MEMORANDUM

To: ESHMC
Fr: Bryce Contor
Date: 6 May 2008

Re: Request for Input on Non-irrigated Inclusions

As discussed in the 6 May 2008 ESHMC meeting, IWRRI proposes using aerial photo analysis of a statistical sample of model cells to establish reduction fractions for non-irrigated lands in each model cell. The calculation of irrigated lands in the Recharge Tool uses equation (1). The Recharge Tool allows unique reduction fractions for sprinkler-irrigated lands and gravity-irrigated lands, for each stress period.

$$\text{Irrigated acres} = \text{Nominal acreage} \times (1 - \text{reduction fraction}) \qquad (1)$$

The goal of the aerial-photo activity is to assign appropriate reduction fractions to scale irrigated acreages from disparate data sets so that, if irrigated acreage had not changed in a given location, equation (1) would give essentially the same result for any irrigated-lands data set. It is proposed that the determination of reduction fraction be based upon hand-digitized polygons from aerial images, of a statistical sampling of model cells, for each irrigated-lands data set.

This memo requests input on the following questions:

1. Definition of irrigated lands.
2. ET adjustment factors.
3. Changes between image dates.
4. Georeferencing discrepancies.
5. Image color differences.
6. Image resolution differences.
7. Sample size.

<u>Definition of irrigated lands.</u>

Ideally, lands represented as "irrigated" in modeling data sets should include all lands where significant ET is present that would not have been present but for irrigation activities. This would include ET on cropped acres as well as ET on adjacent lands that would not have occurred, without the irrigation activity.[1] Examples are vegetation on ditch and canal banks, vegetation on rock piles that are traversed by sprinklers[2] and vegetation in areas where runoff collects.

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[1] Water use on irrigated areas within cities (lawns, parks, ball fields) is part of the calculation of extraction for municipal and industrial areas and is not represented in these "irrigated lands" data sets.

[2] i.e. rock piles that are within a field irrigated by a center pivot or other sprinkler system, so that the irrigation actually crosses over the rock pile and applies full irrigation depth.

However, ET on these marginal lands will usually be less than on crop lands, due to thinness of soil, sparseness of vegetation, road traffic or reduced depth of applied water (in some cases).

For years in the calibration when METRIC or other remotely-sensed ET estimates are used (2000, 2002, 2006 and perhaps additional years), inclusion of these areas within the irrigated polygons seems to be appropriate, because the remote-sensing method will correctly represent the actual ET on these areas.

With traditional ET calculations (applied to most of the years of the calibration period), the ET rasters applied are based on full-production crop lands. Inclusion of all of these marginal lands could result in an over-estimate of ET, while exclusion could result in an under-estimate. If calculation of ET adjustment factors includes these lower-ET lands, and the representation of these lands is consistent across years, the impact of these areas should be implicitly represented within the ET adjustment factor. The only potential concern with this approach is spatial distribution: Figure 1 shows a hand-digitized shape excluding rock piles and rough lands traversed by sprinklers in one location. This is a false-color infra-red image where red colors indicate vigorously growing vegetation. The hand-digitized shape is about 12% smaller than the remote-sensing irrigated lands representation (essentially the entire 49-acre block). Note that the person doing the digitizing interpreted the strip down the middle as a natural drainage and excluded the vegetation growing in the strip, partly because the adjacent irrigated lands appear not to have been irrigated recently, indicating that the vegetation in the drainage[3] may be supported by naturally-occurring water.

Figure 2 shows a parcel in a different area of the same data set. In this case, the hand-digitized parcel would be nearly identical to the remote-sensing determination. The comparison of the two figures suggests that there may be some spatial distortion in the application of ET if a single ET adjustment factor were used on polygons that were overly-generous in inclusion of partially-irrigated lands. Since the Recharge Tool allows for unique adjustment factors for each irrigation entity, the spatial distortion occurs only within an entity; calculating unique adjustment factors for each entity will compensate for between-entity differences.

