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Interstate Commission on the Potomac River Basin

Middle Potomac Watershed Assessment
Modeling Streamflows

Seventh of a multi-part webinar series

February 23, 2012

The webinar will start momentarily.

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Middle Potomac Watershed Assessment
Modeling Streamflows

Speakers

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Heidi Moltz, Interstate Commission on the Potomac River Basin

Project website: http://potomacriver.org/sustainableflows

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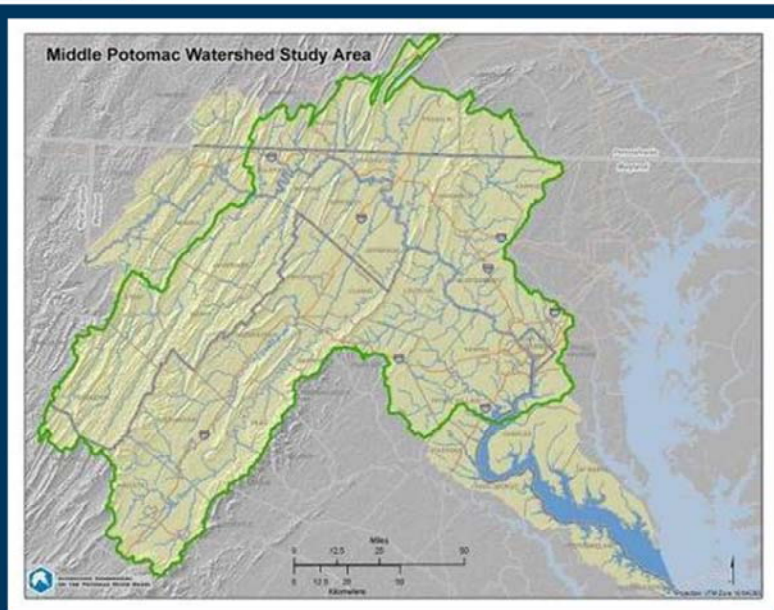
Study Area



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Project Objectives

1) Estimate current and future human water withdrawals and their impacts on flows.

2) Characterize flows needed to support healthy stream biotic communities.

3) Provide baseline information and analyses to support water use decision making.

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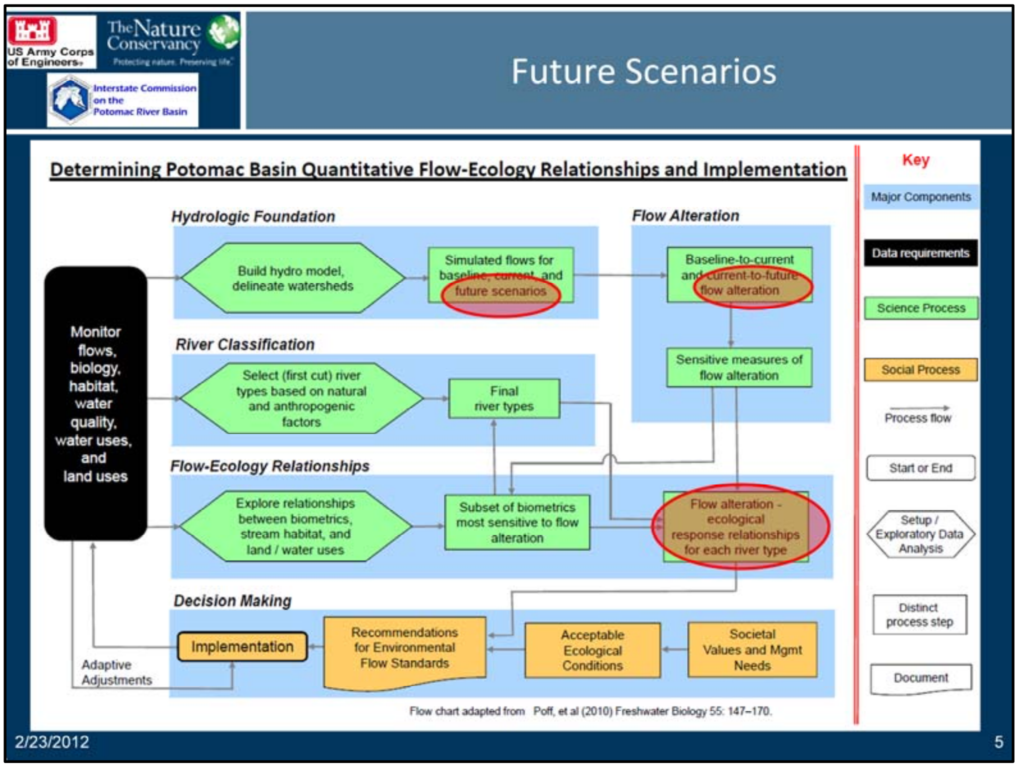
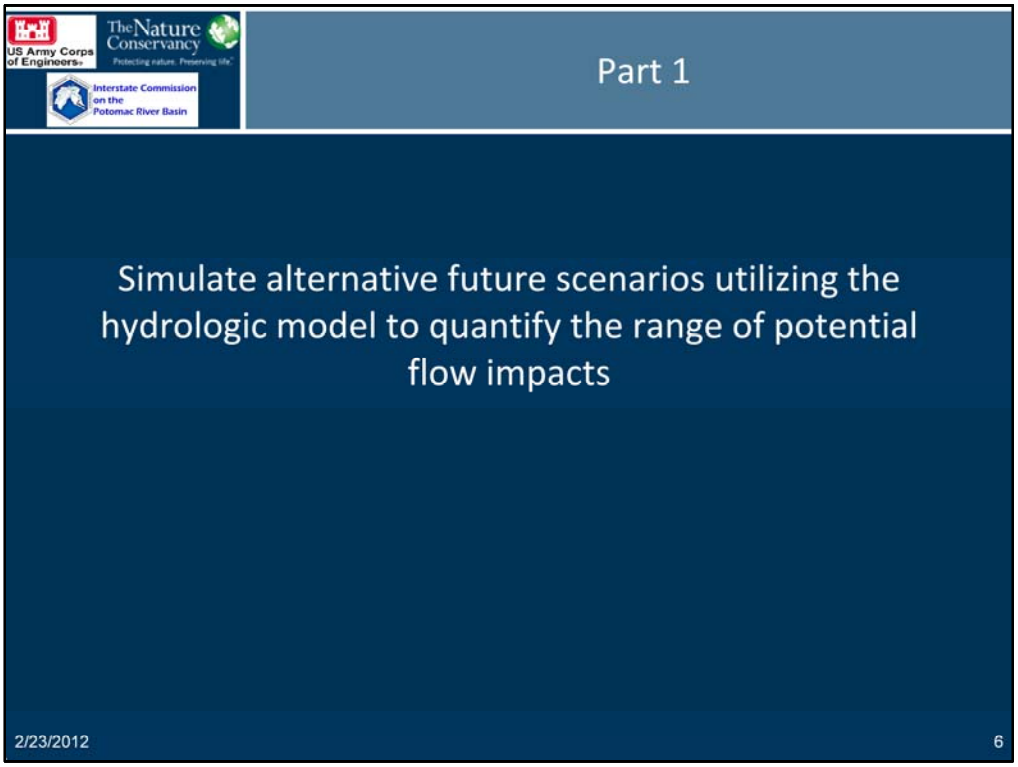


•This is the project schematic we've used throughout the webinar series, showing the different components of the project.

•Today we are going to talk about the development of the future scenarios in the modeling environment, and results of that modeling with respect to flow alteration.

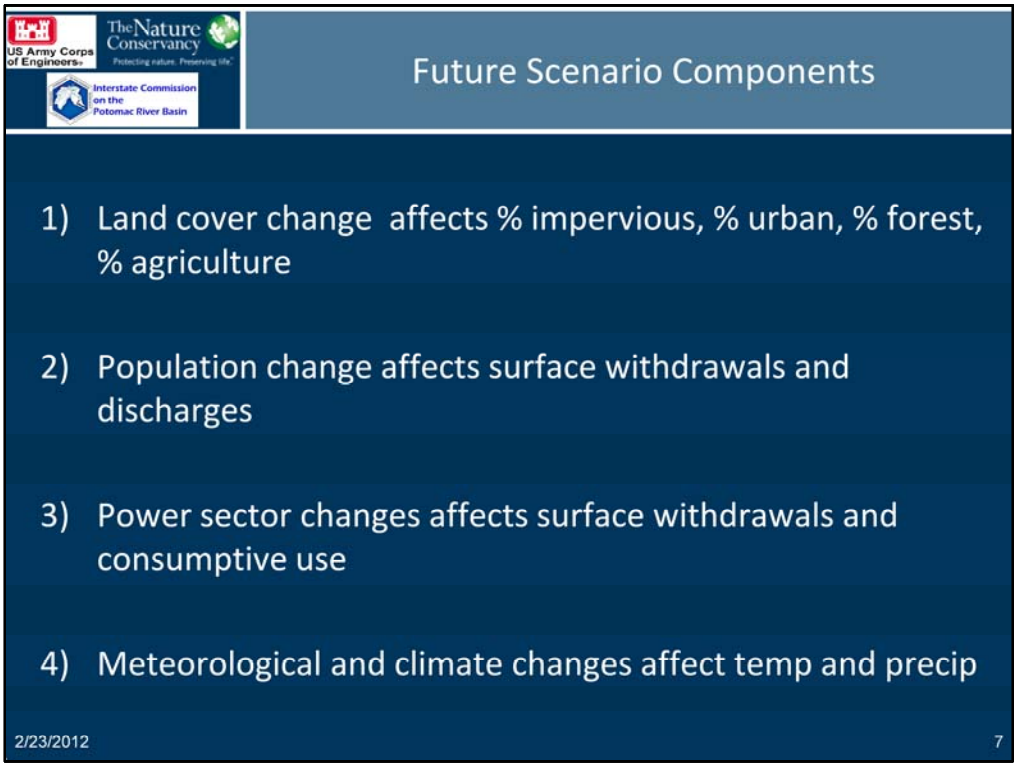
•We will also review some of the key steps in our analytical approach, specifically: identifying anthropogenic factors driving change in flow and linking aquatic biology status to flow alteration, and then applying flow alteration – ecological response relationships to future scenario results to make some observations about how future flow alteration affects the biota.



