inform decisions about such a program. The first study by Huppert et al. (2004) was an analysis of the economic consequences of the CRI for the State of Washington. The second study by Zhang (2004) used the results of Huppert et al. to conduct a cost-benefit analysis of the CRI for the State of Washington.

This report is the second of two reports requested by American Rivers, Inc. related to potential issues stemming from the agricultural components of the Huppert et al. and Zhang studies. The first report is a peer review of the Huppert et al. and the Zhang analyses authored by Dr. Ronald C. Griffin, a Water Resource Economist at Texas A&M University. This second report focuses primarily on assumptions made in the Huppert et al. and Zhang analyses of the benefits related to a potential increase in crop acreage and production in the Columbia River Basin as a result of Washington State's Columbia River Initiative (CRI). After discussing some conceptual issues related to the assumptions made in the Huppert et al. and Zhang analyses, the methodology and data used in the report are discussed. Then baseline projections of the acreage, yield, production, price, and producer revenue for major crops grown in the state of Washington and along the Columbia River are provided along with projections of the likely future demand for those crops. The baseline projections represent what would likely occur over time assuming no increased water use from the Columbia River under the CRI and are compared to the baseline assumptions made by Huppert, et al. Then the impacts of increased water availability in the CRI area on the supply, demand, price, and revenue of crops likely to be grown in that area are calculated as changes from the projected baseline values. The estimated changes are then used to calculate the likely changes in the shares of national consumption of major crops supplied by the state of Washington, the competitiveness of Washington producers, and the impacts of the CRI on agricultural production revenues of Washington State producers. The revenue results are compared to those of Huppert et al and Zhang to determine the extent to which they may have over- or underestimated the agricultural benefits of additional water rights for agricultural production in the CRI area.

Conceptual Issues

In his analysis, based in large part on the findings of the Huppert et al. report, Zhang concludes that "the probable benefits resulting from the proposed rule [to Establish the Columbia River Management Program] are $187.5 million greater than the probable costs…." (p. ii). Given that Zhang's estimate of the benefits from water rights (interruptible and future new water rights) for agricultural production amount to $188.3 million, the finding of positive benefits from the CRI are obviously almost entirely dependent on the benefits attributed to agricultural production on new irrigated acreage. The calculation of those benefits, however, is based on a number of assumptions, several of which have potentially important impacts on the level of the calculated benefits. This section discusses the critical importance of four conceptual issues related to the assumptions behind the calculation of the agricultural benefits of the CRI in the Zhang and Huppert et al. analyses: (1) the assumed elasticities of supply and demand; (2) the choice of crop mix on the new irrigated acreage; (3) the potential intra-state tradeoffs in production; and (4) before/after measurement of changes vs. with/without measurement of changes as highlighted in the peer review report by Dr. Griffin. The remainder of the report then considers the magnitude of impact these assumptions have on the Huppert et al. net revenue calculations.

The Importance of Assumptions Regarding the Elasticities of Supply and Demand

Perhaps the most important assumption underlying the Huppert et al. and Zhang analyses is found on p. 21 of the Huppert et al. report: "The analysis assumes that there is sufficient demand to absorb new production from the additional water rights since crop prices are held constant." This assumption amounts to assuming that the demand for each category of agricultural products considered in the reports is perfectly elastic as illustrated in Panel A of Figure 1 with a horizontal demand curve at price P_{con}. In this case, given a supply increase based on an increase in irrigated acreage devoted to that crop leads to an increase of production and sales of the crop from the level of production and sales without the new irrigated acreage (Q_{wo}) to the new level with the new irrigated acreage ($Q_{with}^{constant\ p}$). The horizontal or perfectly elastic demand curve implies that despite the increase in supply, price is not affected so that the new revenue to producers increases from $P_{con} * Q_{wo}$ (the horizontally lined area in Panel A of figure 1) to the new total revenue of $P_{con} * Q_{with}^{constant\ p}$ so that the increase in total revenue to producers is the area P_{con} * ($Q_{with}^{constant\ p} - Q_{wo}$). However, perfect demand elasticity is only one of several possible, viable assumptions on the price responsiveness of demand that Huppert et al. and Zhang could have made as they recognize in their report (for example, see discussion on pp. 22-23 of the Huppert et al. report). Citing the "difficulty in assessing the potential impact" of the perfectly elastic demand elasticity assumption and suggesting that such an assessment was "beyond the scope of [their] analysis," Huppert et al. chose to use the convenient but "tenuous" (Huppert et al., p. 30) assumption of perfectly elastic demand so that constant prices could be used in the analysis rather than having to measure price impacts of any supply increase and assess the implications for the quantities produced on irrigated acreage in the Columbia River region.

The implications of the Huppert et al. and Zhang assumption of perfectly elastic demand curves for all crops are illustrated in Panel A of Figure 1. If the demand for a given crop is less than perfectly elastic (but still quite responsive to price changes) as is the case with demand curve $D_{elastic}$ in Figure 1, then the same increase in irrigated acreage and in the supply curve as before (from $S^{without}$ to S^{with}) leads to a lower price (P_{with}^{ed}) and a lower level of production and sales (Q_{with}^{ed}) than is the case with a perfectly elastic demand curve. This happens because demand is not sufficient to absorb all the production that producers would like to produce with the new water *at a given price*. Consequently, producers produce less to meet the available demand at the lower price. The implication is that total revenue to producers as a result of the increase in the availability of additional water is lower with a less than perfectly elastic demand curve (P^{ed}_{with} * Q^{ed}_{with}) than with the perfectly elastic demand curve assumed by Huppert et al. and Zhang.

Note that the less responsive the demand for a given crop is to price changes (that is, the more inelastic the demand curve), the lower the total producer revenue from a given rightward shift in the supply curve. If the demand curve is relatively inelastic (that is, relatively unresponsive to price changes) as depicted with the demand curve $D_{inelastic}$ in Panel A of Figure 1, then the same shift of the supply curve as before results in an even lower price (P^{id}_{with}) and quantity (Q^{id}_{with}) and, therefore, an even lower total revenue to producers. *Thus, the Huppert et al. and Zhang assumption of a perfectly elastic demand curve guarantees the highest possible level of revenue accruing to producers from a given shift of the supply curve due to an increase in the availability of water for irrigation.*

In fact, given a sufficiently inelastic demand, the change in total revenue to producers from an increase in irrigated acreage could actually be negative so that producers would be worse off with the increase in irrigated acreage than without the increase. This can be seen in Panels B and C in Figure 1. With a somewhat less than perfectly elastic demand curve such as $D_{elastic}$ in Panel B, note that the price decline implies some lost revenue while the increase in production (from Q_{wo} to Q^{ed}_{with}) creates some additional revenue. If the demand is elastic, then the revenue added will be greater than the revenue lost so that the total revenue to producers following a rightward shift of the supply curve actually increases providing a net revenue benefit of the supply shift to producers. However, if the demand curve is inelastic, as $D_{inelastic}$ in Panel C, then the revenue lost from the price drop will be greater than the revenue increase generated from the production increase. As a consequence, the total revenue of producers actually drops so that they would have been better off without the supply increase.

The problem is even more complicated because the estimate of the revenue benefits also depends critically on the elasticity of the supply curve, that is, the responsiveness of supply to price changes. Because Huppert el al. and Zhang assume a perfectly elastic demand curve, they can then conveniently ignore the issue of the supply curve elasticity because price does not change as the supply increases. However, if any other assumption is made about the elasticity of demand, then the elasticity of the supply curve becomes important in determining the level of the price and output from a given increase in the supply curve. This can be seen in Panel D of Figure 1 which adds a more elastic supply curve to the graph. Note that if the demand curve is perfectly elastic, an equal horizontal shift of an elastic and an inelastic supply curve result in the same price level and the same level of production. Such is not the case with any other assumption regarding the elasticity of the demand curve, however. With a downward sloping demand curve (such as $D_{elastic}$ or $D_{inelastic}$, for example), the same horizontal shift of an inelastic supply curve ($S^{without}_{inelastic}$ to $S^{with}_{inelastic}$) and an elastic supply curve ($S^{without}_{elastic}$ to $S^{with}_{elastic}$) has different effects on both the level of output and price. Specifically, for a given elasticity of the demand curve, a shift of an elastic supply curve has a smaller positive effect on production and a smaller negative effect on price than a corresponding horizontal shift of an inelastic supply curve. Thus, for example, given the downward sloping demand curve $D_{elastic}$ in Panel D of Figure 1, the levels of production and price following a shift of the elastic supply curve from $S^{without}_{elastic}$ to $S^{with}_{elastic}$ are $Q^{ed,es}_{with}$ and $P^{ed,es}_{with}$. Note that those new equilibrium quantity and price levels are respectively less than the production level of $Q^{ed,is}_{with}$ and higher than the price level of $P^{ed,is}_{with}$ that result from an equal horizontal shift of the inelastic supply curve from $S^{without}_{inelastic}$ to $S^{with}_{inelastic}$.

In summary, the assumptions made on the elasticities of supply and demand are critical for the estimation of the revenue effects of increases in the availability of water for additional irrigated acreage. The assumptions used by Huppert, et al. and Zhang lead to the highest possible revenue estimates possible. Any other assumptions on the elasticities of the supply and demand curves lead to lower total revenue effects and even quite plausibly a negative change in producer revenues so that producers would be better off without an increase in irrigated acreage than with such an increase. Economic theory and the vast empirical work that has been reported in the literature suggest strongly that the demand for and supply of specific agricultural commodities are price inelastic while the long-run supply is elastic. Thus, the change in revenues to producers along the Columbia River from an increase in agricultural water rights is more likely to be consistent with the change shown in Panel C than the maximum increase possible assumed by Huppert et al. and Zhang as depicted in Panel A.

In essence, the Huppert et al. and Zhang assumption that demand is perfectly elastic is an excellent example of ignoring the well-known "fallacy of composition" concept taught in virtually every introductory course in agricultural economics and agricultural policy in every land grant university in the country. In this context, the "fallacy of composition" recognizes that that while an individual producer may enhance his/her revenue by a particular action such as expanding production with new water rights, he/she may be worse off if all producers do the same thing. As Professor Daryll Ray (2004) explains: "In crop agriculture, the number of producers is large, and the impact any one individual has on the market is minimal. For the most part, farmers are price-takers not price-setters. If any one farmer finds a way to increase … production[,] that farmer benefits. After all, the production of one farmer does not significantly affect the overall amount of grain available and thus the price is not affected. However, when the neighbor and the neighbor's neighbor and farmers across the country all begin to use this production-increasing technique, the result is a significant increase in production. If demand for that product does not increase at the same rate, what happens? Prices fall. We have all seen that time after time." By assuming "sufficient demand to absorb new production from the additional water rights," Huppert et al. commit the fallacy of composition. They assume that all producers can benefit from doing what benefits one producer because there are no market price consequences from the increase in production by either one producer or many producers.

Choice of Crop Mix on the New Irrigated Acreage

Another potentially important source of error in the Huppert et al. and Zhang estimation of the additional revenues likely to accrue to producers from new production on irrigated acreage stems from their assumption that "the new crop mix being brought into production [on additional irrigated acreage] will be the same as the existing crop mix." This assumption creates two problems. First, as pointed out by Griffin in his review of the Huppert et al. and Zhang reports, the assumption of no change in crop mix with an increase in water available for additional crop production appears to take the value of water "to be a weighted average based on the several crop types" which he concludes is a "clear departure from the required use of 'marginal values' for economic valuation" (p. 8). Because producers are profit motivated, "they are likely to be applying *new* water to the most marginal uses" (p. 9). In rejecting the Huppert et al. assumption that the cropping mix will not change given an increase in agricultural water rights, Griffin asserts that "it is hard to accept the claim that high-valued cropping activities (potatoes, vegetables, and orchards) have much relevance for benefit estimation…because these crops are not the marginal ones given current water supply constraints" (p. 9).

Thus, economic theory suggests that any given an increase in water will be applied to the most marginal uses rather than in a fixed proportion to the existing crops as assumed by Huppert et al. and Zhang.. This concept is clearly understood by Huppert et al. when they suggest that a "possibility" for determining the crop mix is to assume that "high value crops have already pushed out low value crops in many areas that would support them leaving room in the market for new water to bring lower value crops into production" (p. 30). Nevertheless, they opt to assume a fixed crop mix as new irrigated acreage is brought into production presumably because the crop mix for the new acreage can be much more easily calculated from data on the current crop mix than attempting to determine what the crop mix might be under the concept of marginal use valuation. The implication of this assumption is that more higher value crops are estimated to be grown on the new irrigated acreage than would likely be the case. In consequence, the revenues Huppert et al. calculate for the production on the new acreage, particularly with the assumption of constant prices, may be considerably overestimated.

Even if one were to accept the assumption that the crop mix would not change with the addition of new irrigated acreage, the methodology Huppert et al. use to calculate the crop mix that would be applied to the new irrigated acreage still presents a serious problem. In essence, Huppert et al. assume that the crop mix on the new acreage over a 20 year period would never change and remain equal to the crop mix of the late 1990s. This approach is tantamount to assuming that the production of all crops will grow in proportion over a 20 year period and that no new crops could be introduced and no crop would go out of production over that period. A more reasonable approach would have been to generate 20-year forecasts of the production of all crops in the area under the assumption of no increase in agricultural water rights related to the CRI. The forecasted production levels could then be used to calculate a more reasonable likely future crop mix which, in turn, could be used to calculate the production of crops that would likely be grown with new water rights.

Intra-state Tradeoffs in Production with New Agricultural Water Rights

In considering the likely effects of new agricultural water rights, the Huppert et al. and Zhang analyses focus exclusively on the production in the specific counties that currently use water from the Columbia River. Consequently, the new water rights under the CRI have implications only for those specific counties in their analyses. They recognize that increases in production of one crop in the area may "simply push out existing production" particularly if "there is not sufficient demand for new production" (Huppert et al., p. 22), or in other words, if the demand is not perfectly elastic as they assume. However, they fail to recognize the possibility that new production could replace production in other areas of the state of Washington as well so that the net gain for the entire state is zero and results primarily in a transfer of income from some other agricultural producing region in the state to the Columbia River Region. Such transfers may also occur nationally or internationally. For purposes of the analysis of the benefits of the CRI to the state of Washington, however, at least the possibility for intra-state transfers of production ought to be taken into account. For this purpose, it would be most appropriate to consider likely changes in state production over time and as a result of the CRI than simply those likely to take place within the Columbia River region.

Measuring Before /After Changes Rather Than With/Without Effects

Another potentially important error in the Huppert et al. analysis highlighted in the Griffin review is some apparent confusion in measuring before/after changes versus measuring with/without effects of a policy change. In other words, the Huppert et al. calculation of the benefits appear to be confounded by not separating the effects of changes in production, prices, etc. that would occur even if no new water rights were issued under the CRI and the specific effects of issuing new water rights. Figure 2 illustrates the problem with the analysis. In the current year (year 1), production of a given commodity is at point A. Given changes in technology, demand, and other market forces, the production of the commodity grows to point B by year 20. The change in output that occurs is measured as B-A in Figure 2. Assume now that in year 20 some policy is implemented (such as the issuance of new water rights under the CRI) that increases the production of the commodity to point B' by year 20. The proper measurement of the effects of the policy in any given year is the vertical difference between the two dark lines. In year 20, for example, the effect of the additional water rights on production would be measured as B'-B in Figure 2 and not B'-C. The change from A to B over time is the "Before" to "After" change in output that occurs even if the policy is not implemented. The change from B to B' is the effects of the implementation of the policy over time where B represents the level of output "Without" the policy in year 20 and B' represents the level of output "With" the policy in that year. To measure the effects of the implementation of the policy as B'-A is to confound the measurement of the policy effects with the Before/After effects that would have occurred even in the absence of the policy. But this appears to be precisely what is done by Huppert et al. which overestimates the effects of the policy change (in this case, the issuance of new water rights).

As Griffin explains (p. 5): "Huppert et al. does not detail any special attention that would lead readers to think that the without-policy scenario is any different than the current (before) conditions." In other words, by assuming a static baseline, Huppert et al. essentially compare the production level at A (the "Before" level of production) with the production level at B' (the "With" policy level of production and ignore all the market forces that could impact the level of production even in the absence of the policy change. The more appropriate approach would be to forecast the future level of output that would occur in the absence of the policy (the output in each year from point A to point B) in each year first and then measure the effects of the policy as a change from the forecasted production levels in each year (the difference between the two dark lines in each year in Figure 2) rather than as a change in the production levels along the dotted line AC in each year to the line AB' as done by Huppert, et al. and Zhang.

Methodology and Data

This section provides a brief overview of the methodology and the data used in this examination of the Huppert et al. and Zhang analyses of the benefits to Washington state from additional water rights for agricultural production under the CRI. The basic effort was to develop a calculation of the net revenues likely to accrue to agricultural production in the Columbia River area as a result of the new water rights that appropriately accounts for the conceptual concerns relating to the Huppert et al. and Zhang methodology. The end result is an assessment of the extent to which ignoring these potentially critical issues led Huppert et al. and Zhang to over- or underestimate the true net returns. Other than correcting for the methodological errors discussed above, the methodology used in our analysis attempts to stay consistent with the methodology used by Huppert et al. and Zhang so that the specific effects of just those errors on the calculation of the net revenue can be measured.

To insure compatibility with the Huppert et al. and Zhang studies, the focus of the examination is on the following six crop groups: (1) hay; (2) orchard crops; (3) vegetables; (4) potatoes; (5) wheat; and (6) other crops. The orchard, vegetable, and "other crops" groups were defined to include the same individual crops that were included by Huppert et al. and Zhang. Orchard crops were defined to include apples, pears, sweet cherries, and grapes. Vegetable crops were defined to include asparagus, carrots, sweet corn, onions, and green peas for processing. Other corps were defined to include hops, dry beans, corn for grain, corn for silage, and mint (peppermint and spearmint) for oil.