Within entities, however, it appears that the presence of in-field inclusions is spatially variable. In a test of two fairly large entities, a block of uniform points was tested on each end of each entity. Points that appeared to fall in fields where there were large numbers of inclusions were scored “1” and other points were scored “0.” On one entity (IESW032, the Northside Canal Company), the block of points at one end had an average score of 4% to 7%[4] while the other end scored 25% to 28%. For the other entity (IESW002, the Aberdeen-

[3] If indeed this is a natural drainage feature.
[4] 95% confidence interval

Springfield Canal Company) the range was 3% to 5% on one end and 19% to 23% on the other end.

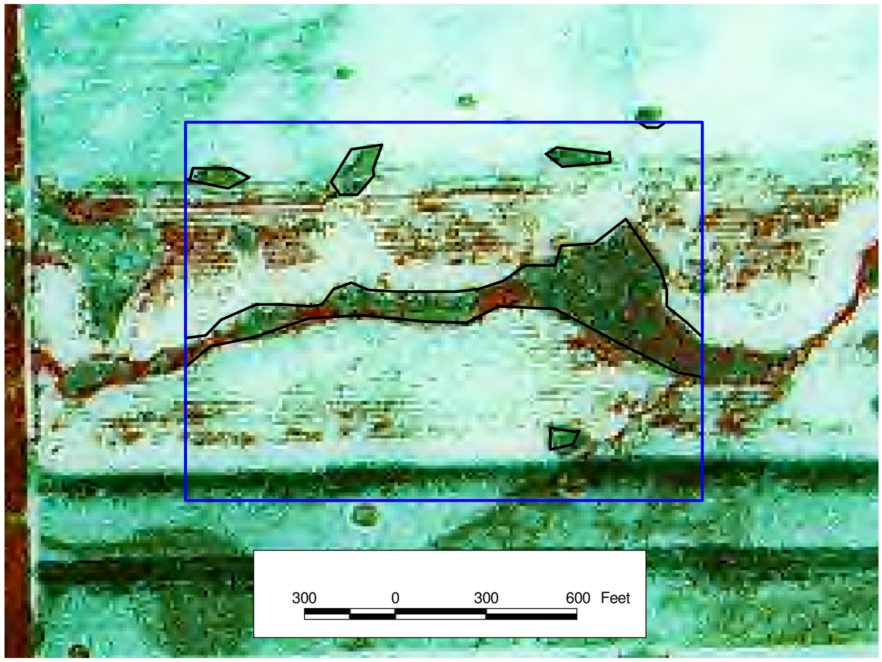

Figure 1

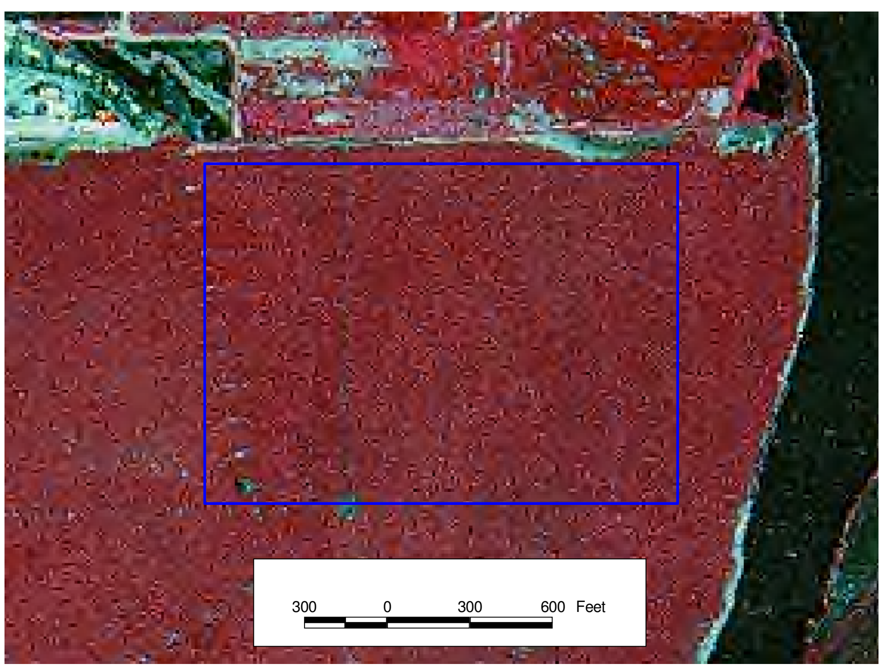

Figure 2

It appears that there are two general approaches that could be taken in constructing polygons for calculation of non-irrigated inclusions. The first would be to attempt to exclude at least the larger areas that, while they may receive irrigation water, do not support the same level of ET as fully-irrigated cropland. The second would be to exclude only non-irrigated lands that either have no vegetation (i.e. roads) or receive no irrigation water (i.e. haystack yards, farmyards) but include internal rock piles, canal seeps, and other lands that have some component of ET due to irrigation. The hazard of the first approach is that some ET that actually occurs on rock piles, etc, that are traversed by sprinklers will be omitted from recharge calculations. The hazard of the second is that there will be some spatial distortion of ET within an irrigation entity.

<u>ET adjustment factors.</u>

In either case, IWRRI proposes that the ET adjustment factors be calculated as follows:

1. For years when remote-sensing ET estimates are used, set adjustment factors to 1.0.
2. Use the comparison between remote-sensing and traditional ET estimates to calculate adjustment factors for each entity. A later memo will request input on procedures to perform these calculations.
3. Apply these derived adjustment factors in years when traditional ET estimates are used.
4. Accomplish these actions by modifying the Recharge Tool so that the adjustment factor is calculated according to equation (2):

$$\text{Adj Factor} = (1 + (\text{Flag} * \text{Parameter})) \qquad (2)$$

where			
	Adj Factor	=	adjustment factor used in ET calculations
	Flag	=	(0) if remote-sensing ET is used, (1) if traditional ET is used.
