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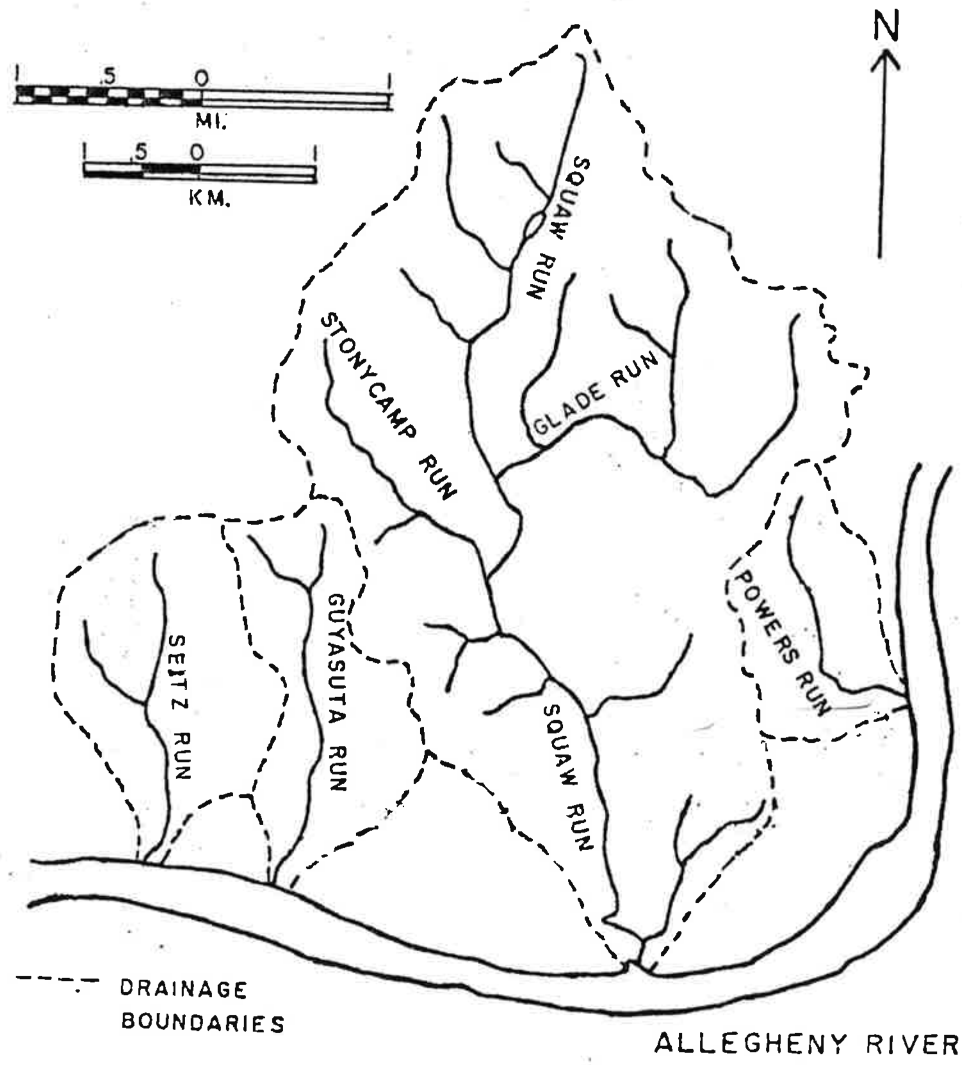
NOTE: Mapped terms are underlined throughout.

SQUAW RUN AREA WATERSHED ASSOCIATION

The Squaw Run Area Watershed Association, Inc., is a tax-exempt, non-profit corporation dedicated to identifying, studying, educating, and responding to environmental concerns; and to advancing solutions and policies which represent a synthesis of economic, social and environmental factors. It was founded and incorporated in 1976. It is interested primarily in the Squaw Run Area Watersheds, which are mapped below. Membership is open to all individuals and organizations; current members include municipalities, citizens' organizations, corporations, developers, and interested citizens. Recent activities have included: 1) detailed topographic and planimetric mapping of the Squaw Run Area at 1"=200' with five-foot contours, 2) portions of a Natural Resource Inventory of the Area, including the detailed mapping of landslide hazard, 3) scientific studies of the impacts of urbanization on the Area's hydrology, 4) educational symposia and workshops, 5) educational and evaluative field trips to valuable and environmentally critical portions of the Area and to important sites elsewhere, 6) lectures to citizens' groups and school students, and 7) participation in county and regional environmental steering committees and task forces. SRAWA and its officers have received awards for conservation activities from the Allegheny County Conservation District, Soil Conservation Society of America, and the Pennsylvania Association of Conservation District Directors, Inc.



I. INTRODUCTION

1. Purposes of this Plan

This report describes the natural environment of Fox Chapel, the implications of that environment for Borough values, and what the Borough can do about it. This study is a foundation for land use ordinances and other Borough programs. It is also a body of scientific evidence to defend Borough actions in court, and a basic factual reference for those who would plan with the environment in the future. Its technical, decision-supporting function has not been met by any other activities in the Borough or the surrounding region.

Fox Chapel Borough authorized the Squaw Run Area Watershed Association to perform this study in a contract dated February 20, 1979, pursuant to Article III of Borough Ordinance No. 361, the "Natural Resources Assessment and Protection Ordinance." That contract specifies "an environmental study identifying the Borough's natural resources and environmental problems, and recommending a program for the conservation of those natural resources and the solution of the environmental problems."

Other persons and organizations will be able to use this Plan. The Guyasuta Joint Municipal Planning Commission (of which the Borough is a member) can apply our research data and performance specifications to much of its region; our mapping format was designed with this in mind. The Allegheny County and Southwestern Pennsylvania Regional Planning Commissions can designate this Plan as an area component of regional studies and plans. Other local governments in the Pittsburgh metropolitan region can apply our findings to their own land use management needs.

2. Synopsis of Recommendations

Our recommendations are in many areas of Borough activity. In this synopsis many important concepts are stated briefly and non-technically. In implementing them, full use must be made of the technical matter in the text in order to get the full and sound environmental benefit. Tables and charts are given in the text to allow the easy calculation of any quantitative concepts.

A. Ordinances

Our recommendations for land use ordinances are substantive only. Writing them into ordinances will require coordinating them with other aspects of Borough ordinances and the Pennsylvania

Municipalities Planning Code. At the time they are written, it would be worthwhile to review and coordinate the Borough's suite of land-use ordinances as a whole to reduce conflicts.

The recommendations are:

* All homes, roads, sewers, pump stations, lawns, other used facilities, and all construction areas (the areas cleared and graded for construction) must be located outside all floodplains, even those of small drainage swales, except at unavoidable road and utility crossings. All roads and the tops of all manholes located in a floodplain must be above the flood elevation. Such placement will prevent flood damage; help prevent urban stormwater flows, road salts, lawn fertilizer and construction sediment from damaging streams; and help preserve the productivity, diversity and other values of the aquatic ecosystem.

* Floodplain reaches that are not crossed by roads or utilities must be specifically protected from disturbances by physical controls of sedimentation and other hazards at the nearby construction area boundaries.

* Unique botanical areas and areas containing rare species (all of which are identified in our maps) must be preserved in their entirety, for ecological, educational and scenic reasons. They must be protected from nearby construction by specific physical controls.

* These runoff and sediment control standards are applicable at any point on a construction area boundary: peak runoff flow after development must not exceed that before development at recurrence intervals of 10 to 50 years. Runoff flow volume must not exceed that before development at the 2-year recurrence interval. No sediment may be released from construction areas.

* All primary drainage systems (those that regularly drain streets, gutters, etc.) must be designed to convey flows at the frequency standards listed in the Pennsylvania Department of Environmental Resources' "Guidelines for preliminary stormwater plan and model ordinance" (draft, 1980). Runoff that overflows the primary drainage system must be conveyed without damage to homes, roads, and other used facilities. Groundwater must be diverted from the foundations of used facilities with foundation drains.

* The area of ponds and wetlands, the number of waterfalls, and the area of cliffs must not be reduced during development. All these features are valuable visual resources.

* The terrestrial area left in successional vegetation on high-productivity land must be at least 50% of that before development. This will ensure future maturity, productivity, diversity and rare species presence in the site's forests. In addition, the total

forest canopy area after development (preserved plus planted) must be at least 75% of that before development. This will preserve the natural forest character of the Borough.

* The overall terrestrial productivity, potential productivity, and species diversity on a site after development must be at least 50% of that before development. In addition, the most mature ecological community on a site after development must be as mature as that before development. This will assure the continued diversity, productivity and other values of the terrestrial ecosystem.

* No new shade-making object of any kind may be placed in the solar "window" of any point on another property at which the placement of a structure is permitted by the Borough Zoning Ordinance, to preserve solar access.

* The lengths of sewers and roads must be minimized in site plans. This will help prevent water pollution by sewage and road salts.

* Existing ponds below golf courses should be maintained as pollutant traps, with dredge spoils disposed updrainage. Campbell's Lake should be similarly maintained as long as the Ottawa treatment plant operates uncontrolled by Fox Chapel.

* For either foundation support or cut slope stability, the supporting slope gradient must be 25% or less when the hazard of the supporting rock formation is "moderate" or "high," unless an adequate engineering solution is documented by a soils engineer.

* The detailed construction of drainage conveyances and other land use components should be modified in certain ways given in the text.

B. Development Evaluation

Land use ordinances will be worthless without vigorous enforcement of them in preliminary review, final review, and construction.

The following evidence maps should be required as part of all preliminary (or tentative) development proposals, all on the same scale:

1. Inventory of important site characteristics. This may be a reiteration of this report's findings, or a new, more detailed survey.

2. Inventory of Borough standards applying to the above characteristics, such as floodplain preservation, landslide-slope requirements, etc.

3. Schematic land use plan, showing construction areas, construction boundary controls, road and utility alignments, etc.

4. Site plan, showing the filling out of the designated construction areas with the desired facilities, construction area boundaries and their controls, primary and secondary drainage routes, and so on.

These maps form a logical sequence which will help designers to set up their plans in a way that will promote compliance with Borough ordinances. The Borough can evaluate them by comparing them with this report's findings, and by confirming that each one is a direct inference from the previous one.

With this body of evidence before it and the recommended ordinances in effect, the Borough's impact assessment can be a mere confirmation of compliance with Borough standards. It should no longer be necessary to search continually for more evaluative variables in open-ended Environmental Reports.

All the technical data in this text provide valuable background information and advice to any developer who wishes to take the time to use it. The data should be made available to the public.

When a developer wishes to encroach on regulated forest, scenic or other areas, an acceptable construction may be worked out by having him stake out pre-preliminary locations of roads, buildings, utility lines, and construction boundaries on the site. Borough representatives can then review the locations and work out, with the developer, modifications of locations, tree-saving designs, aesthetic designs, etc. The preliminary plan can then be prepared, and the preliminary approval can be pursued.

As a supplement to the Borough's police powers, members of the Borough's staff may apply for status as local enforcers of Commonwealth laws, such as those on erosion and sedimentation control.

C. The Official Map

The Borough can increase its control over land development by making and adopting a physical plan - an "Official Map" - for the development of the Borough showing precisely the public streets, watercourses, and public grounds. This form of regulation is permitted under Article IV of the Pennsylvania Municipalities Planning Code. This expansion of the Borough's role could fill the gap that tends to exist between the goals established in Borough plans and ordinances and the actual development that takes place.

It is conceivable that at some future time the Borough could even take over the actual construction of site improvements, eliminating private developers as a source of compromise.

D. Acquisition

The Borough should consider acquiring undeveloped property where the natural environment is extremely valuable or problematic, but where private development compatible with environmental objectives is very unfeasible. Feasibility is determined largely by the proportion of the site occupied by critical resources, slope gradient, and the orientation of road access into the site. Two such sites have been identified for consideration:

* The property southeast of the Fox Chapel-Guys Run Road intersection.

* The property between Longfellow and Hunt Roads.

Before deciding to acquire any undeveloped property, the Borough should do the following: check the ownership of adjacent properties - if they are under the same beneficial ownership, it could influence overall feasibility of development and therefore the necessity for acquisition; prepare trial site plans to double check whether 100% acquisition and conservation is necessary - these site plans may disclose that the Borough need acquire only enough acreage to reduce the property to a size and topography where the number of dwellings permitted by zoning is feasibly buildable; coordinate plans for acquisition with other Borough programs, such as bikeways, footpaths, and the redesignation of unused Borough rights-of-way.

The Borough should also consider acquiring developed property where a valuable structure is subject to severe environmental hazards, where saving the structure by private means is very unfeasible. No such sites have been clearly identified, but future experience might suggest some.

E. Programs for Borough-Owned Land

On all actively used Borough properties, (roads, parks and facilities), the Borough should control regular maintenance operations such as mowing to meet the objectives of the recommended land use ordinances. The rate of application of road salts should be minimized. Squaw Run Road just south of Field Club Road is subject to stream undercutting and should be slightly relocated to avoid the necessity for further rock dumping. Old Mill Road at the old springhouse is subject to landsliding - the only permanent solution here might be the narrowing of the road, or the construction of a bypass through the Squaw Run valley to Squaw Run Road East.

Unused Borough rights-of-way (identified on our maps) may be redesignated as "Conservation Corridors." This would include forbidding most access and leaving them to natural succession. Before deciding on such redesignation, the Borough should check legal records for the necessity to maintain normal access to surrounding properties.

Borough sewers should be sealed as recommended in the Bankson report (1979). All treatment plants and pump stations should be intercepted by gravity sewers. If warranted, the Borough could purchase the Ottawa sewage treatment plant or contract for its operation.

F. Bikeways

A Borough-wide system of bikeways would cut down on vehicular energy use by connecting residential areas to recreational and commercial destinations. Such a system must be coordinated with any similar efforts in O'Hara Township. The system's components would be:

* All existing low-traffic local roads.

* Low-traffic through roads (such as Squaw Run Road East).

* Routes through Borough park lands.

* Unused Borough rights-of-way.

* Routes through private lands, constructed and dedicated at the time of the land's development.

* Routes through private lands with permanent uses, on easements granted by the owners.

Where the gradient is too steep for bikes along a desired connecting route, footpaths and steps can be used instead of bikeways. A possible example is from the parks on Hunt Road to the unused right-of-way off Longfellow Road.

G. Other Activities

The Borough should encourage further research in local environmental science and its importance to Borough programs and ordinances.

Our environmental recommendations should be related to the broader considerations of zoning, subdivision and other Borough affairs through other types of Borough planning. Land use monitoring and planning should be continued to adapt to new issues as they arise, and to further progress in the state of the art of planning.

3. The Need for Decision Science

Because this Plan is a foundation and a body of evidence, it provides very specific and detailed technical information on which to base ordinances and programs. It answers the question of why Borough actions are taken before the question is raised.

When legal questions are raised, evidence is gathered by both sides to support their claims. The depth and quality of the evidence gathered corresponds to the strength of the interest that each side has in the question. If at that time the Borough finds that its ordinances and programs are not based on evidence of natural relationships as good as that produced by the other side, then the Borough may as well have had no programs at all, because its programs will be stricken down. If this report were any less technical or any less thorough than it is, it would not protect the Borough's programs to the extent that it should. Nor would it provide an adequate reference for interpreting Borough ordinances and bills.

The development of appropriate Borough ordinances and programs is made possible by modern "decision science." Decision science is the applied version of the same scientific method that is used in all objective sciences. It postulates that if we know what our objectives are, then we can design an action that will achieve those objectives, or will at least do as well as possible in the particular situation (Ferguson, February, 1980).

The application of decision science involves the completion of a cycle of the scientific method: from facts (the existing problem) to theory (the proposed action) and back to facts (testing the action in the real world). Consequently, this Plan's application of decision science starts with an exact identification of the problem that we are trying to solve (Section II-1), builds a "model" out of equations and maps to describe all the data that are relevant to the problem (Section II-2), and concludes by inferring concrete actions from the model (Section II-3). The testing of the proposed actions must await Borough implementation over the years. In practice there are cycles within the overall cycle: for instance, whether a particular forest type exists in a particular location is a scientific question, requiring one complete application of the scientific cycle for its answer.

What the Borough's objectives are is well established. As stated in the Borough's Natural Resources Ordinance, they are the protection and improvement of the natural environment and related amenities including the land, the quality of air and water, natural features and scenic values, wildlife and natural vegetation, and the Borough's rural/residential character.

Our model of the Borough's natural resources attempts to identify each factor of the natural environment that can affect those objectives, and to identify unequivocally the effect that each factor has. It identifies each factor separately from all the others for the sake of precision, as opposed to a "gestalt" analysis, which combines many factors in a single view and is hence inherently more vague and imprecise. The geographic distribution of each factor is mapped over the entire Borough, to allow the uniform application of Borough ordinances based on them. Never before in the Greater Pittsburgh region has such a comprehensive inventory and analysis of the natural environment been conducted. Several of this Plan's analytical techniques, such as the heat budget, provide a unified concept of the natural environment that has seldom been possible in any study, anywhere.

Mathematical language is used to express the relationships among natural factors and Borough values, because of its precision and conciseness. Mathematical language develops explicit, manipulable relationships that make the complexity of the natural resource problem controllable and permit informed discussion of the issues.

Our recommendations are derived directly from the identified mathematical relationships. Separately identified factors lead to recommendations dealing with separate aspects of land use. Any Borough action following these recommendations will be both reliable and valid, because it will be tied directly to the facts of the Borough's natural resources via the mathematical relationships. These recommendations do not add up to a Borough land use plan, because they deal only with the aspects of land use that are relevant to the Borough's natural resources. A private developer would be free to develop any property in any legal way he wants, as long as he meets the recommended standards. Only two properties have been identified where normal development cannot occur without extremely compromising the recommended standards - these sites are recommended for public acquisition.

4. Acknowledgements

The principal investigators in this study were Bruce K. Ferguson, SRAWA's Natural Resources Assessment Director, and Dr. Norman K. Flint, SRAWA's Geological Consultant. Dr. Flint prepared the geological components of the study, and Mr. Ferguson completed the data generation, compiled the results of previous studies, and made the concluding recommendations. Rupert Friday, an ecological consultant, made the drafts of the ecological maps and the ecological section of the report. Bex Trimble and Ruth Weir did daily temperature monitoring for many months. Other persons who contributed time and knowledge were C. W. Bier, John Colowit, Chris Metelmann, Scott Robinson, and W. O. Robinson.

In consideration of the Borough's limited budget, SRAWA has taken advantage of all the environmental studies previously completed or now in progress. Fourteen such studies, listed in Figure 1, apply to the Fox Chapel or SRAWA area exclusively and in great detail; others, listed in a metropolitan regional bibliography (Ferguson, September 1978), describe regional patterns which occur in Fox Chapel as they do in other parts of the region. Maps and other information in other studies are generally not duplicated here, but are incorporated where appropriate by reference, with conclusions based on that information presented here like any other conclusions. New data are generated only to the extent necessary to round out an understanding of the Borough's environment. Most of the new data were inventoried directly in Fox Chapel, such as the geologic maps; some of them, such as the topoclimatic patterns, were researched efficiently at the metropolitan level, and then applied to Fox Chapel as they could be to any area in the region. SRAWA's excellent aerial photographs and 1"=200' topographic maps, of which the Borough was one of the supporters, allowed the efficient extrapolation of many non-topographic conclusions. The only ways to achieve a higher accuracy than that of this study are with a high geographic density of lengthy calculations, or a high geographic density of on-site monitoring continued over a long time.

Item Studied	Investigator	(Projected) Completion Date
Unique Stands	Metelmann (SRAWA)	Completed
Existing Vegetation Types	SRAWA	Varies
Landslide Hazard	Flint - Rosenquest (SRAWA)	Completed
Aerial Photos	SRAWA	Completed
Topographic Map	SRAWA	Completed
Slope Gradient	SRAWA	Varies
Soils	Weir (SRAWA)	Largely Completed
Water Quality	SRAWA	Varies
Water Quality	Allegheny County, University of Pittsburgh, CMU	Completed and Ongoing
Air Quality	Allegheny County	Completed and Ongoing
Flood Hazard	U. S. HUD	Completed
Stormwater	Green International	1981
Urban Hydrologic Impacts	Morisawa-Laflure	Completed
Urban Sediment Impacts	Morisawa-Nelson	Completed

FIGURE 1. Studies of Fox Chapel's natural resources previous to or concurrent with this study. Detailed citations of completed studies are in the listed References.

II. THE TECHNICAL STUDY

1. The Nature of Fox Chapel's Natural Resources Plan

Before a problem can be solved, it must be identified. Although that may sound simplistic, an exact definition of the problem is sometimes the greatest single service that a researcher can provide.

According to decision scientists, a problem exists only when all of the following conditions exist (Ackoff, 1962, p. 30; Ferguson, February, 1980).

1. There is a decision-maker (this is Fox Chapel, in its role as a member of land-use decision-making systems);

2. The decision-maker desires certain outcomes (ends, objectives);

3. The decision-maker has alternative courses of action which are under his control and which are capable of affecting the achievement of his objectives (these are land uses and their component technologies - the means);

4. There are aspects of the problem environment which are capable of affecting the achievement of the decision-maker's objectives but which are not under his control (these are Fox Chapel's natural resources, into which land uses will be built).

These conditions are the basic components of the problem. To identify these components is to identify the problem. So let's go through each one of them in turn.

A. The Decision-Maker

The decision-maker in a problem is an individual or organization which at an initial time is in a purposive state, and issues at a later time purposive behavior, which at a still later time issues an outcome, or goal-state.

In the Borough's natural resource problem the decision-maker varies from application to application, depending on who controls the land. The decision-maker is seldom a single independent entity; it is more often a "system" of contributors to the decision. A "system" is defined as a set of interrelated elements each of which has a property directly or indirectly in common with every other element, and no subset of which is without this property (Ackoff and Emery, 1972). In this case, no one member of a decision-maker set has the property of decision-making separately. A decision-maker set is assembled one land development at a time by the aggregation of regulatory bodies, designers, banks, contractors and utility companies around the controller of the land. The same set of members may never be assembled for more than one development. The types of decision-maker sets that may exist from time to time in the Borough are summarized in Figure 2.

The members of a decision-making set interact and contribute to the overall decision according to more or less explicit legal rules and procedures. Each member of a set "responds" (as opposed to "reacts") to the actions of each other; that is, alternative actions are always available to each member, and an action of any one of them is co-produced by that member and the actions of other members. Together, the members are co-producers of the land use decision. Each member uses the others as "instruments," that is, it acts to produce the co-production of the decision. Each member is necessary for the decision, but no one of them is sufficient (Ackoff and Emery, 1972).

The decision-making systems of which the Borough may be a member (shown in Figure 2) are those applying to Borough-owned land, privately-owned land, and utility-controlled land. This report is addressed to the Borough as a member of these three systems. Decision-making on land (roads) owned by the County and the Commonwealth is not further considered; this is not a serious omission despite the presence of these lands in the Borough because these lands are small in area, functionally specialized, and essentially fully developed.

The Borough's two agencies that may represent the Borough in a decision-making system are the Borough Council and the Zoning Hearing Board. Their powers to participate in environmental and land use decisions come from the Pennsylvania Borough Code, Constitution, and Municipalities Planning Code (Borough of Fox Chapel, 1977; Brandywine Conservancy, Inc., 1978).

The Borough Council is the Borough's legislative and governing body. It may enact and amend many types of plans and ordinances. In some cases it initiates land acquisition, or modification or maintenance to be carried out immediately. In other cases it enacts plans and ordinances long before a particular land development is proposed and its decision-making system comes into existence, thereby establishing rules ("standards") by which it will tend to contribute to the decisions of future systems. When a particular land development is proposed and a decision-making system has been at least partly formed, the Council may grant or deny preliminary and final approval to planned residential developments, subdivision and land development plans, and conditional use proposals. The

Owner of Land or of Right-of-Way or Easement	Land Use Decision Maker
Fox Chapel Borough	Borough Council (sometimes as part of a system with County, Commonwealth, utility companies, designers, banks and contractors)
Allegheny County	County (sometimes as part of a system with Commonwealth, utility companies, and banks)
Commonwealth of Pennsylvania	Commonwealth (sometimes as part of a system with utility companies, designers, banks and contractors)
Private Individual or Organization	System of Borough Council and Owner/Developer (sometimes with Borough Zoning Hearing Board, County, Commonwealth, utility companies, designers, banks and contractors)
Utility Company	System of Borough Council, utility company and Commonwealth

FIGURE 2. Land use decision makers (land use decision-making systems) that may exist from time to time in Fox Chapel Borough.

Council is advised on environmental and land use matters by the Environmental Advisory Council and the Planning Commission, and on park matters by the Park Commission. In carrying out the decision of a system the Council is represented by the Zoning Officer, who interprets the Borough Zoning Ordinance in its literal terms, makes inspections, and may institute legal proceedings to enforce the Borough's ordinances.

The Zoning Hearing Board is specifically intended to be independent from the Borough Council. It is a quasi-judicial body which hears appeals by developers from the Zoning Officer's interpretations, applications for variances and special exceptions, and challenges to provisions of the Zoning Ordinance (Brandywine Conservancy, Inc., 1978).

As shown in Figure 2, an important type of co-member of decision-making systems in which the Borough may participate is the private developers which from time to time propose the construction or operation of land use facilities in the Borough. Developers may include land developers, speculative builders, homeowners, landowning institutions, and non-profit organizations that take land use actions. The powers of developers to participate in the decisions of systems come from their constitutional rights to use their property and to make contracts. In land use decisions applying to Borough-owned land, the Borough takes on many of the roles of developers in decision-making systems.

B. Desired Outcomes

Each decision-making system desires certain outcomes from its actions. One or more members of a system may desire an outcome which is different from those desired by one or more other members (such as the difference between a developer's financial objective and the Borough's environmental objective), and in most cases the presence of members desiring different outcomes does not eliminate any of the desired outcomes from the overall system. The desired outcomes of a system are therefore usually multiple. The members of a decision-making system are seldom "hostile," that is, a member seldom desires as an outcome the minimization of achievement of an outcome which is desired by another member. However, due to the limited range of actions that a system may take, and sometimes due to the level of communication among its members, the contributions of a member to the overall decision may conflict with (decrease) or cooperate with (increase) the achievement of desired outcomes of other members. Conflict may be "dissolved" if the environment of the conflict changes so that the conflict decreases, "resolved" if the behavior or properties of one or more of the members changes so that the conflict decreases, or "solved" if the system chooses an available course of action of which the expected outcome is satisfactory to all members.

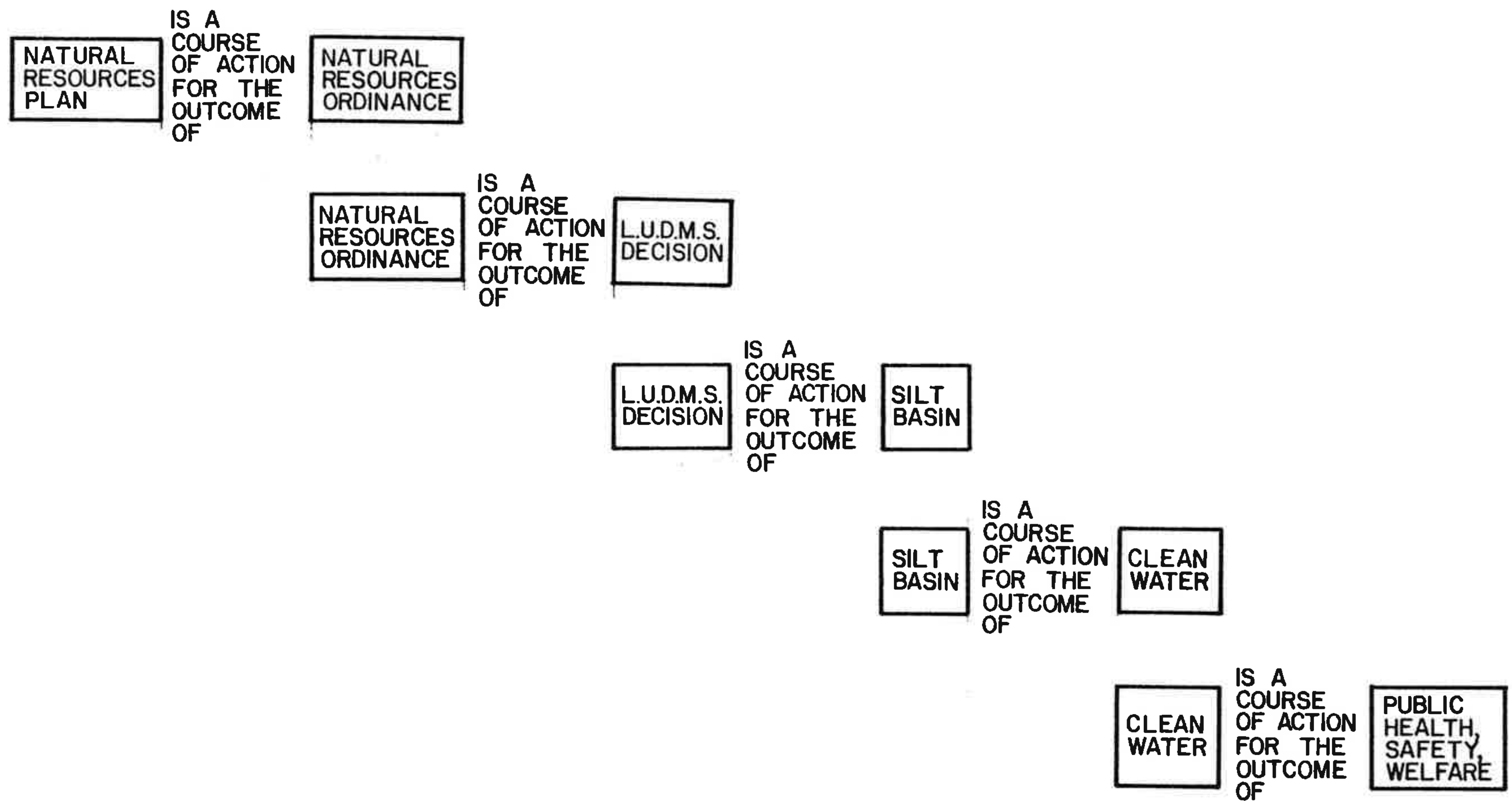


FIGURE 3. Illustration of the relativity of courses of action (means) and outcomes (ends). "L.U.D.M.S." stands for "land use decision-making system."

Usually one of the members of a system - the controller of the land - carries out the system's chosen course of action, while the other members tend to monitor and control the controller's actions to guarantee that the chosen action, and no other, is carried out.

Any course of action ("means," "design") is intended to issue some type of outcome ("end," "performance"). As illustrated in Figure 3, outcomes and courses of action are relative functions. One outcome may be a course of action for a further outcome; which is called "outcome" depends on what level in the sequence we look at. Desired outcomes may change over time (Ackoff and Emery, 1972).

The Borough states in Section I.2 of the Natural Resources Ordinance (Borough of Fox Chapel, 1977) that its "purpose" (or "ideal") is the promotion of the health, safety and welfare of the present and future residents of the Borough; more specifically, that its ideal is the protection and improvement of the natural environment and related amenities including the land, the quality of the air and water, the natural features and scenic values, the wildlife and natural vegetation, and the Borough's rural/residential character. That the Borough should have a specific ideal of this type is justified in the preamble: there are natural resources which are part of the ecological system to which we are all bound and which therefore are the common property of all the people including generations yet to come; the people have a right to clean air, pure water and the preservation of the natural, scenic, historic and aesthetic values of the environment; and the Borough is part of its region. In pursuit of this ideal, Section I.2 of the ordinance goes on to list some "goals" regarding the identification of the Borough's natural resources, the evaluation of environmental impact of land development, the minimization of environmental impacts, the control of the amount of open space and other characteristics of land use, and the acquisition of valuable resources.

Additional presumed Borough ideals are the minimization of costs and the preservation of democratic freedoms of choices and action. In some cases these ideals act against the achievement of environmental ideals.

The outcomes desired by developers vary from developer to developer, although they might be generally characterized as financial (in the case primarily of land developers and speculative builders) or functional (in the case primarily of homeowners and conservation organizations). The right of each individual developer to choose its own desired outcome is constitutionally guaranteed.

The purpose of this study is, given the Borough's stated and presumed ideals, to interpret those ideals as objectives, goals and ends, and to derive courses of action for the Borough (as a participant in decision-making systems) to achieve these outcomes, including to evaluate courses of action that are already in effect. In doing so it meets the stated goals of "identification and analysis of the natural and scenic resources of the Borough and the surrounding region" and "identification of those areas which should have no development or which require special protection;" it also partly meets the objective of "evaluation of the environmental impact of all land development."

C. Courses of Action

The available courses of action in the Borough's natural resource problem are the land use actions which a decision-making system may select and carry out. Fox Chapel is concerned with attaining objectives by molding these actions to the natural resources environment in which they operate. Borough ordinances, plans and approvals are not in themselves land use actions; they are only contributions to the system's selection and carrying out of land use actions.

Expected types of components of land use actions are listed in Figure 4. Any land use action in the Borough will probably consist of some combination of these types of components. The components are anticipable because land use proposals in the Borough have been and are expected to continue to be consistently for relatively light residential construction. Land use components such as sewers and roads build up into land use aggregates such as housing clusters, which in turn build up into general land use types such as residential (Ferguson, February, 1980). Land uses, once established, are very slow to change: most land remains in the same use long enough for many deep and powerful changes in human society and economy to occur during the life of the use.

Many land use actions are already in effect. Relevant aspects of these past actions show up in the inventory of "natural resources," in forms such as "abiotic cover" and "ponds." Any relevant aspect of a future land use action is therefore:

$$\Delta = \frac{\text{proposed state}}{\text{existing state}}$$

The Borough influences land use actions in three ways. It can initiate its own land acquisition, or modification or maintenance of Borough-owned land, subject to other members of the relevant decision-making systems. When a developer proposes a land development on his land, the Borough can grant or deny approval, or grant approval subject to conditions. In preparation for future land development proposals, it can enact plans and ordinances that establish rules ("standards") by which it will tend to contribute to the future systems' decisions. A fourth type of influence - the public decision to construct sewer systems, roads, and other indirect, infrastructural incentives to the locations and types of private land development - has been used in large, growing areas such as Florida counties, but is not worth considering in an area as small and as highly developed as Fox Chapel Borough.

D. The Environment

The environment in the Borough's natural resource problem consists of the natural resource components listed in Figure 5. Any unit of land in the Borough must consist partly of these components. The existing nature, behavior, and geographic distribution of these components are not controlled by the Borough or by any decision-making system. However, they are "instruments" of decision-making systems; that is, they co-produce the outcomes of actions, and the co-production is itself produced by the systems. Both land and land use are necessary to produce outcomes, but neither of them is sufficient (Ackoff and Emery, 1972).

The environment of interest to this study is the Borough's finite, irreplaceable 8.5 square mile land area (Borough of Fox Chapel, 1978). This area is entirely within the "Pittsburgh Plateaus" subprovince of the Appalachian Plateaus physiographic province. The Borough office is at latitude N40°30'53", longitude W79°52'48".

The selection for Borough study of land components from the infinite range of land components in nature was based on the Natural Resources Ordinance (Borough of Fox Chapel, 1977) and the investigators' judgement of the type of understanding of the environment that should result from an applied natural resource inventory. They include the natural factors that are expressed in the landscape: hydrology, ecology, topography, geology, soils, climate and aesthetics. These factors do not include technological factors such as energy use in buildings and waste management, or socio-economic factors such as historic resources and real estate values. Such other factors are briefly mentioned in the Natural Resources Assessment and Protection Ordinance, but they go beyond the stated purpose and goals of the Ordinance and into more general Borough policies, and the amount of work needed to analyze such factors properly are not justified by their brief mention in the context of the Council's limited budget. This study only of the natural environment is valuable because the natural environment is the permanent background of all technological and socioeconomic applications.

E. Problem Structure

The structure of a problem is not one of the problem's components, but understanding it is nevertheless an essential part of understanding the problem. The structure is the suite of subproblems of which the overall problem is composed and their relationships to the overall problem. The nature of the subproblems into which the problem is decomposed is important because it gives direction to the resulting solutions (Ferguson, February, 1980).

The subproblems in the Borough's natural resource problem are the individual land developments for which individual decision-making systems are formed. Each subproblem has its own unique sub-identification, submodel and subsolution, due to its unique mixture of participants, site, and desired outcomes. However, the types of components of each subproblem are anticipable and tend to recur in many, if not all, subproblems.

The overall structure of Fox Chapel's natural resource problem is diagrammed in Figure 6. It is a "hierarchic" structure. This Plan (representing the overall problem) is at a relatively high level of generality; each development (subproblem) is at a relatively high level of specificity. Each subproblem in turn has a hierarchic sequence of steps leading to construction or operation. The monitoring and evaluation of the constructed or operated outcome to revise identifications, models, and solutions is "adaptive planning" and may cause the outcome of one subproblem to influence the solution of subsequent subproblems. The sequence of subproblems is "linear;" that is, they are all on a similar level of generality. The final solution to the Borough's natural resource problem is the cumulative sum of the solutions to the individual subproblems (Ferguson, February, 1980). It will certainly not be attained within this human generation.

F. Summary

Fox Chapel Borough's plans, ordinances and approvals are artifacts at the interface of land and land use. The Borough is concerned with molding land uses to the land environment in which they operate in order to yield desired outcomes. These roles can be summarized by the equation:

$$\text{Outcome} = f(\text{Land, Land Use})$$

- that is, that the yielding of outcomes is a function of the interaction of controlled variables and uncontrolled variables. This Plan is interested in "locational" interactions - that is, it is limited to the interactions between land uses and their sites. This is distinguished from "relational" criteria, which measure the internal functions and efficiencies of land uses without respect for their sites (Ferguson, February, 1980).

The above equation elucidates the familiar but misused terms, "design standards" and "performance standards." A standard is a test or criterion that a municipality uses to determine the acceptability of a land use proposal. Design is the physical

Group	Components

Used Facility	Buildings
	Communication
	   Cables (aboveground, underground)
	Drainage Controls
	Erosion and Sedimentation Controls
	Farming
	Lights, Signs, Mail Facilities
	Operating Structures (utility and related structures)
	Other Utilities
	Pavements
	Recreation Facilities (except meadow playing fields)
	Transportation
	   Path (bike, pedestrian, horse)
	   Road and Parking (engine vehicles)
	Waste Disposal and Recycling Facilities
	   Liquid Waste
	   Solid Waste
	Water Supply Facilities

Other Facilities and Conditions	Conservation Construction Process Geometry and Materials of Components Earthwork Forest Production Other Structures (abutments, walls, supports) Planting, Ground Covers

FIGURE 4. Expected types of land use components in Fox Chapel, both existing and potential.

Sphere	Component
Hydrosphere	Floodplain Poorly Drained Soil Stream Lake Wetland Water Quality
Biosphere	Potential Aquatic Habitats Potential Terrestrial Habitats Current Aquatic Habitats Current Terrestrial Habitats Rare Aquatic Species Rare Terrestrial Species
Lithosphere	Slope Stability Mine Subsidence Shallow Foundation Instability Mineral Resources Groundwater Slope Gradient
Thermosphere	Cold Air Pockets North-Facing Slopes Forests Air Quality

Noosphere	Aesthetics:
	   Cliffs
	   Water Bodies
	   Unique Vegetation
	
	Ownership:
	   Borough of Fox Chapel
	   Commonwealth of Pennsylvania
	   Allegheny County
	   Private

FIGURE 5. Fox Chapel Borough's natural resource environment. The "spheres" are traditional classes of natural science which are useful for understanding the range of components and for the division of labor in collecting base data; they do not enter the problem formulation. Each "sphere" is represented by a chapter in Section II-2; each "component" is defined in the relevant chapter of that section.

geometry and materials of a land use; performance is the value, or outcome, resulting from the interaction of that land use with its land environment. A design standard regulates the form of a land use; a performance standard regulates its effect. Design and performance are relative terms, as shown in Figure 3. Pure design standards include standards for lot size, setbacks, materials, and other specific physical characteristics; pure performance standards include stormwater flow requirements, ecological diversity requirements, and other outcomes that can be determined only by analyzing the interaction of a land use with its site. A standard somewhere between pure design and pure performance might be a limit on the area of impermeable surfaces, which is known to be more or less related to the stormwater flow outcome, but which is not a direct measure of stormwater itself.

We presume that performance standards are preferable to design standards. Performance standards regulate the outcome with which the Borough is concerned, while leaving the designer free to adapt the materials and geometry of land uses to the site, the market, advanced technology, or other relevant influences. Design standards provide greater certainty about the physical characteristics of what will be built in the future, but they tend to avoid the question of what their effect on Borough ideals will be, and limit the options available to the designer in adapting the design to changing sites and times. Nearly pure performance standards are possible in areas where analytical abilities are well developed, as in stormwater. Where they are not well developed, such as aesthetics, we must do the best we can with design standards, as we have in the past. Ideally, we would find direct quantitative measures of performance of the Borough's ideal of "public health, safety and welfare," but the pursuit of such philosophical questions must await many years of research.

A particularly well-known abuse of the term "performance" is in the "performance zoning" promoted by Bucks County (Bucks County Planning Commission, 1973) and former Bucks County staff (Kendig and Connor, 1980). Their publications propose a particular set of standards that are somewhere between pure performance and pure design, such as open space ratios, housing density, and impervious surface ratios, in the context of particular land environments. At the time these proposals were first made, they represented the most advanced state of the art in "performance" standards - that is, their standards were closer to pure "performance" than any previous standards had been. However, the state of the art has advanced since then, and we need not stick to their proposed types of solutions. Nevertheless, since their standards were published under the name "performance," it is easy to think that one is not enacting performance standards unless one follows their publications religiously. That is a mistake.

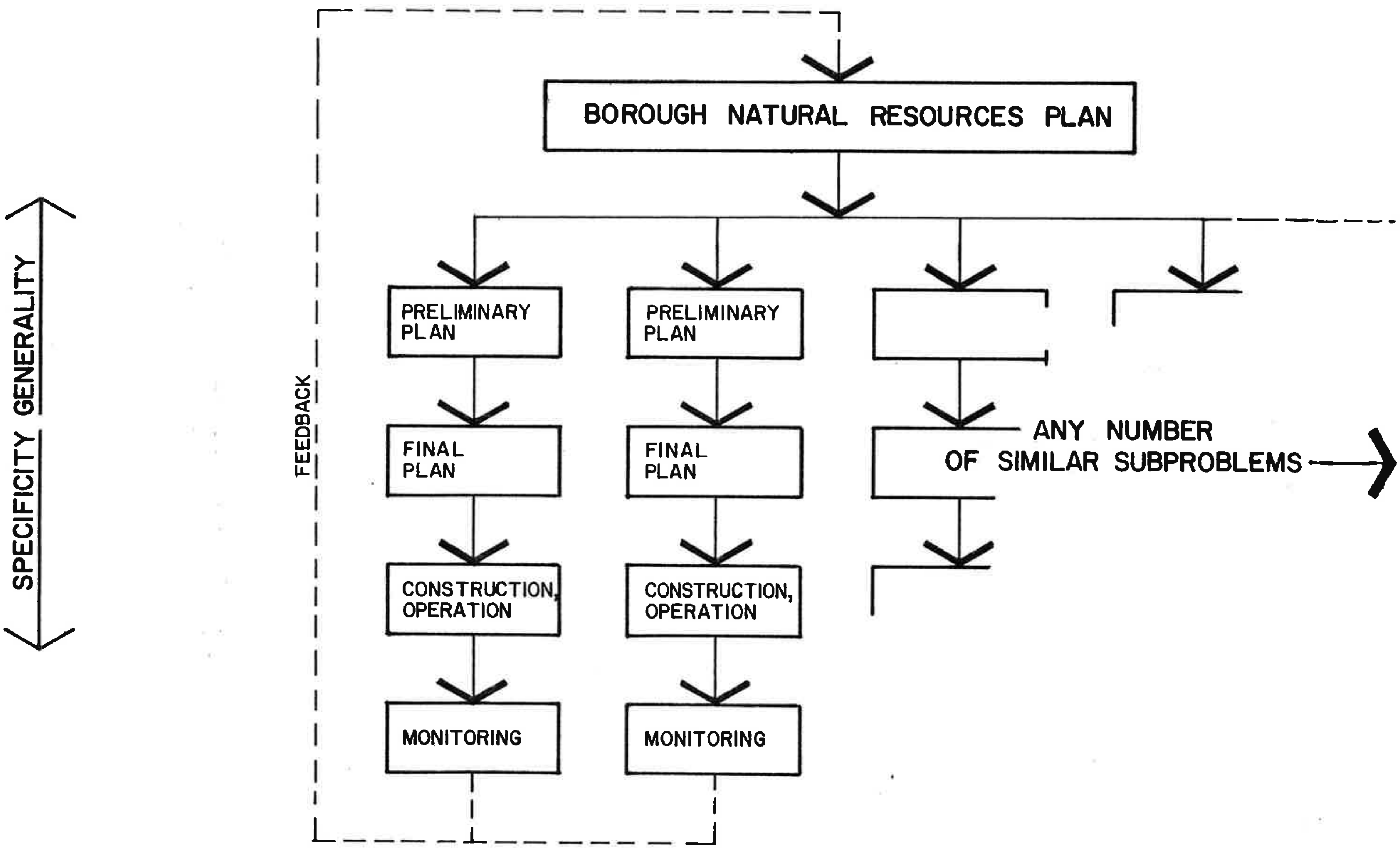


FIGURE 6. The structure of Fox Chapel's natural resource problem. The Borough Natural Resources Plan represents the overall problem; each development is one subproblem.

This Plan is concerned with the yielding of performance. It attempts to identify the desired outcomes of the Borough, and the interactions of land and land use components that affect those outcomes. The following section is the construction of models of these interactions, which will allow us to derive standards of land use and performance.

2. Mathematical Model of Fox Chapel's Natural Resources and their Effects on Desired Outcomes

This section provides the construction of models of interactions between land and land use that yield outcomes. From these models we can derive standards or initiatives for future land use actions.

To build models of a problem requires an understanding of the inner functions of the problem's components: conscientious natural resource planning is impossible without conscientious ecology, geology, and other natural sciences. In order to handle the complexity of the Borough's natural resource environment, we have broken down our overall model of the problem into submodels, corresponding to each natural "sphere" listed in Figure 5 and each chapter in this section. Each chapter is organized into subheadings of "1. Land", "2. Land Use", and "3. Desired Outcomes" - that is, it describes first the behavior of the natural sphere, then the potential interactions of land uses with that sphere, and finally the effects of those interactions on performance.

Each chapter concludes with a set of equations, each of which shows the land-landuse-performance relationship for an interacting set of variables, in the form mentioned on page 19:

$$\text{Outcome} = f(\text{Land, Land Use})$$

The equations are supplemented by the text of each chapter and by the attached maps. The text defines terms that are used in the equations, and explores the behaviors on which the equations are based. The maps show the geographic distributions of features that are defined in the text and used in the equations. The features are intended to be defined in such a way that they can be located conclusively in the field; the maps attempt to locate the features on paper according to the same definitions by reference to base map features, and are subject to any inaccuracy of the base map as well as to any inaccuracy created during mapping. The base map is SRAWA's 1"-200' topographic map. Fox Chapel Borough is included on 12 of SRAWA's 19 sheets. By using this format the Borough's study may tie into any future studies in the SRAWA-Guyasuta area.

Because the equations express interactions among problem components, they can be used to measure the performance of any land use action in terms of the Borough's desired outcomes - that is, they can be used as "evaluative" models. The equations can also be turned around and used to derive standards and initiatives for future land use actions - that is, they can be used as "developmental" models. For this purpose they are transferred to Section II-3, where standards and initiatives are derived.

HYDROSPHERE

1. Land

Water near the surface of the earth moves through a network of events that is called the "hydrologic cycle" because water that originates in precipitation tends ultimately to be returned to the atmosphere, to be precipitated again. The hydrologic cycle in Fox Chapel is diagrammed in Figure 7. The components of the cycle at any natural unit of land, over any unit of time, are summarized by the "water budget" (Dunne and Leopold, 1978):

$$P = I + AET + GWRO + St.RO + \Delta SM + \Delta GWS$$

where all terms are in units of depth per time (equivalent to volume per area per time), and:

P = precipitation: the sum of rain, snow, sleet, and hail.

I = interception: of precipitation by vegetation and other objects above the ground.

AET = actual evapotranspiration: the sum of evaporation and transpiration.

GWRO = groundwater runoff: groundwater flow due to infiltration into and movement through the fractures and pores of the ground below the root zone and above the elevation of major streams, ultimately discharging to the surface. (Not including artificial groundwater injections or withdrawals).

St.RO = stormwater runoff: the sum of Horton overland flow (overland flow due to lack of infiltration), shallow subsurface flow (subsurface flow due to infiltration into and movement through the soil and ultimately discharging to the surface), and precipitation onto any type of overland flow or saturated zone. (Not including floodwater, which enters or leaves the unit area from other areas, or artificial irrigation).

Δ SM = change of soil moisture storage: additions to or subtractions from the porous root zone just below the ground surface.

ΔGWS = change of groundwater storage: additions to or subtractions from the fractures and pores of rock below the root zone and above the elevation of major streams.

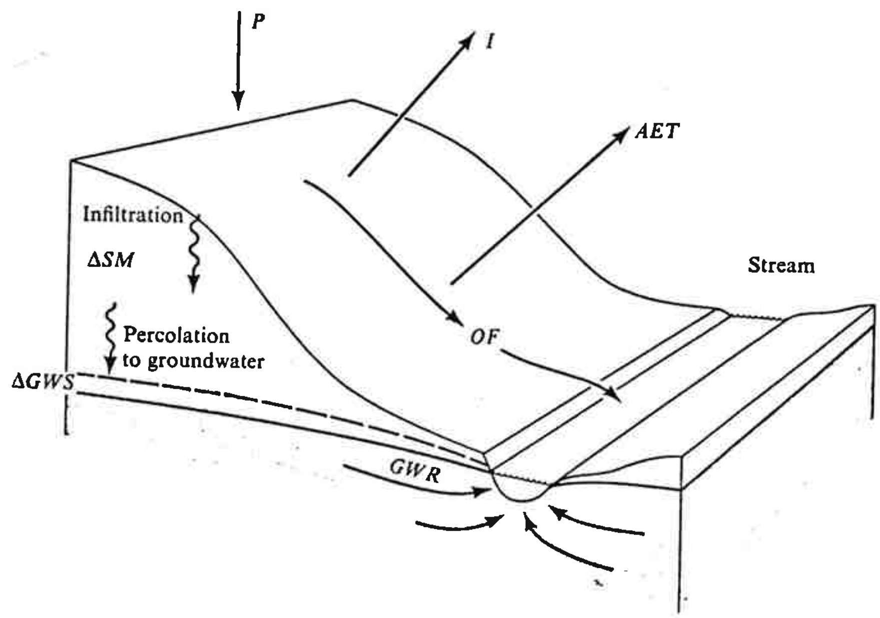


FIGURE 7. Components of the water budget on a typical cross-section of the Fox Chapel landscape.

Each component of the water budget may change over time. An individual storm lasting a few minutes may change P, which causes corresponding changes in other terms. Between day and night radiation and temperature change drastically, causing corresponding changes in other terms. A weather system lasting several weeks may, by controlling temperature, humidity, and radiation change AET, which changes other terms. A combination of climatic and vegetative changes from season to season changes P, I, and AET, which changes other terms. Climatic variations and vegetative succession may occur over many years, controlling all the terms of the water budget. Over any unit of time the climatic controls of the water budget are subject to their probability of occurrence.

Each component of the water budget may also vary geographically. Fox Chapel's steep hills expose their various faces to different solar radiation and wind as described under "Thermosphere"; these influences cause variations in AET, with corresponding variations in other terms. We may distinguish broadly between moist northeast-facing slopes and dry southwest-facing slopes, although micro-variations over space and time of radiation reaching particular slopes, windscreens, frost pockets, and other processes complicate the distributions of components. The moisture variations of these slopes and the way their geographic distributions are modeled are explained under "Thermosphere".

The recurrent seasonal changes in P and St.RO in a typical mature upland Fox Chapel forest are shown in Figure 8. Precipitation is abundant year-round, although there is almost twice as much precipitation in July as there is in February. Stormwater runoff tends to be proportional to precipitation. The relative uniformity of St.RO over the year is confirmed empirically by the seasonal stability of peak discharge in a nearby stream with an undeveloped watershed (Beall, 1977, Figure 15).

The seasonal variations in AET on two typical upland forested Fox Chapel slopes are shown in Figure 9. In the summer evapotranspiration exceeds precipitation, making up the difference by withdrawing ("discharging") water from the root zone of the soil. In the winter AET declines due to the low temperatures; as soon as AET falls below P the excess precipitation "recharges" soil moisture. Due to the higher temperatures on south-facing slopes the AET is higher there, causing greater summer soil moisture discharges and correspondingly greater winter recharges.

The seasonal variations in the remaining water-budget terms are shown in Figure 10. When soil moisture (Figure 9) is balanced, excess precipitation drains through the soil into the fractures and joints of the underlying rocks, recharging groundwater storage and yielding high groundwater runoff. When soil moisture is low, groundwater runoff continues to empty the groundwater storage until both flow and storage are very low. The seasonality of groundwater runoff is confirmed empirically by the corresponding seasonality in average flow in a nearby stream with an undeveloped watershed (Beall, 1976, Figure 15). The groundwater runoff from north-facing slopes is greater than that from south-facing slopes due to the greater balance of soil moisture.

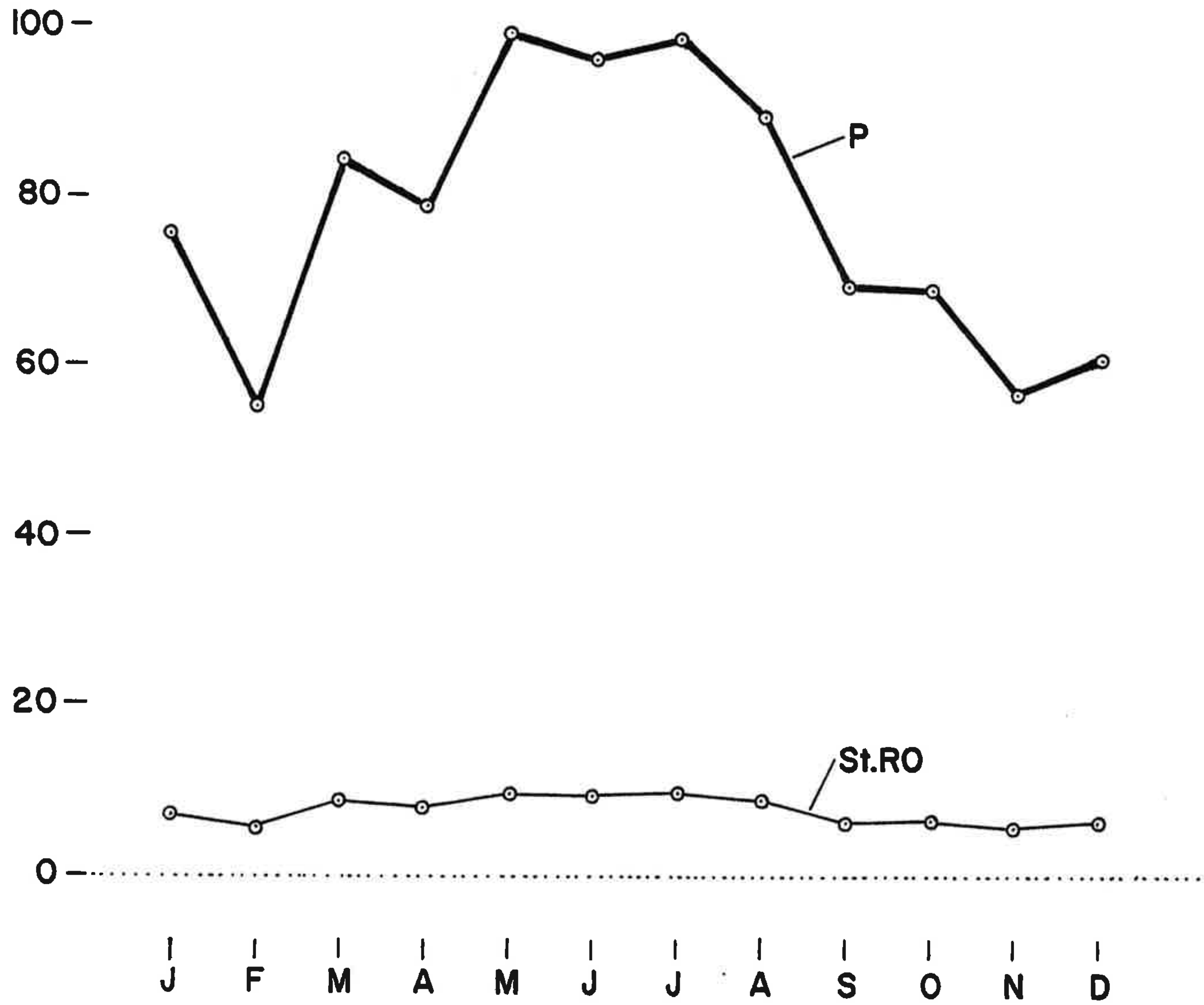


FIGURE 8. The seasonal variations of precipitation (P, heavy line) and stormwater runoff (St.RO.,light line) in a typical mature upland Fox Chapel forest. Units are mm/mo in each month of the year. Source: Figures 11 and 12.

