



Mean Seasonal Precipitation Raster from Drawing B-166

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Table of Contents

Contents

Introduction and Background	1
Purpose	3
Overview	5
Process Details	5
Georectification of Drawing B-166	5
Digitizing Isohyets	6
Raster Interpolation	6
Raster Review	6
Creating Supplemental Isohyets	7
Raster Fill.....	7
Arc Toolbox Model.....	8
Surrounding Counties	9
Alameda County Isohyets	9
Solano County Isohyets.....	9
Surrounding County Isohyets.....	11
State Isohyets.....	11
Final MSP Raster and Isohyets	12
Conclusion.....	12
APPENDIX A LARGE FIGURES	A-1
APPENDIX B DATA CD	B-1

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List of Figures

Figure 1 Close-up Overlay of Dwg. D-2982 Based Isohyets on Dwg. B-166.....	2
Figure 2 Cross Section Through the Raster Created from Layer for Dwg. D-2982.	4
Figure 3 Cross Section Through the Raster Created from the Final MSP Raster.	4
Figure 4 Example of an Arc Toolbox Model Made for this Project.	8
Figure 5 Alameda County Isohyet Comparison.....	9
Figure 6 Solano County Isohyet Comparison	10
Figure 7 San Joaquin County Isohyet Comparison.....	10
Figure 8 DWR Isohyet Map Coverage of the Bay Area	11
Figure 9 Raw Dwg. B-166 – Not Georectified	A-2
Figure 10 Scan of FD-2982	A-3
Figure 11 Dwg. B-166 – Non-Georectified Image Overlaid on Georectified Image.....	A-4
Figure 12 Georectified B-166 with Major Roads GIS layer	A-5
Figure 13 Georectified B-166 with Digitized Isohyets.....	A-6
Figure 14 0.10-inch Interval Isohyets Based on Raster Built from 2.5-inch Isohyets	A-7
Figure 15 Supplemental Isohyet Example showing the “web” used to interpolate the B-166 Isohyets.	A-8
Figure 16 0.1-inch Interval Isohyets Based on Raster Built from Supplemental Isohyets	A-9
Figure 17 Comparison of Contra Costa County Isohyets with Surrounding Counties	A-10
Figure 18 Final Mean Seasonal Precipitation Raster with 0.5-inch Isohyets	A-10
Figure 19 Final Mean Seasonal Precipitation Isohyets from MSP Raster	A-12

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Mean Seasonal Precipitation Raster file from Drawing B-166

Introduction and Background

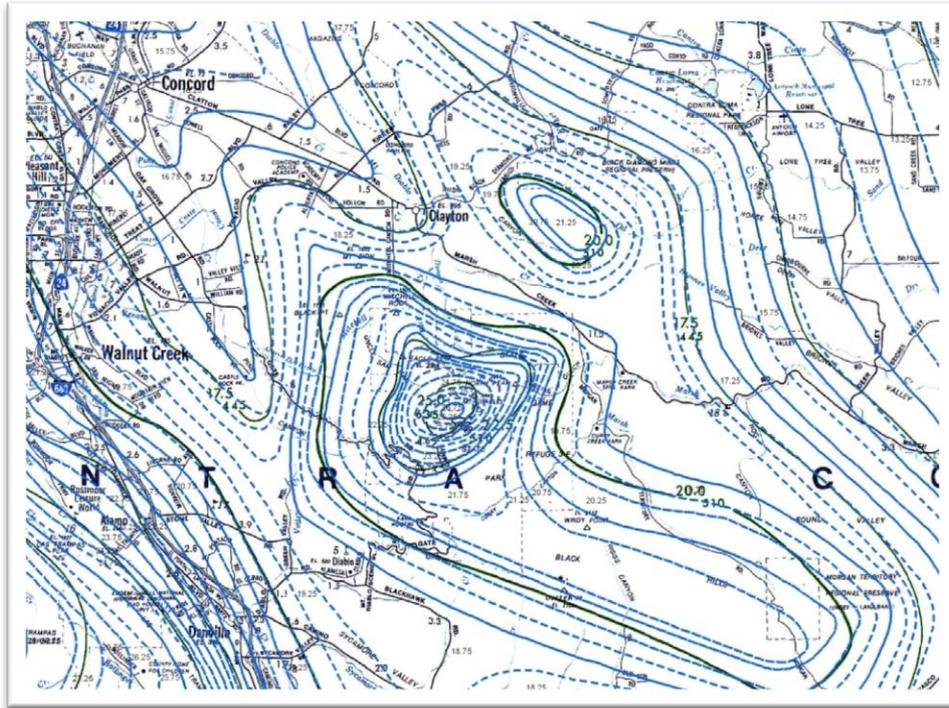
Drawing Number B-166 (Dwg. B-166) (**Figure 9**: see Appendix A) has been the standard for mean seasonal isohyets for Contra Costa County since it was created in December 1977. It is used in conjunction with the Precipitation Duration-Frequency-Depth curves (Dwgs. B-158 thru B-162)¹ to estimate design rainfall amounts for the Contra Costa County Flood Control & Water Conservation District's Unit Hydrograph method and for estimating rainfall intensities for the Rational Method. Dwg. B-166 was created on an American Automobile Association (AAA) base map. Apparently, AAA worked with the Contra Costa County Public Works Department in other mapping projects, which fostered the use of their map as the base map for Dwg. B-166.

Drawing D-2982 (**Figure 10**) was created in September 1985. It was apparently intended to be a larger version of Dwg. B-166. Dwg. D-2982's title "Rainfall/Runoff Stations" indicates that it was primarily intended for showing gauge locations, not enlarging Dwg. B-166 with accuracy. By close inspection, one can see that the isohyets from these two drawings do not perfectly match.

Figure 1 is a close-up overlay of a GIS layer made from Dwg. D-2982 isohyets over Dwg. B-166. The dashed blue lines in the figure are from the Dwg. D-2982 based GIS layer. This figure clearly shows that the Dwg. D-2982 based GIS layer does not accurately represent Dwg. B-166.

¹ The District's standards can be found under [Documents and Standards](http://www.cccounty.us/index.aspx?NID=442) on Contra Costs County's website at <http://www.cccounty.us/index.aspx?NID=442>.

Figure 1 Close-up Overlay of Dwg. D-2982 Based Isohyets on Dwg. B-166



During 1991 and through 1993, the Public Works Department converted the County base maps to CAD² format. A few years later, the isohyets were also digitized into CAD. This was done by digitizing the isohyets on a digitizer tablet. By observation, it is clear that the electronic isohyets were taken from Dwg. D-2982, not Dwg. B-166.

The Isohyet interval for both Dwg. B-166 and Dwg. D-2982 is 2.5 inches, but the interval on the electronic version of Dwg. D-2982 is 0.5 inches. From working drawings in the office, we can see that someone interpolated between the 2.5-inch interval isohyets by hand. These hand-drawn lines were digitized to create the 0.5-inch intervals.

Around 2001 time frame, the CAD data was converted to a GIS format. To have a GIS layer that can be symbolized by various colors for different mean seasonal rainfall depths, a polygon GIS layer was created with the rainfall depth of the polygons equal to the average of the Isohyet lines they were between. This created a “stepped” version of the isohyets.

Using the polygon GIS layer created from Dwg. D-2982, we created a raster³. A profile cut across a part of this raster is shown in **Figure 2**. This figure demonstrates the “stepped” characteristic of the polygon layer. This GIS layer has been used extensively for display purposes and to some extent for calculations. It is unclear how often it has been used and if it has resulted in any significant errors in estimating seasonal or storm rainfall amounts or intensities since it is not based on B-166.

² CAD = Computer Aided Design

³ An example of a “raster” is a digital image that is made-up of a grid of pixels each with a specific color. A raster is a grid where each square of the grid (pixel) can represent other types of data besides color. In this report, the raster is a grid where each pixel represents a mean seasonal precipitation depth.

Purpose

The purpose of this effort is to create an accurate raster based on the B-166 isohyets for use in GIS. Using a raster layer of the Mean Seasonal Precipitation (MSP) would be much more effective and accurate than a vector layer (line or polygon) in many ways. A raster layer represents a smooth surface of the MSP as shown in **Figure 3** rather than a stepped surface seen in **Figure 2**⁴. The new raster can be used for presentations and calculations in more ways than a vector representation. It can also be used more efficiently in GIS hydrology software, such as Arc Hydro and HEC-GeoHMS.

The original B-166 was produced by hand using some “artist’s” license. There are much more sophisticated methods in use today, such as the PRISM⁵ program used by the National Weather Service in their NOAA Atlas project.

The intent of this effort is to represent better the 1977 Dwg. B-166 for future use and replacement of the current Isohyet vector layers. We will also produce a version of Dwg. B-166 overlaid with the detailed isohyets resulting from this work.

⁴ **Figure 3** is a profile taken from the same location as **Figure 2**, but through the final MSP Raster created from this work.

⁵ PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system, developed by Dr. Christopher Daly, PRISM Climate Group director. <http://www.prism.oregonstate.edu/>

Figure 2 Cross Section Through the Raster Created from Layer for Dwg. D-2982.