	Parameter	=	Value associated with sprinkler or gravity irrigation for each irrigation entity. These will hold the places in the input data sets that were held by the adjustment factors in ESPAM1.1 data sets, and are the values potentially adjustable during parameter estimation.

If the ESPAM1.1 adjustment factor was 1.05, the corresponding parameter would be 0.05. For a traditional-ET stress period, the resulting adjustment factor from equation (2) would be 1.05, and for a remote-sensing period the result of equation (2) would be an adjustment factor of 1.0.

IWRRI requests input from the ESHMC on the following, regarding the definition of irrigated lands and the use of ET adjustment factors:

1. Are there other implications to including or excluding the partially-irrigated areas besides those discussed above?
2. Should rock piles and other reduced-ET areas should be included as "irrigated" in constructing polygons for determination of reductions for non-irrigated inclusions? In other words, is the hazard of omitting some ET a greater hazard than creating some spatial distortion of ET within individual irrigation entities?
3. Is the proposed calculation of ET adjustment factors, using a modification to the Recharge Tool, acceptable?
4. Should the reduction for non-irrigated inclusions be set to zero and all these effects represented solely using the ET adjustment factor? Unless all data sets could use the same adjustment factor, this would require additional modification of the Recharge Tool (beyond that discussed above).

<u>Changes between image dates.</u>

For many of the irrigated-lands data sets, the image date will not correspond exactly to the remote-sensing date. This means, for instance, that the hand-drawn "actual" irrigation polygons for the year-2000 irrigated lands map will be based on year-2004 images.[5] Two changes are possible:

1. The geometry of a parcel changes, for instance, due to installation of a new irrigation system or development of part of a parcel.
2. The irrigation status of a parcel changes.

Figure 3 illustrates the first kind of change. The black triangle indicates the lands within the red sample boundary that are shown as irrigated in the year-2000 irrigated lands data. The blue shows the analyst's estimate of actual irrigation from the year-2004 image. Inspection of older images shows that the black triangle is consistent with an earlier, gravity-irrigated parcel in this location.

[5] The satellite data that individual irrigation maps are based upon do not have adequate resolution to draw comparison polygons.