The initial task in this examination was to obtain historical data by year for the state of Washington for the acreage, yield, production, prices, and value of production for each of the crops listed earlier. These data were obtained from the National Agricultural Service (NASS) over the period from 1949 to 2004. Disaggregate information pertaining to the individual crops in each of the six crop groups used to calculate historical acreage, yield, production, prices, and value of production for the six aggregate crop categories as done by Huppert et al. and Zhang. For example, the acreage, production, and value of production of apples, pears, sweet cherries, and grapes were summed to produce the aggregate acreage, production, and value of production for orchard crops. Yield data for the orchard crops group were calculated subsequently as the ratio of the aggregate production of all crops in the orchard group to the total acreage of all crops in the group. Likewise, the orchard group price data were calculated as the ratio of the aggregate value of production across all crops in the group to the aggregate production of all crops in the group. Consequently, yields and prices for each crop group are weighted averages.

The next task was to provide acreage and yield projections from the period 2005 to 2024 for each of the crops. This task was accomplished through the use of trend extrapolation and Box-Jenkins methods. Specifically, acreage projections were made based on regression analysis of historical acreage as a function of acreage in the previous year and the real price of the commodity in the previous year. Real price was defined as the nominal price divided by the index of prices received by farmers. Both the trend extrapolation and the Box-Jenkins methods were used to produce yield projections. Trend extrapolation is tantamount to regressing historical yields as a function of trend, specified as either linear, quadratic, or cubic. Box-Jenkins methods rest on the use of autoregressive integrated moving averages (ARIMA) to forecast yield. The details of the acreage and yield projections for each of the crops are available upon request.

Next, production projections for each of the crops for the State of Washington over the period from 2005 to 2024 were calculated as the product of the previously described acreage and yield projections. To develop baseline production projections for the Columbia River area while maintaining consistency with Huppert et al., the data in Table 3.11 of the Huppert et al. report for irrigated acres for counties relevant to the Columbia River were used. Table 3.11 of the Huppert et al. study reports the number of irrigated acres for hay, orchards, vegetables, potatoes, wheat, and other crops in the Columbia River Basin from the 1997 Census of Agriculture, the latest year providing acreage figures on a county level available to Huppert et al. Consequently, we scaled our acreage projections by using the ratio of these acreage figures to our state-level acreage figures based on the year 1997. The acreage share of the Columbia River Basin relative to the state of Washington in 1997 was 41.9% for hay; 78.4% for orchard crops; 71.7% for vegetable crops; 95.8% for potatoes; 9.1% for wheat; and 75.7% for other crops. These acreage shares were used to scale our state-level projections of acreage to derive acreage projections for the Columbia River Basin. The state yield projections were similarly scaled to provide yield projections for the Columbia River Basin based on the ratio of the yields from the counties using water from the Columbia River to the state-level average yields over the period 2000 to 2002. Using the baseline scaled acreage and yield projections, the baseline production projections for each of the six crop groups the Columbia River area over the forecast period of 2005 to 2024 were then calculated.

The next task was to develop price projections by crop group. For each of the 17 individual crops as well as for the aggregate crop groups (orchards, vegetables, and other crops), nominal prices were forecasted based on historical annual data over the period 1949 to 2004. These baseline price forecasts from 2005 to 2024 were derived based on the construction of ARIMA models. The baseline revenue projections for each crop in the Columbia River Basin were calculated as the product of the baseline production projections and the baseline price projections.

Additionally, the shares of total national disappearance or national production (as proxies for demand in some cases) supplied by the state of Washington were derived using historical data on disappearance or production at the national level. Projected shares of total or national disappearance/production then were constructed from the use of ARIMA models. Projections of national disappearance subsequently were calculated as the product of the projected shares and the state-level projections of production of the individual crops. The data for the Washington state share of national demand provides some insight on the competitiveness of the Washington state production of the crops in each crop group. Moreover, the shares data serve in the calculation of changes in prices and ultimately changes in revenue to producers as a result of adding irrigated acreage in the Columbia River area under the CRI.

U.S. farm policy played little role in the development of the baseline forecasts of acreage, yields, production, prices, and revenues. Because Huppert et al. ignore farm policy, we ignore farm policy as well to prevent a confounding of the results by introducing changes in assumptions other than the ones identified in the preceding section. However, this assumption likely has little impact on the baseline forecasts for each crop for several reasons. First, of all the crops considered, only wheat and corn are deemed "program" or "covered" crops for which substantial production subsidies have been paid over the years. While orchard, vegetable, and various other crops have benefited from government subsidies from time to time, such subsidies are usually periodic and only received in years of substantial supply disruption such as the $268 million paid in three phases through the Apple Market Loss Assistance Program to assist apple growers in offsetting losses due to low market prices in 1998, 1999, and 2000. Even for wheat and corn, however, the historic change in farm policy under the 1996 farm bill eliminated the huge production subsidies to these crops in favor of decoupled, direct payments to farmers. The decoupling of the payments to farmers from the requirement to produce the covered crops implies that production decisions are now much more market determined than in the past. Consequently, while the production of crops like wheat and corn were largely unresponsive to price changes under the old deficiency payment program, under current programs, production is much more responsive to price changes. Finally, with no way of knowing how farm policy might change over the 20 years into the future covered by the baseline forecasts, we assume that the current farm policy continues over the forecast period.

The next step in the analysis was to develop forecasts of the added acreage and the crops produced on that acreage. These forecasts were based on the projected acreage from the Columbia River area and the water availability discussed in the Huppert et al report. In our analysis, we developed two scenarios. Scenario 1, consistent with scenario 1 of Huppert et al., assumes that an additional 1 million acre feet of water are made available for agricultural production in the Columbia River area. Being careful to follow the methodology of Huppert et al. for transforming acre feet of water into acres of crops as reported in Chapter 3 of their report, the additional crop acreage and production for all six crop groups were calculated for each year over the forecast period. Rather than hold the crop shares constant in each year over that period as done by Huppert et al., we follow the more reasonable approach discussed earlier of allowing them to change in each year. The share of total Columbia River area acreage of all six crop groups accounted for by each group was calculated using the previously estimated forecasts of the acreage of each crop group over the forecast period. This process allowed for the calculation of more reasonable likely future crop mix that could then be used to calculate the production of crops that would likely be grown with new water rights over time.

The second scenario considered in this examination responds to the concern discussed earlier and raised by Griffin concerning the choice of crop mix. If Griffin is correct in his analysis, then any new water is likely to be added to marginal crops rather than to all crops in proportion to their share of total acreage as assumed by Huppert et al. and Zhang. To explore this concern, scenario 2 assumes that the new water available for agricultural production under the CRI is applied only to marginal crops. An examination of the data for each of the six crop groups in the Columbia

River area, and particularly the shares of each crop group of national demand, suggests that wheat, hay, and the “other crops” group are the agricultural marginal uses for water. In this scenario, water is allocated to each of the three crops in each year in proportion to their forecast baseline shares of acreage in each year.

The yield forecasts were then used to calculate production on the added acreage each year at fixed prices given the crop mixes in each scenario. Further, the additional revenue generated at fixed prices was calculated for each of the crop groups as the product of the forecasted prices over the period from 2005 to 2024 and the added production from the use of the additional water available from the Columbia River.

Any additional increase in the available supply of a crop at a given price may have negative price consequences which, in turn, would have quantity adjusting effects on the market. Consequently, once the additional supply that would be available from the addition of the new water rights at fixed prices in each year was calculated for each crop group, the consequent price and quantity adjustments that would occur were calculated. This task was accomplished using estimates of the supply and demand elasticities associated with the six crop groups. To calculate the supply elasticities, supply functions for the six crop groups were estimated using regression analysis. In each regression equation, crop production was expressed as a function of crop production in the previous period and a distributed lag of real prices in the previous year. A polynomial distributed lag specification for the prices in each supply function was employed. The degree of polynomial was two in each of the specifications for the six crop groups. The optimal lag length was two based on an examination of the Akaike Information Criteria (AIC) and the Schwarz Bayesian Criterion (SBC). Thus, in each supply function, the price variables were one-, two-, and three-year lags, with adjustments for inflation based on the index of prices received by farmers. The respective short-run supply elasticities calculated for the estimated price coefficients in the supply equation for each crop were as follows: (1) hay, 0.10804; (2) orchard crops, 0.19551; (3) vegetable crops, 0.43126; (4) potatoes, 0.18499; (5) wheat, 0.02393; and (6) other crops, 0.26069. Note that in each case, the short-run elasticity of supply is in the inelastic range (less than one). That is to say, the percentage change in production in response to a price change is estimated to be smaller than the percentage change in price in each case. These results are consistent with economic theory and the empirical literature on the price responsiveness of the supply of agricultural products. Using these elasticities, supply curves associated with the baseline projections were constructed as well as the supply curves associated with the use of additional water available from the Columbia River.

To determine the equilibrium price of each crop group associated with a change in supply, the corresponding demand curves for each crop group were also constructed. These demand curves were developed based on demand elasticities for the six crop groups and the baseline projections of prices and production. The demand elasticities were obtained from Huang (1993) and George and King (1968): (1) hay, -0.1248; (2) orchard crops, -0.5127; (3) vegetable crops, -0.1729; (4) potatoes, -0.3688; (5) wheat, -0.1092; and (6) other crops, -0.1196. Similar to the corresponding supply elasticities, the demand elasticities also are in the inelastic range which, again, is consistent with the economic theory and the wide range of literature related to agricultural crop and food demand estimation.

Using the simple formulas given below, the changes in the equilibrium prices and quantities resulting from an increase in the availability of supply of the six crop groups induced by new agricultural water rights under the CRI were calculated:

$$(1) \qquad Q_E = \frac{\varepsilon_S Q_0 - \varepsilon_D Q_H}{\varepsilon_S - \varepsilon_D} \qquad \text{and} \qquad (2) \qquad P_E = P_0 - \frac{P_0 (Q_H - Q_0)}{Q_0 \, (\varepsilon_S - \varepsilon_D)} \quad .$$

Note that changes in the equilibrium supplies and prices of each crop group in a given year (Q_E in equation (1) and (P_E in equation (2)) are functions of their corresponding elasticities of supply and demand (ε_s and ε_D, respectively), the baseline forecast level of production (Q_0), and the higher level of production at a fixed price given an increase in irrigated acreage (Q_H). Changes in the equilibrium prices are also a function of the baseline price projection (P_0 in equation (2)).

For both scenarios 1 and 2, given the simulated price decline and equilibrium change in production for each crop group, the *gross* production revenues for crop group were calculated over the 2005 to 2024 forecast period. As in the Huppert et al. analysis, U.S. farm policy plays little role in the calculation of the price and quantity changes for each crop as a result of new agricultural water rights under the CRI for all the reasons discussed earlier in connection with the baseline forecasts.

To calculate the *net* revenue from the increased production, we assumed that per acre costs are not affected by the level of production. Thus, to maintain consistency with Huppert et al., we used the per acre costs for each crop implied by Table 3.25 in the Huppert et al. report to calculate the total annual cost for each crop which was then subtracted from the gross revenues to obtain the net revenues for each crop. This cost assumption is conservative because the cost per acre for each crop between 2005 and 2024 is more likely to increase than to stay constant[1].

The final step in this examination of the Huppert et al. and Zhang analyses was to compare their calculated net revenues with those derived in this report to draw conclusions regarding the extent of over- or underestimation of the actual value of net revenues in their results.

Baseline Projections

The first step in determining the effects of additional water availability on producer revenues is to establish a forecast baseline of the acreage, yields, production, prices, and producer revenue

[1] Using the Huppert et al. cost per acre estimates to maintain consistency with their methodology required that we ignore, as they do, any additional fixed costs associated with infrastructural investments required to capture, lift, and distribute the newly allocated water. Griffin points out that such costs should be included in the calculation because the investments "are actually necessary before most of the benefits can be received by water users" (p. 12). If such costs are sizeable, not including them as a component of the fixed costs in the enterprise budgets used by Huppert et al. biases the additional net revenue calculation upwards. For this additional reason, we consider the cost assumption used here to be "conservative."

for the crops likely to be grown in the state of Washington and the Columbia River area of Washington *assuming no increase in agricultural water rights under the CRI*. This step provides the baseline against which any likely changes in quantities, prices, and revenues resulting from increased water rights will be measured. Because any increase in supply has a potential negative impact on price, determining the price effects of any production increase requires knowledge of market demand for that commodity as well as the price responsiveness (elasticities) of both demand and supply. Consequently, a baseline national disappearance of each of the six crop groups was projected as discussed below. The price elasticities used in the analysis were presented in the preceding section on methodology and data. The crop groups considered by Huppert et al. and Zhang include hay, orchard crops, vegetables, potatoes, wheat, and other crops. Orchard crops include apples, pears, sweet cherries, and grapes. Vegetables include carrots, asparagus, sweet corn, onions, and green peas. The other crops group includes dry edible beans, corn for grain and silage, hops, and mint for oil.

The Huppert et al. and Zhang baseline projections are simple and straightforward. They assume that the price and production levels for the crops produced in the Columbia River area remain the same in each year over the next 20 years. In Figure 2, their assumption on production is depicted as the dotted line AC representing no change in production from year to year. With a baseline of no change in price as well, the Huppert et al. and Zhang baseline forecast for producer revenue is exactly the same in each year over the 20 years of their analysis.

Baseline Projections for the State of Washington

The historical and 20-year baseline acreage projections (2005 through 2024) for the State of Washington for the six crop groups considered by Huppert and Zhang are provided in Figures 3 through 8. The baseline projections assume that no additional water rights for agricultural production are made available under the CRI. For three of the crop groups (hay, wheat, and other), the baseline acreage projections are fairly flat implying little year to year growth in acreage over the next 20 years. The area in production of the crops in these three groups has shown little or no growth over at least the last two or three decades and even longer in some cases. The baseline forecast suggests that little or no growth in the area or production of these crops is likely (see Figures 3, 7, and 8).

In the case of the other 3 crop groups (orchards, vegetables, and potatoes), a relatively strong growth in the area in production is expected. The orchard acreage in Washington is forecast to continue the steady growth experienced since about 1970 (Figure 4). Between 1970 and 2004, the orchard area grew at an average annual rate of 3% and is expected to continue growing over the next 20 years but at a somewhat slower annual average rate of about 1.5%.

While the area in vegetable production in the state of Washington has also grown, the annual rate of growth has been more erratic than that of orchards, varying from a decline of 20% in one year to an increase of 20% in another (Figure 5). Since 1949, vegetable acreage has experienced an average annual increase of about 2.1% and an even higher 2.7% average annual growth rate since the mid-1980s. The forecast suggests that vegetable acreage will continue to grow over the next 20 years but at a somewhat slower average annual rate of about 1.7%.

The area in potato production in the state of Washington has also shown remarkable growth since at least the mid-1960s, registering an average annual growth rate between 1964 and 2004 of about 4.3% (Figure 6). Since 1980, however, the annual growth rate was lower at about 2.8%. The annual growth ate in the area in potato production in Washington is expected to slow somewhat over the next 20 years to about 1.45%.

Baseline Projections for the Columbia River Area

In the Columbia River area, the baseline projections for the six crop groups agree in both direction and annual rate of change over the 2005 to 2024 forecast period (Figure 9). More area is dedicated to hay than to any other crop in the Columbia River area, currently about 27% of the total area in production to the six crop groups. As is the case for the state of Washington, little change in the number of acres dedicated to hay in the Columbia River area is forecast, however (Figure 9). The same is true for both wheat and other crops. In contrast, orchard production is expected to increase over the forecast period albeit at a declining rate. The expected annual rate of increase in orchard production declines slightly from about 1.8% to about 1.4%, leading to an average annual rate of increase between 2005 and 2024 of about 1.5%.

Although potatoes and vegetables currently occupy the least amount of acreage in the Columbia River area (10.5% and 12.4%, respectively), both crops are expected to continue to experience steady growth in area over the next 20 years at rates of about 1% per year over the next few years up to about 2.5% a year by end of the 20-year forecast period (Figure 9).

The different relative rates of expected growth in the area dedicated to the six crop groups in the Columbia River area produce changing shares of the total area dedicated to the six crops over the forecast period as shown in Figures 10 through 15. Given the flat growth in hay acreage and the more rapid growth in the acreage dedicated to other crops, the share of total acreage accounted for by hay declines steadily over the forecast period from 27.2% to 22.7% (Figure 10). Huppert et al. assumed the share stays constant over their 20-year forecast horizon at 26%. The result is basically the same for wheat and other crops with their acreage shares dropping from 17.1% and 15.1% to 14.5% and 13.2%, respectively, over the 20-year forecast period (Figures 13 and 14). Huppert et al. assumes the wheat and other crop acreage shares stay constant over time at 18% and 16%, respectively. In contrast, the acreage shares of orchards, vegetable, and potatoes are forecast to increase. The acreage share of orchard crops is expected to increase from about 17.8% to about 20.7% (Figure 11) while those of vegetables and potatoes are forecast to increase from 10.5% and 12.4% to 13.5% and 15.5%, respectively, over the 20-year forecast period (Figures 12 and 13). Huppert et al. assume constant acreage shares for orchards, vegetables, and potatoes of 16%, 11%, and 13%, respectively, over the forecast period .

The difference between the acreage shares resulting from the forecasted changes in the acreage of the six crop groups in the Columbia River area over the next 20 years and the constant acreage shares assumed by Huppert et al. is important in the calculation of the change in revenue from agricultural production in that region resulting from increases in agricultural water rights. Changing shares imply changing production and, hence, changing producer revenues over time rather than constant revenues in each year as assumed by Huppert et al. as will be discussed in more detail in the next section of the report.