READ OBJECTIVE

To address this objective, we'll discuss the watershed characteristics that are expected to change in the future, the model simulations of 5 future scenarios, and the changes in flow metrics that occurred as a result.

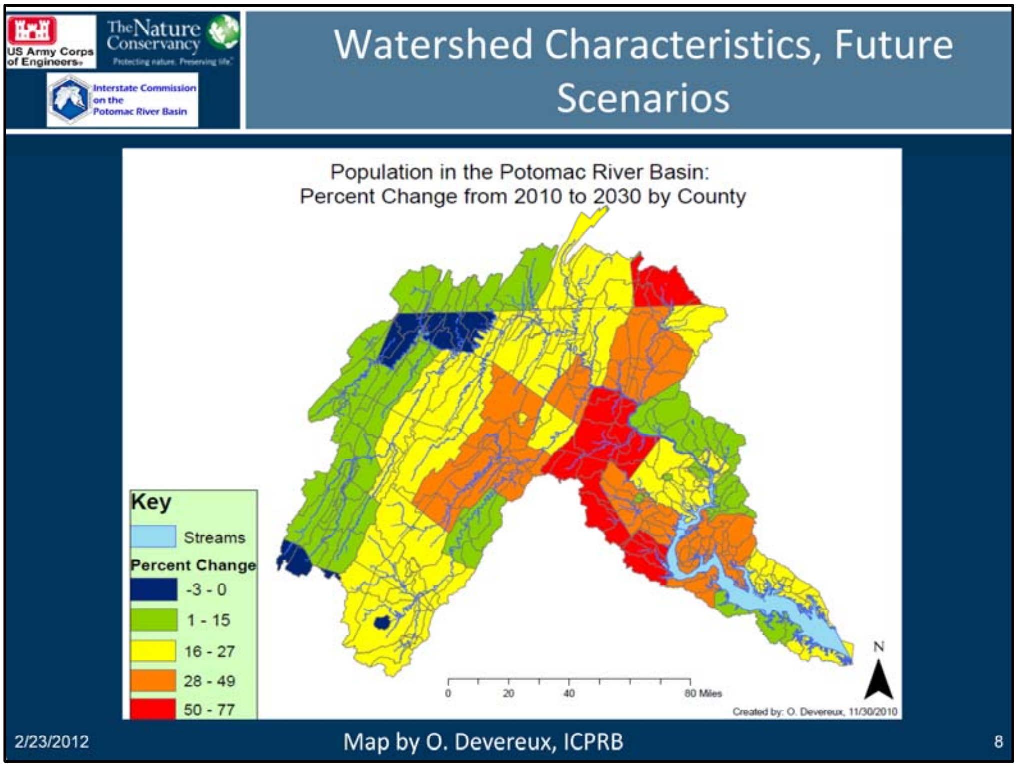
The model used to simulate the future scenario flows was the CBP HSPF Phase 5.2 model. So, the flows were generated at the river segment scale (maps in subsequent slides showing the river segments if you're not familiar with them). The HSPF model decreases the number of modeled watersheds from the 747 discussed in previous webinars that are being simulated with the VADEQ WOOOMM model and reducing the resolution to the 153 river segments in the HSPF model.



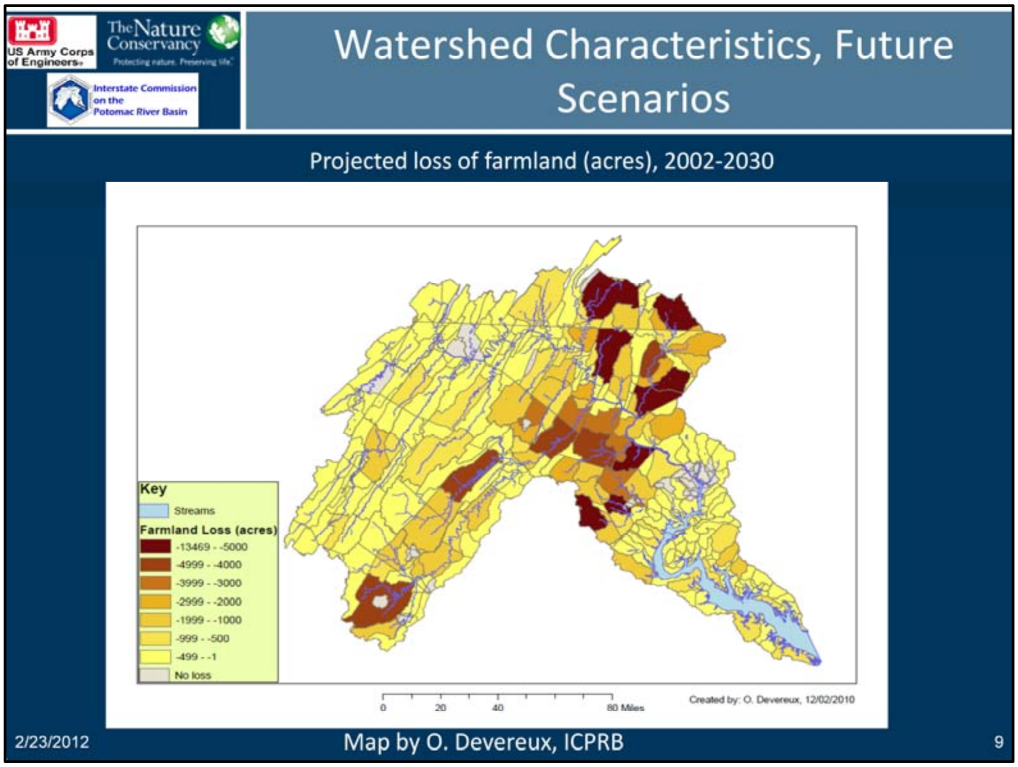
There are a number of watershed characteristics that are expected to change in the future that may affect the hydrology of the Potomac Basin. This slide shows four of those and the model components we utilized to implement those changes.

READ COMPONENTS.

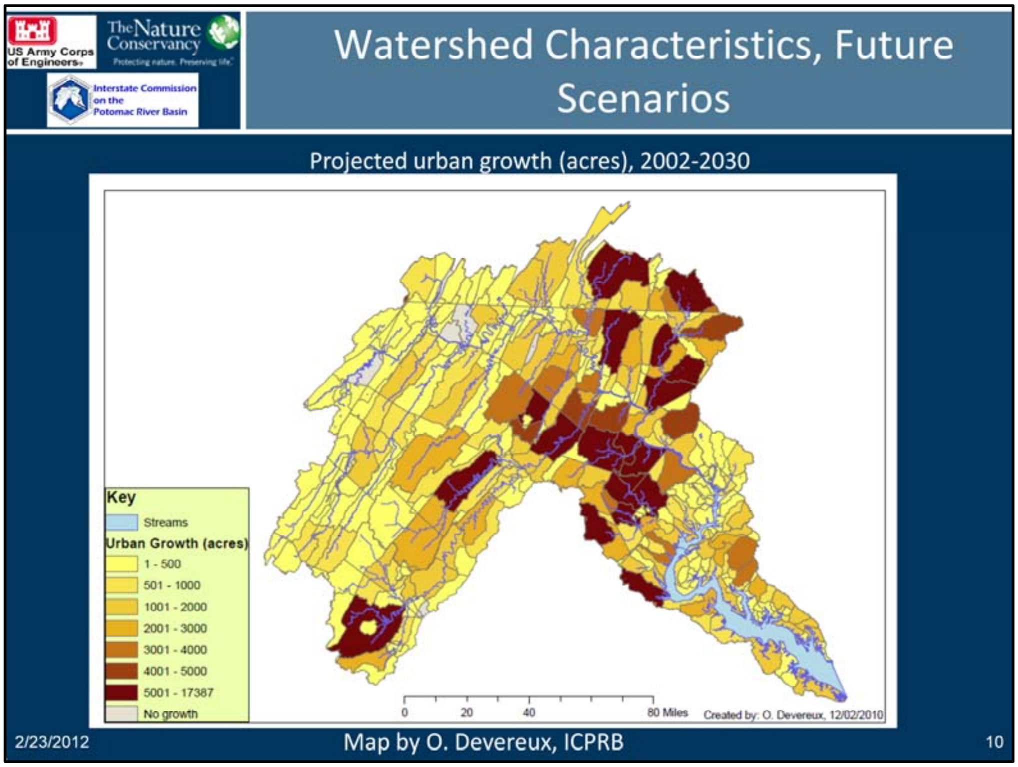
The next set of slides show the spatial distribution of projected watershed characteristics including population and land use.



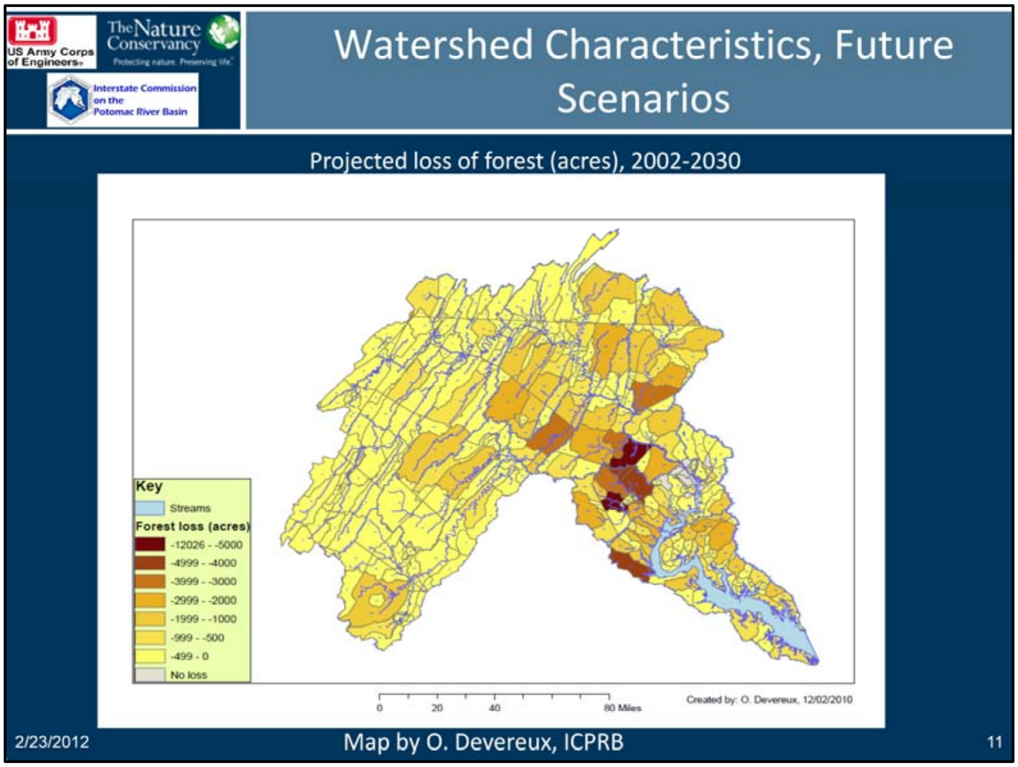
This map is showing anticipated population change from 2010 to 2030 in the Potomac Basin by county. The bright red areas are where the highest amount of population growth is expected (50-77%). The blue counties are expecting no future change or a decrease in population over the next twenty years. Most of the significant growth is occurring in the Monocacy, Shenandoah, Occocquan and other lower portions of the basin.