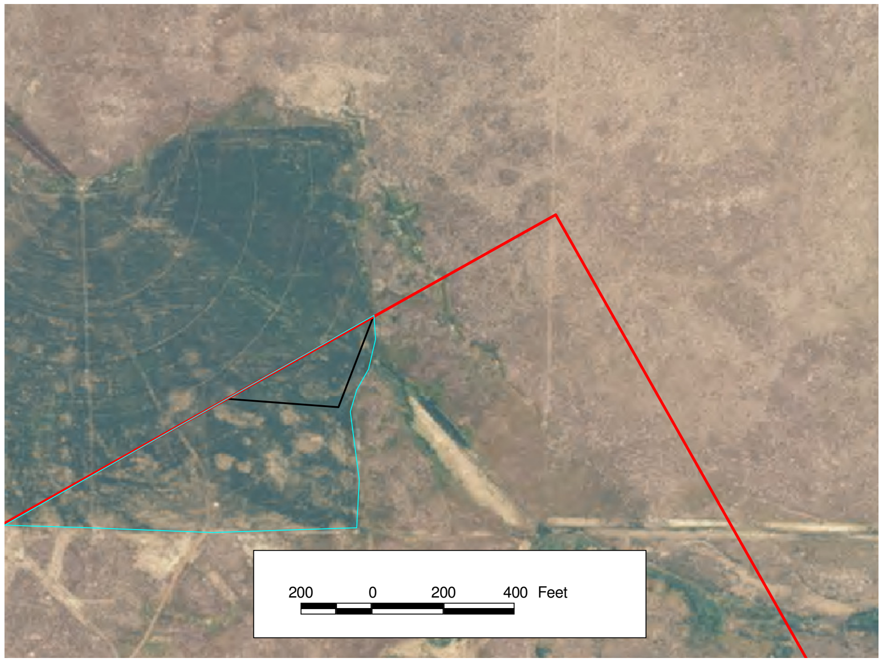

Figure 3

Figure 4 illustrates the second condition. The yellow square is within lands indicated as “irrigated” by remote sensing. The parcel has a regular shape, uniform texture and linear features consistent with irrigated agriculture, but it does not show the bright red color of growing vegetation. It is possible that this parcel was fallowed that year, or that it had already been harvested at the time of the image.

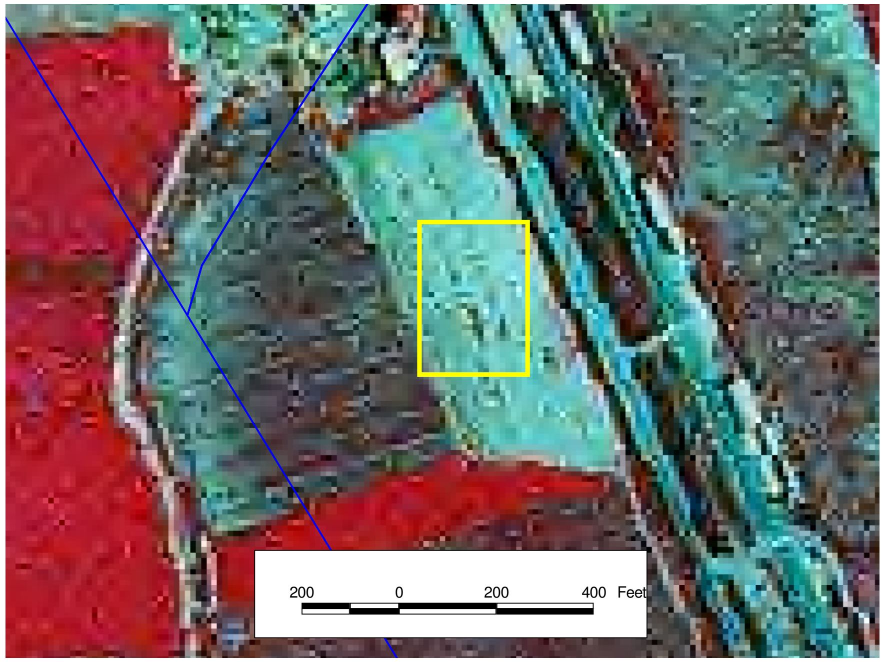

Figure 4

It is proposed that the process of constructing "actual irrigated" polygons for calculation of reduction factors rely upon the following guidelines:

1. If there is indication that the geometry of a parcel has changed, try to find a different image to verify the geometry.
2. If the image-date geometry cannot be verified, eliminate that parcel from both the hand-drawn and remote-sensing samples so that it does not affect the calculation of the reduction factors.
3. Do not consider indications of irrigated or non-irrigated status in the aerial image, except as required to determine parcel geometry. Essentially, trust the remote-sensing determination of irrigation status and rely on the aerial imagery only to determine geometry and non-irrigated inclusions. In Figure 4, then, the hand-drawn polygons would include the parcel boxed in yellow if the irrigation data showed it as irrigated, though there is no bright-red indication of vigorously growing vegetation at the time of this image.