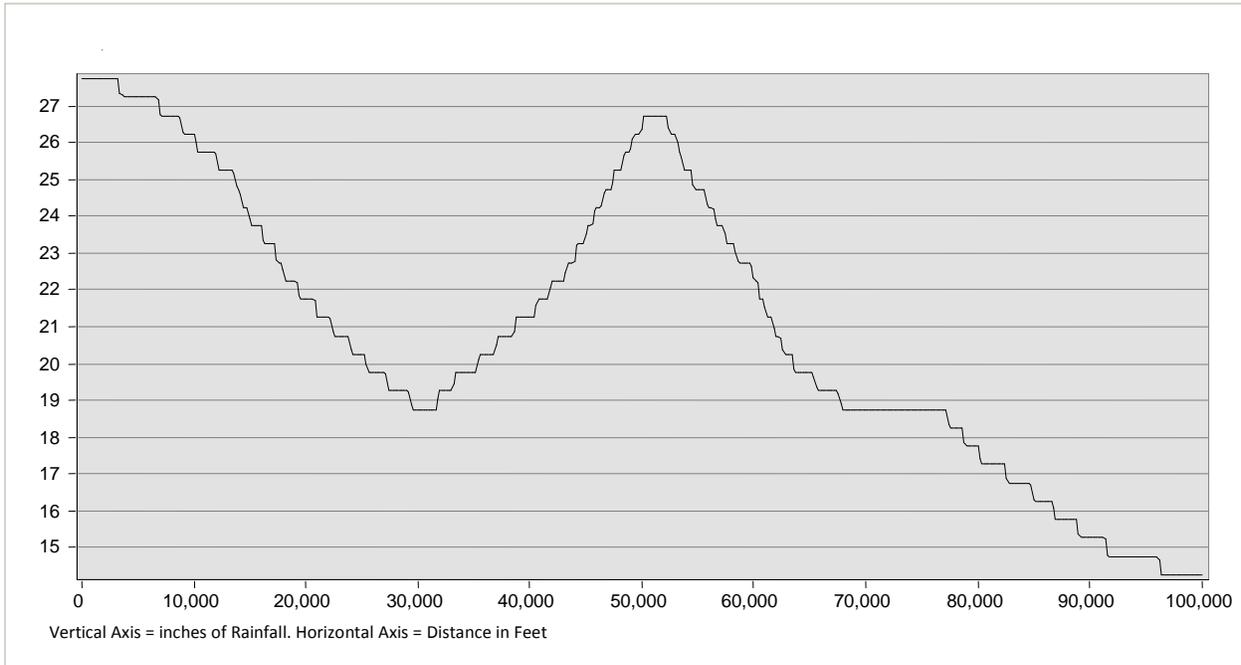
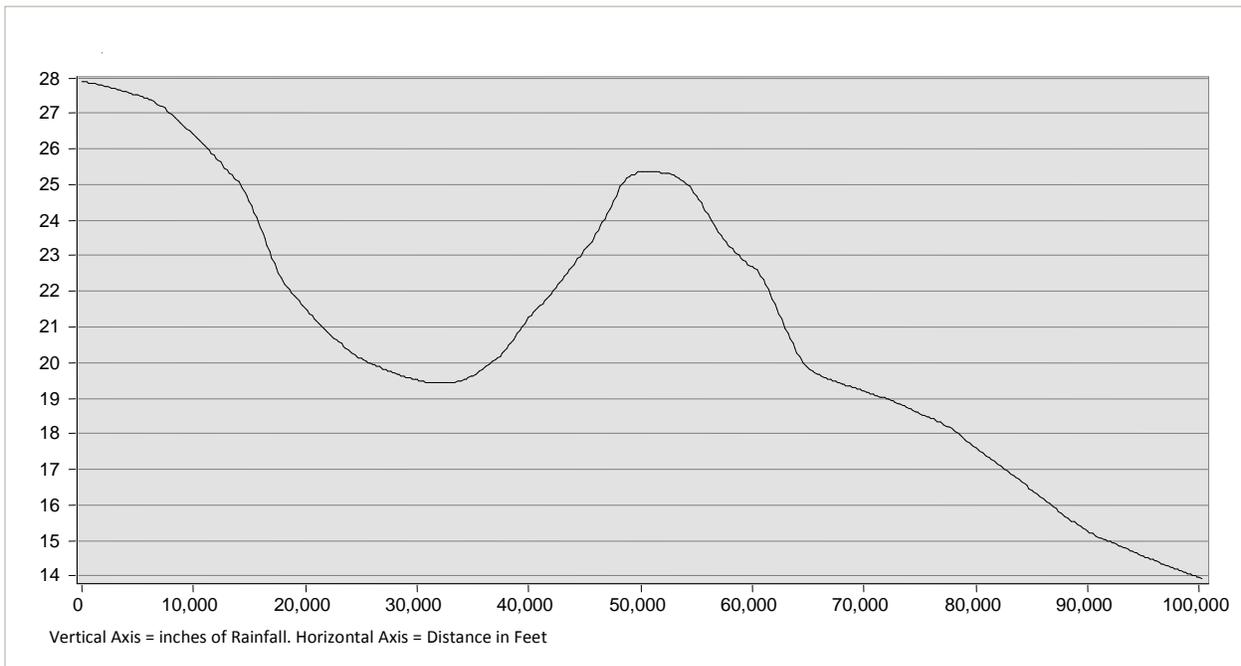


Figure 3 Cross Section Through the Raster Created from the Final MSP Raster.



Overview

After discovering the inaccuracy of Dwg. D-2982, this effort was undertaken to create a raster layer for the mean seasonal isohyets from Dwg. B-166 using the following steps:

1. Georectify Dwg. B-166 using roads for alignment.
2. Digitize the Dwg. B-166 isohyets as polylines with Z-values.
3. Use 3D Analyst Tools for surfaces and contours to create a raster based on the digitized isohyet polylines.
4. Check the Raster:
 - a. Use Spatial Analyst Tools to create isohyets from the raster.
 - b. Visually compare the created isohyets with the digitized isohyets.
5. Revise raster creation layers and methods and repeat process until raster is adequate for use.

Though we were not working with ground elevations and ground contours (topography), use of the 3D Analyst Tools and Spatial Analyst for surfaces and contours was appropriate. The isohyets are isolines just like contours. They are lines of equal mean seasonal rainfall just like contours are lines of equal elevation.

Process Details

This section provides details and figures showing the process followed and the decisions made while creating the MSP Raster. The larger figures are in Appendix A.

Georectification of Drawing B-166

Dwg. B-166 was scanned in color to a jpg file and can be seen in **Figure 9**. In this figure, the image is not perfectly square with the page because it has been aligned to line up best with the next presented image. It has been rotated and resized with a preserved aspect ratio (i.e., it has no distortion from original scan other than scale and rotation).

The georectification of an image can be a tedious process. To do this, one chooses a point on each layer that represents the same geographic location. Then another point is selected on each layer, and another, etc. Each time a point is added, the image being georectified is rotated, stretched, or compressed to hold the previous points based on specific rules. This process is often called “rubber sheeting” because of the way the image is stretched to fit the reference point locations. The more points that are set, the more the image being georectified becomes constrained. In ArcMap, the user can “release” points previously set in an effort to get a better fit. Because the AAA map is likely not in the same geographic projection as the other county GIS layers and because of other reasons (image stretch during scanning, etc.), a perfect fit cannot be expected. In this process, we used the GIS road layer to georeference the Dwg. B-166 image, because the roads were the most prominent countywide feature.

We must keep in mind that we are dealing with an original map that had “flaws” due to the original rainfall data used to create it (limited geographic spread of gauges and limited years of data) and human judgment. Therefore, some level of inaccuracy is inherent in the original. For all we know, errors (if any) that we introduce due to an imperfect fit could be errors in a direction that is more true to reality.

Figure 11 shows a comparison of the raw and georectified images. This overlay was done by matching or holding a point near the center of the map (near the text “Walnut Creek”) and the upper-left corner of the title block. You can see that areas to the northeast, southwest, and northwest of a line between these points are “out of focus.” This gives a feel for how much the image was georectified to fit the roads in the image to the GIS roads layer. **Figure 12** shows the georectified jpg overlain with the major roads layer. This shows how the roads on the map image match-up with the roads in the GIS major roads layer.

Digitizing Isohyets

The isohyets of the georectified image were digitized directly in GIS, not on a digitizing pad, and the results are shown in **Figure 13**. The digitizing process is simple, but tedious. After digitizing, smoothing of the lines was done occasionally using the GIS smoothing tool. This smoothing takes out the “kinks” of the lines that are inherent to manual digitizing. It can also introduce some general “off tracking” of the digitized lines. Careful inspection and adjustments are required after smoothing the digitized lines.

When we created the isohyet polyline shape file, we clicked the “Coordinates will contain Z values” box because a “Z” component is needed when creating raster from a polyline shape file. Then, a “Rainfall” field was added in the data table of new shape file. This field was used later for interpolating the MSP raster.

Raster Interpolation

Using ArcGIS 9.3, we performed a raster interpolation using the **3D Analyst Tools > Raster Interpolation > Topo to Raster** function. The settings used for this operation were as follows; for the rest, defaults were used:

- Raster cell size: 200 feet (initial processing)
- Drainage Enforcement: NO_ENFORCE

Though we were not working with ground elevations and ground contours (topography), use of the Topo to Raster function was appropriate. The isohyets are isolines (like contours) of the mean seasonal rainfall. They are lines of equal mean seasonal rainfall just like contours are lines of equal elevation.

Raster Review

Contours can be created from a Raster using the **Spatial Analyst > Surface > Contours** tool. By creating contours (or isolines) from a generated raster, we can see and compare the subtle characteristics of the MSP raster better than by using the GIS color ramps or other display options. The settings used for this operation were as follows:

- Base Contour: 8.5 inches (units for isohyets instead of contours)
- Contour Interval: 0.1 inches

Figure 14 presents the results. The dark outlined areas on **Figure 14** identify locations where the isohyet pattern needed to be adjusted. In those locations, the isohyets had anomalies and errors inconsistent with what we would expect. In several other places, the created contours are not smooth or they were too far apart.

Creating Supplemental Isohyets

The 2.5-inch isohyets on Dwg. B-166 have some large gaps between the isohyets and, as seen above, they did not produce good, smooth results. Supplemental isohyets were used to “train” the raster creation process to more accurately produce the MSP raster that we would expect if we were to interpolate the isohyets by hand.

We decided to create intermediate isohyets by “interpolating” between the 2.5-inch interval lines. We interpolated by making a temporary “web” of polylines between the main isohyets and then drawing the supplemental isohyets by using Ctrl-F7 to snap to the center of the web segments. With the supplemental isohyets created, we had a set of 1.25-inch interval isohyets in some area of the map. After processing the 2.5-inch (primary) and 1.25-inch (secondary level) interval isohyets, we determined that further definition was needed and created a third level isohyets at 0.625-inch intervals in key locations. **Figure 15** shows many of the “web” lines created and an example of one of the polyline layers used to “interpolate” in between the 2.5-inch isohyets.

The 10-inch isohyet near the north arrow on Dwg B-166 was modified to remove the “hook”. This minor modification resulted in a better looking edge to the MSP raster and resulting isohyets. The overall effect to the County MSP raster was very minor. Only the last two figures in the appendix reflect this change.