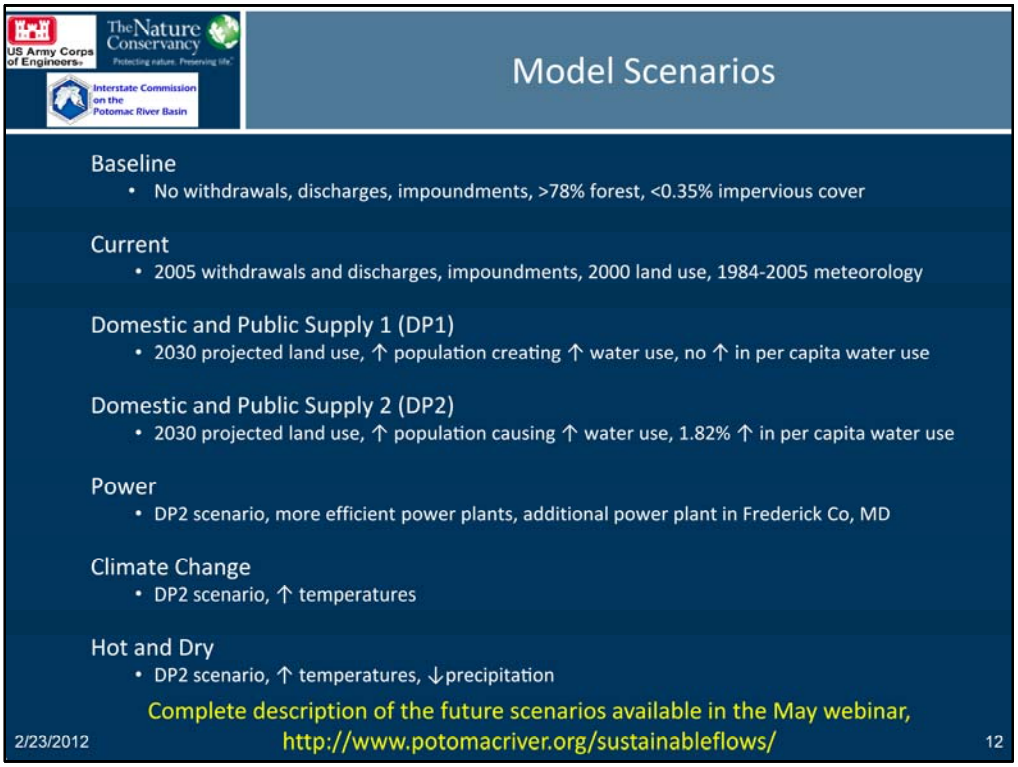
This is the first of several slides that depict projected land use changes that are expected in the basin between 2002 and 2030 as projected by the CBP. The darker the brown on this map, the more farmland that is expected to be lost. Grey areas (such as DC) indicate that no loss of farmland is expected. Notice that the Shenandoah, Monocacy, portions of the Conococheague, and into the upper Occoquon watersheds show the greatest loss of farmland.



This is showing the growth of urban areas from 2002-3030. A similar area to those that are losing farmland (previous slide) is shown here to be gaining urban areas.



This map shows loss of forest. Again, those areas in darkest brown show the greatest loss to forest. The largest changes are occurring in the downstream portion of the basin, but also in other areas that are expecting urban growth.

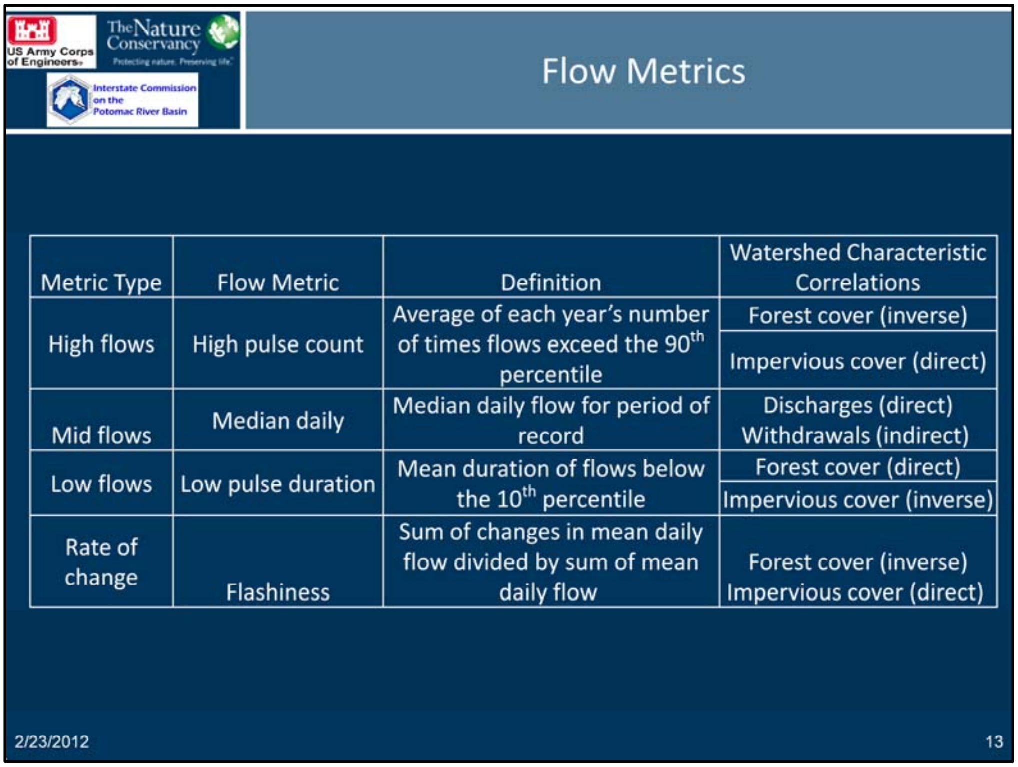


The results of 5 future scenario model runs were compared to current and baseline scenarios to understand what alteration has already occurred, how much is expected to occur in the future, and the total amount of alteration from baseline to future conditions for each of the 153 modeled watersheds. This slide is a reminder of what each model scenario entails. The baseline scenario is estimating flows that have minimal anthropogenic influence so there are no withdrawals, discharges or impoundments and land uses are >78% forest and <0.35% impervious cover. The current scenario takes a snapshot of current withdrawal, discharge, impoundment, and land use conditions and simulates this over a 21 year observed meteorological history.

The five future scenarios are Domestic and Public Supply 1 and 2, Power, Hot and Dry, and Climate Change. All of these scenarios are simulated with projected 2030 land use, and changes in withdrawals/discharges as a function of the 2030 future population projections. These scenarios build on one another. The DP1 scenario starts with 2030 land use and increase in water use due to the population increases, but has no per capita increase in water use. The DP2 scenario then builds on this and increases per capita withdrawal rates by 1.82%. The Power scenario builds on the DP2 scenario by increasing the efficiency of the power sector withdrawals and adds a new power plant in Frederick County, MD. The climate change scenario also uses DP2 as a base and includes a projected increase in temperature. The Hot and Dry scenario reduces precipitation and increases temperatures to simulate a 2 year period of drought-like conditions.

If you're interested in a more complete description of each future scenario, it's available in the May webinar slides – downloadable from the project website shown on this slide.

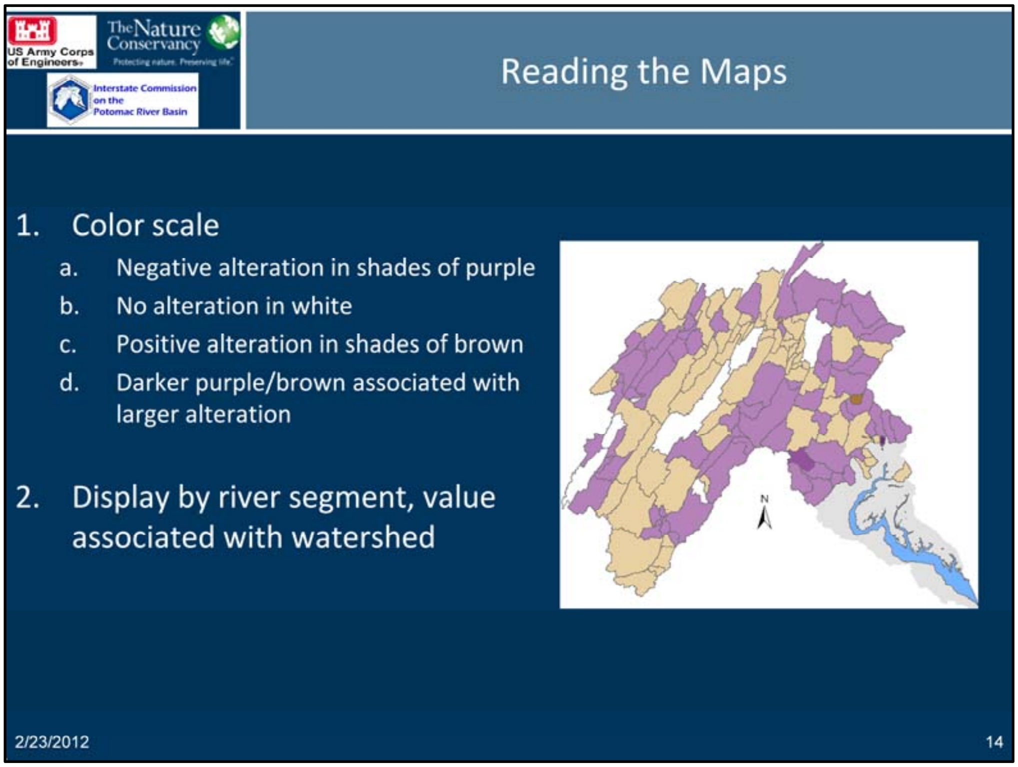
The model output for each of these 7 scenarios is a 21 year daily flow time series for each of the 153 HSPF watersheds from which a number of flow metrics were calculated.