Please comment on the proposed guidelines for dealing with changes between image dates.

<u>Georeferencing discrepancies.</u>

Figure 5 shows two model cells where the remote-sensing irrigated-lands map is georeferenced somewhat east of the underlying aerial image from which comparison polygons would be drawn. Note how the irrigated lands seem to overlie the river and the gap in irrigated lands lies east of the highway/railroad non-irrigated corridor. Figure 6 shows the same model cells with the remote-sensing map manually adjusted. IWRRI requests input on the following question for handling of georeferencing discrepancies:

5. Should georeferencing for each sample location (i.e. for a clipped subset of the irrigated-lands map) be adjusted to a common reference, prior to digitizing polygons for calculation of non-irrigated inclusions?[6]

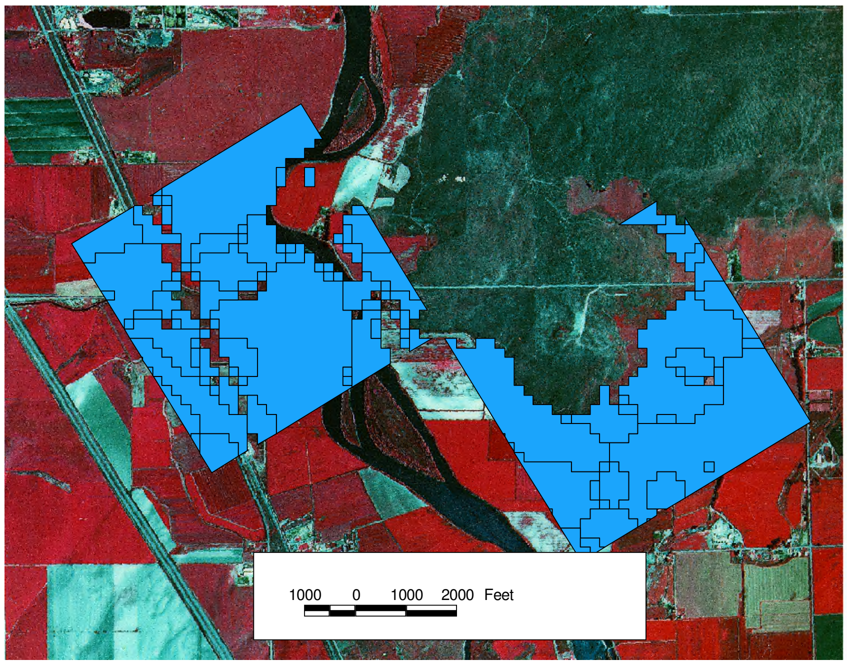

Figure 5

[6] Georeferencing differences between the east and west sides of a given set of images are likely to be as large as those illustrated here. It is likely that no single adjustment of an entire irrigated-lands map will produce a reasonable alignment with all the image tiles. Individual adjustment of clipped samples is proposed.