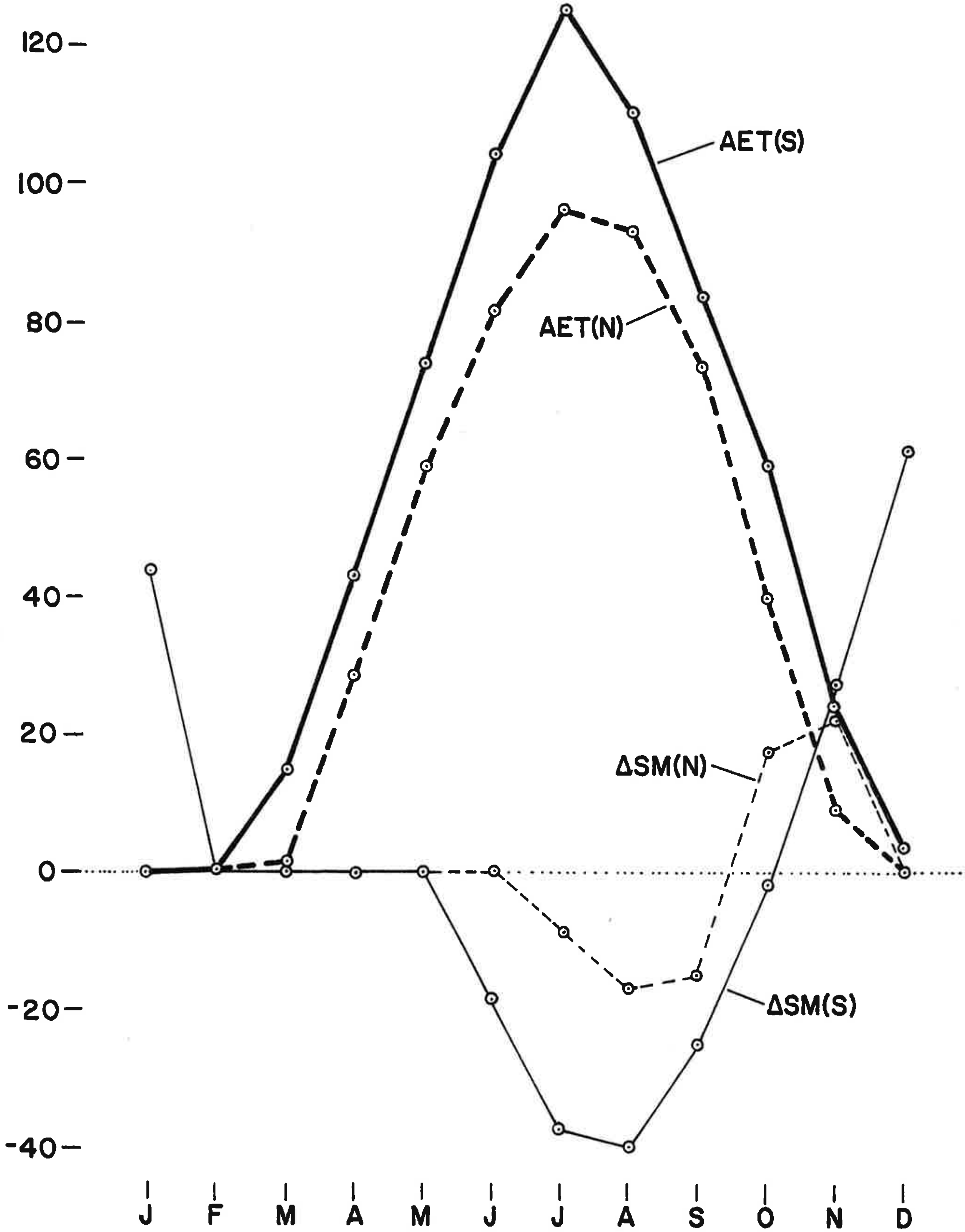


FIGURE 9. Comparison of actual evapotranspiration (AET, heavy lines) and change in soil moisture (ΔSM, light lines), on north-facing (N, dashed lines) and south-facing (S, solid lines) forested upland slopes in Fox Chapel. Units are mm/mo in each month of the year. Positive values of ΔSM are net "recharge"; negative values are net "discharge". Source: Figures 11 and 12.

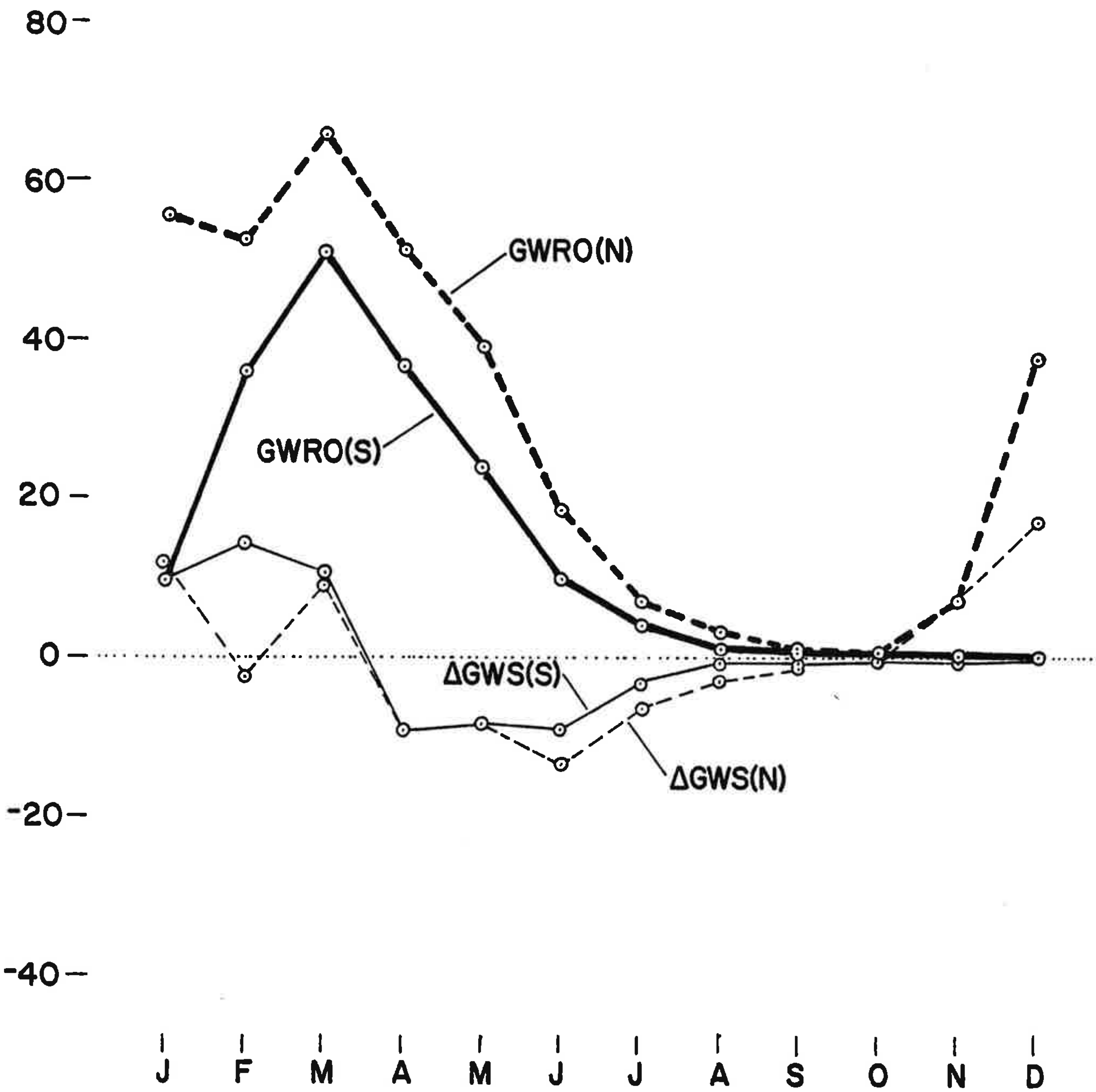


FIGURE 10. Comparison of groundwater runoff (GWRO, heavy lines) and change in groundwater storage (ΔGWS, light lines), on north-facing (N, dashed lines) and south-facing (S, solid lines) forested upland slopes in Fox Chapel. Units are mm/mo in each month of the year. Positive values of ΔGWS are net "recharge"; negative values are net "discharge". Source: Figures 11 and 12.

Component	J	F	M	A	M	J	J	A	S	O	N	D	Year
P	75.4	55.6	84.3	78.2	99.3	96.0	98.6	84.1	64.5	64.0	56.9	61.0	917.9
St.RO	7.5	5.6	8.4	7.8	9.9	9.6	9.9	8.4	6.5	6.4	5.7	6.1	91.8
PET	0.0	0.0	2.1	28.	60.	82.	98.	94.	73.	40.	9.2	0.0	486.3
P-St.RO-PET	67.9	50.0	73.8	42.4	29.4	4.4	-9.3	-18.3	-15.0	17.6	42.0	54.9	339.8
Acc.Pot.WL							9.3	27.6	42.6				
SM	400.	400.	400.	400.	400.	400.	392.	375.	360.	377.6	400.	400.	4,704.6
Δ SM	0.0	0.0	0.0	0.0	0.0	0.0	-8.0	-17.0	-15.0	17.6	22.4	0.0	0.0
AET	0.0	0.0	2.1	28.0	60.0	82.0	96.7	92.7	73.0	40.0	9.2	0.0	483.7
D or S	67.9	50.0	73.8	42.4	29.4	4.4	-1.3	-1.3	0.0	0.0	19.6	54.9	339.8
Σ Avail. for GWRO	93.0	87.2	108.7	85.9	63.7	29.9	12.0	4.8	1.9	0.8	19.6	62.7	570.2
GWRO	55.8	52.3	65.2	51.5	38.2	17.9	7.2	2.9	1.2	0.5	11.8	37.6	342.1
GWS	37.2	34.9	43.5	34.3	25.5	12.0	4.8	1.9	0.8	0.3	7.8	25.1	228.1
Δ GWS	12.1	-2.3	8.6	-9.2	-8.8	-13.5	-7.2	-2.9	-1.1	-0.5	7.5	17.3	0.0
Σ RO	63.3	57.9	73.6	59.3	48.1	27.5	17.1	11.3	7.7	6.9	17.5	43.7	433.9
P	75.4	55.6	84.3	78.1	99.3	96.0	98.6	84.1	64.6	64.0	56.6	61.0	917.6

FIGURE 11. Average monthly and annual water budget on an undisturbed north-facing forested upland slope in Fox Chapel. Units are mm per each unit time. To convert to inches, multiply by 0.03937. For sources and comments, see Figure 13.

Component	J	F	M	A	M	J	J	A	S	O	N	D	Year
P	75.4	55.6	84.3	78.2	99.3	96.0	98.6	84.1	64.5	64.0	56.9	61.0	917.9
St.RO	7.5	5.6	8.4	7.8	9.9	9.6	9.9	8.4	6.5	6.4	5.7	6.1	91.8
PET	0.0	0.5	15.	44.	74.	105.	130.	125.	92.	59.	24.	3.7	672.2
P-St.RO-PET	67.9	49.5	60.9	26.4	15.4	-18.6	-41.3	-49.3	-34.0	-1.4	27.2	51.2	153.9
Acc.Pot.WL						18.6	59.9	109.2	143.2	144.6			
SM	400.	400.	400.	400.	400.	382.	345.	305.	280.	279.	305.2	356.4	4,252.6
Δ SM	43.6	0.0	0.0	0.0	0.0	-18.0	-37.0	-40.0	-25.0	-1.0	27.2	51.2	0.0
AET	0.0	0.5	15.	44.	74.	104.	125.7	115.7	83.0	58.6	24.0	3.7	648.6
D or S	24.3	49.5	60.9	26.4	15.4	-0.6	-4.3	-9.3	-9.0	-0.4	0.0	0.0	152.9
Σ Avail. for GWRO	24.3	59.2	84.6	60.2	39.5	15.8	6.3	2.5	1.0	0.4	0.2	0.1	294.1
GWRO	14.6	35.5	50.7	36.1	23.7	9.5	3.8	1.5	0.6	0.2	0.1	0.1	176.4
GWS	9.7	23.7	33.8	24.1	15.8	6.3	2.5	1.0	0.4	0.2	0.1	0.0	117.6
Δ GWS	9.7	14.0	10.1	-9.7	-8.3	-9.5	-3.8	-1.5	-0.6	-0.2	-0.1	-0.1	0.0
Σ RO	22.1	41.1	59.1	43.9	33.6	19.1	13.7	9.9	7.1	6.6	5.8	6.2	268.2
P	75.4	55.6	84.2	78.2	99.3	96.0	98.6	84.1	64.5	64.0	56.9	61.0	917.8

FIGURE 12. Average monthly and annual water budget on an undisturbed south-facing forested upland slope in Fox Chapel. Units are mm per each unit time. To convert to inches, multiply by 0.03937. For sources and comments, see Figure 13.

Symbol	Variable	Source	Comments
	Water Budget	Dunne and Leopold (1978), pages 238-248.	"I" is assumed insignificant.
P	Precipitation	U. S. National Oceanic and Atmospheric Administration (1971).	Empirical
St.RO	Stormwater Runoff	0.1P (Marie Morisawa, personal communication, Oct. 17, 1979)	Assumed same % in all months and on all slopes. Seasonal and topographic changes in ground cover may actually cause variations.
PET	Potential Evapotranspiration	Dunne and Leopold (1978), Fig. 5-4, at Annual Heat Index = 50 and at monthly slope temperatures given in Figure 37	Average annual total compares satisfactorily with empirical 28.5 in/yr (724 mm/yr) (U.S. National Oceanic and Atmospheric Administration, 1974).
Acc.Pot.WL	Accumulated Potential Water Loss	Sum of negative (P-St.RO-PET) to date.	
SM	Soil Moisture	Dunne and Leopold (1978), Figure 8-3, at water capacity = 400 (silt loam, mature forest).	
Δ SM	Change in Soil Moisture	SM in current month minus SM in previous month.	
AET	Actual Evapotranspiration	AET = PET when PET $\leq$ P AET = P + Δ SM when PET $>$ P	
D or S	Water Deficit or Water Surplus	D = PET - AET when Δ SM $<$ 0 $\therefore$ D $<$ 0 S = (P-St.RO-PET) - Δ SM when Δ SM $\geq$ 0 $\therefore$ S $\geq$ 0	Used in "Ecology"; S = a determinant of remaining variables.

FIGURE 13. Sources and comments for Figures 11 and 12. Continued on next page.

Symbol	Variable	Source	Comments
ΣAvail. for GWRO	Total Available for GWRO	S in current month plus GWS from previous month.	
GWRO	Groundwater Runoff	GWRO = 0.6 (Total Avail. for GWRO), (Dunne and Leopold, 1978, pages 243-244).	
GWS	Groundwater Storage	GWS = (Total Avail. for GWRO) - GWRO = 0.4 (Total Avail. for GWRO).	
ΔGWS	Change in Groundwater Storage	GWS in current month minus GWS in previous month.	
ΣRO	Total Runoff	RO = St.RO + GWRO	Average annual total compares satisfactorily with empirical 13.8 in/yr. (350.5 mm/yr.) on Little Pine Creek near Etna (U. S. Geological Survey, unpublished data, Pittsburgh).
P	Sum of Water Budget	P = AET + St.RO + GWRO + ΔSM + ΔGWS	Confirms balance of water budget (P = P).

FIGURE 13. Sources and comments for Figures 11 and 12. Continued from previous page.

Runoff is all the surface water generated on and occurring on a unit of land; it is the sum of St.RO and GWRO. Figure 14 shows a breakdown of downslope flows more detailed than that in Figure 7. The runoff-producing zone is the zone in which either Horton overland flow or saturation overland flow occurs. The differentiation of this zone from the surrounding hillside is the "partial areas theory"; it differs from many theories, such as the "rational formula", which do not make this distinction. The partial areas theory is tightly related to the "catena" theory of soil geography, in which hydrologic and other properties of soils vary in a gradient from the top of a slope to the bottom, with the wettest and most runoff-producing soils at the bottom. In Fox Chapel under natural conditions Horton flow does not occur (Dunne and Leopold, 1978), and the runoff-producing zone is the zone of saturation overland flow. This zone varies over time and space in response to the climatic and physical properties of the hillside. Obviously, it coincides with the zone of saturated soil.

A Borough-wide empirical inventory of runoff-producing zones is not feasible in this study due to the size of the Borough and the conflict of existing land uses with natural processes (such as the destruction of visible channels). However, studies in similar regions may be combined with local indicators to point the way toward an approximation of their locations. Figure 15 shows the variations in runoff-producing zones in two time scales on a forested watershed of about 10 acres in Danville, Vermont, where the topography and soil are similar to those of Fox Chapel. The saturated runoff-producing areas tend to be near the streams and swales and to extend into concave higher ground during periods of greater moisture. In Fox Chapel, unlike Vermont, the underlying rocks of varying permeability can direct runoff to the surface at elevations high above obvious streams, almost to the tops of ridges; this was discovered in a similar part of Ohio (Amerman, 1965, quoted in Dunne, Moore and Taylor, 1975), and is confirmed by the locations of some springs shown in our maps and by the upland locations of many old springhouses. Size of drainage area can be used for many analytical purposes in place of amount of runoff (and hence the presence of runoff-producing zones) because amount of runoff is highly related to drainage area (Marie Morisawa, personal communication, October 17, 1979). The micro-topography on SRAWA's excellent base map shows that Fox Chapel's known high-ground runoff-producing zones - its high-ground springs and springhouses - can occur on drainage areas as small as about one acre. Hence we may define a useful term for mapping runoff-producing zones:

stream: any point on the ground surface with a drainage area equal to or greater than one acre.

Some peak flows that can theoretically be generated by one acre of Fox Chapel forest area are shown in Figure 16. These flows are significant for land use drainage controls, and confirm the usefulness of the above definition of stream.

The locations of streams are shown on our maps. Streams in Fox Chapel tend to form lines continuously downslope from the one-acre starting point, but in some places the line ends (incongruously but

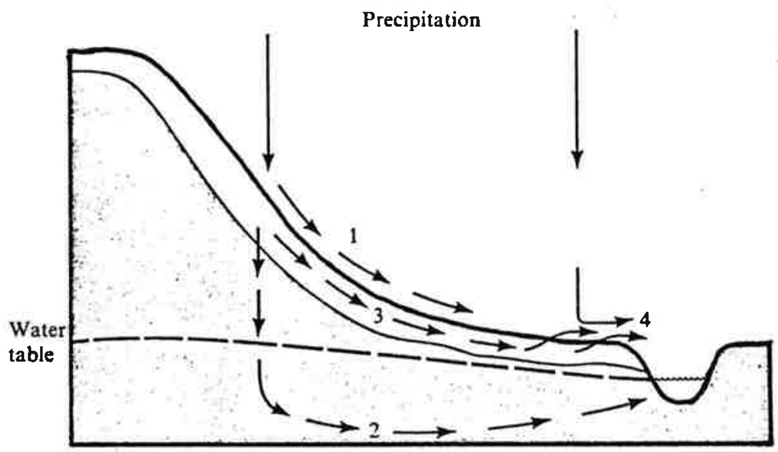


FIGURE 14. Possible paths of water moving downhill. This is a more detailed breakdown of downslope flows than that in Figure 7. The unshaded zone is the porous root zone just below the ground surface; the shaded zone is the relatively impermeable rock below the root zone. Source: Dunne and Leopold, 1978, Figure 9-1.

Legend:

1. Horton overland flow: overland flow due to lack of infiltration.

2. Groundwater flow: deep subsurface flow due to infiltration into and movement through the fractures and pores of the underlying rock, ultimately becoming part of 4.

3. Shallow subsurface flow: subsurface flow due to infiltration into and movement through the soil, ultimately becoming part of 4.

4. Saturation overland flow: overland flow due to groundwater flow and shallow subsurface flow that have discharged to the surface, and precipitation onto the saturated zone.

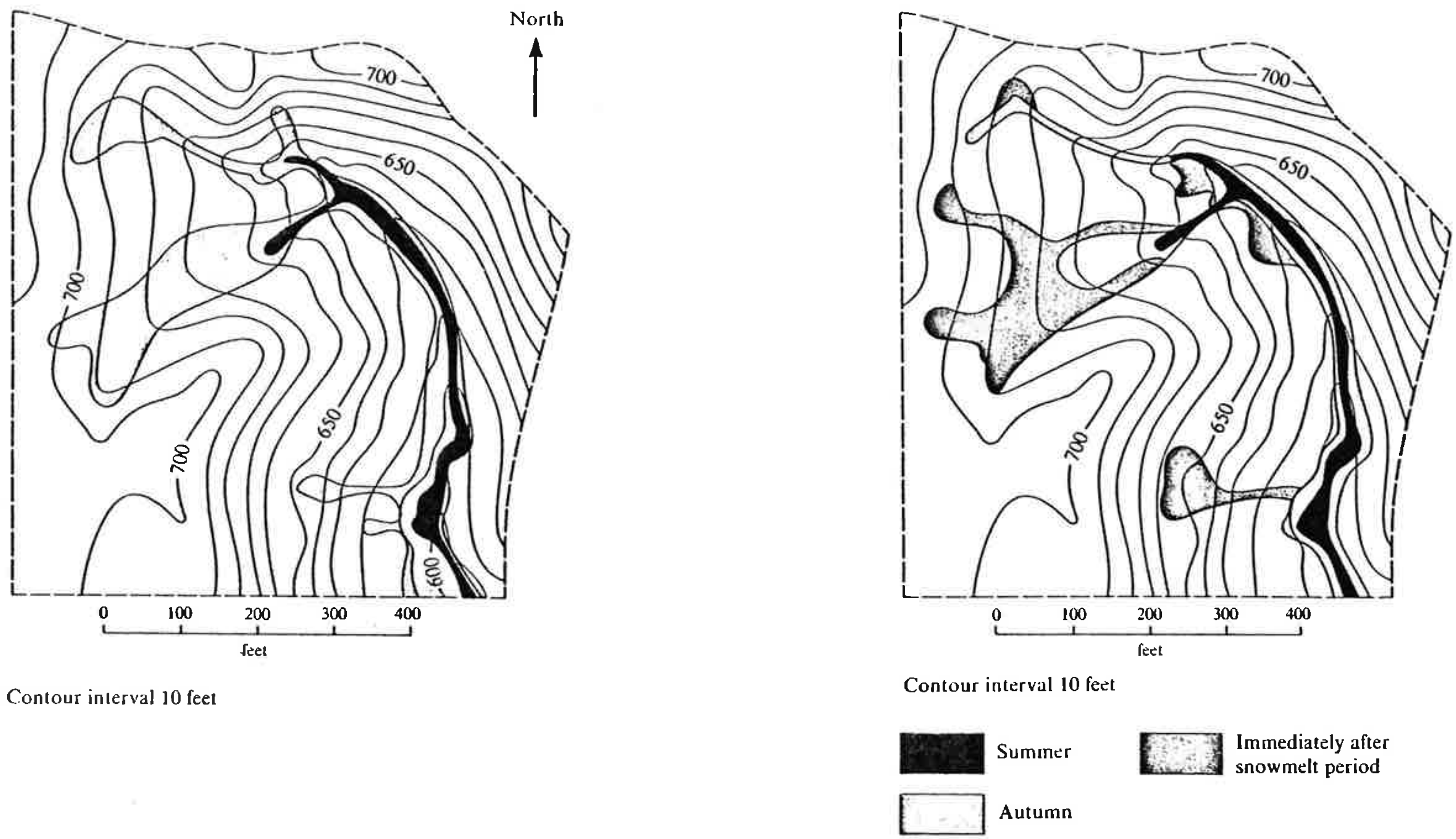


FIGURE 15.

LEFT: Map of a watershed of about 10 acres in Danville, Vermont, showing the variation in saturated area during a storm of 46 mm (1.8 inches). The solid black area is the saturated area at the beginning of the rain; the lightly shaded area is the additional area that was saturated by the end of the storm because the water table had risen to the surface (Dunne and Leopold, 1978, Figure 9-11).

RIGHT: The same watershed, showing seasonal changes in the pre-storm saturated area (Dunne and Leopold, 1978, Figure 9-12).

Variable	Source	Value of Variable at Flow Frequency: 2 yr.	10 yr.	100 yr.
Rational Equation				
time of concentration	assumed	5 min.	5 min.	5 min.
rainfall intensity (i)	Fig. 38	4.3 in./hr.	7.1 in./hr.	9.1 in./hr.
cover factor (c)	U. S. Federal Highway Administration, 1973	0.3	0.3	0.3
area (a)	assumed	1.0 ac.	1.0 ac.	1.0 ac.
PEAK FLOW	Q_p = cai	1.3 cfs	2.1 cfs	2.7 cfs
S.C.S. Method				
hydrologic soil group	Figure	U.C.	U.C.	U.C.
curve number (CN)	U.S. Soil Conservation Service, 1972	73	73	73
rainfall in 30 mins.	Figure 38	0.95 in.	1.4 in.	2.0 in.
peak flow per rainfall	U.S. Soil Conservation Service, 1972, Fig. D-2	1.8 cfs/in.	1.8cfs/in.	1.8 cfs/in.
PEAK FLOW	Q_p = rain x Q_p/rain	1.7 cfs	2.5 cfs	3.6 cfs

FIGURE 16. Some peak flows that can be generated by one acre of Fox Chapel forest - that is, generated at the extreme headwater of a stream. Conditions assumed are forest cover, moderate slope, and well-drained silt loam soil.

truly) where the lower slope is convex and the drainage area disperses. This might explain the description by the Ohio researcher of some upland locations of runoff-producing zones as "seemingly random". Although geologists define a "stream" as an actual flow of water (American Geological Institute, 1974), the above definition probably encompasses the centerlines of most actual and potential future flows under natural conditions, thereby encompassing such types of streams as "ephemeral", "intermittent" and "perennial".

We may now define another useful term:

lowland: any point on the ground surface at or within the depth of the 100-year flood shown on the flood profiles of U. S. Federal Insurance Administration (1975), on streams so profiled; and any point on the ground surface at or within five feet in elevation of the bottom of the nearest stream, on all other streams. On profiled streams, the depth of water above the channel bottom is decisive, not the nominal elevation above sea level of the water surface.

So defined, lowland probably coincides with the maximum area of the Borough's runoff-producing zone as accurately as is feasible. Hence it coincides with the maximum area of the Borough's zone of saturated soil to the same degree.

upland: any point on the ground surface that is not lowland.

Together, lowland and upland encompass the entire landscape. Their characteristics are contrasted in Figure 17. Both of these concepts are intended to be models of runoff-producing zones and other natural features. Their validity is supported by the logic of this section, but empirical testing and improvement of them is suggested as a field for further research. These two classes of land are superimposed on the north-and south-facing slopes discussed above, giving a total four-way hydrologic classification of land. Water budgets for lowlands would include figures for incoming runoff and discharging subsurface flow, unlike those for uplands in Figures 11 and 12.

Once runoff has been generated, it is eligible to become floodwater: water entering or leaving a land unit in the form of surface water.

floodprone zone: any point on the ground surface at which the probability of occurrence of floodwater is equal to or greater than one percent in any one year.

Under natural conditions floodwater, like runoff, occurs only at or downdrainage from a runoff-producing zone. Therefore, lowland probably approximates floodprone zone as closely as is feasible. The other available means of approximating the floodprone zone is the U.S. Soil Conservation Service soil maps (no date); they are considered

Characteristic	Lowland	Upland
Soil moisture	wet	dry
Runoff	high: saturation overland flow and groundwater runoff	none
S.C.S. Hydrologic Soil Group (inferred from other soil characteristics) (U.S. Soil Conservation Service, 1972)	D (high runoff potential; very slow infiltration rate when thoroughly wetted and permanent high water table)	C (slow infiltration when thoroughly wetted); possibly some B (moderate infiltration rate when thoroughly wetted)

FIGURE 17. Some relative comparative characteristics of undisturbed <u>lowland</u> and <u>upland</u> in Fox Chapel.

geographically inferior to the lowland model for reasons which are given under "Soils." Laflure's (1978) empirical hydrologic data is scientifically good, but was not analyzed for probability of flood occurrence or for Borough-wide geographic generalization.

Any floodprone zone has some capacity to dissipate floodwater, reducing the peak flow and lengthening the peak time as the flow moves downstream. Fox Chapel's lowlands have not been analyzed for this capacity because several sections of this Plan conclude that lowlands are places to be conserved, not disrupted for use. The current stormwater study by the Guyasuta Joint Municipal Planning Commission may include this type of analysis and suggestions for use of the capacity.

Under natural conditions, all of the water not removed from the land by evapotranspiration must eventually become floodwater. The rate of flow of floodwater at any point varies over time with all of the water-budget terms described above. Rate of flow is measured in units of volume per time. Any given rate of flow has some probability of occurrence at any one point.

Base flow: the flow on which a flood event is superimposed.

Flood event: flow larger than the base flow for a specified duration.

Peak flow: the greatest instantaneous flow occurring during a given flood event.

Base flows are produced by GWRO and controlled by rocks underlying the watershed. Hence we presume that smaller watersheds behave like geologically similar larger ones at base flow. In Fox Chapel the lowest base flow can be much lower in the fall than in the spring. An undeveloped watershed of 137 square miles near Fox Chapel has been reliably measured to have a low flow (flow exceeded 80% of the time, during the lowest month of the year) of about 0.05 cfs/sq. mi. (Beall, 1978, Figure 17). Laflure (1978, p. 37) measured "low" flow on Squaw Run, where the watershed is 7.4 sq. mi., of about 1.5 cfs/sq. mi. in September of 1978. The exceedance level at the time of Laflure's measurement is not known (that is, we don't know how "low" the low flow was), so we take the 0.5 cfs/sq. mi. of the larger nearby watershed to be the flow that is exceeded 80% of the time during the lowest month for Fox Chapel's streams. Similarly, the mean annual flow on the larger watershed of about 1 cfs/sq. mi. is taken to apply to Fox Chapel.

Peak flows are produced by ΣRO and controlled by the shape of the watershed and its channels. Hence a smaller watershed behaves differently from a larger one at peak flow (Laflure, 1978). In Fox Chapel the highest peak flow may be the same in any season (Beall, 1978). Two simple and well-known methods of estimating peak flow and associated flow characteristics in smaller watersheds are the "rational formula" and the S.C.S. soil-cover complex method. Figure 18 gives some data for use in these methods specifically in Fox Chapel and the surrounding Pittsburgh area that are not widely available elsewhere. The uses of these and more elaborate calculation methods are discussed by Ferguson (September, 1980) and the Pennsylvania Department of Environmental Resources (1980). The refinement of an accepted calculation method for use in small Fox Chapel watersheds is an area for further research. Tying the partial-areas theory and the water budget concept into such a refinement would help to unify our understanding of Fox Chapel's natural environment. Until such research is completed, the accepted methods of peak flow calculation must be used even in uplands, despite the implication of the partial areas theory that no runoff at all is ever produced in uplands.

Floodwater is eligible to be the agent of eroding, transporting and depositing sediment, which is solid matter that is being or has been transported naturally. Under natural conditions silt and clay sediment is delivered to floodwater by stream action and by gravity (Nelson, 1979). The results of the delivering forces are shown in Figure 19a. As the water continues to carry the sediment downstream, the floodwater and sediment combine into an interacting system. Sediment is deposited, picked up again, and deposited again; and more sediment and more floodwater are added from the cumulative drainage area. Most of the total volume of sediment is carried out of Fox Chapel to the Allegheny River. During a flood event most sediment is flushed through a stream reach during the first period of enlarged flow.

The morphologic result is a system of floodwater-sediment features in the floodprone zone (Figure 19b),aligned along the stream's gradient and dynamically in balance with the properties of the drainage area. The entire system of features changes over time, sometimes measurably within a few hours, in response to continuing variations in flows (Laflure, 1978). Compared to other regions, some morphologic characteristics of typical Fox Chapel floodprone zones are (Laflure, 1978):

1. Channel small in cross-section.

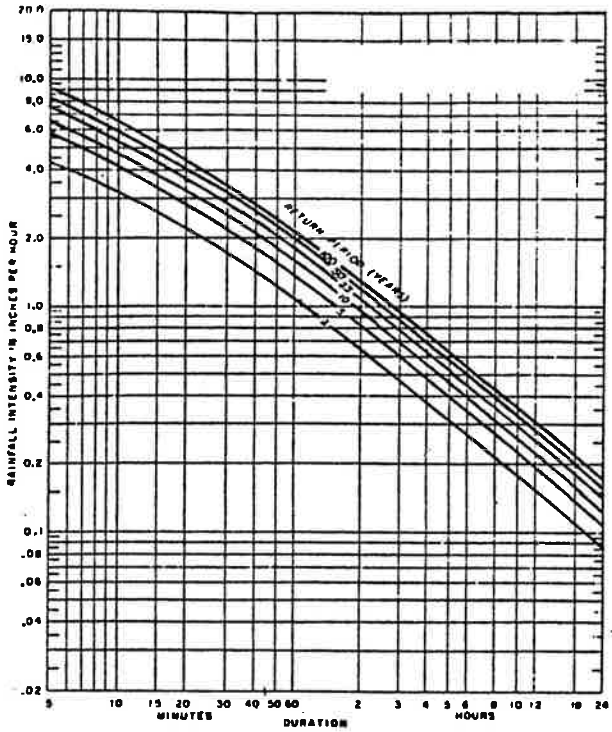
2. Narrow meander belts.

3. Steep gradient.

4. Channel low in sinuosity.

5. Few natural ponds or wetlands.

The morphology of the floodprone zone in turn influences the flow of water through it. In most of the Borough increased storm or seasonal flows are accommodated by increased velocity due to the steep gradients and small channel cross-sections; whereas in the lower reaches of Squaw Run, which are uniquely level and broad, they are accommodated by increased cross-sectional area. During low flows, the flow through the pores of the channel materials may be a large portion of the total, particularly in the large amounts of sediment in the lower reaches of



Storm frequency (years)	storm duration (hr.)						
	0.5 hr.	1 hr.	2 hr.	3 hr.	6 hr.	12 hr.	24 hr.
1	0.75	0.95	1.2	1.3	1.7	1.8	2.3
2	0.95	1.2	1.4	1.6	1.9	2.2	2.6
5	1.2	1.6	1.8	2.0	2.4	2.8	3.3
10	1.4	1.8	2.2	2.4	2.8	3.3	3.9
25	1.6	2.1	2.4	2.8	3.4	3.8	4.4
50	1.8	2.3	2.8	2.9	3.7	4.1	4.9
100	2.0	2.5	3.0	3.4	3.8	4.8	5.2

FIGURE 18. Rainfall intensity, duration, and frequency in the Pittsburgh area, for use in calculating peak flow. Above, for use in the "rational formula" (Pennsylvania Department of Transportation, 1975). Below, for use in the U. S. Soil Conservation Service soil-cover-complex method, in inches of rainfall (U. S. Weather Bureau, 1961).

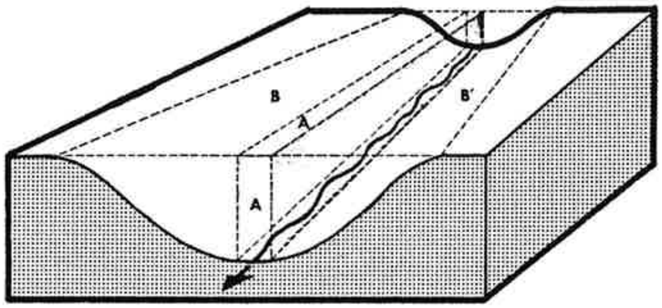


FIGURE 19a. The volume of sediment delivered to floodwater under natural conditions. Volumes B and B' were moved downslope to the water by the gravitational processes of "creep" and landsliding. Volume A was eroded by water abrasion and corrosion (Bloom, 1969).

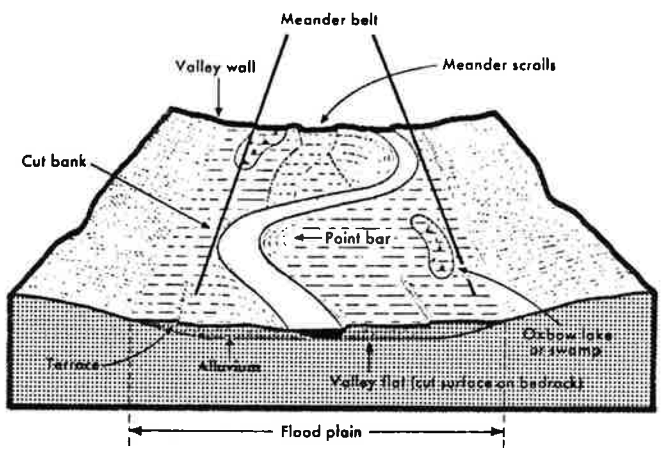


FIGURE 19b. Some morphologic features of floodprone zones created by the dynamics of the floodwater-sediment system (Bloom, 1969).

Squaw Run. Elsewhere in the stream system, the weathering of different rock types yields channel materials which resist erosion to varying degrees, which therefore influence the shape of the channel, and which therefore influence the flows in the channels in different ways (Laflure, 1978).

Most components of the water budget are eligible to be the agent of eroding, transporting and depositing chemical matter. Naturally occurring groundwater and surface water contain some mild chemicals that were derived from watershed materials as the water flowed through them (Piper, 1933).

2. Land Use

Some hydrologic properties of land uses are their ground surface materials; their artificial drainage facilities; their artificial water conveyances; their sediment, chemical and biological outputs; and variations of the above over time and space. All of these properties interact with the flows of the water budget, the physical and chemical composition of water, and the morphology of stream features.

Some characteristics of common ground-surface components of Fox Chapel land uses are compared in Figure 20. A pavement or roof produces Horton overland flow in all rainstorms and snowmelts no matter where it is located, unlike any natural Fox Chapel land (Dunne and Leopold, 1978). This results in a large proportion of stormwater runoff. The water so diverted is unavailable for other terms of the water budget. The potential evapotranspiration on a pavement or roof is higher than in a forest due to the higher average temperatures (see "Thermosphere"), and the water capacity is low due to the near-absence of pores. Consequently, although water budgets on pavements have not been calculated, we can assume that all the water remaining after stormwater runoff is evaporated, and no groundwater flow occurs, either on north-facing or south-facing slopes. Thus pavements and roofs never completely recharge soil moisture or groundwater storage; they add to peak flows; and they subtract from base flows, compared with the native forest. The hydrologic properties of a lawn are generally intermediate between those of a forest and a pavement; consequently it is assumed to affect the water budget the way that a pavement does, but to a lesser degree. These effects of development were confirmed empirically, and their implications for floodwater and morphology elaborated, by Laflure (1978).

However, large parts of Fox Chapel Borough still retain their natural hydrologic functions: the upper 5.4 square miles of Squaw Run's drainage area is only about three percent impervious, with correspondingly high soil storage and steady flow. The actual impermeable portions of Borough-wide zoning districts, including existing undeveloped areas, are shown in Figure 21.

Variable	Mature Fox Chapel Forest	Unshaded Asphalt Pavement or Dark Roof	Unshaded Lawn
Albedo (Reflectivity, α)	0.10 (a)	0.12 (b)	0.20 (a)
Average St.RO $\div$ P	0.1 (c)	0.9 (d)	0.3 (d)
Water Capacity	400 mm (e)	25 mm (e)	250 mm (e)
Average Air Temp. in N-facing cold-air lowland	R - 1.7°C (f)	R - 0.6°C (g)	R - 1.2°C (g)
Average Air Temp. in S-facing warm-air upland	R + 1.7°C (f)	R + 2.8°C (g)	R + 2.2°C (g)
Types of Runoff in runoff producing zone	saturation overland flow, groundwater runoff (h)	Horton overland flow (h)	saturation overland flow, groundwater runoff (h)
Types of Runoff in <u>upland</u>	None (h)	Horton overland flow (h)	None in small storms Horton overland flow in large, intense storms (h)

FIGURE 20. Comparisons of some selected hydroclimatic variables on three important ground covers.

(a) Dunne and Leopold, 1978, Table 5-1; Lowry, 1967, Table 8-5; Geiger, 1971, Table 3.

(b) Calculated from Landsberg and Maisel, 1971, Table 1.

(c) Marie Morisawa, personal communication, October 17, 1979.

(d) Dunne and Leopold, 1978, Table 10-9.

(e) Dunne and Leopold, 1978, Figure 8-3.

(f) Figure 37.

(g) Estimated from (f) and Landsberg and Maisel, 1971, Table 1.

(h) Dunne and Leopold, 1978, Figure 9-2.

Artificial surface drainage facilities start at relatively impermeable (producing Horton overland flow) ground materials of used facilities. The generated surface water is deliberately removed from the surfaces in order to make the surfaces usable. The means of removing it (the "primary drainage system") can be classified somewhere between "conveyed" and "recycled", as diagrammed in Figure 22. An extreme case of conveyed drainage is an impermeable roof or pavement from which runoff is collected and piped directly away. An extreme case of recycled drainage is the collection of roof runoff into a cistern for household use and later slow irrigation. An example of intermediate drainage is the "natural drainage" promoted by John Rahenkamp, in which impervious streets and sidewalks are minimized in width and length through functional specialization, impervious pipes are replaced with pervious swales along the same alignments, and impervious curbs are replaced with bollards. In addition to the primary drainage system, any land use has a "secondary drainage system" which goes into effect when the primary system is inoperable or its capacity is exceeded by large flows. The function of any artificial primary drainage system (when deliberately designed) is to maintain facility convenience by disposing flows smaller than or equal to a "design flow". The function of a secondary system (when deliberately designed) is to prevent damage to land use components by conveying any flows larger than the design flow around them. The sets of primary and secondary drainage technologies are inventoried in the literature listed by Ferguson (August, 1978). The following conclusions by Laflure (1978) should be added to existing conventional primary drainage technology:

1. channels of trapezoidal cross-section (for sediment stability);
2. channel width at bottom at least 10 times water depth at recurrence interval of 2 years;
3. entire conveyance within one pipe or channel, not two or more parallel;
4. permeable sides and bottom;
5. minimize velocity in conveyance with high roughness, large cross-section, and low gradient, at least below the erosion threshold of the channel material;
6. where an artificial conveyance such as a culvert replaces a natural stream, the cross-section area should be at least as large as that of the original channel.

Components may be added to the primary drainage system specifically for reduction of peak flow, including some that increase recharge. The set of peak flow reduction technology, including that portion of it that increases recharge, was inventoried by Ferguson

Zoning District	Range	Average of Areas, Unweighted for Sizes of Areas
A	0.0 - 7.8%	5.3%
B	1.2 - 11.8%	7.2%
C	5.2 - 16.0%	9.3%
D	5.2 - 18.0%	13.1%
CD (Park)	0.0 - 0.0%	0.0%

FIGURE 21. The actual impermeable portions of Borough zoning districts, measured at each homogeneously zoned land area. Existing undeveloped areas are included; the "D" District is nearly fully developed, unlike the others. Calculated from Nelson, 1979.

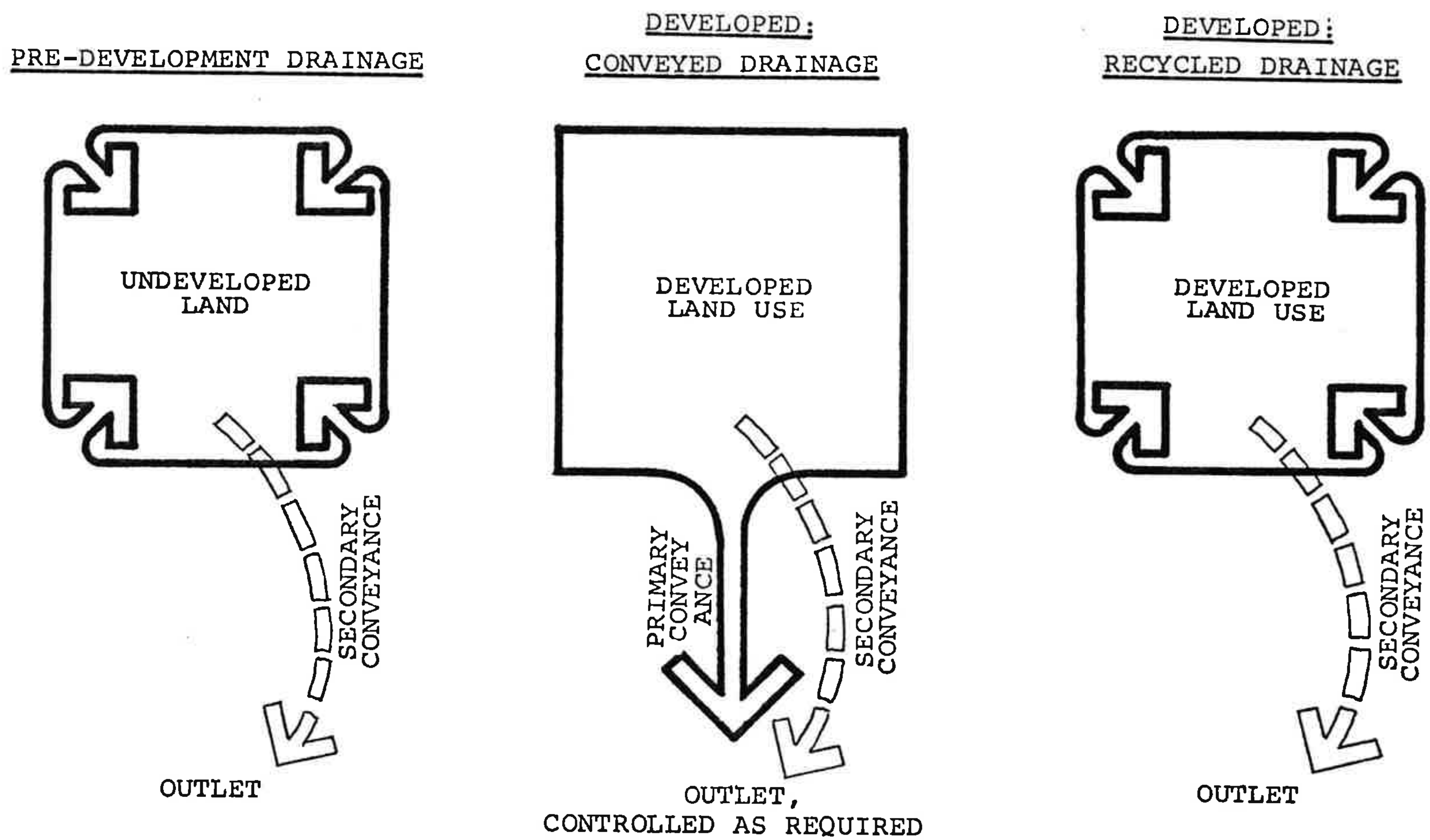


FIGURE 22. Diagrammatic comparison of natural predevelopment hydrology in Fox Chapel with the two extreme types of artifical drainage systems (Ferguson, September, 1980).

(October, 1980), but Tourbier's (in progress) inventory may include important supplements when it is published. A point seldom emphasized in the literature but very relevant to this Plan is the importance of the location of the construction area boundary. This boundary differentiates the area to be disturbed from the area that will be protected from disturbance, and is the line along which flow standards are applied. Areas to be protected must include all properties under different ownership, and all areas under the same ownership that are intended for conservation. When lowlands are intended for conservation, the control of flows will necessarily be on a lot-by-lot or other small-drainage-area basis. See Figure 24.

Structures vulnerable to flooding are those within lowlands; they are identifiable in the maps. Floodwater may be diverted from a used facility by dikes and channels, reduced by updrainage detention or recharge, or conveyed rapidly past the facility by increased drainage capacity.

Any structures vulnerable to flooding are vulnerable also to poor soil drainage. Water may be removed from the soil near subsurface parts of used facilities, in order to make them livable or to stabilize their foundations. The set of technology for diverting GWRO and shallow subsurface flow was inventoried in the literature listed by Ferguson (August, 1978), but is being rapidly supplemented by research in pavement permeability such as that of Cedergren, O'Brien and Arman (1972) and Thelen and Howe (1978).

Some components of artificial drainage systems or other land use components may interact with natural flows and features (Figure 23). Cuts, fills or culverts may hasten or obstruct the natural generation of runoff or the flow of floodwater. Artificial ponds may enlarge lowlands. The natural dynamics of floodwater may destabilize artificial drainage conveyances. Sediment may accummulate, obstructing conveyances: most existing culverts in the Borough are partially filled with sediment deposited when floods rapidly receded (Nelson, 1979). Used facilities may be inundated or destabilized by surface or subsurface water. Channelization may increase velocity or overbank flows.

Water is supplied to land uses artificially. The Allegheny River, the gravels adjacent to that River, and groundwater below the elevations of major streams are the most important regional water sources (Gallaher, 1973). Soil moisture over the entire landscape is an important link in recharging and stabilizing these sources. Shallow subsurface flows in runoff-producing zones were water sources in the past judging from Fox Chapel's springhouses. A potential future water source is direct precipitation.

After withdrawal from sources, water supplies are stored at high elevations for pressure, then distributed to intense land uses in a looping network of pipes. Leaks and occasional discharges may occur at any point in the storage, distribution and use of supplied water;

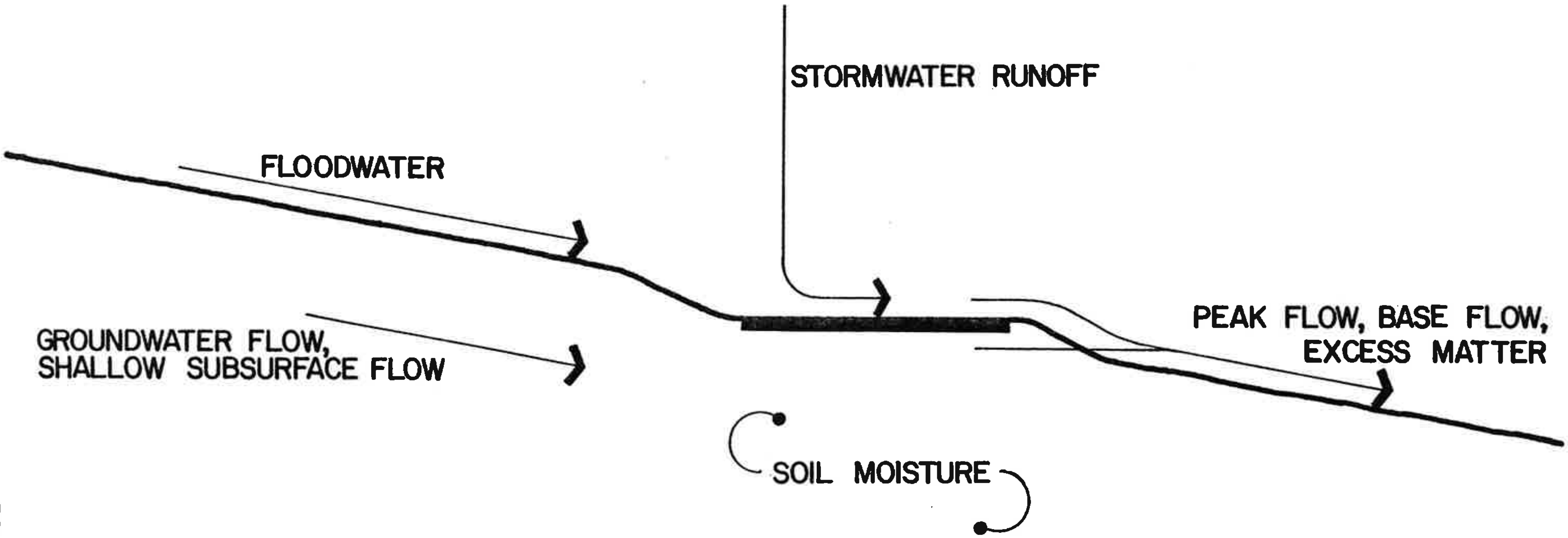


FIGURE 23. Some interactions of land use technology (a road is shown in cross-section) with natural flows and features of water.

examples are water tower flushings, fire hydrant flushings, and swimming pool discharges. These outflows are usually small in volume compared to the landscape's water budget, but may be large and energetic peak flows relative to the point of occurrence.

During use, depressurized supplied water is mixed thinly with household materials. The resulting sewage is transported in pipes to septic tanks for leaching into the local soil, or to collector sewers and out of Fox Chapel. Sewer facilities in or directly influencing Fox Chapel are the Ottawa treatment plant (in Indiana Township), pump stations, and the pipes and manholes that extend through most of Fox Chapel's watersheds.

The Ottawa treatment plant discharges treated effluent into Squaw Run at the northern (upstream) boundary of Fox Chapel. The effluent comprises most of the stream flow, and dominates the water quality between the plant and Campbell's Lake. Major constituents of that quality are BOD, solids, nutrients and bacteria. Suspended solids are deposited in this reach during frequent low flows. Aquatic life is thereby damaged: while Squaw Run supports a diversified taxa above the treatment plant, only one genus has been found immediately below it. During higher flows the deposited solids are probably scoured into Campbell's Lake; these solids and the plant's nutrients accelerate the eutrophication of Campbell's Lake. Thus, although the plant performs a service by treating sewage, it is a pollutor because it is the outfall point of that sewage, and we may classify the affected reach as a polluted stream (Water Supply and Pollution Control Program, pp. 16-17).

The Borough's pump stations and conveyances pollute streams in similar ways, but to a much smaller degree. Leaks and overflows in conveyances cause discharges into the environment. These can be greatly accelerated by infiltration during storms, by flooding where the facilities are subject to it, and by combined storm and sanitary sewers. Outflows in runoff-producing zones are more likely to reach streams and groundwater supplies due to the greater amounts of water available for transportation (Dunne, Moore and Taylor, 1975). Pump stations are particularly noticeable discharge points because they are deliberately designed to overflow during storms in order to bypass the pump. Many points at which interaction of sewers with the environment could be reduced have already been identified by Bankson Engineers (1979). The current regional planning study by Green International may assist further in solving sewer problems.

Means of local sewage disposal, such as land recycling, are not considered here due to the regional powers of the Allegheny County Sanitary Authority. Therefore, although local disposal may increase the annual runoff by up to 50 percent, sewage is not considered a significant part of Fox Chapel's water budget.

A drainage system may deliver unnaturally high rates of sediment to a stream by conveying or discharging water at velocities greater than the local erosion thresholds. Also, clearing and soil disturbance during construction can cause soil erosion and its delivery to streams at rates far in excess of those under the natural conditions shown in Figure 19a. Nelson (1979) measured an increase in sediment delivery of 100 times at an uncontrolled construction site near Fox Chapel. With an increase of this magnitude we may qualitatively distinguish, from all other sediment:

disturbance sediment: sediment that is originating or has originated at a disturbed area.

Disturbance sediment originating in a runoff-producing zone is more likely to reach streams than that originating in uplands due to the larger amounts of water available for transportation. The general types of technology for reducing generation and outflow of disturbance sediment were inventoried by Ferguson (July-August, 1978, Table 1), and some design guidelines for use in Fox Chapel are given by Allegheny County Department of Planning and Development (1973). To those guidelines the following considerations should be added:

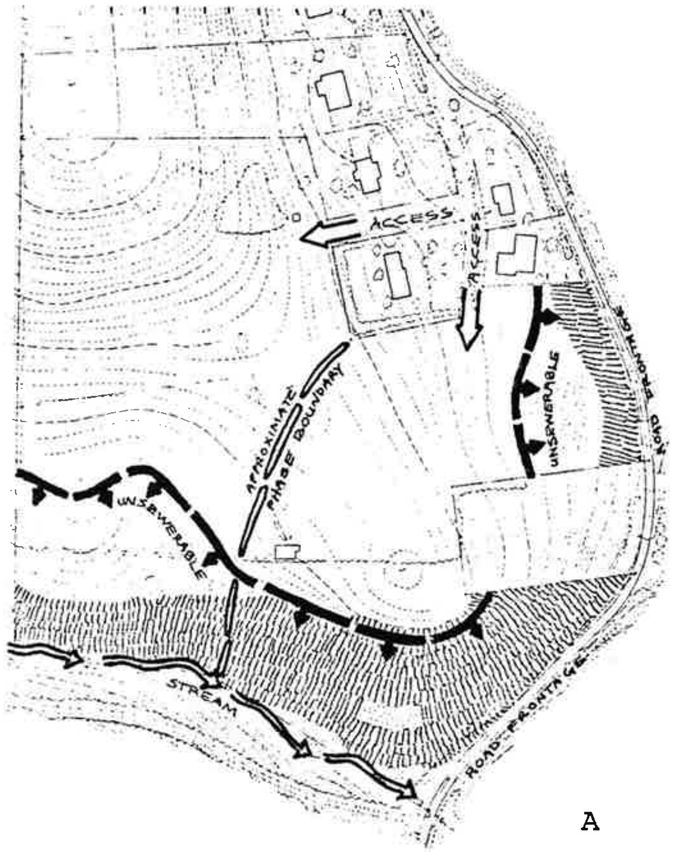
1. Fine-grained soils such as those in Fox Chapel are only partly captured in sediment basins with perforated-pipe outlets, due to the long suspension time of the soil particles in water. Basin outlets should be wrapped with filter blankets to trap the remaining soil. Alternatively, water can be disposed by evapotranspiration from a closed basin, leaving all sediment in the basin; this is particularly true in summer when both erosion and evapotranspiration are most rapid.

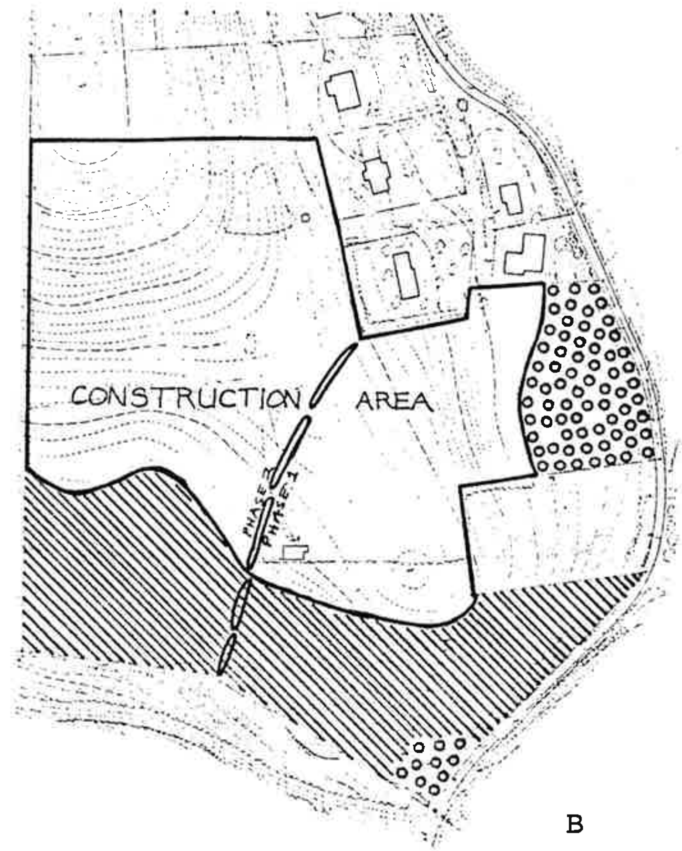
2. The applications of the most widely used method for calculating rates of erosion, the Universal Soil Loss Equation, were recently summarized by Wischmeier (1978).