Raster Fill

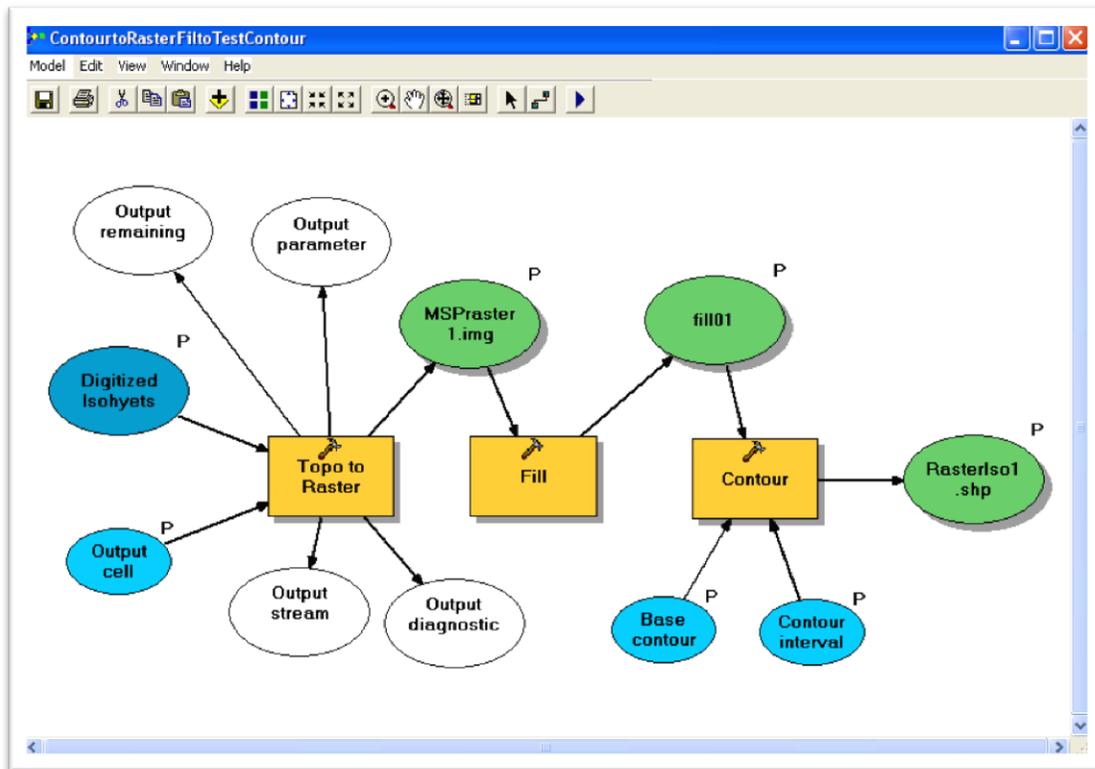
We found that it was necessary to “fill sinks” in the created raster. A “sink” is a cell in the raster grid that has the lowest value of all the cells around it. The **Spatial Analyst > Hydrology > Fill** tool was used to perform this task. This function raises low spots in the raster so that no cells are sinks. The placement of supplemental isohyets reduced the number of fill areas. There were originally three locations where the raster dipped and had sinks where we thought it should not. Only two of those were in Contra Costa County and the max fill depth is less than 0.09 feet. In the end, the supplemental isohyets eliminated the sinks except for one in Alameda County. That sink was filled by the fill process, though it has little bearing on the Contra Costa County isohyets.

Arc Toolbox Model

To make these three steps easily repeatable, an Arc Toolbox model was created. This allowed for quick changes and runs of the process without having to worry about specific settings that remained the same. **Figure 4** is a screen shot of one of the early models used. Later models became more complex and included clipping the results for different presentation in this report and for the final GIS layers.

Once a model is run, it can be copied and the input and output layers can be changed. When the first input layer (digitized isohyets) is changed, you have to check the “Topo to Raster” tool to ensure that the correct attribute table field is selected. For new runs with new polyline files (dark blue oval), output files (green ovals), you have to rename files if you do not want to overwrite previous work. We did not use the optional outputs (white ovals) for the Topo to Raster tool and so they show up as uncolored. It was helpful to keep the results from each iterative step for comparison during this iterative process.

Figure 4 Example of an Arc Toolbox Model Made for this Project.

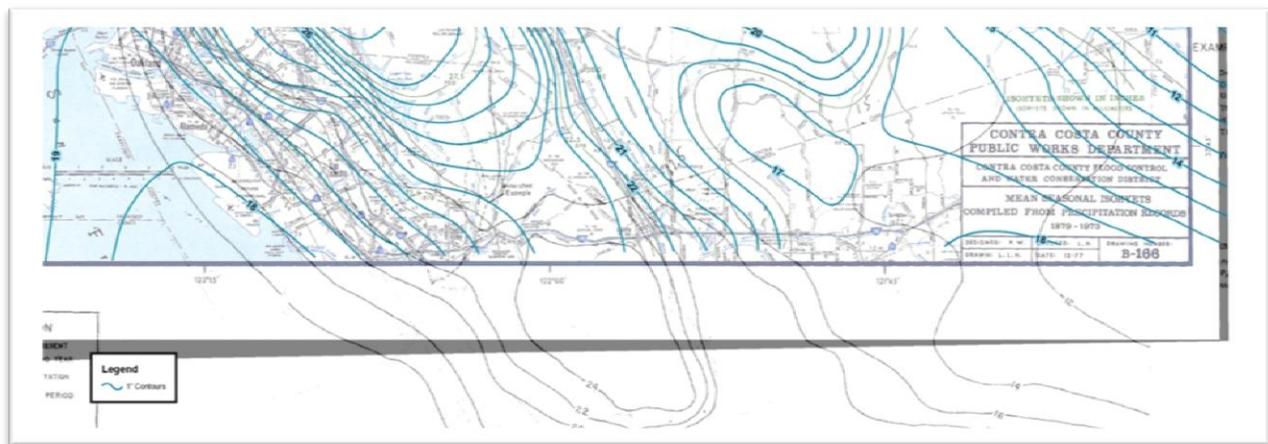


Surrounding Counties

Alameda County Isohyets

A copy of the Alameda County isohyet map was scanned and georectified to best fit Dwg. B-166. **Figure 5** is a view of the border with the Alameda County isohyet map superimposed on Dwg. B-166 along with 1-inch interval isohyets generated from a near complete MSP raster. The correlation is not very good between the two counties except at the east limits of our shared boundary. In general, the Contra Costa County isohyets are higher (more conservative) than the Alameda County isohyets.

Figure 5 Alameda County Isohyet Comparison



An area centered around the Collier Canyon Road was one of the sinks. We noted that the 14-inch isohyet has a similar shape as, but is offset from, our 17.5-inch isohyet on B-166. Our opinion is that the Alameda County isohyet shape is consistent with ours and so we could use it. We copied a 16-inch isohyet that we had created, trimmed it at the county border, traced the Alameda County 14-inch isohyet, used the fillet tool to make a smooth transition between them, and joined them (see **Figure 16**). This made a supplemental isohyet that we could use in the creation of the MSP Raster. The result was the reduction of the sink in a logical manner and keeping some continuity between the two counties' isohyets.

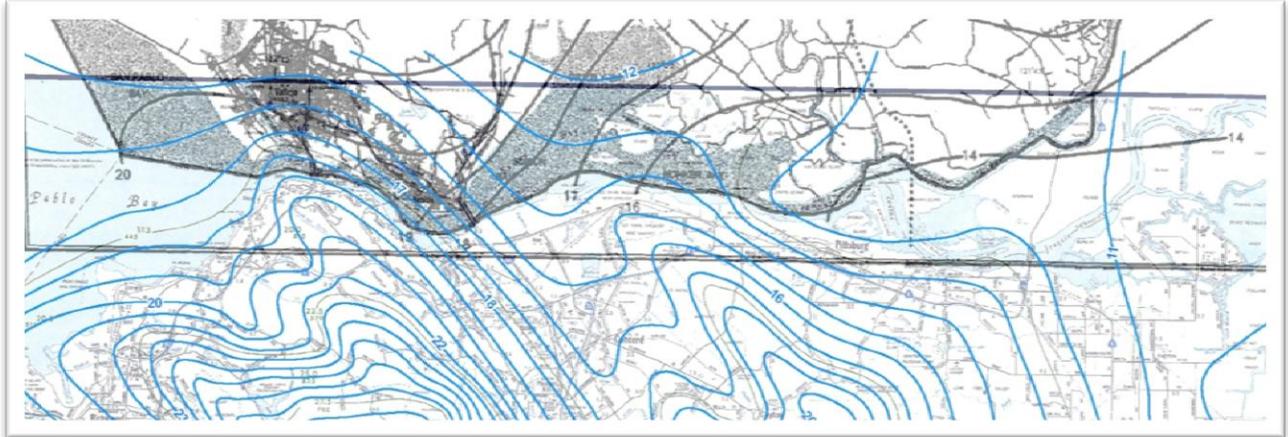
Rectifying the disparity along the county line was not in the scope of this effort. It will suffice to note the difference and accept the Contra Costa County MSP as either more accurate, or more conservative.

Solano County Isohyets

A copy of the Solano County isohyet map was scanned and georectified to best fit Dwg. B-166. **Figure 6** is a view of our county border with the Solano County isohyet map superimposed on Dwg. B-166. From this figure, we can see that the isohyets do not line up. The trend of rainfall depths on the Solano map is that the depth increases from Contra Costa County north. In some places, Solano County's MSP is higher and in others, it is lower than Contra Costa County's. As with Alameda County, there was a "sink" in the north of our MSP Raster north of Pittsburg and Antioch. To eliminate this sink, we copied an 11-inch isohyet that we created and modified it to extend almost due north. The resulting MSP Raster and contours generated from it were used in the final MSP Raster.

Again, correcting the disparity along the county line was not in the scope of this effort. It will suffice to note the difference and accept the Contra Costa County MSP. We may pursue a future effort to understand and reconcile the difference between the two counties' isohyets.

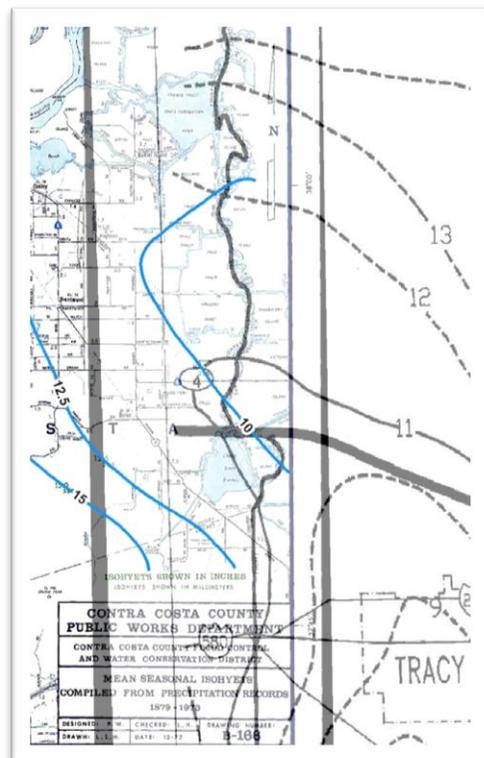
Figure 6 Solano County Isohyet Comparison



San Joaquin County Isohyets

A copy of the San Joaquin County isohyet map was scanned and georectified to best fit Dwg. B-166. **Figure 7** is a view of that county border with the San Joaquin County isohyet map superimposed on Dwg. B-166. Again, the isohyets do not match well. No adjustments were made to the Contra Costa County isohyets.

Figure 7 San Joaquin County Isohyet Comparison



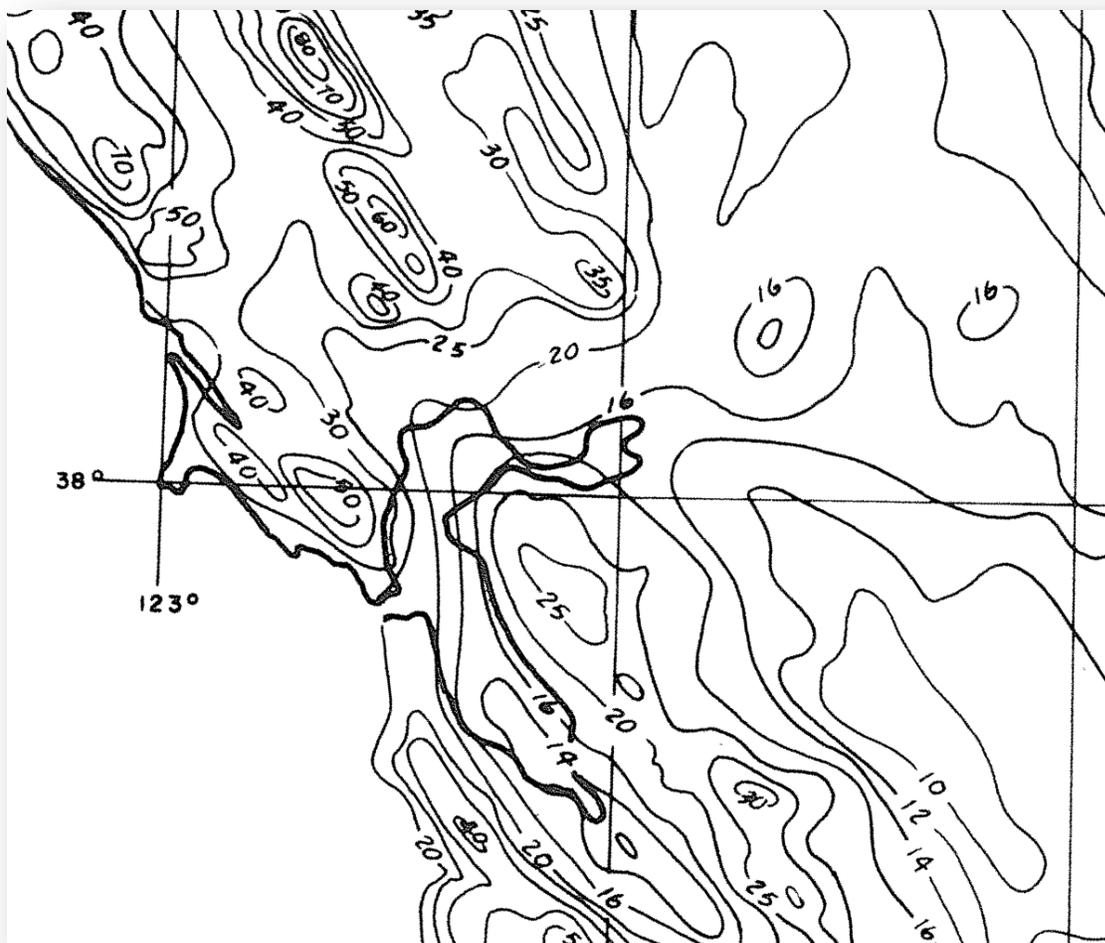
Surrounding County Isohyets

The disparity of isohyets during comparison between the three surrounding counties prompted a quick study of the composite of all three. A very rough digitization of each county's respective isohyets was done. An Arc Tool model was built to systematically perform a comparison of the Contra Costa isohyets with each of the other counties and display the results in an exhibit. **Figure 17** is the results of that effort, and it shows the relative differences where the isohyets of the other counties cross the Contra Costa 1-inch interval isohyets. This figure is only for information and no other action was prompted by the results that it shows.

State Isohyets

We located, via Caltrans, a 1976 State isohyet map from the Department of Water Resources Bulletin 195. We later located what appears to be the same map from a California Rainfall Summary dated July 1981. The portion that covers the Bay Area is shown in **Figure 8**. No study to rectify these data sources was undertaken.

Figure 8 DWR Isohyet Map Coverage of the Bay Area



Final MSP Raster and Isohyets

After several iterations, a final MSP Raster was created. The final version was created with 100 x 100 foot grid cells. Copies of the GIS layers used to create the raster are included on the attached CD with the layers used to create the raster. Because MSP values produced outside of the primary isohyets are less and less valid the farther away you get from them, we set a limit of 1 mile outside of the County line and clipped the raster. The clipping buffer was modified slightly to not leave small segments of the 0.1-inch isohyets “hanging”. The raster is intended for use for watersheds within, or draining to or from, Contra Costa County.

This final raster is on the attached CD and named:

- HYD_MSP.img = MSP Raster (100 x 100 grid)

Isohyets created from this raster are as follows:

- HYD_MSPIso250.shp = 2.50-inch isohyets
- HYD_MSPIso100.shp = 1.00-inch isohyets
- HYD_MSPIso050.shp = 0.50-inch isohyets
- HYD_MSPIso025.shp = 0.25-inch isohyets
- HYD_MSPIso010.shp = 0.10-inch isohyets

The final MSP Raster is shown in

Figure 18. The isohyets from the final MSP Raster are shown in **Figure 19**.

Conclusion

The final MSP Raster and isohyets created by the above procedure will provide more detailed and accurate hydrologic data for use in hydrology calculations. By more accurate, we mean that the values found in the MSP Raster and isohyets will be more true to the Dwg. B-166 than the current GIS layers. These new layers should replace those in the data servers.

The comparison with other counties' isohyets shows that some future regional collaboration may produce a better isohyet map. At the time of this writing, the author is aware of work being done by NOAA to update the NOAA Atlas for Northern California. The Contra Costa County Flood Control & Water Conservation District has taken action to have its data include the NOAA atlas update. The outcome of that update may provide a regional MSP map of much higher accuracy and consistency than Dwg. B-166.

At the publishing of this document, files for this project were saved at: **P:\GIS USERS - Development\FC\Hydrology\Projects\Isohyets**. We assume that after publishing, the official raster and feature class files will be copied or moved to another directory. They may also be renamed to match a particular naming convention.

MB:cw

G:\fldct\Hydrology\Hydrology Standards\Isohytes\11-09-09 Mean Seasonal Precipitation Raster from Drawing B-166.docx