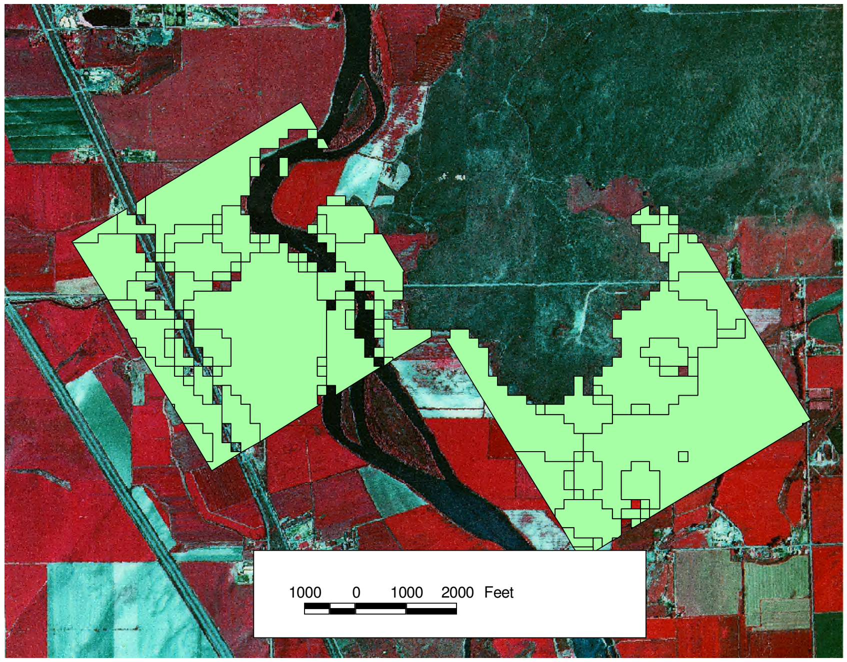

Figure 6

Image color differences

Some of the images available for constructing hand-drawn polygons use false-color infrared data, where vigorously-growing vegetation is represented as bright red. Other images use true-color visible-light data, where all vegetation appears green. There seems to be less indication of vigor than with the false-color infrared. Figure 7 shows inclusions, perhaps farm roads or ditch banks, which appeared to be "not irrigated" in the false-color image. Figure 8 shows the same inclusions in a true-color image from a different year, where they could be construed as "irrigated."

Figure 7

Figure 8

The goal of constructing polygons from these images is that the constructed polygons from two different images would be very similar or identical, if there had been no change in the underlying irrigated lands. Ideally, we should simply use a single type of data for all years. The problem is that we do not have the luxury of a full temporal coverage of *any* of the available image types. One set of aerial false-color photos (not illustrated here) are available only for 1980, with partial coverage for 1983. The false-color images shown in Figure 7 are available only for 1986. True-color NAIP photos (Figure 8) are available for 2004 and 2006.[7] IWRRI requests suggestions from the ESHMC on procedures that might aid in overcoming differences that might be introduced solely by the image color schemes of the different images.

Image resolution differences.

Figure 9 and Figure 10 show two different images of the same location. The resolution of the image in Figure 10 allows finer detail in construction of the comparison polygons.[8] It could be possible that finer resolution would allow exclusion of small non-irrigated areas that also existed in the other image but were not apparent, thereby causing an artificial difference in the calculated reduction fraction.

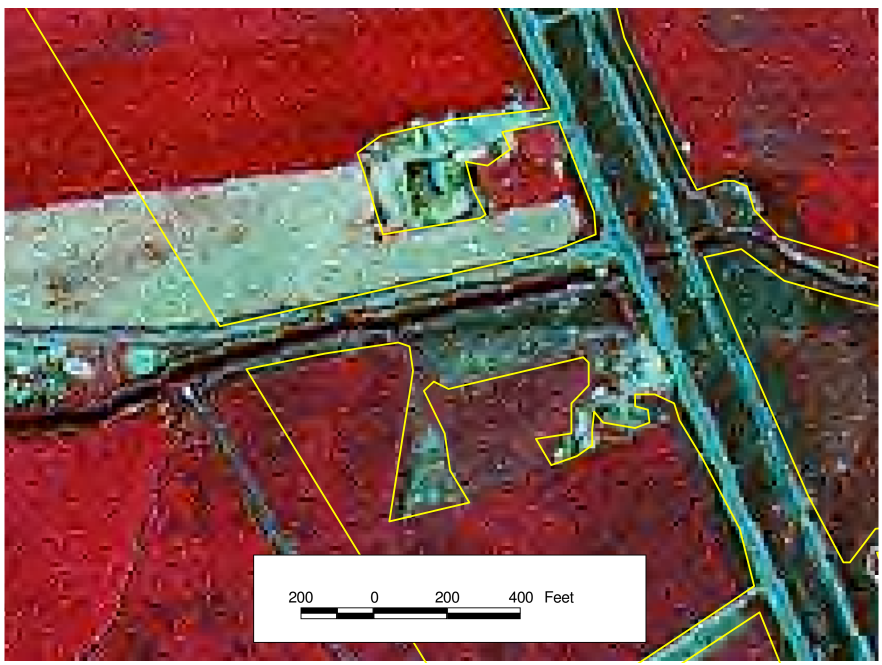

Figure 9

[7] Even then, the resolution differs between 2004 and 2006.
[8] The irrigated lands on the west of both figures are omitted because they are outside the sample model cell.