3. The location of the construction area boundary is critical, because that boundary differentiates the area that will be disturbed from the area that will be protected from disturbance (Ferguson, July-August, 1978). Some steps in locating the boundary are shown in Figure 24. Areas to be protected must include all properties under different ownership, and all areas under the same ownership that are intended for conservation. When lowlands are intended for conservation, the control of sedimentation will necessarily be on a lot-by-lot or other small-drainage-area basis.

After construction is completed, apparently accelerated erosion and sedimentation can continue for a long time if surface water flows are above predevelopment levels. These flows erode the receiving channel itself, thereby inducing the same impacts as on-site erosion. This is confirmed by Laflure's (1978) observation that channel morphology is restabilized only long after a watershed's land uses are stabilized, with increased flow accommodated in the meantime by increased velocity and increased overbank flows.

Lawns can generate water-borne nutrients and organic matter by periodic fertilization and harvesting. Matter generated on lowlands is more likely to reach streams or groundwater supplies than that on





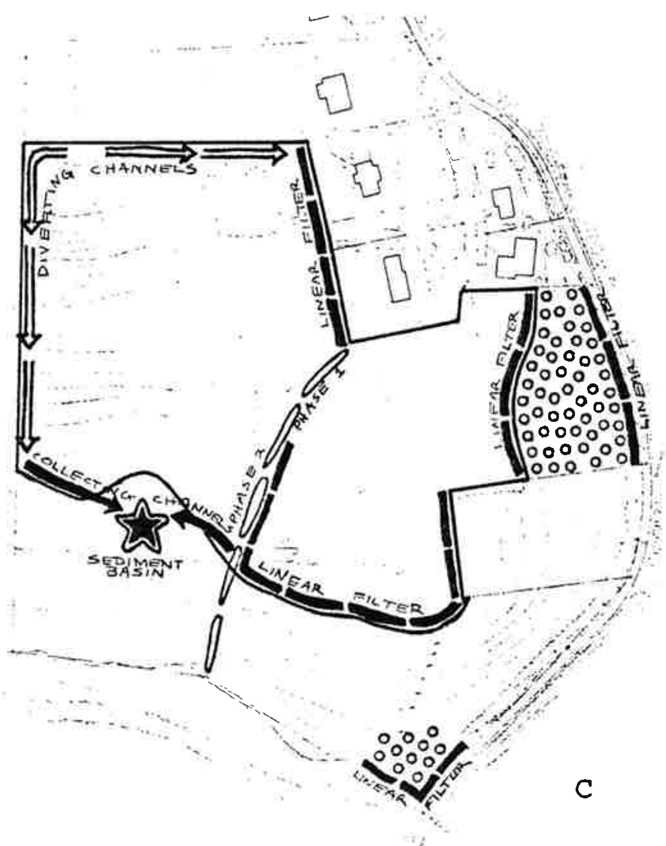


FIGURE 24. Some steps in locating the construction area boundary at a 21-acre development in Washington County, Pa. (Ferguson, July-August, 1978). A: Land use planning factors. Hatched areas are 25% + slopes. B: Construction areas and phasing. Open-dotted areas are minor, isolated construction; hatched areas are undisturbed. C: Construction boundary controls of drainage and sedimentation.

uplands due to the greater amounts of water available for transportation. That generated on uplands is relatively likely to be absorbed by plants or filtered by soil before reaching a concentration of water (Dunne, Moore and Taylor, 1975). Some persons have speculated that Fox Chapel's golf courses are important pollutors. However, strong nutrient concentrations did not show up at their outlets in the Water Supply and Pollution Control Program study. The ponds at the outlets of the two club golf courses are functioning as nutrient traps, insulating downstream reaches from the golf courses.

As a result of many of the above land use processes, some stream reaches contain chemical or physical variations from the "base" load of natural minerals and groundwater-controlled temperatures. Variations in water quality are monitored quarterly by the Allegheny Department of Health in the lower reaches of Squaw Run and Guyasuta Run (Bancroft, 1980). Their results show that these reaches are normally within the applicable water quality standards (listed in Figure 25). However, to see the variations in water quality in other reaches, more local studies must be done. Such a study was done by Water Supply and Pollution Control Program in 1976. Although it did not study every stream reach and was not as detailed or as long-term as might be hoped, this study did produce some important conclusions. (Other sources that can help to interpret their data are Beulah Frey's work at the Fox Chapel School District, David Wiel's students at Shadyside Academy, and Darby).

Seven major potential types of influences on water quality can occur in land uses. They are sewer facilities, road salts, lawns, ponds, construction sites, and increased stormwater flows. Of these, sewers, lawns, construction sites and increased stormwater flows were discussed above. Probably the strongest and most ubiquitous influence in Fox Chapel is sewer facilities.

Road salts have been a subject of discussion in Fox Chapel for many years. Chlorine and other salt chemicals are washed readily from road surfaces into streams, soils and groundwater.

Ponds can be pollutors of sorts by increasing water temperature, particularly when the pond's water discharges from the top of the pond. Increases of 3.5 and 5.0°C due to Campbell's Lake were noticed in the Water Supply and Pollution Control Program (p. 17). However, ponds can also improve water quality by trapping solids and nutrients. From this viewpoint the locations of many of Fox Chapel's ponds are fortuitous. Campbell's Lake traps effluent from the Ottawa Treatment Plant; Glade Lake traps that from the Fox Chapel Golf Club golf course; a series of ponds traps that from the Pittsburgh Field Club golf courses. Although this function accelerates the eutrophication of the ponds, they can be periodically renewed by dredging. As long as the dredge spoils are disposed updrainage of the pond, the ponds will continue to insulate downstream reaches from upstream pollutors.

Pa. DER Symbol	Parameter	Pennsylvania Department of Environmental Resources (Ch. 93) Standards
pH_4	ph	Not less than 6.0 and not more than 8.5
DO_2	Dissolved Oxygen	Minimum daily average 5.0 mg/l, no value less than 4.0 mg/l; for the epilimnion of lakes, ponds and impoundments, minimum daily average of 5.0 mg/l, no value less than 4.0 mg/l.
F_e	Iron	Total iron not more than 1.5 mg/l.
$Temp_2$	Temperature	Not more than a 5^oF rise above ambient temperature or a maximum of 87^oF, whichever is less, not to be changed by more than 2^oF during any one-hour period. (Ambient temperature: the temperature of the water body upstream of a heated waste discharge or waste discharge complex. The ambient temperature sampling point should be unaffected by any sources of waste heat).
TDS_2	Dissolved Solids	Not more than 1,500 mg/l at any time.
Bac_5	Bacteria	The fecal coliform density in five consecutive samples shall not exceed a geometric mean of 200 per 100 ml.

FIGURE 25. Water quality standards applicable to streams in Fox Chapel (Pennsylvania Department of Environmental Resources, Chapter 93).

3. Desired Outcomes

The foregoing information has prepared us to specify a set of concrete, measurable desired outcomes in the form:

Outcome = f(Land, Land Use)

These outcomes are derived from the "ideals" stated in "Fox Chapel's Natural Resources Problem", specifically for the hydrological aspects of the problem. The relationships of the outcomes to other desired outcomes will be specified, and resulting courses of action selected, under "Conclusions."

For any used facility:

$$Fld = \frac{Prim}{Sec\ U_p}$$

where:

Fld = annual probability of occurrence of surface water (either runoff or floodwater) on the used facility. Desired outcome: minimize Fld.

Prim= annual probability of flow to which the primary drainage system in and around the used facility is constructed.

Sec = the application of a secondary drainage system to the used facility, for protection from flows of all probabilities, including floodwater flows. Sec is either 1 (yes) or 0 (no).

U_p = location of the used facility in upland. U_p is either 1 (yes) or 0 (no). (Note that U_p has the same meaning in the following equation).

A corollary of Fld is that every facility that crosses a stream must receive primary drainage without the stream's water entering on the used facility. For example, a road that crosses a stream must convey water under the road by culvert, and not onto the road's gutter. Where a cut slope intercepts a stream, the stream water must be conveyed down the slope by a controlled channel or culvert. Recurrence intervals for the design of primary and secondary drainage facilities are discussed in Pennsylvania Department of Environmental Resources (1980), Ferguson (September, 1980), and Newcomb (1967).

For any used facility:

$$Sub = \frac{1}{Div\ U_p}$$

where:

Sub = probability of occurrence of subsurface water (either groundwater runoff or shallow subsurface flow) in subsurface parts of a used facility. Desired outcome: minimize Sub.

Div = the application of technology for diverting subsurface water around the used facility. Div is either 1 (yes) or 0 (no).

U = location of the used facility in <u>upland</u>. U_p is either 1 (yes) or 0 (n0).

For any point on the border of any <u>lowland</u>:

$$\Delta Q_p = \frac{Q_p\ post}{Q_p\ pre}$$

where:

ΔQ_p = the ratio of peak flow at the border point at a design frequency after development, to that before development. Desired outcome: minimize ΔQ_p.

Q_p post = peak flow at the border point at the design frequency after development.

Q_p pre = peak flow at the border point at the design frequency before development.

A corollary of ΔQ_p is that a construction area boundary shall not cross the boundary of a <u>lowland</u>. ΔQ_p may be calculated at the construction area boundary if it is updrainage from the <u>lowland</u> boundary. Note that if the partial areas theory is strictly interpreted, both Q_p pre and Q_p post must equal 0.

For any point on the border of a lowland:

$$\Delta Q_{vol} = \frac{Q_{vol}\ post}{Q_{vol}\ pre}$$

where:

ΔQ_{vol} = the ratio of flow volume at the border point at a design frequency after development, to that before development. Desired outcome: minimize ΔQ_{vol}.

Q_{vol} post = flow volume at the border point at the design frequency after development.

Q_{vol} pre = flow volume at the border point at the design frequency before development.

A corollary of Q_{vol} is that a construction area boundary should not cross the boundary of a lowland. ΔQ_{vol} may be calculated at the construction area boundary if it is updrainage from the lowland boundary. Note that if the partial areas theory is strictly interpreted, both Q_{vol} pre and Q_{vol} post must equal 0. Although time to peak (t_p) has been suggested as a subject of control, any change in t_p will be trivial if ΔQ_p and ΔQ_{vol} are successfully applied - thatis, if lowland boundaries are not crossed. Hence, t_p is not discussed further here.

At any point on the border of any lowland:

$$\Delta Sed = \frac{Sed\ post}{Sed\ pre}$$

where:

Δ Sed = the ratio between the rates of disturbance sediment at the border point after development to that before development. Desired outcome: minimize ΔSed.

Sed post = rate of disturbance sediment at the border point during and after development.

Sed pre = rate of disturbance sediment at the border point before development.

Note that Sed pre probably equals 0. A corollary of ΔSed is that construction area boundaries should not cross lowland boundaries.

For any lawn with a given rate of fertilization:

$$P_{lawn} = \frac{A_{lawn}\ F}{U_p}$$

where:

P_{lawn} = the relative probability that pollutants from the lawn will reach either groundwater or a <u>stream</u>. Desired outcome: minimize P_{lawn}.

A_{lawn} = area of the lawn.

F = rate of fertilization, spraying or other application to the lawn per area per time.

U_p = location of the lawn in an <u>upland</u>. U_p is either 1 (yes) or 0 (no).

At the outlets of Fox Chapel's two club golf courses, which have extraordinarily high $A_{lawn}\ F$ factors, existing ponds may be maintained as traps of lawn pollutants, with any dredge spoils being disposed updrainage of the ponds.

For any land area:

$$P_{sewer} = \frac{\left(\frac{Low\ L}{L}\right) L}{T}$$

where:

P_{sewer} = the relative probability that a given rate of sewage will reach a <u>stream</u>. Desired outcome: minimize P_{sewer}.

L = length (or flow rate, if not a conveyance), of sewer facility in the land area.

$\frac{Low\ L}{L}$ = proportion of the sewer facility in a <u>lowland</u> location.

T = application of the technology for sealing sewer facilities from the environment. Either 1 (yes) or 0 (no).

Although some crossings of lowlands by sewer lines are unavoidable, all manholes and pump stations can be feasibly located in uplands and at least five feet above the nearest stream. Sealing techniques can be applied to existing sewer according to the Bankson report. To reduce deliberate discharges, pump stations and treatment plants may be intercepted by gravity conveyances. If further experience warrants, the Ottawa plant may be purchased, or Fox Chapel may contract for its operation. Campbell's Lake may be maintained as a trap of sewer pollutants, with any dredge spoils being disposed up-drainage of the Lake.

For any land area:

$$\text{Salt} = \left(\frac{\text{Low L}}{\text{L}}\right) LR_S$$

where:

Salt = the relative probability that a given rate of road salt will reach a stream. Desired outcome: minimize S.

L = length of roads in the land area.

$\frac{\text{Low L}}{\text{L}}$ = proportion of the road length in lowland locations, plus proportion of upland roads that are drained into lowland areas.

R_S = rate of application of road salt per length of road.

Certain aspects of hydrology are the subject of detailed study in the Guyasuta Joint Municipal Planning Commission's current stormwater study. That study may produce further conclusions which Fox Chapel may take into account in implementing any of the results of this Plan.

THERMOSPHERE

1. Land

Heat near the surface of the earth moves through a network of events that is diagrammed in Figure 26. The components of the network at any unit of land, over any unit of time, are summarized by the "heat budget" or "energy balance" (adapted from Dunne and Leopold, 1978; Geiger, 1965; and Lowry, 1971):

$$\text{net } S + L + Q_{1w} + Q + AET + N + \Delta B = 0$$

where all terms are in units of energy per area per time, and:

net S = net solar radiation, the amount of solar energy absorbed by the land.

L = vertical sensible heat transfer, in the air by conduction and mass exchange.

Q_{1w} = net long wave radiation.

Q = horizontal sensible heat transfer, in the air by wind.

AET = the heat content of evapotranspiration.

N = the heat content of precipitation and runoff.

ΔB = the change in heat stored in the soil and forest.

In any of these components a positive value is a net flow downward into the soil and forest; a negative value is upward. The heat budget is intimately tied to the water budget by AET and N.

Some basic data on Fox Chapel's climate are reproduced in Figures 27-32. Figure 27 is reproduced here as a basic reference. Figures 28-32 are a detailed climatic analysis that is valuable for planning and design purposes (although it is based on old data) of which copies are rare.

Each component of the heat budget may change over time. An individual cloud covering the sun for a few minutes changes S, which causes corresponding changes in other terms. Between night and day, S changes drastically, causing and associated with changes in other terms. An air mass inhabiting the region for several weeks controls temperature, humidity and cloudiness, which control S, AET and other

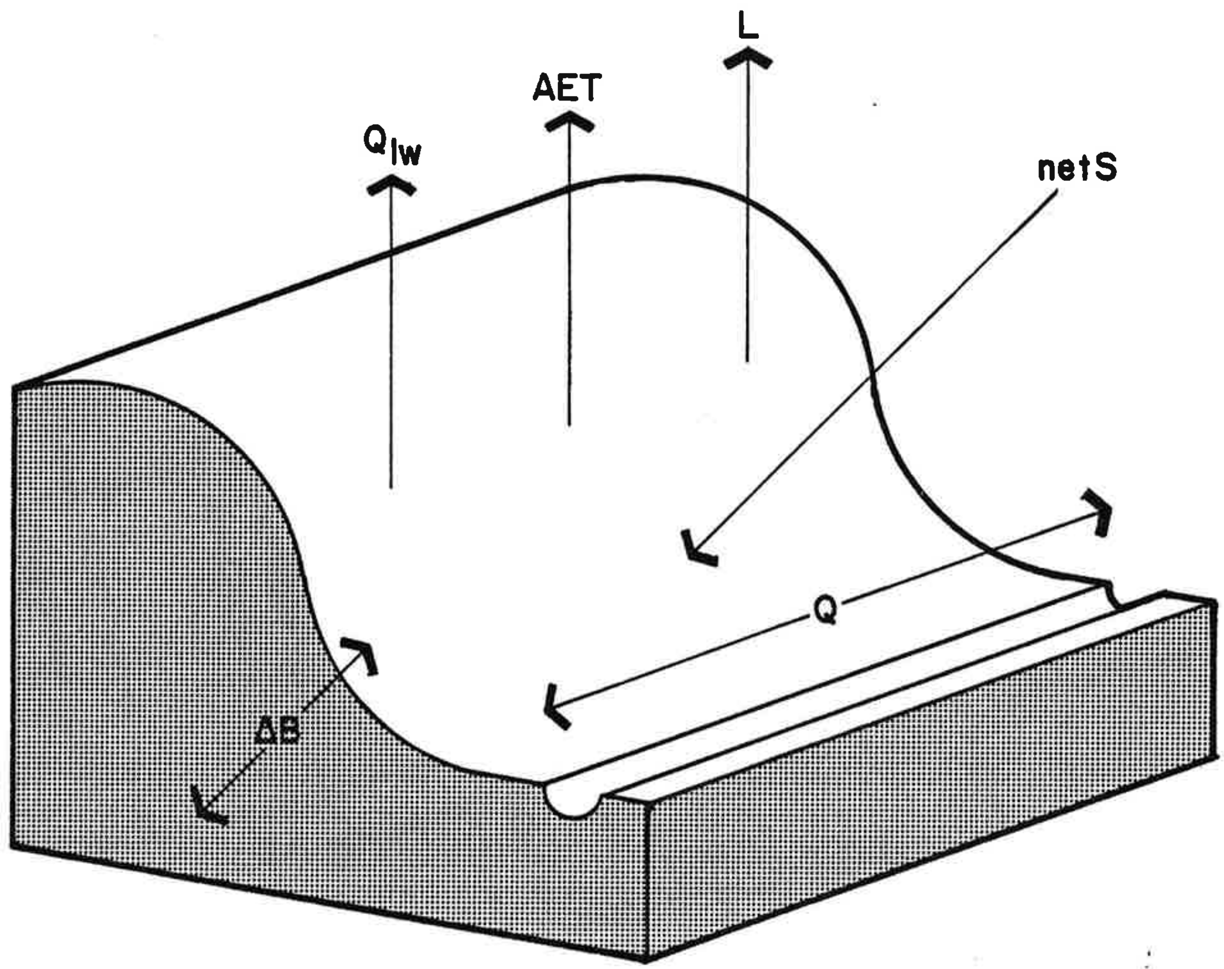


FIGURE 26. Components of the heat budget on a typical cross-section of the Fox Chapel landscape.

Month	Temperatures °F: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Extremes: Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches: Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)				26		26					26		26		26	
J	35.4	20.8	28.1	68	1972	-18	1963	1144	0	2.79	6.25	1978	1.06	1967	1.43	1978
F	37.3	21.3	29.3	69	1954	-9	1963	1000	0	2.35	5.98	1956	0.51	1969	2.30	1975
M	47.2	29.0	38.1	80	1977	-1	1960	834	0	3.60	6.10	1967	1.14	1969	2.00	1964
A	60.9	39.4	50.2	87	1970	15	1977	444	0	3.40	7.61	1964	0.48	1971	2.15	1964
M	70.8	48.7	59.8	91	1962	26	1970	208	46	3.63	6.36	1968	1.21	1965	2.44	1971
J	79.5	57.7	68.6	96	1971	34	1972	26	134	3.48	5.08	1974	0.90	1967	1.93	1955
J	82.5	61.3	71.9	99	1954	42	1963	7	221	3.84	7.43	1958	1.82	1965	2.97	1971
A	80.9	59.4	70.2	97	1953	40	1965	16	177	3.13	7.56	1975	0.78	1957	3.06	1956
S	74.9	52.7	63.8	97	1954	31	1959	98	62	2.52	5.42	1972	0.74	1964	2.25	1975
O	63.9	42.4	53.2	87	1959	16	1965	372	7	2.52	8.20	1954	0.16	1963	3.56	1954
N	49.3	33.3	41.3	82	1961	-1	1958	711	0	2.47	4.70	1972	0.90	1976	1.38	1961
D	37.3	23.6	30.5	72	1971	-7	1976	1070	0	2.48	5.24	1978	0.40	1955	1.76	1978
YR	60.0	40.8	50.4	99	JUL 1954	-18	JAN 1963	5930	647	36.23	8.20	OCT 1954	0.16	OCT 1963	3.56	OCT 1954

Month	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity pct. Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ½ mile or less	Temperatures °F Max. (b) 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	Average station pressure mb. Elev. 1225 feet m.s.l.
(a)	26		26		19	19	19	19	26	11	26	26		26	26	26	26	26	26	26	26	26	19	19	19	19	6
J	40.2	1978	14.0	1966	73	76	66	67	10.8	WSW	52	23	1978	35	8.0	3	6	22	17	4	*	2	0	15	27	3	973.2
F	24.2	1972	12.3	1960	70	74	62	63	10.9	WSW	58	26	1967	39	7.8	3	6	19	14	3	*	1	0	11	25	1	972.4
M	21.3	1960	14.7	1962	69	74	58	59	11.1	WSW	48	25	1954	43	7.6	4	6	21	16	2	2	1	0	4	19	*	971.6
A	5.9	1961	3.9	1953	66	72	50	52	10.7	WSW	46	27	1974	49	7.2	4	8	18	13	*	4	1	0	*	9	0	972.3
M	3.1	1966	3.1	1966	72	76	51	54	9.3	WSW	42	25	1957	52	6.9	5	9	17	12	*	5	1	*	0	1	0	971.0
J	0.0		0.0		77	79	52	57	8.2	WSW	40	27	1957	58	6.4	5	12	13	11	0	7	1	2	0	0	0	972.7
J	0.0		0.0		80	82	53	59	7.5	WSW	51	25	1956	59	6.4	5	13	13	11	0	7	2	3	0	0	0	973.6
A	0.0		0.0		82	86	56	62	7.1	WSW	46	29	1963	58	6.2	7	12	12	10	0	6	2	1	0	0	0	975.3
S	0.0		0.0		82	86	57	66	7.6	WSW	32	02	1960	59	6.1	8	10	12	9	0	3	2	1	0	0	0	974.9
O	1.8	1972	1.6	1972	76	81	54	62	8.5	WSW	35	27	1959	54	6.1	9	8	14	10	*	1	2	0	0	4	0	975.6
N	11.0	1958	10.5	1958	75	79	63	68	10.0	WSW	45	29	1969	39	7.7	4	6	20	13	1	*	2	0	2	14	*	974.4
D	21.2	1974	12.5	1974	74	76	67	70	10.6	WSW	48	25	1968	30	8.2	3	5	23	17	3	*	2	0	11	25	1	972.6
YR	40.2	JAN 1978	14.7	MAR 1962	75	78	57	62	9.4	WSW	58	26	FEB 1967	49	7.1	60	101	204	153	14	36	18	7	42	124	5	973.3

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
AIRPORT - Highest temperature 102 in July 1936; maximum monthly precipitation 10.25 in June 1951; maximum snowfall in 24 hours 17.5 in November 1950.
CITY OFFICE - Highest temperature 103 in July 1936; lowest temperature -20 in February 1899; minimum monthly precipitation 0.06 in October 1874; and maximum precipitation in 24 hours 4.08 in September 1876.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

Temperature data may be suspect for the period November 1977 through July 1978 due to intermittent instrument problems.

FIGURE 27. Some basic data on Fox Chapel's climate, reproduced here for reference.
Source: U. S. National Oceanic and Atmospheric Administration, 1978.

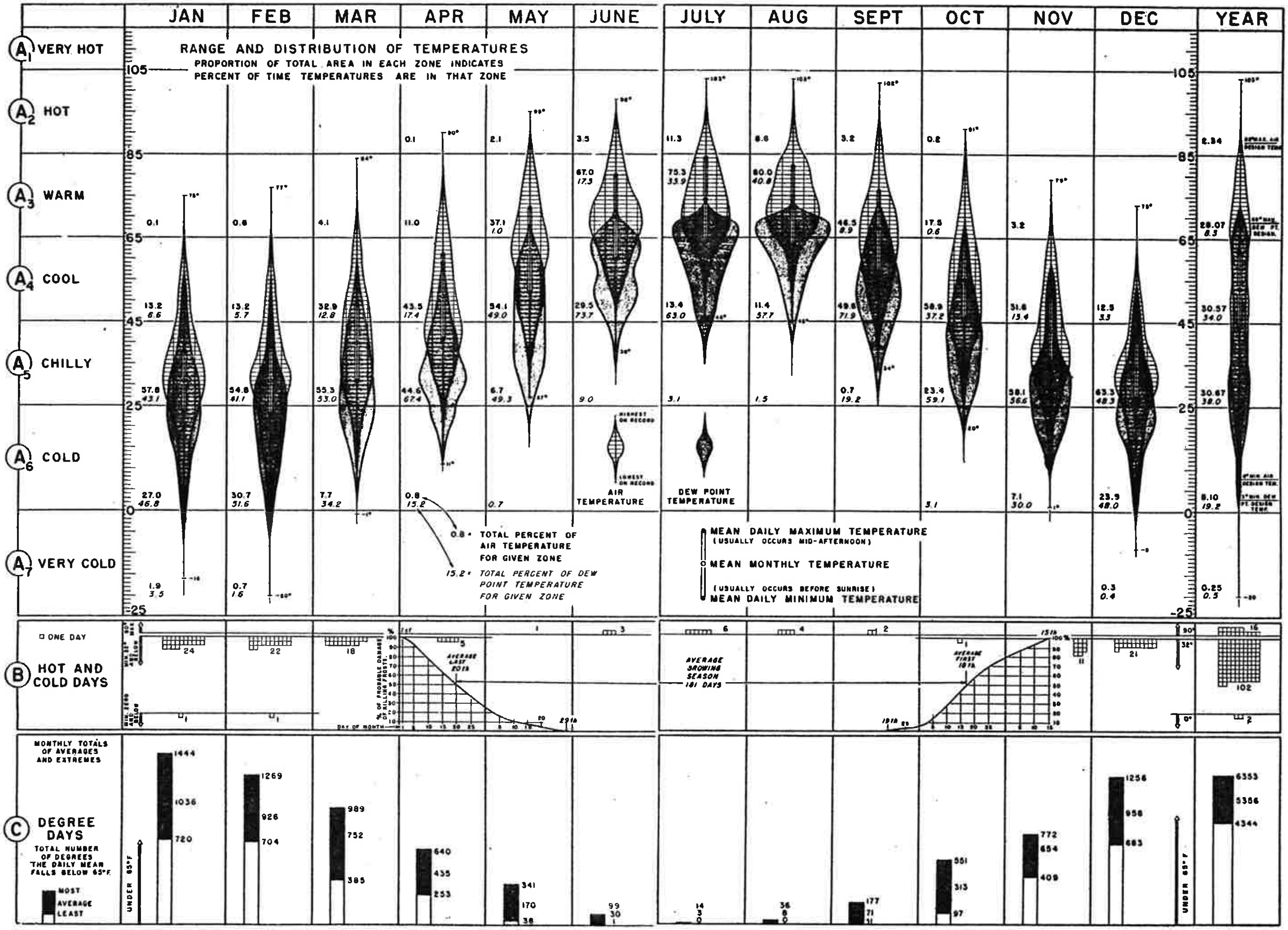


FIGURE 28. Thermal analysis of Fox Chapel's climate (U. S. Weather Bureau data), for planning and design. Source: Bulletin of the A.I.A., May 1951, pp. 4-5.

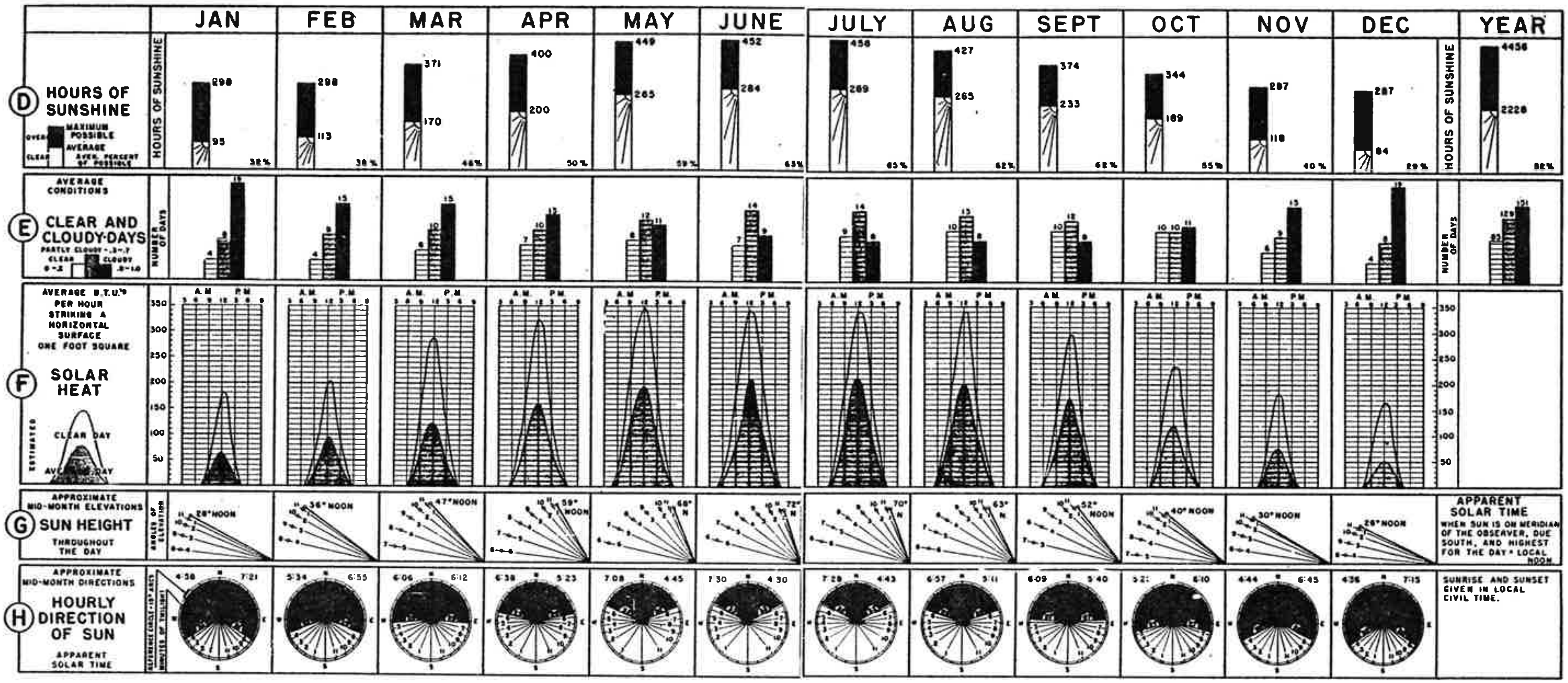


FIGURE 29. Solar analysis of Fox Chapel's climate (U. S. Weather Bureau data) for planning and design. Source: Bulletin of the A.I.A., May 1951, pp. 8-9.

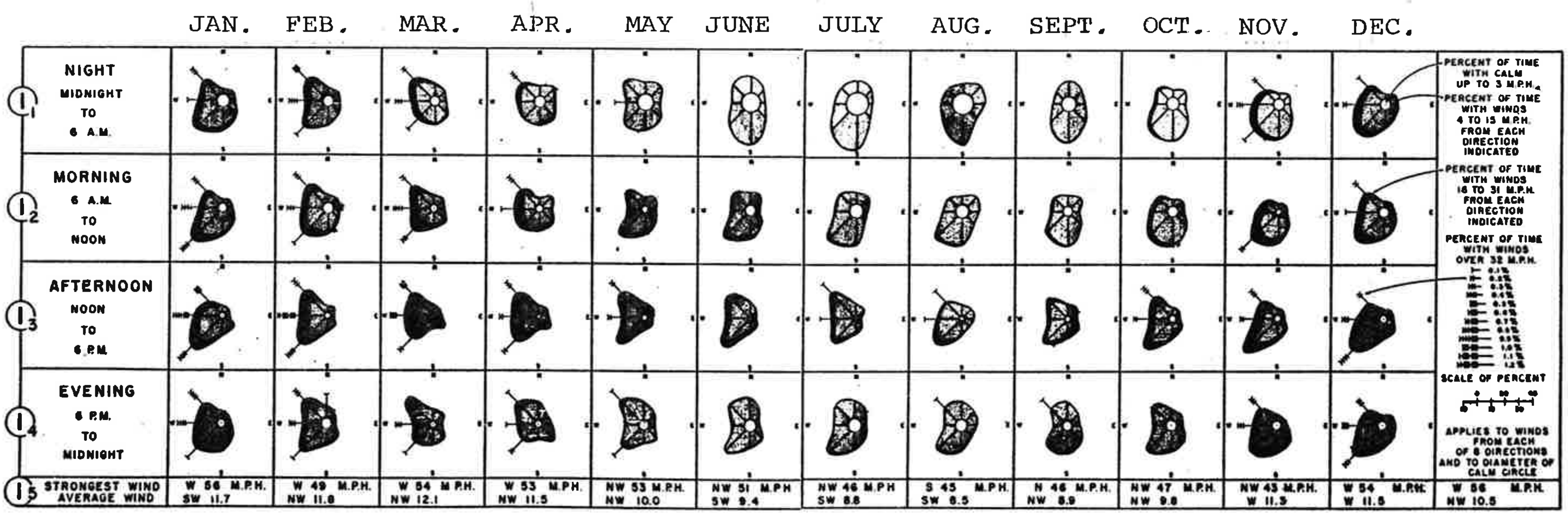


FIGURE 30. Wind analysis of Fox Chapel's climate (U. S. Weather Bureau data) for planning and design. Source: Bulletin of the A.I.A., pp. 8-9.

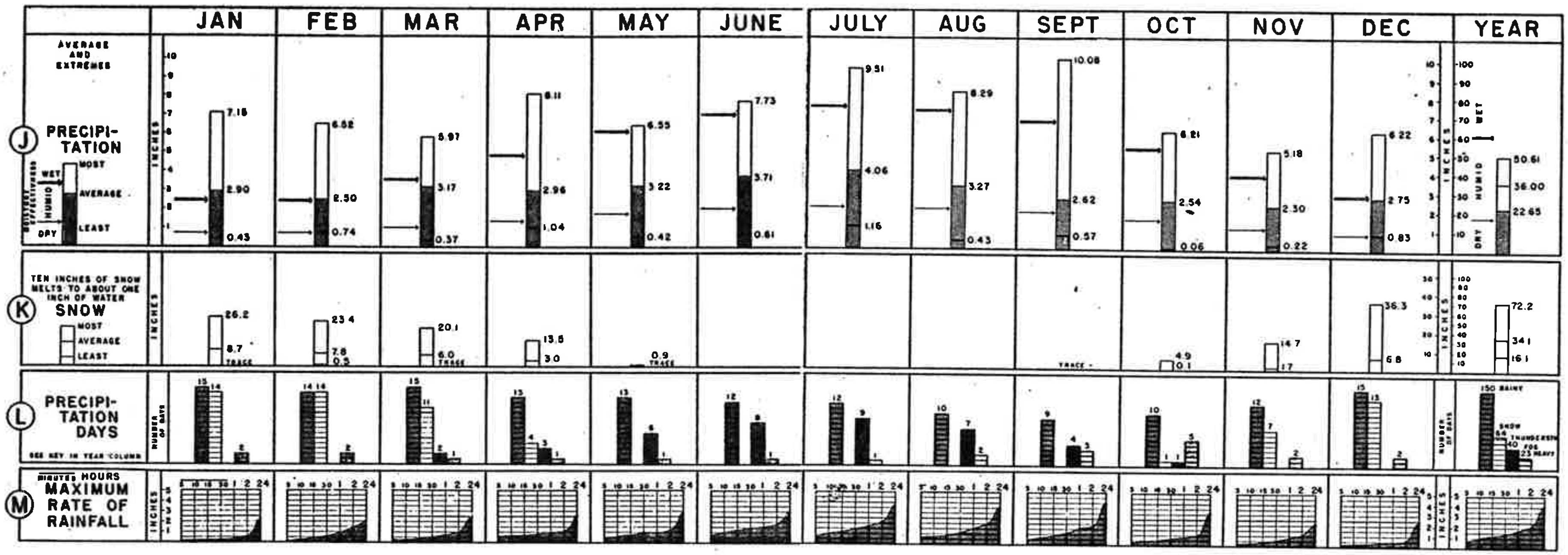


FIGURE 31. Precipitation analysis of Fox Chapel's climate (U. S. Weather Bureau data) for planning and design. Source: Bulletin of the A.I.A., May 1951, pp. 12-13.

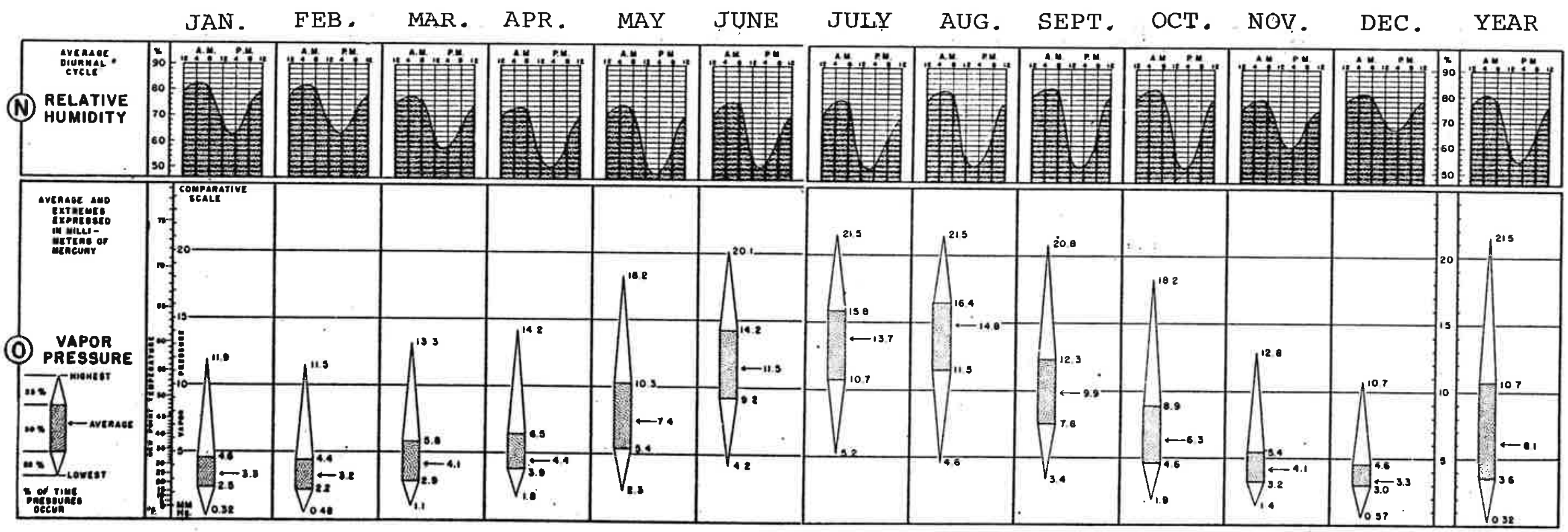


FIGURE 32. Humidity analysis of Fox Chapel's climate (U. S. Weather Bureau data) for planning and design. Source: Bulletin of the A.I.A., May 1951, pp. 12-13.

terms. A combination of cloudiness, solar (Figure 33), vegetative, and ground cover (Figure 36) changes from season to season changes net S, and thereby other terms. Climatic variations and vegetative succession may occur over many years, controlling all the terms of the heat budget. Over any unit of time the climatic controls of the heat budget are subject to their probability of occurrence. The regional variations of weather over time are well known from long-term federal observations at the Greater Pittsburgh Airport and elsewhere.

Each component of the heat budget may also vary geographically, Fox Chapel's steep hills expose their various faces to different solar radiation (Figure 33) and wind; these influences cause corresponding variations in other terms. We may distinguish broadly between: cool northeast-facing and warm southwest-facing slopes, although micro-variations over space and time of radiation reaching particular slopes, shading, wind screening, and other processes complicate the distributions of components (Geiger, 1965). Because of the close association of these climatic land classes with the site index classes defined under "Ecosphere" we can use the site index classes as approximations of climatic northeast and southwest-facing slopes.

Also, in regionally calm air, elevational differences in air density redistribute air of different temperatures. We may distinguish broadly between:

cold-air lowland: zone into which cold air from higher elevations drains, and

warm-air upland: any point not a cold-air lowland.

A Borough-wide empirical inventory of cold-air lowlands is not feasible in this study due to the size of the Borough, the complexity of the topography, possible cold-air dams such as forest edges, and the variations in cold-air lowlands over time. However, it is known that cold air drainage is highly related to size of drainage area (Geiger, 1965). Therefore lowlands (defined and explained under "Hydrosphere") approximate the distribution of cold-air lowlands as closely as is feasible. Similarly, upland approximates the distribution of warm-air upland. Cold-air lowlands and warm-air uplands are superimposed on the two slope classes, giving a total four-way climatic classification of land paralleling that used in "Hydrosphere".

Fox Chapel is near Pittsburgh's "urban heat island". Heat islands are typically centered on the area of greatest urban concentration, with some drifting downwind; they may concentrate in river valleys (Lowry, 1971). However, Fox Chapel is apparently not within the island: its elevation and distance from Pittsburgh are just enough to maintain its locally created climate (Hank Ek, Allegheny County Health Department, telephone conversation, July 30, 1979).

The micro-geographic variation of climate in western Pennsylvania has not been studied either by recordings or by temperature-sensitive aerial photographs, as discovered by communications with the National

Variable	J	F	M	A	M	J	J	A	S	O	N	D	Year
ΣS_H	94	169	216	317	429	491	497	409	339	207	118	77	
Days	31	28.25	31	31	31	30	31	30	30	31	30	31	365.25
A	31	40	49	60	68	73	71	63	52	43	33	28	
ΣS_N	2,331	3,915	5,812	8,987	12,501	14,067	14,598	11,331	8,980	5,387	2,712	1,717	92,338
ΣS_s	3,635	5,633	7,580	10,667	14,097	15,393	16,216	13,209	11,360	7,447	4,368	3,057	112,662

FIGURE 33. Calculation of gross solar radiation reaching two different slopes in Fox Chapel, monthly and annual. Legend:

ΣS_H = mean daily solar radiation reaching a horizontal surface, cal/cm^2/day (U. S. National Oceanic and Atmospheric Administration, 1974).

Days = number of days per month.

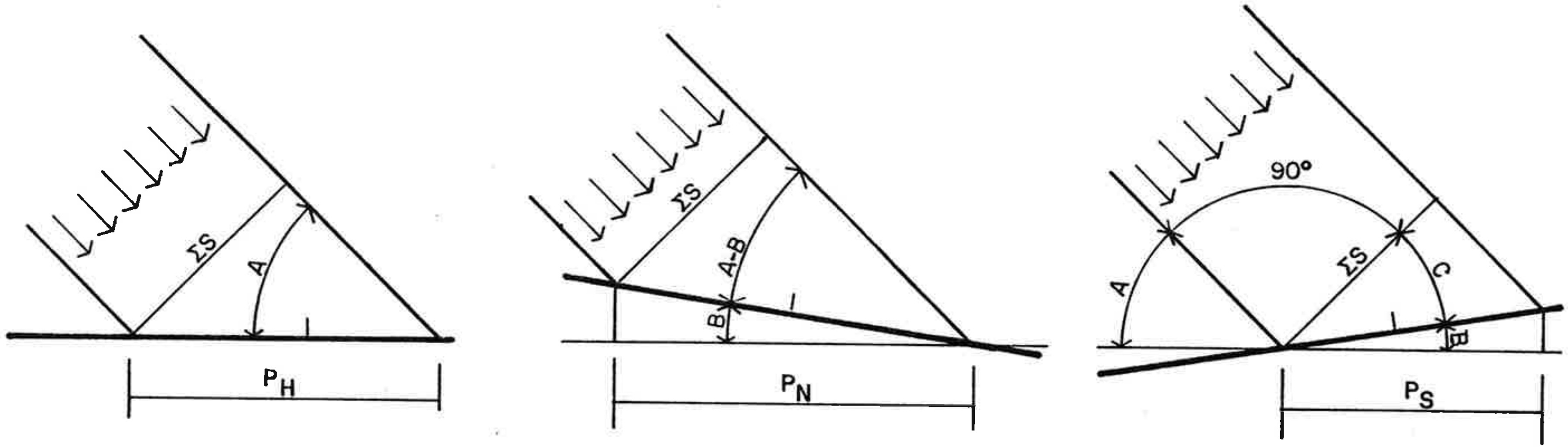
A = monthly average altitude of sun at solar noon, degrees from horizontal (interpolated from Figure 35).

ΣS_N = monthly solar radiation reaching a plane inclined to the north at 15% ($8^o53'$), cal/cm^2/mo, if all ΣS_H is at angle A, using Figure 34.

$$\Sigma S_N = \Sigma S_H \left(1 - \frac{\cos A \sin 8^o53'}{\sin A \cos 8^o53'}\right) \text{(Days)}$$

ΣS_s = monthly solar radiation reaching a plane inclined downward to the south at 15% ($8^o53'$), cal/cm^2/mo, if all ΣS_H is at angle A, using Figure

$$\Sigma S_s = \Sigma S_H \left(1 + \frac{\cos A \sin 8^o53'}{\sin A \cos 8^o53'}\right) \text{(Days)}$$



HORIZONTAL

$$P_H = \frac{\Sigma S}{\sin A}$$

NORTH-FACING

$$P_N = \Sigma S \left(\frac{\cos B}{\sin (A - B)} \right)$$

$$\therefore \frac{P_N}{P_H} = 1 - \left(\frac{\cos A \sin B}{\sin A \cos B} \right)$$

SOUTH-FACING

$$P_s = \frac{\Sigma S \cos B}{\sin (A + B)}$$

$$\therefore \frac{P_s}{P_H} = 1 + \left(\frac{\cos A \sin B}{\sin A \cos B} \right)$$

FIGURE 34. Derivation of solar intensity on three slope orientations. Legend:

ΣS = energy in solar beam
A = altitude of sun above horizontal
B = slope gradient
C = angle between slope and cross-section of solar beam
I = projection of solar beam on slope
P = projection of solar beam on horizontal plane = solar intensity per unit area

(Note that if B = 15%, or $8^{o}53'$, and the range of A is as shown in Figure 35 then $0^{o} < (A - B_N) < 90^{o}$ and $0^{o} < (A - B_S) < 90^{o}$)

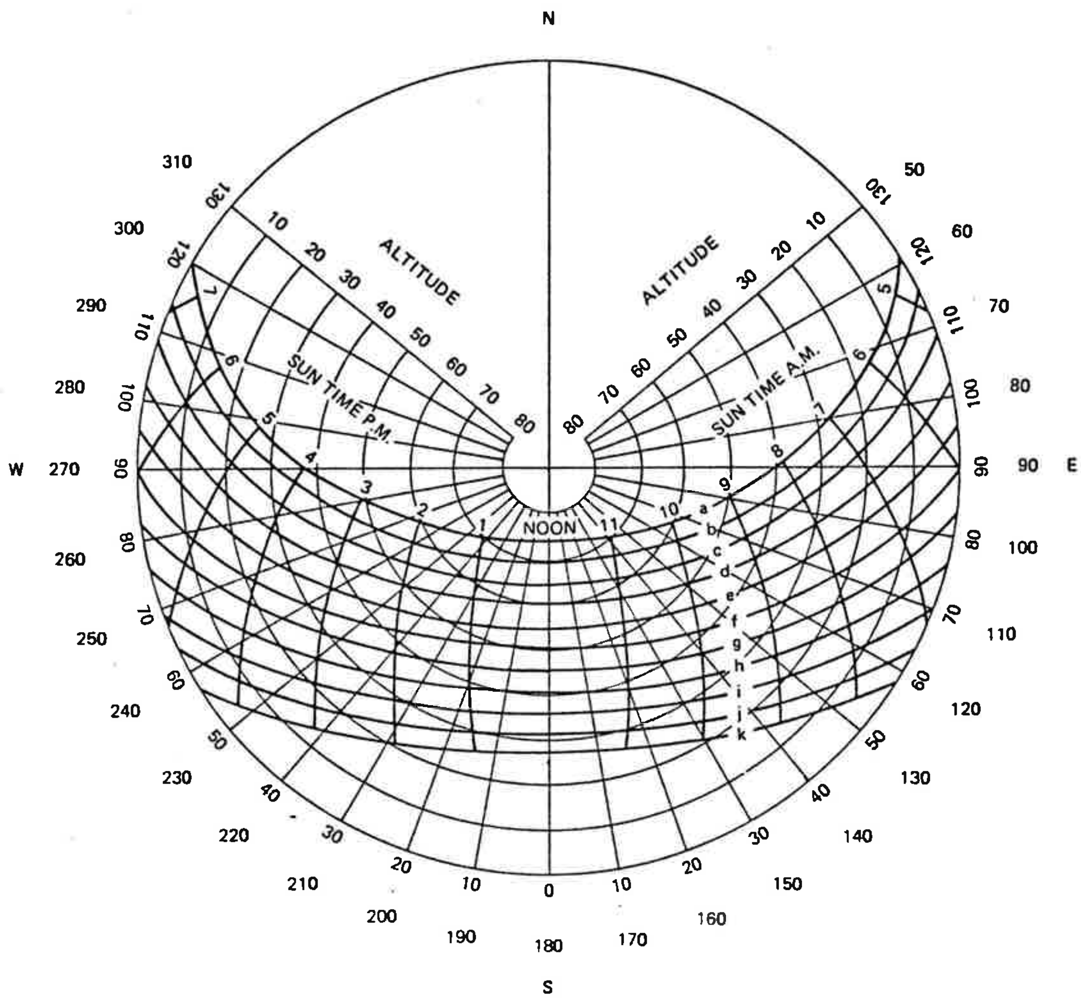


FIGURE 35. Variation of the path of the sun over the year, relative to a point on the surface of the earth at the center of the circle, at latitude 40° North (Brown, 1973, Figure 4). Legend:

Path	Declination	Dates
a	$+23^{\circ}\ 27'$	June 22
b	$+20^{\circ}$	May 21 & July 24
c	$+15^{\circ}$	May 1 & Aug. 12
d	$+10^{\circ}$	Apr. 16 & Aug. 28
e	$+5^{\circ}$	Apr. 3 & Sept. 10
f	0°	Mar. 21 & Sept. 23
g	-5°	Mar. 8 & Oct. 6
h	-10°	Feb. 23 & Oct. 20
i	-15°	Feb. 9 & Nov. 3
j	-20°	Jan. 21 & Nov. 22
k	$-23^{\circ}\ 27'$	Dec. 22

Variable	J	F	M	A	M	J	J	A	S	O	N	D	Year
P_s	11.0	10.6	10.4	1.6	0.3	0.0	0.0	0.0	0.0	0.2	4.2	9.0	47.3
$D_{P_{s1}}$	3	3	3	0.3	0.1	0.0	0.0	0.0	0.0	0.2	1	3	13.7
$\overline{\alpha}$	.27	.30	.29	.12	.11	.10	.10	.10	.10	.11	.17	.27	

FIGURE 36. Calculation of average albedo (reflectivity) of a forest in Fox Chapel, in each month of the year. Snow cover is here assumed equal on all slopes, although it has been observed to be more common on NE-facing slopes.

P_s = mean snowfall, including sleet and ice pellets, inches (U. S. National Oceanic and Atmospheric Administration, 1971).

$D_{P_{s1}}$ = mean number of days with snowfall or ice pellets of 1.0 inch or more (U. S. National Oceanic and Atmospheric Administration, 1971).

$\overline{\alpha}$ = monthly weighted average albedo of deciduous forest:

$$\overline{\alpha} = 0.70 \text{ (monthly snow cover fraction)} + 0.10 \text{ (1 - monthly snow cover fraction)}$$

where:

0.70 = average albedo of snow(Lowry, 1967, Table 8-5)
0.10 = albedo of forest without snow (Lowry, 1967, Table 8-5)

$$\text{monthly snow cover fraction} = \left[D_{P_{s1}} + 0.4 \left(75 \frac{P_s/mo}{P_s/yr} - D_{P_{s1}}\right)\right] \div \text{Days}$$

$D_{P_{s1}}$ = assumed number of days with 100% snow cover

75 = number of days per year with snow cover of 100% or less (Lull, 1968).

$75 \frac{P_s/mo}{P_s/yr}$ = assumed number of days per month with snow cover of 100% or less.

0.4 = assumed snow cover fraction when not 100%.

Days = number of days per month (Figure 33).

Climatic Center, Asheville, North Carolina (February, 1979), Duquesne Light Co., Pittsburgh (January 29, 1979), National Aeronautics and Space Administration, Washington, D. C. (January 30, 1979), EROS Data Center, Sioux Falls, South Dakota (early 1979), and U. S. Environmental Data Service (early 1979). Consequently, an observation program was established. Due to the limited budget of this Natural Resources Plan, this program was relatively informal and limited, but it did result in the first data of its kind for Western Pennsylvania, and permitted some important qualitative distinctions in the Fox Chapel landscape.

The observation program was intended to indicate the differences in air temperature at different ground elevations, slope orientations and slope positions, at nearly the same time, and minimizing differences in ground cover. Two sampling routes were selected; one was near Ferguson's office in the West Hills and the other in Fox Chapel. Each route contained 10 sampling points and could be completed in an hour. The sample points were well distributed among the relevant topographic variables. At each point the air temperature was measured at eye height with a hand-held thermometer. After completing the tenth point the first point was again measured to check for temperature changes during the sampling hour. The sampling was performed at the times of day when temperatures were either highest (±2:00 P.M. EST) or lowest (±5:00 A.M. EST) so that topoclimatic variations were most developed (Geiger, 1965) and temperature variations during the sampling hour were minimized. A total of 66 temperature samples were taken.

Our assumptions of typical geographic temperature distributions resulting from an inspection of the data and a general understanding of solar geometry and cold-air drainage are shown in Figure 37. From these assumptions we calculated the evapotranspiration given in Figure 9 using Penman's equations quoted in Dunne and Leopold (1978). The calculation of evapotranspiration allowed us to complete overall heat budgets.

Contrasting heat budgets for our most extreme geographic classes are shown in Figure 38. Solar radiation is the only significant source of heat, peaking in the summer. Early in the summer excess heat is disposed from the soil and forest by transferring heat into the air (L). Later in the summer, when the temperature of the soil-forest-air system has risen, evapotranspiration peaks as a means of disposing heat, and L declines in importance. In the winter the solar driving force declines, and both means of disposing heat decline correspondingly. All terms of the heat budget are larger on the southwest-facing warm-air upland than on the northeast-facing cold-air lowland. Other terms of the heat budget were found to be insignificant, as follows:

1. Longwave radiation outward from the earth (Q_{lw}) was calculated as shown in Figures 39 and 40, and found to be only a couple of percent of S, L, or AET.

Slope Position	Slope Orientation: cold northeast-facing slope	Slope Orientation: warm southwest-facing slope
Cold-air lowland	R - 1.7°C	R + 0.
warm-air upland	R + 0.	R + 1.7°C

FIGURE 37. Assumptions of typical temperatures in topographic classes, when forested, based on informal observations. "R" is mean regional temperature recorded by U. S. National Oceanic and Atmospheric Administration (1978).

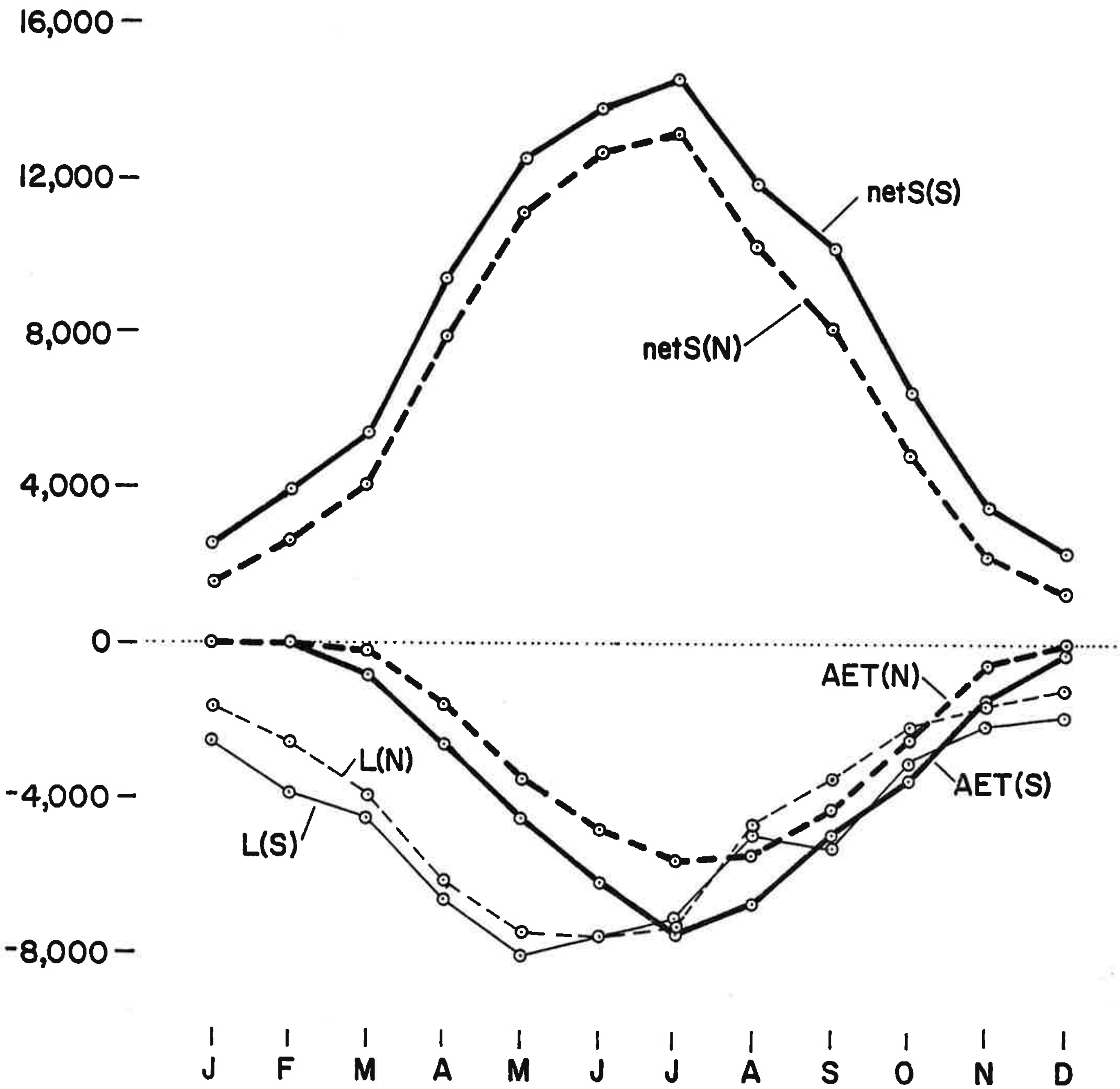


FIGURE 38. Heat budgets on forested northeast-facing cold-air lowland (N, dashed lines) and forested southwest-facing warm-air upland (S, solid lines) in Fox Chapel. Units are cal/cm^2 (langley) in each month of the year. Positive values are additions of heat to the soil-forest system; negative values are substractions. Sources: Figures 39 and 40. Legend:

AET (very heavy lines)	actual evapotranspiration
net S (heavy lines)	absorbed solar radiation
L (light lines)	sensible heat transfer

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Σ S (cal/cm^2)	+3,635.	+5,633.	+7,580.	+10,667.	+14,097.	+15,393.	+16,216.	+13,209.	+11,360.	+7,447.	+4,368.	+3,057.	+112,662.
α	.27	.30	.29	.12	.11	.10	.10	.10	.10	.11	.17	.27	.17
Net S (cal/cm^2)	+2,654.	+3,943.	+5,382.	+9,387.	+12,546.	+13,854.	+14,594.	+11,888.	+10,224.	+6,628.	+3,625.	+2,232.	+96,957.
T_2 (^oK)	273.0	273.1	277.4	284.1	290.1	294.9	297.0	296.3	292.6	286.4	279.6	274.5	
e_2 (mb)	4.5	4.5	5.2	7.4	11.5	16.0	17.0	17.0	16.0	8.5	6.5	4.7	
$\frac{n}{N}$	.37	.39	.47	.50	.55	.61	.63	.63	.63	.58	.41	.32	
Q_{lw} (cal/cm^2)	-110.	-115.	-137.	-143.	-143.	-138.	-140.	-138.	-137.	-170.	-119.	-100.	-1,586.
AET (cal/cm^2)	0.	-30.	-885.	-2,596.	-4,366.	-6,160.	-7,416.	-6,826.	-4,897.	-3,457.	-1,416.	-218.	-38,267.
L (cal/cm^2)	-2,544.	-3,798.	-4,360.	-6,648.	-8,037.	-7,556.	-7,038.	-4,928.	-5,190.	-3,001.	-2,090.	-1,914.	-57,104.

FIGURE 39. Monthly and annual heat budget on a southwest-facing forested warm-air upland in Fox Chapel. Units are as shown for each unit of time. For sources and comments see Figure 41.

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Σ S (cal/cm^2)	+2,331.	+3,915.	+5,812.	+8,987.	+12,501.	+14,067.	+14,598.	+11,331.	+8,980.	+5,387.	+2,712.	+1,717.	+92,338.
α	.27	.30	.29	.12	.11	.10	.10	.10	.10	.11	.17	.27	.17
Net S(cal/cm^2)	+1,702.	+2,741.	+4,127.	+7,909.	+11,126.	+12,660.	+13,138.	+10,198.	+8,082.	+4,794.	+2,251.	+1,253.	+79,981.
T_2 (^oK)	269.6	269.7	274.0	280.7	286.7	291.5	293.5	292.9	289.2	283.0	276.2	271.1	
e2 (mb)	4.5	4.5	5.2	7.4	11.5	16.0	17.0	17.0	16.0	8.5	6.5	4.7	
$\frac{n}{N}$	.37	.39	.47	.50	.55	.61	.63	.63	.63	.58	.41	.32	
Q_{1w} (cal/cm^2)	-104.	-107.	-130.	-137.	-136.	-132.	-133.	-128.	-131.	-162.	-114.	-95.	-1,509.
AET (cal/cm^2)	0.	0.	-124.	-1,652.	-3,540.	-4,838.	-5,705.	-5,469.	-4,307.	-2,360.	-543.	0.	-28,538.
L (cal/cm^2)	-1,598.	-2,634.	-3,873.	-6,120.	-7,450.	-7,690.	-7,300.	-4,601.	-3,644.	-2,272.	-1,594.	-1,158.	+49,934.

FIGURE 40. Monthly and annual heat budget on a northeast-facing forested cold-air lowland in Fox Chapel. Units are as shown for each unit of time. For sources and comments see Figure 41.

Symbol	Variable	Source	Comments
	Heat Budget	Adapted from Geiger (1965), Lowry (1971) and Dunne and Leopold (1979).	Δ B, Q and P are assumed insignificant as described in text.
Σ S	Total Solar Radiation reaching the land surface, cal/cm^2.	Figure 33.	
α	Albedo (Reflectivity).	Figure 75.	
net S	solar radiation absorbed by the land, cal/cm^2.	net S = $\Sigma S (1 - \alpha)$	
T_2	Air temperature at two meters above the ground, average ^oK per unit time.		
e_2	Atmospheric vapor pressure (e_a) at two meters above the ground, average mb per unit time.	Lowry, Figure 5-4, at T_2.	
$\frac{n}{N}$	Fraction of possible sunshine per unit time.	U. S. National Oceanic and Atmospheric Administration, 1978.	
Q_{1w}	Long-wave radiation from land upward cal/cm^2.	$Q_{1w} = T_2^4 (.56 - .08\sqrt{e_a})(.1 + .9 \frac{n}{N})$ (Dunne and Leopold, 1978, Equation 4-12).	

FIGURE 41. Sources and comments for Figures 39 and 40. Continued on next page.

Symbol	Variable	Source	Comments
AET	Energy content of evapotranspiration, cal/cm^2.	(AET in mm shown in Fig. 24) X(590 cal/cm^3) x (.1 cm/mm)	
L	Vertical sensible heat transfer by atmospheric conduction and mass exchange, cal/cm^2.	$L = -1(\text{net } S + Q_{1w} + AET)$	L balances heat budget and absorbs insignificant terms.

FIGURE 41. Sources and comments for Figures 39 and 40. Continued from previous page.

2. If most of the heat stored in the soil-forest system is in the 40 cm of soil moisture (Figures 11 and 12), ΔB is 40 cal/cm^2 for each ^{o}C change in temperature. This amounts to only a few percent of S, L, or AET in each month. Dunne and Leopold (1978, page 134) predicted that ΔB could be ignored for any period of a day or longer.

3. Runoff of about 4 cm/mo exchanges 4 cal/cm^2/mo for each ^{o}C that it changes temperature while in or on the ground in a liquid state. This amounts to a very small fraction of S, L, or AET in each month. Although the quantities of water flowing in precipitation and runoff are comparable to that in AET, the heat content of AET is 590 times that of liquid water due to water's latent heat of vaporization.

4. The heat content of wind (Q) can be assumed insignificant compared to the other terms (Geiger, 1965).

The resulting proportions of heat budget components shown in Figure 38 are broadly similar to those measured or calculated in other regions at similar latitudes (Geiger, 1965, Figures 123, 124 and 126).

Weather events may be associated with the warm and cold fronts that separate warm and cold air masses. Rain, hail, thunderstorms, and blizzards all occur with moderate frequency. Different topographic positions are variously exposed to winds, lightning, and other components of these events, but the factors that control their distribution are not well known.

The atmosphere may be the agent of eroding, transporting and depositing physical or chemical matter. The Allegheny County Health Department (Hank Ek, telephone conversation, July 30, 1979) monitors atmospheric SO_2 at the Pittsburgh Field Club, because it is an easy and inexpensive chemical to monitor and it is a rough index of other industrial pollutants. The results at this location have always been well within health standards. Other potential pollutants are therefore probably equally low throughout the Borough. Any pollutants in the Borough are due largely to atmospheric importation from more industrialized and densely populated parts of Allegheny County, or to "acid rain" originating in distant industrial areas (Pack, 1980). Although Pittsburgh's lower elevations are susceptible to pollution concentrations during night inversions, even the lowest elevations of Squaw Run in Fox Chapel are not part of the polluted area due to the low concentration and low frequency of pollutants at the edge of the inverted air pool.

2. Land Use

Some climatic properties of land uses are their ground surface materials, their artificial energy supplies and uses, their sediment and chemical outputs, and variations of the above over space and time. All of these properties interact with the flows of the heat budget and the physical and chemical composition of the air.

Some characteristics of common ground-surface components of Fox Chapel land uses are compared in Figure 20. No matter where a pavement or roof is located, if it is not shaded it raises the average temperature by about 2^{o}F above the native forest. This is a result of greater heat flow into the material during daylight, so that although its temperature is the same as the forest's at noon, at night the stored heat returns to the surface and warms the material and the air above it (Landsberg and Maisel, 1971). The climatic properties of a lawn are generally intermediate between those of a forest and a pavement.

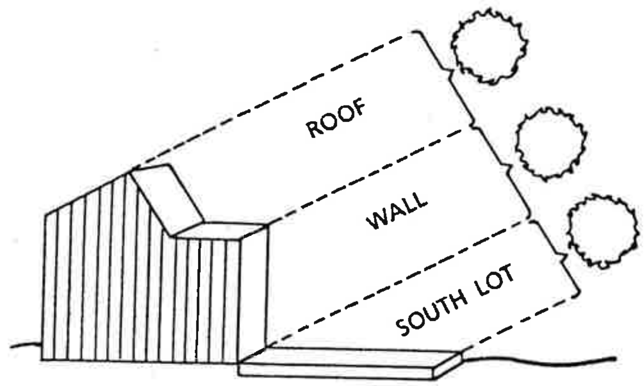
Energy is supplied to land uses artificially. In Fox Chapel electricity (from burning coal and nuclear fission) and natural gas are the most common sources for buildings, and gasoline is that for vehicles. These are supplied from outside the Borough by networks of wires and pipes, or brought in by vehicle. As described under "Lithosphere", no course of action in the Borough can affect these sources significantly. At this time technological, social and political adjustments are being made to energy sources. The future outcomes of these adjustments are not known.

Some important potential future sources of energy in Fox Chapel are solar, water, wind and wood, each of which has its own set of technology. Their rates of supply are compared in Figure 42. Solar power for space heating is becoming rapidly more common although any such installation in this area will almost certainly require a non-solar backup system (Asbury, Maslowski and Mueller, 1979). As shown in Figure 43, solar collectors may be located in various relationships to the associated building. Various purposes of installations require various angular "windows" toward the sun for appropriate seasonal supply (Figure 44). Access to solar, water, wood and wind flows may be preserved; this is particularly meaningful to direct solar radiation, which is qualitatively different from shade. Wood energy has the unique characteristic that is is stored naturally on the local land; therefore it is a unique emergency space heating energy stock. One acre of a 40-year-old stand can heat one typical residence for about four and one half winters, at 50% conversion efficiency and at demand levels explained below. Wind energy has the unique characteristic of geographic indeterminancy: it is present to some degree almost everywhere in Fox Chapel with only the efficiency and economy of extraction varying from place to place (Gustavson, 1979). Hence, preservation of access to wind power is not as meaningful as that of access to other energy forms. Since any development of wood or water power would involve direct conflicts with the hydrologic, aesthetic and ecological values of floodplains and hillsides, the preservation of wood or water power access is not considered a Borough objective.

No matter what source of energy is used, the amount of energy consumed in a building is a function of the thermal environment in which the building is located and the set of technology for energy use reduction. The thermal environment of a building is indicated by "degree days": the amount of energy used to heat or to cool the building is directly proportional to degree days (McGuiness and Stein, 1971). At used facilities that are not artifically heated or cooled, degree days indicates the difference between the desired "comfort zone" and the ambient environment.

Supply Type	Rate of Supply: $cal/cm^2/mo.$ annual average	Rate of Supply: $cal/cm^2/mo.$ in lowest month	Source
Solar (on horizontal surface)	8,480.	2,390.	Figure 33
Water	±3.4; varies locally with stream gradient	±0.54; varies locally with stream gradient	Unpublished estimate, in Ferguson's office.
Wind	±10 total; ±100 on selected land	±8 total; ±80 on selected land	Calculated from McAvin and Ferguson, 1975
Wood	± 6 (±3,500 cal/cm^2 in 50-year-old standing crop)	(Same as annual average due to comulative storage)	Calculated from McAvin and Ferguson, 1975

FIGURE 42. Comparison of potential future energy sources in Fox Chapel. Extractable wind power varies widely with the size and spacing of wind machines, their distance from roughness elements, etc.; "selected land" tends to be exposed ridges oriented north-south. Values shown are total available and must be multiplied by conversion efficiencies to find useful energy.



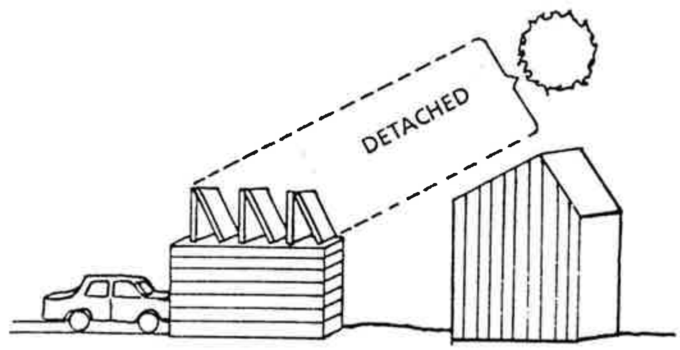


FIGURE 43. Possible locations of solar collectors relative to the associated buildings (Jaffe and Erley, 1979, Figure 16). Above, attached; below, detached.

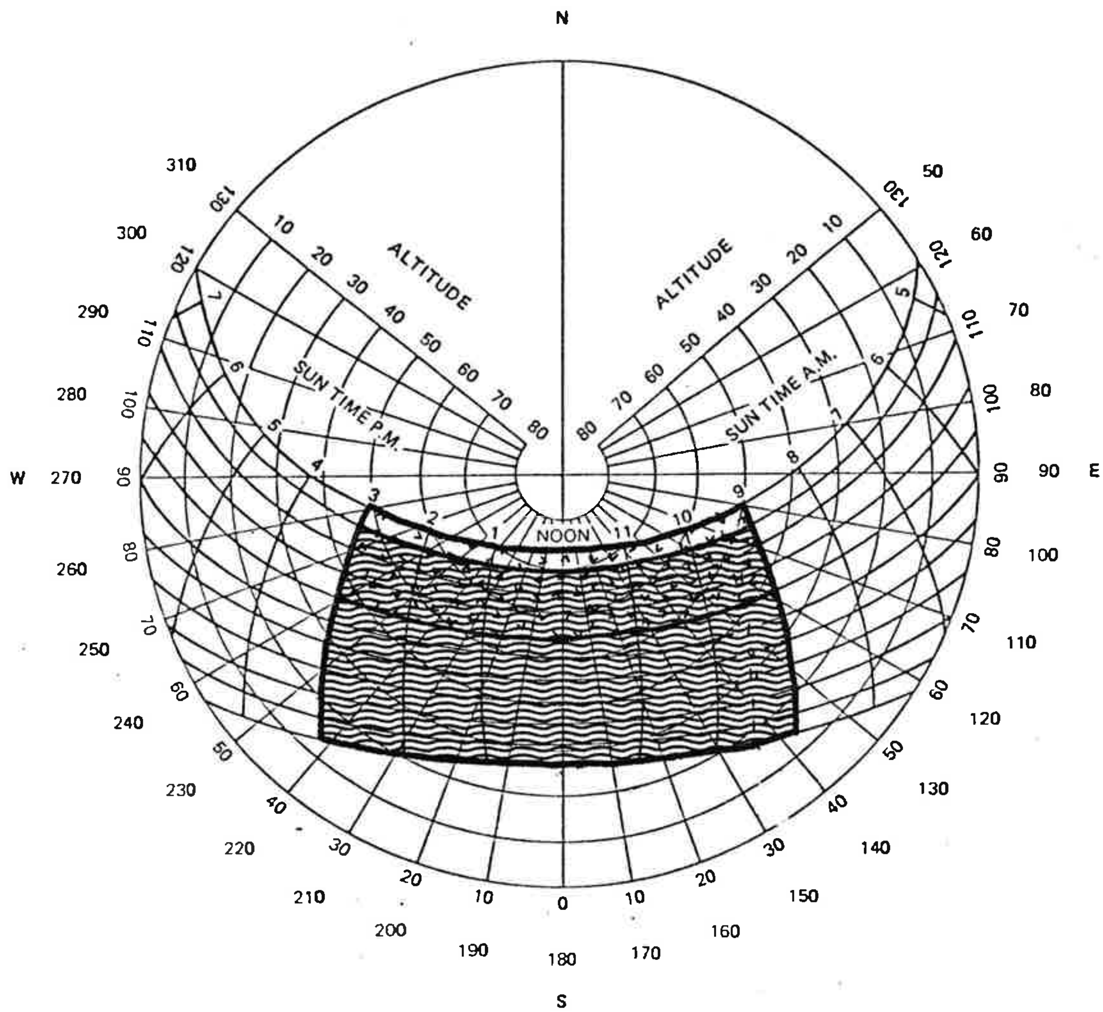


FIGURE 44. Angular "windows" necessary for supply of solar energy to a collector, with the collector located in the center of the circle. Waves indicate the window for space heating, using the heating season of September to May shown on Figure 45. Checked pattern indicates the window for space cooling, using the cooling season of May to September shown on Figure 45. The entire block containing both waves and checks indicates the window for year-round water heating or electric generation. The limit of three hours on each side of solar noon is from Jaffe and Erley (1979).

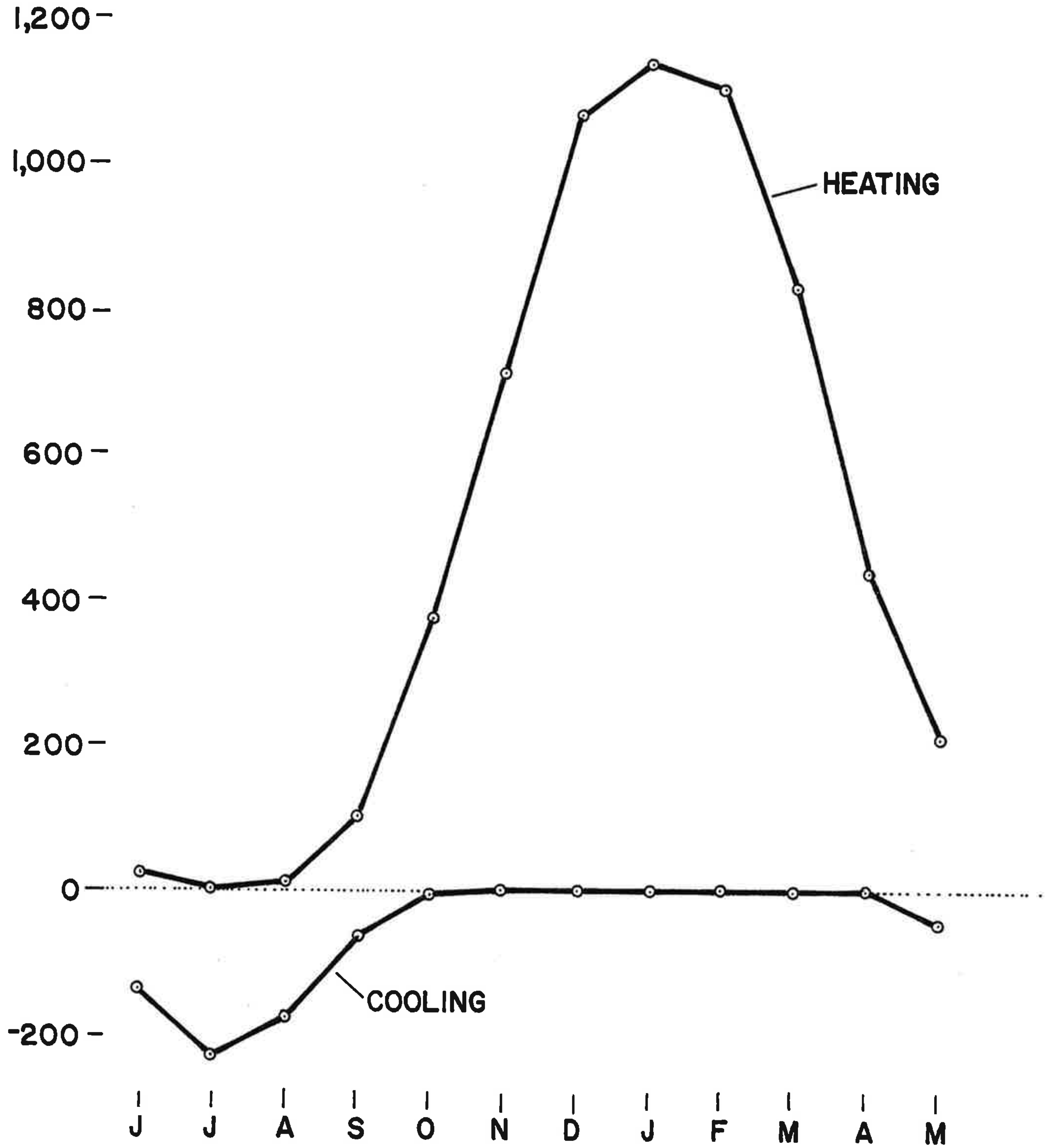


FIGURE 45. Mean degree days recorded at the Greater Pittsburgh Airport in each month of the year (U. S. National Oceanic and Atmospheric Administration, 1978). Positive values are heating degree days; negative values are cooling degree days. Note that the "year" starts with June in order to show the heating and cooling seasons without breaks.

$$DD = (65^{o}F - \text{hourly outdoor temperature}) \div 24 \ \frac{\text{hour}}{\text{day}}$$

where:

DD = degree days. When positive it is "heating" degree days, that is, the environment in which a building is usually heated artifically. When negative it is "cooling" degree days, that is, the environment in which a building is usually cooled artifically (Conrad and Pollak, 1950).

As shown in Figure 45, regional heating degree days are far more important than cooling degree days. Buildings without any artificial cooling are present in Fox Chapel, but all intensely used buildings have artificial heating.

Since DD is a function of outdoor temperature, the thermal environments classified in Figure 37 are environments of energy use. A typical residence uses (very roughly) 10,000 Btu/DD for heating (McAvin and Ferguson, 1975), which implies a total of 59,000,000 Btu/yr in Pittsburgh's regional 5,930 DD/yr. (U. S. National Oceanic and Atmospheric Administration, 1978). After use, the energy is dissipated into the environment.

Sets of technology are available for insulating used facilities from climatic components in any thermal environment. The placement of large trees shown in Figure 46 can reduce energy use in the heating season by 10 to 15 percent, and in the cooling season by 75 percent (DeWalle, 1978). The quantitative extent of sunscreening by different tree species is shown in Figure 47. Buildings may be constructed with high resistance to heat transmission, and appliances may be constructed for efficiency. Used facilities may be protected from lightning, violent winds, and other weather events.

The actual rates of energy consumption in buildings and the sources of their supply will be regulated by costs and by Federal incentives, as well as by any possible Borough standards. We feel that actual rates of consumption and types of supply should not be regulated by Fox Chapel, due to the possibility of adverse effect on the remainder of the energy-supply system (Rossin, 1980) and the undemocratic implication that consumption of other resource flows - food, materials, water, etc. - should be similarly regulated. Instead, Fox Chapel should leave open the option for individual decisions by continuing not to regulate designs rigidly and by preserving access to local supplies as discussed above. Also, buildings can be regulated to stay out of cold-air lowlands since they cover limited areas and are the subject ot other regulations, but cold northeast-facing slopes cover such large areas that their regulation would apparently be impractical, and their distribution is shown in the maps only for the information of individual property owners.

Energy is also used in lawn care. Apart from the set of technology for energy reduction, energy use for this purpose is a function of the area of lawn.

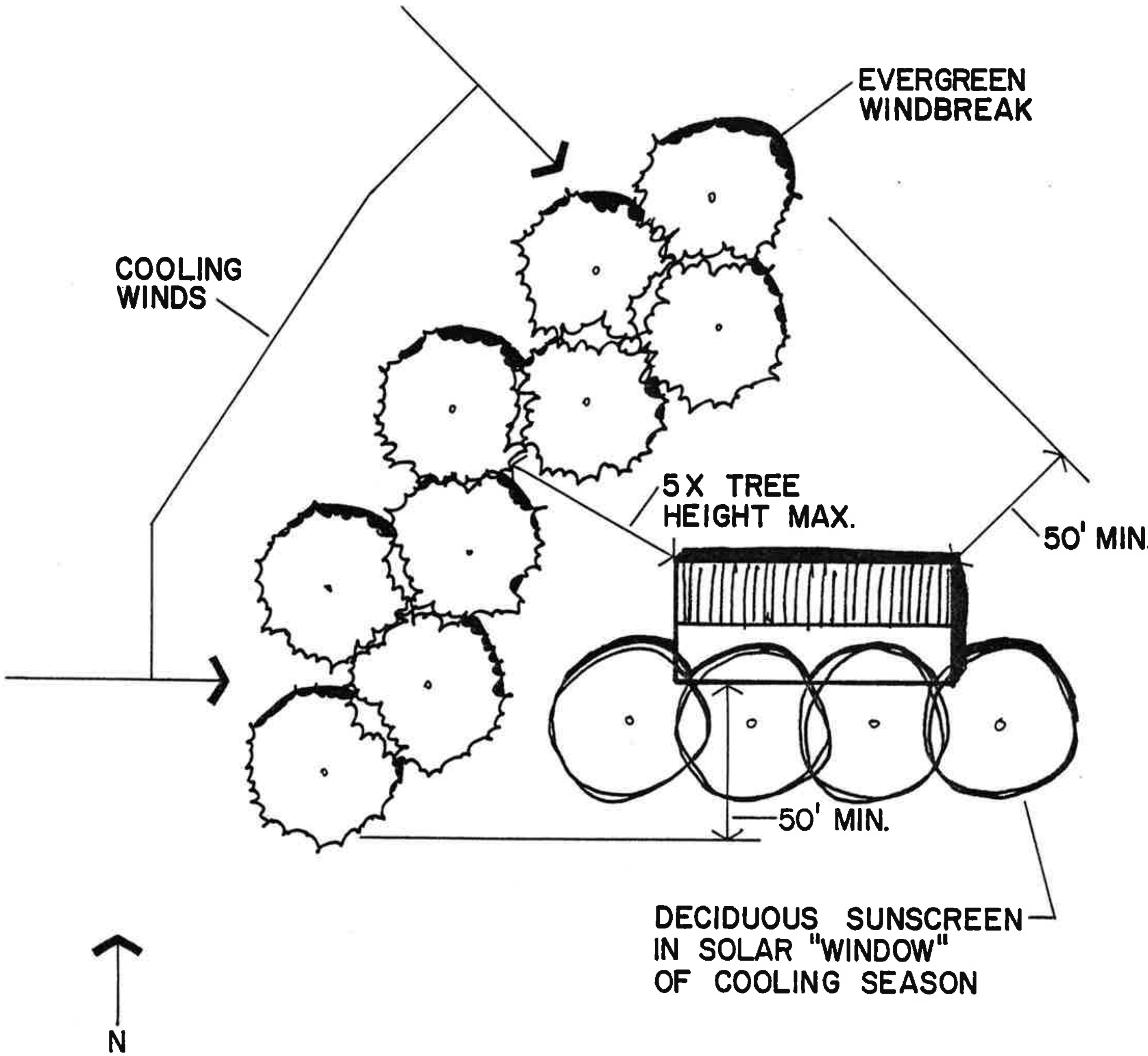


FIGURE 46. Optimum site technology for reduction of energy use in buildings (DeWalle, 1978). The regional cooling winds, determined by combinations of frequency, speed and temperature, are from the west to northwest (Joe DeNardo, DeNardo-McFarland Weather Service, Pittsburgh, personal communication, April, 1978), but local topography, structures, etc., may deflect the wind. The solar "window" in Fox Chapel's cooling season is shown in Figure 44.

	% Solar Blocking	
Species	Summer	Winter
Silver Maple	74	56
Norway Maple	69	37
Red Maple	56	35
Pin Oak	55	53
Black Walnut	62	45
Tulip Tree	59	43
Dogwood	57	47
Beech	56	63
Black Locust	50	61
Red Bud	38	26
Linden	37	43
Sweet Gum	67	53
Sycamore	36	33

FIGURE 47. Percent solar blocking by some northeastern trees. These figures are from unpublished data by Ben Johnson at Virginia Tech, who made horizontal readings with a pyranometer five feet above the ground, at the northernmost point along the dripline.

Atmospheric emissions of physical and chemical matter from Fox Chapel land uses are more or less proportional to energy use, whether in or associated with used facilities. Also, during construction of a land use, dust may be generated, but its importance is not equal to that of water-borne disturbance sediment (Allegheny County Health Department, 1972).

3. Desired Outcomes

The foregoing information has prepared us to specify a set of concrete, measurable desired outcomes in the form:

Outcome = f(Land, Land Use)

These outcomes are derived from the "ideals" stated in "Fox Chapel's Natural Resources Problem", specifically for the climatic aspects of the problem. The relationships of these outcomes to other desired outcomes will be specified, and resulting courses of action selected, under "Conclusions."

For any building (McGuiness and Stein, p. 217):

$$E_B = (E_B/DD)(DD)$$

where:

E_B = annual energy consumption for space heating in the building. Desired outcome: minimize E_B.

E_B/DD = energy consumption in the building for space heating per heating degree days.

DD = number of heating degree days per year at the building's location.

E_B may be measured in dollars or other costs that are proportional to energy rather than in energy directly.

For any land area:

$$\Delta P_{vmt} = \frac{P_{vmt\ post}}{P_{vmt\ pre}}$$

where:

ΔP_{vmt} = the ratio of unshaded pavement after development to that before development. Desired outcome: minimize ΔP_{vmt}.

$P_{vmt\ post}$ = area of pavement unshaded by vegetative canopy after development.

$P_{vmt\ pre}$ = area of pavement unshaded by vegetative canopy before development.

The intent of ΔP_{vmt} is to minimize changes in ambient air temperature. Roofs could have the same effect, but vegetative shading of a roof could involve side effects such as structural damage and increased maintenance costs, and in Fox Chapel roof areas are small compared with pavement areas. Borough implementation of this objective is practical only on Borough-owned land, not through land use ordinances.

For any land area:

$$E_{lawn} = (E_{lawn}/A_{lawn})(A_{lawn})$$

where:

E_{lawn} = annual energy consumption for lawn care in the land area. Desired outcome: minimize E_{lawn}.

E_{lawn}/A_{lawn} = energy consumption per unit area of lawn.

A_{lawn} = area of lawn in the land area.

E_{lawn} may be measured in dollars, work, or other costs, rather than in energy. Borough implementation of this objective is practical only on Borough-owned land, not through land use ordinances.

For any point on the land at which the placement of a structure is permitted by the Borough Zoning Ordinance:

$$E_{acc} = \frac{W - Sh}{W}$$

where:

E_{acc} = accessibility of solar energy at the point. Desired outcome: maximize E_{acc} (up to 1).

W = area of the block of year-round solar "windows" shown in Figure 81.

Sh = the portion of W preempted by shade-making objects located on other properties.

For Fox Chapel as a whole, or for any given subarea of Fox Chapel:

$$E_{TRANS} = \sum_{v=1}^{v=n} (DFE)$$

where:

E_{TRANS} = energy used in transportation per unit time by traffic originating in the area. Desired outcome: minimize E_{TRANS}.

$\sum_{v=1}^{v=n}$ = sum of the applications of the following product to each type of vehicle used for transportation in the area.

D = average distance traveled per trip by each type of vehicle.

F = frequency of trips by each type of vehicle per unit time.

E = energy use by each type of vehicle, per distance traveled.

The implementation of this objective is practical only on Borough-owned land, not through land use ordinances.

BIOSPHERE

1. Land

Living things distribute themselves and grow in strong relation to their physical environments. Underlying all biotic processes is a complex of energy, moisture and chemistry that exists in a unique combination at each point on the earth's surface.

The assemblage of plants and animals living together in the same space at a given point in time is a community (Smith 1974, p. 256). A community that is in a stable, self-perpetuating equilibrium with its physical environment is a climax community (Cooper and Hotaling, 1970, p. 2). Each type of environment has its own inherent climax. A community that is for any reason temporarily out of equilibrium with its environment tends to evolve toward the composition and structure of that environment's climax, through the growth and replacement of individuals and species. This trend is succession. Although the appropriate climax community may not occupy a given location at a given point in time, the climax is the potential community for that environment, toward which any other type of community will evolve as long as natural processes are allowed to occur. The process of succession may involve several intermediate steps between the current and potential communities. The successional sequences among the community types that will be described below are summarized in Figure 48.

The combination of a community and a homogeneous physical environment that it occupies is an ecosystem (Odum 1971). Any ecosystem is characterized by its productivity, diversity, stability, complexity, food webs, nutrient cycling and other functions, in addition to the structure and species composition of its community. For practical geographic analysis and land use regulation, various attempts have been made in the past to predict some of these functions from known characteristics of the physical environment. The approaches that are available in Fox Chapel are summarized in Figure 49.

One predictive approach to terrestrial ecosystems goes from actual evapotranspiration (Meentmeyer and Elton 1977), moisture deficit (Kalstein et al), or other water-budget variables to some measure of productivity. Water-budget variables ought to be able to indicate the regulatory power of the physical environment well, because they integrate the effective energy and moisture endowments to the community (see "Hydrosphere" and "Thermosphere"). Hence this would be a useful approach if more were known about the direct correlation of Fox Chapel's ecosystem characteristics with water-budget variables, and about the detailed variations of water-budget variables over Fox Chapel's topography including the influence of downslope moisture variations. Further research may open up these possibilities.

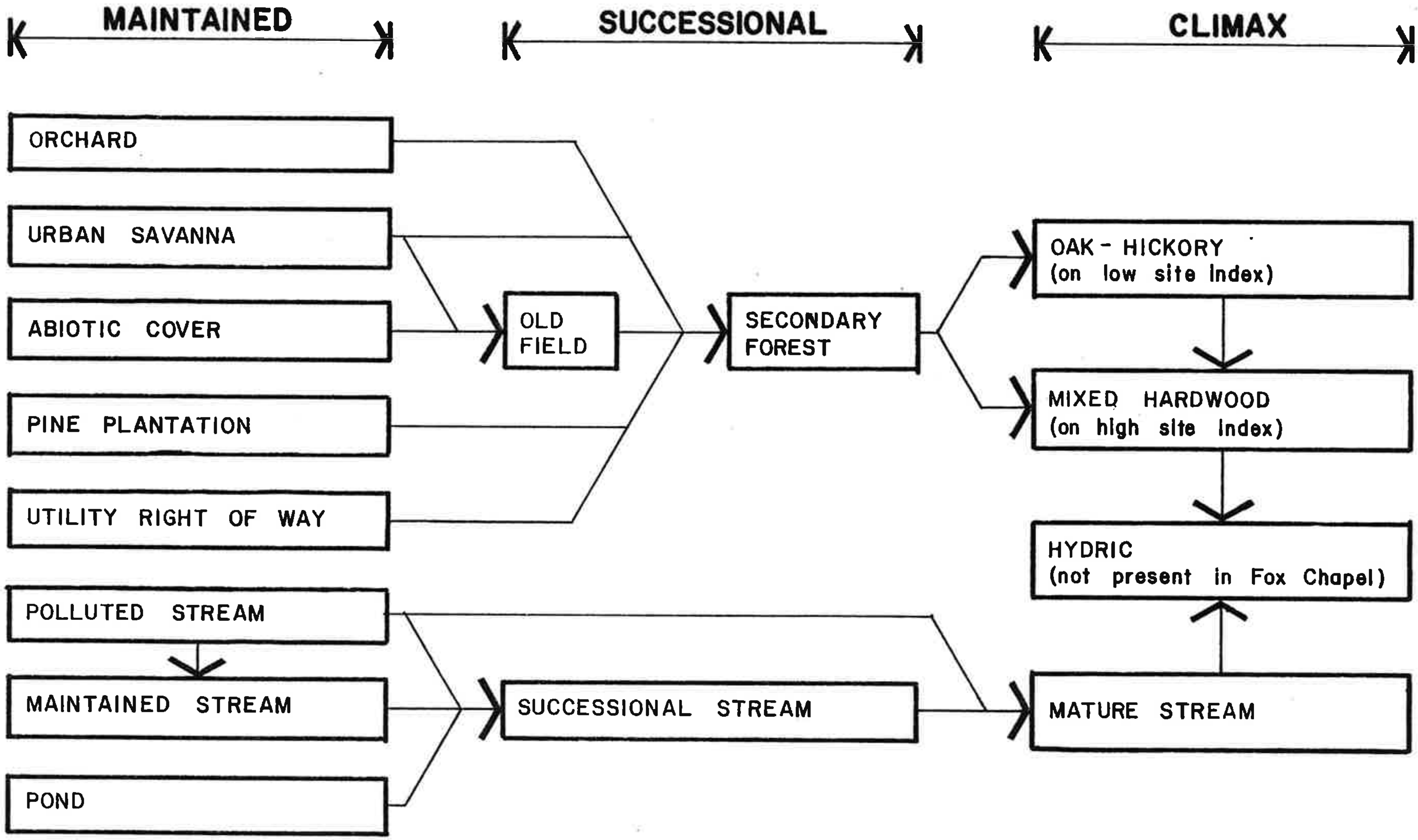


FIGURE 48. Successional sequences among Fox Chapel's community and cover types. Whether urban savanna becomes old field or secondary forest depends on the savanna's local canopy height and density. The evolution of climax communities toward hydric (peneplain) conditions occurs over geologic (extremely long) time, and is not significant to this Plan.

application	source	physical predictor	predicted ecosystem function or index
terrestrial	Meentemeyer and Elton (1977)	actual evapo-transpiration	total productivity
terrestrial	Kalkstein et al (no date)	moisture deficit	corn yield
terrestrial	U. S. Soil Conservation Service (1973)	soil type	site index
terrestrial	Trimble (1964)	slope orientation, position and gradient	site index
terrestrial	Carmean (1967)	slope orientation, position, gradient, shape and length	site index
terrestrial	Auchmoody and Smith (1979)	slope orientation, position, gradient, shape and soil depth	site index
aquatic	Core (1966), and Odum (1971)	general surface water conditions	general aquatic functions

FIGURE 49. Alternative available approaches to prediction of terrestrial and aquatic ecosystem functions, from known characteristics of Fox Chapel's physical environment.

Four other approaches (Figure 49) take site index as a central indicator of terrestrial ecosystem functions. Site index is defined generally as the height of a given species of tree, growing in specified community conditions, at an arbitrarily chosen age (Schwarz, Thor and Elsner 1976). For the four studies relevant to Fox Chapel, site index is the height of red oak growing in an even-aged canopy at fifty years (Carmean, 1964). Site index has been found highly correlated with forest yield, forest structure, species composition, and other ecosystem functions and community characteristics (Trimble and others 1974), although the energy and moisture endowments that regulate it are not well understood (Lee and Sypolt, 1974).

The U. S. Soil Conservation Service (1973) uses soil type to predict site index, but serious questions about both the accuracy of soil maps (Amos and Whiteside, 1975; see "Soils")and the accuracy of soil types as a predictor of site index (Carmean 1961) make soil type of secondary value when more suitable information is available. More suitable information is available for Fox Chapel in the form of three studies (Figure 49) which use regression equations to predict site index from factors of topography and soil. These equations can be applied to overlay maps to derive the geographic distribution of site index (Ferguson, no date). Of the three studies, one (Trimble, 1964) was done in the Appalachian Mountains of West Virginia and is therefore less applicable to Fox Chapel than those that were done in the Appalachian Plateau of Ohio and West Virginia (the reasons for this are described in Ferguson, no date). Of the remaining two studies, one (Auchmoody and Smith, 1979) became available only after this report was substantially completed. The available one (Carmean, 1967) has been used in this report; but in future studies both Auchmoody and Smith (1979) and Meentemeyer and Elton (1977) should be compared to Carmean in the light of then-available research for their relative suitabilities.

Carmean's study (1967) predicts site index from five topographic factors and one soil factor. However, the topography and soils (U. S. Soil Conservation Service, 1973) of Fox Chapel indicate that no soils "having restricted internal drainage" are present in the Borough (this is confirmed by the insignificant presence of hydric species, discussed below); hence Carmean's soil variable is uniform in Fox Chapel, and all predictions can be based on his "Table 1", which uses only "well-drained" soils.

Of Carmean's five topographic factors, two - slope position and slope length - are not defined quantitatively. This makes the mapping application of his equation impossible in Fox Chapel's terrestrial landscape of knobs, saddles, terraces and swales. A telephone conversation with Carmean (July 10, 1979) failed to elucidate this problem (the problem is discussed further in Ferguson, no date). Consequently, Carmean's data were analyzed for their ability to predict site index using only the three topographic variables that could be confidently mapped. Figure 50 shows the result: the three variables do predict site index within certain ranges, as long as the limited accuracy of

topographic variables						
slope orientation	horizontal slope shape	slope gradient	site indexes at all slope lengths and slope positions	mean (avg.)	median	assumed site index class
NE	convex	steep	64, 68, 68, 73, 73, 78, 78, 83	73.125	73	70+
		gentle	62, 66, 67, 71, 72, 76, 77, 82	71.625	71/72	70+
	linear	steep	66, 71, 71, 76, 76, 81, 82, 87	76.25	71/76	70+
		gentle	65, 70, 70, 75, 75, 80, 80, 86	75.125	75	70+
	concave	steep	69, 74, 74, 79, 80, 85, 86, 91	79.75	79/80	70+
		gentle	68, 73, 73, 78, 78, 84, 84, 90	78.5	78	70+
	convex	steep	56, 60, 60, 64, 65, 69, 69, 74	64.625	64/65	69-
		gentle	60, 64, 64, 69, 69, 74, 74, 79	69.125	69	69-
	linear	steep	59, 63, 63, 67, 67, 72, 72, 77	67.5	67	69-
		gentle	63, 67, 67, 72, 72, 77, 77, 83	72.25	72	70+
	concave	steep	61, 65, 66, 70, 71, 75, 76, 81	70.625	70/71	70+
		gentle	66, 70, 70, 75, 76, 80, 81, 86	75.5	70/75	70+

FIGURE 50. Analysis of Carmean's (1967) Table 1 data for their ability to predict site index using only the three topographic variables that can be quantitatively mapped.

slope orientation (NE = 335^{o} - 95^{o} azimuth; SW = 96^{o} - 354^{o} azimuth)	horizontal slope shape	slope gradient (steep = 35% +; gentle = 35% -)	site index class
NE	all	all	70+
SW	convex	all	69-
	linear	steep	69-
		gentle	70+
	concave	all	70+

FIGURE 51. Simplified key for predicting site index classes from mappable topographic variables. Source: Figure 50. All topographic variables are measured at the contour lines shown on SRAWA's topographic map. Where the presence of a terrestrial climax community conflicts with this table, the existing community rules.

the result is acknowledged (Carmean, July 10, 1979). The predicted ranges allow the classification of terrestrial topography into the two broad classes shown in Figure 51: site index 70 is a critical breaking point, with natural communities on either side of it being qualitatively distinguishable in many ways (Trimble and others, 1974); these differences will be discussed further below. A regrouping of the data in Figure 50 results in the simplified key in Figure 51 which is used in this Plan to predict site index as a central indicator of ecosystem functions and community characteristics.

Figure 51 shows that its site index classes and their associated potential communities are distributed predictably in significantly different terrestrial environments. High site index tends to occur in the cool, moist environments of gentle coves and northeast-facing slopes; low site index tends to occur in the hot, dry environments of steep convex slopes and southwest-facing hillsides. The northeast- and southwest-facing orientations used to differentiate heat and water budgets in other sections of this report (see "Hydrosphere", "Thermosphere") correspond roughly to the high and low site index classes. Although available studies have not permitted a quantitative connection, Fox Chapel's ecology is strongly associated with other aspects of its terrestrial natural resources, through both geographic correlation and cause-and-effect relationships. These physical environments are the context within which all terrestrial plants and associated animals grow.

The climax (potential) community in the high site index environment is the mixed hardwood type. That in the low site index environment is the oak-hickory type (Trimble and others, 1974). These are the communities that are most in equilibrium with their respective environments; they are the ultimate products of any terrestrial succession in Fox Chapel, and were presumably the dominant communities before white men settled the land (Smith, 1974, pp. 536, 575-576). Since each type of climax community occupies a homogeneous physical environment, it is also a type of ecosystem. Where either of the climax communities was found to exist currently, the site index level associated with it was taken as the level there - in other words, the community map superceded the site index map.

The oak-hickory community type corresponds to the "forest types" of the same name of the U. S. Forest Service (1973) and Brown (1974), the "white oak-red oak-hickory forest cover type" of the Society of American Foresters (1967) and the "xeric forest type" of Core (1966). Dominant oaks and hickories, with an absence of sugar maple, black-birch, beech, basswood, hemlock and sycamore are diagnostic of this community type. This climax community type contains some subclimax subcommunities where the xeric ecosystem is evolving into a mesic one long after a cutting in a transitional environment; this is indicated by the presence of a mesic younger generation below a xeric canopy (Brown, 1974). This type also contains sunlit pockets where old trees have fallen over, dominated by ground vegetation, vines and successional species until larger trees close the canopy in 10 to 15 years.

In the oak-hickory community important tree species are white oak, black oak, chestnut oak, hickory, black cherry, ash, and red maple. Chestnut was an important tree species before the chestnut blight;

now it is virtually absent. Less important tree species are tulip tree, slippery elm and others. Vines both lie on the ground and climb the trees; they include grape, virginia creeper and, in sunnier areas, poison ivy. Shrubs and small trees include dogwood, hornbeam, sassafras, serviceberry, young of the large trees, viburnum, spice-bush, witchhazel and some brambles. The herbaceous layer is thin with scattered ferns and spring and fall wildflowers (asters, golden-rods, snakeroot and others). An inch or two of humus from the community's organic debris covers the ground. Animals that depend heavily on the oak-hickory community include squirrels, chipmunks, small mammals, woodpeckers, cavity-nesting birds, insectivorous birds that nest in the shrub layer such as wood warblers and verios, larger birds, and deer during spring gestation.

The mixed hardwood community type corresponds to the "Appalachian mixed hardwoods forest type" of the U. S. Forest Service (1973), the "beech-sugar maple forest cover type" of the Society of American Foresters (1967), the "mixed mesophytic forest type" of Braun (1974), and the "mesic forest type" of Core (1966). It is a southern variant of the beech-birch-sugar maple forest type. Dominant sugar maple, basswood, sycamore, black birch, beech and hemlock are diagnostic of this community type. Sycamore and basswood would be considered indicators of a hydric community type if they occupied a significantly large area, but since they do not they are here absorbed into the mesic type, and Fox Chapel is considered to have no separate hydric communities.

The mixed hardwood community type has an extremely high tree diversity because it has representatives of all the species present in the oak-hickory type scattered between the mesic trees. In addition to these xeric trees and the dominant mesic trees, other trees in the mixed hardwood type include ash, oaks, red maple, black cherry, serviceberry, slippery elm, hornbeam, dogwood, tuliptree and others. Tulip tree, sugar maple and black birch may appear earlier in succes-sional stages than other major trees. The herbaceous layer is very diverse, with early spring wildflowers being especially common. Shrubs and small trees include hornbeam, dogwood, serviceberry, witch-hazel, wild hydrangea, and viburnum; this layer becomes dense in sunlit pockets. The ground cover varies from thick leaf litter, to moss and bare talus on steep slopes. Animal species in the mixed hardwood are highly diverse, due to the great number of plant species and other variables.

Since mixed hardwood occurs in relatively moist locations, natural surface water tends to occur within this type. The relative openness over the water allows more light to reach lower levels of the community, creating denser shrub and herb layers near the water. Flooding of the water may disturb the plants to create a local floodplain (hydric) variant of the mixed hardwood community.

Where old mixed hardwood trees have fallen over, sunlit pockets are dominated by ground vegetation, vines and brambles. Large trees close the canopy after 10 to 15 years.

Climax aquatic communities - mature streams (Figure 40) - occur in canopied unpolluted flowing surface water in unmaintained lowlands. Mature streams can potentially occur in any stream. To be mature, all of a stream's upstream lowland must be unmaintained and overhung by a tree canopy at least as high and dense as secondary forest (Figure 52). The surrounding terrestrial plants are the sources of two-thirds of the aquatic ecosystem's energy supply and the regulators of its temperature and quality.

Flowing surface water contains a sequence of pools, riffles, and meanders, aligned along the stream's gradient. In Fox Chapel the gradient tends to be steep except over the gravel terraces and in the lowest reaches of Squaw Run. The water supports many species of invertebrates (including insects and crayfish), frogs, salamanders and small fish.

2. Land Use

Both past and prospective land uses are relevant to Fox Chapel's ecology, because ecology is such a fragile aspect of natural resources. Although Fox Chapel's development for farming was done decades to centuries ago and no further development is expected, ecological remnants of farming land uses exist today, and are an important aspect of the ecological context within which future land use changes may take place. Suburban land development and subsequent resuccession have been superimposed on the farming remnants, leaving further residues of their own.

Farming development was superimposed on the pattern of climax communities discussed under "Land". Farming land uses are a network of fields (including pastures, meadows and cultivated fields), forests, hedgerows and orchards. Earthworks and abiotic surfaces were minor. In installing these uses, the preexisting climax communities were modified or removed by clearing, replanting and maintenance for fields, forests and hedgerows, and by cyclical cutting of forests that were maintained for wood production. Some ice ponds and millponds were built in valley bottoms. The greatest disturbance - clearing - tended to be on the gentler hilltops, leaving the steep hillsides and narrow valleys to regenerate their potential communities - mostly mixed hardwood - after each cutting.

Suburban land development and light construction have been superimposed on the pattern of climax communities and farming land uses left from earlier farming development. Suburban land uses are a network of lawns, buildings, pavements, and small forests. The most intense developments have tended to occur in farm fields, again leaving mostly high site index environments to preservation and natural regeneration. In installing these uses the preexisting climax and farm communities were modified by further clearing of forests, hedgerows and orchards; earthwork that created new physical environments for plant growth; erosion of disturbed soil into surface water bodies; abiotic paving and roofing; planting of lawns and ornamental woody plants; and maintenance of lawns by fertilizing and cutting.

Both farming and suburban developments have left a residue which is in itself, a third process of biotic modification: ongoing natural succession of abandoned areas. Fields that are no longer maintained for farming, and abandoned portions of suburban developments such as cut and fill slopes, tend to revert to their potential communities in accord with the physical environment that remains after the earlier disturbance. Many areas are now at various intermediate steps in their transitions back to climax communities. The earlier disturbances had reduced the area's productivity, diversity and stability. In the absence of artificial maintenance, these functions are being gradually restored through the natural invasion, growth and replacement of individuals and species (Smith, 1974, p. 8; Cooper and Hotaling 1970, p. 2).

As a result of these successive processes of modification, Fox Chapel's biota and land cover of today are an intricate patchwork of:

1. Climax communities discussed under "Land". Although no virgin communities have been identified in the Borough, many communities have been permitted to regnerate long enough that they can be considered climax communities, essentially in equilibrium with their respective physical environments. These include oak-hickory, mixed hardwood and mature stream.

2. Communities and land covers that are currently maintained for farming or suburban purposes. In Fox Chapel these can be classified most easily and usefully as urban savanna, utility right-of-way, abiotic cover, orchard, pine plantation, maintained stream, polluted stream, and pond. Their functions and characteristics are regulated mostly by the artificial maintenance expenses of energy, materials and land management, and not by their natural physical endowments.

3. Successional communities. These have received some sort of disturbance in the past, but are now at intermediate steps in regenerating back to their respective climaxes. Terrestrial successional communities form a continuum of successional stages from recently disturbed to climax, but for practical purposes old field and secondary forest can be broadly distinguished from each other. Some orchards, pine plantations and ponds are not heavily maintained and are in various stages of succession, but they are not distinguished from their maintained counterparts because of their relative insignificance in the Borough. Immature streams are successional if they are not polluted and their lowlands are not maintained.

The nine disturbed (maintained and successional) community and cover types are described below.

Urban savanna is a cleared or partly cleared area that has been partly replanted with cultivated species. It is the most common type of community in the Borough. Its diagnostic characteristic is a ground level (herbaceous) layer dominated by maintained lawn and garden. Both native and non-native trees and shrubs are scattered within this area. Many of the woody plants occur in hedgerows, and many are evergreen. The savanna's maintenance always includes mowing, and may include applications of pesticides and fertilizers. One variant of urban savanna, the golf course, tends to be particularly heavily maintained: pesticides and fertilizers are applied in large quantities, excess water is removed by subsurface pipes, and irrigation occurs at frequent intervals. Despite its maintenance, urban savanna is subject to a certain type of aging: individual trees enlarge, become more productive, and develop cavities for nesting; shrubs grow into continuous hedges and overtake small former lawn areas; some new species of animals invade the new habitats (a few of which are well adapted to the overall savanna environment and become overabundant pests). On the whole the savanna is not diverse, but certain of its occasional components provide habitats that are seldom found elsewhere, such as its crabapples and conifers (Geibert 1979).

Abiotic cover is any hard artificial surface such as those of buildings, roads, driveways, parking areas, patios, walkways, swimming pools, tennis courts and small upland ponds. It preempts the productive land surface. It supports essentially no biotic activity or biomass, and resists succession through its solid, hard, hot, dry character. It tends to occur within areas of urban savanna, but is distinguished here from its savanna environment.

Utility right-of-way is given only enough maintenance to prevent a degree of regeneration that would be unacceptable to its maintainers. This results in a diagnostic community that is indistinguishable from old field or secondary forest (discussed below), plus the presence of an electric or gas line that indicates maintenance. The maintenance is either by cutting or by the spraying of herbicides. This type of maintenance occurs and the resulting type of community exists, only where no higher level of maintenance occurs along the utility's alignment, such as that of urban savanna. Dominant species may include old field herbs and brambles, pruned sassafras, and pruned oaks. Right-of-way can increase animal diversity by locally increasing the plant diversity in the forest or other environment through which the narrow utility corridor passes (Geibert, 1979).

Orchard is a variant of urban savanna that is planted with a high density of small fruit trees. Most of Fox Chapel's orchard communities are not heavily maintained; many are in a state of transition to successional types of communities. All of them provide intense animal food and shelter.

Pine plantations are dense plantings of large evergreen trees. Their level of active maintenance is low, but their evergreen cover and acid litter tend to resist succession during the life of the trees. Many pine plantation communities are interspersed with volunteer native species. Their evergreen cover and cone production make them uniquely important to certain types of animals. They can moderate local winter climate significantly (see "Thermosphere").

Immature streams are streams of which lowlands are covered with canopies less high and dense than that of secondary forest (Figure 52), or which are polluted. They are either maintained or successional, depending on maintenance. One visible example of a maintained stream is Glade Run where it flows through the Fox Chapel Golf Club golf course: it is warm and unproductive because of its lawn surroundings. The only known significantly polluted stream in Fox Chapel is the reach of Squaw Run between the Ottawa Treatment Plant and Campbell's Lake. Streams that are seriously disturbed by excess stormwater flows will presumably be identified by the regional stormwater plan currently being prepared by Green International.

All of Fox Chapel's ponds are dammed streams. Some were created for mill purposes (such as Campbell's Lake) and some for ice purposes (such as Salamander Pond). None of them are large enough to create true lake (still water) conditions; they are only a relative modification of the flowing-water environment of streams. When not heavily maintained, ponds are susceptible to succession through filling by sediment and organic litter, and dam decay. Both of these processes tend to smooth out the pond along its stream's gradient, and to re-equilibrate it with its flowing-water environment. (Some very small water bodies have been dug in terrestrial locations for aesthetic purposes; these are absorbed in the abiotic cover type).

Old field is the youngest terrestrial successional community type in the Borough. Dominant unmaintained grasses and non-woody species are diagnostic of this type. Common species are goldenrod and aster; other species present are blackberry, raspberry, grey dogwood, young black cherry, hawthorn, alder and sumac. Trees and shrubs cover less of the ground area than do the grasses and herbs; the overall effect can be a patchwork of tree clumps,brushy patches and herbaceous areas. Animals in old fields include deer, rabbit, fox, small mammals, pheasant, sparrow, finch, other seed-eating birds, hawk, and owl. The further succession of old field consists of the growing of larger trees, which shade out the herbaceous layer in 10 to 15 years and transform the area into secondary forest.

Secondary forest is the broad transitional step in terrestrial succession between old field and climax. It ranges from fields that have been mostly overgrown with trees, to dense forests of tree species that require light and therefore cannot regenerate in the environment that they create. An overall tree cover without dominant oaks, hickory, sugar maple, beech, blackbirch, hemlock, basswood and sycamore are diagnostic of secondary forest.

A younger secondary forest may consist of a patchwork of uneven-aged trees and smaller plants due to the invasion of different parts of the site by trees at different rates. The structure becomes more uniform as the forest ages. Either an early or late secondary forest may include a brushy layer of brambles and mixed herbaceous species; in the few middle years right after the canopy has closed over, the canopy is so dense that no light can penetrate it and no subtree plants, or associated grazing animals such as deer, can survive. Grape vines may climb into some trees and retard the forest succession. Gradually a secondary forest builds up a layer of leaf litter on the ground.

The dominant and associated plants in a secondary forest may include black cherry, slippery elm, black locust, ash, red maple, dogwood, sassafras, young black birch, hawthorn, ailanthus, sumac, aspen and some ornamentals. When the trees reach about 35 years old the forest begins to develop cavity nesting sites, seed production and understory growth, all of which support increased animal populations (Hassinger and others 1979, pp. 27-28). At about the same time species representative of climax communities begin to invade the shady environment of the forest.

Old field, secondary forest and young terrestrial climax communities may contain some ornamental species, hedgerows and very large, old individual trees ("grandfather" trees) as remnants of previous habitation of the site. These remnants add to the diversity of the community and provide animal habitats not available in younger native plants. "Grandfather" trees contribute intensely to the habitat diversity of their surroundings through their cavity sites and large seed production. They are also symbols of the agricultural way of life. Hence "grandfather" trees are defined as unique trees.

Each community combines with its homogeneous environment to form an ecosystem. Each of the Borough's eleven community types and their respective ecosystem types can be characterized in terms of maturity, productivity, diversity and rare species presence. These are common denominators by which any community or ecosystem can be measured. Communities can be characterized also in terms of their effects on given aspects of their physical environments, such as climate, water, etc.; these effects are described in the relevant sections of this report, such as "Thermosphere" and "Hydrosphere".

Maturity (age) is the amount of time required for a community to reach its present state through the process of succession. It is a measure of the amount of time for a community to regain its current state after a given proposed disturbance. Hence it is also a measure of potential community rarity: a mature community that is destroyed may remain absent for many human generations, whereas a young community may be regenerated quickly, either on the original site or on some other unmaintained site. In Fox Chapel's range of ecosystems, maturity is a characteristic only of an existing community, not of the physical environment that regulates it. The relative maturities of Fox Chapel's community and cover types are summarized in Figure 103.

Productivity (biomass/time/area) is the rate at which the physical endowments of an ecosystem are bound into organic matter (Whittaker 1970). It is a basic contribution of any ecosystem to the biosphere. It is an indicator of potential farming or forest production, presaging a direct potential contribution to the human economy. Productivity is a function of both an existing community and its physical environment. A subclimax community's productivity is out of equilibrium with its environment and is not taking full advantage of its endowment, so in subclimax ecosystems we may distinguish between current productivity (represented by the community) and potential productivity (represented by site index). A climax community takes full advantage

Characteristic	Community or Cover Type											
	Abiotic Cover	Urban Savanna	Orchard	Pine Plantation	Old Field	Secondary Forest	Oak-Hickory	Mixed Hardwood	Utility Right of Way	Pond	Successional, Polluted and Maintained Streams	Mature Stream
Maturity (Minimum Number of Years to Replicate)	0	1	10	15	3	20	100	100	15	3	1	20
Productivity (mean gm/m^2/yr.) (Whittaker, 1970)	3	600	600	700	500	1,000	1,300	1,600	750	500	250	500
Diversity (Number of Plant Species in Canopy) (Braun, 1950, Table 13)	0	5	2	2	5	7	10	14	5	3	3	3
Relative Uniqueness as Animal Habitat (no units)	0	2	9	9	5	3	8	7	6	10	2	9
Relative Canopy Height and Density	0	1	3	8	1	7	9	10	3	0	0	0

FIGURE 52. Characteristics of Fox Chapel's community and cover types.

Potential Future Characteristic	Site Index Level 69-	Site Index Level 70+
Maturity (Minimum Number of Years to Replicate)	100	100
Gross Productivity (means $gm/m^2/yr.$) (Whittaker, 1970)	1,300	1,600
Diversity (Number of Plant Species in Canopy) (Braun, 1950, Table 13)	10	14
Relative Uniqueness as Animal Habitat (no units)	8	7
Relative Canopy Height and Density	9	10

FIGURE 53. Potential future characteristics of Fox Chapel's site index levels.

of its endowment, so here current productivity equals potential productivity. The contrasting productivities of different site index classes (and their corresponding climax communities) were shown in an earlier study of nearby forests (Bennett and Ferguson 1975) in which long-term average cordage yields were found of 0.5 cord/acre/year in oak-hickory communities, and 0.61 cord/acre/year in mixed hardwood communities. The total productivity of any community is in the vicinity of 1% of the incoming solar radiation (Gieger 1971, p. 310), averaging in Fox Chapel about 0.01 g/cm^2/year, or 50 cal/cm^2/year. The relative productivities of Fox Chapel's current communities and covers are summarized in Figure 52; potential productivities (site index classes) are mapped.

Diversity is the number of species (not individuals) per area. It is a basic contribution of any ecosystem to the biosphere's genetic pool. A more productive ecosystem is able to support greater diversity; so diversity, like productivity, has both current and potential forms. Current diversities are summarized in Figure 52; potential diversities are indicated by site index in our maps, where current communities are not climax.

The diversity of animal species is not always directly proportional to the diversity of the overall communities that they inhabit. Animals that are at low levels in food webs, such as fishes and butterflies, have relatively simple interactions with each other and their habitats; each species inhabits only one or two community types, and the diversity of this type of animals is proportional to that of their overall community. However, most reptiles, amphibians, birds and mammals rely on several different community types within their ranges, so their populations are functions of the Borough's overall geographic distribution of community types. Fox example, one aspect of geographic distribution is the concept of "corridors", which measures the continuity of community types over long distances. Such continuity allows animals to move freely among different micro-habitats and to participate fully in their complex interrelationships. Although the general concept of "corridors" is well known to ecologists, no quantitative definition of them is known, so they have not been mapped or otherwise evaluated. However, we can say that Fox Chapel's linear systems of stream valleys and steep hillsides do tend to perpetuate continuous bands of mature, diverse communities in the context of suburban development: as long as some portions of communities are preserved (in terms of area), the preserved portions tend to merge together over long distances (continuity). In addition to animals that move around the Borough, many species of animals have ranges that extend well beyond the Borough including migratory birds and bats that inhabit the Borough for only a short time in spring and fall; in these cases the entire Borough is only a small part of a regional or continental distribution of habitats. At the current state of the art is is impossible to evaluate the Borough's overall geographic distribution of communities or its function in larger geographic arrangements. However, Figure 52 shows the relative importances of community and cover types in the context of current regional characteristics and frequencies. Beyond the preservation of community types, intense habitat management depends on subtle variation in vegetation management. It tends not to be implemented over long periods of time in suburban land uses, and its results are difficult to evaluate even in the short term. Hence it is impractical to attempt to control intense habitat management in existing or future land uses.

The Borough's current known populations of birds, mammals, amphibians and reptiles are listed with notes in Figures 54-56. These lists elucidate the evaluations of diversity in Figure 52, and provide a 1979-80 data base for any future estimates of changes in diversity, and any future supplements to this Plan in the light of wildlife evaluation and planning techniques that may become available in the future. The lists are limited to four animal groups because these groups are relatively well studied and easily observed, have relatively rigid habitat requirements, and are indicators of overall animal populations including the numerous smaller species with which they interact.

Rare species presence is one critical aspect of diversity. Rare species are close to extinction. Any extinction reduces the net diversity of the entire ecosphere, reduces complexity of species interactions and therefore stability of the ecosphere, and reduces man's chances to study and benefit from the species. Rare species are more likely to show up in more diverse communities, but whether they do actually inhabit any particular site can be determined only by on-site investigation.

For plant species such an investigation has been made by Chris Metelmann and his SRAWA vegetation team. They found the regionally rare species listed in Figure 57. No plant species have been found in the Borough that are in danger of extinction. A state-wide survey of rare plant species is by Wiegman (1980).

For large animal species an investigation of the Borough as a whole has been made by Rupert Friday and his sources;the results are listed in Figures 54-56. Although no species living in the Borough are listed by the U. S. Fish and Wildlife Service (1979) as endangered, several species so listed migrate through the Borough; these include bald eagle and peregrine falcon (recorded by Scott Robinson). The endangered Indiana bat and Kirtland's warbler have never been identified in Fox Chapel, but have been banded in Pennsylvania; hypothetically they could pass through Fox Chapel during migration (Parkes 1956, p.40). In addition to the endangered species, the populations of many species of birds are declining over a large region around Fox Chapel, are sensitive to habitat destruction or modification, and are therefore in danger of local extinction (National Audubon Society 1979). Species of birds that formerly nested in the Borough and that have become locally extinct within the last 15 or 20 years due to habitat loss include sharp-shinned hawk, red-shouldered hawk, bob-white quail, whip-poor-will and Eastern blue bird (observations by Friday and records of Robinson; Figure 54). Species of birds that breed currently in the Borough are listed in Figure 54; some of them are very intolerant to loss of their habitats. Amphibians are sensitive to

FIGURE 54. Birds of Fox Chapel

The following list of birds of Fox Chapel Borough was prepared by Scott Robinson in December 1979. Species are listed by their accepted common name with notes on the occurence of each species in different seasons. The list has been reviewed by Rupert Friday and C.W. Bier. Notes have been added indicating: locally significant residents (summer and winter), populations sensitive to local habitat changes, recognised endangered species, and species listed on the Audubon Society's "Blue List" (an early warning list).

The list was compiled from field observations of S. Robinson, W.O. Robinson, and casual observations of C.W. Bier, R. Friday, and others.

Symbols Used

A . . .	Abundant	R . . .	Rare
VC . . .	Very Common	Cas . .	Casual (3-6 records)
C . . .	Common	Acc . .	Accidental (1-2 records)
FC . . .	Fairly Common	Hyp . .	Hypothetical
U . . .	Uncommon	* . .	Known or presumed to breed

Seasons

W . . . Winter (Dec. 1-Feb. 15)
S . . . Spring (Feb. 16-May. 30)
X . . . Summer (June 1-Aug. 30)
F . . . Fall (Sept. 1-Nov. 30)

Value Codes

S . . . Populations sensitive to local changes
\+ . . . Locally significant residents
Bl . . Species listed on the Audubon Society Blue List
End . Species listed as Endangered or Threatened
( ) . Birds in parentheses have not been seen since the early sixties

(continued on following page)

FIGURE 54. Continued from previous page.

Habitats

GC . . . Golf Courses (Field Club, Fox Chapel Golf Courses)
DF . . . Deciduous forest (Trillium Trail, "The Forest")
DW . . . Deciduous woods (late second growth - locust, bl. cherry)
DS . . . Deciduous scrub (overgrown fields, multiflora rose, hawthor
F . . . Grassy Fields (occasionally mown)
P . . . Ponds (Campbell's Pond, Golf Course Ponds, etc.)
S . . . Streams
PW . . . Pine Woods (S.S.A. Middle & Senior Schools, N. ridge Trillium Trail)
WS . . . Wet Scrub (Willows, etc. - partially inundated - esp. Salamander Park)
US . . ."Urban Savannah"
O . . . Overhead
WB . . . Wooded bog (esp. Salamander Park)

Species	Value codes	W	S	X	F	Habitats	Notes
Pied-billed Grebe		Acc				P	(2 records)
Great Blue Heron		Acc	R		R	O	
Green Heron	+/S		U	U*	U	P,S,WS	(2 prs nest)
American Bittern		Cas				P,WS	
Whistling Swan			Acc		Acc	O	(2 records)
Canada Goose	+		FC	FC*	FC	O,P	(nest at golf course)
Mallard	+	R	FC	R*	FC	P,WB	(2-3 prs. nest)
Black Duck		Cas	Cas		Cas	O,P	(formerly at Campbell' pond)
(Gadwall)	-	-	-	-	-	-	" " "
(Pintail)	-	-	-	-	-	-	" " "
Green-winged Teal			Cas		Cas	P	
Blue-winged Teal			Cas		Cas	WS,P	
American Wigeon			Acc		Acc	P	
(Shoveler)	-	-	-	-	-	-	(formerly at Campbell's pond)
Wood Duck			R	?	Cas	WB,P,S	(may have nested)
(Redhead)	-	-	-	-	-	-	(formerly at Campbell's pond)
(Ring-necked Duck)	-	-	-	-	-	-	" " "
(Canvasback)	Bl	-	-	-	-	-	" " "
Lesser Scaup			Acc			P	(2 records)
Common Goldeneye			Acc		Acc	P	(3 records)
Bufflehead			Acc			P	(1 record)
Ruddy Duck			Acc			P	(1 record)
Hooded Merganser			Acc			P	(1 record)
Turkey Vulture			Cas		Cas	O	
Goshawk		Hypo				DF	(hypothetical feeder record)

(continued on following page)

FIGURE 54. Continued from previous page.

Species	Value codes	W	S	X	F	Habitats	Notes
Sharp-shinned Hawk	Bl	R	R	R*	U	DW, DF, US, PW, O	
Cooper's Hawk	+/Bl/S	R	R	R*	U	DF, DW, US, PW	(1 pr. nesting)
Red-tailed Hawk	+/S	FC	FC	U*	C	O, DS, F, DW, DF	(2 prs. ")
Red-shouldered Hawk	Bl	R	R	Cas*	U	O, F, DS	(nested nearby onc
Broad-winged Hawk	+/S		FC	U*	FC	O, DF, DW, DS	(2-3 prs nest
Rough-legged Hawk		Cas	Acc		Acc	O, F	(5 records total)
Bald Eagle	End		Acc			O	(1 record)
Marsh Hawk	Bl		Acc		R	O, F	(10+ records)
Osprey	Bl		Acc		Acc	O	(2 records)
Peregrine Falcon	End	Acc	Acc		Acc	O	(6 records)
Merlin	Bl	Acc	Cas		Cas	O, GC	
Am. Kestrel	+/Bl/S	R	R	R*	U	O, F, GC	(nests nearby)
Ruffed Grouse	+/S	U	U	U*	U	DW, DF, DS	
Bobwhite						DS	(locally extinct)
Ring-necked Pheasant	+/S	FC	FC	FC*	FC	DS, F	(declining)
Turkey		Acc					(mystierious record)
(Virginia Rail)	-	-	-	-	-		(formerly at Campbell's pond)
Sora					Acc	WS	(1 record)
Am. Coot			Cas		Cas	P	
Killdeer		R	U	U*	U	P, F, O	
Am. Woodcock	+/S		U	U*	U	WS, F, DW, S	
Com. Snipe		R		R		WS, P, S	
Spotted Sandpiper	+/S		U	U*	Cas	S, P	
Solitary Sandpiper			Cas	Cas	Cas	S, WS, P	
Greater Yellowlegs			Acc	Acc	Acc	O, WS, P	
Lesser Yellowlegs			Acc			O	(1 record)
Pectoral Sandpiper			Cas			F, P	
Least Sandpiper			Acc			P	(1 record)
Ring-billed Gull					Acc	O	(1 record)
Rock Dove		U	FC	FC	FC	O, US	
Mourning Dove	+	A	VC	C*	VC	F, GC, PW, DW, DS, US	(feeders
Yellow-billed Cuckoo	+/Bl/S		U	U*	U	DW, DF, DS	
Black-billed Cuckoo	+/S		U	R*	U	DW, DF, DS	
Barn Owl			Acc				(1956 record)
Screech Owl	+	C	C	C*	C	DW, DS, PW, US	
Great Horned Owl	+/S	U*	U	U	U	DF	
Barred Owl	Bl	R	?	?	?	DF	
Long-eared Owl		Acc				PW	(1 old record)
Short-eared Owl	Bl		Acc			DS, F	(1 record CW Bier)
Saw-whet Owl					Acc	DF	(1 record R Friday)
(Whip-poor-will)	+/S	-	-	-	-		(formerly common summer residents)
Com. Nighthawk			C	VC*	A	O	(1 Nov. record)
Chimney Swift	+		VC	VC*	VC	O	
Ruby-throated Hummingbird	+/Bl		FC	FC*	FC	US, DF, DW, DS, F, etc.	
Belted Kingfisher	+/S	U	U	U*	U	S, P	
Common Flicker	+/S	U	VC	VC*	VC	DW, DF, DS, US, GC, etc.	
Pileated Woodpecker	+/S	U	U	U*	U	DF, DS	(3-4 pairs)
Red-bellied Woodpecker		R	?	?	?	DW, US	
Red-headed Woodpecker	Bl		Acc			DW	(1 record)
Yellow-bellied Sapsucker		U	FC		FC	DF, DW, US, PW, etc.	
Hairy Woodpecker	+/Bl/S	C	C	C*	C	DF, DW, US, PW, etc.	
Downy Woodpecker	+/S	VC	VC	VC*	VC	all habitats	

(continued on following page)

FIGURE 54. Continued from previous page.

Species	Value codes	W	S	X	F	Habitats	Notes
Eastern Kingbird	+/S		R	R*		F	
Great Crested Flycatcher	+/S		FC	FC*	U	DW,DS,US	
Eastern Phoebe	+/S		FC	FC*	FC	S,US	
Yellow-bellied Flycatcher			U		FC	DS,DW,DB,DF	(late May approx. May 25; Sept.)
Acadian Flycatcher	+/S		FC	FC*	?	DF,S,WB	
Willow Flycatcher	+/S		R	U*	?	WS,WB,DS	
Alder Flycatcher			Acc		?	WS	(1 record)
Least Flycatcher	+		C	Cas	VC	DF,DW,DS,<u>etc</u>.	(may nest)
E. Wood Pewee	+/S		U	FC*	U	DF,US	
Olive-sided Flycatcher			Acc		R	DF,DW	
Horned Lark	+	R	Acc		Cas	F,O,GC	
Tree Swallow			R		R	P,O	
Bank Swallow			R	R		P,O	
Rough-winged Swallow	+/S		U	U*		S,P,O	
Barn Swallow	+/S		U	U*		F,P,O	
Cliff Swallow			R			P,O	
Purple Martin	Bl		Cas			O	
Blue Jay	+	VC	VC	C*	A	DF,DW,US,PW	
Common Crow	+	C	C	C*	C	O,GC,F,DF	
Black-capped Chickadee	+	A	VC	VC*	A	all habitats	
Carolina Chickadee		Cas	?	?	?	locally extinct ?	
Tufted Titmouse	+	A	A	A	A	all habitats, esp. US, DF, DW,PW	
White-breasted Nuthatch	+	A	C	C	A	all . . . " " . . .	
Red-breasted Nuthatch		R-U	U		U	esp. PW, also DW,DF	
Brown Creeper	+/S	FC	C	R*	C	DF,DW,US,PW	(1 pr. neste in 1971)
House Wren	+	hypo	C	C*	C	US,DF,DW,DS,PW,<u>etc</u>.	
Winter Wren	+W/S	R-U	FC		FC	DF,DW,DS	
Bewick's Wren	Bl	hypo				feeder JT. ?	
Carolina Wren	+	R-A	R-A	R-A*	R-A	all habitats, population level fluctuates	
Long-billed Marsh Wren			Acc			F	
Mockingbird		R	R	?	R	US,DS	
Gray Catbird	+	R	VC	VC*	VC	DS,DW,PW,US	
Brown Thrasher	+	R	C	C*	C	DS,DW,US	
Am. Robin	+	U	A	A*	A	all habitats	(immense roost)
Wood Thrush	+/S	VC	VC*	VC		DF,DW,US	
Hermit Thrush	+W/S	R	FC		FC	DF,DW,PW,DS	
Swainson's Thrush			C	Acc	VC	DF,DW,PW	(1 male possibl bred)
Gray-cheeked Thrush			U		FC	DF,DW	
Veery	+/S		FC	FC*	FC	DF,S,DW	
Eastern Bluebird	Bl/S	R	R		R	O,DS,US	(preveous breede
Blue-gray Gnatcatcher	+/S		VC	C*	U	DF,DW,DS	
Golden-crowned Kinglet	+W	U-FC	VC		VC	DF,DW,US,DS,PW	
Water Pipit			Acc		Acc	O	
Bohemian Waxwing		hypo				US	(possibly w/ Cedar Waxwings)
Cedar Waxwing	+	C	C	C*	VC	US,DS,DF,DW	
Starling	+	A	A	A*	A	US	
White-eyed Vireo	+/S		U	U*	U	DS	(increasing)
Yellow-throated Vireo	+/S		FC	FC*	FC	DF,DW,US	

(continued on following page)

FIGURE 54. Continued from previous page.

Species	Value codes	W	S	X	F	Habitats	Notes
Solitary Vireo			FC		FC	DF	
Red-eyed Vireo	+		C	C*	C	DF,DW,DS,US	
Philadelphia Vireo			U		FC	DW,DS,WS,WB	(esp. willows
Warbling Vireo	Bl		R	R*		US	
Black-and-White Warbler	+/S		C	R*	C	DF,DW,US,PW	
Prothonotary Warbler			Acc			WS	(1 record)
Worm-eating Warbler			U-R	R*		DF	
Swainson's Warbler			hypo			S	(heard - WO Robinson)
Golden-winged Warbler	+/S		U	R*	?	DS	(declining)
Blue-winged Warbler	+/S		FC	FC*	U	DS	
Tennessee Warbler			A		A	WB,WS,DF,US,DW	
Orange-crowned Warbler			U		U-FC	DW,PW,DS,DF,US	
Nashville Warbler			VC		C	DW,PW,DS,DF,US	
N. Parula			FC		U	DF,US	
Yellow Warbler	+/Bl/S		C	C*	R	S,WB,WS	
Magnolia Warbler			C		A	DF,DW,DS,PW	
Cape May Warbler			U-C		FC	DF,DW,DS,PW	
Black-throated Blue Warbler			C		C	DF,DW,DS	
Yellow-rumped Warbler		R	A		A	DF,DW,PW,DS,US	
Black-throated Green Warbler	?		A		A	DF,DW,PW,US	
Cerulean Warbler	+		A	VC*	R	DF	
Blackburnian Warbler			A		A	DF,DW,US	
Chestnut-sided Warbler	+/S		VC	R*	VC	DW,DS,DF	(formerly nested
Bay-breasted Warbler			C-VC		A	DF,DW	
Blackpoll Warbler			FC		A	DF,DW,US,DS,WB,<u>etc.</u>	
Wilson's Warbler			U		FC	DS,WB,WS	(willows)
Canada Warbler			FC		FC	DF,DW,DS	
Am. Redstart	+/S		VC	FC*	C	DF,DW,DS,US	
Pine Warbler		hypo	R		R	PW,DW,DS	
Prairie Warbler	+/S		R	R*	R	PW,DS,DW	
Palm Warbler			U		R	DF,DW,DS	
Ovenbird	+/S		C	C*	C	DF,DW,DS,PW	
Nothern Waterthrush			U		FC	WB,S,WS	
Louisiana Waterthrush	+/S		FC	FC*		S	
Kentucky Warbler	+/S		FC	FC*	U	DF,DW	
Connecticut Warbler			R		R-U	DS,DF,DW	
Mourning Warbler			R			DS	
Yellowthroat	+/S		FC	FC*	C	DS,WS,WB	
Yellow-breasted Chat	+/BL/S		FC	FC*	U-R	DS,WS	(declining)
Hooded Warbler	+/S		FC	FC*	FC	DF,DW	
House Sparrow	+	A	A	A	A	US	
Bobolink			Acc			O,F	
Eastern Meadowlark	+/S	R	FC	FC*	FC	F	
Red-winged Blackbird	+	R	A	A*	A	F,WS,WB,P,<u>etc.</u>	(roost-25,00
Orchard Oriole	+/S		R			DW	
Northern Oriole	+/S		C	FC*		DW,US	
Rusty Blackbird		Acc	U		U	WS,GC,P,WB,S	
Common Grackle	+	Cas.	A	A*	A	all habitats	(roost-250,00
Brown-headed Cowbird	+	R	VC	VC*	VC	all habitats	
Western Tanager		Acc				DF	(1 record)
Scarlet Tanager	+/S		C	FC*	C	DF,US	

(continued on following page)

FIGURE 54. Continued from previous page.

Species	Value codes	W	S	X	F	Habitats	Notes
Cardinal	+	A	A	A*	A	all habitats	
Rose-breasted Grosbeak	+		C	C*	C	DF,DW,DS,US	
Indigo Bunting	+/S		C	VC*	C	DF,DW,DS,US	
Dickcissel	Bl	Acc				feeder (JT)	
Evening Grosbeak	+W	R-U	R		R	O,feeders	
Purple Finch	+W	R-U	FC	Cas	C	DF,US,feeders	(may occ. nest)
House Finch	+	FC	FC	FC*	FC	US,feeders	
Pine Grosbeak	+W	R-FC				DF (erratic)	
Common Redpoll	+W/S	R-VC				DS,DW,DF,US	(2 years since 1966)
Pine Siskin	+W/S	R-C	R-U	Cas?	R-U	all habitats	(probably nested)
Am. Goldfinch	+/S	C	VC	VC*	A	all habitats	
Red Crossbill	+	R-U	R?			O,PW	(may have nested)
White-winged Crossbill		Cas				O,PW	
Rufous-sided Towhee	+/S	R	VC	VC*	VC	DF,DW,DS,PW,US	
Savannah Sparrow			R	R*	R	F,WS	(may nest)
Grasshopper Sparrow	Bl		R	R*		F	(" ")
Vesper Sparrow	+/Bl/S		R		R	F,DS,WS	
Dark-eyed (Slate-colored) Junco	+W	A	A		A	all habitats	
Dark-eyed (Oregon) Junco		R				feeders,DS	
Tree Sparrow	+W/S	C	U		U	DS,F	
Chipping Sparrow	+/S	R	A	VC*	A	DF,W, etc.	
Clay-colored Sparrow					Acc	DS	(1 record)
Field Sparrow	+/S	U	A	A*	A	DS,PW,F	
White-crowned Sparrow		Cas	U		U	US,DS	
White-throated Sparrow	+W	A	A		A	DS,DW,DF,PW,US	
Fox Sparrow			U-R		U	DS,DF,DW	
Lincoln's Sparrow			R		U	WS,WB	
Swamp Sparrow	+W/S	R	U	?	U	WS,WB	
Song Sparrow	+/S	VC	A	A*	A	US,DS,F,S,WS,WB	
Snow Bunting	+W	Cas				O,F	
Brewster's Warbler			R	R		DS	

Total of 213 species recorded 1950-1979 (Dec.24). Thirty (30) year list of 213 species includes 2 locally extinct and 4 hypothetical species plus 7 species that stopped showing up after the development of Campbell's pond area. The list includes one race (Oregon Junco) and 4 "vagrants" (Western Tanager, Clay-colored Sparrow, "Oregon" Junco, Dickcissel). There are approxamately 197 species that are still likely to occur in Fox Chapel and about 82 breeding species.

Other species rumored to be present: (<u>i.e</u>. could occur)

Yellow-throated Warbler
Short-billed Marsh Wren
Black-crowned Night Heron
Red-breasted Merganser
Semipalmated Sandpiper
Upland Sandpiper
Short-billed Dowitcher
Common Tern
Black Tern

FIGURE 55. Mammals of Fox Chapel

The following list of mammals was compiled by R. Friday from personal observations and hypothetical distributions of species abstracted from known ranges of the species. The list was compiled in December 1979 and is intended to be a current inventory ommitting locally extinct species. C.W. Bier reviewed the list and added observations. Mammals of Pennsylvania published by The Pennsylvania Game Commission was used as an additional reference for ranges and habitat information.

Species (common name)--Scientific Name	Habitats	Notes
* Opossum Didelphis marsupialis virginiana	V, esp. MH,OH	needs forest
Masked Shrew Sorex cinereus	MH,OH,MS	
Smoky Shrew Sorex fumeus	MH	
Rock Shrew Sorex dispar	MH	local status unknown
* Short-tailed Shrew Blarina brevicauda	V	
Least Shrew Cryptotis parva	F	
* Hairy-tailed Mole Parascalops breweri	V	common
* Star-nosed Mole Condylura cristata	wet soil, near streams	
*[1] Little Brown Bat Myotis lucifugus	V	summer resident
* Eastern Cottontail Rabbit Sylvilagus floridanus	US,F	brushy areas
* Eastern Chipmunk Tamias striatus	US,MH,OH	near seed producing tre
* Woodchuck Marmota morax	F,US	
* Grey Squirrel Sciurus carolinensis	US,OH,MH	needs large seed producing trees
* Fox Squirrel Sciurus niger	V	requires open areas with scattered trees
* Red Squirrel Tamiasciurus hudsonicus	C	requires conifers
* Flying Squirrel Glaucomys sp.	US,MH,OH,MS	needs a nesting cavity (probably eastern species Glaucomys volans)
* Deer Mouse Peromyscus maniculatus	US,V	
* White-footed Mouse Peromyscus leucopus	V	
* Meadow Vole Microtus pennsylvanicus	F,US	
Pine Vole Pitymys pinetorum	V	
* Muskrat Ondatra zibethicus	Streams and Ponds	
* Norway Rat Rattus norvegicus	US	
* House Mouse Mus musculus	US	
* Meadow Jumping Mouse Zapus hudsonius	F	
* Woodland Jumping Mouse Napaeozapus insignis	MH,OH	

(continued on following page)

FIGURE 55. Continued from previous page.

Species (common name)--Scientific Name	Habitats	Notes
* Red Fox *Vulpes fulva*	V	needs broken forest
* Gray Fox *Urocyon cinereoargenteus*	MH,OH,MS	
* Raccoon *Procyon lotor*	V, esp. MH,OH	needs a cavity for nesting and winter den
Ermine (Short-tailed Weasel) *Mustela erminea*	V, ?	
Least Weasel *Mustela rixosa*	?	
Long-tailed Weasel *Mustela frenata*	V	
Mink *Mustela vison*	V	near water
* Skunk *Mephitis mephitis*	V	
* White-tailed Deer *Odocoileus virginianus*	V	

1. Other bats migrate through the Fox Chapel Area and some species may spend summers. Species other than the Little Brown Bat have not been identified and their distributions are unknown.

* indicates that the species has been captured or positively identified in the Borough. Other species listed are expected to be present in Fox Chapel but have not been seen.

Habitat symbols used

MH . . . Mixed Hardwood Forest

OH . . . Oak-Hickory Forest

MS . . . Mixed Successional Forest

V . . . Variable habitats

F . . . Fields

C . . . Conifers

US . . . Urban Savanah

FIGURE 56. Reptiles and Amphibians of Fox Chapel

The following list is an inventory of species that have been found in Fox Chapel Borough. Population densities and trends have not been studied and the status of most species is unknown. Habitat distruction for housing developments has contributed to the recent decline of many species.

I thank John Colowit for providing most of information on amphibians in the borough. C.W. Bier reviewed the list and contributed notes on snakes from his records.

R. Friday

February 1980

Species (Common Name) - Scientific Name

Snapping Turtle <u>Chelydra serpentina</u>

Spotted Turtle <u>Clemmys guttata</u>

Wood Turtle <u>Clemmys insculpta</u>

Eastern Box Turtle <u>Terrapene carolina carolina</u>

Midland Painted Turtle <u>Chrysemys picta marginata</u>

Northern Water Snake <u>Natrix sipedon sipedon</u>

Queen Snake <u>Natrix septemvittata</u>

Eastern Garter Snake <u>Thamnophis sirtalis sirtalis</u>

Northern Ringneck Snake <u>Diadophis punctatus edwardsi</u>

Northern Black Racer <u>Coluber constrictor constrictor</u>

Smooth Green Snake <u>Opheodrys vernalis</u>

Black Rat Snake <u>Elaphe obsoleta obsoleta</u>

Eastern Milk Snake <u>Lampropeltis triangulum triangulum</u>

Timber Rattlesnake <u>Crotalus horridus horridus</u> locally extinct ?

Spotted Salamander <u>Ambystoma maculatum</u>

Red-Spotted Newt <u>Notophthalmus viridescens viridescens</u>

Northern Dusky Salamander <u>Desmognathus fuscus fuscus</u>

Mountain Dusky Salamander <u>Desmognathus ochrophaeus</u>

Red-Backed Salamander <u>Plethodon cinereus cinereus</u>

Slimy Salamander <u>Plethodon glutinosus glutinosus</u>

Spring Salamander <u>Gyrinophilus porphyriticus</u>

Northern Red Salamander <u>Pseudotriton ruber ruber</u>

Northern Two-Lined Salamander <u>Eurycea bislineata bislineata</u>

Long-Tailed Salamander <u>Eurycea longicauda longicauda</u>

(continued on following page)

FIGURE 56. Continued from previous page.

Species (Common Name) - Scientific Name

American Toad *Bufo americanus* *

Fowler's Toad *Bufo woodhousei fowleri* *

Spring Peeper *Hyla crucifer*

Western Chorus Frog *Pseudacris triseriata triseriata* **

Mountain Chorus Frog *Pseudacris brachyphona* **

Green Frog *Rana clamitans melanota*

Wood Frog *Rana sylvatica*

Northern Leopard Frog *Rana pipiens*

Pickerel Frog *Rana palustris*

* These toads interbreed and resulting hybrids have characteristics of both parents.

** These frogs have not been captured in the borough but have been heard at Salamander Park.

Site Code	Site Name	Map Sheet Number	Locally Rare Species	Comments
FCBF	Beechwood Farms	2		many habitats
FCCBL	Campbell's Lake	3	escaped iris	
FCD	Delafield Road	14		
FCFWD	Fox Wood Drive	6	Trailing Arbutus	
FCOC	Old Abandoned Cemetry	3		
FCOMR	Old Mill Road	5		
FCPC	Poplar Drive Cemetery	9		
FCPS	Pump Station	14		
FCRO	Rockingham North	14		described by Ferguson (1979)
FCSAL	Salamander Park	14		
FCSC	Stoney Camp Park	9, 10		
FCTTN	Trillium Trail North	9		
FCTTS	Trillium Trail South	9		
FCTTW	Trillium Trail West	9		
O'HGY	Guyasuta Reservation	9, 13		
TA	(Two Trailing Arbutus Locations)	13	Trailing Arbutus	two sections; three habitats in lower section
UH	Unique Hemlock Stand	6		Pure Hemlock

FIGURE 57. Fox Chapel's unique stands. All except UH are inventoried on Chris Metelmann's computer printout of species observations, where they are indexed by the"site codes" listed here.

the loss of wet soils and water bodies, since they are relatively immobile. Most mammals are adaptable and can survive in modified habitats; but large mammals need large ranges, and can become locally extinct when their habitats are reduced in size and surrounded by conflicting land uses.

Unique stands are particular areas within one or more contiguous communities that are remarkable for their degree of diversity, productivity, rareness, or other qualities. Fox Chapel's unique stands are listed in Figure 57, and mapped. Fox Chapel has two types of unique stands. Firstly, Chris Metelmann and his SRAWA vegetation team have identified 16 sites that contain mixtures of plants that are diverse and unique enough to be worth repeated visits by interested persons such as the members of the Western Pennsylvania Botanical Society. These characteristics are over and above those of the overall community type in which they are located. Metelmann has maintained a computer data bank of species observations in these sites, cross-indexed by species and location. Copies of printouts are available from Metelmann or through SRAWA; the inventory is not reprinted here due to its size, continuous updating, and technical coding. Metelmann's large botanical photographic slide collection supplements the data bank, and is similarly cross-indexed. These 16 unique stands are mostly local variants of the mesic, mature mixed hardwood community type, but also include some xeric or immature sites of escaped or unique species. They were identified by word-of-mouth reputation among residents, garden clubs, and experts such as the Western Pennsylvania Conservancy staff; and about four years of casual observation and intense investigation. The selection process was informal, but it was long and intense. The mapped boundaries of these sites are very approximate; the actual boundaries must be mapped in the field when a land use action is proposed. The second type of unique stands was discovered by Rupert Friday in the course of mapping the Borough's vegetation types. It is a pure stand of hemlock, being a local variant of the mixed hardwood community. Such stands are regionally rare, and create an evergreen, needle-carpeted environment that is unlike any other in the region. For both types of communities their distinction is of the overall habitat, and not of individual species within them. Hence, if a unique stand is to be preserved, it must be preserved as a regenerating stand (discussed below), not as a group of individual trees.

The biotic characteristics of projected land uses are summarized in Figure 58. They consist of abiotic cover, maintained urban savanna, recreational activities in the surrounding biota, enclosure of water bodies, and flows of water pollutants.

In the future, the construction areas of suburban developments will be superimposed on the current communities of the site. Pre-existing terrestrial communities will be removed by clearing, grading and the installation of abiotic covers, and converted to urban savanna by landscape maintenance and a generally new physical environment which causes species changes among all plant and animal life. Aquatic communities will be removed by grading and by culverts which shut off light and replace the bottom structure. Biota outside the construction area will be converted to successionally younger subcommunities by the increased light, and reduced in natural regeneration by construction and recreational traffic and pollutant flow. The stability of any community during such environmental changes is low: a critical proportion of the area of every community in or near the construction area is removed or converted. By definition, suburban development does not take place inside preexisting communities; although particular designs may preserve individual trees or thin bands of land, suburban development is an intense land use change which removes or converts all communities in and near its site. Nor can a natural community be established in or near a development site after construction is completed: because of the light, traffic, and uncontrollable residential maintenance, the entire would-be community would be one big "edge" (see below), if not an informally maintained urban savanna, and would never be a regenerating community. In summary, all of Fox Chapel's communities are uniformly unstable during suburban development. Preservation of regenerating communities within construction areas is impossible.

Individual trees within a construction area may be preserved by technology discussed by Zion (1968). To that technology may be added the maintenance of soil moisture levels by dispersing stormwater recharge facilities in local sites throughout a construction area, as opposed to central collection and recharge.

To be certain that communities outside a construction area are preserved, we must first be certain that construction operations will in fact be limited to a defined construction area. Hence we define construction area boundary: a closed line within which all construction operations, including grading, trenching, storage, foot traffic and equipment traffic are strictly contained. In practice such a boundary must be physical, strong and clearly visible. Where diversions or collectors for the control of erosion, sedimentation or stormwater are necessary at the outer edge of construction, such channels make suitable construction area boundaries (see "Hydrosphere"). Where such channels are not necessary (where the construction edge is exactly perpendicular to the topographic contours or where the up-drainage watershed is very small), the boundary must be maintained in some other form such as snow fences or flagged wires.

In order for a protected community to regenerate successfully, the community must be able to control its own internal environment and be subject to minimal future maintenance extending from adjacent areas. Hence we define a regenerating stand as a completely undisturbed terrestrial area, subject to no maintenance, at least 100 feet wide in any direction. It must be surrounded by a completely undisturbed buffer strip with canopy height and density the same as the stand (Figure 52), subject to no maintenance, an additional 20 feet wide all around the regenerating stand. This gives a total minimum width of stand plus buffer of 140 feet in any direction. However, where the existing stand plus buffer strip is less than 140 feet in width (such as some unique stands), the required total width is that of the existing stand plus buffer (if any).

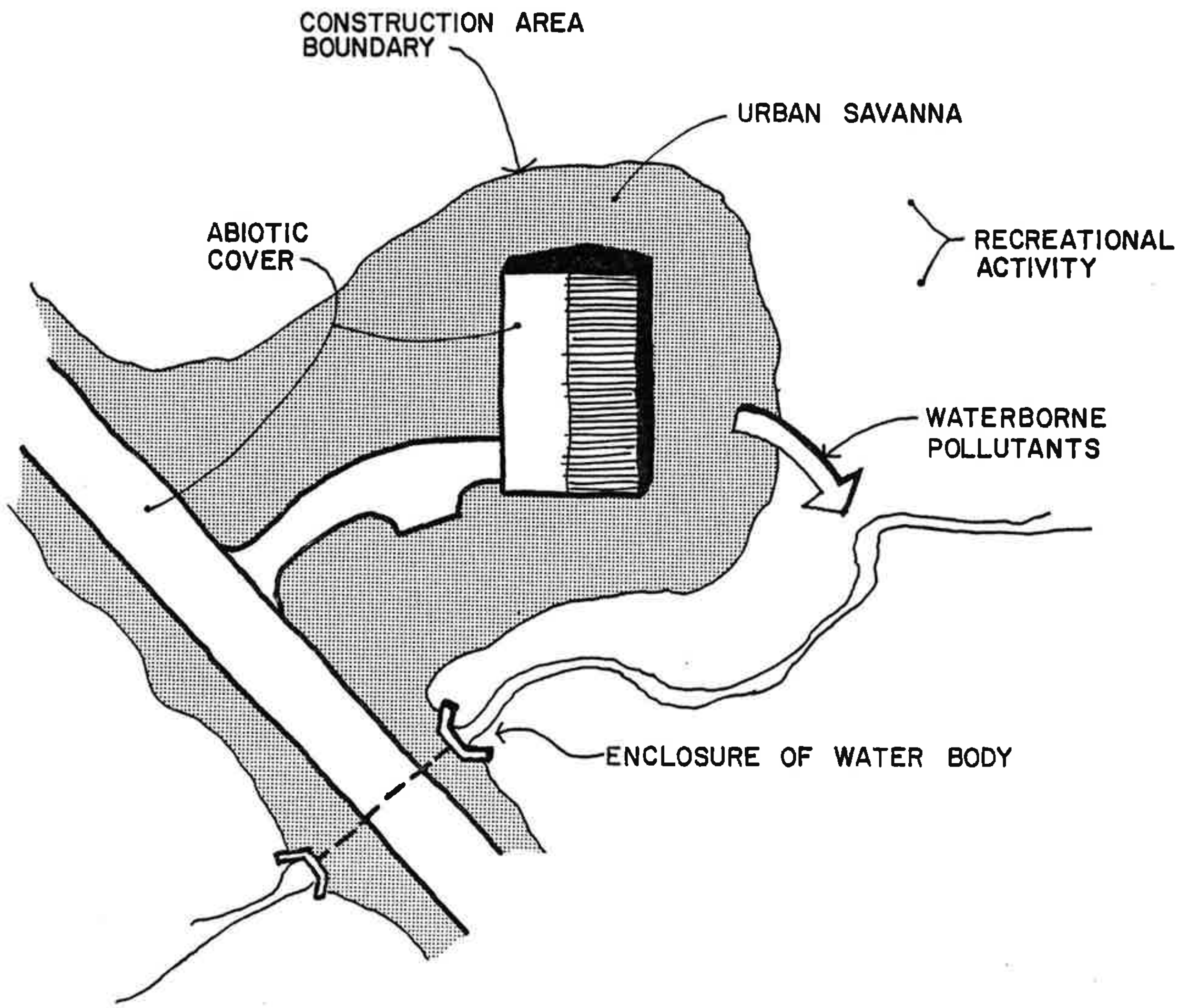


FIGURE 58. Some biotic characteristics of suburban land uses.

We define a regenerating stream as any point on a stream of which the lowland is completely undisturbed and subject to no maintenance for at least 20 feet both upstream and downstream (giving a total length of 40 feet), and upstream of which there is no significant pollution source without an intervening pollution trap.

To assure that buffer and lowland strips function as intended and that regenerating communities are thereby preserved, the nearest edge of any construction area boundary must be at least five feet away from the drip line (farthest branch spread) of any tree that is considered part of a buffer area or protected lowland, in addition to meeting buffer or lowland width requirements. Tree wells and walls are one way to move a boundary around a tree, into the would-be construction area (Zion, 1968).

These technologies for preserving regenerating stands and regenerating streams outside construction areas are summarized in Figure 59.

Disturbed areas may be counted as future regenerating stands or streams if they are reconstructed and reforested in such a way that they will succeed naturally toward community types having the desired characteristics, and they meet the appropriate buffer (or lowland) and maintenance requirements. Some of the species and methods for doing this are suggested by Brainerd (1973); Griswold, Winters, Swain, and Mullin (1973); and Schiechtl (1980).

The Borough's existing ecology is a patchwork of communities, stands, covers and individual trees reflecting physical endowments and successive farming development, suburban development and natural succession. The patchwork of existing biota was mapped by Rupert Friday using a combination of stereo orthophotographs (Squaw Run Area Watershed Association, April 1977), topographic map (Squaw Run Area Watershed Association, 1977) and extensive field observation of diagnostic species and characteristics.

In addition to the characteristics and functions of individual ecologic units discussed above, the geographic combinations of different units create edges and overall animal populations.

Edges ~~are~~ the zones of transition between communities (Ricklefs, 1976). On the vegetation map, edges are represented by pen lines where two community types meet. In reality an edge has a width, in which the two communities blend into each other. This width varies from a few feet (such as between an old field and the mowed lawn of an urban savanna) to about twenty feet (such as between a climax forest and an old field to the south of the forest). Within this width species from both types of community are intermingled: young trees grow out into open areas, and shrubs, vines and light-loving trees take advantage of the light near the edges of forests. Hence edges combine some characteristics of both communities, but their great diversity adds some biotic and physical characteristics that are unique to edges.

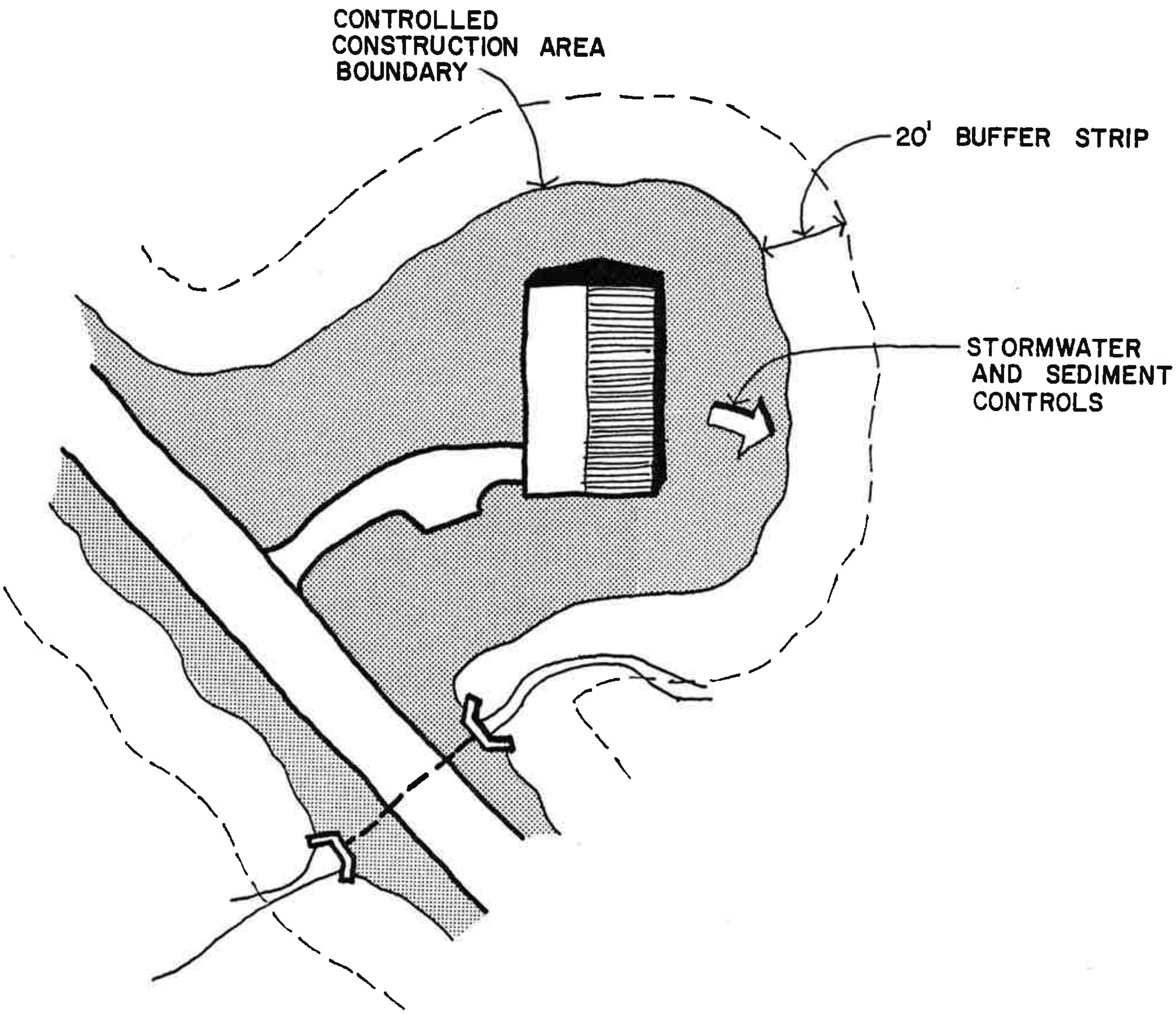


FIGURE 59. Some technologies for preserving regenerating stands outside a given construction area.

3. Desired Outcomes

The foregoing information has prepared us to specify a set of concrete, measurable desired outcomes in the form:

Outcome = f(Land, Land Use).

These outcomes are derived from the "ideals" stated in "Fox Chapel's Natural Resource Problem", specifically for the ecological aspects of the problem. The relationships of these outcomes to other desired outcomes will be specified, and resulting courses of action selected, under "Conclusions."

In the following equations indicators such as site index are used as surrogates for productivity, biomass, and other ecosystem characteristics. The results of further research may allow the future expression of such quantitative concepts in real units.

For any land area containing a set of unique stands:

$$\Delta A_u = \frac{RA_u \cdot post}{A_u \ pre}$$

where:

ΔA_u = ratio of area of unique stands in the land area after development to that before development. Desired outcome: maximize A_u.

R = the application of technology for preserving regenerating stands to the area $A_{u\ post}$. R is either 1 (yes) or 0 (no).

$A_{u\ post}$ = area of unique stands in the land area after development, to which R is applied.

$A_{u\ pre}$ = area of unique stands in the land area before development.

For any land area containing a set of site index classes:

$$\Delta F = \frac{\Sigma_{post} [(SI)\ AR]}{\Sigma_{pre} [(SI)\ A]}$$

where:

ΔF = ratio of potential future productivity, diversity and rare species presense in the land area as a whole after development to that before development. Desired outcome: maximize F.

Σ_{post} = sum of the applications of the following product to all site index areas on the land area after development.

Σ_{pre} = sum of the applications of the following product to all site index classes on the land area before development.

SI = site index of the area A.

A = size of the area having site index SI.

R = the application of the technology for preserving regenerating stands to the area A. R is either 1 (yes) or 0 (no).

For any land area covered by a set of current terrestrial community and cover types:

$$\Delta D = \frac{\Sigma_{post}\ (D_C A_C R)}{\Sigma_{pre}\ (D_C A_C)}$$

where:

ΔD = ratio of diversity (number of species present in the land area) in the land area as a whole after development to that before development. Desired outcome: maximize ΔD.

Σ_{post} = sum of the applications of the following product to each of the community or cover type on the land area after development.

Σ_{pre} = sum of the applications of the following product to each of the community or cover type on the land area before development.

D_C = diversity of the community or cover type having area A_C.

A_C = area of the community or cover type having diversity D_C.

R = application of the technology for preserving regenerating stands to the area A_C. R is either 1 (yes) or 0 (no).

For any land area covered by a set of current terrestrial community and cover types:

$$\Delta P = \frac{\Sigma_{post}(P_C A_C)}{\Sigma_{pre}(P_C A_C)}$$

where:

ΔP = ratio of productivity of the land area as a whole (biomass per time) after development to that before development. Desired outcome: maximize ΔP.

Σ_{post} = sum of the applications of the following product to each community or cover type on the land area after development.

Σ_{pre} = sum of the applications of the following product to each community or cover type on the land area before development.

P_C = productivity of the community or cover type having area A_C (all communities within 20 feet of construction area boundaries are counted as urban savanna).

A_C = area of the community or cover type having productivity P_C.

For any land area:

$$\Delta M_{strm} = \frac{RL_{M\ strm\ post}}{L_{M\ strm\ pre}}$$

where:

ΔM_{strm} = the ratio of mature stream length after development to that before development. Desired outcome: maximize ΔM_{strm}.

R = the application of the technology for preserving regenerating streams to the stream length $L_{M\ strm\ post}$.

$L_{M\ strm\ post}$ = length of mature stream in the land area after development, to which R is applied.

$L_{M\ strm\ pre}$ = length of mature stream in the land area before development.

In calculating $L_{M\ strm\ post}$, any stream length to which R is applied may be counted as mature stream, no matter whether the upstream reach is mature. On polluted streams R must include a pollutant trap at the uppermost end of $L_{M\ strm\ post}$. The trap may be a pond that is dredged when needed, with dredge spoil being disposed updrainage of the pond.

For any given land area covered with a set of current terrestrial community and cover types.

$$\Delta M_{MAX} = \frac{RM_{MAX\ post}}{M_{MAX\ pre}}$$

where:

ΔM_{MAX} = ratio of maturity of the most mature community or cover type in the land area after development, to that before development. Desired outcome: maximize ΔM_{MAX}.

R = the application of the technology for preserving regenerating stands to the community or cover type having maturity $M_{MAX\ post}$. R is either 1 (yes) or 0 (no).

$M_{MAX\ post}$ = maturity of the most mature community or cover type in the land area after development.

$M_{MAX\ pre}$ = maturity of the most mature community or cover type in the land area before development.

For any land area containing one or more unique trees:

$$\Delta U = \frac{TU_{post}}{U_{pre}}$$

where:

ΔU = ratio of number of unique trees in the land area after development to that before development. Desired outcome: maximize ΔU.

T = application of the technology for preserving individual trees or regnerating stands to the number of unique trees U_{post}. T is either 1 (yes) or 0 (no).

U_{post} = number of unique trees in the land area during and after development, to which T is applied.

U_{pre} = number of unique trees in the land area before development.

Implementation of this objective is practical only on Borough-owned land, not through land use ordinances.

AESTHETICS

1. Land

Researchers may never find a way to measure beauty directly. However, measurable variables with which scenery is correlated may be inventoried. Such quantification of scenery is dependent on breaking down a gestalt scene into attributes that are both relevant and measurable, and finding the logical and mathematical relationships that make those attributes relevant (Dunne and Leopold, 1978, ch. 22; Iverson, 1975).

An area of land within a relatively homogeneous physiographic region has a composite "character type" (Stone, 1978) as a result of repeated patterns of topography, hydrology, geology, ecology, climate and land use. Fox Chapel's character type is, like that of the rest of the "Pittsburgh Plateaus" region, one of forests, streams and slopes. It is enclosed and detailed, almost never panoramic or focal. It is visually stable (Iverson, 1975) due to the visual variety of highly regenerative vegetation. It has characteristics of "form", "texture", "color" and "line" (Stone, 1978 and Iverson, 1975) listed in Figure 60.

Within the character type, individual scenes may be differentiated and evaluated by contrast with the character type (Stone, 1978). The contrasting variables shown in Figure 61 have been accepted as evaluative variables in many visual resource assessments in other regions (Dunne and Leopold, 1978, ch. 22; Zube, Brush and Fabos, 1975, part III); they are slightly paraphrased here in order to be more conclusively measurable and to contrast more directly with the Pittsburgh Plateau's character type. They are correlated with other variables for mappability. The importance of each variable may be tested locally by interviewing, under controlled conditions, sampled persons who are shown scenes or pictures of scenes and decomposing their reactions (Dunne and Leopold, 1978, ch. 22); this Plan has not done this due to its limited budget. Instead, this Plan relies on the acceptance of these terms in previous studies, and informal confirming statements by Borough residents, officials and visitors.

In general, the "contrast" variables in Figure 61 presume that a landscape is more spectacular when it is more big, rugged, active and wild (Dunne and Leopold, 1978, ch. 22). Such scenes are rare in the Pittsburgh Plateaus, and exist in and contrast with a matrix of infinitely many local scenes more typical of the region.

The visible horizontal widths of water and rock are "ΔH" 's measured from any edge of the material to the nearest opposite edge. This is measured without relation to any particular observation point because in Fox Chapel the ΔH's are always small enough to be potentially visible in one view from some position. Large water dimensions

Variable	Near View: Natural	Near View: Modified	Distant View: Natural	Distant View: Modified
Form	Absent, except micro-landforms	Dominant: structures	Dominant: hills	Dominant: hills, forest masses
Texture	Dominant: forest floor	Dominant: lawns	Dominant: forest vegetation	Dominant: forests, lawn
Color	Present: gray, green, brown, white	Dominant: natural colors plus structures	Present: gray, green, white	Dominant: natural colors plus structures
Line	Dominant: tree trunks, surface water edges	Dominant: natural line plus edges of roads, paths, fences	Present: hill silhouette, horizon	Dominant: natural line plus edges of roads, paths, fences, clearings

FIGURE 60. Visual attributes of the Pittsburgh Plateaus character type under different conditions of distance and preexisting naturalness of appearance, for use in measuring contrast between a proposed use and its environment. Natural views have little variety (few "dominant" attributes) and are therefore difficult to match. All types of lines may be variously geometric, curved or irregular.

Variable	Pittsburgh Plateaus Character Type	Contrast with Character Type	Source Map	Mapped Variable with High Aesthetic Quality
Ground Material	Silt Loam, Forest Litter	Water, Rock	1	pond, stream, waterfall, cliff
Average Horizontal Water Width (ΔH)	Small	Large	1	pond, stream
Average Horiztonal Rock Width (ΔH)	Small	Large	1	cliff
Average Water Gradient (G)	Low	High	1	waterfall
Average Rock Gradient (G)	Low	High	1	waterfall, cliff
Vegetation Uniqueness	Low	High	2	unique stand, unique tree
Vegetation Height (ΔV)	Variable, Modified	Large, Natural	2	high, dense canopy

FIGURE 61. Relevant variables in Fox Chapel's natural scenery. ΔV, ΔH and G are defined in Figure 67.

tend to occur on ponds and on streams with large base flows. Large rock dimensions tend to occur on exposed bedrock and on rock bodies fallen out of exposed bedrock due to undercutting streams. The visible gradients are "G"'s measured from the lowest visible point on the body of material to the highest visible point on the same cross-section through the body of material; they may be approximated without relation to any particular observation point by measuring them over relatively short homogeneous reaches of material. Water with a high G is a waterfall; rock with a high G is a cliff.

Uniqueness and height of preexisting vegetation are functions of vegetation type. Uniqueness is judged qualitatively, relative to the Pittsburgh Plateaus' character type. Height is a "ΔV" measured from the ground surface to the average highest point of vegetation.

Each component of scenery listed in Figure 61 may change over time. An individual storm lasting a few minutes, or a weather system lasting several weeks, may change visible distance. Between day and night, light, and therefore visible distance, can vary drastically. A combination of climatic and vegetative changes from season to season changes many scenic components. Climatic variation, vegetative succession, and ground weathering over many years may change all scenic components. Over any unit of time the climatic controls are subject to their probabilities of occurrence.

2. Land Use

The internal arrangements of land uses have visual and symbolic attributes (their "internal harmony") such as those of Fox Chapel's barns, springhouses, steeples and courtyards. The assessment of internal aesthetic attributes is still in its infancy (Stone, 1978). They are not considered here because they are not part of Fox Chapel's natural resources problem. However, it may be mentioned that the aesthetics of artifacts is a traditional study of architecture and landscape architecture. Hubbard and Kimball's (1971) treatise on the subject is still respected. Some alternative types of arrangements for Fox Chapel's expected land uses were listed by House and Home (1973) and Tunnard and Pushkarev (1963). The arrangement of land uses may influence the location, direction, focus, and rate of viewing, and type of viewer (degree of concern about aesthetics) of any internal or external scene.

Land uses may interact with the surrounding landscape (their "external harmony") by their effects on the operational variables listed in Figure 61. Any visible component of land uses may interact with these variables in some way. Techniques for making the visual properties of land uses similar to those of their environments were suggested by Griswold, Winters, Swain and Mullin (1973) and U. S. Forest Service (1975 and 1977).

With grading, land uses may modify visual access to water and rock. The visible ΔH and G of water may be modified with ponds, pond outlets and aquaducts. The visible ΔH and G of rock may be modified where stable rock masses are found in cuts (U.S. Forest Service, 1973).

The uniqueness and height of vegetation may be modified by manipulating the environment in which natural succession occurs. The time to reach a successional stage may be modified by the relationship between land uses and the composition and environment of the prospective stage.

For any extraordinarily disruptive land use not anticipated in this Plan, the visual contrasts between the proposed use and its environment may be estimated by the rapidly developing techniques briefly introduced by Stone (1978) and Iverson (1975). These techniques assess the land use's "form, "texture", "color" and "line" relative to those of the environment. Figure 60 provides a base for any such evaluation.

3. Desired Outcome

The foregoing information has prepared us to specify a set of concrete, measurable desired outcomes in the form:

$$\text{Outcome} = f(\text{Land, Land Use})$$

These outcomes are derived from the "ideals" stated in "Fox Chapel's Natural Resource Problem", specifically for the aesthetic aspects of the problem. The relationship of these outcomes to other desired outcomes will be specified, and resulting courses of action selected, under "Conclusions."

For any land area containing any visually accessible length of <u>streams</u>:

$$\Delta L_{strm} = \frac{RL_{strm\ post}}{L_{strm\ pre}}$$

where:

ΔL_{strm} = ratio of length of visually accessible <u>stream</u> in the land area after development to that before development. Desired outcome: maximize ΔL_{strm} (up to 1.0).

R = the application of the technology for preserving regenerating <u>streams</u> to the <u>stream</u> length $L_{strm\ post}$. R is either 1 (yes) or o (no).

$L_{strm\ post}$ = length of visually accessible stream in the land area after development, to which R is applied.

$L_{strm\ pre}$ = length of visually accessible stream in the land area before development.

For any land area containing a set of ponds and wetlands:

$$\Delta A_p = \frac{RA_{p\ post}}{A_{p\ pre}}$$

where:

ΔA_p = ratio of total area of ponds and wetlands in the land area after development to that before development. Desired outcome: maximize ΔA_p.

R = the application of the technology for preserving regenerating streams to the area $A_{p\ post}$. R is either 1 (yes) or 0 (no).

$A_{p\ post}$ = total area of ponds and wetlands in the land area after development.

$A_{p\ pre}$ = total area of ponds and wetlands in the land area before development.

For any land area containing a set of waterfalls:

$$\Delta W = \frac{RW_{post}}{W_{pre}}$$

where:

ΔW = ratio of number of visually accessible waterfalls in the land area after development to that before development. Desired outcome: maximize ΔW.

R = the application of the technology for preserving regenerating streams to the number of waterfalls W_{post}. R is either 1 (yes) or 0 (no).

W_{post} = the number of visually accessible waterfalls in the land area after development, to which R is applied.

W_{pre} = the number of visually accessible waterfalls in the land area before development.

For any land area:

$$\Delta C = \frac{RC_R + NC_N}{C_{pre}}$$

where:

ΔC = ratio of total area of cliff in the land area after development to that before development. Desired outcome: maximize ΔC.

R = the application of the technology for preserving regenerating stands to the cliff area C_R.

C_R = area of C_{pre} remaining in the land area after development, to which R is applied.

N = the application of the technology for creating new cliff to the area C_N.

C_N = area of new cliff if the land area to which N is applied.

C_{pre} = area of a cliff in the land area before development.

For any land area containing a set of unique stands:

$$\Delta A_u = \frac{RA_{u\ post}}{A_{u\ pre}}$$

where all the variables have the same meaning as in the same equation on page 119. Desired outcome: maximize ΔA_u.

For any land area:

$$\Delta H = \frac{TH_T + NH_N}{H_{pre}}$$

where:

ΔH = ratio of area of high and dense canopy in the land area after development to that before development. Desired outcome: maximize ΔH.

T = application of the technology for preserving regenerating stands or individual trees to the canopy area H_T.

H_T = area of H_{pre} remaining after development to which T is applied.

N = application of the technology for creating new high and dense canopy to the area H_N.

H_N = area of new high and dense canopy, to which N is applied.

H_{pre} = area of high and dense canopy in the land area before development.

LITHOSPHERE

1. Topography and Drainage

Introduction

Fox Chapel Borough is a hilly area with local relief on the order of a few hundred feet. The lowest point in the Borough is located where Squaw Run enters Squaw Valley Park in O'Hara Township at an elevation just below 770 feet. The highest point in the Borough is the hilltop in The Forest plan east of Shadow Ridge Road adjacent to the Harmar Township boundary line at elevation 1,304 feet. Thus, the total relief within the Borough is 535 feet. There are several other high areas in the northern part of Fox Chapel having elevations above 1,200 feet. One is a hill north of Old Timber Trail, also adjacent to Harmar Township; another is a hill between Fairview Road and Foxhurst Drive on which an old cemetery is located, and a third is just north of Fairview Manor. An extensive high-standing area between 1,200 and 1,250 feet lies in the corner of Fox Chapel bounded by Fox Chapel Road and West Chapel Ridge Road. This high area also extends north and south of East Chapel Ridge Road and includes the site where once stood the original chapel for which the Borough is named. The terrain along Dorseyville Road is high. Sites along this road above elevation 1,200 feet occur at Mayflower Drive and in the vicinity of Beechwood Farms.

The topography of Fox Chapel is depicted by 5-foot contours on a 1977 base map at a scale of 1 inch to 800 feet. (See Plate 1). Where contours are closely spaced on the map, slopes are steep. Where contours are spread, slopes are gentle. In general the steepest slopes of more than 25% grade occur along the valley walls of Squaw Run and its major tributaries, Stoney Camp Run, the upper part of Glade Run (in The Forest), and along an unnamed tributary whose source is near Dorseyville Road. The latter stream flows in the valley between Millview Drive and Hallsborough Drive and enters Squaw Run at Old Mill Road. Steep slopes also occur on the valley walls of a stream that runs parallel to Hunt Road from Riding Trail Lane to the Fox Chapel Racquet Club. Two smaller valleys with steep slopes are one paralleling Edgewood Road and terminating at Delafield Road and Eton Drive (O'Hara Township), and another that heads at West Waldheim Road and extends to Delafield Road and Shady Lane. A broad valley whose slopes are notably subdued is that of lower Glade Run where the Fox Chapel Golf Club course is located. This is a wide ancient valley that was once used by the Allegheny River thousands of years ago as it made a long loop around the high ground now occupied by Shadyside Academy and the Crofton area of O'Hara Township. After this broad valley was abandoned when the Allegheny took a new course, namely the one it now follows, Glade Run "took over" the abandoned valley as an oversize valley for a relatively small stream. This is discussed in more detail on page 144.

Squaw Run Drainage

The principal drainage lines of Fox Chapel Borough are shown in Map 1. This map also shows ponds, wetlands (swampy areas), waterfalls, and the location of culverts through which the streams flow. The major stream system of the Borough is Squaw Run and its tributaries. The headwaters of Squaw Run are in Indiana Township. The stream emerges from a culvert on the south side of Fox Chapel Road and flows in a general southerly course through the Borough into O'Hara Township and to the Allegheny River. There is a major ponding of the stream in its upper reaches at Campbell Lake, a lake contained by an earthfill dam about 20 feet high. The lake is 1,000 feet long and 260 feet wide at its widest place near the dam. The water level in the lake is at elevation 1,036 feet. A smaller ponding is present on the floodplain of Squaw Run 700 feet downstream from the site where Old Mill Road crosses it. The edge of this pond is just 50 feet away from (west) Squaw Run itself. The pond is 150 feet long and 60 feet wide, and is at a water elevation of 919 feet. A third pond is also located on the floodplain 700 feet downstream from the crossing of Squaw Run Road East on Pittsburgh Field Club property. This pond is fed by a small tributary of Squaw Run from the northeast, a tributary whose source is on the Field Club golf course. Overflow from the pond is to the west into Squaw Run through a 60-foot long concrete sluiceway. The water elevation of this pond is 862 feet.

The only natural ponding of water along Squaw Run occurs in Salamander Park just upstream from the Fox Chapel Road crossing. At that site there is a partly silted-in remnant of Squaw Run which at one time flowed along a course that hugged the steep north valley wall. When the stream changed its course at some unknown time in the geologic past, a narrow, elongate pond about 400 feet long was preserved at the edge of the floodplain. The size of the pond was enlarged when a low dam was constructed. Water elevation in the pond is now about 795 feet.

Squaw Run drops a vertical distance of 300 feet in flowing from the northern boundary of Fox Chapel Borough at Fox Chapel Road to the southern boundary at Squaw Valley Park. This is a horizontal distance of 4.1 miles, making the average gradient of the stream in the Borough 72 feet-per-mile. It flows on a thin cover of alluvial sediments in most places, particularly where it crosses the outcrop areas of clay and shale members in the stratigraphic section, but locally where it crosses the outcrop of sandstone members, there is sandstone bedrock exposed along the stream bed. One such place is just downstream from Campbell Lake where the flaggy sandstone of the Birmingham member forms a "pavement" in the stream. In most valleys in the Borough streams that flow across the outcrop of the Birmingham member have waterfall (either single or double) at that site, but Squaw Run has eroded down its valley sufficiently through geologic time to have eliminated any waterfall that might have once been present in that valley. Outcrops of the Birmingham sandstone and shale do occur intermittently along the stream channel from the Fairview Road bridge down past the Millstone Drive plan and in places form a cliff-like slope, particularly on the west side. Another place where Squaw Run is flowing over sandstone "pavement" is in the vicinity of its junction with Glade Run. There the stream is flowing over the upper part of the Saltsburg Sandstone member. A few sites occur along Squaw Run between the Fox Chapel Racquet Club and Fox Chapel Road crossing where the sandstone below the Woods Run clay member is exposed in the stream bed. This is the Powers Run Sandstone.

A fairly prominent tributary valley of Squaw Run enters from the west at Fox Chapel Racquet Club. This tributary parallels Hunt Road from its head near Surrey Lane and crosses Hunt Road via a culvert at Riding Trail Lane. Upstream from there the valley is shallow and has gentle slopes, but downstream from Riding Trail Lane it becomes a deep, steep-walled valley containing a 25-foot waterfall where the stream flows over the Birmingham sandstone-shale member. There has been considerable slumping of soil and rock along the steep valley walls, some of which endangers Hunt Road itself.

This Hunt Road tributary is joined by another tributary from the south whose headwaters are west of the Guyasuta Road-Grandview Drive North intersection. This tributary occurs in the valley between Longfellow Road and Marvelwood Place, and flows under Hunt Road some 300 feet from its junction with the Hunt Road tributary. Upstream 400 feet from the Hunt Road crossing is located one of two waterfalls in this stream. This is a washboard-type fall with about a 10-ffot drop; 200 feet upstream from it is located the upper, more precipitous waterfall having a drop of some 18 feet. Both of these waterfalls occur where the stream flows over the Birmingham sandstone-shale member. The valley is narrow and steep-sided from these two waterfalls downstream, but upstream it is broader, and has much less imposing slopes.

Another Squaw Run tributary runs parallel to Guyasuta Road. The source of this stream is near the intersection of Guyasuta Road and Longfellow Road. There is also a waterfall (about 12 feet high) in this stream where it flows over the Birmingham. The location of the waterfall is in the valley adjacent to the Guyasuta Road-Fieldview Lane intersection. Just at the foot of this waterfall, a mass of landslide debris from the slope on the Guyasuta Road side forms a constriction in the valley. This landslide, which occurred in the weak Schenley Redbeds, also affected Guyasuta Road to the extent of requiring repairs at the time of the slide. Downstream, this tributary is conducted under Squaw Run Road by means of a culvert. It enters Squaw Run 300 feet down from the Field Club road crossing near the upstream end of Salamander Park.

Several smaller tributary streams flow westerly into Squaw Run between Field Club Road and Squaw Valley Park (O'Hara Township). The largest of these enters Squaw Run on the opposite side of the road from Salamander Park. This stream has two main branches. The headwaters of the northern branch are near the Fox Chapel-O'Hara Township boundary at Springhouse Lane. There is a small pond in the stream's course on the upper side of North Drive. On the downstream side of North Drive this branch flows in a narrow, steep-sided valley for a few hundred feet as it crosses the Birmingham sandstone-shale outcrop. The valley broadens out into a swampy wetland on the upstream side of Hillcrest Road. This swamp was formed by the partial obstruction of the stream at the culvert under Hillcrest Road. The swampy area has been filled with sediment because at times of large discharge the culvert is not adequate to accommodate all the flow, the result being the deposition of sediment in the "backed up" water and the development of a swamp. On the lower side of Hillcrest Road, the stream forms a low cascade where it flows over the Saltsburg Sandstone. It joins the southern branch 400 feet below this cascade. The source of the southern branch is in RIDC Industrial Park adjacent to Kappa Drive. A private home straddles the stream on the upper side of Hillcrest Road. Both the north and south branches have eroded their valley down through the high-level alluvial deposits of the ancient Allegheny River. These unconsolidated silty deposits occur along Hillcrest Road above elevation 935 feet. Well-rounded sandstone boulders as much as 6 feet in long dimension eroded from the basal part of the alluvium can be seen along both of these branches below the 935 level, particularly where the two branches join to form a single larger stream. As the two branch streams eroded down through the alluvium they moved these boulders from their in-place position to downstream locations. Below the junction of the branches the valley broadens and becomes swampy near Fox Chapel Road. This swampy condition exists because of partial stream obstruction at the culvert under a private drive adjacent to Fox Chapel Road. Downstream from the culvert, the stream flows close to and parallel to Fox Chapel Road to join Squaw Run on the lower side of the bridge on Fox Chapel Road.

Another Squaw Run tributary enters the main stream adjacent to the intersection of Fox Chapel Road and the private drive described above. The source of this stream is near Fox Chapel Road and Springhouse Lane. From there it flows past the west end of Hawthorne Road to its junction with the above-described tributary. There is a small ponding of this stream on the property at 143 Fox Chapel Road. Upstream from the pond by 500 feet the stream flows over a cascade with about a 10-foot drop where it crosses the Saltsburg Sandstone. At that locality the valley is narrow and steep-sided, but above there nearer the source of the stream, the valley becomes shallow and has such gentle slopes where it crosses the high-level alluvial deposits of the old Allegheny River that it is hardly recognizable as a valley. There is an abundance of large, rounded sandstone boulders in the stream channel near the contact of these alluvial deposits and the red shale bedrock that overlies the Ames Limestone.

A Squaw Run tributary of special significance because of its geologic history is Glade Run. The lower part of Glade Run is using a valley that does not "belong to it," that is, a valley that was eroded by a much larger stream, in the distant geologic past (see Figure 62). That larger stream was the ancient Allegheny River which in pre-glacial times flowed in a long loop from the Powers Run area in O'Hara Township through the Fox Chapel High School-Yorkshire Drive area (O'Hara), the Fox Chapel Golf Club course, around the Shadyside Academy complex of buildings and athletic fields, through the Pittsburgh Field Club golf course, through the area that includes Field Club Road near Hickory Hill Road, Hawthorne Road, Hillcrest Road, Royston Road, and through RIDC Industrial Park to the present Allegheny Valley at Blawnox. This old valley was abandoned thousands of years ago when the Allegheny River cut off that large segment of its valley and straightened its course to its present one. Since abandoning this loop, the river has eroded downward more than 200 feet, and its tributary streams have eroded downward to keep pace. The floor of the high-level abandoned valley is covered with alluvial deposits having an original maximum thickness of about 75 feet. Erosion since the time the valley was abandoned has completely removed these ancient alluvial deposits in some places and has only partially removed them in others. Those that remain are shown on the geologic map (Plate 1) by means of the "Is" and "Ig" symbols. These alluvial sediments of the ancient valley are also shown in cross-section A-A' on Plate 3. The alluvium is of different texture in different places. In the RIDC area it consists of gravel with pea-size to marble-size texture. This is also true at the Veterans Hospital in Aspinwall and in adjacent parts of Fox Chapel in such places as South Pasadena Drive, Glenover Drive and the upper part of East Waldheim Road, The Maples, and Alpine Circle. Elsewhere in the main valley loop farther away from the present river the alluvium consists of finer-grained material of clayey and sandy-silt type. It is notable that a layer of large rounded boulders consisting almost entirely of sandstone and conglomeratic sandstone occurs at the bottom of these high-level alluvial deposits. The presence of these boulders is a good clue to identifying sites where the alluvium occurs. In stream beds they can be distinguished from other sandstone boulders on the basis of rounding. Those of the ancient alluvial deposits are well-rounded, whereas others from adjacent bedrock outcrops show more angularity. Some of these rounded sandstone boulders have a diameter of as much as 6 feet and many of them are in the 3 to 4-foot range. The greater roundness of the high-level alluvial boulders indicates that they have been transported over a longer distance but the history of their occurrence is not well understood. These deposits are further discussed

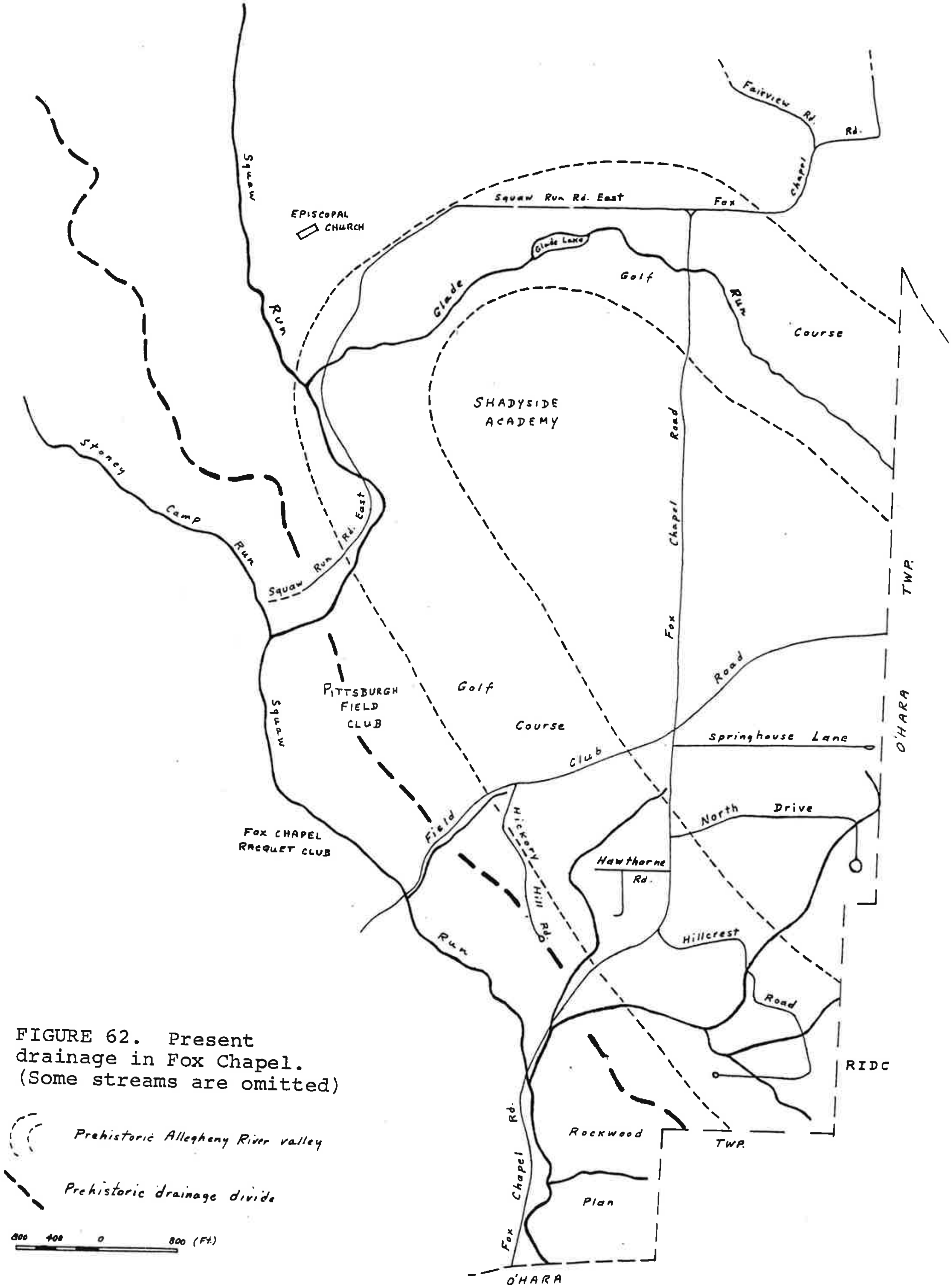


FIGURE 62. Present drainage in Fox Chapel. (Some streams are omitted)

under the topic of "Carmichaels Formation" on pages 180-181.

As stated above, lower Glade Run uses the valley of the ancient Allegheny River. From the Fox Chapel Road crossing of Glade Run down to the mouth at Squaw Run Road East where the stream joins Squaw Run, Glade Run has eroded below the level of the ancient alluvium (an abundance of rounded boulders from the basal part can be seen in the channel just west of Fox Chapel Road), but back away from the stream itself the alluvium is preserved as, for example, along much of Squaw Run Road East. From Fox Chapel Road upstream on the golf course, Glade Run flows on the ancient alluvium. The stream emerges from a 42-inch culvert located between the Fox Chapel-O'Hara Township boundary and the northwest corner of the High School football field. Between there and a culvert on the east side of Powers Run Road the stream flows underground in the Yorkshire Drive area of O'Hara Township.

The valley of Glade Run from Powers Run Road upstream through The Forest represents what was at one time a tributary valley to the pre-glacial Allegheny River. This part of the valley has a distinctly different character from that of lower Glade Run, being much narrower and with steeper valley slopes. Near Powers Run Road the valley bottom is swampy because the culvert at Powers Run Road causes the water to back up in times of large-volume flow. This has caused silt deposition and the development of the swampy valley bottom.

The headwaters of Glade Run are in Harmar Township just north of The Forest. From there it flows in a southerly course for more than a half mile, turns to a southwesterly course mostly in O'Hara Township for another three-fourths of a mile, and upon emerging from a culvert west of Yorkshire Drive, follows a long semicircular route in the abandoned valley of the ancient Allegheny River to its junction with Squaw Run. This peculiar course of flow is explained by the stream's geologic history as discussed earlier. The gradient of the stream in its two segments is quite different. The upper part of Glade Run from its source to Powers Run Road has a gradient of 145 feet per mile, whereas the lower part where it flows in the ancient valley has a gradient of only 50 feet per mile.

Glade Lake is a man-made lake in the course of the stream on the Fox Chapel Golf Club course. It is one of the larger impoundments in the Borough, being 600 feet long and nearly 200 feet wide. Water level in the lake is 917 feet.

One of the larger tributaries of Glade Run heads near Fox Chapel Road and West Chapel Ridge Road and flows southerly, parallel to Fox Chapel Road. The stream flows through a culvert at Foxhurst Drive, at Woodland Farms Road, at Greenwood Road, and Fox Chapel Road at Fairview Road. A small swampy valley-bottom area has developed upstream from Foxhurst Drive, and a ponding about 200 feet long exists on the floodplain of the stream 300 feet downstream from the Fox Chapel Road crossing at Fairview Road. The edge of this pond is only 25 feet from the stream. Water elevation is 957 feet. From the pond southward, the stream flows across the golf course in the previously described ancient Allegheny Valley to join Glade Run. From Woodland Farms Road down-valley for a half mile the stream flows across the outcrop of the Birmingham Sandstone-Shale member, but there is no waterfall as in many valleys at the same stratigraphic level. There are outcrops of sandstone here and there along the valley walls and in the stream channel, but in general the valley has a subdued appearance.

Another tributary rises at the head of the valley adjacent to Fairview Manor and flows southerly to enter Glade Run downstream from Glade Lake. Where this stream crosses the Birmingham Sandstone-Shale outcrop, a low waterfall with a 3 or 4-foot drop has developed near the top of the Birmingham and a washboard-type cascade of about 5-foot drop is present a few hundred feet downstream in the lower part of the Birmingham. Between the two sites a picturesque gorge-like valley is present. In its lower reaches above and below Squaw Run Road East this stream has cut its valley down through the high-level alluvial deposits and is flowing on bedrock near the level of the Ames Limestone.

Another segment of the Squaw Run drainage system is a stream that flows through the Pittsburgh Field Club golf course. The head of this stream is located just west of Fox Chapel Road between Catalpa Ridge Road and Pheasant Drive. It flows over the Birmingham member in its upper reaches, and from a locality west of the Fox Chapel Borough Building where the stream enters the golf course area it flows on the alluvial deposits of the old Allegheny River. It is underground part of the way before discharging into a series of four in-tandem ponds on the golf course property. All of these ponds are man-made impoundments of the stream. At about the level of the uppermost pond the stream has eroded its valley below the elevation of the high-level alluvium, and from there downstream flows first over the strata above and below the Ames Limestone. Below the fourth pond to the junction with Squaw Run it flows over the Saltsburg Sandstone. In the lower reaches of the stream there is an abundance of well-rounded sandstone boulders along the channel. These have been transported downstream from their outcrop position in the basal part of the high-level alluvium. Upstream from the junction of Squaw Run and Glade Run, there are several tributaries that flow from the west into Squaw Run. The longest of these enters at the Old Mill Road crossing. In its headwater area there are several branches, three of which have small ponds in them near Dorseyville Road. These branches join to form the main tributary stream near the Indiana Township boundary where that township has a southern projection into Fox Chapel. The easternmost of the branches flows in the valley west of Wilmar Drive. From the site where the main tributary begins, down the valley for a quarter mile, the stream flows over the Birmingham Sandstone-Shale. Within that stretch, there is a small waterfall (4 to 5-foot drop) and downstream from it there are exposures of sandstone and shale in the channel and along the valley walls. A prehistoric landslide originating in the Schenley Redbeds moved down to the valley bottom 800 feet downstream from the waterfall. This ancient landslide caused the stream to make a pronounced swing to the north. Where the stream flows from the Birmingham onto the underlying softer shale and claystone beds its valley becomes continuously broader down to its junction with Squaw Run. A minor tributary joins the stream from the west. Five hundred feet up this tributary from its mouth, there is a waterfall with a drop of 12 feet in the Birmingham Sandstone. At that site the tributary valley is narrow and steep-sided. Near the source, east of Millview Drive, the stream is impounded by an earth-fill dam at elevation 1,084. The pond is 200 feet long and 75 feet wide.

Another of the tributaries entering Squaw Run from the west flows in the valley that is crossed by Old Mill Road at Millview Drive. The head of this valley is located several hundred feet up from Old Mill Road, but the perennial stream in it is mostly confined to the part of the valley below Old Mill Road. This lower valley segment contains two waterfalls, an upper one of about 5-foot drop at the base of which are large moss-covered sandstone boulders, and a lower falls of 15-foot drop. Both of these occur in the Birmingham Sandstone. In the vicinity of the falls the valley walls are precipitous. Recurrent landsliding has taken place on the north wall adjacent to Old Mill Road, requiring periodic repair of the road. This landsliding occurs in the weak claystone of the Schenley Redbeds which lie between the Birmingham Sandstone and the Morgantown Sandstone. At this site, Old Mill Road is built on the weak claystone, and natural undercutting of the valley wall by the stream maintains a very steep slope on which the landsliding occurs. On the upper side of the Old Mill Road and just west of the Millview Drive intersection, there is a spring (and springhouse) at the contact of the Morgantown Sandstone and the Schenley Redbeds. This spring supplies water to a small pond immediately adjacent to the road. Another spring at this same geologic contact occurs a few hundred yards northeast of this site on the steep west slope of Squaw Run valley. This was at one time known as Silver Spring. Water from it was bottled and distributed in East Liberty for domestic drinking water. Now the spring water flows down the slope to the ditch on the west side of Old Mill Road and into Squaw Run at the Old Mill Road crossing.

A third tributary flowing from the west into Squaw Run rises in Indiana Township near the Fox Chapel Road-Dorseyville Road intersection. It flows east of Fairview Elementary School, under Shannon Drive via a culvert and under Fairview Road by the same means. There is a low waterfall (3-foot drop) where the stream crosses the Morgantown Sandstone near the intersection of Fairview Road and Flower Hill Road. A somewhat higher waterfall (5 to 6-foot drop) is present downstream where it flows over the upper part of Birmingham member. The latter site is 600 feet up from the junction with Squaw Run.

Still another western tributary rises near the end of Oak Knoll Road in Indiana Township and, in its lower reaches, flows parallel to Willow Run Road to join Squaw Run 500 feet upstream from Campbell Lake. This tributary stream flows through a culvert under Spring Forest Drive. Its gradient steepens somewhat as it flows for a distance of 200 feet across the Morgantown Sandstone just below Spring Forest Drive, then becomes more gentle below that as it crosses the Schenley Redbeds outcrop to its mouth. A similar tributary stream flows parallel to Fox Chapel Road to enter Squaw Run just downstream from the Walnut Ridge Drive intersection. The source of this stream is near the intersection of Highview Road and Fox Chapel Road. Near its mouth it flows through a culvert under a private road. The valley bottom for a few hundred feet upstream from the culvert is swampy and contains an abundance of cattails where there has been sedimentation from periodic backup of water at the culvert site.

Squaw Run has two eastern tributaries upstream from Campbell Lake. One drains the valley in which Dietrich Road is located. This valley has three branches, the northern one of which heads at Fox Chapel Road east of Shirl Drive. The middle branch heads south of the high ground where Fox Chapel Road makes a right angle turn at Guys Run Road, and the third (southern) branch heads west of the Methodist Church in the Chapel Oak Court area. The water from all the branches collects to form the main tributary 350 feet east of Old Mill Road where the stream flows through a culvert. Below Old Mill Road (west) the stream flows over the Morgantown Sandstone outcrop before entering Squaw Run. The valley bottom at the mouth is relatively broad because the stream has eroded into the weak claystone of the Schenley Redbeds that underlie the Morgantown Sandstone.

Another eastern tributary joins Squaw Run 200 feet up from Campbell Lake at Willow Run Road. The headwaters are in the area northwest of the intersection of West Chapel Ridge Road and Easton Road. There is a swampy valley bottom for 200 feet on the upper side of Old Mill Road where cattails grow in abundance. This is another example of a swampy area formed because of restricted flow through a culvert, this culvert being one of 18-inch diameter that conducts the stream under Old Mill Road. Just before entering Squaw Run the stream flows between Willow Run Road and a tennis court located 50 feet from the road.

A third tributary from the east is a somewhat lesser stream than those described above. It drains to Campbell Lake as an underground stream between Fairview Road and the lake. One of the two branches of this stream heads at a sharp bend in Fairview Road west of Fairview Manor and flows southwesterly; the other branch which is the larger of the two flows northerly from the high ground southeast of Campbell Lake. The two branches meet just south of the intersection of Old Mill Road and Fairview Road. There is a drainage problem on Fairview Road where the northern branch of this tributary is located because the road at the site of the sharp bend is built in the valley itself. Geologically this site lies at or near the contact between the permeable Connellsville Sandstone and the impermeable Clarksburg Redbeds that underlie it. Springs at this stratigraphic contact emit water onto the road, thereby causing the drainage problem.

Stoney Camp Run is a major tributary of Squaw Run. The headwaters of Stoney Camp Run are at Dorseyville Road where a western branch has its source south of Chapel Crest Terrace (O'Hara Township) and an eastern branch, considered the main branch, has its source close to Cross Keys Hotel. These branches join about 0.3 of a mile downstream to form a single stream that flows to its junction with Squaw Run near the intersection of Squaw Run Road and Squaw Run Road East. There is a small pond (100 x 30 feet) on the main branch where a private road crosses the stream. The ponding is caused by an earth fill on which the road is built. A culvert conducts the stream under this fill. The pond is now mostly silted-in and has a profusion of cattails growing in it. Its water level is at 1,149 feet. Down Stoney Camp Run, west of Staffordshire Place, the stream flows over a small outcrop of Morgantown Sandstone where there is a local steepening of the stream gradient. Downstream from there, beginning at the junction of a western tributary from the Crawford Lane area and extending down to Old Mill Road, there are several places where the Birmingham Sandstone is exposed in the stream bed, but no waterfall is present as in some other valleys.

A picturesque site in Stoney Camp Run valley is located just downstream from the Squaw Run Road bridge. There the black shale of the lower part of the Birmingham member is in contact with the underlying Duquesne Coal, a 1 to 2-inch layer immediately underlain by the Duquesne Claystone. The stream is riffled where it flows over the brittle, thin-bedded shale, and forms a small cascade as it flows from the more resistant shale onto the weaker claystone below. This stretch of the stream is particularly scenic when autumn leaves are falling into the stream and along its borders. A tributary entering Stoney Camp Run from the south, about a quarter mile down valley from the above-described site, contains a double waterfall where the stream flows over the Birmingham Sandstone. This is within Trillium Trail park. The lower fall is 10 feet high, the upper one 12 feet high. Upstream from there by a distance of 400 to 500 feet there is a pond of 175-by-75 feet dimensions formed by a concrete dam. Water level in this pond is at elevation 1,007 feet. Another tributary 1,000 feet north also has a double waterfall of the same magnitude on the Birmingham Sandstone. The stream in this tributary valley is not perennial, that is, it flows only in wet periods of the year.

Stoney Camp Run flows across the outcrop of the Ames Limestone about 400 feet upstream from the Trillium Trail parking lot on the south side of Squaw Run Road. The Ames is a 3-foot limestone bed containing a myriad of small fossil shells that attest to its marine origin. A large block of this limestone has been moved from its outcrop position to the Trillium Trail parking area on the north side of Squaw Run Road. Close inspection of this limestone block with a pocket magnifier reveals the details of the many fossilized shells that are about 300 million years old.

Prehistoric drainage changes have taken place in the Squaw Run, Stoney Camp Run, and Glade Run system. There is evidence in the terrain and in the drainage pattern that Stoney Camp Run and the lower part of Squaw Run were at one time a single stream that flowed on the west side of a drainage divide (ridge) parallel to the western segment of a long loop of prehistoric Allegheny River (see Figure 63). At the same time, the upper part of Squaw Run was just a tributary of the prehistoric Allegheny, joining it west of Shadyside Academy near the site where Glade Run now joins Squaw Run. It is postulated that in those days there were four short tributaries flowing westerly from the divide toward what is here referred to as "prehistoric Stoney Camp Run" (see Figure 63). On the east side of the divide, the ancient Allegheny River was flowing in a wide valley whose boundaries are plotted in Figure 62.

It is further postulated that the northernmost of the four tributaries eroded its valley headward (eastward) so as to intersect the old Allegheny valley which had probably already been abandoned by the river in favor of the new course that it now follows. This short tributary of prehistoric Stoney Camp Run, upon breaching the divide by headward erosion, was able to "capture" the drainage of upper Squaw Run, thereby establishing Squaw Run as we know it today. This explains why Squaw Run changes flow direction from southeasterly to southwesterly and back to southeasterly again in the stretch from the junction of Glade Run down to its junction with Stoney Camp Run, which is now a Squaw Run tributary. The two middle tributaries of the four that once flowed into prehistoric Stoney Camp Run have eroded their valleys well below the level of the ancient Allegheny valley, just as Squaw Run and the lower part of Glade Run have. This is why the old valley is difficult to detect in that segment of it. The "new" valleys that cut across it have altered the original shape to such an extent that its former presence must be verified by mapping remnants of alluvium laid down along a once-continuous valley bottom. This condition is shown in cross-section B-B' of Plate 1. West of Shadyside Academy, Squaw Run has eroded its valley well below the old valley floor, leaving remnants of the alluvium (mapped as "Is," Plate 3) on both the east and west sides of the existing valley. Geologic section A-A' (Plate 3) also shows where a Squaw Run tributary has cut its valley below the level of the old valley in the vicinity of Hillcrest Road.

The eastern part of the old valley, where Fox Chapel Golf Club course is located, is more easily identified both on the basis of its form and alluvial deposits. This remnant valley also extends through the Yorkshire Drive area and the High School and Junior High School athletic fields of O'Hara Township all the way to the present Allegheny valley in the vicinity of Powers Run Road. Powers Run itself is flowing on the old valley floor where it crosses under the road at the intersection of Field Club Road and Powers Run Road, but has cut deeply below the valley floor from the Crown Meadows development down to the stream's junction with the Allegheny River. Glade Run flows on the old valley floor through most of the Fox Chapel Golf Club course.

In Fox Chapel, as mentioned above, several tributaries of ancestral Stoney Camp Run have breached the divide that once separated the ancestral Allegheny valley. These tributaries have extended themselves headward to different extents. The one where Field Club Road is now located has eroded away completely the high-level alluvium of the old Allegheny valley in the vicinity of the intersection of Field Club Road and Hickory Hill Road and has cut down into the underlying bedrock. Another tributary along which part of Fox Chapel Road is built has also eroded away these alluvial deposits and "destroyed" the form of the ancient valley just west of Hawthorne Road and also at the junction of Hillcrest Road and Fox Chapel Road.

Still another tributary has accomplished even more extensive erosion. This is the tributary that now joins Squaw Run near the entrance to the new Rockwood Plan and extends easterly into three branches. One branch has its headwaters near the upper end of Springhouse Lane. It flows under North Drive and Hillcrest Road in a direction perpendicular to the trend of the old valley and has eroded its own valley completely through the high-level alluvial deposits down into the bedrock below. Another branch heads in RIDC Industrial Park and flows under Hillcrest Road. From Hillcrest Road downstream, this tributary has also deepened its valley below the level of the alluvial deposits. The third branch has its headwaters in the southeast corner of Fox Chapel adjacent to RIDC and also flows under Hillcrest Road near the end of that road. High-level alluvium has been removed along almost the entire length of this branch.

If all this erosion by these tributary streams had not occurred, one would still see the preserved shape of the old Allegheny valley from RIDC through the Hillcrest Road-Hawthorne Road-Field Club area. And if the segment of Squaw Run between the mouth of Glade Run and the junction with Stoney Camp Run had not eroded deeply into the terrain, the old valley would be identifiable on the basis of its form along that stretch of Squaw Run Road East from the Pittsburgh Field Club pond to Kakakitty Lane.

Guyasuta Run Drainage

The southwestern part of Fox Chapel is drained by upper Guyasuta Run and its tributaries. The headwaters of this stream consist of a western and an eastern branch. The western branch has its source in O'Hara Township near the intersection of Kittanning Pike and Dorseyville Road; the eastern branch has its source in Fox Chapel a few hundred yards south of the Dorseyville Road-Squaw Run Road intersection. These two branches join 500 feet upstream from Hunt Road. The west branch is straddled by a private home at Wedgewood Lane.

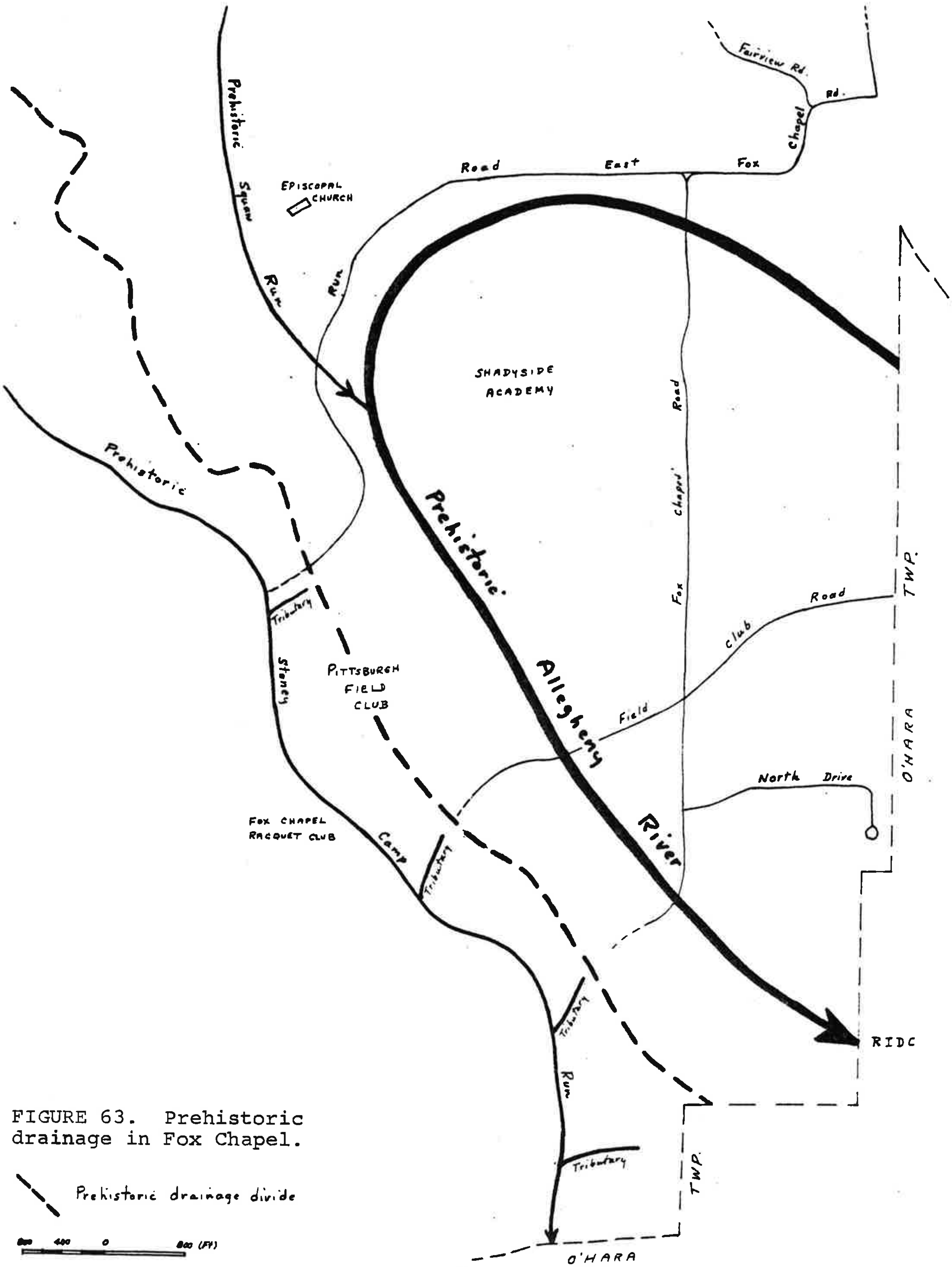


FIGURE 63. Prehistoric drainage in Fox Chapel.

Near the intersection of Wedgewood Lane and Woodbrook Drive this branch of the stream flows over the Morgantown Sandstone and forms a low waterfall about 4 feet high. The east branch passes through a culvert at Wedgewood Lane. Upstream from there for 1,500 feet or so the valley bottom is a swampy, wetland area created by the partial interruption of drainage by the culvert itself. A similar swampy valley bottom is present where a smaller tributary to the south flows through a culvert at Hunt Road and Wedgewood Lane.

Guyasuta Run valley is particularly scenic from Hunt Road down to a waterfall near the boundary of the Boy Scouts of America reservation in O'Hara Township. This location is west of the end of Wynnwood Drive. The valley is wooded and the stream flows along a winding course on the upper part of the thin-bedded Birmingham Sandstone-Shale. Approaching the waterfall, which is known as Darlington Falls or Washboard Falls (because the water cascades over the projecting edges of thin sandstone beds of the Birmingham member), there are cliffs along the valley sides ranging up to 20 feet in height.

Downstream from Washboard Falls by one-quarter mile an eastern tributary enters Guyasuta Run. The junction of these streams is in O'Hara Township, but most of the tributary valley occurs within Fox Chapel. A new housing area (The Pines) is being developed in the upper part of the valley and adjacent to it. What is probably the highest waterfall in Fox Chapel occurs where this tributary flows over the Birmingham Sandstone-Shale member. The waterfall is about 50 feet high. Here the entire thickness of the Birmingham member forms the waterfall, whereas in valleys where there is a double waterfall, harder zones in the upper and lower parts of the member cause two waterfalls to develop. Upstream from this 50-foot waterfall by 500 feet is another waterfall about 10 feet in height where the stream flows over the Morgantown Sandstone. The valley is narrow and its walls are steep from these waterfalls down to the junction with Guyasuta Run, but upstream from the upper falls to Berkshire Drive the valley broadens out and has gentle slopes in the area where The Pines development is located.

Direct Drainage to Allegheny River

There are a few small streams in the southern part of Fox Chapel that flow directly to the Allegheny River; that is, they are not tributaries of Squaw Run or Guyasuta Run. The largest of these rises in the valley at Westchester Drive and Buckingham Road, and flows from Fox Chapel into O'Hara Township where it is conducted underground beneath an extensive fill on which the River Oaks development is built. The upper part of this stream, the part in Fox Chapel, flows over the unexposed Schenley Redbeds and then cascades over the upper part of the Birmingham Sandstone in a narrow, steep-walled valley prior to entering a 48-inch culvert at Guyasuta Road adjacent to River Oaks.

Another stream, in the extreme southern part of the Borough, is in the valley where Shady Lane is located. The head of this stream is situated on the north side of West Waldheim Road and west of Pasadena Drive. Just south of West Waldheim Road it flows over the poorly exposed Morgantown Sandstone, and 500 feet downstream from there it has developed a waterfall where it flows over the Birmingham Sandstone. The valley walls are very steep along the outcrop of this sandstone member. There is also a waterfall and cliff-like slopes in a small tributary valley west of the intersection of West Waldheim Road and Warwick Place. The gradient of the main stream flattens out as it crosses the shale and claystone strata above and below the Ames Limestone near the end of Shady Lane, then steepens somewhat as it crosses the Saltsburg Sandstone. About 500 feet up-valley from Delafield Road the stream enters a culvert and flows underground.

Valley Drive is located in a steep-walled valley of semi-circular shape whose mouth is in the vicinity of Valley Drive, Rutledge Road, Shady Lane, and Delafield Road. There is no surface stream in this valley. However, there are three short tributaries whose headwaters are near West Waldheim Road. The westernmost tributary is in O'Hara Township; the others are in Fox Chapel. These tributaries have intermittent surface streams that flow into culverts on the upper side of Valley Drive. The tributaries flow over the Birmingham Sandstone in narrow, steep-sided valleys. The easternmost tributary has a waterfall with about a 10-foot drop. The middle one rises on the north side of West Waldheim Road where its course has been modified by grading and filling. This disruption of natural drainage may explain a drainage problem of excess water on adjacent 12th street in Aspinwall.

Another small stream has its source near the intersection of The Oaks and Riverview Terrace. It flows to a culvert that conducts it under the Route 28 Expressway. The channel of this stream contains abundant rounded sandstone boulders, some up to 4 feet in diameter, as well as gravel derived from the basal part of the high-level alluvial deposits of the Allegheny River. Where the stream flows over the Saltsburg Sandstone there are small exposures of the sandstone in and adjacent to the channel. Near the culvert the stream flows on the Woods Run Claystone.

Little Pine Creek Drainage

Three streams that are part of the Little Pine Creek drainage system have headwaters in Fox Chapel. One is a southern tributary of Harts Run on Beechwood Farms Nature Reserve in the northwest part of the Borough. The headwaters are near Dorseyville Road at the Beechwood headquarters. Dorseyville Road is on the divide between Little Pine Creek drainage and Squaw Run drainage. In flowing to Harts Run Road, the stream crosses the Morgantown Sandstone (which is inconspicuous at this locality), and the Birmingham Sandstone-Shale unit where there is a washboard-type cascade with a drop of about 10 feet. One of the hiking trails on the Reserve crosses the stream at the top of the cascade. Another stream, also on Beechwood Farms flows southwesterly toward the Chapel Crest Terrace area of O'Hara Township. The upper reaches of this valley are broad and gently sloped, but near the boundary of the reserve where the stream flows over the Birmingham there are two waterfalls, an upper and lower one. At the upper one the water falls over a vertical cliff with a 10-foot drop; the lower fall is a sloping washboard cascade with a drop of 15 feet. These two falls are separated by a distance of about 175 feet along the stream. Below the lower one the stream flows under an extension of Chapel Crest Terrace Road.

A third stream in the Little Pine Creek system rises in Fox Chapel at Poplar Drive near Pine Creek Cemetery and flows westerly into O'Hara Township to Little Pine Creek. Less than one-quarter mile of this stream's upper reaches are within Fox Chapel. Near the boundary with O'Hara there is a waterfall (7-foot drop) made by the outcropping Birmingham Sandstone. There is a similar waterfall in a branch stream just to the north, also near the municipal boundary. At the site of the waterfall the valley is narrow, but it broadens out downstream where the stream flows across the soft shale overlying the Ames Limestone.

Campbell Run Drainage

A few tributaries of Campbell Run have their headwaters in Fox Chapel. One of these has three branches east of Fox Chapel Road between Old Indian Trail Road and Chapel Ridge Road. These branches are intermittent streams that funnel their water into the main tributary, which about a quarter mile down from Fox Chapel Road in Harmar Township, is impounded at a water elevation of 994 feet. These branch streams flow over strata that lie between the Morgantown Sandstone and the Pittsburgh Coalbed. Another Campbell Run tributary rises at the head of the valley between Chapel Ridge Place and Chapel Ridge Court and enters its parent stream below the abovementioned impoundment. It has a waterfall where it crosses the Birmingham Sandstone 300 feet up from its mouth. The valley there is very steep-sided and narrow.

South of Chapel Ridge Road there is another tributary of Campbell Run. Its source is near the end of Quail Hill Road. The stream is fed by a spring at the contact of the Connellsville Sandstone and the underlying Clarksburg Redbeds. Down valley about 300 feet from the Fox Chapel-Harmar boundary there is a waterfall where the stream crosses the Birmingham Sandstone. Just upstream from the fall the valley gradient is low where the stream crosses the soft Schenley Redbeds. There has been slumping on the valley walls in that area, particularly on the north side.

Guys Run Drainage

The headwaters of two streams tributary to Guys Run occur in Fox Chapel in The Forest plan. Wise Hill Road follows one of these valleys, the head of which is bounded by Field Club Road, Wise Hill

Road, and Shadow Ridge Drive. On the south valley wall about 800 feet down the valley from Field Club Road, 20 feet of Connellsville Sandstone is exposed in a cut slope presumably made at the site of future housing. Down valley farther the stream crosses the Morgantown Sandstone and in the vicinity of the Harmar Township boundary flows over the Birmingham Sandstone. Another stream in the Shadow Ridge Drive area has its source in the valley head between Field Club Road and Shadow Ridge Drive, but flows mostly in O'Hara Township and Harmar Township. It has a southeasterly course that takes it under the Allegheny Valley Expressway and Freeport Road on its way to the Allegheny River.

2. Stratigraphy

Introduction

The stratigraphy of Fox Chapel Borough deals with the various rock layers that occur one on top of the other from the lowest or oldest one to the highest or youngest one. These are all sedimentary rock layers, most of them of bedrock type, but some of unconsolidated non-bedrock type are also present. The bedrock types include shale, sandstone, clay (or claystone), limestone, and coal in order of decreasing abundance. These are consolidated rocks that were deposited as layers of sediment some 300 million years ago and have become compact through time as they were weighted down by rocks deposited on top of them. Although they are all consolidated, some types such as claystone are relatively soft, whereas other types like sandstone are relatively hard. Commonly, the bedrock layers are not "pure," that is, sandstone is not all sandstone, shale is not all shale, etc. It is common to find sandstone that is partly shaly (shaly sandstone), shale that is partly sandy (sandy shale), and claystone that contains some limestone (limy or calcareous claystone). It is also true that a given layer of rock does not maintain constant composition laterally. In one place a sandstone layer or member may be composed of essentially all sandstone and in another place it may have thin layers of shale alternating (interbedded) with sandstone. So too does the thickness of the layers change from place to place, but there is an overall continuity to both the thickness and the composition (lithology) of the various rock layers that allows them to be traced throughout the Borough.

Overlying the bedrock are the alluvial deposits, or in other words, stream-laid deposits that are unconsolidated. Geologically speaking these are very young. They consist of clay, silt, sand, and gravel deposited in layers. Some of these deposits are classified as Recent alluvium, meaning that they were deposited by existing streams within the last few hundred years. Others are classified as Pleistocene high-level deposits. They were laid down during the Glacial Epoch (Pleistocene) in a now-abandoned valley of the Allegheny River about 200 feet above the level of the present river. These glacial-age deposits are thousands of years old, but since they have never been buried beneath any younger deposits, they are not yet consolidated.

The stratigraphic column (succession of rock layers) of the Borough is subdivided into various units. These units are, from the largest to the smallest: system, group, formation, and member. All the bedrock of Fox Chapel Borough is placed within the Pennsylvania System whereas Pleistocene and Recent alluvium are in the Quaternary System. (The time unit during which a system of rocks is deposited is known as a period). Reference to Plate 2 shows that several systems, from the Permian through the Tertiary, are missing in the Borough. This is because any rocks of those systems that may have been deposited here have long since been eroded away. There is represented a huge gap in time of almost 300 million years between the time of deposition of the youngest bedrock unit of the Borough and the time of deposition of the Pleistocene alluvium, but there are no such gaps represented among the bedrock layers themselves because they were deposited one after another in succession. The break between the bedrock layers and the alluvial layers is known as an unconformity, this particular kind being known more specifically as a disconformity. Rocks from the Mississippian System downward are present in the subsurface below Fox Chapel.

Plate 2 shows that the Pennsylvanian strata (rock layers) are subdivided into four groups: Pottsville, Allegheny, Conemaugh, and Monongahela. Only the Conemaugh and Monongahela Groups are represented in the surface rocks of Fox Chapel. It is the Conemaugh Group that contains practically all of the Borough strata. Only about 50 feet of Monongahela Group rocks are present, and these occur in just a few of the higher hilltop areas. In contrast, about 400 feet of Conemaugh strata are present in the Borough. Further subdivision breaks the Conemaugh down into the Glenshaw Formation and the Casselman Formation, and a still more detailed breakdown is into members, such as the Ames Limestone member, the Morgantown Sandstone member, the Clarksburg Redbeds member, etc. The various names applied to these stratigraphic units are derived from places where they were first studied and named. Thus, Conemaugh Group rocks are named for exposures along the Conemaugh River, Monongahela Group rocks for exposures along the Monongahela River, Casselman Formation rocks for the Casselman River in Somerset County, and Glenshaw rocks for the Glenshaw area of Pittsburgh. Other names such as Morgantown and Clarksburg are from those towns in West Virginia, whereas Schenley (of Schenley Redbeds) is for Schenley Park in Pittsburgh, Birmingham (of Birmingham Sandstone-Shale) for Pittsburgh's South Side which was once known as Birmingham, Ames (of Ames Limestone) for Ames Township in Athens County, Ohio, etc.

The subdivisions of the stratigraphic column in this study are not the conventional subdivisions used by most geologists. The subdivisions are selected on the basis of the susceptibility to landsliding of the rocks within them. Certain units are susceptible and others are not, as described later. This does not mean that the stratigraphic layers are not accurately depicted with respect to thickness, composition, and relative position to one another, but simply that boundaries between stratigraphic units are chosen so as to focus on slope stability. In general, the claystone and soft shale members which are more likely to produce slope instability are placed in separate stratigraphic units, and the sandstone and sandy shale members that tend to produce more stable slopes are placed in other units.

In Plate 2, a graphic representation of the stratigraphic section in Fox Chapel is presented. This shows bedrock strata as they would appear in a hole drilled from the top of a hill that contains the uppermost layer down through to the lowermost one. However, in actuality there is no one place where all these layers occur in a single hill. The total stratigraphic section was prepared from partial sections measured at different sites throughout the Borough, and then "pieced together" to establish the one shown in Plate 2. The uppermost layer represents the youngest bed that has escaped the erosion which removed beds that were once present above it. This occurs on a hilltop in The Forest. The lowermost one represents the oldest bedrock unit that has surface exposure in the Borough. This occurs where Squaw Run enters Squaw Valley Park in O'Hara Township.

The composition of the various bedrock units is represented in Plate 2 by graphic symbols as well as by word description. All but one member are also identified by letters, for example, "Cprb" for the Pittsburgh Redbeds. The upper case "C" stands for Conemaugh which is the group name of the stratigraphic unit to which the redbeds belong; the lower case "prb" stands for Pittsburgh Redbeds. Another example is "Mpc" for Pittsburgh Coalbed. The "M" is for Monongahela Group; the "pc" for Pittsburgh Coalbed. A third example is "A" for Ames Limestone. The single letter "A" is used to depict this one unit because it is so thin (2 to 3 feet) that a single line on the geologic map (Plate 1) represents it, whereas bands of various width represent other stratigraphic units that are thicker. The reason for mapping such a thin unit as the Ames is because it is an excellent "key bed," i.e., it is laterally persistent, easily recognized, and can be used as a stratigraphic reference in determining the identity of other less easily recognized units. It is also noted that the Ames Limestone is the unit that separates the Glenshaw Formation from the Casselman Formation of the Conemaugh Group, the top of the limestone being the boundary.

To understand the lateral extent of the various rock layers, one must visualize the area as it was when the sedimentary materials were being deposited. The hills and valleys we see today did not exist. Instead, there was an extensive delta plain in the Pittsburgh area, of which Fox Chapel was a part. Streams flowed westerly across this plain to the sea whose shoreline position changed with time. At one time a shallow sea covered the Fox Chapel area. This was when the Ames Limestone was being deposited. The Ames contains an abundance of fossil shells representing animals that lived in the salt water of the sea. Layer upon layer of different sedimentary material was deposited over an extensive area as time went on. At times sand was deposited. At other times clay, lime mud, and vegetal matter were deposited to provide for the later development of claystone and shale, limestone, and coal as the sediments were compacted under the weight of those deposited on top. An event that came much later, after this depositional interval had terminated, was the erosion of the already compacted sedimentary rocks. Erosion by streams cut valleys hundreds of feet deep, leaving high-standing remnants which are the existing hills and ridges. In other words, the streams have "etched" what was once a flattish plain into an area with relief of several hundred feet.

Exposure of the rock layers to the atmospheric elements causes the original rock materials to "weather," that is, there is change in composition and texture (grain size). The end product of this weathering process is soil which forms a veneer a few feet thick on the bedrock in most places. Where the soil has been removed, either by nature or by man, a rock "outcrop" or "exposure" occurs. The type of soil that forms at a given site is largely determined by the nature of the parent rock from which it forms. For example, sandstone bedrock produces sandy soil and claystone bedrock produced clayey soil. On a slope, soil is susceptible to downslope movement either as imperceptibly slow movement (soil creep) or as faster, perceptible movement (landsliding). There are several variables that determine the susceptibility to downslope movement as discussed later in the report.

Referring again to Plate 2, the high-level unconsolidated alluvial deposits are shown disconformably overlying bedrock members. The position of these alluvial deposits in the stratigraphic column is somewhat misleading. They are placed above the youngest bedrock because they are younger (much younger) than that. However, at no place in Fox Chapel do these deposits directly overlie the youngest bedrock layer. What they do overlie are various bedrock layers along the bottom of the ancient, now-abandoned Allegheny River valley. Stratigraphically these layers range from the Pittsburgh Redbeds (Cprb) up to the Birmingham Sandstone-Shale (Cb) as shown on the geologic map (Plate 1).

Also shown in Plate 2 are the Recent alluvial deposits in the uppermost part of the stratigraphic section. As stated above, their position in the section is misleading. They are positioned at the top because they are the youngest deposit of any in the Borough, but they do not lie directly on the high-level alluvium as one might infer. The Recent deposits are found along the floodplain of the larger streams of the Borough, and disconformably overlie a wide range of bedrock members from the lowest one, the Powers Run Sandstone (Cpr) in the lower reaches of Squaw Run valley to the Morgantown Sandstone (Cm) in the upper reaches of that valley.

The major characteristics of the various members of the stratigraphic column are discussed below.

Description of Stratigraphic Section and Areal Distribution of Its Members

In the following discussion the various members of the stratigraphic section in Fox Chapel are discussed in sequence, beginning at the bottom of the column and proceeding upward to the uppermost ones. Also described are the principal areas in which the members appear, plus other pertinent information that relates to these units. For the areal distribution of the stratigraphic units and a graphic representation of the stratigraphic column, the geologic map (Plate 1) should be consulted.

Powers Run Sandstone (Cpr)

The lowest stratigraphic unit having surface exposure in Fox Chapel is a sandstone for which there is no formal name in the geologic literature. An informal name is herein applied for convenience. The chosen name is Powers Run Sandstone because it is well exposed in a gorge-like ravine along lower Powers Run valley adjacent to the Camberwell Drive area of O'Hara Township. This sandstone is exposed in Fox Chapel in various places along the banks of Squaw Run from Squaw Valley Park upstream past Hunt Road to the bridge over Squaw Run. It disappears from surface exposure in the bed of Squaw Run between the Racquet Club and Squaw Run between the Racquet Club and Squaw Run Road East. Outcrops of it are seen at the intersection of Fox Chapel Road and Delafield Road, at Fox Chapel Road and Squaw Run Road, and on both valley walls of Squaw Run in the Salamander Park area. It is also exposed on the north bank, both upstream and downstream from Field Club Road. Between Field Club Road and Fox Chapel Road there are several places where this sandstone has been quarried on a small scale in the past, probably for use in retaining walls, bridge and barn foundations, and similar purposes. This sandstone member is also exposed at the entrance to the new Rockwood plan where a cut was made in it to provide fill for a retention pond and to establish a suitable grade for the access road.

The Powers Run Sandstone is at least 45 feet thick in Fox Chapel. The base of it is not exposed anywhere in the Borough so its total thickness is not known, but it is probably not much thicker than 45 feet. Squaw Run is flowing essentially at the level of the bottom of this unit or at about the level of the Pine Creek Limestone which underlies it where the stream leaves Fox Chapel and enters O'Hara Township. The sandstone ranges from thin-bedded to thick-bedded, but generally is thin to medium-bedded. The thicker bedding is more prominent in the upper part. The sandstone layers are commonly interbedded with shaly sandstone and sandy shale. Layers of sandstone tend to be flaggy or platy which was a desirable characteristic from the standpoint of quarrying the stone for use in construction.

Powers Run Sandstone occurs on stable slopes in general, although in places where it crops out along the bank of Squaw Run, it has been undercut near stream level to form an overhang that produces rockfalls. The slope profile changes markedly at the top of the sandstone unit.

Steep slopes are formed by the sandstone itself, but the soft Woods Run Clay that overlies it forms more gentle slopes so that benching is noted at this level. This benching is particularly well developed above McCahill Memorial Field at Guyasuta Road.

Woods Run Claystone (Cwr)

The Woods Run Claystone immediately overlies the Powers Run Sandstone. The claystone bed averages 15 feet in thickness and has a range of 12 to 18 feet. The claystone is silty in most places and of red, reddish brown, and gray color. Commonly nodules of impure limestone are dispersed through the lower part. This unit occurs from 50 to 75 feet above the level of Squaw Run on either side of Fox Chapel Road, but is only about 25 to 50 feet above it along Squaw Run Road between Fox Chapel Road and Hunt Road.

The areal distribution of the unit is shown on the geologic map as "Cwr." It extends along Squaw Run valley upstream to about the position of a pond on Pittsburgh Field Club property where it goes below drainage level. Outcrops of this unit are not common but about halfway between this pond and the junction of Squaw Run and Stoney Camp Run in the steep bank on the south side of Squaw Run there is a small outcrop of the clay just above stream level. Overlying the claystone, there is a 5-inch coal seam exposed. This is the Bakerstown Coal. The Woods Run Claystone is also exposed in the bed of the small stream that flows past the Fox Chapel Racquet Club, and in the road cut at the entrance to the Rockwood development. Another place where the Woods Run Claystone crops out is in the bed of two tributary streams 500 feet down from Hillcrest Road near the junction of the two streams. As noted above, there is generally a gentle slope or benching in the topography along the outcrop area of the Woods Run Clay. Woodcliff Road is built on this bench as is part of Squaw Run Road near its intersection with Fox Chapel Road. Also, a private road to houses at 335 and 337 Fox Chapel Road is built on the bench.

Slopes where the Woods Run Clay occur are susceptible to landsliding. There has been landsliding in this claystone, or in the colluvial soil developed from the weathering of it, on the slope 300 feet north of the intersection of Fox Chapel Road and Delafield Road. There is also evidence of soil creep on this same slope around the bend toward Delafield Road and Eton Drive. A small landslide occurred in this unit in the road cut at the entrance to the Rockwood plan shortly after the cut was made in the winter of 1980. Colluvial soil at the level of the claystone also occurs on the north slope of the valley where this plan is being developed. Another locality where there has been landsliding in the unit is on the steep east-facing slope between Fox Chapel Road and the end of Hickory Hill Road.

Bakerstown Coal (Cwr)

The Bakerstown Coal is just a few inches thick and is of no economic value. It is included in the "Cwr" mapping unit along with the Woods Run Claystone. There is some question as to the identity of this coal. In some parts of Allegheny County, the Bakerstown Coal lies between the Upper and Lower Saltsburg Sandstone, but in Fox Chapel this coal bed lies immediately on what is interpreted to be the Woods Run Claystone. In some places, there is a Woods Run Limestone (marine) overlying the clay bed of the same name, but this limestone is not recognized in Fox Chapel.

One place where the Bakerstown Coal can be seen in Fox Chapel is on the bank of Squaw Run as described above. The coal is 5 inches thick there. It is probable that the coal bed is laterally discontinuous, that is, it was not deposited as a continuous bed.

Saltsburg Sandstone (Csa)

In this study the unit mapped as Saltsburg Sandstone includes the interval from the top of the Woods Run Claystone (or Bakerstown Coal where present) up to the bottom of the Pittsburgh Redbeds. The unit is in a somewhat shaly facies in Fox Chapel, that is, it consists of interbedded layers of sandstone, sandy shale, and shaly sandstone. At other places such as its type locality at Saltsburg (Indiana County) it is a thick-bedded to massive sandstone throughout. The outcrop area of the Saltsburg is shown on the geologic map by the symbol "Csa."

The thickness of the Saltsburg Sandstone in Fox Chapel is in the 40 to 45-foot range. The percentage of shale is higher in the lower half; the percentage of sandstone is higher in the upper half. The sandstone layers in general are 3 to 5 inches thick, fairly uniformly bedded, and commonly flaggy. In general the unit is thin-bedded to medium-bedded.

There is an outcrop area of the Saltsburg along the valley walls of Squaw Run, generally on the lower third of the slope, from Delafield Road to Hunt Road. Up-valley from Hunt Road, the sandstone occurs near the bottom of the valley slopes, and disappears below the valley bottom a few hundred feet up from the junction with Glade Run. There is also an extension of this sandstone into the mouth of Stoney Camp Run valley for about a quarter mile where it is at the level of Squaw Run Road. The Saltsburg Sandstone outcrop area extends into the valley that Hillcrest Road crosses, and into one adjacent to the end of Hawthorne Road. It occurs also in smaller tributary valleys on both sides of Squaw Run. In the southern extremity of the Borough, the Saltsburg is present in the valley leading from The Oaks down to Route 28, and in the Shady Lane valley although it is not at all conspicuous there. On Fox Chapel Road on the hill just south of Hillcrest Road there is a road cut on the east side that exposes the shaly lower part of the Saltsburg.

About 25 feet of the upper part of the Saltsburg Sandstone is exposed in the cliff along Squaw Run between the Fox Chapel Road crossing and a pond on Pittsburgh Field Club property. In that same area there is a 20-foot-high cliff that exposes it on the west side of Squaw Run Road East. It is this segment of Squaw Run valley that has been eroded down below the level of the bottom of the previously described ancient Allegheny River valley.

The Saltsburg Sandstone forms a cascade of a few feet drop in the stream near the end of Hawthorne Road and also in the stream west of 135 Hillcrest Road. The east valley wall at the latter site shows a 15 to 20-foot cliff where this sandstone crops out. There have been rockfalls at the cliff.

The profile of valley slopes steepens at the position of the Saltsburg Sandstone. Below the level of the sandstone the profile is more gentle on the Woods Run Claystone and above the sandstone the profile flattens out at the level of the Pittsburgh Redbeds. Slope stability is generally good where this sandstone occurs, but there are rockfalls at a few places where steep, undercut slopes have been formed in it by stream erosion.

Pittsburgh Redbeds (Cprb), Ames Limestone (A), and Ames-to-Birmingham Interval (Cd)

The Pittsburgh Redbeds lie between the Saltsburg Sandstone and the Ames Limestone. In some places there is a thin coal bed a few inches thick between the redbeds and the limestone, but this has not been observed in Fox Chapel. Various names have been applied to the unit here called the Pittsburgh Redbeds. The unit is also known in the literature as "Pittsburgh red shale" and "Pittsburgh reds," but neither of these is preferred. The unit is composed of unbedded claystone which is somewhat silty to sandy. It has closely spaced, randomly oriented fractures. The claystone readily slakes upon wetting, that is, it crumbles into smaller pieces. Although red coloration is dominant in the unit it also occurs as gray claystone or as both red and gray types. It is notoriously prone to landsliding where colluvial soil has formed from it, as it has in many places. Of all the stratigraphic units in Allegheny County, it is probably the one in which more landsliding has occurred than in any other. This unit together with the overlying Ames Limestone plus the shaly and clayey beds that extend up to the base of the Birmingham member make a total interval of 55 to 60 feet that is landslide-prone. These units are discussed together because in effect they comprise a single weak-rock zone between two stronger rock units; the Saltsburg Sandstone below and the Birmingham Sandstone Shale above.

The Ames Limestone is a marine, fossiliferous limestone of about 3 feet in thickness. It is remarkably persistent, not only in Fox Chapel, but elsewhere in southwestern Pennsylvania, and is a good key bed. The top of the Ames marks the boundary between the Glenshaw

Formation and the Casselman Formation of the Conemaugh Group. It is an impure limestone of no economic value because of its impurity and its thinness. The Ames itself is fairly strong rock, but because it is such a thin unit within a thicker sequence of weak claystone and shale, it is subject to downslope movement by landsliding and creep along with the claystone and shale. Where the Ames crops out on cliff-like slopes, it develops an overhang because the claystone of the Pittsburgh Redbeds below weathers faster than the Ames itself. This condition produces rockfalls when the overhanging limestone breaks loose.

Overlying the Ames is a 20-foot interval of soft shale for which there is no stratigraphic name. This shale is commonly red in color, but may also be gray or a combination of red and gray. It differs from the Pittsburgh Redbeds claystone in that it is bedded, therefore it is shale and not claystone. However, it is not the hard, silty to sandy shale that is relatively strong. Instead it is a fairly soft shale with minor silt content.

Overlying this unnamed shale is a thin, inconspicuous sandstone unit on the order of 3 to 5 feet thick. This represents the Grafton Sandstone which is much more prominent in other areas like Grafton of Taylor County, West Virginia, for which it is named. This sandstone is in turn overlain by clay containing nodular limestone in its lower part. The thickness of the clay and included limestone nodules is 6 to 7 feet. Together these lithologies form a unit that represents the Duquesne Claystone. In some places the limestone forms a distinct bed below the claystone, but in Fox Chapel it is in the form of nodules a few inches in diameter scattered through the lower part of the claystone. Although the thin Duquesne Coal overlies the claystone in some places, it is not present in Fox Chapel. The claystone is soft and plastic, and typically weathers faster than the overlying shale of the Birmingham member to produce overhangs and rockfalls.

On the geologic map (Plate 1) the Pittsburgh Redbeds are mapped as "Cprb," the Ames as a single line "A," and the unnamed shale above the Ames together with the Grafton Sandstone and Duquesne Claystone collectively as "Cd." The areal distribution of all these units from the Pittsburgh Redbeds up through the Duquesne Claystone is essentially the same. Generally speaking, they occur in outcrop only in the southern half of the Borough. The units are exposed along Squaw Run valley in the middle to lower third of the slopes as far up as Glade Run. The Ames Limestone is at stream level where Old Mill Road crosses Squaw Run, and the Duquesne Claystone is in that position just downstream from the Millstone Drive plan. Up-valley from there all of these units are below drainage. Outcrops are not common because these beds weather relatively fast and have formed colluvial soil in many places. There have been numerous landslides in this stratigraphic interval, both in prehistoric and in historic times. Of all the units in the stratigraphic column in Fox Chapel, it is this one that is most landslide-prone, and in which soil creep is most common.

Along the outcrop area of these units it is common to find hummocky terrain, trees with tilted and curved trunks, poor drainage, landslide scars both old and new, and open swaths in wooded areas, all of which attest to previous and/or current movements of the soil. Also, there are numerous places where material excavated from this zone has been used as fill without adequate drainage, and landsliding within the fill has occurred.

These beds are also found in tributary valleys of Squaw Run. Delafield Road follows one of these short tributaries. The effect of soil creep is readily seen on the north side of Delafield Road in the vicinity of Woodshire Drive. Another tributary extending north from Eton Drive to Edgewood Road shows evidence of landsliding and soil creep in this interval.

On the east side of Squaw Run, the Pittsburgh Redbeds and associated overlying units extend into tributary valleys, but the upper part of the total unit, that is the Duquesne Claystone, and part of the shale above the Ames has been eroded away by the ancient Allegheny River which deposited alluvium in the position of these units. In one tributary valley, in which Field Club Road is located, that ancient valley floor was eroded below the Ames down into the Pittsburgh Redbeds in the vicinity of Hickory Hill Road. In Glade Run valley, the Pittsburgh Redbeds extend up to Glade Lake where they go below drainage. In that same area the high-level alluvial deposits ("Is") are in contact with the shale above the Ames Limestone. Although the redbeds do not commonly crop out, they are exposed in a gully and adjacent stream bank on the south side of Glade Run, north of Shadyside Academy. Squaw Run valley from Glade Run to Old Mill Road has a gentle gradient and fairly wide valley bottom because along that stretch the stream flows over the relatively weak Pittsburgh Redbeds.

Two western tributaries of Squaw Run are Stoney Camp Run and the stream that parallels Hunt Road. In Stoney Camp valley the Pittsburgh Redbeds to Duquesne Claystone interval occurs on the lower slopes in the Trillium Trail area and goes below drainage on the downstream side of the Squaw Run Road crossing at Old Mill Road. The wooded slopes of this area are a good example of the topographic effects of soil creep and slumping in this stratigraphic zone. There is a fairly well-developed bench on these weak beds between the Saltsburg Sandstone and Birmingham member. On the bench the terrain is generally hummocky because of soil movement. Many trees are tilted downslope and have curved trunks, indicating soil creep.

In the vicinity of Trillium Trail, the outcrop position of the Ames Limestone is about 10 feet above the level of Squaw Run Road. The limestone also crops out in the bed of the stream 200 feet upstream from the upper of two bridges at that site. A large block of Ames Limestone has been placed at the edge of the Trillium Trail parking area on the north side of Squaw Run Road one quarter to a half mile down valley. Close inspection of that block shows an abundance of marine fossil shells that furnish evidence that Fox Chapel was inundated by a shallow sea when that limestone was being deposited.

The Duquesne Claystone does not crop out in many places because it readily forms soil by weathering. However, it is well exposed in the bed of Squaw Run for a distance of about 400 feet beginning at a low waterfall in the stream just below the bridge on Squaw Run Road at the Old Mill Road intersection. The waterfall, only a few feet in height, occurs at the contact of the softer Duquesne Claystone member and the overlying, harder Birmingham member.

In Hunt Road valley the Pittsburgh Redbeds, Duquesne Claystone and associated beds occur on the lower part of very steep slopes some 300 to 400 yards up from Fox Chapel Racquet Club. These beds also extend for 175 yards into the tributary valley that Hunt Road crosses. The Ames Limestone crops out inconspicuously in the bank of Hunt Road just down from this valley crossing at elevation 904. In the main valley, beside Hunt Road, there has been slumping in the weak beds from the Duquesne Claystone down to the Pittsburgh Redbeds. Overhangs are developed where the stronger Birmingham member extends in cantilever fashion out over the more easily weathered Duquesne Claystone. This causes periodic fall or toppling of blocks of Birmingham. Some slumping also involves the Schenley Redbeds that overlie the Birmingham Sandstone-Shale. One of these slumps is hazardous to Hunt Road itself in such a way as to require periodic repair.

The Pittsburgh Redbeds to Duquesne Claystone interval is also present on the slopes of Shady Lane valley and the small valley extending from The Oaks down to Route 28. The outcrop area of these beds crosses Delafield Road in the vicinity of The Maples intersection. This probably explains the presence of a seep of water through the pavement of Delafield Road just above The Maples intersection at elevation 875 feet during the wetter times of the year. This seep represents ground water emerging where the more permeable Ames Limestone is in contact with the impermeable Pittsburgh Redbeds below. A similar flow of water occurs at 210 Rutledge Road at the same elevation and for the same reason. The upper end of Shady Lane is built on the Pittsburgh Redbeds. These beds plus the Ames Limestone, its overlying red shale, and the Duquesne Claystone extend up the valley from there for 150 yards and into a small tributary valley to the east. At both sites the Duquesne Claystone is overlain by the Birmingham member, and a waterfall has developed in the Birmingham.

In the area of The Maples, The Oaks, Riverview Terrace, Alpine Circle, and part of East Waldheim Road, the shale above the Ames Limestone is directly overlain by gravel deposits of the ancient high-level Allegheny River. The bottom of the gravel at this locality is at about elevation 895 feet. These deposits also underlie the Veterans' Hospital and part of Woodshire Drive area in O'Hara Township.

Birmingham Member (Cb)

The name Birmingham was first applied in 1876 to a stratigraphic unit that is conspicuous in the bluffs overlooking the Southside of Pittsburgh which in those days was known as Birmingham. The name used for this unit was "Birmingham shale." In other parts of the Pittsburgh area, such as in Fox Chapel, the unit contains more sandstone than shale, and the shale that it contains is mostly silty to sandy making the total unit a strong one that resists weathering and forms outcrops in many places. Many valleys in Fox Chapel have waterfalls where a stream flows over the outcrop of the Birmingham.

In this report, the original name "Birmingham shale" is modified to "Birmingham Sandstone-Shale" because sandstone and not shale is the dominant lithology. It is also referred to here as the Birmingham member. The unit is typically 50 to 55 feet thick in the Borough. The bottom one or two feet are composed of black, brittle shale that is a good marker bed. This black shale is in sharp contact with the underlying Duquesne Claystone or in a few places, with a few inches of Duquesne Coal. Commonly, on cliff-like slopes an overhang forms at this contact because of differential weathering. Close scrutiny of the black shale with a hand lens may reveal the presence of tiny vertebrate fossils including the scales, spines, and teeth of fish. Delicately preserved impressions of insect wings have also been reported in this black shale from other places, but they are rare. Above the black shale unit, the shale becomes gray and has a silty to sandy texture. This sandy shale in turn grades upward into sandstone with interbedded sandy shale to make up roughly the lower half of the total Birmingham member. In the middle of the member there is a zone of silty to sandy shale on the order of 10 feet thick. This shale grades upward into sandstone with shale interbeds that form the upper part of the unit. In some valleys there is a double waterfall at the Birmingham horizon -- an upstream fall developed in the sandy upper part, and a downstream fall developed in the sandy lower part. However, some valleys have just one waterfall in either the upper or lower part of the unit. The larger more deeply eroded valleys such as Squaw Run valley do not have any waterfall at the Birmingham horizon.

The Birmingham member is widely distributed throughout most parts of Fox Chapel. Along Squaw Run valley and its tributaries it is in mid-position on slopes for the most part, but in the upper valley it is on the lower slopes or at stream level as it is from Glade Run to Campbell Lake where the Birmingham goes below drainage. As described above it is a waterfall-forming unit. Virtually all waterfalls plotted on Map 2 are Birmingham waterfalls although a few are in the Morgantown and Saltsburg sandstones. The location and approximate height of Birmingham waterfalls are described in Figure 64.

Many of the cliff-like slopes in the Borough are formed on the Birmingham member. Outcrops of this member are more numerous than others, partly because of its resistance to weathering and erosion and partly because it is more widely distributed than other resistant units like the Powers Run Sandstone. One area where it is not expressed

Location	Approximate Height (Feet) Upper Fall	Lower Fall	Single Fall
1. Shady Lane valley, west of Notre Dame Place (2 falls, one in each fork of valley).			10
2. Small tributary of Shady Lane valley, south-west of intersection of Waldheim Road and Warwick Place.			15
3. Tributary valley off Valley Drive, west of St. James Place.			10
4. Valley north of Delafield Road, east of Edgewood Road.			10
5. Valley south of Guyasuta Road, southwest of intersection of Guyasuta Road and Fieldview Lane.			12
6. Valley between Marvelwood Place and end of Longfellow Road.	18	10	
7. Valley north of Hunt Road, 1/4 mile above Racquet Club.			25
8. Guyasuta valley tributary, south of end of Berkshire Drive.			50
9. Guyasuta valley, east of Oakhurst Road (known as Washboard Falls or Darlington Falls).			15
10. Stoney Camp Run tributary, south of Squaw Run Road, 300 ft. down valley from pond in Trillium Trail area.	12	10	
11. Stoney Camp Run tributary, 800 feet southeast of intersection of Squaw Run Road and Old Mill Road.			
12. Squaw Run tributary, southeast of intersection of Old Mill Road and Millview Drive.			15
13. Little Pine Creek tributary, northwest of Pine Creek cemetery and Poplar Drive (2 falls, one in each fork of valley).			7, 11
14. Glade Run tributary, northeast of Episcopal Church.	4	5	

FIGURE 64. Waterfall sites in Birmingham Sandstone-Shale in Fox Chapel. (Continued on following page).

Location	Approximate Height (Feet) Upper Fall	Lower Fall	Single Fall
15. Squaw Run tributary, 600 feet down valley from pond in valley adjacent to Millview Drive.			12
16. Valley west of 315 Hallsborough Drive.			5
17. Squaw Run tributary, between Fairview Road and end of Westport Drive.			6
18. Little Pine Creek tributary, Beechwood Farms Nature Reserve near Chapel Crest Terrace (in vicinity of Fox Chapel-O'Hara Twp. boundary).	10	15	
19. Campbell Run tributary, southeast of pond adjacent to Old Indian Trail.			12
20. Campbell Run tributary, south of the end of Chapel Ridge Place.	7	5	

FIGURE 64. Waterfall sites in Birmingham Sandstone-Shale in Fox Chapel. (Continued from previous page).

in the form of steep slopes or in abundant outcrop is along the boundaries of the ancient Allegheny River valley. On most valley slopes there is a rather abrupt change in profile at the outcrop position of the Birmingham member. The slope below it is relatively gentle on the Duquesne Claystone and Pittsburgh Redbeds, and the slope above commonly shows a prominent bench at the Schenley Redbeds level. Also, where streams flow across the Birmingham outcrop, the valley width is narrower than where streams flow over weaker members of the stratigraphic section.

Two sets of nearly vertical joints are well developed in the Birmingham. These joints are at nearly a right angle to each other. Intersecting joints bound large blocks of sandstone that are prone to toppling where overhangs have formed. Such blocks have also moved along bedding planes by "block-gliding" in a few places. Otherwise, slopes on which the Birmingham occurs are realtively stable.

The Birmingham Sandstone-Shale is permeable to groundwater whereas the underlying Duquesne Claystone is not. This causes a perched water table to develop locally within the Birmingham. (Perched water tables are further described on page 195.) In places the Birmingham is in contact with rather impermeable high-level alluvium. This contact between more permeable beds above and less permeable ones below causes springs to occur at the contact. One such spring is on Powers Run Road at the Lutheran Church site. There the Birmingham is in contact with the high-level alluvium which is silty and only moderately permeable. Seepage of groundwater from this road bank which is opposite 1611 Powers Run Road is almost year-round. Some of this water drains northerly by means of a ditch to a nearby stream and some permeates under the road and moves either as groundwater or in a drainpipe through the wet, mushy yard at 1611 Powers Run Road (O'Hara Township) to the low wet ground adjacent to the Fox Chapel Golf Club course. In winter, water on Powers Run Road at this site presents a traffic hazard during below-freezing weather, and also causes the pavement to crack and break up.

Another spring at a similar stratigraphic position is located behind (northwest of) the Fox Chapel Borough Building where there is a spring house and a small pond. A third spring is on the west side of Fox Chapel Road about 125 feet below South Drive where the unexposed Birmingham sandstone is estimated to be in contact with high-level alluvium of the ancient Allegheny Valley. This spring water is generally confined to the ditch along the road, but in times of strong flow it extends onto Fox Chapel Road and creates a traffic hazard.

Schenley Redbeds (Csch)

The Schenley Redbeds are named for the Schenley Park area in Pittsburgh. They lie between the Birmingham Sandstone-Shale member and the Morgantown Sandstone, and are from 20 to 28 feet thick. In some parts of southwestern Pennsylvania there is a bed of clay and a thin overlying coal bed (Wellersburg) just below the Morgantown Sandstone but those units are not recognized in Fox Chapel. The Schenley Redbeds consist predominantly of non-bedded claystone of red coloration. However, in the lower 3 or 4 feet soft, bedded shale of variegated red, pale green, and gray colors is present. This shale represents a gradational change from the sandy Birmingham beds below to the claystone of the Schenley Redbeds above. The upper contact with the Morgantown Sandstone is generally a sharp one, and is one where spring water commonly flows out onto the surface. Overall the Schenley represents a weak unit that produces abundant colluvial soil which is landslide-prone. The claystone has an abundance of small randomly oriented fractures like the Pittsburgh Redbeds claystone.

In places a gentle slope or even a flattish bench has formed where the Schenley Redbeds are present. The most prominent benching occurs stratigraphically at the base of the Schenley and uppermost part of the Birmingham. Some roads in Fox Chapel are built on this bench, for example, Fieldview Lane, Windsor Road, Elmhurst Road, the lower part of Edgewood Road, Waldheim Road between Elmhurst and Notre Dame Place, and Fox Chapel Road most of the way between Powers Run Road and Bending Oak Lane. A small segment of Old Mill Road is on this bench at Millview Road (see Plate 1).

The Schenley Redbeds are widely distributed in Fox Chapel. They are in an intermediate to high position on the slopes of Squaw Run valley in the southern part, but are progressively lower on slopes to the north. The redbeds are in the valley bottom under Campbell Lake. From there they extend up-valley under alluvial cover to Fox Chapel Road. These redbeds also extend up Stoney Camp Run valley to the Crawford Lane-Staffordshire Place area, up Hunt Road valley to Riding Trail Lane, and up the valley of a Glade Run tributary to Quail Hill Road. In the upper part of Glade Run valley itself they are present in The Forest from the Borough boundary line up to the end of Hidden Spring Lane. The Schenley also occurs on the subdued slopes of lower Glade Run valley where the stream uses the large, abandoned Allegheny valley. These are the slopes facing the Fox Chapel Golf Club course. Adjacent to lower Squaw Run valley, a prominent topographic bench is present at the level of the basal Schenley Redbeds on the long slope extending from the hilltop at the upper end of Edgewood Road down to Delafield Road. There is a large open field on this bench at elevation 990 to 1,005 feet. A similar bench occurs at the same level east of Squaw Run, partly in Fox Chapel and partly in the RIDC area of O'Hara Township. A small portion of the upper Rockwood Plan is on this bench.

Another place where a prominent bench at the top of the Birmingham and bottom of the Schenley is developed is west of the intersection of Fairview Road and Fox Chapel Road. This is at elevation 1,010 to 1,025 feet. Also, at the lower end of Nantucket Drive there is a prominent bench at this stratigraphic level, but at a slightly higher elevation from 1,020 to 1,035 feet. A continuation of this bench to the north is seen at Greenwood Road. In the same general area, but across the valley to the east, Fox Chapel Road is built on the bench at this level.

In The Forest, Glade Run valley has an outcrop area of Schenley Redbeds on both sides of the valley in the area of Silent Run Road. A narrow bench at elevation 1,050 to 1,065 feet on the Schenley Redbeds has been utilized for home sites along Silent Run Road and across the valley as well.

Landsliding is fairly common in colluvial soil at the Schenley Redbeds level in Fox Chapel. This soil has low permeability and is susceptible to movement when saturated with water. Springs occur at the contact of the Schenley Redbeds and the overlying Morgantown Sandstone. Such spring water in places slowly seeps into the redbeds colluvium until pore pressure increases sufficiently to cause landsliding. The most susceptible areas are where colluvial soil occurs on a steep slope and where water is available. A few places where landsliding has occurred at the Schenley Redbeds level are:

1. Old Mill Road diagonally across from the entrance to Millstone Drive (front yard and driveway).
2. Old Mill Road, 100 feet east of Millview Drive (undercut stream bank below road).
3. Hunt Road, 800 feet down (east) from Buckingham Road (steep valley wall below road).
4. Near end of Fieldview Lane (movement of house foundation during construction).
5. Guyasuta Road, 350 feet up from (west of) Fieldview Lane (valley wall on south side of road).
6. Edgewood Road, on steep valley wall diagonally across road from 12 Edgewood Road.

There are small outcrop areas of the Schenley Redbeds in Beechwood Farms Nature Reserve, one near Hart's Run Road, and the other in the valley north of the Chapel Crest Terrace plan in O'Hara Township. In the northeast corner of the Borough, valleys north and south of Chapel Ridge Place also contain small areas of Schenley Redbeds. These valleys are in the Campbell Run drainage area. Even smaller areas of Schenley occur in The Forest near the Harmar Township line along Wise Hill Road and in the valley north of Tree Farm Road.

Morgantown Sandstone (Cm)

The name Morgantown Sandstone is from Morgantown, West Virginia, where this member was first named. It can be traced from the Morgantown area into southwestern Pennsylvania where it is widely distributed. Stratigraphically the Morgantown lies between the Schenley Redbeds and the Clarksburg Redbeds. This is an interval of about 75 feet, of which only the lower 10 to 15 feet generally contains medium-bedded to massive sandstone in Fox Chapel. There are some areas in Fox Chapel where this sandstone is as thick as 25 feet. It is this lower part of the interval that is here mapped as Morgantown Sandstone. The rest of the interval up to the Clarksburg Redbeds is unnamed and is mapped as "Cmu" on Plate 1. Compared to other parts of Allegheny County, the Morgantown Sandstone is not a prominent unit in Fox Chapel. However, it can be traced rather easily because of exposures in stream beds and road cuts. It is probable that the sandy shale beds that overlie the Morgantown in Fox Chapel become sandstone laterally in other areas to make a thicker sandstone unit in the 30 to 50-foot thickness range.

The areal distribution of the Morgantown Sandstone is essentially the same as that of the underlying Schenley Redbeds. It extends from lower Squaw Run valley all the way up to Fox Chapel Road, and up Stoney Camp valley to the Crawford Lane-Staffordshire Place area. Along a Glade Run tributary valley, it is present upstream to Foxhurst Drive. In The Forest, the Morgantown Sandstone occurs on the lower slopes of Glade Run valley upstream as far as Hidden Spring Lane where it is at stream level.

Morgantown Sandstone to Clarksburg Redbeds Interval (Cmu)

The stratigraphic section in Fox Chapel from the Morgantown Sandstone to the uppermost unit which overlies the Pittsburgh Coalbed is difficult to establish in detail because in general these beds occur on the upper slopes and in hilltop areas where exposures are not abundant. Four units in that interval can be identified with reasonable accuracy. These are the Clarksburg Redbeds, Connellsville Sandstone, Lower Pittsburgh Limestone, and Pittsburgh Coal.

The interval between the Morgantown Sandstone and the Clarksburg Redbeds is here mapped as one unit (Cmu) because it has an overall homogeneity even though there are beds of differing lithology within it, including a soft shale unit about 10 feet thick at the base and an overlying sandstone from 50 to 10 feet thick that appears to lens out laterally in places. Above that sandstone up to the Clarksburg Redbeds the interval is composed of silty to sandy shale with occasional thin interbedded layers of fine-grained, platy sandstone. Bedding in the unit is thin to medium and is generally rather even or regular. The total thickness of the unit mapped as "Cmu" is 50 feet.

With regard to slope stability, it is a unit that in general produces stable slopes. Landsliding is not common at this level. The most susceptible part to landsliding and poor drainage is the basal few feet where soft, clay-shale beds occur.

Inspection of the geologic map (Plate 1) shows that the "Cmu" unit occurs in rather wide bands of outcrop compared to most other mapped units. This is true for two reasons. One is that its 50-foot thickness is greater than that of most mapped units, and the other is that in many places it occurs on gentle slopes near hilltops, or in some places, at the top of hills. However, in upper Squaw Run valley and other valleys in the northern part of the Borough it occurs on the lower to middle slopes. It is present in virtually all parts of the Borough.

Some of the roads that traverse this interval are Wynwood Drive, Wedgewood Lane, lower Woodbrook Drive, Hunt Road from Buckingham Road for a quarter mile toward Surrey Lane, Marvelwood Place, Poplar Drive, lower Riding Trail Lane (from #105 to #126), Hallsborough Drive from Jamesborough to its end, Staffordshire Place, Willow Road, Westport Drive, Fairview Road from Flower Hill Drive to Elm Drive, Spring Forest Drive, Old Mill Road from Fairview to Fox Chapel Road, Foxhurst Drive, Fox Chapel Road from Foxhurst to Quail Hill Road and from Old Mill Road to Highview Road (Indiana Township), Foxwood Drive (except the end), Wildberry Road from Highland Road to #311, Field Club Road between Ridgedale Lane and the O'Hara Township boundary line near the high school, Ridgedale Lane and the O'Hara Township boundary line near the high school, Ridgedale Lane, West Waldheim Road from Notre Dame Place nearly to the O'Hara Township boundary, and Marvelwood Place (see Plate 1).

Hilltop establishments built on the rocks of this "Cmu" interval between the Morgantown Sandstone and Clarksburg Redbeds are Shadyside Academy (main school) and the Pittsburgh Field Club. A few places in the Borough where outcrops of the unit can be seen are in the east bank of Fox Chapel Road where Old Mill Road crosses (from elevation 1,115 to 1,140 feet), on Fairview Road near Campbell Lake between the private drive at #500 and #521 in north bank (from elevation 1,015 to 1,035 feet), on the slope west of Squaw Run at Millstone Drive along a "jeep trail" to Wilmar Drive (from elevation 1,075 to 1,090 feet), and on Highland Road between Forest Drive and Silent Run Road (from elevation 1,100 to 1,115 feet). The headwaters of Stoney Camp Run flow over this unit, but do not reveal outcrops of it. Likewise, the headwater area of a stream between Longfellow Road and Buckingham Place and a stream that heads near the Longfellow Road-Guyasuta Road intersection and flows to Squaw Run are in this unit.

Clarksburg Redbeds (Ccl)

The Clarksburg Redbeds are named for Clarksburg, West Virginia. The original name was "Clarksburg red shale," but because these beds like the Pittsburgh Redbeds and Schenley Redbeds have similar lithology (namely claystone) they are now referred to as Clarksburg Redbeds and not Clarksburg red shale. Like the Pittsburgh and Schenley, the Clarksburg Redbeds form colluvial soil that is poorly drained and prone to landsliding. However, the Clarksburg Redbeds in general are considered less of a hazard in that respect in Fox Chapel because they occur fairly high on hills where gentle slopes are present, and also because the Clarksburg is somewhat thinner than the other two units. The Clarksburg member is 15 feet thick in the Borough. The main concern with these redbeds is poor drainage in house foundations, in the yards of houses, and on slopes where fill is placed.

In Fox Chapel the Clarksburg Redbeds generally contain scattered nodules of limestone, particularly in the lower part. This limestone in some other areas occurs in distinct beds in which case it is known as the Clarksburg Limestone. The redbeds are overlain by the Connellsville Sandstone. They occur in most parts of Fox Chapel except the east central part. East of Squaw Run between the southern Borough boundary and Glade Run valley these beds are not present because their stratigraphic level is above that of the highest hills with the exception of the hill at Foxtop Road where a small area of the redbeds is present. Otherwise the Clarksburg member is found either high on valley slopes or near the top of hills. Places where it is close to the top of a hill are in the upper part of Woodbrook Drive and Tomahawk Drive, along the high part of Millview Drive, and along Dorseyville Road between Brownshill Road and Cross Keys Inn. The Beechwood Farms Nature Reserve headquarters building on Dorseyville Road is located at this level. These redbeds are also near hilltop elevations north of the Episcopal Church and above Shadyside Middle School.

Many roads in the Borough cross the outcrop area of the Clarksburg Redbeds, but few are built along it because, being a thin unit only 15 feet thick, it does not form a bench of sufficient size for road construction. However, there are numerous places where small flattish areas in this unit have been selected as home sites. Generally, poor drainage is encountered at such sites. Poor drainage in this unit is noted where Edgewood Road makes a right-angle bend above Colbert Drive. At that locality drainage has been established in road ditches by placing a permeable medium (coarse slag) in the ditches. Poor drainage in the Clarksburg Redbeds has also been noted in places on upper Woodbrook Drive where drain tile is required to prevent a soggy soil condition.

Springs occur at the contact between the low permeability Clarksburg Redbeds and the overlying permeable Connellsville Sandstone. One such spring is present on what used to be a farm at the end of Quail Hill Road (#125). This spring feeds a small stream that flows easterly to Campbell Run.

Landsliding also occurs at the Clarksburg level, particularly where this unit crops out on a steep slope as it does south of Chapel Ridge Place. Prehistoric landsliding occurred there in both the Clarksburg and Schenley Redbeds on the very steep slope facing the valley at 100 Chapel Ridge Place. This early slumping was followed by recent slumping at the Schenley level when a sewer was installed. The functioning of the sewer line was disrupted because of it. The early landsliding was probably initiated by stream undercutting in the soft Schenley Redbeds at the foot of the slope, and then extended upslope to the level of the soft Clarksburg Redbeds. Other landsliding in the Clarksburg occurred on the slope west of Squaw Run at Millstone Drive along a "jeep trail" leading up to Wilmar Drive. This slumping (at about elevation 1,100 feet) disturbed an underground gas pipeline. A third example of Clarksburg slumping is on Guyasuta Road 800 to 900 feet down from Longfellow

Road. That is the site where recent slumping took place below the road in the Schenley Redbeds, requiring road repairs, but the Clarksburg Redbeds were also involved in prehistoric landsliding at that locality. There is morphologic evidence in the topography that ancient landsliding has occurred on this slope, beginning at the Clarksburg Redbeds some 40 to 50 feet above the road and extending down across the road (long before it was built) to stream level where the stream has eroded into the soft claystone beds of the Schenley Redbeds. At this site Guyasuta Road is built across an old landslide "chute" where landsliding dates back many thousands of years.

Connellsville Sandstone (Cc)

The Connellsville Sandstone is named for Connellsville, PA, much of which is built on this sandstone member. In Fox Chapel the sandstone lies immediately above the Clarksburg Redbeds, but in some places there is a thin coal bed (Little Clarksburg Coal) between the redbeds and the sandstone. An unnamed stratigraphic unit overlies the Connellsville.

The sandstone is 15 to 20 feet thick in the Borough. It is thin-to-medium-bedded, somewhat flaggy, and cross-bedded. Like the Clarksburg Redbeds which it overlies, it is found mostly on the upper slopes of valleys and near or at hilltops. It is the caprock of several hills including one partly encircled by Woodbrook Drive, the top of Tomahawk Drive, the ridgetop north of the middle section of Millview Drive, the hill north of the Episcopal Church, and one on the east side of Dorseyville Road between Glen David Drive (O'Hara Township) and Willow Road. This sandstone also occurs at the end of Foxtop Road where a small exposure of it can be seen at the cul-de-sac. It extends from there into the Crofton area of O'Hara Township at the end of Wickford Drive. A few roads in the Borough are built on it. One is Forest Drive for its entire length, and another is a private drive to houses at #232 and #234 Hunt Road.

Connellsville Sandstone also occurs in the recently developed Davonshire Drive-Fairgrove Drive area in O'Hara Township on the west side of Dorseyville Road. A good outcrop of the sandstone in Fox Chapel can be seen on the north-facing slope south of Wise Hill Road where 15 to 20 feet of it is exposed in a hillside cut between elevation 1,155 and 1,175 feet. This site is about 300 yards east of Field Club Road.

Connellsville Sandstone to Lower Pittsburgh Limestone Interval (Cpl)

From the top of the Connellsvile Sandstone to the base of a limestone here identified as the Lower Pittsburgh Limestone, there is a stratigraphic interval of 30 feet which is unnamed. The interval contains mostly silty to sandy shale, but in some places there is a foot or two of red claystone at the base. This 30-foot unit does not present slope stability problems. It occurs high up on hillsides or on hilltops and in general is found on gentle slopes. Several ridgetop areas are capped by this unit. These include the Orchard Drive-

Mayflower Drive area, the higher portion of Beechwood Farms Nature Reserve, and the ridge extending north from Haverford Road for more than a half mile. Field Club Road between the Borough boundary and Tree Farm Road is also built on this unit.

Lower Pittsburgh Limestone (Clp)

A limestone member lying about 40 feet below the Pittsburgh Coalbed is here described as the Lower Pittsburgh Limestone. There is confusion regarding the terminology of the limestone. In some reports it is referred to as Pittsburgh Limestone. In others, two limestone beds are described, one lying immediately below the Pittsburgh Coal (Upper Pittsburgh Limestone) and another lying "a few feet above" the Connellsville Sandstone (Lower Pittsburgh Limestone). It is the latter limestone bed which is present in Fox Chapel. The exact thickness of it is difficult to assess because good exposures are so rare, but it is probably from 50 to 8 feet thick in most places, including some interbedded shaly limestone. Although good outcrops are scarce, its presence can be affirmed throughout most of its outcrop area by means of large boulders encountered during excavation for roads and buildings. Commonly such boulders, of roughly rectangular shape, on the order of 3 or 4 feet in long dimension, are placed around the periphery of lawns and patios and along driveways as decorative stone. The limestone is gray to dove gray on fresh surfaces, but weathers to a light gray or whitish color with patches of rusty brown.

The Lower Pittsburgh is a nonfossiliferous limestone of freshwater origin. It occurs in beds one to three feet thick, with thin interbedded layers of shaly limestone and calcareous shale. Typically, the unit is sufficiently weathered at the outcrop to show loose blocks of limestone in a calcareous clay matrix. It is these loose blocks that are commonly placed as decorative pieces on properties where they are excavated, or on nearby properties. This limestone unit is the most conspicuous one in Fox Chapel. The only other bedded limestone unit in the Borough is the Ames which is less pure and generally does not weather out in such large blocks. Also, the Ames occurs low topographically and is seen mostly in stream-bed outcrops, whereas the Lower Pittsburgh Limestone occurs high topographically, mostly in developed areas where it is encountered during excavation.

Some places where the Lower Pittsburgh Limestone is found are Berkshire Drive, Nottingham Circle, Westchester Drive, Buckingham Road, Riding Trail Lane (upper part), and Wilmar Drive (southern area). It is noted that the above localities are all in roughly the western half of the Borough. Although the stratigraphic level of this limestone occurs in the northeastern quarter of Fox Chapel on the higher hills (area of Fairview Road, Chapel Ridge Road, Old Timber Trail, and Shadow Road), evidence of its presence is not as clear as in the western half. The best outcrop of the limestone seen in the Borough is on Guyasuta Road just west of the Buckingham Road intersection in the road bank on the upper side at elevation 1,145 to 1,153 feet.

The Lower Pittsburgh Limestone generally presents no slope stability problems, but the clay with which it is associated creates poor drainage conditions. The limestone is of no economic value except in a minor way for ornamental use in yards as described above.

Lower Pittsburgh Limestone to Pittsburgh Coal Interval (Cp)

This is a 35 to 40-foot interval for which there is no name. It is very poorly exposed in Fox Chapel because it occurs so high topographically. It is probably composed mostly of shale which is partly silty and partly calcareous, but its makeup is not well known because of a lack of outcrops. The unit is present only on high hills where slopes are gentle, and for that reason is not a slope stability problem unit. Neither is it known to produce soil with poor drainage.

This stratigraphic unit has more restricted areal distribution than any of those previously discussed because of its high stratigraphic level. Only hilltop areas that are generally in the 1,175 to 1,200-foot range or higher contain it. These include ones adjacent to Berkshire Drive, Westchester Drive, and Buckingham Drive in the southwestern part of Fox Chapel. In the north it caps the highest hill traversed by Wilmar Drive, and is present on the ridge in the northeast corner where Fox Chapel Road makes a right-angle turn at Guys Run Road. It also occurs on the hilltop at the end of Fairview Manor, and at or near hilltops in The Forest.

Pittsburgh Coalbed (Mp)

The Pittsburgh Coal takes its name from the city of Pittsburgh. It is extensively mined in southwestern Pennsylvania, but the seam is now considered "mined out" in Allegheny County. The Pittsburgh seam is remarkably persistent in thickness and quality. It is found not only in southwestern Pennsylvania but also in West Virginia and Ohio where it is also extensively mined. It forms the stratigraphic boundary between the Conemaugh Group and the Monongahela Group of rocks, the base of the seam being at the base of the Monongahela (hence the map symbol "Mp" for Monongahela and Pittsburgh).

In Fox Chapel there are three small areas where the seam is still present and one where it has been mined out. It is (or was) present near the top of four hills; two in The Forest, one at an old cemetery site above the end of Bobcind Drive, and the fourth adjacent to Buckingham Road. The seam has been strip-mined on one of the hills in The Forest. This hill is mostly in Harmar Township north of Old Timber Trail and west of a new plan being developed in Harmar. Another hill in The Forest is underlain by Pittsburgh Coal. This is the highest hill in Fox Chapel (1,304 feet) and is one that also extends into Harmar Township. It is adjacent to Shadow Ridge Drive where the Pittsburgh Coal was exposed when a cut was made in the slope behind the house at #113 Shadow Ridge Drive. The base of the coal bed there is at elevation 1,258 feet; and the seam is 6 or 7 feet thick. The outcrop trace of the coal extends along the slope at that elevation behind the houses on the upper side of the road to the end of the road and beyond into Harmar Township. This coal seam was also encountered in the excavation for the house foundation at #111 Shadow Ridge Drive, but no foundation problems are associated with it.

A small "patch" of Pittsburgh Coal occurs under the hill immediately west of the end of Bobcind Drive and north of Fairview Road. At the top of this hill there is an old, unkept cemetery (locally known as the "Strohm Cemetery") with a growth of small trees in it. Although the coal bed cannot be seen in outcrop, its base is estimated at elevation 1,235 feet, and its thickness is estimated at 6 or 7 feet.

The largest area of Pittsburgh Coal in Fox Chapel is in the hill bounded by Westchester Drive, Buckingham Road and the new development known as The Pines. A Fox Chapel Authority water tank is located at the top of this hill. Although there is no surface indication of the presence of the coal seam there, it is estimated to occur at a basal elevation of 1,195 feet and have a thickness in the 6 to 7-foot range as is typical of the Pittsburgh seam.

Strata Above the Pittsburgh Coal (Ml)

Rock strata above the Pittsburgh Coal are essentially unexposed in the Borough and therefore not well known. These beds extend to the top of the four hills in Fox Chapel where the Pittsburgh Coal occurs, as described above. They are the youngest bedrock layers in the Borough. Others that once overlaid them have long since been eroded away. These existing beds above the coal seam are estimated to be interbedded layers of thin-bedded sandy shale and shaly sandstone. In Fox Chapel the maximum thickness of these beds is 35 to 40 feet, on the highest hill of the Borough in The Forest at elevation 1,304 feet. A similar thickness of these beds is present on another hill north of Old Timber Trail, but this hill is mostly in Harmar Township. Because the areal distribution of this stratigraphic unit is very restricted, it is of little significance.

Carmichaels Formation

All stratigraphic units previously described are part of the exposed bedrock sequence of the Borough. These strata are on the order of 300 million years old. They are consolidated rocks that were once overlain by some unknown thickness of younger rocks, long since eroded away. Lying on the surface of this eroded bedrock in certain places are much younger, unconsolidated deposits, perhaps only a few thousand years old, deposited by the Allegheny River when it was flowing along a different course and at a level about 200 feet higher than that at which it is flowing today. These old river deposits are composed of alluvium belonging to the Carmichaels Formation. The name "Carmichaels" is from the village by that name in Greene County, Pennsylvania. This village is situated within an abandoned loop of the Monongahela River on unconsolidated alluvial deposits laid down by the prehistoric Monongahela River when it was flowing at a level about 200 feet above its present one. All such deposits in western Pennsylvania are known as the Carmichaels Formation.

In Fox Chapel these deposits occur on what was once the valley floor of a broad valley loop that extended from the Boyd School area of O'Hara Township past O'Hara Junior High School and Fox Chapel Area High School, through the Yorkshire Drive area (O'Hara Township), through Fox Chapel Golf Club course, around the high ground where Shadyside Academy is located, through the Pittsburgh Field Club golf course and the Hawthorne Road-Hillcrest Road area into RIDC Industrial Park of O'Hara Township (see Figure 62). The bottom of these deposits in Fox Chapel is at elevations ranging from 895 to 940 feet. The top is estimated at elevation 975 feet, but the deposits are not 80 feet thick at any one place as this thickness range might imply. Since the time this alluvium was deposited it has been partially eroded away so that its thickness at a given site is commonly in the 20 to 40-foot range. The top of the deposits is difficult to identify because they blend in with soil on gentle slopes and commonly do not crop out. However, the bottom is recognizable in several places where streams have eroded through them to expose a layer of sandstone boulders that occurs at the base of the formation. These boulders range from about one foot to several feet in diameter and are well-rounded, indicating that they have been transported into the area from an outside source. Some of them are conglomeratic in part (pebbly) and represent a type of sandstone not known to occur in the bedrock layers of the Borough. This further suggests that they were brought down the ancient Allegheny River from an up-valley position, and were moved by a large-volume, fast-flowing stream. In the field, one can sense being close to the exposed bottom of the Carmichaels Formation by noting these round boulders which have been placed at the edge of the lawns and driveways as decorative stone.

The sandstone boulder layer occurs at the bottom of the Carmichaels Formation throughout its extent in Fox Chapel, but the overlying material is of two different types, or in other words, of two different facies. One is a fine-grained, clay, silt, fine-sand facies; the other is a pea-size to marble-size gravel facies. The former is much more widely distributed than the latter. On the geologic map (Plate 1), the fine-grained facies is mapped as "Is." Inspection of the map shows this to be distributed throughout the ancient Allegheny valley loop in Fox Chapel (see also Figure 62). Only in the extreme southern part of the Borough in the South Pasadena Drive-East Waldheim Road-Maples area is the gravel facies present (see geologic section A-A; Plate 3), except for one other small patch in the Rockwood Plan adjacent to the end of Rockingham Road (O'Hara Township). This small patch in Fox Chapel is just the fringe of a larger area extending into Oakhill Manor and RIDC Industrial Park of O'Hara Township. Likewise, the gravel of the South Pasadena Road area extends into the Veterans Hospital property and the Woodshire Drive area of O'Hara Township. It is clear that the gravel facies of the Carmichaels occurs closest to the existing Allegheny River (but 200 feet above it), whereas the clay, silt, fine-sand facies occurs in the abandoned valley loop that extends from the Boyd School area of O'Hara Township around the high ground where Shadyside Academy is located, and back to RIDC.

Recent Alluvium

The youngest deposits of Fox Chapel Borough are those that have accumulated in floodplains of existing streams in the last few hundred years. These are shown on the geologic map (Plate 1) by the symbol "Ral." The map shows that the deposits occur mainly along Squaw Run valley, but also occur along lower Glade Run valley, roughly from Glade Lake downstream. There are a few small patches of alluvium along Stoney Camp Run, but these are too small to map at the 1-to-800 scale of the geologic map.

In Squaw Run valley, there are places where no Recent alluvium has accumulated. Instead, the stream flows on bedrock of sandstone or sandy shale type. Such areas occur just below Campbell Lake where it flows over the outcrop of the Birmingham Sandstone-Shale, and upstream from the Racquet Club where it flows over the upper part of Powers Run Sandstone. However, from the Racquet Club downstream, there are alluvial deposits in the floodplain of the stream, in places on the west side, in places on the east side, and in some places on both sides. These floodplain deposits are of wide extent (300 to 350 feet) at McCahill Memorial Field. They are nearly this wide between Squaw Run Road East and the stream near its junction with Stoney Camp Run.

Another locality of extensive floodplain alluvium is just upstream from the junction of Glade Run where the floodplain is 400 feet wide. From there the alluvium extends upstream to Old Mill Road with a progressive narrowing of the floodplain to about 100 feet at Old Mill Road itself. It is along this stretch between Glade Run and Old Mill Road that Squaw Run flows over the soft Pittsburgh Redbeds Claystone, and where its gradient is relatively low. The alluvium overlies this claystone bedrock between these two sites.

On the upper side of Old Mill Road the floodplain widens again to about 200 feet where a tributary stream whose headwaters are near Dorseyville Road joins Squaw Run. There, too, in the lower reaches of the tributary, the stream flows over soft shale, in this case the shale that overlies the Ames Limestone.

From Campbell Lake up to Fox Chapel Road there are floodplain alluvial deposits ranging from 100 to 200 feet wide. Along this stretch, Squaw Run flows over the soft Schenley Redbeds Claystone. Campbell Lake itself is acting as an "obstruction" in the stream's course. The lake, in effect, is a local base level which interrupts the natural gradient of Squaw Run and causes sedimentation from there upstream to Fox Chapel Road. This sedimentation will continue in the future with the noticeable effect of "silting in" at the upper end of the lake.

There is no information available from drilling on the thickness of Recent alluvial deposits along Squaw Run valley. Their estimated thickness is between 5 and 15 feet. At most places the deposits are probably in the 5 to 10-foot range.

3. Geologic Structure

Introduction

Geologic structure refers to the inclination of rock layers (dip) and to joints and faults (fractures). Jointed rocks and inclined rock layers do occur in Fox Chapel, but there are no known faults. Inclined beds, as they occur in a large "fold" that is present throughout the Borough are described below, as are joints.

McMurray Syncline

The bedrock layers (or strata) of Fox Chapel are stacked one on top of the other in parallel fashion. The layers are laterally continuous except where they have been removed by erosion as they have been where valleys now occur. In places these rock layers crop out, that is, they are not covered by soil and are visible at the surface. Exposed strata appear to be horizontal, that is, they appear to have no inclination with respect to a horizontal plane. However, the rock layers are indeed inclined. Their inclination can be detected if a given bed is traced throughout the area, in which case it is noted that the elevation above sea level of the bed is different in different places. Because the various beds are stacked up like a pile of pancakes, they are therefore parallel to each other, and by determining the inclination of a given bed, the inclination of all beds that lie above and below it is also determined.

Inclined beds are said to have a dip, that is, they change to lower and lower elevations at a certain rate (angle) and in a certain compass direction. The angle of dip and the direction of dip change from place to place. These changes can be detected at a glance on the geologic map (Plate 1) which reveals them by means of "structure contours." A structure contour is a line of equal elevation on some bed used as a datum. In this study the Ames Limestone is the datum bed chosen for this purpose. The elevation of Ames Limestone outcrops was determined at numerous places and plotted on an overlay worksheet at the same scale as the geologic map. Using these points of known elevation, lines of equal elevation (structure contours) were plotted at 10-foot vertical intervals (the structure contour interval). These contour lines were then transferred to the geologic map itself. By means of these lines one can see that the Ames Limestone (and therefore other rock layers) dips in different directions (south, southeast, southwest, etc.) in different places. The dip direction is, of course, toward the lower contour numbers. The spacing of the structure contours shows the rate of dip. The closer the spacing, the steeper the dip. For example, where the limestone dips a vertical distance of 10 feet (say between the 920 and 910 contours) in a map distance of 1,000 feet, the amount of dip is 10 feet per 1,000 feet, or one percent. Converted to feet-per-mile this represents a dip of 52.8 feet-per-mile. In terms of degrees it is a little more than one-half degree. In most outcrops such a gentle dip cannot be seen, but the structure contours clearly show it.

The geologic structure of Fox Chapel Borough is synclinal. This means that strata are folded downward in a broad fold known as a syncline (an upfold is an anticline). The size of this fold is such that it occupies all of Fox Chapel Borough. The low part of it, that is the axis or trough of the syncline, has a northeasterly trend from the place where it enters the Borough between Berkshire Drive and Woodcock Drive and the place where it leaves the Borough north of Chapel Ridge Court (see Plate 1).

This syncline is one of a series of synclines and anticlines in southwestern Pennsylvania. It is known as the McMurray Syncline because it can be traced southwesterly to the McMurray area of Washington County where it was named. It can also be traced northeasterly into Buffalo Township of Butler County. The syncline is bounded on the west by the Kellersburg Anticline whose trend is northeasterly through Allison Park in Hampton Township. It is bounded on the east by the Amity Anticline named for that village in Washington County.

In Fox Chapel, rock strata west of the axis of the McMurray Syncline dip southeasterly toward the axis, and those on the east side dip southwesterly toward it. These dipping strata are shown in three geologic cross-sections (Plate 3). Cross-section A-A' is drawn across the southeastern part of the Borough; cross-section B-B' is drawn across the central part; cross-section C-C' is drawn across the northern part of Fox Chapel. It is the latter that best shows the opposing southeasterly and southwesterly dip of the synclinal structure. This broad synclinal basin or trough also has a plunge to the southwest at the rate of about 23 feet-per-mile (less than one-half percent) toward Sharpsburg, except at its northeast extremity in Fox Chapel where there is a reverse, northeasterly plunge into Harmar Township.

Its plunge can be better understood by using an analogy. If one were to crease a sheet of paper so as to make a V-shaped trough in paper-airplane fashion, the crease itself would represent the synclinal axis, and the sides of the paper sloping toward the crease would represent the dipping Ames Limestone in the syncline. If the crease were very gently tipped or inclined (toward the southwest) this would cause the whole paper airplane (syncline) to plunge in that direction as does the syncline in Fox Chapel. In reality, however, the syncline does not have a sharp, creased axis like that of the sheet of paper, but instead has a broadly rounded one within which the dip direction reverses over a distance of several hundred feet. This is better described as an axial "zone" rather than an axial line. Along the axial zone the rate of plunge of the syncline is not uniform. There is a flattening out of the plunge to nearly horizontal in the Hunt Road-Riding Trail Lane area, and there is another flattening of it in Fairview Road-Foxhurst Drive area. Northeast of Foxhurst Drive the plunge direction reverses to a northeasterly one as previously described. Using again the analogy of the paper airplane, this reversal of plunge can be simulated by making an arch in the crease of the paper so that the crease is inclined in two different directions (southwest and northeast). These represent the plunge directions.

The rate of dip on the flanks of the syncline (sides of the paper airplane) is not everywhere the same although it does not differ markedly. The steepest dip is in the northwest part of the Borough in the area of Dorseyville Road, Wilmar Drive, Millview Drive, and Mayflower Drive. In those places, beds dip southeasterly at the rate of about 35 feet-per-mile. A somewhat more gentle dip prevails on the east flank of the syncline where a dip on the order of 30 feet-per-mile is common. This occurs in the area encompassed by Shadyside Academy, Pittsburgh Field Club, Hillcrest Road, and Guyasuta Road.

The steepness of hillside slopes or valley wall slopes is not to be confused with the dip of rock strata. The contours of the surface topography are independent of the structure contours on the Ames Limestone. Surface contours show the configuration of topographic features like hills and valleys whereas structure contours show undulations of a rock layer in the subsurface.

The folds or undulations in the strata of southwestern Pennsylvania, including the McMurray Syncline, were produced when the layers were squeezed many millions of years ago (perhaps 250 million years ago), whereas the surface topography represents an "etching" into these bedrock layers by stream erosion through the last few million years.

Returning to the structure contours on the Ames Limestone, one might ask how they can be used. One of their important uses is in predicting the position of other beds that lie above and below the Ames. This can be done when structure contours are used in conjunction with the stratigraphic section and surface contours of the base map (Plate 1). For example, if it is known that the stratigraphic interval from the Ames Limestone to the Clarksburg Redbeds is 190 feet (as the stratigraphic column shows), and that the 920-foot structure contour on the Ames passes through Shadyside Academy (main school) at a surface elevation of 1,060 feet, then it follows that there will be no Clarksburg at that site because the surface is not high enough to include it. The surface would have to be at least as high at 1,110 feet to have the Clarksburg present (920' plus 190' = 1,110'). A glance at the geologic map shows that the Clarksburg Redbeds are not present there, so it could be asked, "why use the structure contours?" The point is that they were useful in making the map itself and in predicting what rock layers would be found at different places in advance of field checking for their presence. This is a useful procedure because rock outcrops are so limited in abundance that it is not possible to trace a given layer continuously for any distance.

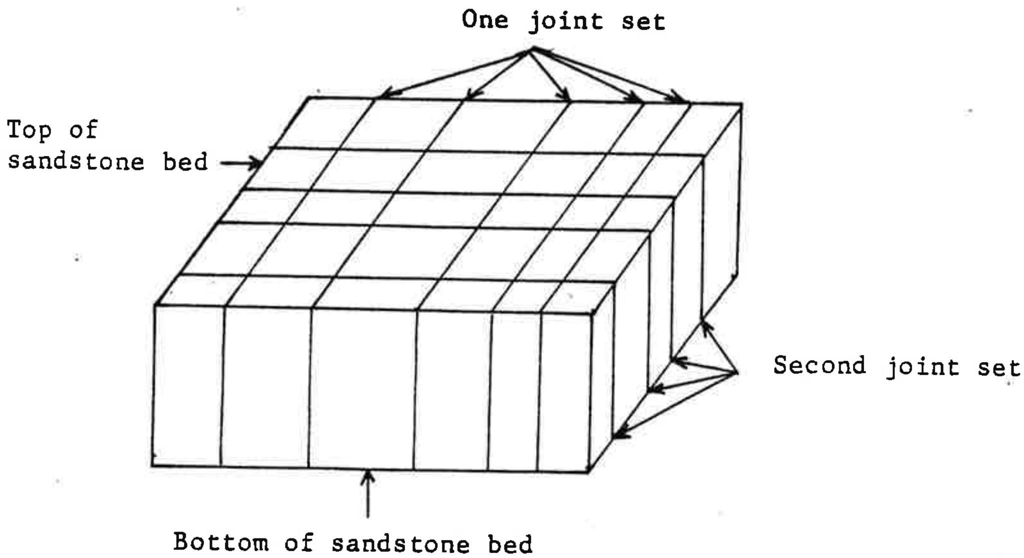
Structure contours can also be used in predicting the presence and depth of rock layers in the subsurface. For example, if it is known that the stratigraphic interval from the Ames Limestone down to the Upper Freeport Coalbed (the one mined at Harmarville and under parts of Fox Chapel) is 325 feet, then one can determine how deep that coal bed is anywhere in Fox Chapel Borough by using the geologic map as follows. Assume that we want to know how deep the coal is below the Borough Building (Fox Chapel Road near Field Club Road). The elevation of the Ames Limestone at that site is 925 (by interpolation between the 920 and 930 structure contours) and the surface elevation is 1,000 feet (shown by surface contours of the base map). The elevation of the coal is 600 feet (925' minus 325') which places it 400 feet below the Borough Building (1,000' minus 600'). This procedure was used in preparing the map showing depth to the Upper Freeport Coal (Plate 4).

Perhaps one wishes to know how deep a water-bearing sandstone (aquifer) lies below his property. The same procedure can be used to determine this. Assume that the Powers Run Sandstone is the target aquifer and we want to know how deep it lies below the tennis courts at Pittsburgh Field Club. From the stratigraphic section (Plate 3) we see that the interval from the Ames to the top of the Powers Run Sandstone is approximately 80 feet. The elevation of the Ames at the Field Club is 905 feet (by interpolating between the 900' and 910' contours) and the tennis courts are at approximately 1,060 elevation (from base map contours). Thus, the elevation of the top of the Powers Run Sandstone is 825 feet (905' minus 80'). Therefore, a well would have to be drilled 235 feet deep to penetrate the Powers Run Sandstone (1,060' minus 825').

Still another use of structure contours to geologists is in predicting the presence of oil and/or gas in reservoir rocks at depths of thousands of feet in so-called "anticlinal traps." Oil and/or gas rise to the top of an anticline (upfold) and are trapped if the reservoir rock containing them (sandstone generally) is overlain by an impermeable seal (generally shaly or clayey rock). Thus a suitable drilling site can be selected where an anticlinal crest is revealed by structure contours. However, in Fox Chapel Borough this is not an applicable procedure because the geologic structure is synclinal and not anticlinal. This is not to say that no oil or gas exist in the subsurface below Fox Chapel, because other types of trap may be present such as stratigraphic traps which involve lateral changes in the permeability of a reservoir rock. (See page 193).

Joints

Joints are another structural feature of rocks. All bedrock strata in Fox Chapel are jointed. Joints are fractures that "break" the homogeneity of a rock, and are extremely abundant. There are thousands and thousands of them. They probably formed millions of years ago when regional stresses were applied to the rocks of southwestern Pennsylvania. Many joints are linear, elongate fractures that extend for hundreds of feet through a rock mass. It is common for rock layers to have two sets of joints trending essentially perpendicular to one another. A joint "set" is a group of roughly parallel joints. The spacing of joints ranges from a few inches to a few feet. In the idealized sketch below two perpendicular sets of joints are shown cutting through a hypothetical bed of sandstone.



There can also be a third set of joints, which is diagonal to the other two. No study has been made in Fox Chapel of such things as preferred orientation of joints, their spacing in different rock types, or of the continuity of joints either vertically or laterally. It is known, however, that sandstone and shale units in the Borough are prominently jointed and typically have two sets of nearly vertical joints oriented roughly perpendicular to each other. Also, it is known that claystones have quite a different pattern of jointing. The latter contain a myriad of small, closely spaced fractures that are randomly oriented so as to cause exposed claystone to break up (weather) into small irregularly shaped pieces and form a "pulverized" mass. On the other hand, joints in sandstone and sandy shale beds are spaced on the order of several inches to several feet apart so that at the surface, where weathering is effective, large blocks become loosened from the "solid" rock mass because of expansion of joints. On cliff-like slopes such blocks are susceptible to toppling. On some steep slopes these sandstone blocks may slowly "glide" along bedding planes to a down-slope position. Thus, jointing of rocks is a contributory factor to landsliding.

Joints are also significant from the standpoint of groundwater movement (see page 194). The flow of groundwater through subsurface rocks requires a certain degree of permeability. There must be openings in the rock through which the water can move. One type of opening is that provided by joints. In the subsurface, away from the weathered zone, joints tend to be "closed" yet they still impart some permeability that allows groundwater to move at the rate of inches per day through them.

Faults

Faults are another type of geologic structure. They are fractures along which there has been movement or displacement of adjacent bedrock masses on either side. Faults are caused by stress, either compressional, tensional, or shearing stress, applied to the extent that the rock yields by breaking or faulting, and is displaced. When such rupturing occurs the adjacent rock masses are set into a wave-like motion, thereby producing an earthquake. There are no known examples of faults in Fox Chapel Borough. Although the rock strata were deformed by the stress that produced the large synclinal fold described previously, there is no indication at any locality of the displacement of rock masses by faulting.

4. Landslide Hazards and Drainage Characteristics of Stratigraphic Units

The Pittsburgh area is landslide-prone, and Fox Chapel is no exception. This is true because of a combination of factors that include 1) steep slopes, 2) weak rock layers, 3) colluvial soil masses, 4) periodic heavy rainfall, 5) disturbing of natural slopes by cutting and filling, and 6) altering of the surface-water and groundwater regime. In a previous study (1979) by the Squaw Run Area Watershed Association, landslide-hazard maps of the entire Borough were made. These color-coded maps at a scale of 1"=200' classify slopes with regard to susceptibility to landsliding as high-risk, moderate-risk, or low-risk. The maps also show the location of all known landslides, both historic and prehistoric, and have an accompanying explanation of how to use them. They are on file at the Fox Chapel Borough Building.

In the current study, that landslide work was not duplicated, but the geologic map (Plate 1) that was produced can be used in a general way to identify areas that are more landslide-prone than others. Such identification is based on outcrop areas of weak claystone beds. Where these beds crop out it is common to find clay-rich soil developed from the weathering of the claystone, and in numerous places along these outcrop areas there has been movement of that soil, by creep or landsliding, to form a mass of colluvium or colluvial soil (out-of-place soil). Such colluvium is generally unstable if disturbed by excavation or if drainage is altered so that more water enters the colluvium than previously. Both the colluvium and the in-place claystone have low permeability so that drainage is poor where house foundations are located in these materials. On the other hand, sandstone, and sandy shale units represent low landslide risk and provide generally good drainage. The geologic map can therefore be used both to predict the potential for landsliding and poor drainage conditions in house foundations. Figure 65 evaluates the various stratigraphic units that are plotted on the geologic map according to their landslide risk and drainage conditions.

Map Symbol	Stratigraphic Unit	Landslide Risk: Slump & Earthflow Types					Rockfall Type					Drainage Conditions				
		H		M		L	H		M		L	G		F		P
Ral	Recent alluvium					x					x					x*
Is	High-level alluvium (clay, silt, fine sand)					x					x				x	
Ig	High-level alluvium (gravel)					x					x	x				
Ml	Unnamed beds above Pittsburgh Coal					x					x		x			
Mp	Pittsburgh Coal					x					x		x			
Cpl	Interval between Pittsburgh Coal and Lower Pittsburgh Ls.					x					x			x		
Clp	Lower Pittsburgh Ls.				x						x				x	
Ccu	Interval between Lower Pgh. Limestone and Connellsville Ss.			x							x			x		
Cc	Connellsville Sandstone					x					x	x				
Ccl	Clarksburg Redbeds		x								x					x
Cmu	Interval from Clarksburg Redbeds to Morgantown Ss.				x						x			x		
Cm	Morgantown Sandstone					x			x			x				
Csch	Schenley Redbeds	x									x					x
Cb	Birmingham Sandstone-Shale					x	x					x				
Cd and A	Interval from Birmingham to Ames Limestone		x								x					x
Cprb	Pittsburgh Redbeds	x									x					x
Cs	Saltsburg Sandstone and Shale					x	x					x				
Cwr	Woods Run Claystone		x								x					x
Cpr	Powers Run Sandstone					x	x					x				

FIGURE 65. Classification of stratigraphic units in Fox Chapel according to drainage conditions and susceptibility to landsliding. Legend:

H = high M = moderate L = low;
G = good F = fair P = poor;
* = high water table
(note that intermediate evaluations are made between the above classes).

5. Mineral Resources

Fox Chapel is not an area of abundant mineral resources. In southwestern Pennsylvania, mineral resources exploited at various places are coal, oil and gas, clay, limestone, sandstone, and sand and gravel. Of these, coal is the principal resource in the Borough. Presently there is underground mining of the Upper Freeport Coalbed by Consolidation Coal Company in the northern part of Fox Chapel. Entrance to these underground workings is at Harmarville. Because of ordinances that prevent surface mining and the construction of industrial plants in Fox Chapel there is no exploitation of surface resources. In the past there has been some production of oil and gas and sandstone, but at present there is none.

Coal

There is no coal of economic value in Fox Chapel in the rocks that appear above drainage, that is, in rock strata that have surface exposure, with the exception of three small areas where the Pittsburgh Coal occurs in hilltop locations. Those three areas are shown on the geologic map by the symbol "Mp." The largest of these three areas lie just west of Westchester Drive and Buckingham Road and east of an area now being developed known as The Pines. A water tank of the Fox Chapel Authority is located on the hill underlain by the Pittsburgh Coal. It is estimated that there are approximately 5 acres of quality coal having a thickness between 6 and 7 feet, assuming no past mining. The cover (overburden) on it is less than 25 feet. This coal occurs in the "backyard" of eight homes along the upper side of Westchester Drive and Buckingham Road. A ninth house is actually located on the coalbed.

Another small area in Fox Chapel underlain by Pittsburgh Coal of 6 to 7-foot thickness is in The Forest in the hill adjacent to Shadow Ridge Drive. This coal also extends into Harmar Township to the east. The coal crops out on the slope produced by a backyard excavation at 113 Shadow Ridge Drive, and it also occurs at the level of the house foundation at 111 Shadow Ridge Drive. The elevation of the bottom of the seam is 1,258 feet. The outcrop trace of the coalbed extends along the slope behind other houses on that street from number 113 to number 121 at the Harmar Township boundary. The thickness of overburden on the seam ranges from zero up to about 40 feet. The total area underlain by the coal on the Fox Chapel side is estimated at approximately 4 acres.

A third occurrence of Pittsburgh Coal in the Borough is in the hill just west of the end of Bobcind Drive and north of Fairview Road. An old cemetery is located on the top of this hill. The area underlain by the seam is estimated at about 2 acres. Although the coal cannot be seen because of soil cover, its thickness is estimated at 6 to 7 feet as is typical of the Pittsburgh seam. The maximum overburden thickness is only 10 to 15 feet. From the standpoint of geologic structure it is noted that this hill lies at the axis (bottom) of the McMurray Syncline which extends through this site in a northeasterly direction.

There is one other area in the Borough where the Pittsburgh Coal was once present, but has been removed by strip-mining and possibly by underground mining as well. This is on the hill in The Forest north of Old Timber Trail. Most of the coal-bearing area lies in Harmar Township, but part of it is at the southwest end of the elongate hill that lies in Fox Chapel. A bench representing the bottom of the old strip mine is recognizable at this site, as are spoil piles left from the mining operations. The area is now mostly overgrown with small trees.

Aside from the Pittsburgh Coal, the Bakerstown Coal is the only other coalbed that occurs above drainage in Fox Chapel. However, this coal is only a few inches thick and is of no economic value.

In the subsurface below parts of Fox Chapel there is at least one mineable coalbed and maybe more. The one now being mined is the Upper Freeport seam; other seams that are probably present are the Lower Freeport, the three Kittanning seams (Upper, Middle and Lower), the Clarion and Brookville seams, and the Mercer Coal. The stratigraphic position of these seams is shown in Plate 2. As the plate shows, the Upper Freeport seam lies approximately 325 feet below the Ames Limestone and about 195 feet below the lowest beds that crop out in the Borough. Because of hilly terrain the depth to this coal seam differs from place to place. It is of course deeper beneath hilltops than below valley bottoms. Plate 4 shows the area where Upper Freeport Coal has already been mined and the area of probable future mining. The plate also shows by means of isopach lines (lines of equal thickness) the depth of the Upper Freeport Coalbed throughout the Borough. These lines represent the thickness of overburden above the Upper Freeport seam. The range in depth of the coal is from approximately 190 feet to 660 feet. The average depth is on the order of 425 feet. The map shows that the shallowest occurrence of the coal is in Squaw Run valley near the O'Hara Township boundary at Delafield Road where the seam is about 190 feet below the ground surface. The seam is also relatively shallow, at a depth of about 240 feet, at Delafield Road and Valley Drive. In most of the hilltop areas the depth to the coal is in the 400-foot to 600-foot range. It is deepest in The Forest below the hilltop seat of Shadow Ridge Drive where it is approximately 660 feet below the surface.

The depth of a mineable coal seam such as the Upper Freeport is a factor in estimating the risk of surface subsidence as a result of mining. Coal mining produces voids which are filled as the overburden collapses. This collapse produces fractures and settling in the overburden rock which may or may not extend to the surface. Surface effects have been noticed in parts of the Pittsburgh area where the overburden is as much as 600 feet, that is, where the coal lies at a depth of 600 feet. Although the incidence of subsidence that has damaging effects at the surface is greater at shallower depths, it appears that there is some risk even where the coal is several hundred feet deep.

For Upper Freeport coal mining, the evidence suggests that the greatest probability of the occurrence of damaging surface subsidence is where the overburden is 200 feet or less thick. As previously noted, Plate 2 shows that in Fox Chapel there is only one small area, in Squaw Run valley near Delafield Road, where this condition prevails. But the problem is not a real one there because that locality is one in which the Upper Freeport Coal is too thin to be mined in the forseeable future.

The next 200-foot overburden thickness category, between depths of 200 and 400 feet, can be classified as one in which there is low risk of surface subsidence where the Upper Freeport Coal is of mineable thickness. Areas in which the overburden is more than 400 feet (from 400 to more than 650 feet) and the coal is mineable, bear a very low risk (yet some) of surface subsidence based on occurrences in other municipalities where Upper Freeport Coal is being or has been mined. Areas outside the mineable coal in the Borough where there is no risk are left unpatterned in Plate 4.

In the above discussion, only the Upper Freeport Coal is considered. This is because it is the only seam now being mined in the Fox Chapel area. However, there are other seams below the Upper Freeport Coal. The stratigraphic position of these seams is shown in Plate 2. Although the thickness and mineability of these seams in the Borough may be known to private companies from drill data, such information is not available to the public. It is highly unlikely that all those seams, or even the majority of the seams lying below the Upper Freeport are of mineable thickness and quality for the future, but it is possible that at least one is. All of those seams either have been or are being mined somewhere in western Pennsylvania, and although none is now being mined in Fox Chapel, there is a possibility that one or more will be mined when reserves of the more accessible Upper Freeport Coal are exhausted, and when coal is in even greater demand than it is at present.

Assuming that one or more of these seams might be mineable (or might become so), it is not likely that the mineable and unmineable coal areas such as shown for the Upper Freeport Coal in Plate 2 will coincide with those of the Upper Freeport. Without thickness data from drilling the mineable and unmineable areas for these lower coal beds cannot be determined.

The depth to any of the lower seams can be inferred from the map of Plate 4. For example, from Plate 2 it can be seen that the Upper Kittanning Coal lies about 100 feet below the Upper Freeport and the Lower Kittanning Coal lies about 200 feet below the Upper Freeport. Thus, on Plate 4 the isopach line showing a depth of 300 feet to the Upper Freeport Coal also shows a depth of 400 feet to the Upper Kittanning Coal and a depth of 500 feet to the Lower Kittanning Coal. The depth of all other coal seams can be inferred throughout the Borough in a similar manner. It is obvious that any future mining of these seams will be at depths below those of Upper Freeport mining, therefore subsidence should not be a major problem.

Legislation relevant to coal mining and surface subsidence is the "Bituminous Mine Subsidence and Land Conservation Act of 1966" enacted by the Commonwealth of Pennsylvania. The act requires coal operators to leave coal in place beneath churches, schools, hospitals, and cemeteries in existence before the effective date of the act, April 27, 1966. Owners of buidlings constructed after that date have the right to purchase, before mining, a portion of the coal underlying such buildings to protect them from subsidence. Generally this portion amounts to about 50 percent of the coal. Further details on this act are available from the organization that administers it, at the following address:

Division of Mine Subsidence Regulation
Department of Environmental Resources
Donaldsons Crossroads
203 South Washington Road
McMurray, PA 15317

Oil and Gas

There is currently no oil or gas production in Fox Chapel, but there has been in the past. A 1932 geologic map (Richardson, 1932) shows the location of several oil and gas wells within the confines of what is now Fox Chapel. There was a cluster of at least 20 oil wells along Dorseyville Road extending roughly from Mission Lane past Brownshill Road (O'Hara Township) to about the site of Cross Keys Hotel. Most of these were in O'Hara Township, but at least 4 of them were in what is now Fox Chapel on the east side of Dorseyville Road across from the Chapel Crest Terrace area(see Plate 4). Two other oil wells were located on the hill crossed by Millview Drive, and another was located between the upper end of Bobcind Drive and Foxhurst Road. There was also a gas well at the latter site. Five wells were located along Fairview Road at Nantucket Drive; 15 others were drilled in the northeastern part of the Borough, as shown in Plate 4.

A detailed study has not been made to identify all wells that once existed, nor to accurately determine the reservoir rocks from which these wells produced. However, a general summary is given, based on information from a report on the geology of the area by Richardson (1932). The principal producing horizons (reservoir rocks) of the area extend from the Murrysville Sandstone down through the Speechley Sandstone. These are depicted in columnar fashion in Plate 2, a generalized section showing potential oil- and gas-bearing strata in Fox Chapel. This section shows that the Murrysville Sandstone lies about 1,450 feet below the Ames Limestone, a key bed used as a datum in this study, and that the Speechley Sandstone lies about 2,800 feet below the Ames. There are more than a dozen sandstone units between the Murrysville and the Speechley that might contain oil or gas. Whether they contain it in commercial quantities is a question that can be answered only by drilling. It is probable that most Fox Chapel wells produced from sandstones about 1,700 to 1,800 feet below the Ames Limestone. One of the producing horizons was the

Thirty Foot Sand, as known to drillers. This may be the equivalent of the Rosenberry Sandstone of Plate 2. The Lower Nineveh Sandstone, or its equivalent, was likely another producing horizon.

To be a good producing sandstone, a rock must be permeable enough so that oil and/or gas can move through it to a well. Generally the sandstones shown in Plate 2 have permeability that ranges from low to moderately good. Locally they have good permeability and are therefore good reservoir rocks. The secret to finding an oil or gas "pool" is to find an oil and/or gas-bearing sandstone with good permeability. In the Fox Chapel area this is pretty much a hit-or-miss proposition because the permeability characteristics of the sandstone units change laterally and, aside from drilling, there is no good method of determining where a reservoir rock will have the necessary permeability.

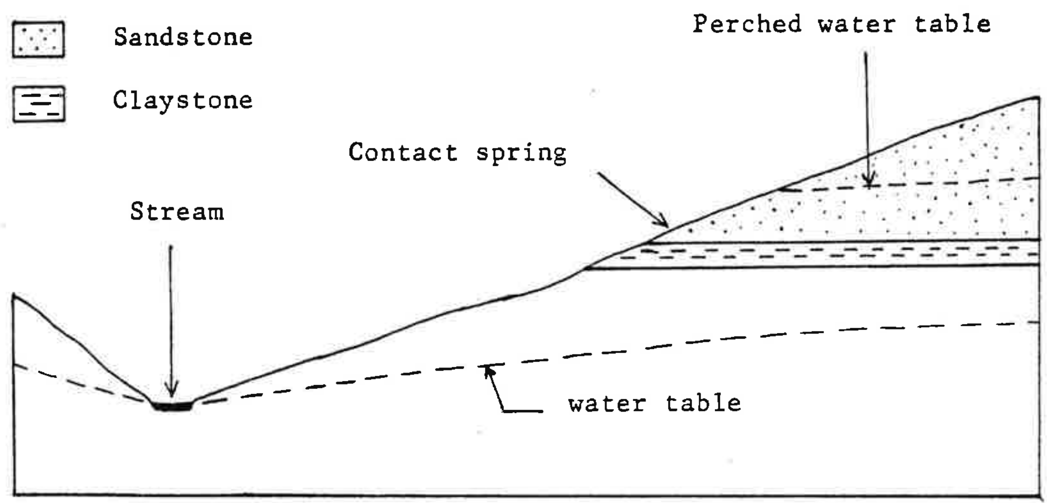
One oil well drilled in 1899 in the nearby Glenshaw Field of Shaler, O'Hara, and Indiana Townships had an initial daily production of 800 barrels. By 1917 (18 years later) the production had dwindled to only 18 barrels per month. This is because the area of permeable sandstone within the producing formation was not large enough to maintain good production for a longer time. Other wells probably had a similar history. Because of the lateral variation of permeability in sandstone reservoir rocks in Fox Chapel, the difficulty in predicting where the permeable rock areas are located, and the prospects of only modest production in the long term, Fox Chapel is one of the less attractive areas for future oil and gas exploration.

A deep reservoir rock that is well known as a natural gas producer in western Pennsylvania is the Oriskany Sandstone. This lies several thousand feet below the Ames Limestone in Fox Chapel, and presumably is untested as a source of gas. It is not considered a good prospect, however, because gas "pools" in it are generally located in anticlinal structures and the geologic structure in Fox Chapel is synclinal.

Groundwater

Groundwater is an important mineral resource in areas where it is used for industrial purposes and air-conditioning, and where it is a source of domestic and farm water supplies. None of these uses is particularly pertinent to Fox Chapel, although there might be a need to augment water supplies on certain properties from groundwater sources. A brief description of the occurrence of groundwater is appropriate because groundwater is the feeder of streams that keeps them flowing year round in periods of sparse rainfall and it is the source of springs that occur on many properties. Springs in the Borough are a "mixed blessing." On some properties there are attractive spring houses and ponds fed by springs that are aesthetically pleasing. On others there are springs that contribute to slope instability where spring water permeates into clayey soil to create drainage problems and make the soil more susceptible to movement (landsliding).

Groundwater is the water that occurs below the ground surface. It is water in the tiny pore spaces between rock grains, and not in open "pools." The water table is the top of the subsurface zone that is saturated with water. In this zone, openings in the rock are completely filled with water. Above the water table, rocks are unsaturated, meaning that small openings in the rock are only partly filled with water. The depth to the water table varies from place to place. It intersects the surface wherever there is a stream, pond, swamp, or spring. Wells that produce water are wells drilled into the saturated zone below the water table. In Fox Chapel there are numerous perched water tables, meaning water-saturated zones that occur at some level above that of the general water table of the area, as illustrated in the sketch below.



The presence of a perched water table is explained by the presence of rock layers of different permeability in contact with each other. Where a permeable sandstone unit overlies an impermeable (or relatively impermeable) claystone unit, a perched water table is likely to form. This is because surface water (precipitation) moves downward through permeable sandstone to the level of impermeable claystone through which it cannot move. Thus, groundwater accumulates in the sandstone to form a saturated zone with a water table at its top. If the contact between the sandstone and claystone has a slight dip toward the surface, as opposed to a dip into the hill, then the groundwater moves in the direction of that dip until it reaches the surface, thereby forming a hillside spring. A "line" of discontinuous springs is common on slopes where such a contact exists. The stratigraphic section in the Borough contains several sandstone-claystone combinations of this type, namely, Connellsville Sandstone above Clarksburg Redbeds, Morgantown Sandstone above Schenley Redbeds, Birmingham Sandstone-Shale above Duquesne Claystone, and Saltsburg Sandstone above Woods Run Claystone (see Plate 2). Localities where springs can be expected at these horizons can be identified on the geologic map (Plate 1). For example, the dashed line representing the contact between the zones labeled "Cm" and "Csch" on the map. By following this line, one is following a line along which springs are likely to occur. In a similar fashion, other areas where springs are prevalent can be identified by following the lines on the map representing the contacts between the other sandstone-claystone combinations mentioned above.

In addition to using these contacts to identify potential spring areas, structure contours can also be used, in the following way. Since groundwater flow from perched water zones is enhanced by the dip of rock layers, the likelihood of contact-type springs is greatest where beds are dipping "out of the hill," that is, toward the surface on a hillside. Structure contours on the geologic map show the direction of dip throughout the Borough, the dip being perpendicular to the trend of structure contours and toward the contour of lower number, for example, from the 980-foot contour toward the 970-foot contour, or from the 950-foot contour toward the 940-foot contour. As a further example, in the northwestern part of Fox Chapel where beds dip southeasterly, and where one or more of the sandstone-claystone combinations crop out, contact-type springs can be expected on southeast-facing slopes. One such spring is Silver Spring (as it was formerly known) on the west side of Old Mill Road between Millview Drive and the bridge over Squaw Run. This spring is at the Morgantown Sandstone-Schenley Redbeds contact at a site where there is a gentle dip toward Old Mill Road.

The occurrence of groundwater in rocks is related to the size of pores between the grains that compose the rock. Pore spaces are relatively large (the size of a pinhead) between the sand grains of a sandstone, and are relatively small (visible only under high-powered microscope) between the tiny clay grains of a claystone. This means that water cannot move freely through claystone, even though all the pores are filled (water-saturated) whereas water can move freely (at a rate of a few inches to a few feet per day perhaps) from one pore to the next in a sandstone. In other words, sandstones are permeable and claystones are not. Another factor, in addition to pores, that controls water movement are fractures (joints) and bedding planes (the plane separating beds one from another). Claystones have no bedding planes but sandstones do. Fractures in claystones, though abundant, are such that they are essentially "sealed," but in sandstones, joint fractures are not completely sealed and they represent openings along which water can move. Sandstones are said to be "aquifers" (water-bearers and water transmitters), whereas claystones are "aquicludes" or water seals.

Shale is an abundant rock type in Fox Chapel that may contain various amounts of water. It may be permeable or it may be essentially impermeable, depending on the type of shale. Shale that contains considerable sand in addition to the dominant clay grains may be fairly permeable because of the presence of sand grains. This type is known as "sandy shale." However, shale that does not contain sand grains has low permeability. This is the clay-shale type.

The best aquifers in Fox Chapel are the sandstone units whose names are Connellsville, Morgantown, Birmingham, Saltsburg, and Powers Run. If a groundwater supply is sought from a drilled well, one of these sandstones should be the "target" aquifer. Since the Connellsville Sandstone lies high topographically near hilltops it has less of a "collecting area" for water than stratigraphically lower sandstone units, and is therefore a less important aquifer than others. Also, in the valley bottoms of larger valleys, most of these sandstones have been eroded away, or are so close to the surface that they are not good aquifers.

The depth at which the sandstones occur can be predicted from the geologic map. To give an example of the use of the map in predicting the depth to which a well would have to be drilled to penetrate a given aquifer, assume that at Shadyside Academy (main school) an auxiliary water supply is sought from a drilled well. The well is to be drilled just north of the football field where the surface elevation is 983 feet (taken from topographic contours on base map). The geologic map shows that the Birmingham Sandstone-Shale unit crops out at that site, so this unit is not a source of groundwater for that reason. The Morgantown Sandstone, another potential aquifer of the area, crops out at a higher elevation which is above the level of the upper tennis courts, thereby eliminating it as a possibility. The Connellsville Sandstone is not present at all because even the hilltop at Shadyside has been eroded down to a level below that sandstone. So in the subsurface, at the site where the well is to be drilled, the Saltsburg and Powers Run Sandstones are the two possibilities among the aquifers that occur in the stratigraphic section represented in surface exposure in the Borough. There are also deeper aquifers that do not crop out anywhere in Fox Chapel. These are described later.

First, to predict the depth of the Saltsburg Sandstone at Shadyside the surface elevation of 983 feet is taken into account. Then the elevation of the Ames Limestone at the well site is determined from the structure contours. By interpolation, the Ames is estimated at elevation 915 feet, thus the depth to the Ames is 68 feet (983' minus 915'). The columnar stratigraphic column (Plate 2) shows that the interval from the Ames to the top of the Saltsburg Sandstone is about 25 feet, therefore the depth of the well to the top of the Saltsburg would be 93 feet (68' plus 25'), and if the well is drilled into the water-bearing sandstone itself another 10 or 15 feet, the total depth would be 103 to 118 feet. In case an adequate supply of water is not found in the Saltsburg Sandstone the well could be deepended to penetrate the next aquifer below, namely, the Powers Run Sandstone. This would require drilling to a depth of 153 feet since the interval from the Ames to the top of the Powers Run is about 85 feet (68' plus 85' = 153').

Although no specific information on aquifers that lie below the Powers Run Sandstone has been obtained in the current study, it is known from studies in other areas that water-bearing sandstones below the Powers Run Sandstone do occur in Allegheny County. These sandstones are shown in columnar section in Plate 2. All the sandstones from the Buffalo downward are below the level of the deepest valleys at Salamander Park, where the surface elevation is about 800 feet and where the Powers Run Sandstone crops out, that well would have the possibility of penetrating various water-bearing sandstones, first the Buffalo at a depth of approximately 110 feet, then the Mahoning at about 180 feet, the Butler at 230 feet, and so on.

However, there is the possibility of finding salt water (brine) and not fresh water in these deeper aquifers. Generally speaking, wells which penetrate to a depth of more than 100 feet below the level of the nearest major stream in Allegheny County are likely to encounter salt water. For Fox Chapel, where the nearest major stream is the Allegheny River (at elevation 720 feet), wells that extend to a depth below elevation 620 feet would be in this category. This means that in the valley bottom of Squaw Run in the southern part of the Borough, sandstones below the Buffalo at a depth greater than 200 feet or so are likely to contain brine. But wells drilled at higher elevations, for example, at an elevation of 1,150 feet, could be drilled to a depth of nearly 550 feet and still be in the fresh-water zone. If this hypothetical well were drilled where the out-cropping rock unit at the 1,150 feet elevation is the Connellsville Sandstone, then the Mahoning Sandstone and Butler Sandstone would likely contain fresh water, but other sandstone below the Butler would be expected to contain brine.

As another example, a water well drilled in The Forest on the hill adjacent to Shadow Ridge Drive at an elevation of 1,260 feet would start at the Pittsburgh Coal and could be drilled to a predicted depth of about 650 feet before encountering salt water. In such a well there would be potential fresh-water aquifers down through the Butler Sandstone which would be at an estimated depth of 650 feet, and at elevation 610 feet above sea level.

It is likely that any well in the Borough drilled deeply enough to penetrate the Freeport Sandstone would encounter brine. This also applies to wells that go deeper than the Freeport Sandstone.

No specific information is available on water yield from Fox Chapel aquifers, but estimates can be given based on yields from the same aquifers at other localities in Allegheny County and in Butler County. Sandstone aquifers in the Conemaugh Group, namely the Connellsville, Morgantown, Birmingham, Saltsburg, Powers Run, Buffalo, and Mahoning Sandstones have water yields ranging from a few gallons per minute up to about 100 gallons per minute. The large range in yield is related to permeability changes in the sandstones. Since these sandstone units change laterally from more sandy facies to more shaly facies, so too does the permeability change accordingly. The larger yields come from the more sandy facies.

Sandstone aquifers in the Allegheny Group have a higher range of water yield than those in the Conemaugh Group, namely, from a few gallons per minute up to about 300 gallons per minute. As for Conemaugh sandstones, those of the Allegheny Group show lateral facies changes and therefore permeability changes. Even though higher yields can be expected from Allegheny Group sandstones, only the uppermost one, the Butler Sandstone, is likely to be in the fresh-water zone. The underlying Freeport Sandstone and others below it are predicted to contain salt water in Fox Chapel.

Sandstone

Although sandstone has been quarried on a small scale for local use in Fox Chapel in the past, there is no high-quality sandstone of economic value in the Borough. The one locality where several small abandoned quarries are located is in Squaw Run valley between the sites where Fox Chapel Road and Field Club Road cross Squaw Run. In that stretch of nearly one-half mile there are four places, two on each side of the stream, where the Powers Run Sandstone has been quarried from the steep valley walls. The sandstone outcrop extends vertically from stream level up the valley wall for about 25 feet. The sandstone is medium-grained and occurs in beds from a few inches to 3 feet thick. In part the sandstone is flaggy, that is, its bedding is sufficiently uniform to allow it to break out into tabular-shaped chunks. This is a desirable characteristic for building stone, but the presence of interbedded layers of shaly sandstone is an undesirable feature. It is not precisely known when the quarrying in this area was done. Probably it was about 75 years ago when farming was prevalent in the area and the stone was used for such things as barn and bridge foundations and retaining walls. Some of it was probably used in constructing walls at the pond where Salamander Park is now located. That pond was allegedly used as an ice pond in earlier days.

There are no other places in Fox Chapel where old sandstone quarries such as these occur. However, there are numerous sites where one or more of the sandstone units shown in the stratigraphic section of Plate 2 crop out and where loose stone has been hand-picked from the outcrop for local use on private property. Currently the sand-stone used for retaining walls and other construction in the Borough is brought in from outside sources. There is a minor use though of sandstone blocks dug up when excavating for new homes. In some places these blocks are used as decorative stone on lawns, along driveways, etc.

Sand and Gravel

Sand and gravel are used extensively in the Pittsburgh area in construction as aggregate mixed with cement to make concrete. There is no indication, however, that deposits of sand and gravel have ever been worked for commercail production in the past in Fox Chapel even though there are suitable deposits wihtin the Borough limits near its southern extremity. The deposits occur in the area encompassed by East Waldheim Road, The Maples, Alpine Circle, The Oaks, Glenover Place, and South Pasadena Drive from elevation 895 or 900 feet up to about 950 feet (the highest elevation in that area). These deposits also extend into the Veterans Administration Hospital site and into the upper side of Woodshire Drive in O'Hara Township. There is a very small area of these deposits adjacent to the end of Rockingham Road (O'Hara Township) where the Rockwood Plan is currently being developed. These deposits also extend through the upper Oakhill Manor development and the RIDC area of O'Hara Township. Another locality is in the upper part of Blawnox where there was formerly a commercial gravel pit on Boyd Avenue. (A recently constructed apartment building is now located at that site.)

On the geologic map the sand and gravel deposits are shown by the symbol "Ig" (for Illinoisan gravel), as differentiated from "Is" which refers to the sand-silt-clay facies of the Carmichaels Formation. These deposits are unconsolidated because they are geologically young and have never been buried beneath other deposits. Although they are not as high quality as the sand and gravel dredged from the Allegheny and Ohio Rivers, the material is suitable for commercial use as aggregate. There is currently a gravel pit at Acmetonia from which this type gravel is being extracted.

A much more extensive area of Carmichaels Formation in Fox Chapel is that mapped as "Is," extending through the Fox Chapel Golf Club and Pittsburgh Field Club properties and into the Hickory Hill Road-Hawthorne Road-Hillcrest Road area. But this is a fine sand-silt-clay facies of the Carmichaels not suitable for use as aggregate because of its fine grain size. However, this material has been used in other places, along the Monongahela and Youghiogheny River valleys,in making building brick, stoneware, and roofing tile.

Clay and Shale

Clay occurs in Fox Chapel in two types of deposit. One is the clay admixed with silt and fine sand in the unconsolidated Carmichaels Formation described immediately above, and the other is consolidated claystone occurring as bedrock in stratigraphic units known as the Woods Run Claystone, Duquesne Claystone, Schenley Redbeds (claystone), Pittsburgh Redbeds (claystone), and Clarksburg Redbeds (claystone). Shale occurs in thinly bedded bedrock layers ranging from clay shale to silty and sandy shale.

In western Pennsylvania, clay and shale are used for making various products such as building brick (common brick), refractory brick, stoneware, sewer pipe, and roofing tile. High quality clay is needed for making refractory brick. Such clay does not exist in Fox Chapel. For making the other products listed, material specifications are less rigid. Probably all of the claystone units in Fox Chapel, with the exception of the Duquesne which contains too much calcium carbonate (limestone) are suited for this. The Milliken Brick Company, operating in nearby Indiana Township, utilizes the claystone of the Pittsburgh Redbeds and the unnamed shale above the Ames Limestone ("Cprb" and "Cd" on the geologic map) in making red building brick. These units in Fox Chapel have similar characteristics as at the Milliken Brick site.

Limestone

Limestone is used in several ways in western Pennsylvania. Some is used as dimension stone (building stone), some is crushed and used as aggregate in concrete, and some is "burned" to make lime. There is no limestone in Fox Chapel suitable for any of these purposes. The two limestone units that do occur in the Borough, the Ames and the Lower Pittsburgh are thin, impure, and without economic value. However, as described in the section on stratigraphy, the Ames is of particular geologic interest because of its abundant marine fauna (fossil shells) and its usefulness as a key bed of the stratigraphic column.

6. Desired Outcomes

The foregoing information has prepared us to specify a set of concrete, measurable desired outcomes in the form:

$$\text{Outcome} = f(\text{Land, Land Use})$$

These outcomes are derived from the "ideals" stated in "Fox Chapel's Natural Resource Problem", specifically for the geologic aspects of the problem. The relationships of the outcomes to other desired outcomes will be specified, and resulting courses of action selected, under "Conclusions."

For the foundation of any road, building or other valuable structure:

$$I_{SF} = H_{SF} \; G_F$$

and:

$$I_{RF} = H_{RF} \; G_F$$

where:

I_{SF} = foundation instability with respect to slumps and earthflows. Desired outcome: minimize I_{SF}.

H_{SF} = slump and earthflow hazard of rock type on which the foundation rests (vs. which surrounds the foundation wall) -- (all known slumps and earthflows are classified "High" hazard).

G_F = slope gradient immediately downslope from the foundation. G_F should be measured over three consecutive 5-foot contours.

I_{RF} = foundation instability with respect to rockfalls. Desired outcome: minimize I_{RF}.

H_{RF} = rockfall hazard of rock type on which the foundation rests (vs. which surrounds the foundation wall) -- (all known rockfalls are classified "High" hazard).

For any portion of a cut slope homogeneous with respect to the slump-earthflow hazard classfication of the outcropping rock type:

$$I_{SC} = H_{SC}\ G_C$$

where:

I_{SC} = stability of the cut slope portion with respect to slumps and earthflows. Desired outcome: minimize I_{SC}.

H_{SC} = slump and earthflow hazard of the outcropping rock type (all known slumps and earthflows are classified "High" hazard).

G_C = gradient of the cut slope at the outcropping rock type. G_C should be measured over three consecutive 5-foot contours.

For any portion of a cut slope homogeneous with respect to the rockfall hazard classification of the outcropping rock type:

$$I_{RC} = H_{RC}\ G_C$$

where:

I_{RC} = stability of the cut slope portion with respect to rockfalls. Desired outcome: minimize I_{RC}.

H_{RC} = rockfall hazard of the outcropping rock type (all known rockfalls are classified "High" hazard).

TOPOGRAPHY

1. Land

Topography is the shape of the ground surface, distributed over space and changing over time. That topography is relevant to natural resources problems is well known. However, speculations about the nature of this relevance have been diverse and usually ambiguous. Figure 66 shows that there is little agreement over the way the most well-known topographic characteristic, slope gradient, interacts with applied problems.

This apparent confusion results from the indirectness of topography's relevance to natural resources problems. Topography has no direct, lone relationship to such problems. Its well-known relevance occurs only through its interaction with other natural features and processes. Some characteristics of topography that interact with other features and processes that are described elsewhere in this report are listed in Figure 67. These and other characteristics also interact with other features, processes and technologies, such as amounts of cut and fill, volume of erosion, and time of runoff concentration. These interactions are described in the appropriate sections of this report, and are not discussed further here.

Generally, Fox Chapel's topography is hilly and steep. Ridges are in systems of connected knobs between stream valleys. There are no closed depressions. The highest elevation (near "The Forest") is 1,304 feet above sea level; the lowest (where Squaw Run leaves the Borough near Fox Chapel Road) is 769 feet, which gives a total relief of 535 feet.

Source	Gradient Class Boundaries (%)
U. S. Geological Survey, 7.5 minute quadrangles, clinometric series	0 - 8 - 16 - 25 - ∞
U. S. Geological Survey, 7.5 minute quadrangles, landslide hazard maps, Greater Pittsburgh Region	0 - $15\pm$ - ∞
Soil Survey (U.S.S.C.S., 1973)	0 - 3 - 8 - 15 - 25 - 35 - 45 - 75 - 80 - ∞
Carmean, 1967 (re Site Index)	0 - 35 - ∞
Borough Grading Ordinance (1973)	0 - 15 - 20 - 25 - 33-1/3 - 50 - 66-2/3 - ∞
Borough Subdivision Ordinance (1964)	0 - 24 - ∞
Borough Natural Resources Ordinance (1977)	0 - 8 - 15 - 25 - ∞
Borough Comprehensive Plan (1963)	0 - 25 - ∞

FIGURE 66. Some existing systems for classifying slope gradient in Fox Chapel or in the general Pittsburgh Plateaus. Many of these systems were devised for the same purposes.

Symbol	Topographic Characteristic	Definition	Some Interactions with other Features and Processes
V	Elevation	Vertical Distance above a datum	Degree Days ("Thermosphere")
ΔV	Vertical Distance	$V_2 - V_1$	Visible Relief ("Aesthetics")
H	Horizontal Location	Horizontal Distance from a datum	Geographic Distribution (Maps)
ΔH	Horizontal Distance	$H_2 - H_1$	Visible Horizontal Distance ("Aesthetics")
G	Slope Gradient	$\Delta V \div \Delta H$	Slope Gradient ("Lithosphere")
None	Horizontal Slope Shape	Digression of Contour from a straight line	Site Index ("Biosphere")
None	Slope Orientation	Orientation of Contour Line relative to a horizontal direction	Site Index ("Biosphere")
A_D	Drainage Area	Area that contributes surface water to a given point if all rainfall flows on the ground surface	Drainage Area ("Hydrosphere")

FIGURE 67. Some characteristics of topography that interact with other natural features and processes described in this report.

SOIL

1. Land

Soil is formed and distributed geographically by a network of processes that are summarized by the equation (Jenny, 1961):

$$S = f(C, O, R, P)t$$

where:

S = soil
C = climate
O = organisms
R = relief
P = parent material
t = extension of the above over time.

The resulting soil is defined in terms of the influence upon it of these formative factors:

soil: "the collection of natural bodies occupying portions of the earth's surface that support plants and that have properties due to the integrated effect of climate and living matter, acting upon parent material, as conditioned by relief, over periods of time" (U. S. Department of Agriculture, 1951, page 8).

So defined, soil is the same as most concepts of "land". It is a synthetic phenomenon, incorporating all characteristics of the landscape in a single view. A soil type is therefore a "gestalt" interpretation of the landscape, judged directly from observation of the field or of a summary representation without consideration of the indentity of individual landscape components.

The U. S. Soil Conservation Service (1973) mapped Fox Chapel's soil according to the above definition. Its classification of soil types was qualitative, polythetic, and agriculturally biased; hence the ability of a soil type to predict land properties pertinent to specialized tasks is limited. Its mapping methods relied almost absolutely on the correlation of changes in soil type with some visible change in landscape characteristics. Hence its mapping accuracy was limited by forest uniformity, microtopographic changes, etc., which disguised soils at the scale of mapping; and its ability to predict land properties, sich as site index or floodprone zones, which may leave few marks on the land, was limited (McAvin, Ferguson and Bockheim, in progress). The accuracy limits were confirmed by a study (Amos and Whiteside, 1975) which found that S.C.S. soil maps may be grossly inaccurate at the scale with which decision-makers similar to Fox Chapel are concerned.

In addition to "gestalt", the two other types of landscape interpretation are "logical" and "mathematical". Logical interpretations are verbal rules that express qualitative relationships among separate landscape characteristics, such as that landslide hazard exists on certain combinations of rock type and slope. "Mathematical" interpretations are symbolic equations that express quantitative relationships among separate landscape characteristics, such as an equation for runoff, $Q = cai$. Logical and mathematical interpretations can be applied to any known landscape characteristics in order to yield other, unknown, landscape characteristics or to produce land use plans. "Overlaying" is the inference of the geographic distribution of a dependent variable from that of one or more independent variables: if the independent variables are mapped or mappable, then their dependent variables are in turn mappable by logic or mathematics. Such derivation may be tailored to particular specialized planning purposes (Ferguson, February, 1980).

Unlike the S.C.S. surveys, this Natural Resources Plan uses logical and mathematical overlays to identify and to map landscape characteristics that are relevant to Fox Chapel's desired outcomes. The quality of its base data (known independent variables, such as SRAWA's topographic map), its explicit derivation of conclusions from separate landscape components, and its budget per unit area make its results contrast with those of S.C.S. in the way shown in Figure 68.

Judging from Figure 68, this Plan is more detailed than the S.C.S. survey and tailored more specifically to the needs of Fox Chapel; hence its identification and mapping of relevant variables are more accurate. The accuracy of this Plan is limited by the accuracy of SRAWA's topographic map, the accuracy of our logical and mathematical relationships, and the mechanics of overlaying; the result is confidently presumed to be superior to the S.C.S. maps in accuracy and in relevance.

Consequently, in seeking the identification, distribution and relevance to performance of uncontrolled variables, the decision-maker should refer to the appropriate specialized sections of this report, and not attempt to break apart the gestalt concepts of the Soil Survey. The terms defined in this report that may replace some terms in S.C.S.'s report are given in Figure 69.

Study Characteristic	S.C.S. Soil Survey	Fox Chapel Borough Natural Resources Plan
Scale	1" = 1,320'	1" = 200'
Independent Variables (Base Data)	Aerial Photographs (qualitative)	5' topographic contours, and as noted
Smallest Mapped Area	±3 acre	±.02 acre
Purpose of Mapping Unit Definition	Agricultural	Natural Resources Plan
Form of Mapping Unit Definition	Gestalt	Logical and Mathematical
Types of Mapped Boundaries	Visible	Measured and Calculated

FIGURE 68. Contrast of this Natural Resources Plan with the soil survey prepared by the U. S. Soil Conservation Service (1973).

Term Defined in this Plan	Soil Characteristic or Interpretation Defined by S.C.S.
runoff-producing zone	hydrologic soil group
floodprone zone	flood hazard
site index	capability class, site index
landslide hazard	landslide hazard
zone of wet soil	soil drainage
disturbance sediment	erodibility
community	associated species

FIGURE 69. Correspondences between some of the defined terms in this Plan and soil characteristics or interpretations given by the Soil Conservation Service (1973).

3. CONCLUSIONS

The "Desired Outcomes" portions of Section 2 produced a set of concrete, measurable desired outcomes in the form:

Outcome = f(Land, Land Use).

All technologies, environments and outcomes mentioned in these equations are defined in the relevant chapters.

This section specifies the relationships among the outcomes, selects resulting courses of action, and compares the selected actions with existing Borough management.

Each of the performance (outcome) equations represents one action of the overall, complicated land use action that must be decided in any subproblem. These decisions will occur under conditions of relative certainty - that is, the nature, behavior and geographic distributions of the uncontrolled variables are relatively well known as a result of this study. Thus, given a subproblem which occurs at a given location and therefore in a given resource environment, the solution is the selection of the suite of land use (controlled) actions that optimize the combination of performance variables in that resource environment (Levin and Kirkpatrick, 1978).

OWNERSHIP AND COURSES OF ACTION

Existing ownership determines who is susceptible to natural hazards, and who controls natural resources. As listed in Figure 13, property owners in the Borough include three levels of government, about 1,600 (extrapolated from Borough of Fox Chapel, 1978) private individuals and organizations, and some utility companies.

Existing ownership is inventoried on the new Squaw Run Area Property Line Map (Ferguson,July,1980), which may be viewed at the Borough office or at SRAWA. In addition to the direct ownership shown on that map, increased road right-of-way widths are expected gradually to be dedicated to government as a result of the Borough Subdivision requirements requirements. Also, utility and other easements are not shown on the Property Line Map; the locations and conditions of these easements depend on the contractual agreements by which they were established.

The relationships of potential Borough actions to land ownership are summarized in Figure 70.

Land use developments on privately-owned lands are proposed by private developers. In anticipation of future such proposals, the Borough may pass maintenance or development requirements to which the developments must conform. Standards must be established uniformly and in the abstract, not in expectation of particular proposals on particular sites. Ideally, Fox Chapel should set the right standards, set them strongly, and stick to them when developments are proposed. When an existing developed site is threatened by an environmental hazard, the Borough may step in with its own corrective measures.

On Borough-owned land, the Borough may initiate its own developments or modify maintenance. Where problems or resources cannot be adequately handled by private means, the Borough may acquire the land in order to take the initiative.

RECOMMENDED COURSES OF ACTION

All of the information presented so far has prepared us to infer courses of action for the Borough from our understanding of the relationships of land, land use and performance. This is done in Figure 70. In Figure 70 all technologies, terms, etc. are defined and explained in the relevant portions of "Fox Chapel's Natural Resources and Their Importance." In implementing our recommendations, reference must be made to those discussions. The courses of action recommended in Figure 70 are "performance" standards where enough is known about the variables to make statements possible; otherwise, they are "design" standards.

As listed in Figure 70, different actions are implementable on lands either owned by the Borough or influenced by the Borough through land use ordinances.

Borough-owned lands are: the Borough Building property, about 200 acres of parks, active Borough roads, and unused Borough rights-of-way. On all actively used properties the Borough can design its regular maintenance operations to meet the recommended actions (such as minimizing mowed area), subject to other practical considerations.

Actively used Borough properties that are susceptible to severe environmental hazards can be repaired. Where important land use or environmental processes would conflict with feasible repairs, the Borough facility can be relocated. Specifically, Old Mill Road at the springhouse-landslide area is an example of a major land use-environmental conflict, and the relocation of the road to the Squaw Run valley (connecting to Squaw Run Road East) could be a long-term goal for the development of that valley. Squaw Run Road just south of Field Club Road is an example of conflict with stream undercutting; moving the road might be easier than controlling the stream by further rock dumping.

RECOMMENDED COURSE OF ACTION	ADD TO: Construction & