Research Technical Completion Report Project A-086-IDA

REMOTE SENSING DETERMINATION OF HYDROGRAPH RECESSION CHARACTERISTICS

by

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ABSTRACT

A review of literature indicates that little work is being done on determining base or minimum flows from basin characteristics using remote sensing techniques. The majority of the work being done on base flows is by the use of mathematical models using information that can be obtained from topographic maps. Remote sensing techniques have been used mainly for determining water quality, inventories, and determining hydrological characteristics that could be determined from topographic maps as well. The effects of vegetation cover, unique geological factors, moisture content of soil, and weather patterns are recognized but not utilized within the mathematical models. Information obtainable by the use of remote sensing should be useful for revising existing mathematical models to provide more accurate predictions of not only base or minimum flows but of average and peak flows.

INTRODUCTION

The ability to predict minimum stream (base) flows in ungaged watersheds is a valuable tool in many areas. Short-term reservoir regulation, flood warning, forecasting assured streamflows, system planning for water supplies, recreation facilities, and natural resources preservation are examples in which prediction would benefit. Minimum flows in the past have been determined largely by various methods which depend upon hydrographs developed from gaging station records. It is difficult to correlate and predict minimum flows from these records to ungaged areas. New remote sensing techniques could be used for determining watershed characteristics from which minimum flows could be predicted, thus improving prediction capabilities.

A computer search of published literature has been done to determine the extent of research using remote sensing to determine base flows. Existing remote sensing techniques were also reviewed to determine if such an approach is realistic. A bibliography resulting from this review of published literature pertinent to the remote sensing and minimum flow has been included at the end of this report.

Recent research has shown a need for determining realistic factors associated with basin characteristics and base flow. It appears that in predicting flows from high ranges to low ranges that the midrange flow predictions were more accurate than the high range and the high range predictions were more accurate than low flows (Hall). The need for accurate forecasting of base flows has been established for ungaged basins by Thomas (1970), Osborn (1974), and Wilson (1979). The problem has been in arriving at reliable indices for the many factors that affect base flow. To date, basin area, length, slope, elevation and precipitation have generally been the main items used to predict low flows. Thomas and Benson (1970) have listed many of the various items affecting low flow and recognize the problems in dealing with all the variables. Generally the problem has been approached by using information obtained from gaging stations of a particular drainage basin and applying it to a similar ungaged basin, or by developing mathematical models of a watershed using computer solutions. Recent advances in remote sensing techniques, combined with the above methods, would be quite useful in predicting realistic base flows.

Most recent research on the subject of base flow has used the geomorphic characteristics of stream length, basin length, perimeter, relief, width, area, drainage density, elevation and channel slope combined with precipitation. Some work has been done considering evaporation and transpiration where cutting and herbiciding decreased the rate of recession (Federer).

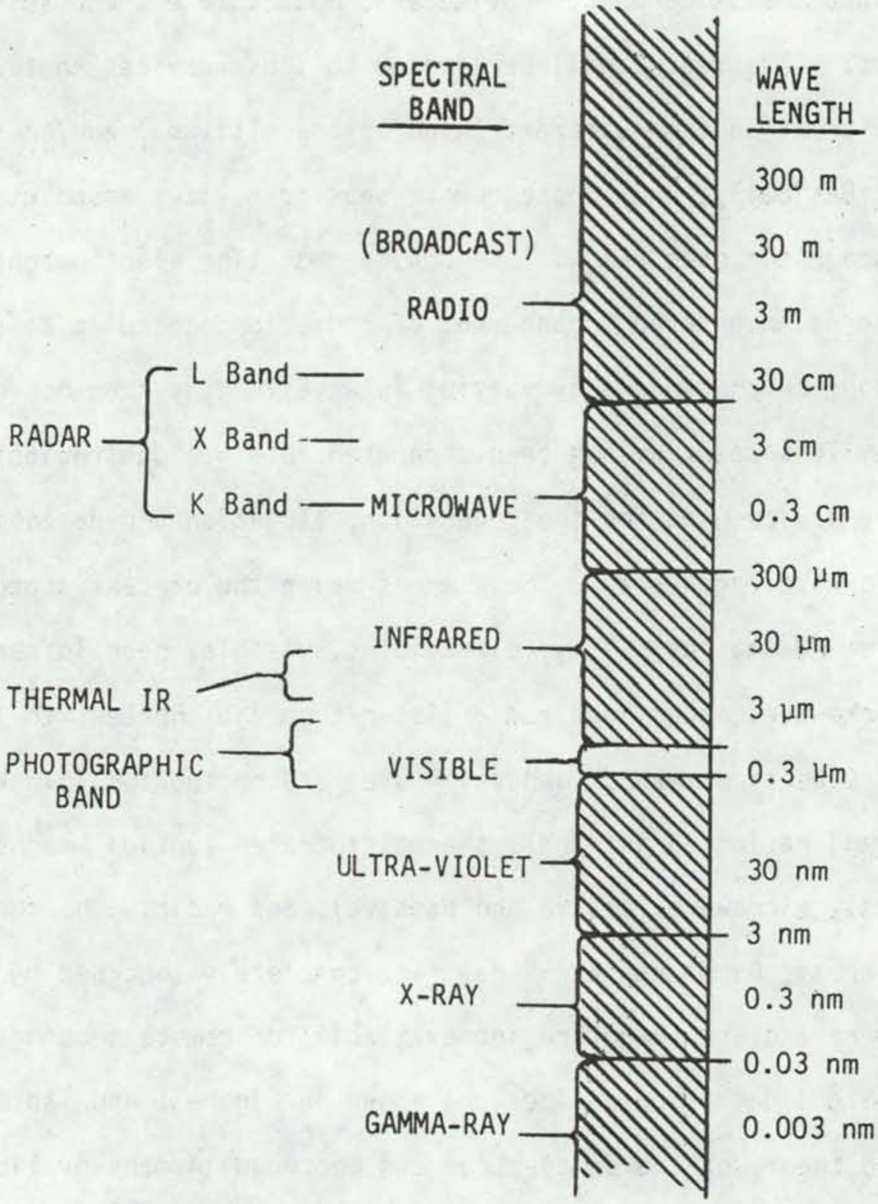
Other sources reviewed have included items such as surface storage, forested areas, soils index, alluvial area, channel characteristics, mean annual precipitation, mean monthly precipitation, snow, precipitation intensity, average annual evaporation, thunderstorm days, temperature, last major storm, azimuth, latitute and longitude (Minshall (1968), Thomas (1970), Aron (1973), Farvolden (1973), Bingham (1979)). This research indicated that remote sensing techniques have not been used to full advantage for determining base flow.

REMOTE SENSING

Remote sensing is the measurement or collection of information concerning some property of an object by a recording device that is not in physical contact with the object. This information can be obtained by measurements of force fields, electromagnetic radiation or acoustic energ Devices used are cameras, lasers, radio frequency receiving radar systems, sonar, seismographs, gravimeters, magnetometers and scintillatio counters. This report will be limited to those devices that can gather this information from aircraft (high or low altitude) and/or space platforms. Basically, only those remote sensing devices associated with the electromagnetic spectrum will be considered. The electromagnetic (EM) spectrum is an ordered arrangement of radiation according to wavelength, frequency, or photon energy varying in wave lengths from microns to kilometers. This spectrum has been separated into various regions depending upon the device used for the generation, isolation and detection of the specific wavelength area. These areas using the present state of the art, are: Gamma ray, X-ray, ultraviolet, visible, near infrared, infrared, microwave, radar, and radio listed from the shortest to longest wave lenth. Detection methods generally used are photograph (black and white, color, and reflected infrard), thermal infrared (optical-mechanical scanners), microwave (active and passive), and radar. The shortest wave length areas, Gamma ray and X-ray, are completely absorbed by the upper atmosphere and are therefore not available for remote sensing. The EM spectrum and detection devices are shown in Figure 1 and Table 1. More detailed theory of the EM spectrum can be found in many publications.

REMOTE SENSING AND HYDROLOGY

The application of remote sensing to hydrology, especially base flows, will be discussed in sections according to the detecting tool:



REMOTE SENSING BANDS
WITHIN THE ELECTROMAGNETIC SPECTRUM

Figure 1

Ultra-violet, visible photographic range, infrared, and the microwave and radar range.

A. ULTRA-VIOLET

The ultra-violet wave length is the least useful remote sensing tool considering the present state of the art. Ultra-violet wave lengths less than 0.3 μm are completely absorbed by the atmosphere and those between 0.3 and 0.4 μm which are detectable on film are severely scattered. The range between 0.4 and 0.7 μm can be detected on film and photodetectors but at present this range has been used only to monitor oil films because of the fluorescent characteristics. It is possible that this characteristic could be helpful in determining some types of geological forms. It appears that ultra-violet detectors would be of little advantage in hydrology or base flow studies.

B. VISIBLE PHOTOGRAPHY

The oldest and most widely used remote sensing tool is photography, which includes black and white, color, and infrared color film. All have their own advantages and disadvantages, but they all have in common the ability to provide stereoscopic viewing which is necessary to obtain accurate geometry of the terrain. The most obtainable photography is, of course, black and white. Stereo coverage of most of the United States is obtainable from various altitudes and at a modest price. Overlapping or stereo coverage is necessary in order to accurately determine items such as area, slope and relief. Photointerpretation is limited using black and white photographs but some geology, plant forms, and water can be distinguished. Black and white photos can be enhanced by the proper combinations of film and filters to acquire wave lengths ranging from 0.7 to 0.9 μm which is reflected solar radiation or photographic infrared energy. This process does improve photointerpretation but still has the disadvantages of black and white film as compared to color.

Recent improvements in the technique of producing mapping from stereo-photos using color film has all but eliminated the usefulness of black and white film except for cost of film. However, at the present time there is limited coverage of most areas of the United States in color film. As more coverage is acquired it is generally worth the extra cost to provide color. The human eye can distinguish many more shades of color than it can tones of gray. Color also is an indicator of vegetation, water, and soil types. Infrared (IR) sensitive color film also can be used to enhance photointerpretation the same as black and white IR film. Basically the IR color film is sensitive to the 0.5 to 0.7 μm wave lengths and blue light is eliminated by the use of a yellow filter. Therefore, green leaves are recorded in various shades of red depending on type and how healthy they are. IR color film is not sensitive to heat as is true of thermal IR which will be discussed later. Color and IR color photos can be used stereoscopically for determining area, slope, etc. and for photointerpretation concerning vegetation and water areas. IR color also has additional advantages such as the ability to distinguish the difference between vegetation and water when mapping drainage areas, especially in heavily forested terrain, and in recognizing damp ground. Certain geological forms are also easier to detect on the IR color photograph.

C. THERMAL INFRARED

Infrared information is obtained from that portion of the electromagnetic spectrum ranging in wavelength from 0.7 to 300 μm (which includes the reflected IR range). The thermal infrared range basically covers the wavelengths from 3 to 14 μm and since this range is completely absorbed by glass lenses, special detection and optical-mechanical scanners are used to detect and record images. Thermal infrared radiation is not transmmitted uniformly and the narrow band between 9 and 10 μm is absorbed by carbon dioxide, ozone, and water vapor. The band between 3 to 5 μm, the shorter wave lengths, indicates higher temperatures and is useful for detection of forest fires and volcanoes. The band between 8 to 14 μm corresponds to the 9.7 μm radiant peak of the earth and therefore is ideal for remote sensing. Data generated by the thermal infrared scanner would be useful for hydrology studies because of the ability to determine 1) vegetation cover and land use 2) vegetation stress 3) groundwater determination and 4) classification of geological structure.