Metric Type	Flow Metric	Definition	Watershed Characteristic Correlations
High flows	High pulse count	Average of each year's number of times flows exceed the 90th percentile	Forest cover (inverse) Impervious cover (direct)
Mid flows	Median daily	Median daily flow for period of record	Discharges (direct) Withdrawals (indirect)
Low flows	Low pulse duration	Mean duration of flows below the 10th percentile	Forest cover (direct) Impervious cover (inverse)
Rate of change	Flashiness	Sum of changes in mean daily flow divided by sum of mean daily flow	Forest cover (inverse) Impervious cover (direct)

To demonstrate the effect of the future scenarios in the brief time we have today, we've selected four flow metrics representing high, mid, and low flows as well as the rate of change in flows - shown in the table here. The metrics are high pulse count, median daily flow, low pulse duration, and flashiness. Many other metrics have been calculated and evaluated and will be available for review in the final project report, but these have been selected to demonstrate the types of impacts the future scenarios have.

The watershed characteristics from the previous slides, and others including withdrawals, discharges, and impoundments, can influence the hydrology of an area. For each flow metric, watershed characteristics that it is correlated with are provided. So, for example, if we look at flashiness, forest cover has an inverse relationship with flashiness, meaning that an increase in forest corresponds to a decrease in this flow metric. Conversely, an increase in impervious cover was shown to increase the flashiness (understandably since systems with more impervious cover/more urban are more flashy). We will discuss each watershed characteristic's influence on the flow metrics as we go through the rest of the slides.

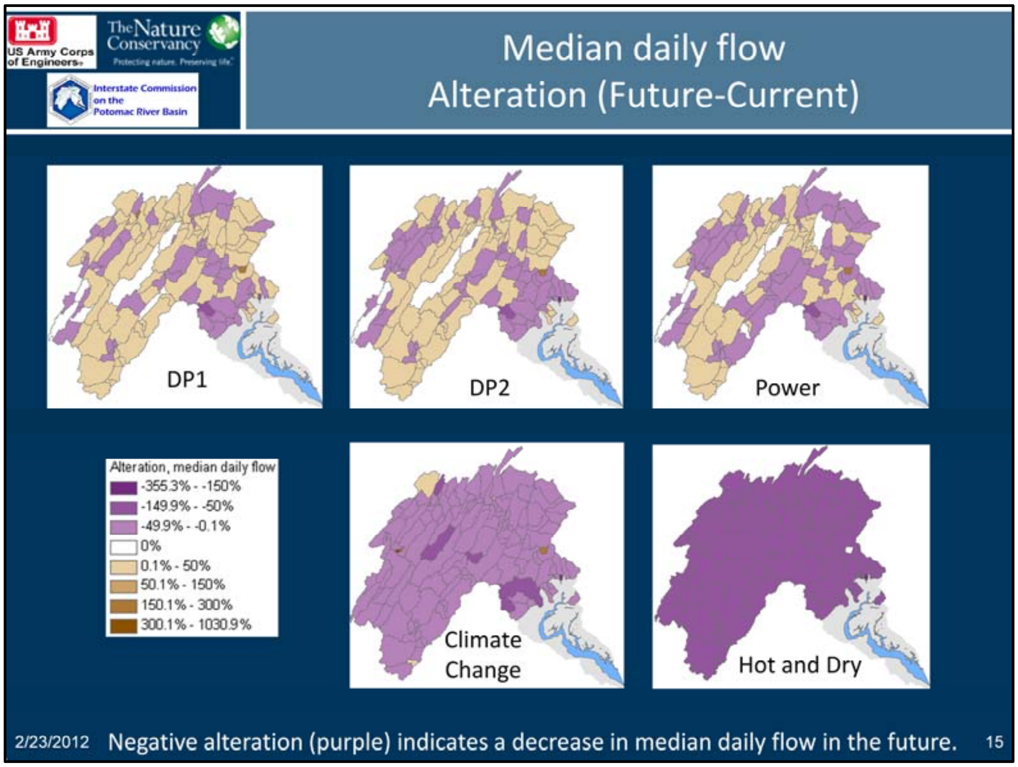


OK, so let's get into the results of the future scenarios. We'll flip through a series of slides to look at the changes in these four flow metrics under the 5 alternative future scenarios. A few notes about the maps before we get started…

Color scale – Although the color pattern will be different from map to map, each map has a similar color scheme to the one shown here. Negative alteration is shown in purple, no alteration in white, and positive alteration in brown. The darker the purple or brown, the larger the alteration. Note that positive and negative alteration do not correspond to "good" or "bad" – instead, it is an indication of the direction of change in the metric from the current conditions.

I also want to point out again that hydrologic modeling was conducted at the HSPF river segment scale (shown in the different polygons on the map) – so a color associated with a particular polygon corresponds to the entire upstream watershed. For display purposes, to eliminate overlapping polygons, the color is only shown at the downstream most river segment. So if you see a dark purple color on a mainstem Potomac river segment, it means there is a negative alteration of the particular flow metric for the entire basin upstream of that location.

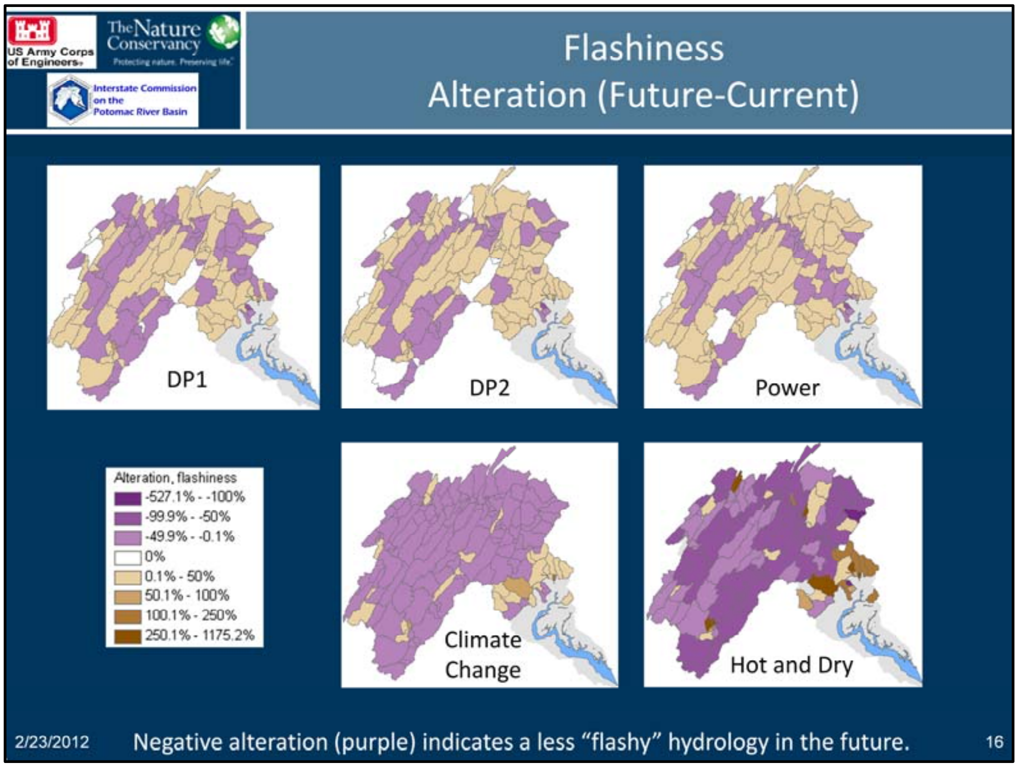
The maps on the next series of slides show the alteration expected in the future under the different scenarios.



This slide shows the alteration in median daily flows for each of the five future scenarios. Alteration shown here is calculated to indicate the expected change that will happen in the future – in relation to current conditions. So a negative alteration value, shown in purple, indicates a decrease in median daily flows in the future.