Figure 10

IWRRI seeks input on how to ensure that differences in resolution of underlying images do not introduce differences in the calculated reduction for non-irrigated inclusions.

Sample size.

Based on the standard deviation of calculated reductions for non-irrigated inclusions for three different images, IWRRI has calculated approximate sample-size requirements for various desired precision levels. These are only approximate because the sample (rather than population) standard deviation was used, it was based on only six sample model cells, and the cells were not chosen randomly. Table 1 records the results:

Table 1
Approximate Sample-size Calculations

Value	**RASA 1980**	**ESPAM1.1 1992**	**IDWR 2000**
$Z_{(0.025)}$[9]	1.96	1.96	1.96
sample std. deviation	0.050	0.066	0.040
sample size, 0.01 precision	95	166	61
sample size, 0.02 precision	24	41	15
sample size, 0.03 precision	11	18	7

For efficiency in travel arrangements, IWRRI needed to scan hard copies of 1980 images for this analysis at the state IDWR office during the 6 May 2008 ESHMC meeting. Therefore, 100 randomly-selected model cells have already been identified on irrigated lands and assigned sequential random numbers. All the cells intersect at least one irrigated-lands map, and most intersect multiple maps. Most cells intersect images for most dates. IWRRI proposes:

1. For each model cell processed, a “sprinkler” flag will be set to 1.0 if more than 75% of the irrigated acreage appears to be sprinkler irrigated, and a “gravity” flag will be set to 1.0 if more than 75% appears to be gravity irrigated. If these criteria are not met or if the irrigation type cannot be determined from the photos, both flags will be set to zero. This will be based on a visual assessment and not on a formal calculation of percentages.
2. Sample cells will be processed in batches of 25 cells. After each batch, the combined reduction factor for non-irrigated inclusions will be calculated based on all cells, and sprinkler or gravity factors will be calculated from the cells with appropriate flag values.
3. For each image, additional batches of 25 cells will be processed until the single-source precisions are better than +/- 0.03 or the combined precision is better than +/- 0.015.
4. No additional cells will be selected if these limits have not been reached after processing all of the cells (out of the sample of 100) that intersect a given irrigation map and available images.
5. For a given image, if the unique gravity and sprinkler reductions are statistically different from each other, they will be used. Otherwise (as was done in ESPAM1.1) the overall reduction factor will be used.

IWRRI seeks input on the sample-size proposal.

[9] This is a 95% confidence level, since this is a two-tailed test.

Summary

IWRRI proposes that assessment of irrigated acres appearing in aerial photos, for a statistical sampling of model cells, be used to assign reductions for non-irrigated inclusions for ESPAM2 calibration. Input, comments and ideas from the ESHMC are requested on the following items:

1. Are there other implications to including or excluding the partially-irrigated areas besides those discussed above?
2. Should rock piles and other reduced-ET areas should be included as "irrigated" in constructing polygons for determination of reductions for non-irrigated inclusions? In other words, is the hazard of omitting some ET a greater hazard than creating some spatial distortion of ET within individual irrigation entities?
3. Is the proposed calculation of ET adjustment factors, using a modification to the Recharge Tool, acceptable?
4. Please comment on the proposed guidelines for dealing with changes between image dates.
5. Should georeferencing for each sample location be adjusted to a common reference, prior to digitizing polygons for calculation of non-irrigated inclusions?
6. IWRRI requests suggestions from the ESHMC on procedures that might aid in overcoming differences that might be introduced solely by the image color schemes of the different images.
7. IWRRI seeks input on how to ensure that differences in resolution of underlying images do not introduce differences in the calculated reduction for non-irrigated inclusions.
8. IWRRI seeks input on the sample-size proposal.

Please respond to bcontor@if.uidaho.edu by 20 May, 2008.