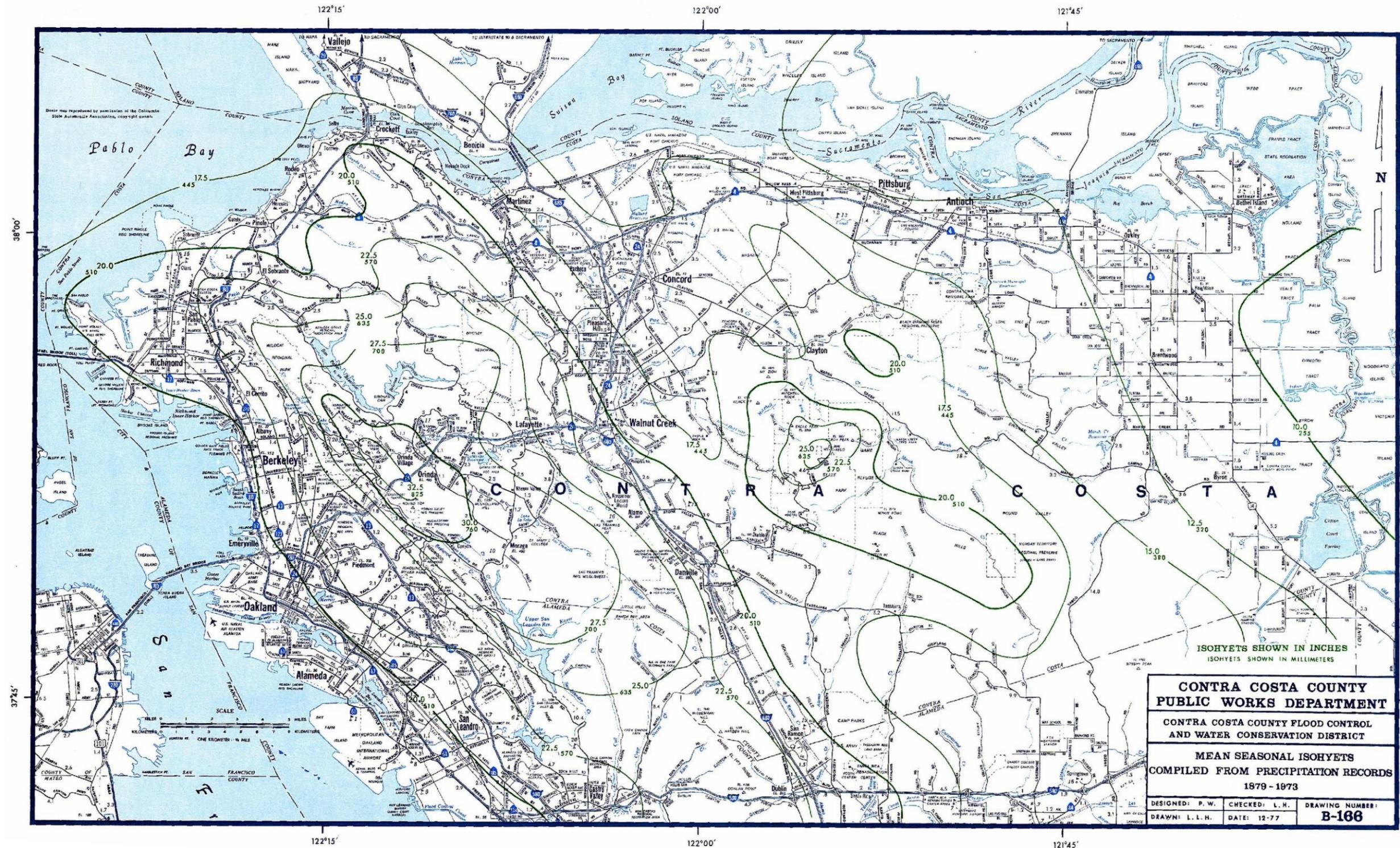
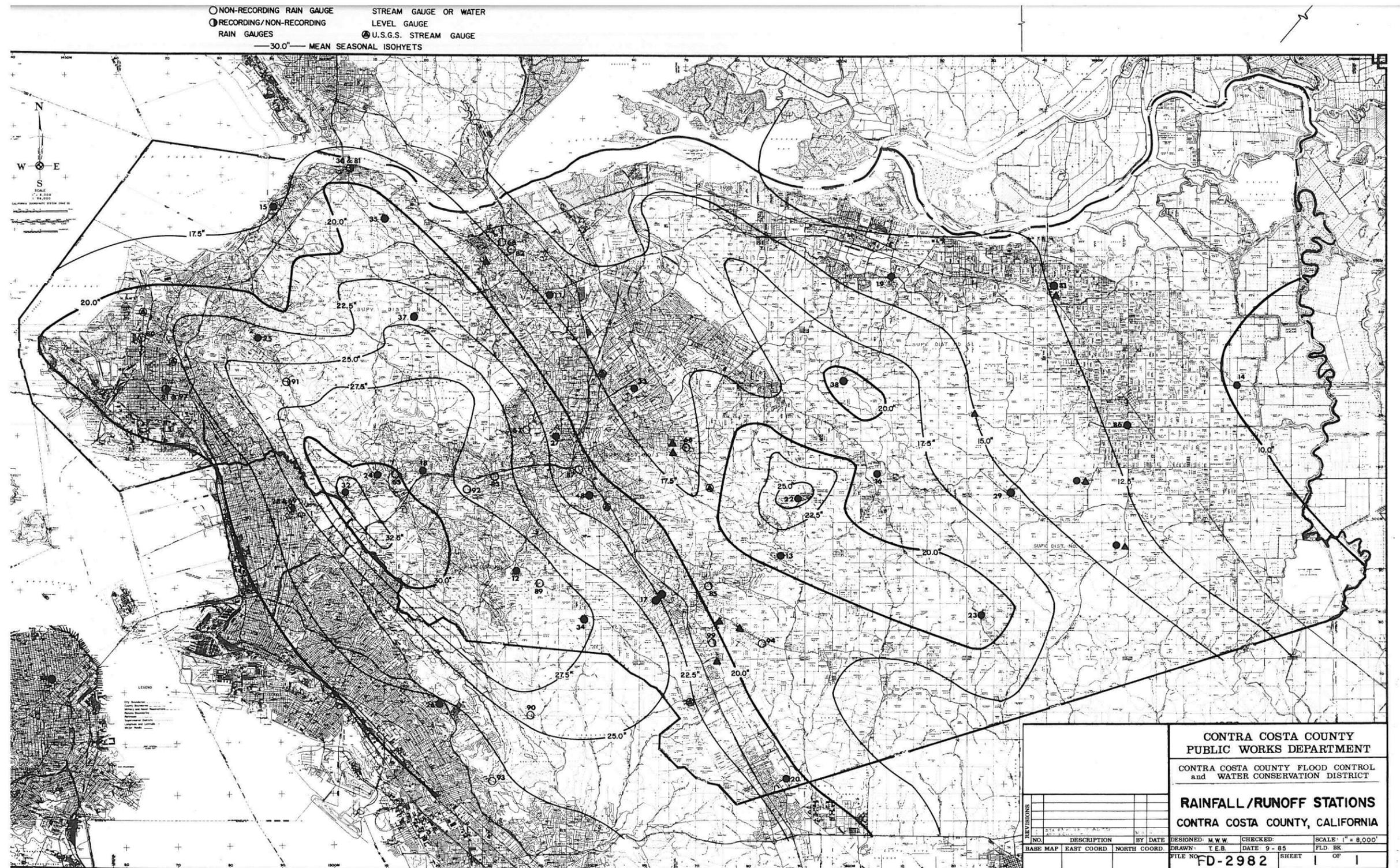


Figure 9



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Figure 10

Figure 11 Dwg. B-166 – Non-Georectified Image Overlaid on Georectified Image

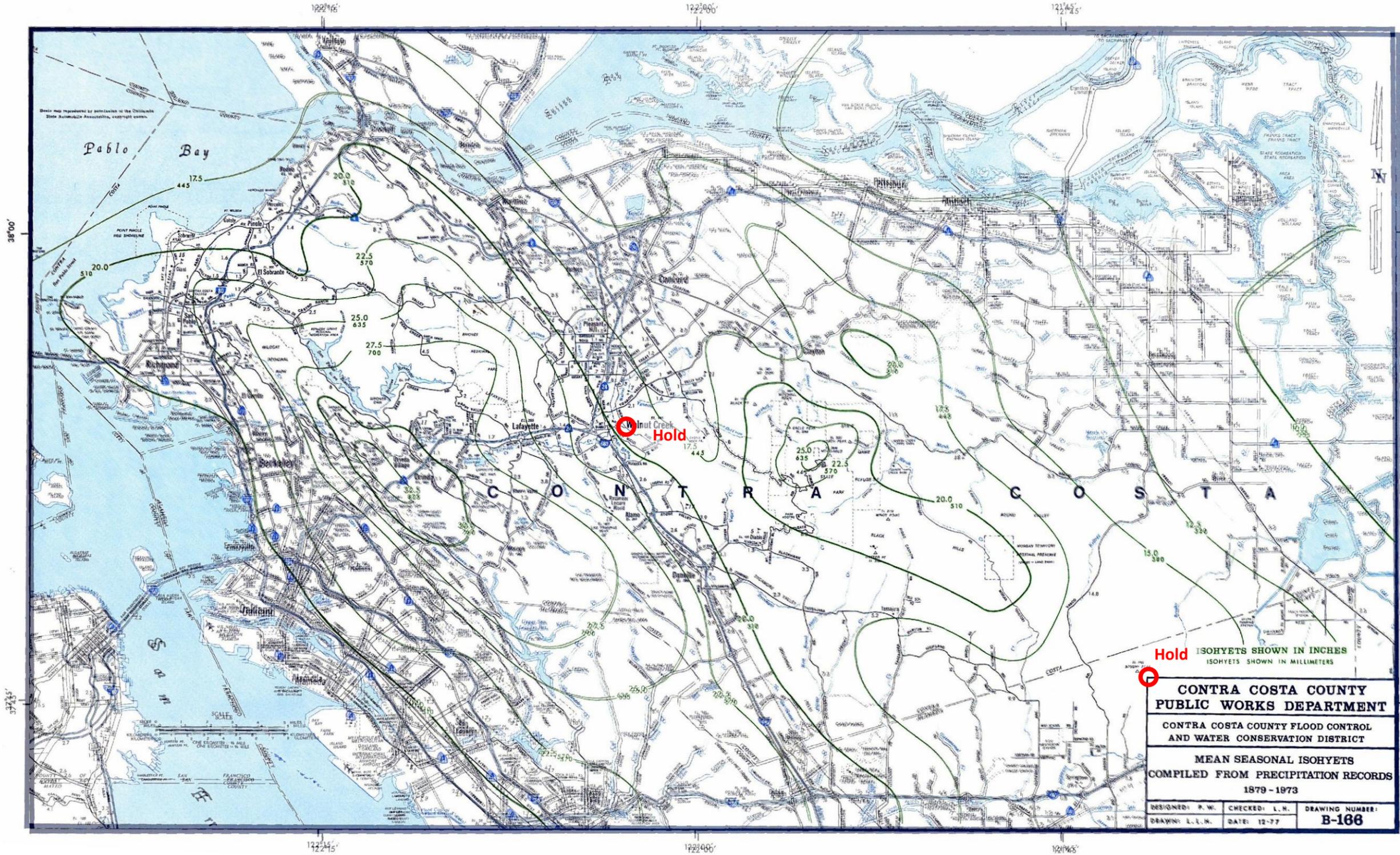


Figure 11

Figure 12 Georectified B-166 with Major Roads GIS layer

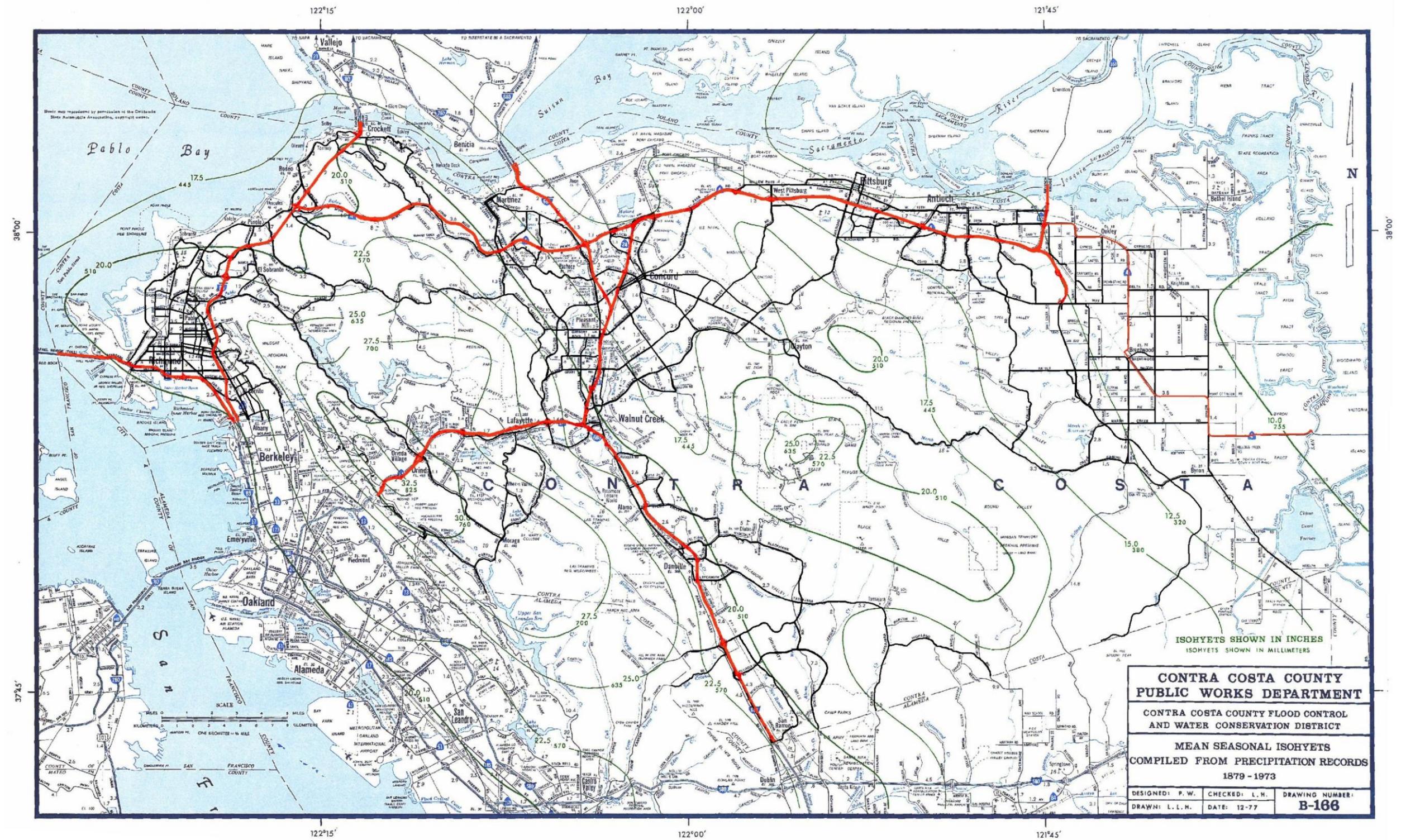


Figure 12

Figure 13 Georectified B-166 with Digitized Isohyets

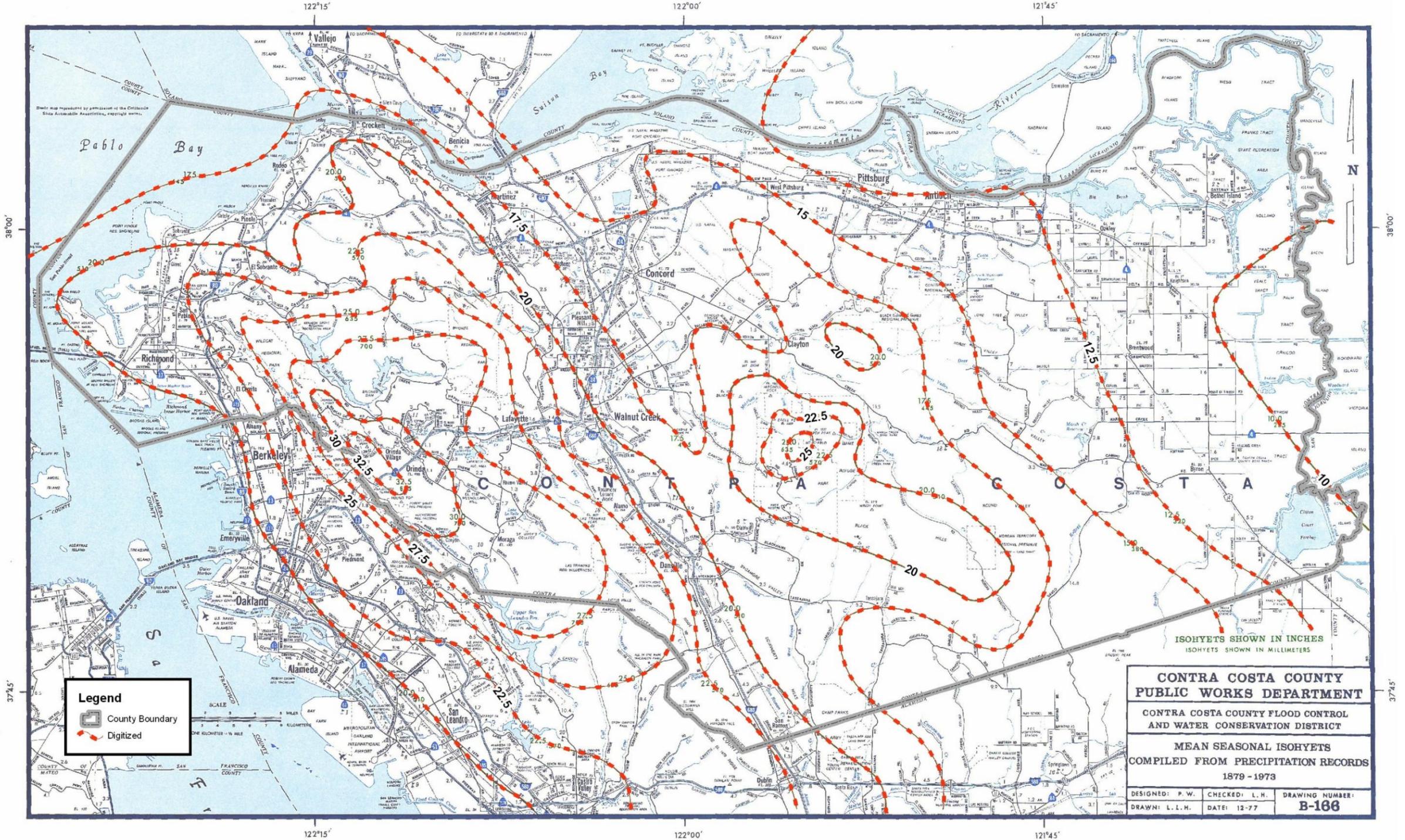


Figure 13

Figure 14 0.10-inch Interval Isohyets Based on Raster Built from 2.5-inch Isohyets

Key
 The "error" areas indicate locations where the isohyets are not generated as would be expected. This indicates the need for supplemental isohyets to "train" the MSP raster.

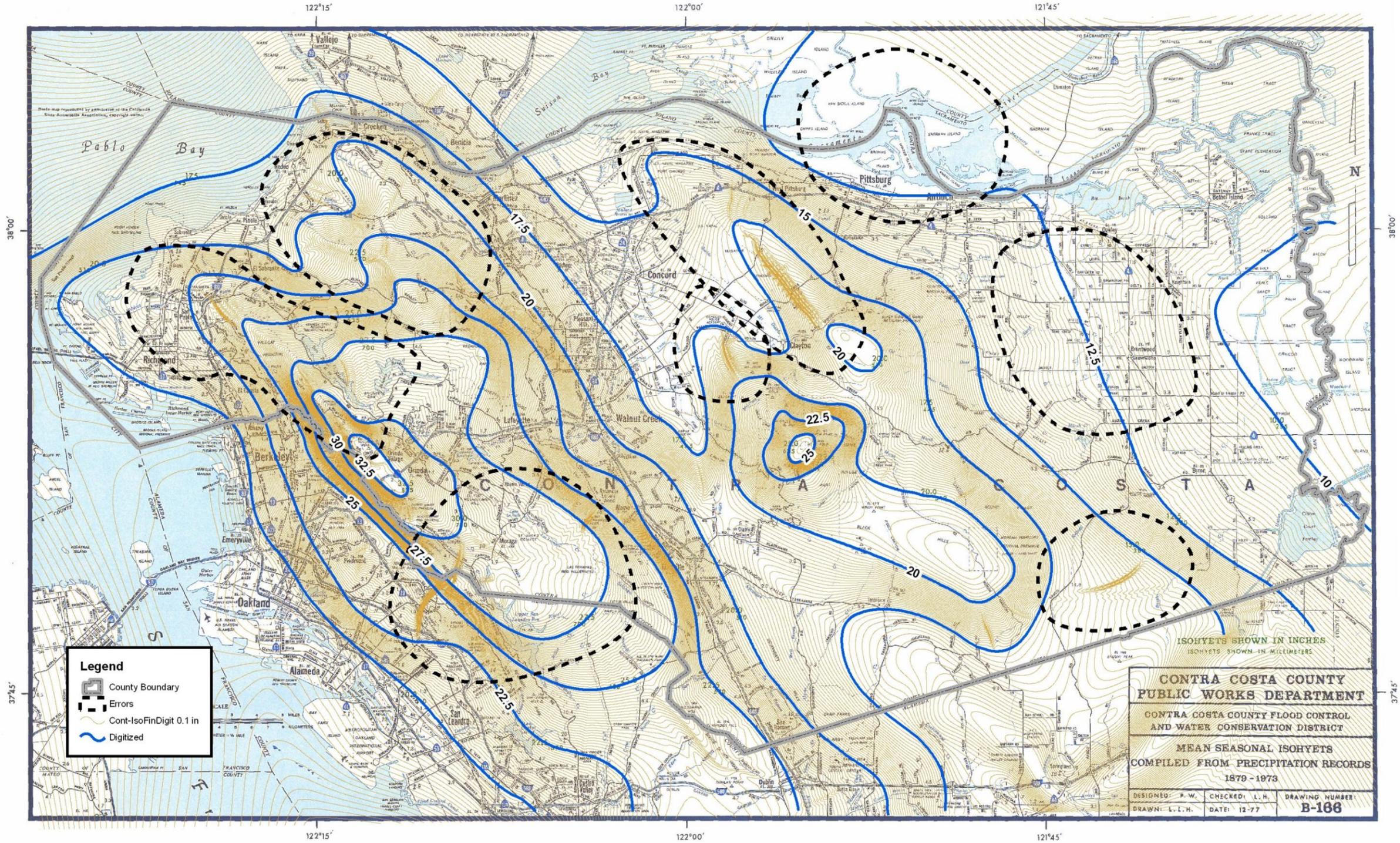


Figure 14

Figure 15 Supplemental Isohyet Example showing the “web” used to interpolate the B-166 Isohyets

Key
 The web lines were snapped to the primary isohyets to create the second level isohyets and to the second level isohyets to create the third level isohyets. The isohyets are snapped to the midpoint of the web polyline segments, effectively placing them exactly between higher-level isohyets.