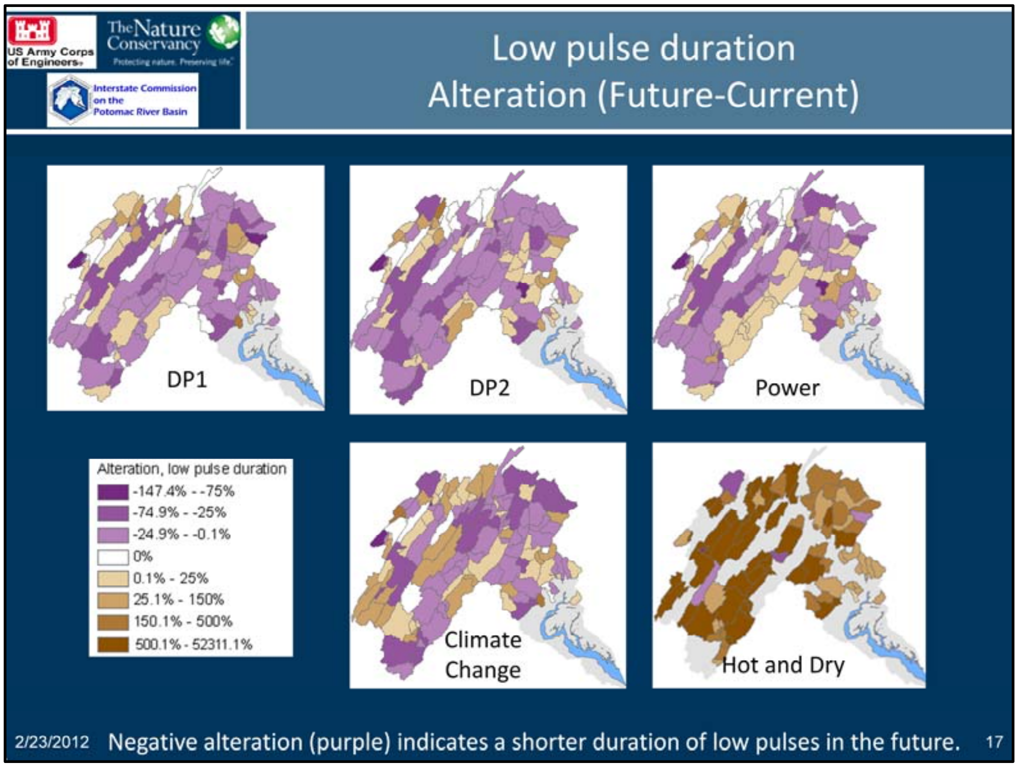
The DP1, DP2, and power scenarios (shown on the top row) include changes in land use, withdrawals, and discharges. In these scenarios, portions of the basin are expected to experience increases in median daily flow (shown in brown) resulting from a decrease in forest. Removing forests decreases the amount of water lost to evapotranspiration and makes more water available for streamflow. Other portions of the basin under those same scenarios are expected to have a decrease in median daily flows in the future due to urbanization, population growth, and an increase in net withdrawals – depending on the watershed.

The climate change and hot and dry scenarios, on the other hand, show substantial decreases in median daily flow across almost the entire basin primarily due to the meteorological stressors associated with the two scenarios. Almost all watersheds in the hot and dry future scenario have a median flow of 0 .



This series of maps shows future alteration associated with flashiness. A negative alteration in flashiness, shown in purple, indicates a less flashy hydrology in the future.

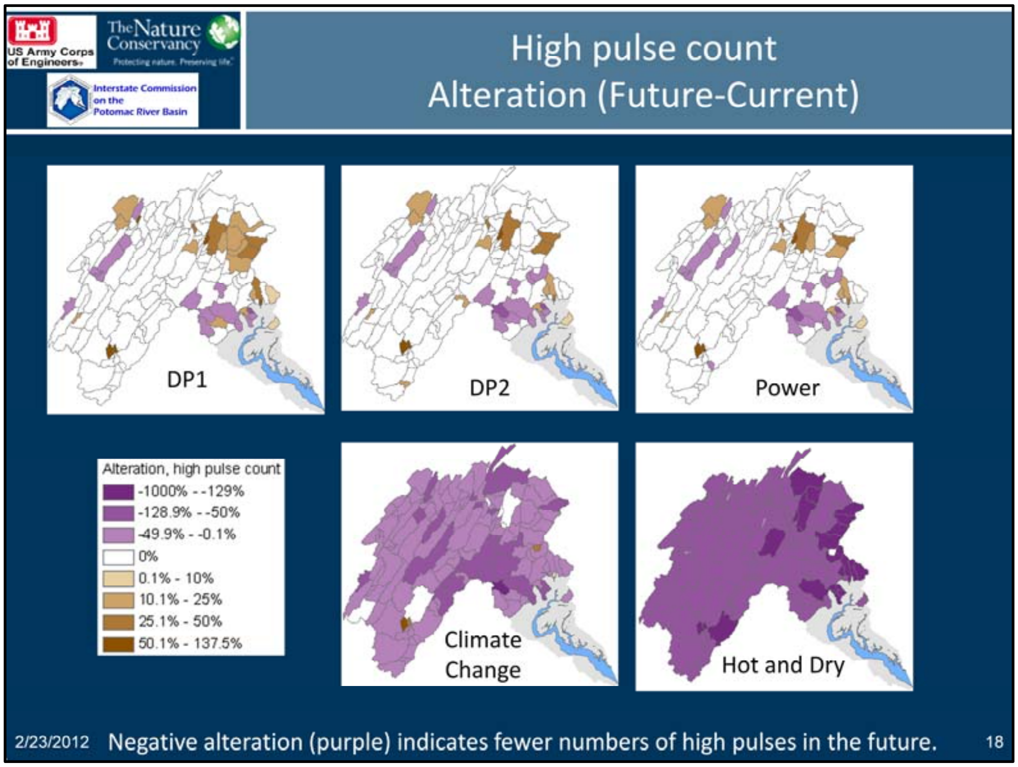
Flashiness is expected to increase over much of the basin associated with future urban growth and reduction in forests in the DP1, DP2, and power scenarios. However, some decreases are expected in the North Branch and the mainstem Potomac River itself, associated with the largest withdrawals in the basin. A similar pattern to this shows up in the 3 day maximum flow metric – not selected for presentation here. There is mostly a decrease (purple) in flashiness in the climate change and hot and dry scenarios due to an overall decrease in the amount of water available with hotter conditions and less rain. However, in some of the most urban watersheds around DC and in the Occoquon, flashiness is still increasing due to extreme amounts of impervious cover.



The next flow metric we're going to look at is the low pulse duration. This metric is a measure of how many days flows go below the 10th percentile flows. Negative alteration, shown in purple, indicates a shorter duration of low pulses in the future.

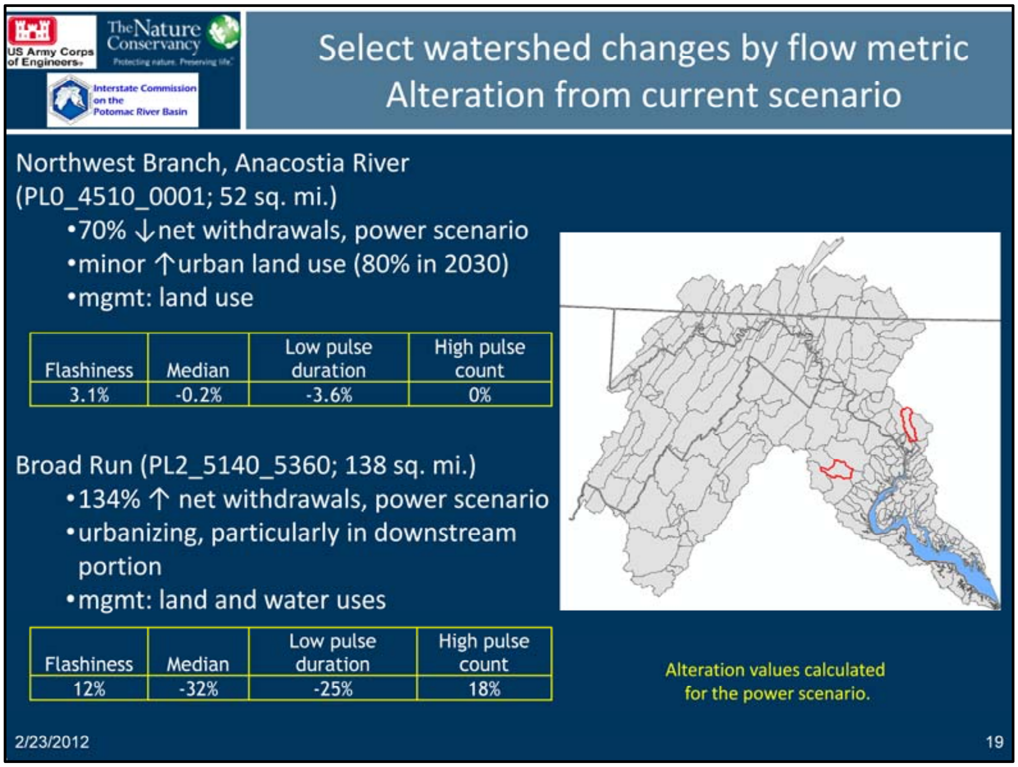
In the DP1, DP2, and power scenarios the watersheds showing no alteration (shown in white) are associated primarily with exports of water (meaning they have more discharges than withdrawals) or include only very small withdrawals (<0.1MGY). Purple watersheds indicate a decrease in the duration of low pulses, likely due to increased impervious cover or decrease in forest. Increases in low pulse duration (shown in brown) are sometimes the result of an increase in withdrawals where there is little increase in impervious cover. Examples of this are the North Branch and Capapon River, areas with little impervious cover.

A drastic change in the low pulse duration occurs during the Hot and Dry scenario, which increases temperature and decreases precipitation. The majority of the basin turns brown under hot and dry conditions, indicating a sharp increase (up to >52,000%) in the duration of low pulses. Watersheds displayed as grey for low pulse duration had so many zero flow days in the hot and dry scenario that IHA did not count a value for duration of low pulses.



The final metric is high pulse count. High pulse count is the number of times flows exceed the 90th percentile. The future changes in the number of high pulses are limited to a number of watersheds in the DP1, DP2, and Power scenarios. Increases in the number of high pulses, shown in brown, are likely a results of decreasing forest or increasing impervious cover, while decreases (shown in purple) correspond with additional withdrawals among other characteristics. The Hot and Dry and Climate Change scenarios again show more extreme results, with large decreases in the number of high pulses – which makes sense because less water is available overall given the meteorological changes.

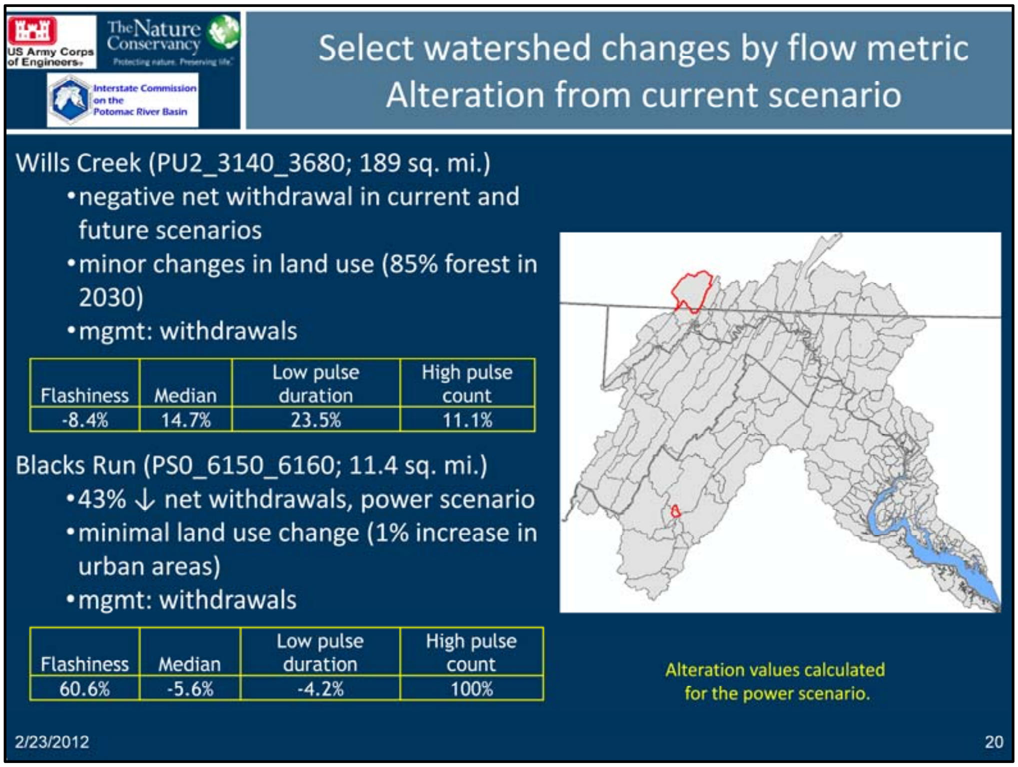
So, the results of the four metrics presented here for the five future scenarios were selected to provide some information on the types of alteration seen in the simulated future scenarios. Overall, the 2 year drought simulated in the hot and dry scenario has the most extreme impacts on the hydrology, followed by the climate change scenario, then the power, DP2, and DP1 – which have fairly similar results.



The next two slides pull out a handful of watersheds from across the basin and look at the 2030 watershed characteristics and the associated change in flow metrics.

Let's start with the Anacostia River. This watershed is approximately 52 square miles in DC and Maryland. It is already highly urbanized and is expecting a slight increase in urban areas in the future. There are three agricultural withdrawals in the upper portion of the watershed that are expected to decrease water use in the future with the increase of urban areas. Under the power scenario, these conditions cause flashiness to increase 3.1% (likely due to the impervious cover), the median flow decreases by 0.2%, the duration of low pulses decreases 3.6% and the number of high pulses remains the same. Overall, there was a relatively small amount of hydrologic alteration in this watershed for the DP1 scenario – likely due to the fact that this is already highly urbanized. However, because the overall major source of alteration in these watersheds is from land use, management efforts in this watershed may wish to focus on the effects of land use change.

Broad Run occupies 138 square miles in Virginia. There are 6 withdrawals in this watershed for multiple purposes including commercial, industrial, water supply, and mining. These withdrawals are projected to increase by 134% by 2030 according to the power scenario. This watershed is also experiencing urbanization - the most extreme urbanization is occurring in the lower portion of the watershed. These future watershed changes are causing an increase in flashiness of 12%, primarily because of the increase in impervious cover, a decrease in the median flow by 32% (because of the additional withdrawals), a decrease in the length of low pulses and an increase in the number of high pulses by 18%, primarily because of the increased flashiness in this system. Management efforts to maintain the median flows should be focused primarily on the withdrawals, while management efforts related to alteration in the other metrics may be primarily land use driven.



And two final watersheds…

Wills creek occupies 189 square miles in PA and MD. Discharges in the watershed are greater than withdrawals, indicating an import of water or that there are a number of smaller, non-reporting withdrawals in the watershed that are not accounted for in the model. (Currently in the model there is one water supply surface withdrawal and one discharge – there is also a very small groundwater withdrawal that is not included in the model but would not make up the difference anyway). Only minor land use changes are expected in this watershed in the future as it is expected to still have 85% forest in 2030. These watershed characteristics result in a decrease in flashiness by 8.4%, median flow increases by 15%, the duration of low pulses increases by 24% and the number of high pulses increases by 11%. The majority of the alteration in this watershed is a result of the withdrawals. Therefore, a priority for management in this watershed may focus on the water uses, rather than the land uses.

Blacks Run occupies 11.4 square miles in Virginia. This watershed is expected to experience a 43% decrease in net withdrawals in the power scenario. It also has a relatively small, 1% increase in urban land use by 2030. These watershed changes result in a 61% increase in flashiness, a 6% decrease in median flow, a 4% decrease in low pulse duration, and a 100% increase in the number of high pulses. Similar to Wills Creek, the majority of the alteration in Blacks Run is a result of the withdrawals. Therefore, a priority for management in this watershed may be related to the withdrawals.

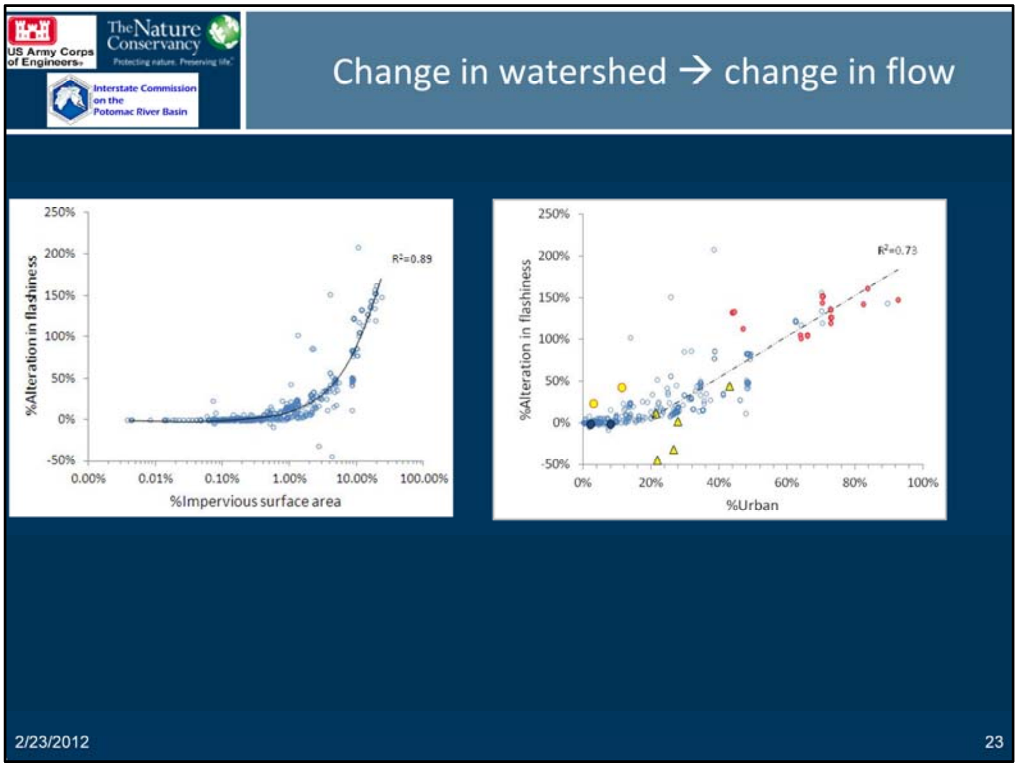
Information on this handful of watersheds was presented to give you an idea of the watershed characteristics that are changing in the future scenarios and the types of effects they're having on some of the flow metrics. With that, I'll turn it over to Carlton who will discuss the effects that this hydrologic alteration may have on the biota in the basin.

Part 2

Key steps in analytical approach toward
flow alteration – biological status relationships

Technical Approach

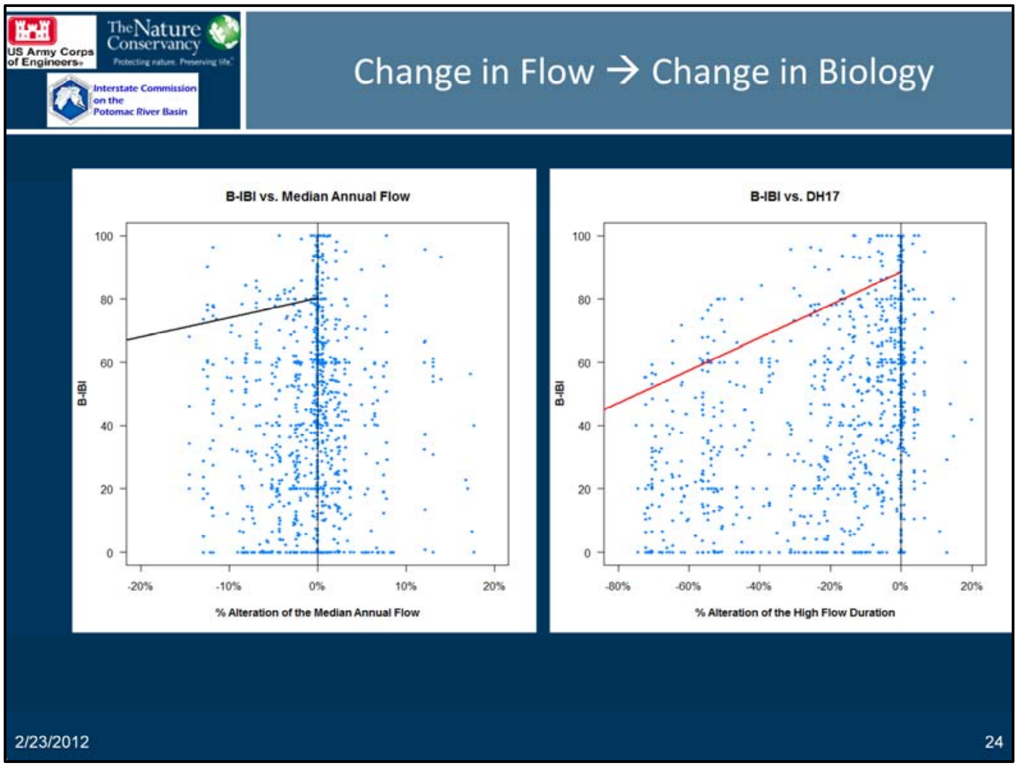
1) Benthic macroinvertebrates, only, are basis for flow alteration – biological status relationships.
   a) Seven biometrics representing different feeding habits.
   b) 747 locations → delineated watersheds
2) Model generated flow time series.
   a) Analysis of gaged watersheds → preliminary assessment of factors causing change and determination of "baseline" conditions.
   b) Calculate Baseline, Current Conditions, and Future Scenarios, flow time series.
   c) Multiple tests with simulated and observed flows:
      i. demonstrate model performance
      ii. identify factors affecting flow characteristics
      iii. Identify best flow metrics



Key watershed characteristics are
-Land Use: % impervious area, % Urban, %Agriculture, % Forest
- Water Use: Fraction of median flow withdrawn, fraction discharged, fraction impounded.

This is an example plot showing % Urban area vs % Alteration in flashiness for all our watersheds, plus particular subsets highlighted.

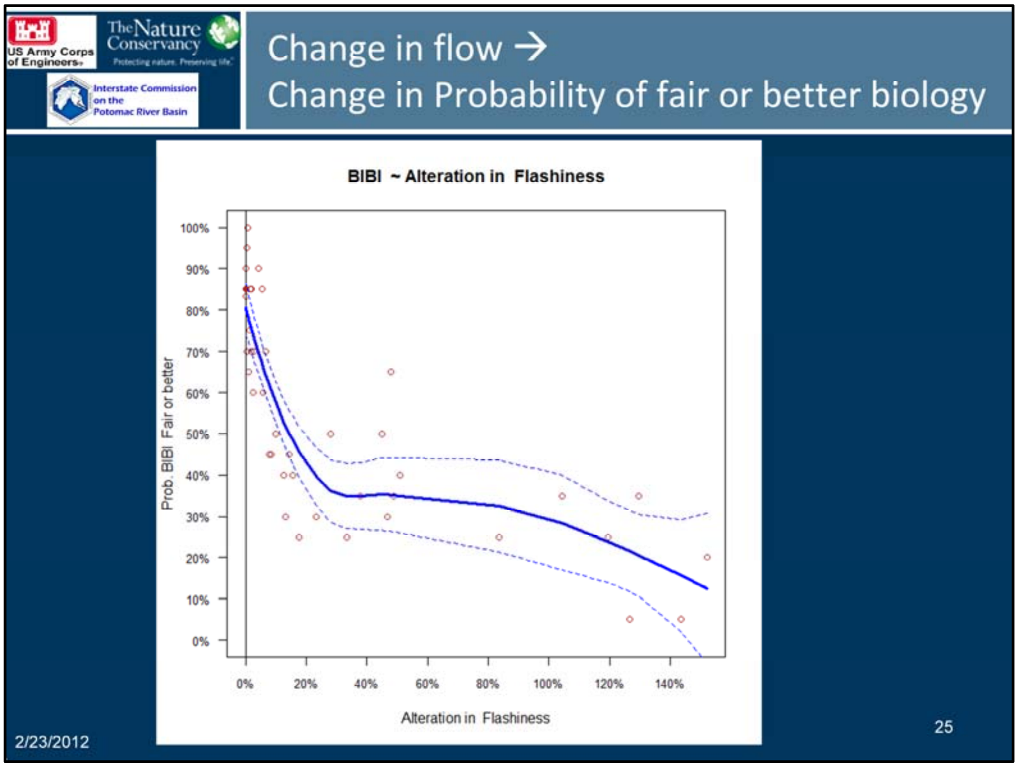
Outliers can be explained …
Red dots: Impervious surface > 10%, <6% Agriculture, few or no withdrawals, impound, or discharges
Yellow dots: Withdrawals > 65% of median flow and highly forested watersheds
Yellow Triangles: Discharges > 20% median flow.



Two example plots:
change in Median Annual Flow vs B-IBI value
DH17 vs B-IBI value

Note
-For any amount of flow alteration, there is a wide range of B-IBI scores
-Line across top of plot is a 90th percentile quantile regression, indicating a decline in the best possible biology values, significant at the p = 0.05 level (black line) or at the p = 0.01 level (red line).
-The declining QR line is interpreted as showing that, as flow alteration increases, there is a decrease in the best possible biometric value, indicating a decline in ecological status. The many points with lower biometric values show the impact of the many other factors affecting biological status.
- Most flow alteration typically occurs in one direction or another.
- Significant quantile regressions most frequently occur in only one direction of flow alteration.
-These relationships tested for many flow statistic – bio metric pairs. There is not always a significant quantile regression.

-Problems with using these plots to define flow alteration – biological response relationships
-QR is linear
-Different scales for different biometrics
-Some biometrics upward direction is better, others downward direction is better
-Criteria for “Fair”, “Good” status for given biometric varies by bioregion



These issues with plotting flow alteration vs biometric value can be resolved by plotting instead

Flow alteration vs Probability of the biometric = Fair or better status.

Each biometric data value is converted to its particular “Good – Fair – Poor” status and, within small regions along the X-axis, a probability of meeting Fair or Good status is calculated.

Explanation of plot:

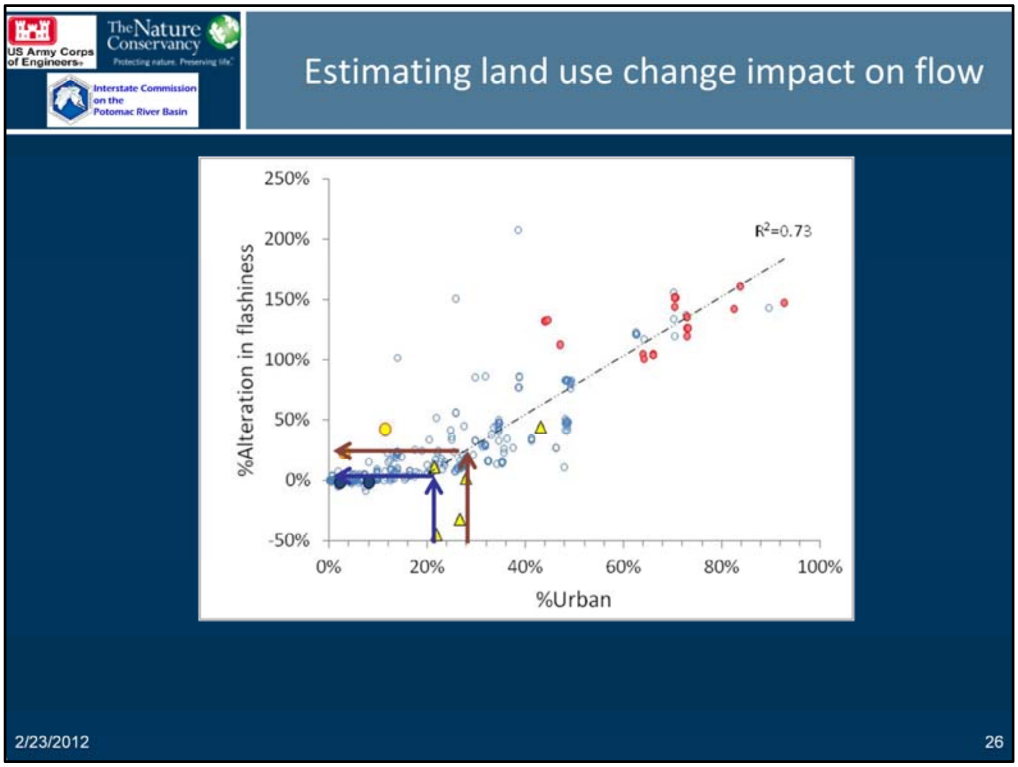
-Red circles represent bins of 20 data points and for those 20 points the fraction that have a Fair or better status.

-Dark red solid point on the 0% alteration line is the probability of biometric status = Fair or better for samples in Reference watersheds (current conditions = reference criteria)

-Solid blue line is a loess smoothed regression line through the bin points

-Dashed lines are .05 confidence interval.

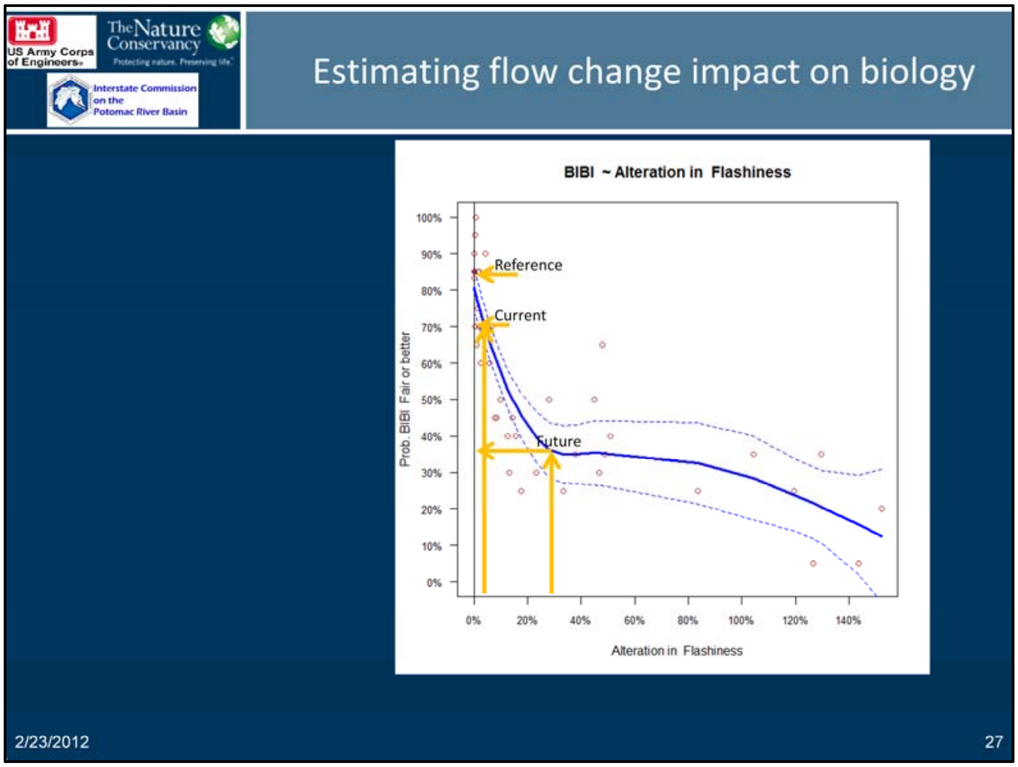
-We have drawn these plots for all flow alt – biology relationships for which there is a significant QR.



This slide shows one example of how one can use these relationships to relate a change in the watershed to a change in flow characteristics.

The blue arrows are for a hypothetical watershed with approx 20% Urban area in its Current Condition.
Flashiness has already been altered from its Baseline value by a small value (not visible on scale of this polt)
The red arrows show the impact on Flashiness of an increase in %Urban area to 30%.

This information is translated into an impact on biology in this next slide….

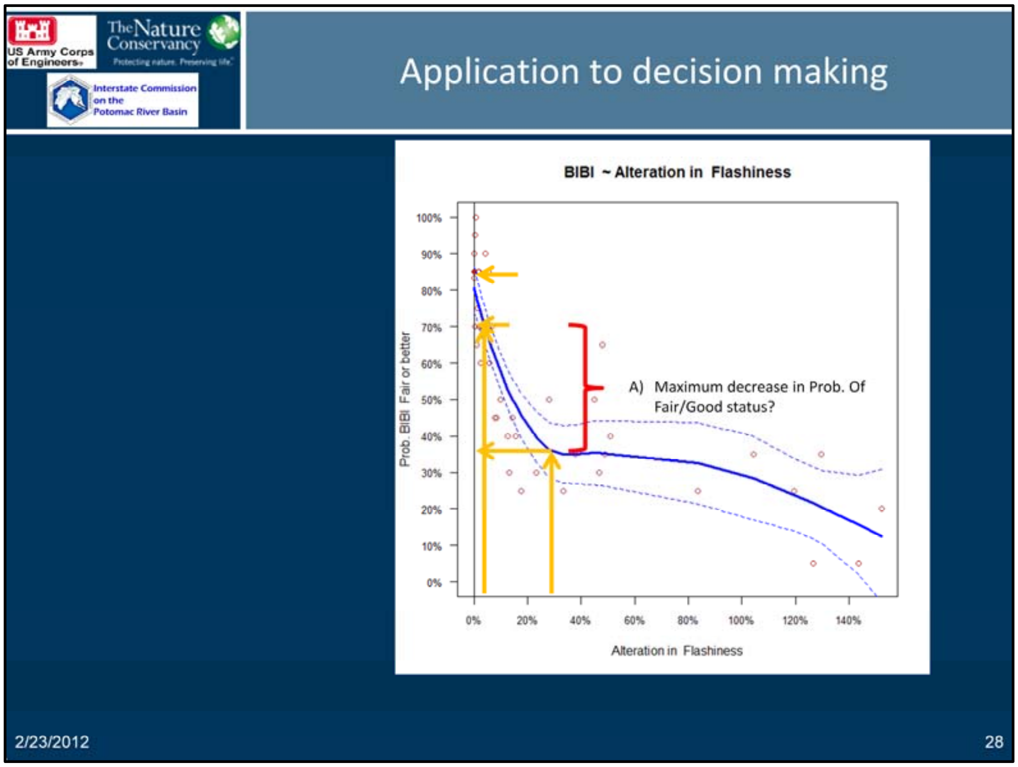


Here, flow alteration in Flashiness is on the X-axis and the Probability of B-IBI being Fair of Better is on the Y-axis.

Remember that, because many other factors affect biological condition, we can't predict precisely how a change in flow is going to impact the biota, but based on the data we have for this watershed, we can say that alteration of, in this case, Flashiness is associated with a decreased probability of any site having Fair or Better B-BI

In this example, I've indicated Probabilities for Reference conditions (less than 100%), for Current Conditions, and for the hypothetical increase in flashiness.

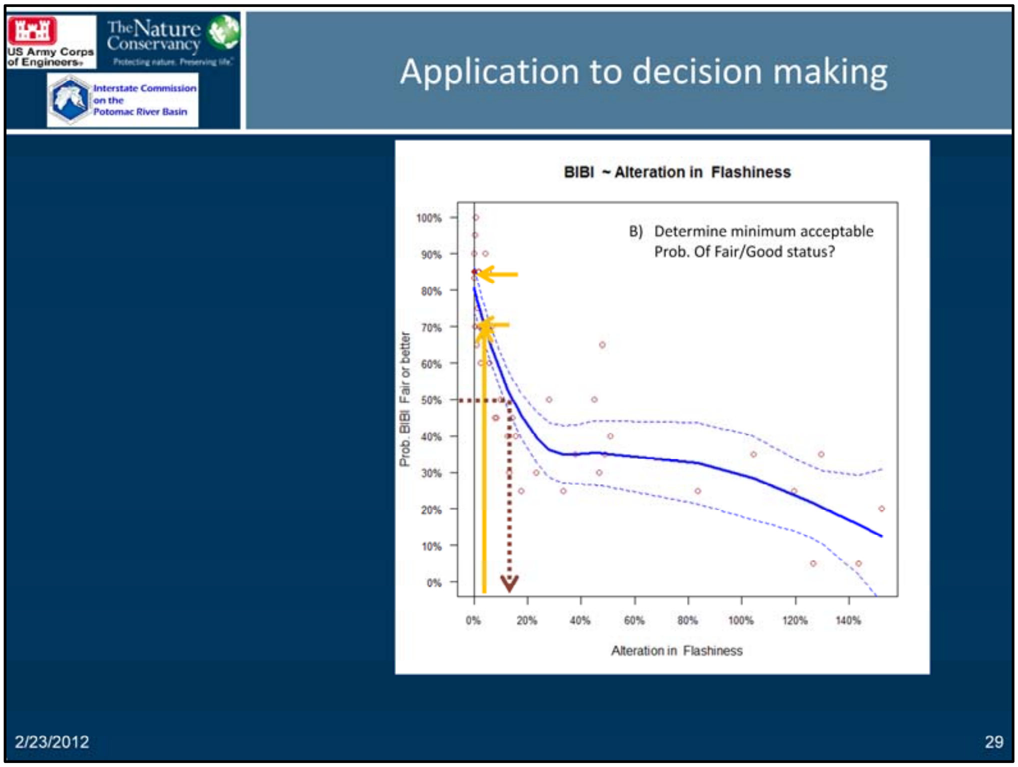
How can we apply this information in a decision making context?



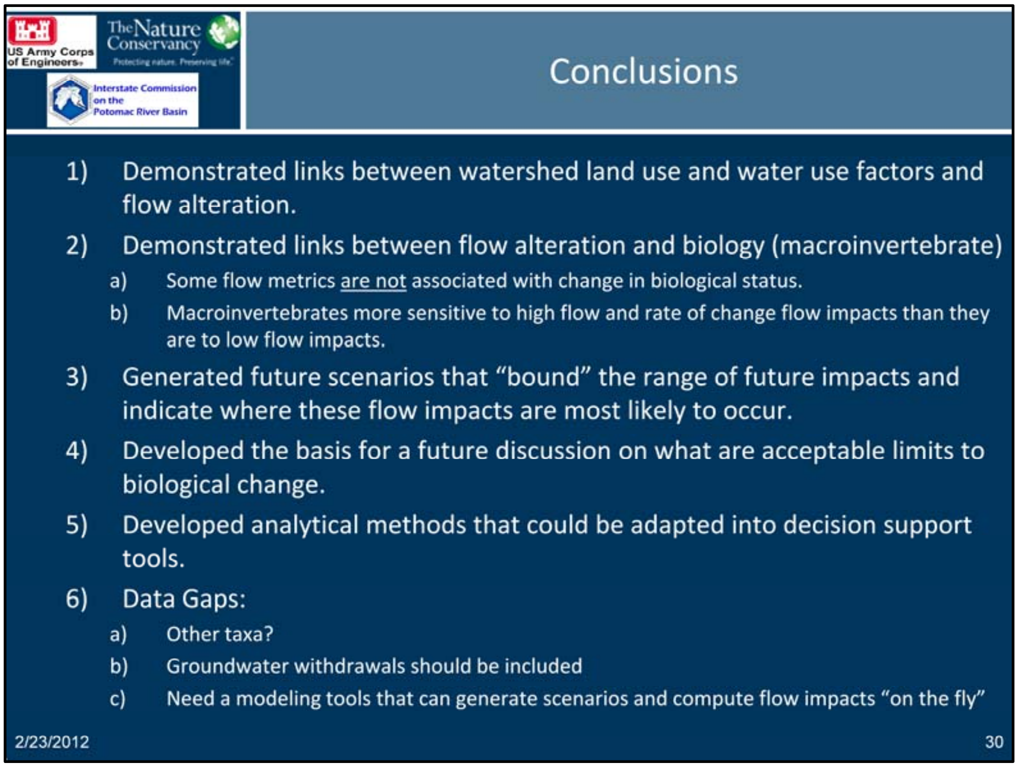
-Two ways.

-One possibility is to evaluate a the amount of decrease in Probability. Recognizing that differnet locations have already experienced some change.

-The red bracket indicates the decline in Probability from Current to possible future scenario.



-An alternative approach is to set limits for minimum acceptable probabilities for Fair or Better status and work backward from there to define limits to flow alteration.



With the flow alteration – biological status plots one can see the basis for developing tools that facilitate an estimate of impact on biology of proposed changes to a watershed: either land or water use changes.

Thank You!

http://potomacriver.org/sustainableflows/

Discussion

- Raise your hand by clicking on the button on the webinar menu.
- Please remain muted until the conference organizer calls on you.
- Once called upon, un-mute your phone by selecting *7.
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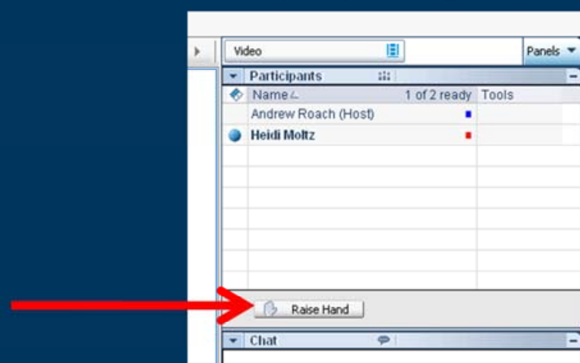

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