Another component for the calculation of producer revenues is crop yields. Consequently, a set of baseline forecast yields were developed for each crop group following the methodology described in the preceding section of the report (Figure 16). By far, the highest yielding crop of the six crop groups is potatoes at about 30 tons/acre. After a slow start, in the next several years, potato yields are expecting to increase at about 1.5%-1.6% per year, realizing an average annual increase of about 1.4%. Vegetables yields are expected to grow slightly more on an annual average than any of the other 5 crops at about 2% a year. Starting out in the next few years at an annual average growth rate of less than 1%, vegetable yields are forecasted to grow annually at an increasing rate up to about 3.5% by the end of the 20-year period of 2005 to 2024. Orchard crop yields, in contrast, are expected to grow at a decreasing annual rate from about 2%-2.5% per year to less than 1% per year. The yields of wheat, hay, and other crops are all expected to grow annually as well but at relatively low rates of around 1%.

The acreage and yield forecasts for the six crop groups generate production forecasts for each crop group (Figure 17). Given the relatively higher growth rates of their acreage and yields, the forecast production of vegetables, potatoes, and orchard crops exhibit the most rapid average annual rates of growth of the six crop groups over the 20-year forecast period (3.8%, 3.0%, and 2.6%, respectively). Note that the vegetables grow from being the fifth largest crop in the Columbia River area to the third largest behind potatoes and orchard crops. The production of wheat, hay, and other crops also sustain positive but lower rates of annual growth over the forecast period of 2.2%, 1.8%, and 1.2%, respectively.

The final component necessary for the calculation of the baseline revenues accruing to producers of the six group crops over the next 20 years that must be forecast is the average price of each crop group. Figure 18 shows that at a little over $500/ton, the average price for orchard crops is currently by far the highest for any of the six crop groups. Over the forecast period, a relatively strong national demand results in a relatively high average annual growth in the price of orchard crops over the forecast period of about 1.3% although the rate declines from about 2% in 2005 to about 1.2% at the end of the forecast period. The price of vegetable crops, however, experience the most rapid annual average increase of the six crops at about 1.9%. The prices of potatoes, hay, wheat, and other crops are forecast to grow at annual average rates of about 1.1%-1.2%.

Given the baseline forecasts of production and price for each of the six crop groups, the baseline revenue likely to accrue to producers in the Columbia River area over the next 20 years assuming no additional agricultural water rights under the CRI can be calculated. As expected, given the forecasts of production and prices, vegetables, orchards, potatoes experience the largest projected annual increases in producer revenue over the forecast period at 5.8%, 4.0%, and 4.1%, respectively (Figure 19). The projected annual baseline growth in producer revenues for wheat, hay. and other crops are still positive but smaller than those of the other three crops.

The total projected baseline revenue aggregated across all 6 crops in each year increases from about $2.8 billion in 2005 to about $5.9 billion in 2024, an increase of 11.4% and an annual average growth rate of about 4% (Figure 20). Huppert et al. assumed that the baseline producer revenue is the same from year to year and equal to the first year, as depicted with the dotted line in Figure 20. In other words, they assumed an annual average growth rate of zero for aggregate producer revenue.

Baseline Projections of National Demand

The projections for national demand for each of the crop groups are characterized here in terms of the shares of national disappearance of each crop group supplied by the Columbia River area to provide some context for the demand projections (Figure 21). The shares also provide a means of analyzing the likely changes in the competitiveness of the Columbia River area in U.S. agricultural production.

As shown clearly in Figure 21, the Columbia River area currently supplies less than one percent of the national disappearance of wheat and other crops and no more than two percent of hay. Over time, the Columbia River area is expected to supply even less than is currently the case. In other words, the Columbia River area is not competitive in the national markets for hay, wheat, and the other crops group and is expected to fall even further behind for these crops over the next 20 years. Consequently, any increases in the Columbia River area production of those three crops as a result of additional agricultural water rights are unlikely to have much impact on national markets and prices of those crops over the next 20 years. On the other hand, the Columbia River area currently supplies about 23%-24% of the national disappearance of potatoes and orchard crops and 18% of the national disappearance of vegetables (Figure 21). Obviously, the Columbia River area is highly competitive in the national market for these crops and is projected to become even more competitive.

The shares of the national potato and vegetable crops accounted for by the Columbia River area are projected to increase markedly from 24% and 18% to 53% and 42%, respectively, over the forecast period. The Columbia River share of national orchard crop markets is also projected to increase but more modestly from 23% to 29% over the 20-year forecast period. Consequently, any increase in production of these three crops in the Columbia River area as a result of increased agricultural water rights under the CRI are likely to have important implications for national markets and prices. These likely market and price impacts were ignored by Huppert et al. but must be accounted for in an appropriate measurement of the revenue effects of changes in agricultural production in the Columbia River area as a result of the CRI.

Analysis of the Net Returns from New Agricultural Water Rights Under the CRI

Following the methodology outlined earlier, two scenarios of the likely effects of an increase in water availability under the CRI on the net revenues accruing to agricultural producers in the Columbia River area are analyzed. The results are then compared with the net revenue calculations of Huppert et al. and Zhang. The first scenario assumes, as done by Huppert et al. and Zhang, that any new water made available for agricultural irrigation under the CRI is allocated to each crop group in proportion to that crop group's share of the total crop acreage. Unlike Huppert et al. and Zhang, however, we adopt the more reasonable assumption that the acreage and share of production accounted for by each crop group can change from year to year. Consequently we generate 20-year baseline forecasts of the acreage of all six crop groups and calculate the implied crop mix in each year from those forecasts. In the second scenario, the production and crop mix are still allowed to change over time but any new water is applied only to the marginal crops defined as hay, wheat and the other crop group as discussed earlier.

The analysis for both scenarios proceeds by calculating the likely levels of acreage, production, price, and revenues likely to occur in each year over the next 20 years *with* and *without* new agricultural water rights under the CRI that would make additional water available for agricultural irrigation and, consequently, increase the number of irrigated acres in that region. The *without* condition is represented by the baseline forecasts of prices, quantities, and revenues presented in the preceding section and defines the levels of each that are likely to occur in each year over the next 20 years if no new agricultural water rights under the CRI are made available. The *with* condition is calculated following the methodology described earlier to determine the levels of prices, quantities, and revenues that are likely to occur in each year over the next 20 years if the CRI makes new water rights for agricultural irrigation available in the Columbia River area. Differences between the *with* and the *without* values of the prices, quantities, and revenues are measures of the likely effects of the CRI on those variables. Because no other change in any other policy or condition is allowed to occur, this process effectively isolates the effects of the CRI on agricultural crop revenues in the Columbia River area.

Scenario 1: New Water Applied Proportionally to All Crops

The analysis indicates that over the next 20 years (2005 to 2024), an increase in acreage under production to the six crop groups as a result of 1 million acre feet of new agricultural water rights under the CRI would substantially reduce the market prices of orchard crops, vegetable crops, potatoes, and wheat but have little negative effect on the prices of hay or other crops (Table 1). The largest price declines would likely occur for potatoes and vegetable crops for which the annual average decline over the next 20 years would be about 12% or 13%.

The analysis also indicates that the price declines would lead to producers to pull back production from the levels that Huppert et al. assumed would occur if no price decline occurred. Looking back at Figure 1, Huppert et al. assumed that in any given year, production would increase from Q_{wo} to $Q_{with}^{constant\ p}$ at a constant price P_{con} because they assume that consumers would simply consume all that is available at that price. Our analysis concludes, however, that an increase in the production of the six crops would depress market prices to varying extents and lead producers in the Columbia River area to produce less of each crop than the maximum amounts that they would produce if consumers were willing to consume all additional supplies produced without regard for the price as Huppert et al. and Zhang assume. In fact, however, increases in supply lead to price declines precisely because consumers are not typically willing to consume everything that producers might be able to produce at a given price. In fact, for agricultural and food products, the market is typically quite unwilling to absorb additional supply without a relatively larger decline in price in percentage terms. As a consequence, in the agricultural and food sector, supply increases typically lead to price reductions (such as from P_{con} to P^{id}_{with} in Figure 1) and result in market clearing levels of production (such as Q^{id}_{with} in Figure 1) that are less than the maximum level that might be produced if prices did not fall (such as $Q^{constant\ p}_{with}$ in Figure 1). Because price tends to decline, producers are unwilling to expand production beyond what consumers are willing to take off the market at the lower price.

As shown in Table 2, the increase in water available for irrigation increases the production of the crops in all six crop groups. Wheat registers the largest annual percentage increase at nearly 16% followed by orchard crops (13.8%), potatoes (12.9%), and hay (10.5%). Vegetable production only increases by 5.4% and other crops by 6.1%. Even though the production of each crop increases, the increases are less than the maximum levels that would occur at fixed prices (the Huppert et al. assumption). On average over the 20 year forecast period, the simulated production levels of the six crops are on average almost 7% below the maximum levels possible (Table 2).

Given the price and production changes likely to occur in the *with* case (additional water available for irrigation), the gross producer revenues by crop can be calculated (Table 3). The results indicate that the gross revenues for hay, orchard crops, wheat, and other crops would increase on average over the forecast period by 8.3%, 3.3%, 5.6%, and 5.8%, respectively. On the other hand, because the percentage decline in their prices are greater than the percentage increases in their production in most years over the forecast period, the gross revenues for vegetable crops and potatoes decline by an annual average of 7.5% and 2.1%. The increase in revenues accruing to hay, orchard crops, wheat, and other crops are sufficient to outweigh the revenue losses of vegetable crops and potatoes in all but the last few years of the forecast period.

In terms of total gross revenues, the results are positive (Table 4). The simulated average annual increase in producer revenue is about $62.4 million or nearly $1.2 billion in total over the next 20 years. Nevertheless, the simulated gross revenue results are much below the level calculated by Huppert et al. as expected. In fact, the results indicate that nearly 90% of the Huppert et al. gross revenue calculation is an overestimate. Note that in Table 4, the calculated gross revenue level attributed to Huppert et al. is $584.1 million. However, they report an even higher gross revenue calculation of $733.2 million in Table 3.1 of their report. The difference is due to having updated the Huppert et al. calculation using 2005 estimated prices and production levels to maintain consistency and comparability between this report and the Huppert et al. report.

In terms of net revenues (gross revenues minus production costs following the procedure discussed in the Methodology and Data section of this report), the results are clearly negative. In other words, on average over the period, the additional water under the results indicate that the CRI would lead to an annual average net decline in producer revenues of just over $70 million compared to the $353.8 million increase that would result under the Huppert assumptions and methodology. In other words, the results of our analysis indicate clearly that agricultural producers in the Columbia River area would be better off economically *without* additional irrigated acreage than they would be *with* additional irrigated acreage given the water allocation scheme assumed by Huppert et al.

Scenario 2: New Water Applied Proportionally Only to Marginal Crops

This scenario follows the same process and procedures as the first scenario except that rather than allocating the additional water under the CRI to crops in proportion to their share of total acreage, the additional water is allocated only to marginal crops (defined as hay, wheat, and other crops) in proportion to their shares of their total acreage. This water allocation scheme would seem to be more in line with the "required use of 'marginal values' for economic valuation" (Griffin, p. 8). Table 6 indicates that allocating all the water to the three marginal crops would lead to larger price declines for each crop than estimated for scenario 1. This result is reasonable since scenario 2 implies a greater increase in the supply of each crop and, therefore, a larger decline in their market prices. Table 7 shows that the increase in supply of each crop to their equilibrium levels is much larger for each crop. For hay, the average annual increase in production in scenario 2 is 19% compared to 11% in scenario 1. For wheat the corresponding average annual supply increases are 28% in scenario 2 and 16% in scenario 1 and 11% for other crops in scenario 2 and about 6% in scenario 1. On average over the 20-year forecast period the production of the three "marginal" crops increases by 17% in scenario 2 compared to about 11% in scenario 1.

In terms of additional gross revenues from agricultural production, the simulation indicates that the increases for the three crops are larger under this scenario than under scenario 1 (Table 8). For the three "marginal crops," the aggregate gross revenue from scenario 2 is smaller then the aggregate gross revenues estimated for scenario 1 over the first 11 years (Table 9). Thereafter, the gross revenue under scenario 2 is larger than that of scenario 1. In total over the 20-year forecast period, the gross revenue under scenario 2 (about $1.5 billion) is larger than the corresponding aggregate gross revenue in scenario 1 ($1.2 billion). The implication is that if additional water becomes available for irrigation, producers would be better off in the long run by applying the water to marginal crops than to the higher value crops. However, even though aggregate gross revenues are larger in scenario 2 than in scenario 1, when the production costs are subtracted from the revenues (following the procedure outlined in the Methodology and Data section), the net revenues are negative even under scenario 2 (Table 10). Consequently, regardless of how the water is allocated, the net benefits from additional irrigated acreage in the Columbia River area are negative.

Summary and Conclusions

This study is an independent analysis of the likely effects of additional agricultural water rights under the Columbia River Initiative on net agricultural revenues in the state of Washington over the next 20 years. The study was designed to follow the Huppert et al. and Zhang methodology in principle but correct for four methodological errors that were serious enough to have a potentially large impact on the net revenue calculations by Huppert et. al and, therefore, on the cost-benefit analysis performed by Zhang. The first and most costly methodological error was their implicit assumption that the demand for the crops produced along the Columbia River is perfectly price elastic. As a consequence, the increases in supply calculated by Huppert et al. as a result of an increase in the water available for agricultural production in the Columbia River area have no price implications and, therefore, lead to the highest possible gross revenue calculations. In this study, we estimate elasticities of the supply for the crops produced in the Columbia River area. Then, we use the supply elasticities along with elasticities of the demand for those crops taken from other studies to calculate the price and quantity implications of increased water available for agricultural production in the Columbia River area.

The second error in the Huppert et al. and Zhang calculation of the net revenues to agricultural producers from increased irrigated acreage relates to their choice of crop mix. They assume that any additional water is applied to crops on the new acreage in proportion to their shares of total existing acreage. Moreover, they assume that the crop mix on new acreage does not change over the 20-year period of analysis. In this analysis, we allow the crop mix to change over time by forecasting the likely acreage, yields, and supply of each crop that would occur over the 20-year period assuming that no additional water becomes available. The acreage forecasts are used to calculate the crop mix in each year over the forecast period. Since the acreage of each crop is forecast independently, there is no constraint on how the crop mix might change over the 20-year time period. Also, their assumption that water is applied to crops in proportion to their existing shares of total acreage in production is not consistent with received economic theory that any additional water would be applied to the marginal uses. Consequently, besides following the Huppert et al. method of applying water proportionally to all crops, we analyze a second scenario in which water is applied only to the marginal crops which we define as wheat, hay, and an "other" crops group.

The third error in the Huppert et al. methodology was their exclusive focus on the Columbia River region. The problem arises in using the Huppert et al. revenue calculations to infer benefits from the CRI to the state of Washington since any production increase in the Columbia River region with increased availability of water could well be offset by a reduction in production of that crop elsewhere in the state. This is particularly the case since the increase in water in the Columbia River region enhances the competitiveness of that region and puts other regions at a disadvantage in production. We attempt to address this problem by working from the state level down to the Columbia River region in our baseline forecasts and by allowing for supply induced declines in price that discourage production outside the Columbia River region as well.

The final methodological problem in the Huppert et al. calculation of net revenues is in not explicitly distinguishing between the levels of production and revenues that would have existed even without new water rights and the levels that result as a consequence of the new water rights. To address this problem, we first established a forecast baseline of the levels of acreage, yields, prices, production, demand, and prices in the Columbia River area that would likely exist over the next 20 years assuming no additional water rights for agricultural production under the CRI. Then we simulate the impact of the addition of new water as changes in prices, quantities, and revenues from the forecast baseline levels, thereby insuring that the consequent calculated changes in production revenue result only from the change in water availability and not from any other economic force that might affect the markets and producer revenues for those crops.

In general, our analysis concludes that the errors in the Huppert et al. and Zhang methodology support a policy prescription that is just the opposite of what would be in the best economic interest of the state of Washington and the Columbia River region. After correcting for the four errors in the Huppert et al. methodology, we demonstrate that the Huppert et al. methodology actually leads to a negative net revenue calculation rather than the highly positive net revenue they reported. Thus, rather than supporting the implementation of the Columbia River Initiative and the granting of new water rights to agricultural producers in that region, a net revenue analysis that corrects for the errors in the Huppert et al. methodology actually leads to a conclusion that producers in the Columbia area and the state of Washington would be better off economically without the new water rights under the CRI.

Our results simply support the well known principle of the "fallacy of composition." This principle warns that "even though it is profitable for any individual farm to expand production, if all farms expand, profits decline for all farms" (Knutson, Penn, and Flinchbaugh 1998, pp. 21-22). In the context of the CRI, any individual producer may well benefit economically by increasing production through an increase in irrigated acreage made possible by new agricultural water rights under the CRI but if all producers in the Columbia River region also increase their production as a result of new water rights, prices will decline and the revenues of all producers will also fall. How far the revenues of all producers would fall depends on the price elasticities (responsiveness) of market supply and demand. Using measures of the elasticities of the supply of agricultural commodities in the Columbia River area that we derive using sophisticated statistical procedures and measures of the elasticities of the market demands for those commodities available from other well-known studies, we show that a production increase from new agricultural water rights in the Columbia River area would reduce prices for those commodities and result in profit losses (negative net revenue gains) for producers in that area.

In summary, our analysis leads to the following conclusions:

- The Huppert et al. assumption that demand is sufficient to absorb all the additional supply (perfectly elastic demand) guarantees that, given their assumption on prices and quantities, the gross revenue they calculated was the highest level possible.
- Any assumption on the elasticity of supply and demand other than those made by Huppert et al. will necessarily lead to a lower net revenue calculation than reported by Huppert et al.
- Using empirically estimated elasticities of crop supply and reasonable estimates on the price responsiveness of demand found in the literature, this report concludes that Huppert et al. and Zhang substantially overestimated the net revenues accruing to producers in the Columbia River area from an increase in irrigated acreage under the CRI. We find that the overestimate was severe enough that the additional net revenues are more likely to be negative than positive.
- This same conclusion holds even if water is allocated only to marginal crops as suggested by economic theory would occur rather than to all crops in proportion to their share of total existing acreage as assumed by Huppert et al.