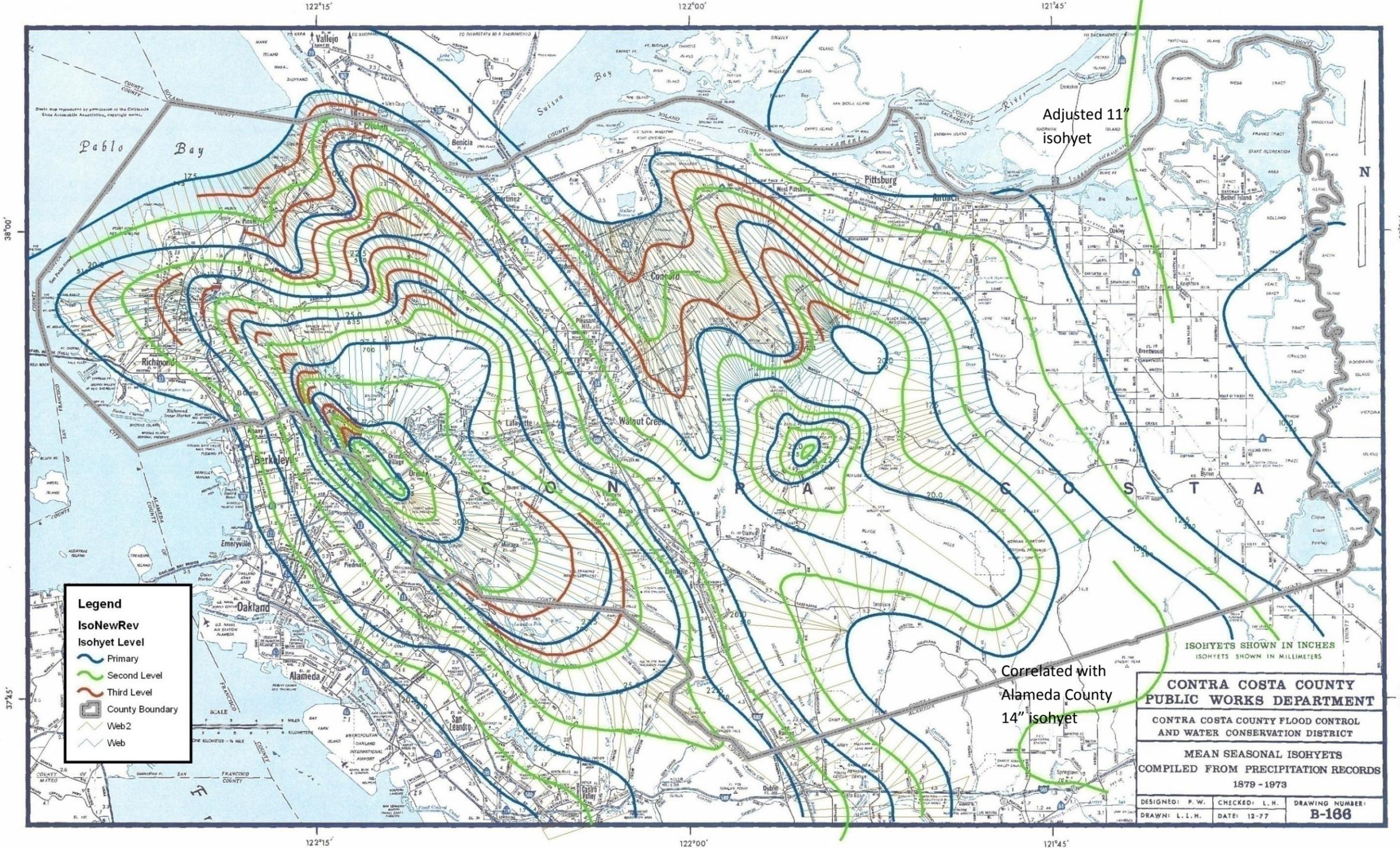


Figure 15

Figure 16 0.1-inch Interval Isohyets Based on Raster Built from Supplemental Isohyets

Key Note
 Isohyets produced outside of the primary isohyets are less and less valid the farther away from them that you get. These are trimmed in the final raster.
 The "error" areas indicate locations where the isohyets were not generated as would be expected. The supplemental isohyets from Figure 15 worked to correct these problems.

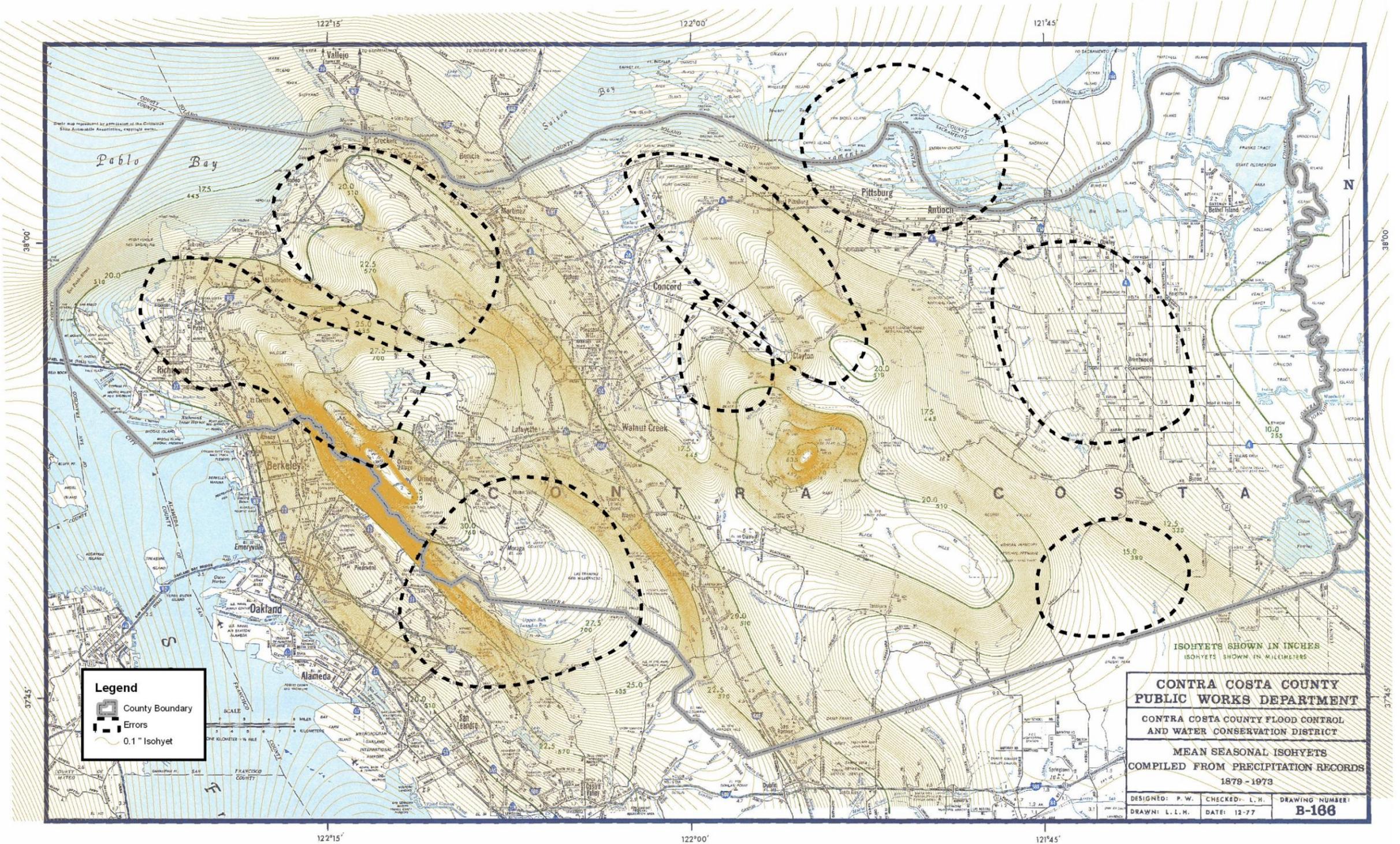
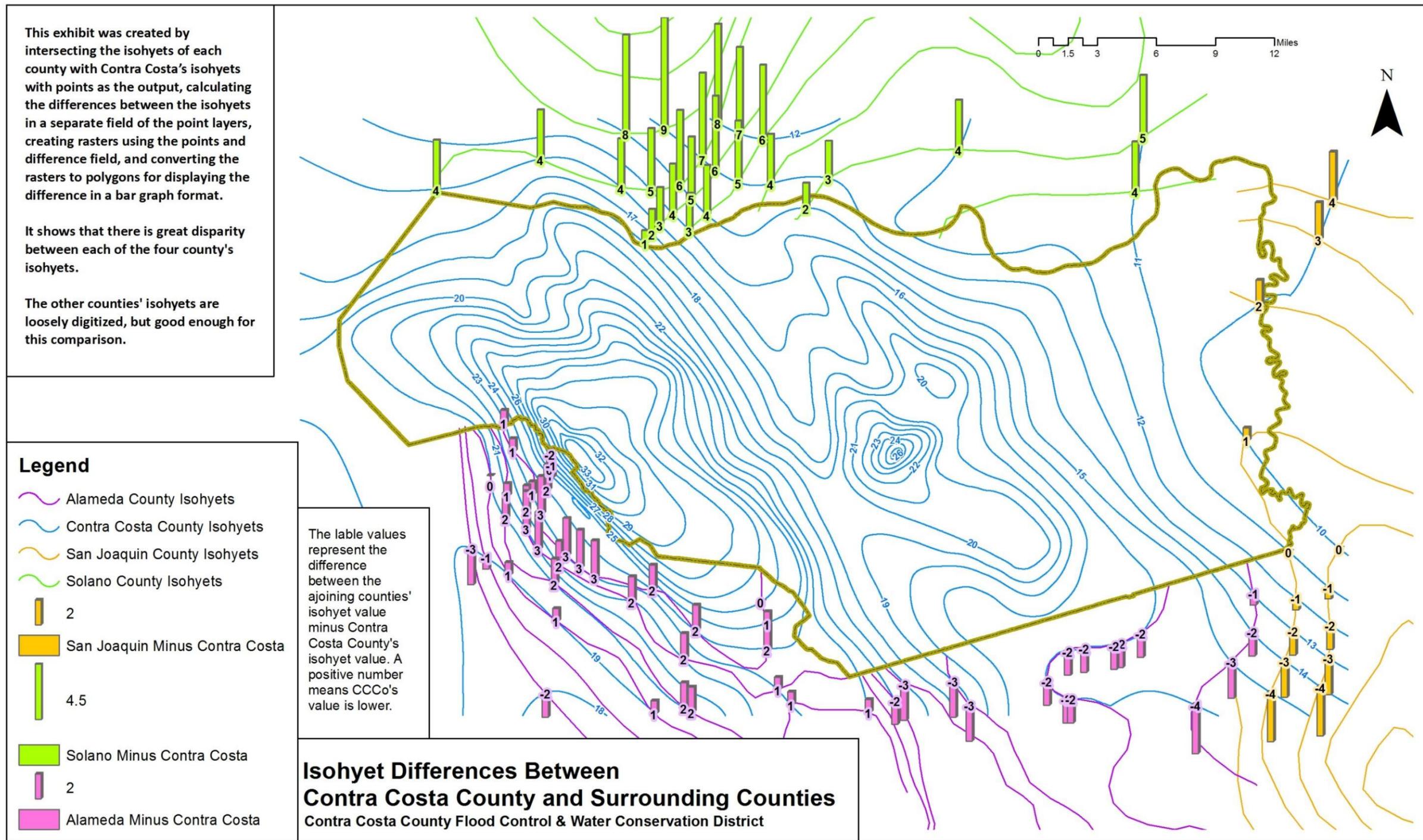