The time of day data are acquired is important because of the effect of differential solar heating. During the day water bodies have a cooler surface temperature than earth. At night the surface temperatures reverse and the thermal image of water bodies will have warmer indications than the surrounding soil. Damp ground will always be cooler because of the evaporation which causes a cooling effect. Vegetations also have different images depending upon the time, water content and type. For geological interpretation, night time or predawn imagery is generally desirable because of the decreased effects of differential solar heating. The cost of obtaining IR imagery will be at least three times the cost of aerial photography and existing coverage is not as available as aerial photography.

D. MICROWAVE OR RADAR

Microwave wavelengths cover the 0.3 to 300 cm portion of the electromagnetic spectrum. For all practical purposes the term microwave is used when referring to passive imagery systems and the term radar when referring to active imagery systems. The imagery produced from detection of enery radiated by the earth is passive and that detected by the reflection of radio waves from solid objects is active (Radar or Radio Detection and Ranging). Passive systems depend upon the temperature and emissivity of the surface while active systems depend on the surface roughness and detective properties.

Three general bands or wavelengths generally are used for acquiring radar images. These classification and their associated average wavelength are: K-band, 1.5 cm; X-band, 3 cm; L-band, 25 cm. The longer wavelength bands are more capable of penetrating precipitation or beneath a surface. The transmitted energy tends to be polarized in either the vertical or horizontal plane; upon striking the earth the return energy has the same polarization. The energy thus recorded is designated HH (horizontal transmit and horizontal return) or VV (vertical transmit or vertical return). There also tends to be a depolarization which is attributed to the multiple reflection of uneven surface characteristics. Some radar systems use a second antenna system that receives the depolarized energy; this imagery is termed cross polarized and may be HV (horizontal transmit and vertical return) or VH (vertical transmit and horizontal return). The HH image is the most common because it produces the strongest return signals. The different images can produce important information for interpretation of items such as vegetative cover, geology and moisture contact.

More detailed information about passive and active systems may be found in publications such as the "Manual of Remote Sensing" published by the American Society of Photogrammetry and from texts such as the one by Floyd F. Sabins, Jr. entitled "Remote Sensing Principles and Interpretations".

CONCLUSIONS

Remote sensing imagery can be used to develop and extend basic characteristics for determining base or minimum flows. Black and white and color photography are available in stereoscopic pairs for determination of basic geomorphology such as area, basic slope, relief, etc. Color IR and thermal IR may be available (or economically feasible to obtain) as an aid in determining vegetation cover, geology monitors, and other characteristics. Microwave imagery may also be available covering some areas for additional geological and moisture determination. Active and passive microwave imagery is especially applicable to hydrological problems because of the all-weather capability of microwave sensors and because of the dominant interaction of moisture within the earth's surface due to its distinctive properties. Table 1 indicates the various remote sensing imagery and its application to basin characteristics including the effect of time, weather and altitute to achieve the desired results.

Future satellite missions more than likely will be equipped with multi-spectral sensors such as visible, color-infrared, thermal infrared, and passive and active microwave. This type of system combined with digital image processing can integrate various types of information including graphical and tabular data into a data base. One existing system developed by the Jet Propulsion Laboratory's Image Processing Laboratory is the VICAR/IBIS (Video Image Communication and Retrieval) (Franz (1980), Smith (1980)). The VICAR/IBIS (Image Based Information System) system is presently available thru DIAL (Digital Image Analysis Laboratory) at the Washington State University Computing Service Center.

Another area of interest is the effect of weather patterns such as the direction of storms and intensity. The use of weather satellite

TABLE 1
HYDROLOGICAL CHARACTERISTICS AND REMOTE SENSORS

HYDROLOGICAL CHARACTERISTICS	ULTRA-VIOLET UV				VISIBLE OR PHOTOGRAPHIC RANGE: Black & White B&W				Color C			
	T	W	S	P	T	W	S	P	T	W	S	P
VEGETATION a) Forests b) Shrubs c) Grasses ROCK a) Rock (Boulders) b) Outcrops c) Cliffs (Barriers) SOIL a) Bare b) Dry c) Wet WATER a) Streams b) Rivers c) Lakes d) Water Sheds	DAYLIGHT	CLEAR	NOT APPLICABLE	LOWER ALTITUDES	DAYLIGHT WITH MINIMUM SHADOWS	CLEAR	USEFUL	ALL ALTITUDES INCLUDING SATELLITE	DAYLIGHT WITH MINIMUM SHADOWS	CLEAR	USEFUL	ALL ALTITUDES INCLUDING SATELLITE
TOPOGRAPHY a) Elevation b) Slope c) Terrain Changes (Relief) d) Channel Gradient e) Slope Length f) Zonal Variation g) Area							NECESSARY				NECESSARY	

HYDROLOGICAL CHARACTERISTICS	VISIBLE OR PHOTOGRAPHIC RANGE: Infrared Color IC				THERMAL INFRARED IR			
	T	W	S	P	T	W	S	P
VEGETATION a) Forests b) Shrubs c) Grasses ROCK a) Rock (Boulders) b) Outcrops c) Cliffs (Barriers) SOIL a) Bare b) Dry c) Wet WATER a) Streams b) Rivers c) Lakes d) Water Sheds	DAYLIGHT WITH MINIMUM SHADOWS	CLEAR	USEFUL	ALL ALTITUDES INCLUDING SATELLITE	NIGHT BEST BUT KNOWLEDGE OF TIME NECESSARY	AFFECTED BY HEAVY CLOUDS AND WIND	NOT APPLICABLE	LOWER ALTITUDES 5000' GENERALLY OPTIMUM
TOPOGRAPHY a) Elevation b) Slope c) Terrain Changes (Relief) d) Channel Gradient e) Slope Length f) Zonal Variation g) Area			NECESSARY					

HYDROLOGICAL CHARACTERISTICS	MICROWAVE OR RADAR RANGE: K BAND				X BAND				L BAND			
	T	W	S	P	T	W	S	P	T	S	W	P
VEGETATION a) Forests b) Shrubs c) Grasses ROCK a) Rock (Boulders) b) Outcrops c) Cliffs (Barriers) SOIL a) Bare b) Dry c) Wet WATER a) Streams b) Rivers c) Lakes d) Water Sheds	ANY	AFFECTED BY RAIN SNOW AND/OR SLEET	USEFUL	ALL ALTITUDES INCLUDING SATELLITE	ANY	AFFECTED BY HEAVY THUNDERSTORMS	NOT APPLICABLE	ALL ALTITUDES INCLUDING SATELLITES	ANY	UNAFFECTED BY PRECIPITATION	NOT APPLICABLE	ALL ALTITUDES INCLUDING SATELLITES
TOPOGRAPHY a) Elevation b) Slope c) Terrain Changes (Relief) d) Channel Gradient e) Slope Length f) Zonal Variation g) Area			NECESSARY				NECESSARY				NECESSARY	

T = TIME OF DAY

W = WEATHER CONDITIONS

S = STEREOSCOPIC

P = PLATFORM
(Generally the lower the altitude the more information gained)

imagery may be a useful tool in providing more accurate forecasts of basin hydrologic response. A study of weather patterns in specific areas could produce very useful information in determining storm direction in relation to basin configuration. It appears that there is little or no research in this area.

Research at this institution could be limited by availability of equipment. At the present time the only equipment available for determining items requiring stereoscopic viewing are outdated Balplex and Kelsh plotters. The College of Forestry has some digitizing equipment and of course there is access to the VICAR/IBIS system at WSU. Obtaining photographs and tapes through various government agencies could also require funds.

Based on the findings of this report, it is recommended that additional research be initiated, with consideration of availability of existing remote sensing imagery covering an area in Idaho that has stream gaging information. Hydrological models should then be developed using half the gaged basins and checking against the remaining gaged basins for reliability. The feasibility of using satellite weather information to establish storm patterns and their relatively to hydrology should also be investigated.

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16. Abstract

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17a. Descriptors

*Remote sensing, Hydrology, Base flow, Photogrammetry, Basin characteristics, Precipitation, Groundwater.

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