- An increase in water for agricultural irrigation in the Columbia River area, assuming the water is applied to all crops proportionally, would tend to depress prices of all crops but particularly those of orchard crops and vegetables. The production of those crops has been growing relatively rapidly both in absolute terms and in relationship to their corresponding national consumption. Consequently, changes in the Columbia River area production of those crops have relatively greater impacts on national markets and prices than changes in the Columbia River production of crops like hay and those included in the "other crops" group which account for less than 1%-2% of the national consumption of each.
- While increasing the availability of water for irrigation in the Columbia River region would boost crop production in the region, the increases would be generally less than the maximum that could be achieved with no price declines as supply increases. The price declines would work as a disincentive to production in the region so that producers would likely expand the irrigated acreage by less than what the increased water supplies would allow at constant prices.
- For vegetables and potatoes, the percentage increase in their supplies as a result of new water availability would be outweighed by the percentage decline in their prices on average over a period of 20 years given the price responsiveness (elasticities) of supply and demand assumed in this study. The consequence would be declining gross revenues to vegetables and potatoes with additions of new irrigated acreage.
- In contrast, the production expansion from the addition of new water supplies would tend to be greater in percentage terms than the corresponding negative effect on prices for orchard crops, wheat, and other crops leading to increases in gross revenues for those crops (again given the price elasticities of supply and demand used in this study).
- The positive gross revenue effects of orchard crops, wheat, and the "other crops" group given an increase in new water supplies would likely be sufficient to offset the negative gross revenue effects from vegetables and potatoes over a 20-year period leading to a positive gross revenue result of $1.25 billion over that period, an average of $62.4 million per year.
- The more likely increase in total gross revenue of $1.2 billion over a 20 year period of time calculated in this study is $10.4 billion less than the $11.7 billion estimate of aggregate gross revenues that results from using the flawed Huppert et al. gross revenue calculation methodology.
- The net returns to producers from an increase in irrigated acreage allowed by new water rights under the CRI would likely be negative under reasonable assumptions regarding the price responsiveness of supply and demand for the crops grown in the Columbia River region. In other words, new water rights that allowed for an expansion of irrigated acreage in the Columbia River region would cost the region and state about $1.4 billion over a 20-year period, an annual average loss of about $70 million. In contrast, using the flawed Huppert methodology to calculate net revenues suggests that the region and state would gain rather than lose in excess of $7 billion over 20 years (an annual average of $353.8 million) from granting the new agricultural water rights.

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FIGURES AND TABLES

Figure 1: Effects of Alternative Supply and Demand Elasticity Assumptions on Estimated Value of Crop Revenue from Additional Irrigated Acreage

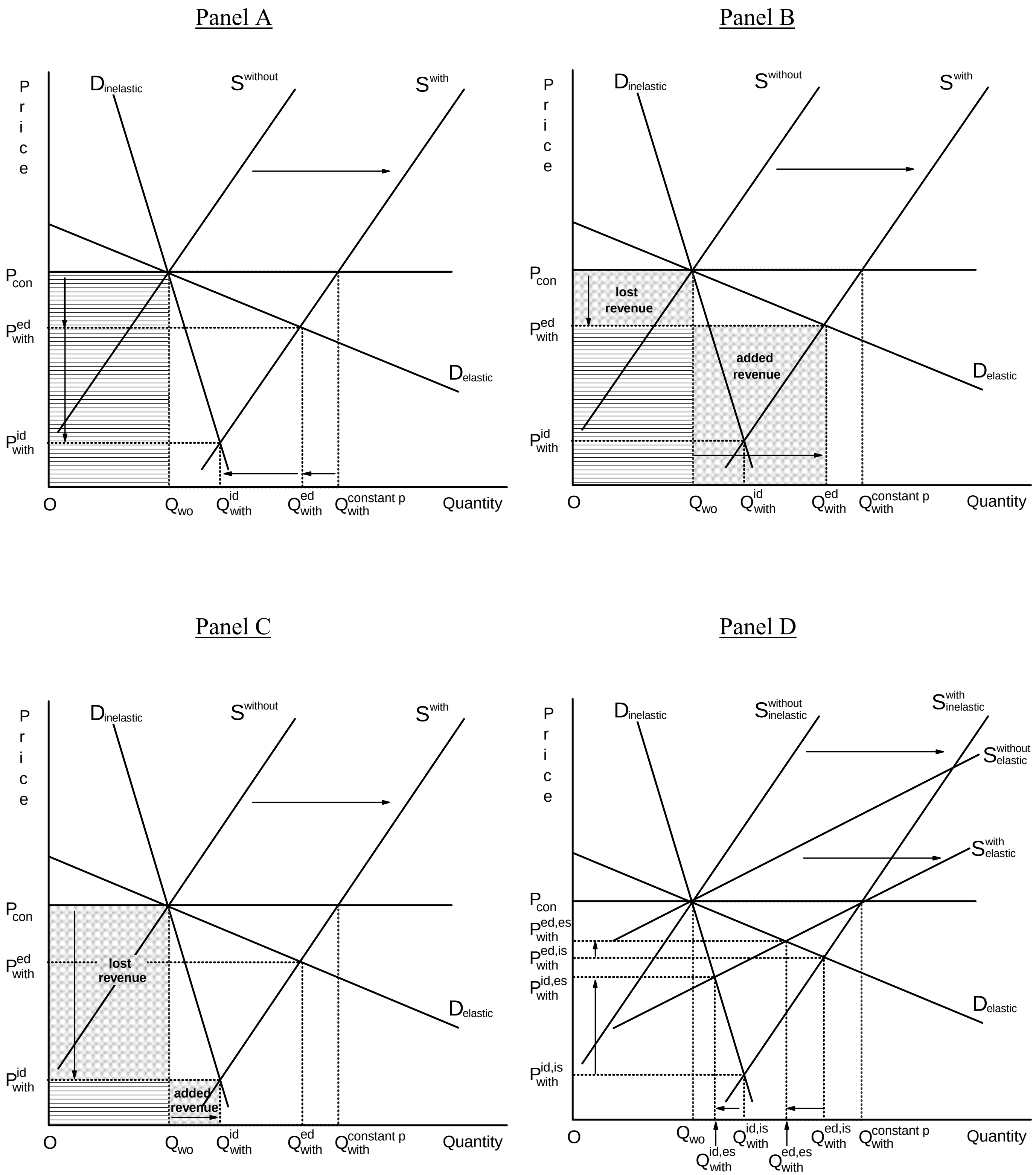


Figure 2: Measuring Before/After and With/Without Changes

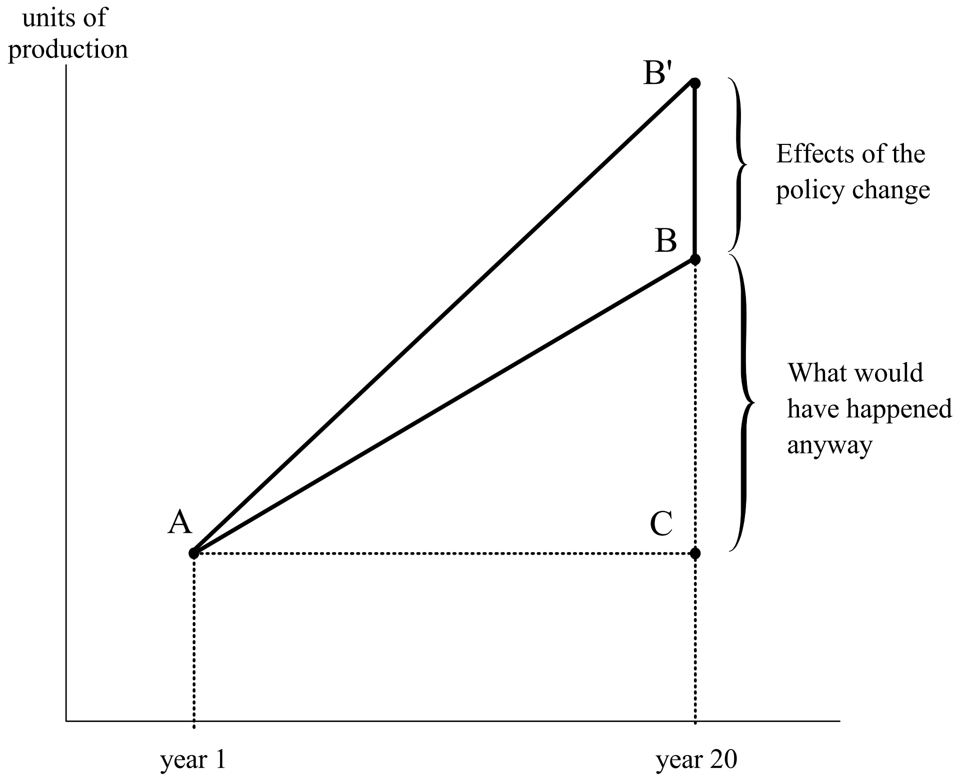


Figure 3: Hay: Washington State Historical and Forecasted Acreage, 1949-2024

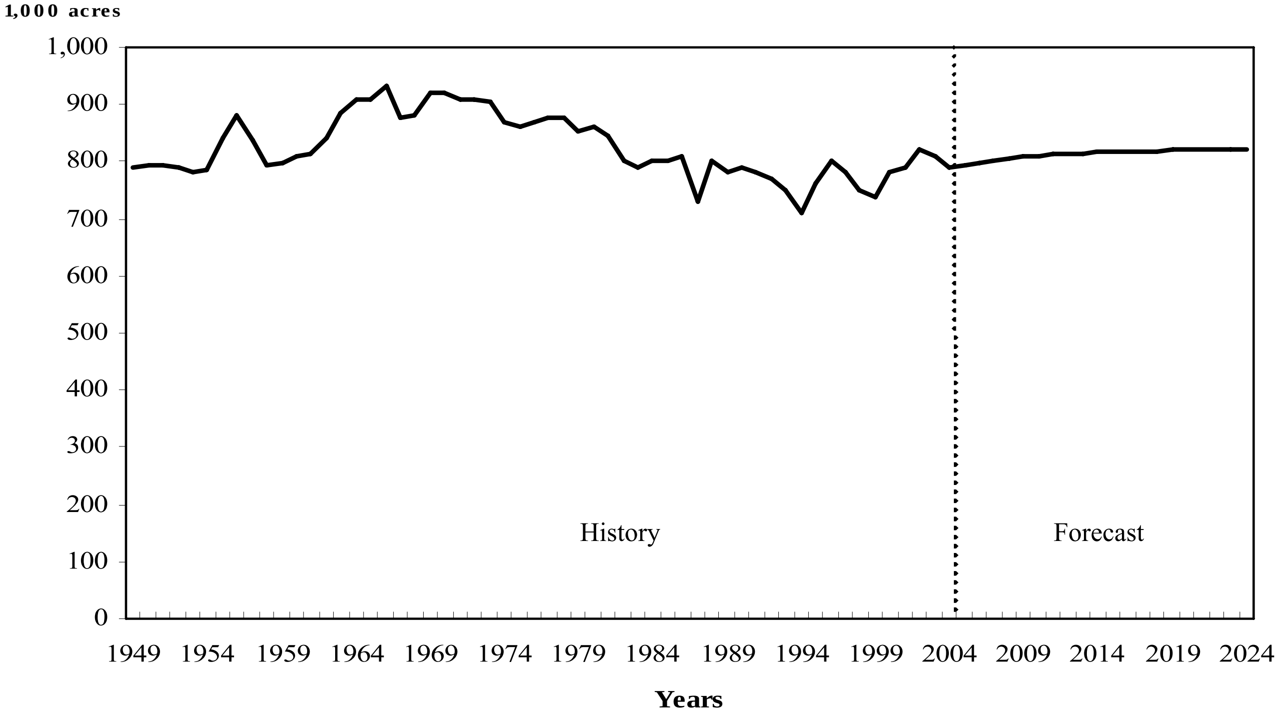


Figure 4: Orchards: Washington State Historical and Forecasted Acreage, 1949-2024

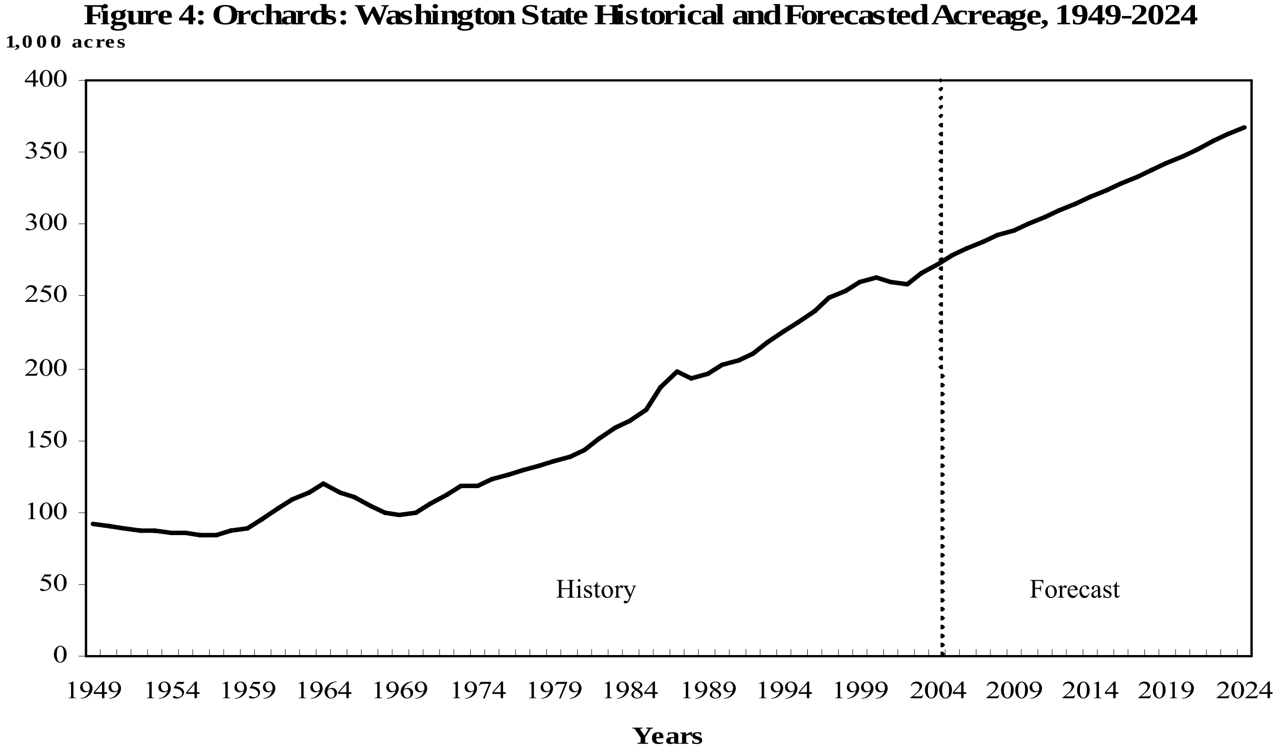


Figure 5: Vegetables: Washington State Historical and Forecasted Acreage, 1949-2024

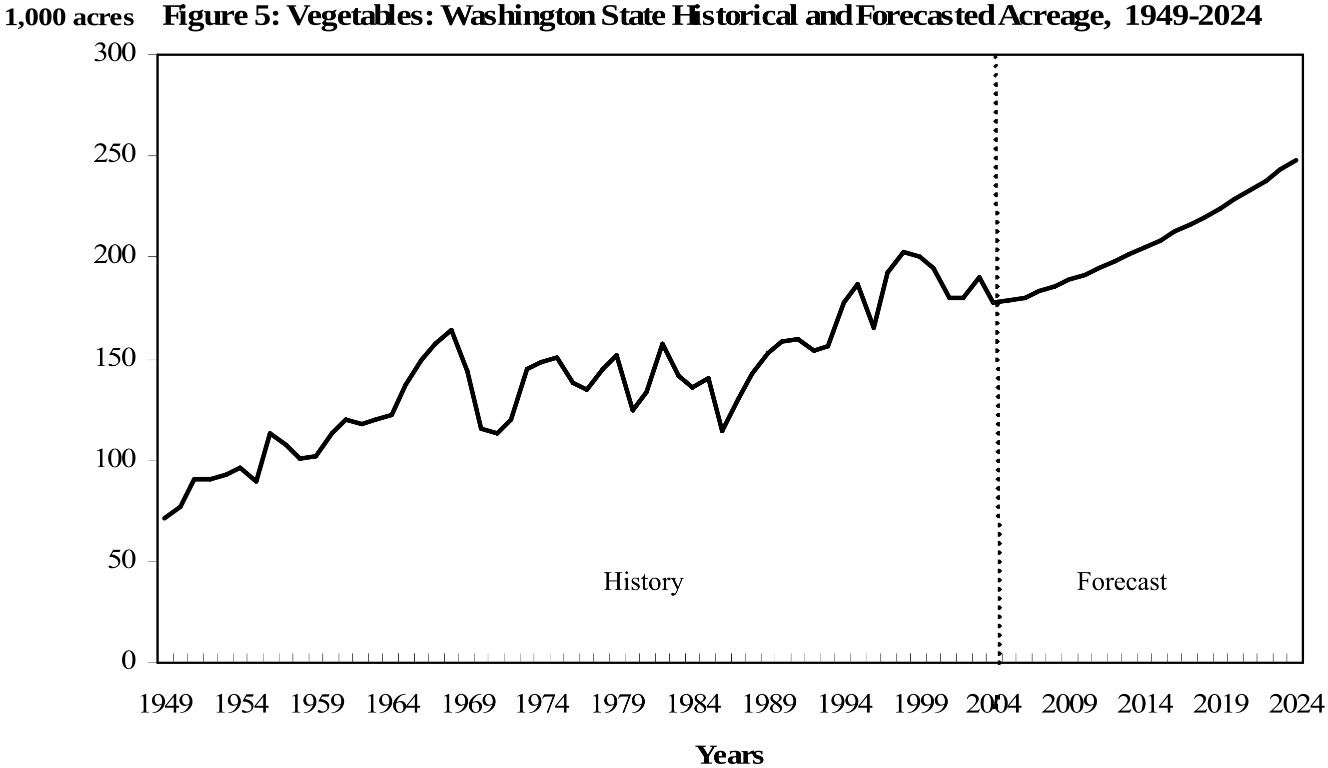


Figure 6: Potatoes: Washington State Historical and Forecasted Acreage, 1949-2024