Figure 16

Figure 17 Comparison of Contra Costa County Isohyets with Surrounding Counties



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Figure 17

Corrected 11/29/2011

Figure 18 Final Mean Seasonal Precipitation Raster with 0.5-inch Isohyets

Note
 The final raster is clipped 1.0 mile outside of the Contra Costa County Boundary. The raster shown in this figure was clipped to fit with Dwg. B-166. The final raster is not clipped.

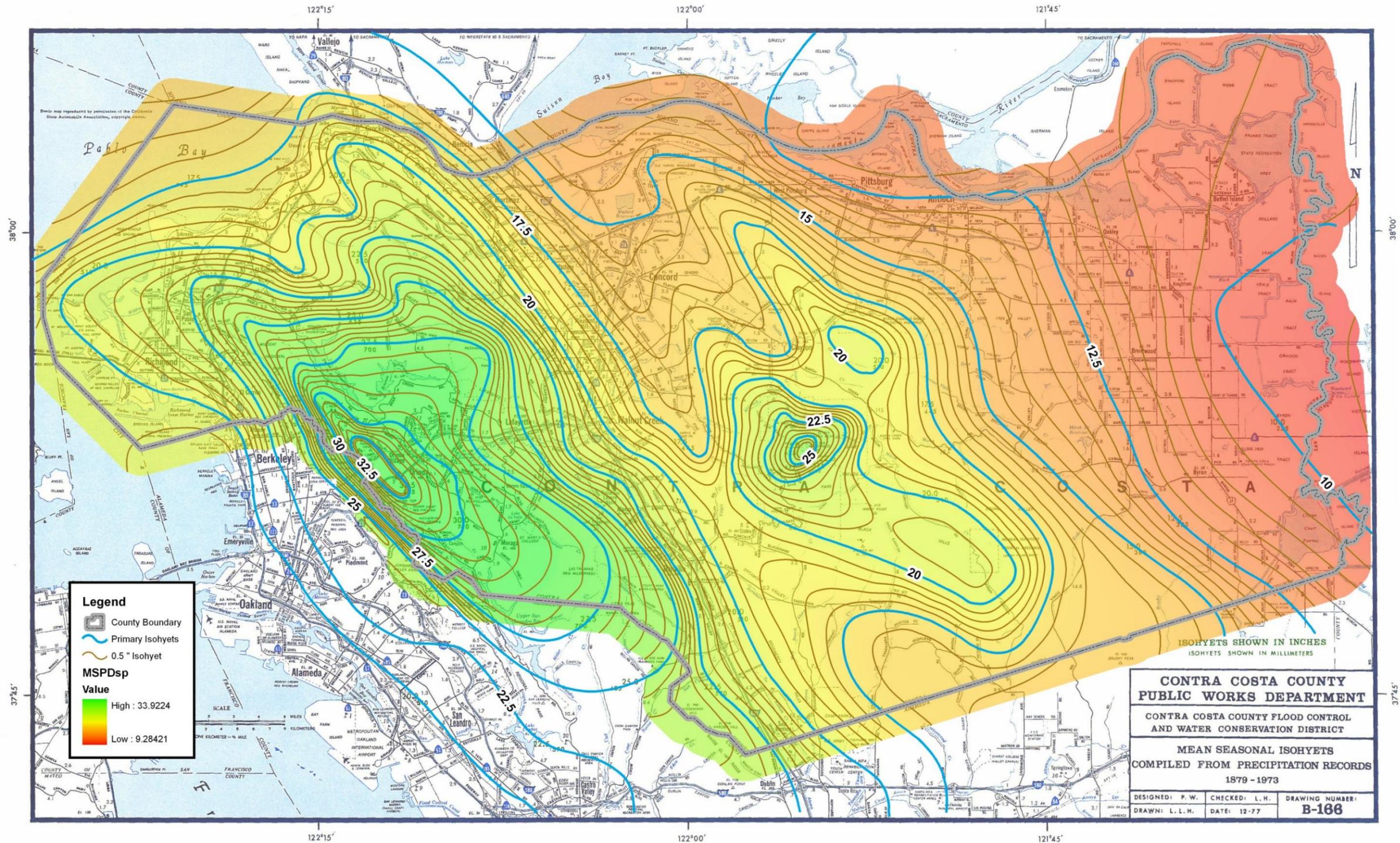


Figure 18

Figure 19 Final Mean Seasonal Precipitation Isohyets from MSP Raster

Note
 The final isohyets were clipped 1.0 mile outside of the Contra Costa County Boundary. The isohyets shown in this figure were clipped further to fit with Dwg. B-166 boarder.

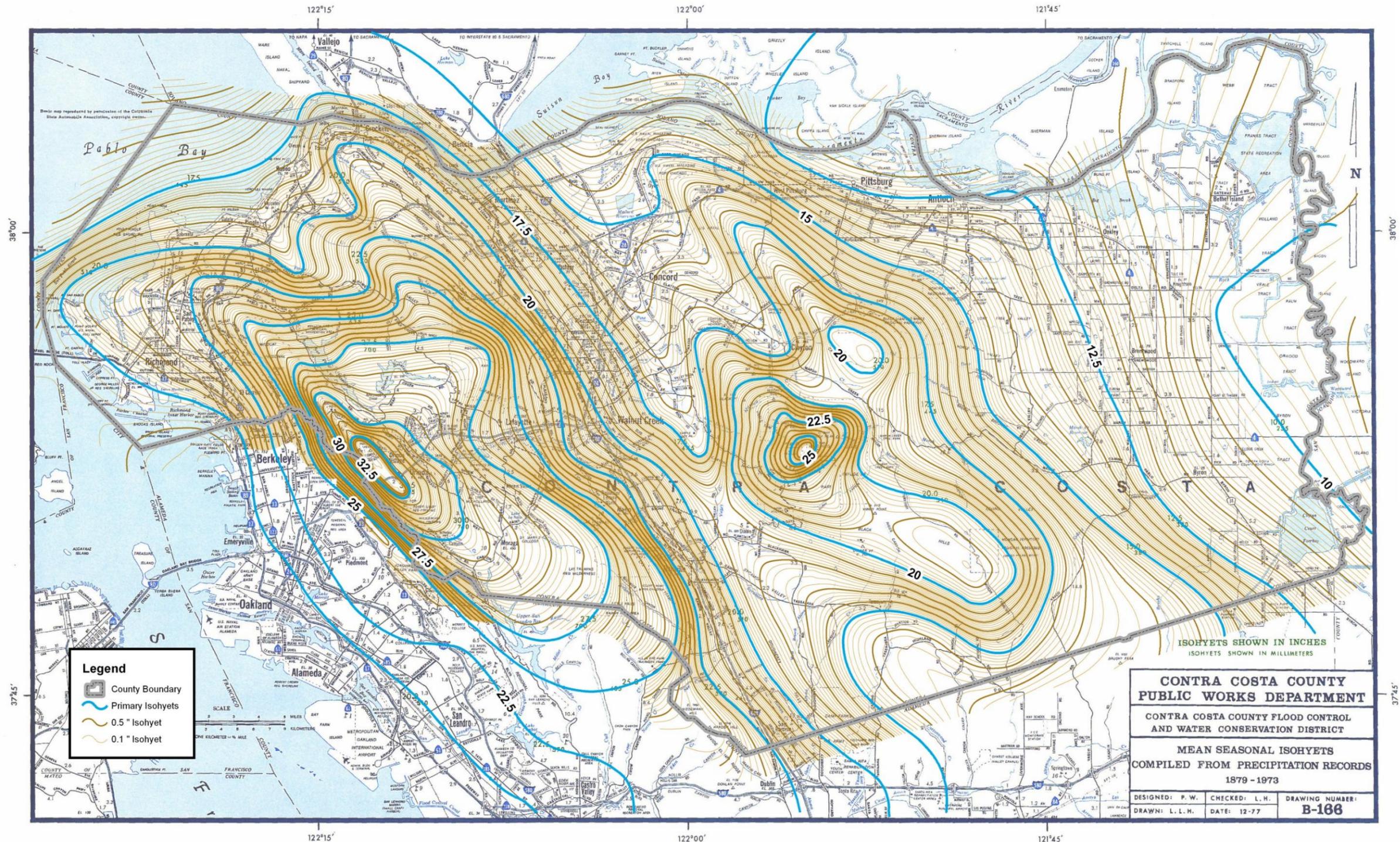


Figure 19