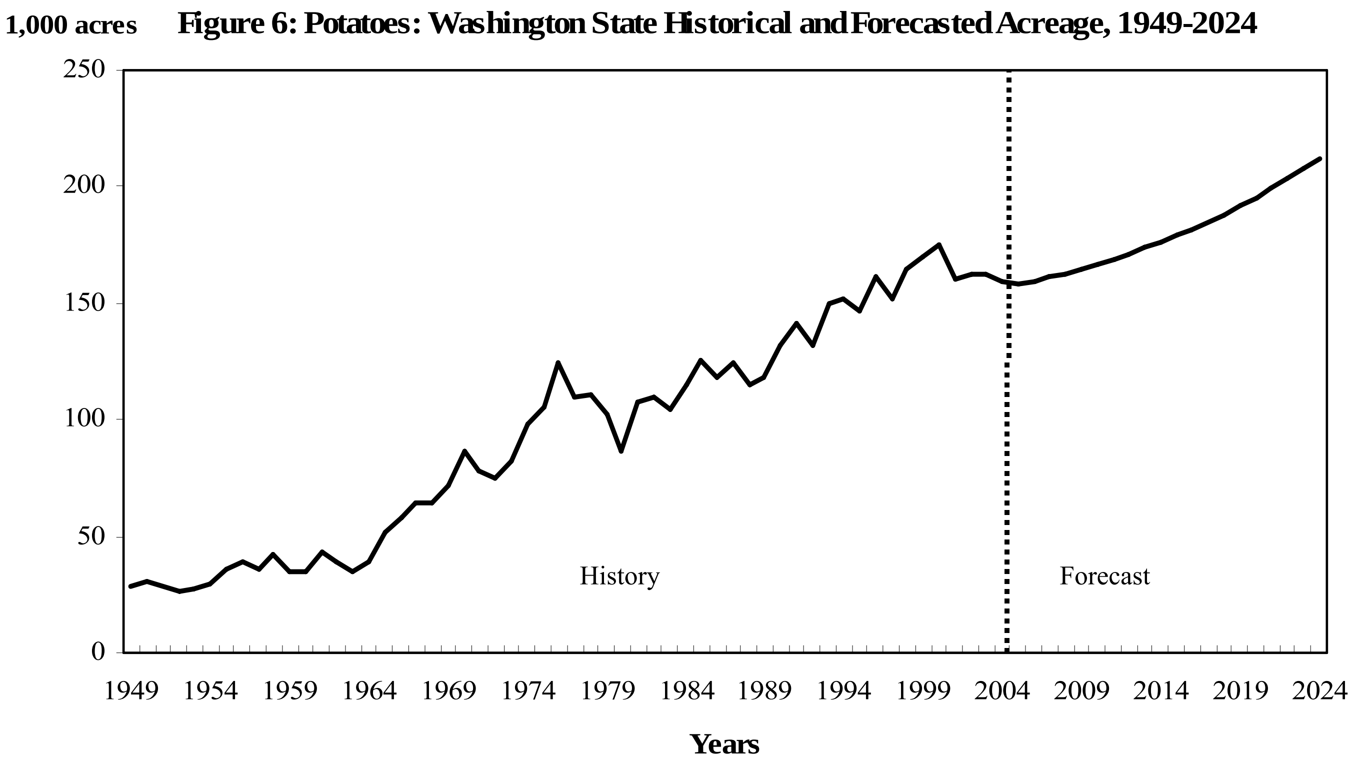


Figure 7: Wheat: Washington State Historical and Forecasted Acreage, 1949-2024

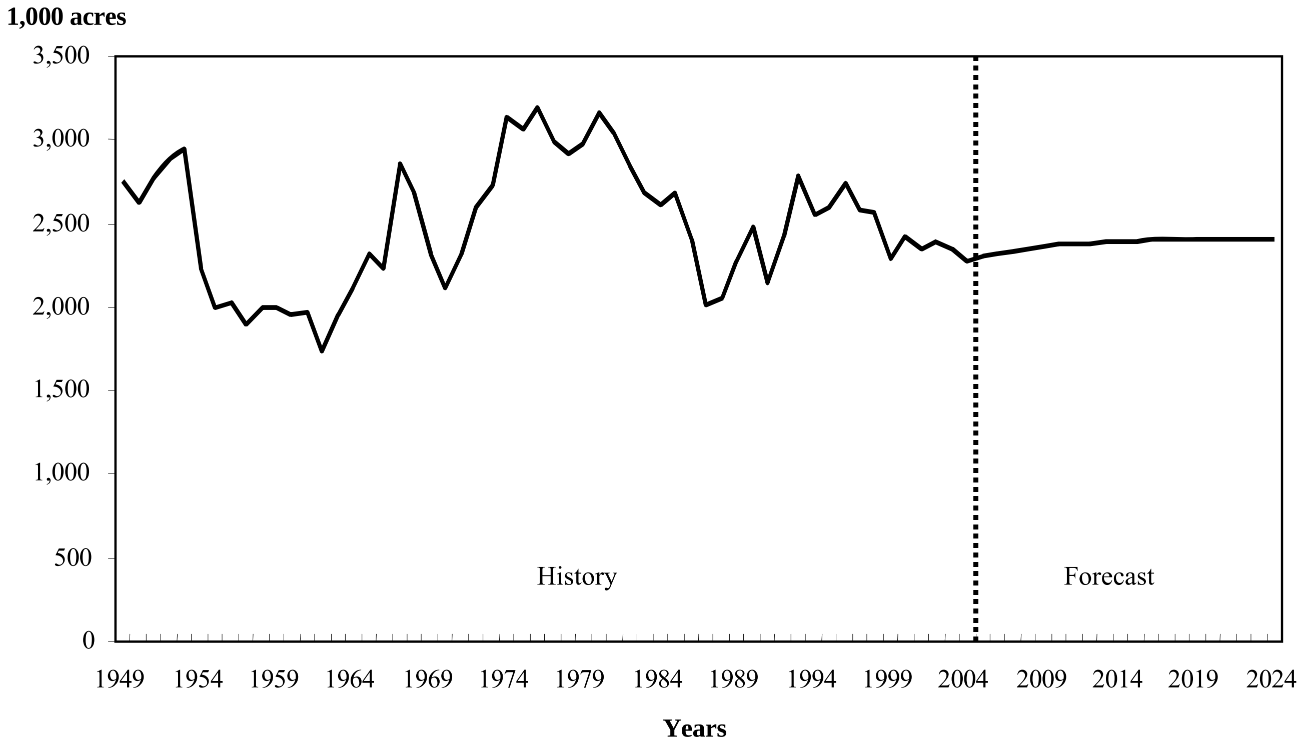


Figure 8: Other Crops: Washington State Historical and Forecasted Acreage, 1949-2024

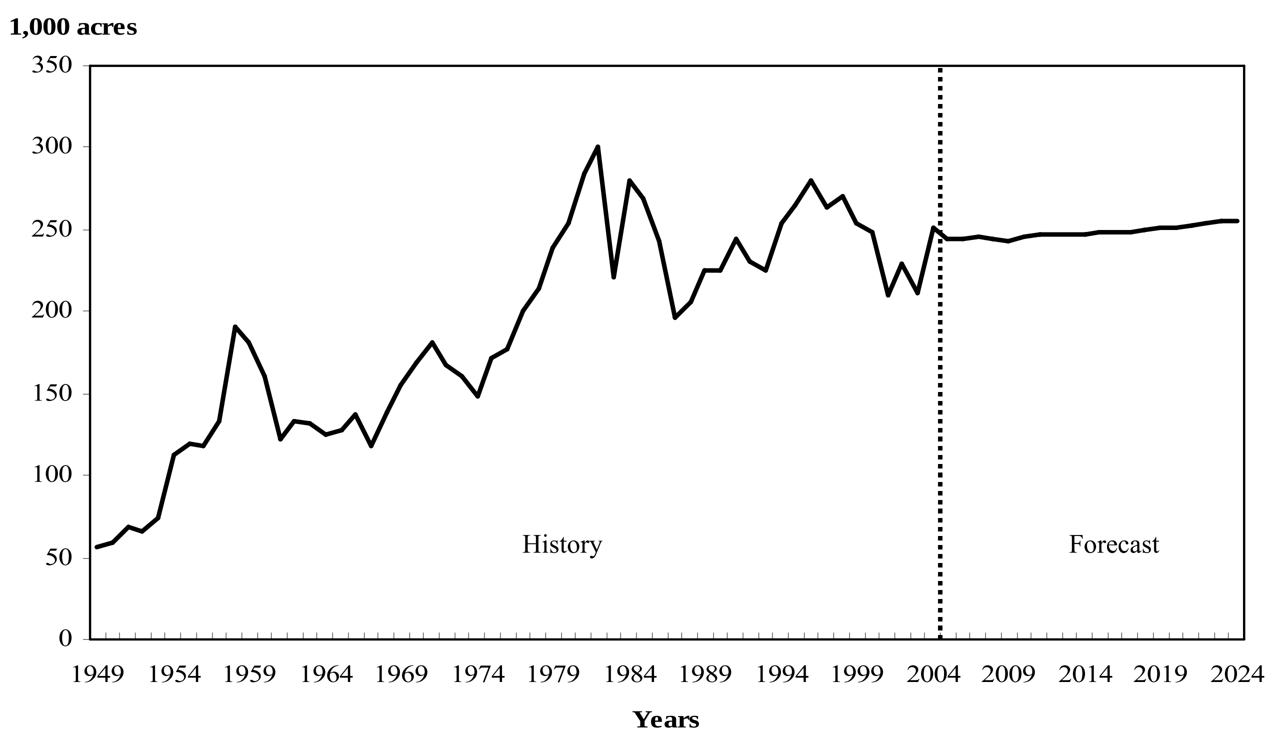


Figure 9: Columbia River Area Baseline Forecast Acreage, 2005-2024

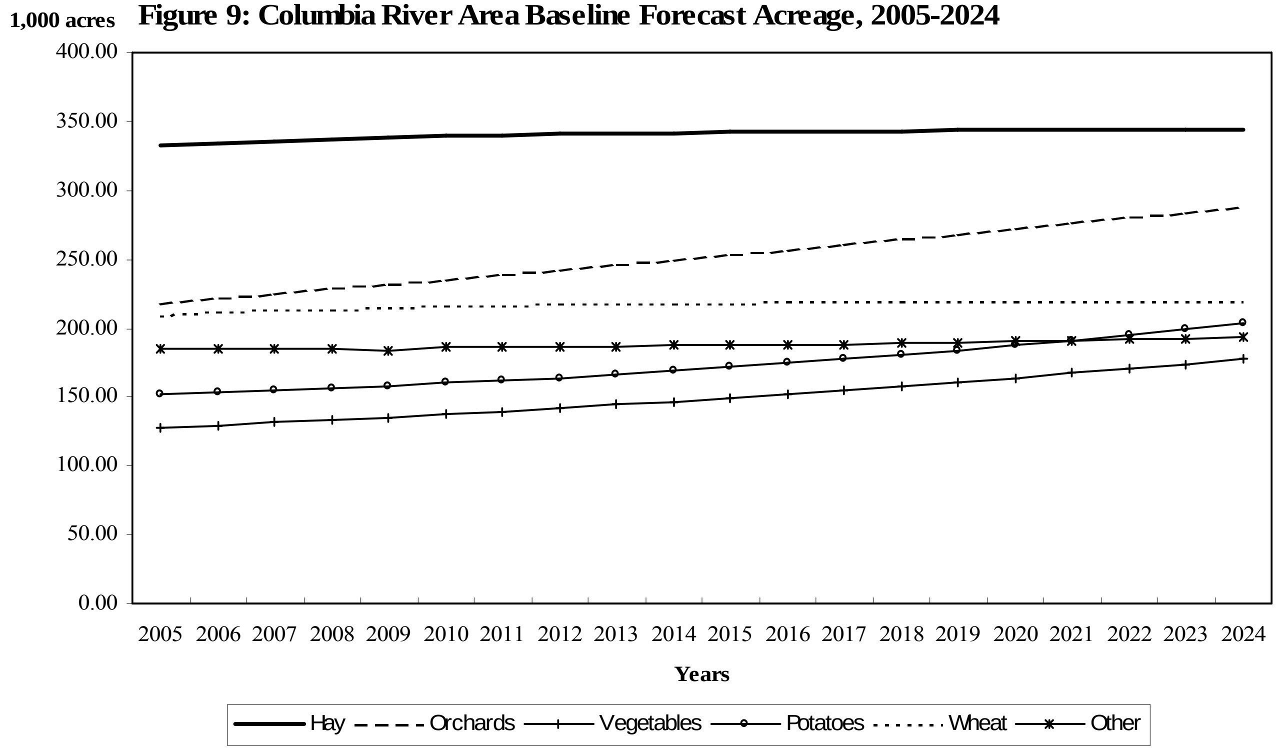
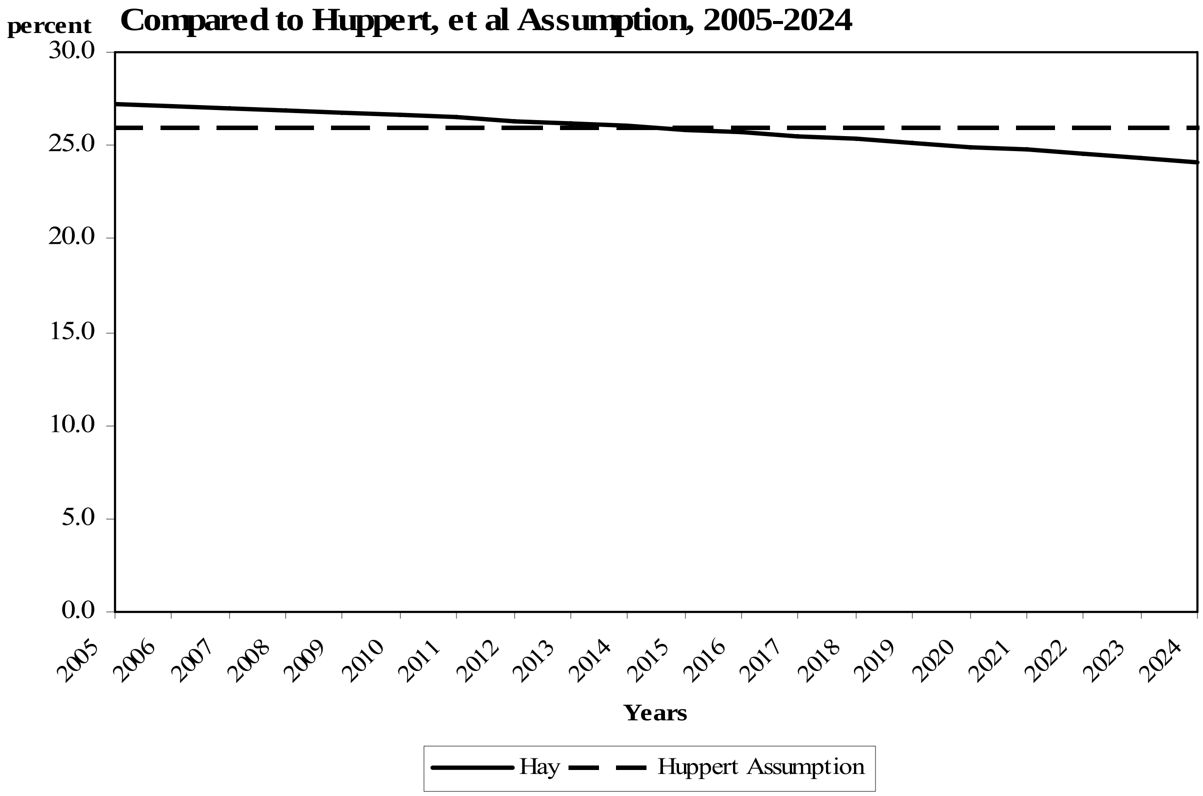


Figure 10: Hay: Forecast Acreage Share for Columbia River Basin Area Compared to Huppert, et al Assumption, 2005-2024



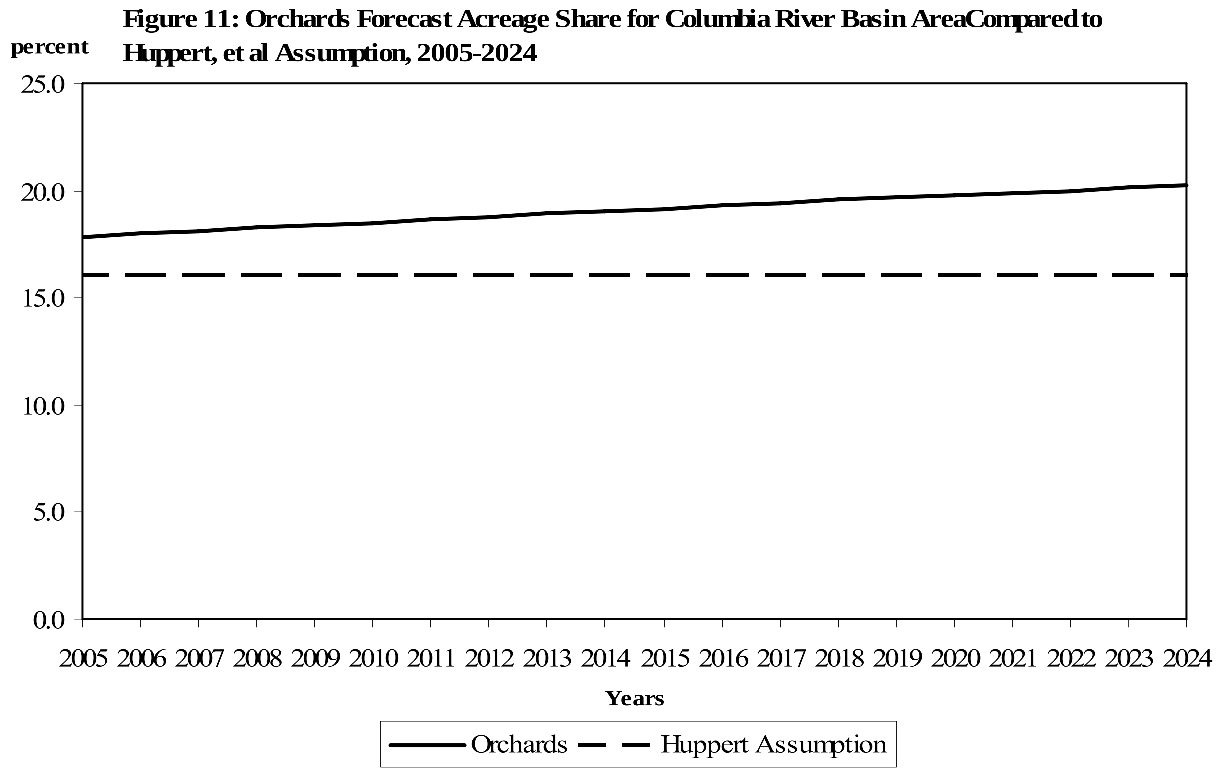


Figure 11: Orchards Forecast Acreage Share for Columbia River Basin AreaCompared to Huppert, et al Assumption, 2005-2024
percent
25.0
20.0
15.0
10.0
5.0
0.0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
Years
Orchards
Huppert Assumption

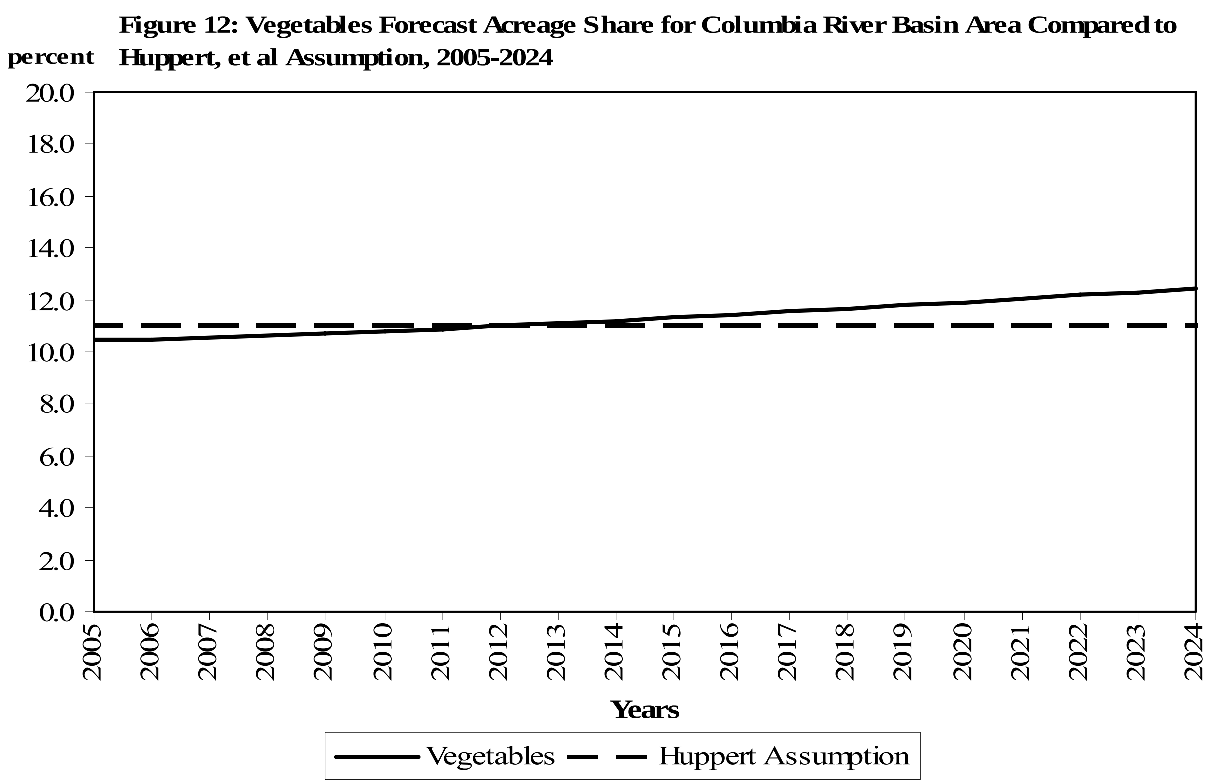


Figure 12: Vegetables Forecast Acreage Share for Columbia River Basin Area Compared to Huppert, et al Assumption, 2005-2024
percent
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
Years
Vegetables
Huppert Assumption

Figure 13: Potatoes Forecast Acreage Share for Columbia River Basin Area Compared to the Huppert, et al Assumption, 2005-2024

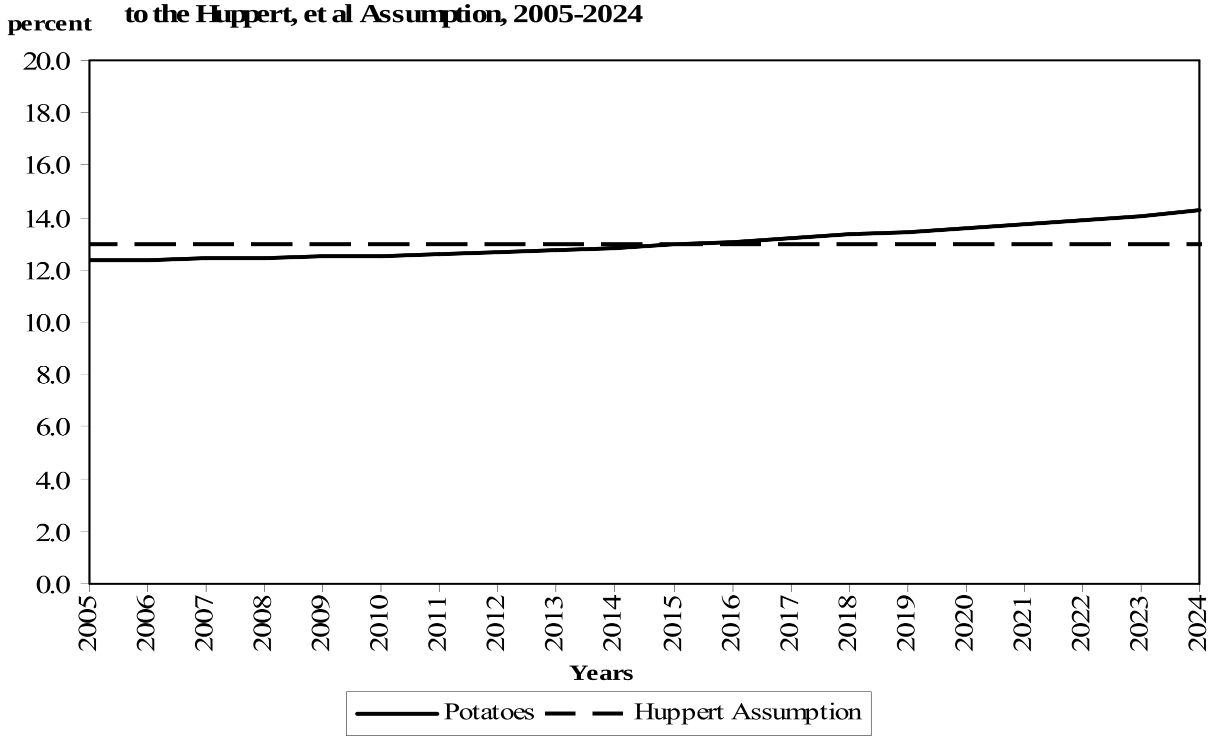
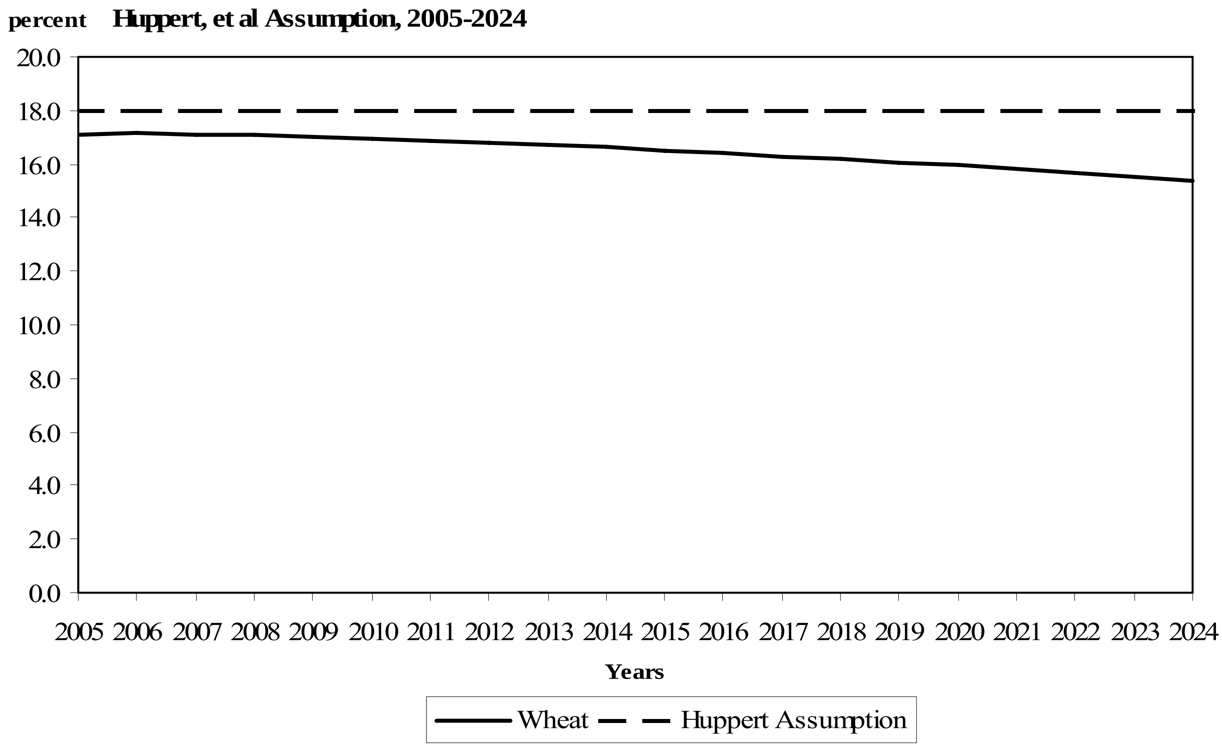


Figure 14: Wheat Forecast Acreage Share for Columbia River Basin Area Compared to Huppert, et al Assumption, 2005-2024



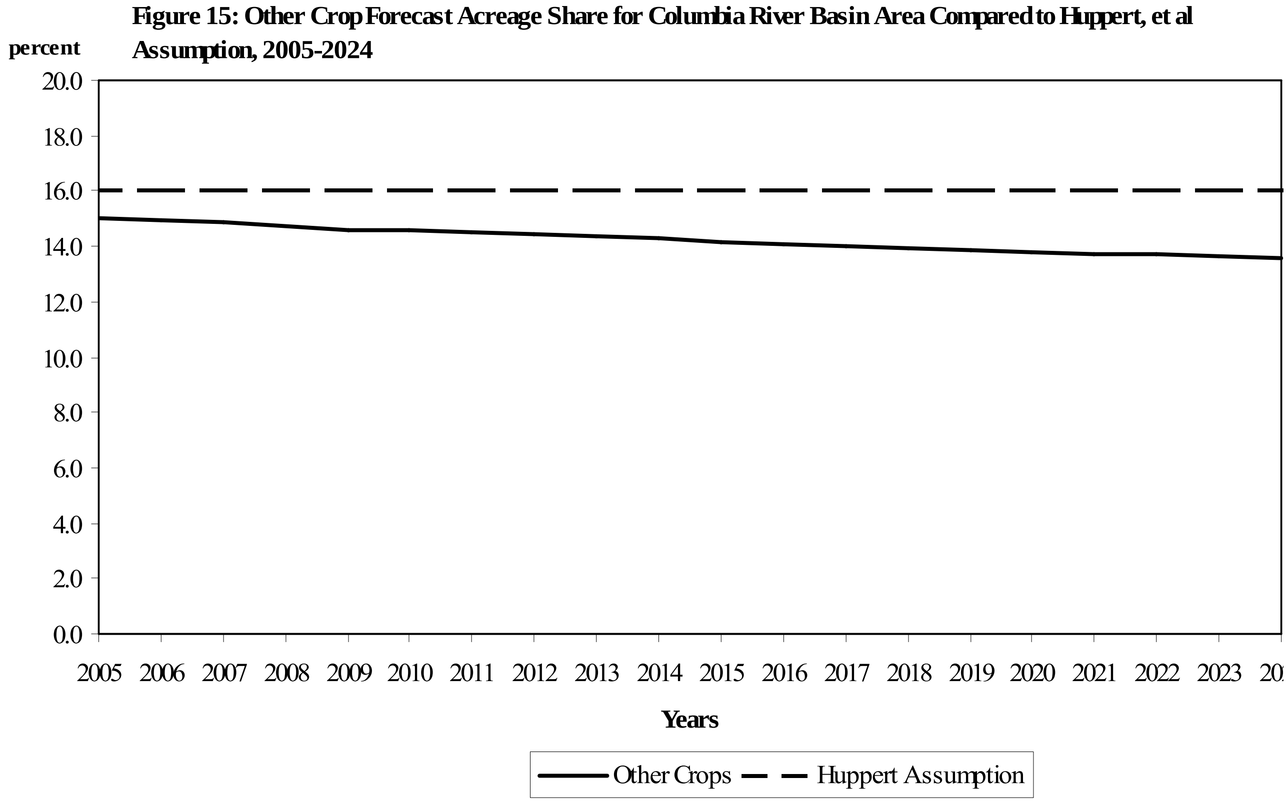


Figure 15: Other Crop Forecast Acreage Share for Columbia River Basin Area Compared to Huppert, et al Assumption, 2005-2024
percent
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Years
Other Crops
Huppert Assumption

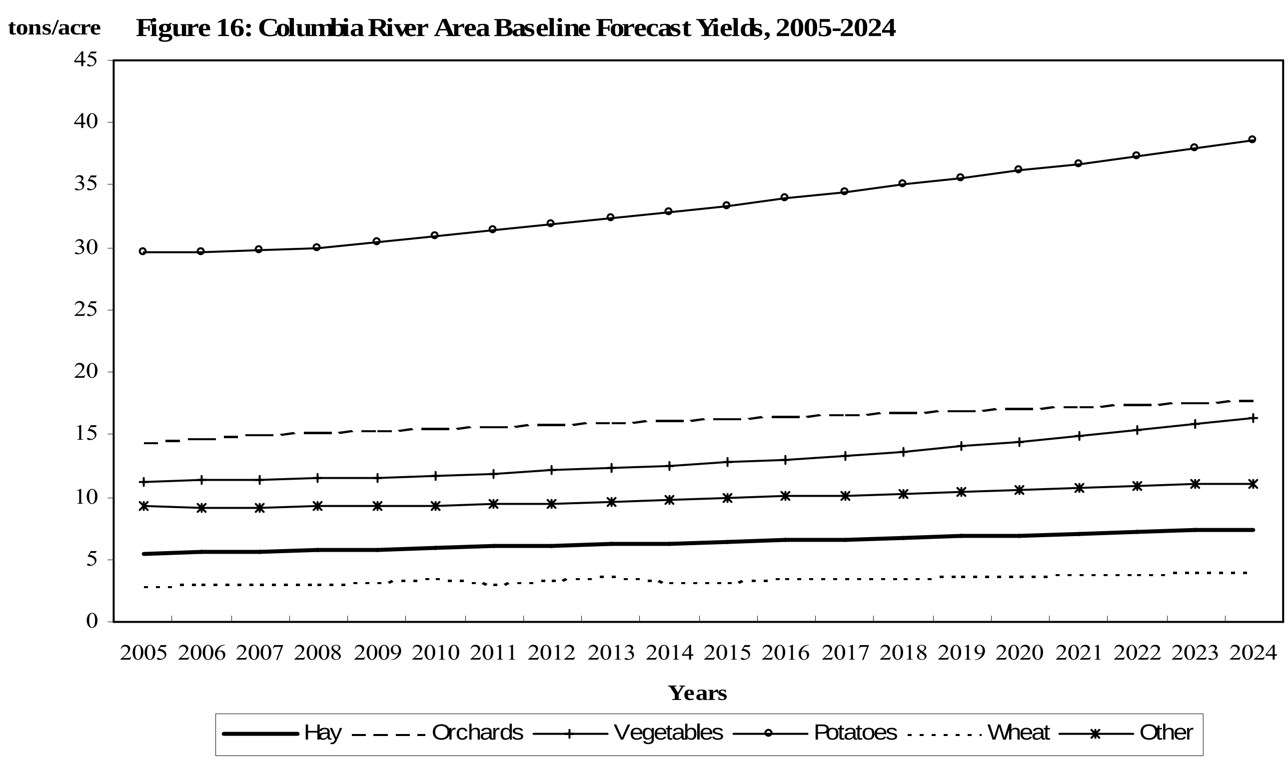


Figure 16: Columbia River Area Baseline Forecast Yields, 2005-2024
tons/acre
45
40
35
30
25
20
15
10
5
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Years
Hay
Orchards
Vegetables
Potatoes
Wheat
Other

Figure 17: Columbia River Area Baseline Forecast Production, 2005-2024

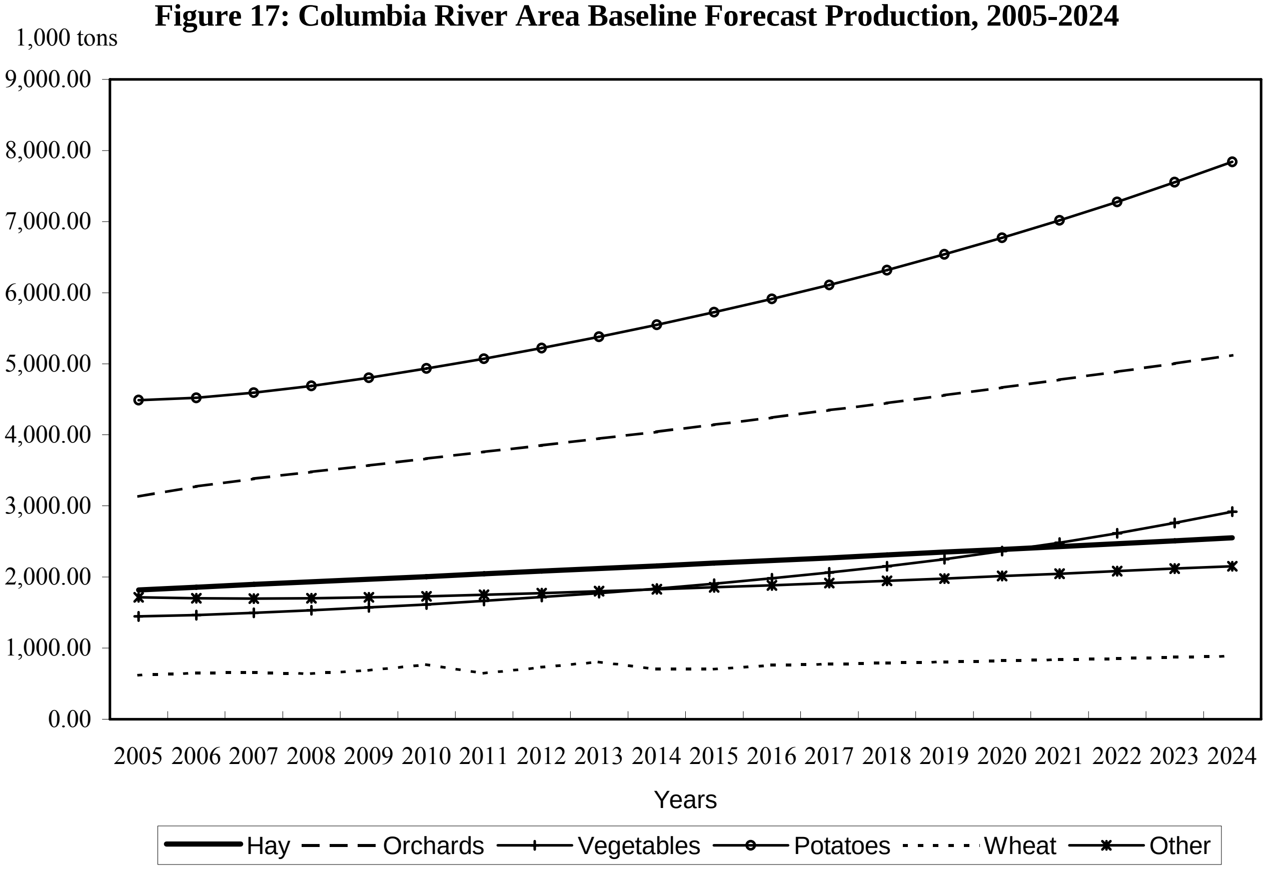
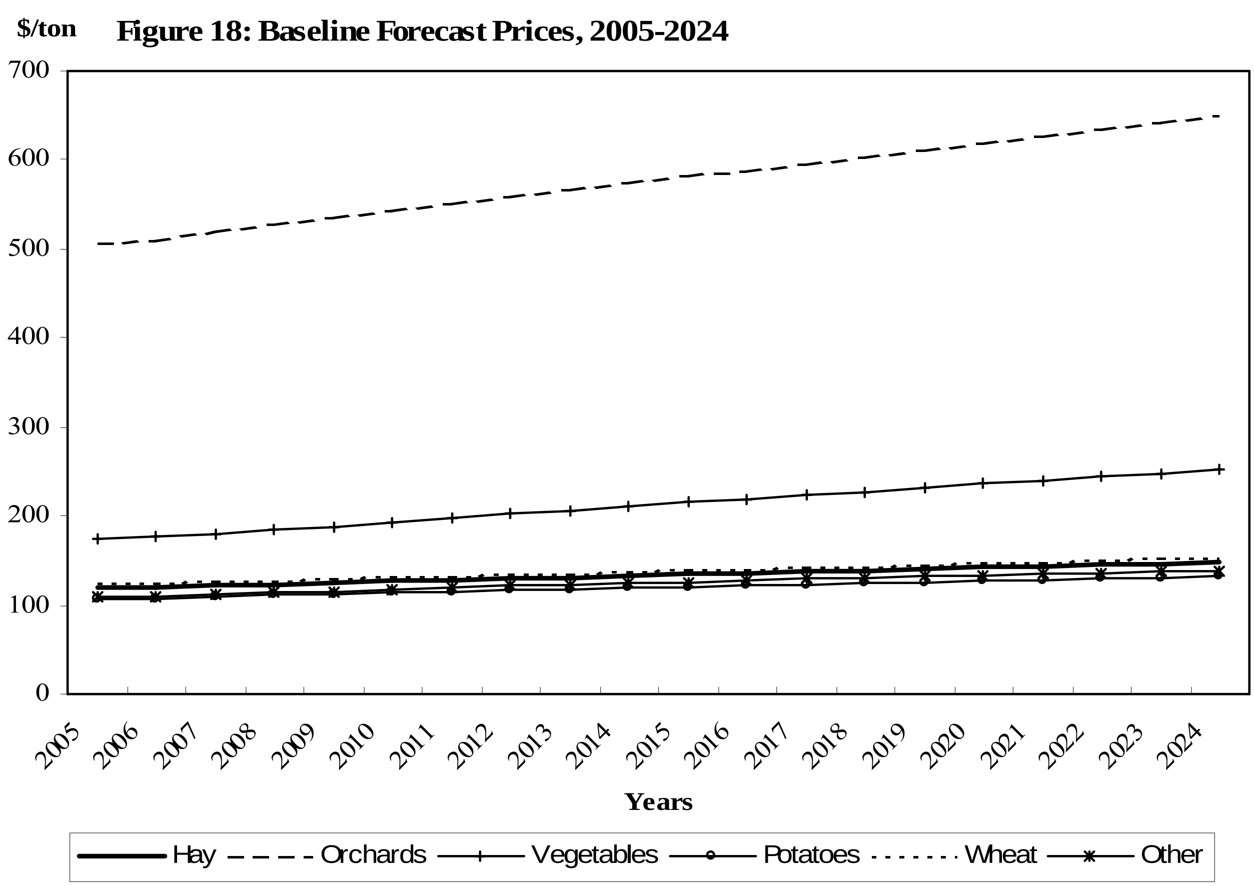


Figure 18: Baseline Forecast Prices, 2005-2024



$ million **Figure 19: Columbia River Area Baseline Forecast Revenues, 2005-2024**

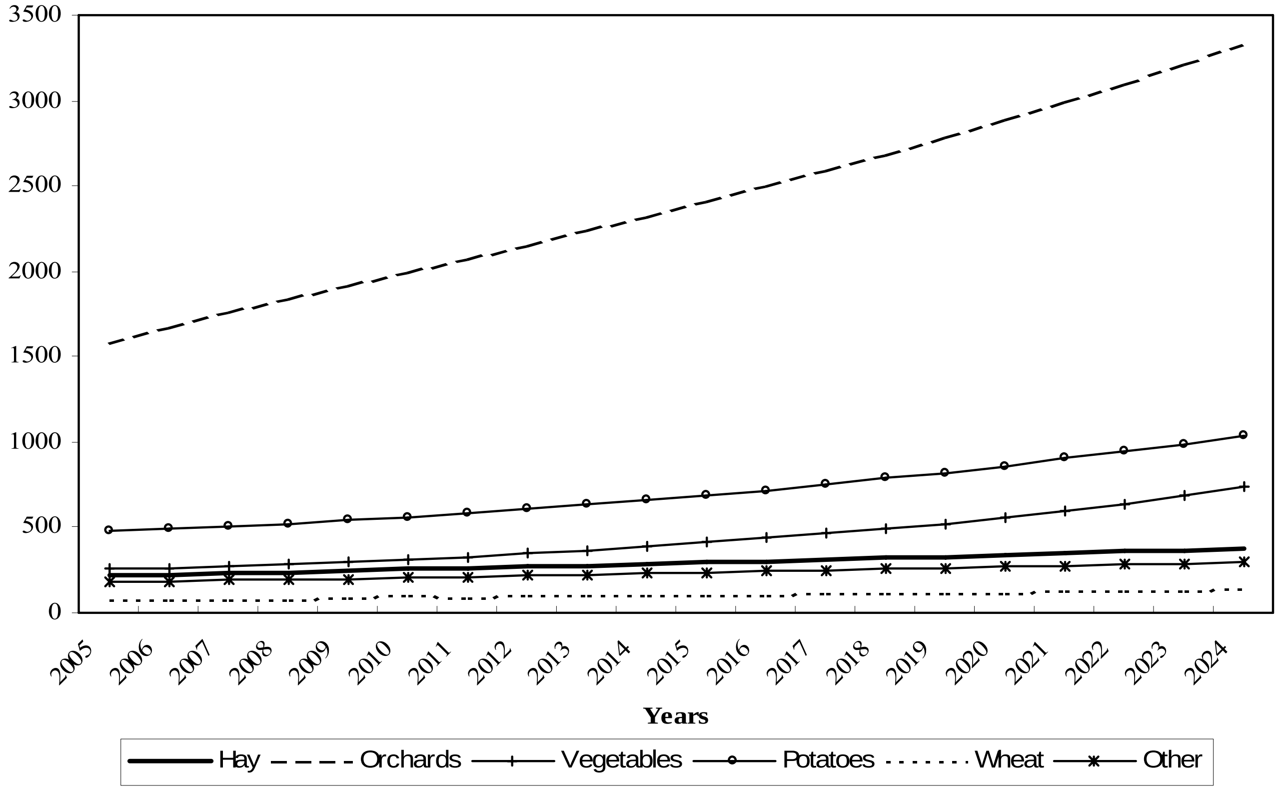


Figure 20: Aggregate Annual Producer Revenues: Comparison of Baseline Forecast to Huppert et al. Assumption, 2005-2024

$ million

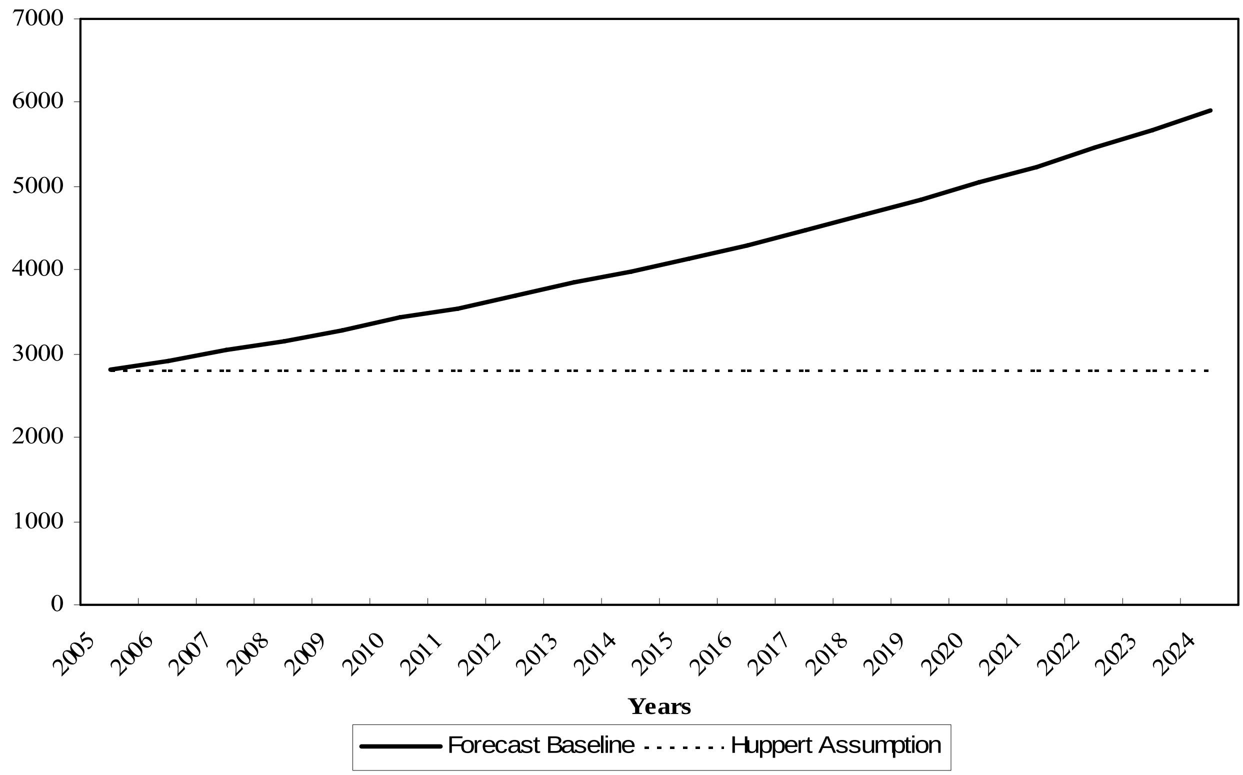


Figure 21: Historical and Forecast Baseline Shares of National Disapperarnce Supplied by the Columbia River Area, 1980-2024

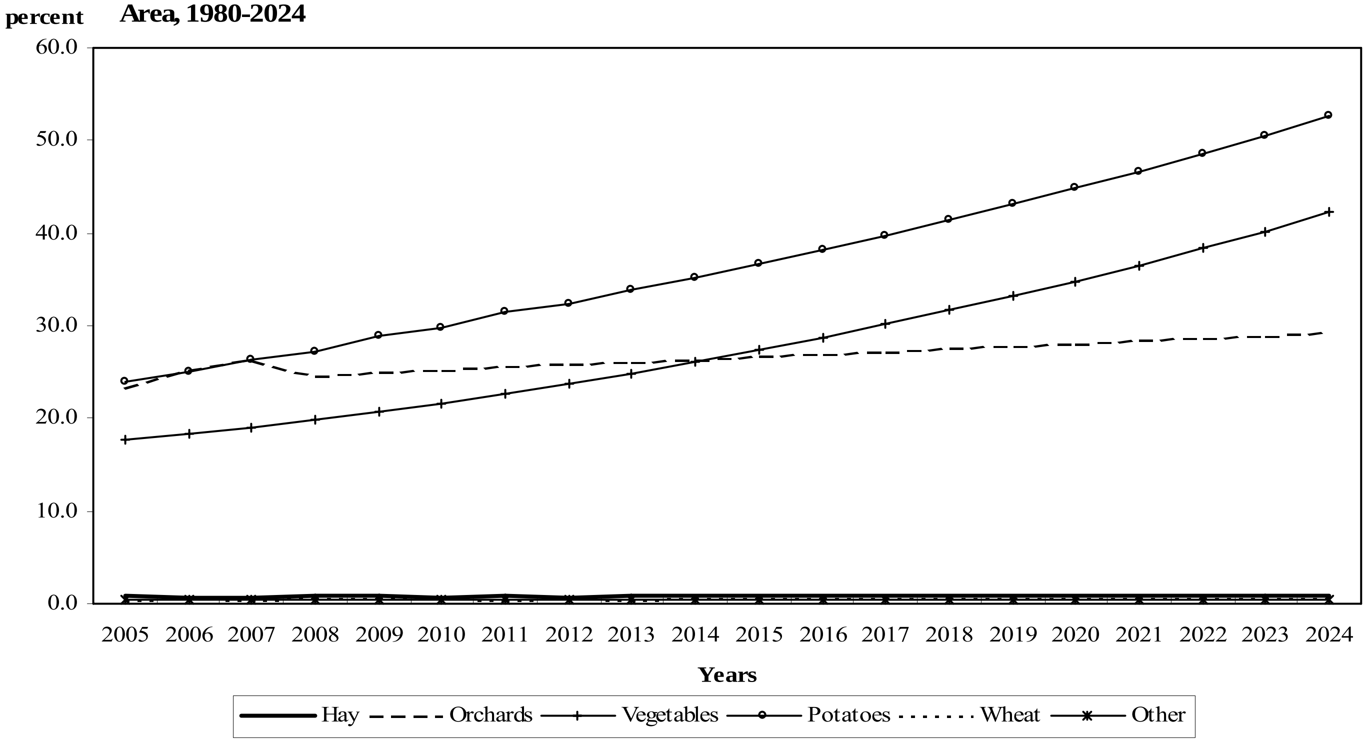


Table 1: Scenario 1 - Market Price Effects for the Six Crop Groups from Additional Agricultural Water Rights under the Columbia River Initiative, 2005-2024

	Hay	Orchards	Vegetables	Potatoes	Wheat	Other
	------------------	------------------	percent change	------------------	------------------	------------------
2005	-2.02	-8.73	-8.53	-9.42	-9.18	-0.30
2006	-1.98	-9.42	-8.71	-9.73	-9.28	-0.30
2007	-1.98	-9.74	-8.96	-10.17	-8.39	-0.30
2008	-1.97	-9.05	-9.28	-10.45	-9.05	-0.29
2009	-1.98	-9.13	-9.63	-11.00	-9.53	-0.29
2010	-1.97	-9.13	-10.00	-11.20	-10.05	-0.29
2011	-1.97	-9.16	-10.40	-11.80	-8.15	-0.29
2012	-1.97	-9.18	-10.82	-12.05	-9.32	-0.29
2013	-1.97	-9.21	-11.26	-12.53	-8.31	-0.28
2014	-1.97	-9.24	-11.73	-12.90	-10.12	-0.29
2015	-1.97	-9.27	-12.21	-13.36	-8.94	-0.28
2016	-1.97	-9.30	-12.72	-13.78	-8.87	-0.28
2017	-1.97	-9.32	-13.24	-14.24	-8.81	-0.28
2018	-1.97	-9.35	-13.78	-14.70	-8.74	-0.28
2019	-1.97	-9.36	-14.34	-15.18	-8.67	-0.28
2020	-1.97	-9.38	-14.92	-15.67	-8.59	-0.27
2021	-1.96	-9.40	-15.52	-16.17	-8.52	-0.27
2022	-1.96	-9.42	-16.14	-16.68	-8.44	-0.27
2023	-1.95	-9.43	-16.78	-17.20	-8.37	-0.27
2024	-1.95	-9.44	-17.44	-17.74	-8.29	-0.27
Average	-1.97	-9.28	-12.32	-13.30	-8.88	-0.28

Table 2: Scenario 1 - Production Effects for the Six Crop Groups from Additional Agricultural Water Rights under the Columbia River Initiative, 2005-2004

	Hay	Orchards	Vegetables	Potatoes	Wheat	Other	Average
	--- percent change ---						
2005	11.32	11.17	5.97	13.88	17.10	6.56	11.22
2006	11.21	14.96	5.92	13.77	16.95	6.50	12.09
2007	11.12	14.83	5.86	13.64	16.81	6.44	12.00
2008	11.04	14.73	5.82	13.55	16.69	6.40	11.92
2009	10.94	14.63	5.78	13.46	16.57	6.35	11.86
2010	10.85	14.50	5.73	13.34	16.43	6.30	11.79
2011	10.77	14.39	5.69	13.24	16.30	6.25	11.66
2012	10.68	14.28	5.65	13.14	16.18	6.20	11.60
2013	10.60	14.18	5.60	13.04	16.06	6.16	11.54
2014	10.52	14.07	5.56	12.95	15.95	6.11	11.42
2015	10.44	13.97	5.52	12.85	15.83	6.07	11.33
2016	10.36	13.86	5.48	12.75	15.71	6.02	11.25
2017	10.28	13.75	5.44	12.65	15.58	5.98	11.16
2018	10.19	13.65	5.39	12.55	15.46	5.93	11.07
2019	10.10	13.54	5.35	12.45	15.34	5.88	10.98
2020	10.02	13.42	5.31	12.35	15.21	5.83	10.88
2021	9.93	13.31	5.26	12.24	15.08	5.78	10.78
2022	9.84	13.19	5.21	12.13	14.94	5.73	10.67
2023	9.74	13.07	5.17	12.02	14.81	5.68	10.56
2024	9.59	12.95	5.12	11.91	14.67	5.62	10.44
Average	10.48	13.82	5.54	12.90	15.88	6.09	11.31
Average % Less than the Maximum	7.44	4.64	11.58	5.42	2.92	11.12	6.74

Table 3: Scenario 1 - Producer Gross Revenue Effects for the Six Crop Groups from Additional Agricultural Water Rights under the Columbia River Initiative, 2005-2024

	Hay	Orchards	Vegetables	Potatoes	Wheat	Other	Average
	----------	----------	----------	percent change	----------	----------	----------
2005	9.06	1.47	-3.08	3.15	6.35	6.23	2.39
2006	9.01	4.14	-3.31	2.70	6.10	6.18	3.80
2007	8.92	3.64	-3.63	2.09	7.01	6.13	3.39
2008	8.85	4.35	-4.00	1.68	6.13	6.09	3.65
2009	8.75	4.16	-4.41	0.97	5.46	6.04	3.36
2010	8.67	4.05	-4.84	0.64	4.73	5.99	3.16
2011	8.58	3.91	-5.30	-0.12	6.82	5.95	2.93
2012	8.50	3.79	-5.78	-0.50	5.35	5.90	2.69
2013	8.43	3.66	-6.29	-1.13	6.42	5.86	2.48
2014	8.35	3.53	-6.82	-1.62	4.21	5.81	2.17
2015	8.26	3.41	-7.37	-2.23	5.47	5.77	1.93
2016	8.18	3.28	-7.93	-2.78	5.44	5.72	1.67
2017	8.11	3.15	-8.52	-3.39	5.41	5.68	1.39
2018	8.02	3.03	-9.13	-3.99	5.38	5.63	1.11
2019	7.94	2.90	-9.75	-4.62	5.34	5.59	0.81
2020	7.85	2.78	-10.40	-5.26	5.31	5.54	0.50
2021	7.78	2.66	-11.08	-5.91	5.27	5.49	0.17
2022	7.69	2.53	-11.77	-6.57	5.24	5.45	-0.16
2023	7.60	2.41	-12.48	-7.25	5.20	5.40	-0.51
2024	7.45	2.29	-13.21	-7.94	5.16	5.34	-0.88
Average	8.30	3.26	-7.45	-2.10	5.59	5.79	1.80

Table 4: Scenario 1 - Simulated Change in Total Gross Revenue Compared to Huppert Gross Revenue Assumption, 2005-2024

	Simulated Change in Gross Revenue	Huppert Assumed Change in Gross Revenue[a]	Huppert Overestimation	Percent Overestimation[b]
	---------- $1,000 ----------			---------- % ----------
2005	66,961.56	584,068.36	517,106.79	88.5
2006	110,350.54	584,068.36	473,717.82	81.1
2007	103,131.11	584,068.36	480,937.25	82.3
2008	115,122.30	584,068.36	468,946.06	80.3
2009	110,222.80	584,068.36	473,845.56	81.1
2010	108,232.22	584,068.36	475,836.14	81.5
2011	103,913.30	584,068.36	480,155.05	82.2
2012	99,558.19	584,068.36	484,510.17	83.0
2013	95,237.85	584,068.36	488,830.51	83.7
2014	86,198.70	584,068.36	497,869.65	85.2
2015	79,869.94	584,068.36	504,198.42	86.3
2016	71,880.03	584,068.36	512,188.32	87.7
2017	62,308.08	584,068.36	521,760.28	89.3
2018	51,481.74	584,068.36	532,586.62	91.2
2019	39,120.41	584,068.36	544,947.95	93.3
2020	24,970.77	584,068.36	559,097.59	95.7
2021	9,170.89	584,068.36	574,897.47	98.4
2022	-8,732.25	584,068.36	592,800.60	101.5
2023	-29,093.10	584,068.36	613,161.46	105.0
2024	-52,269.00	584,068.36	636,337.35	108.9
Total	1,247,636.08	11,681,367.15	10,433,731.07	89.3
Average	62,381.80	584,068.36	521,686.55	89.3

[a] Updated Huppert gross revenue using data for 2005 and the Huppert et al. assumption that demand is sufficient to absorb any additional production at the given price and then replicated for 20 years.

[b] The overestimation as a percent of the Huppert assumption level of gross revenue

Table 5: Scenario 1 - Simulated Change in Total Net Revenue Compared to Huppert Net Revenue Assumption, 2005-2024

	Simulated Change in Net Revenue	Huppert Assumed Change in Net Revenue	Huppert Overestimation	Percent Overestimation[a]
	------------------ $1,000 ------------------			------ % ------
2005	-58,098.42	353,831.05	411,929.48	116.4
2006	-22,488.05	353,831.05	376,319.10	106.4
2007	-29,791.46	353,831.05	383,622.51	108.4
2008	-17,879.78	353,831.05	371,710.83	105.1
2009	-22,785.16	353,831.05	376,616.21	106.4
2010	-24,750.12	353,831.05	378,581.17	107.0
2011	-29,062.83	353,831.05	382,893.88	108.2
2012	-33,418.90	353,831.05	387,249.95	109.4
2013	-37,744.58	353,831.05	391,575.63	110.7
2014	-46,782.00	353,831.05	400,613.06	113.2
2015	-53,095.37	353,831.05	406,926.42	115.0
2016	-61,067.21	353,831.05	414,898.27	117.3
2017	-70,619.62	353,831.05	424,450.67	120.0
2018	-81,419.88	353,831.05	435,250.93	123.0
2019	-93,741.13	353,831.05	447,572.18	126.5
2020	-107,846.59	353,831.05	461,677.65	130.5
2021	-123,603.74	353,831.05	477,434.80	134.9
2022	-141,455.88	353,831.05	495,286.94	140.0
2023	-161,752.73	353,831.05	515,583.79	145.7
2024	-184,659.71	353,831.05	538,490.76	152.2
Total	-1,402,063.16	7,076,621.07	8,478,684.23	
Average	-70,103.16	353,831.05	423,934.21	119.81

[a] The overestimation as a percent of the Huppert assumption level of net revenue

Table 6: Scenario 2 - Market Price Effects for the Six Crop Groups from Additional Agricultural Water Rights under the Columbia River Initiative, 2005-2024

	Hay	Orchards	Vegetables	Potatoes	Wheat	Other
	-- percent change --					
2005	-3.41	0.00	0.00	0.00	-15.46	-0.51
2006	-3.35	0.00	0.00	0.00	-15.69	-0.51
2007	-3.36	0.00	0.00	0.00	-14.23	-0.50
2008	-3.37	0.00	0.00	0.00	-15.42	-0.50
2009	-3.39	0.00	0.00	0.00	-16.32	-0.50
2010	-3.39	0.00	0.00	0.00	-17.28	-0.50
2011	-3.41	0.00	0.00	0.00	-14.08	-0.50
2012	-3.43	0.00	0.00	0.00	-16.19	-0.50
2013	-3.44	0.00	0.00	0.00	-14.52	-0.49
2014	-3.46	0.00	0.00	0.00	-17.78	-0.50
2015	-3.49	0.00	0.00	0.00	-15.81	-0.50
2016	-3.51	0.00	0.00	0.00	-15.79	-0.50
2017	-3.52	0.00	0.00	0.00	-15.77	-0.50
2018	-3.55	0.00	0.00	0.00	-15.75	-0.50
2019	-3.57	0.00	0.00	0.00	-15.73	-0.50
2020	-3.60	0.00	0.00	0.00	-15.71	-0.50
2021	-3.60	0.00	0.00	0.00	-15.69	-0.50
2022	-3.63	0.00	0.00	0.00	-15.66	-0.50
2023	-3.65	0.00	0.00	0.00	-15.64	-0.50
2024	-3.68	0.00	0.00	0.00	-15.62	-0.51
Mean	-3.49	0.00	0.00	0.00	-15.71	-0.50

Table 7: Scenario 2 - Production Effects for the Six Crop Groups from Additional Agricultural Water Rights under the Columbia River Initiative, 2005-2004

	Hay	Orchards	Vegetables	Potatoes	Wheat	Other	Average
	---------- percent change ----------						
2005	19.12	0.00	0.00	0.00	28.80	11.04	17.23
2006	19.01	0.00	0.00	0.00	28.65	10.99	17.26
2007	18.96	0.00	0.00	0.00	28.50	10.93	17.23
2008	18.91	0.00	0.00	0.00	28.44	10.91	17.16
2009	18.81	0.00	0.00	0.00	28.38	10.88	17.20
2010	18.75	0.00	0.00	0.00	28.25	10.83	17.33
2011	18.70	0.00	0.00	0.00	28.17	10.80	16.96
2012	18.66	0.00	0.00	0.00	28.11	10.78	17.13
2013	18.63	0.00	0.00	0.00	28.06	10.76	17.24
2014	18.60	0.00	0.00	0.00	28.02	10.74	16.96
2015	18.58	0.00	0.00	0.00	27.98	10.73	16.91
2016	18.55	0.00	0.00	0.00	27.94	10.71	16.98
2017	18.52	0.00	0.00	0.00	27.91	10.70	16.97
2018	18.50	0.00	0.00	0.00	27.87	10.69	16.95
2019	18.47	0.00	0.00	0.00	27.83	10.67	16.93
2020	18.44	0.00	0.00	0.00	27.80	10.66	16.91
2021	18.42	0.00	0.00	0.00	27.76	10.64	16.90
2022	18.39	0.00	0.00	0.00	27.72	10.63	16.88
2023	18.36	0.00	0.00	0.00	27.68	10.61	16.86
2024	18.06	0.00	0.00	0.00	27.64	10.60	16.71
Average	18.62	0.00	0.00	0.00	28.08	10.77	17.03

Table 8: Scenario 2 - Producer Gross Revenue Effects for the Six Crop Groups from Additional Agricultural Water Rights under the Columbia River Initiative, 2005-2004

	Hay	Orchards	Vegetables	Potatoes	Wheat	Other	Average
	----------	----------	----------	percent change	----------	----------	----------
2005	15.06	0.00	0.00	0.00	8.89	10.48	2.11
2006	15.03	0.00	0.00	0.00	8.47	10.43	2.06
2007	14.96	0.00	0.00	0.00	10.22	10.37	2.07
2008	14.91	0.00	0.00	0.00	8.64	10.35	1.99
2009	14.79	0.00	0.00	0.00	7.43	10.33	1.93
2010	14.73	0.00	0.00	0.00	6.09	10.28	1.89
2011	14.66	0.00	0.00	0.00	10.12	10.25	1.94
2012	14.60	0.00	0.00	0.00	7.37	10.23	1.86
2013	14.55	0.00	0.00	0.00	9.47	10.21	1.91
2014	14.50	0.00	0.00	0.00	5.26	10.19	1.75
2015	14.44	0.00	0.00	0.00	7.75	10.17	1.79
2016	14.39	0.00	0.00	0.00	7.74	10.16	1.77
2017	14.35	0.00	0.00	0.00	7.74	10.14	1.75
2018	14.29	0.00	0.00	0.00	7.73	10.13	1.73
2019	14.24	0.00	0.00	0.00	7.73	10.12	1.70
2020	14.19	0.00	0.00	0.00	7.73	10.11	1.68
2021	14.15	0.00	0.00	0.00	7.72	10.09	1.66
2022	14.09	0.00	0.00	0.00	7.72	10.08	1.63
2023	14.04	0.00	0.00	0.00	7.71	10.06	1.60
2024	13.72	0.00	0.00	0.00	7.71	10.04	1.56
Average	14.48	0.00	0.00	0.00	7.96	10.21	1.82

Table 9: Change in Simulated Total Gross Revenue - Comparison of Scenarios 1 and 2, 2005-2024

	Scenario 1	Scenario 2	Difference	Percent Difference[a]
	----------------------------------	$1,000	----------------------------------	---------- % ----------
2005	66,961.56	59,179.09	-7,782.47	-11.6
2006	110,350.54	59,896.97	-50,453.57	-45.7
2007	103,131.11	63,058.27	-40,072.84	-38.9
2008	115,122.30	62,719.99	-52,402.31	-45.5
2009	110,222.80	63,457.03	-46,765.77	-42.4
2010	108,232.22	64,567.13	-43,665.09	-40.3
2011	103,913.30	68,701.43	-35,211.87	-33.9
2012	99,558.19	68,822.68	-30,735.51	-30.9
2013	95,237.85	73,564.64	-21,673.22	-22.8
2014	86,198.70	69,869.86	-16,328.84	-18.9
2015	79,869.94	74,047.87	-5,822.07	-7.3
2016	71,880.03	76,365.65	4,485.61	6.2
2017	62,308.08	78,400.44	16,092.36	25.8
2018	51,481.74	80,413.91	28,932.17	56.2
2019	39,120.41	82,473.43	43,353.02	110.8
2020	24,970.77	84,566.08	59,595.31	238.7
2021	9,170.89	86,764.19	77,593.31	846.1
2022	-8,732.25	88,938.06	97,670.31	--
2023	-29,093.10	91,158.81	120,251.91	--
2024	-52,269.00	92,403.96	144,672.96	--
Total	1,247,636.08	1,489,369.48	241,733.40	19.4
Average	62,381.80	74,468.47	12,086.67	19.4

[a] -- indicates change from a negative to a positive number.

Table 10: Change in Simulated Total Net Revenue - Comparison of Scenarios 1 and 2, 2005-2024

	Scenario 1	Scenario 2	Difference
	--	$1,000	--
2005	-58,098.42	-71,086.14	-12,987.72
2006	-22,488.05	-70,437.43	-47,949.38
2007	-29,791.46	-67,460.03	-37,668.57
2008	-17,879.78	-67,932.71	-50,052.93
2009	-22,785.16	-67,135.85	-44,350.69
2010	-24,750.12	-66,024.19	-41,274.07
2011	-29,062.83	-61,914.48	-32,851.66
2012	-33,418.90	-61,809.82	-28,390.92
2013	-37,744.58	-57,082.73	-19,338.16
2014	-46,782.00	-60,776.00	-13,993.99
2015	-53,095.37	-56,591.78	-3,496.41
2016	-61,067.21	-54,252.14	6,815.08
2017	-70,619.62	-52,191.77	18,427.85
2018	-81,419.88	-50,139.33	31,280.55
2019	-93,741.13	-48,037.25	45,703.87
2020	-107,846.59	-45,890.28	61,956.32
2021	-123,603.74	-43,635.83	79,967.91
2022	-141,455.88	-41,394.51	100,061.37
2023	-161,752.73	-39,105.19	122,647.54
2024	-184,659.71	-36,945.39	147,714.33
Total	-1,402,063.16	-1,119,842.84	282,220.32
Average	-70,103.16	-55,992.14	14,111.02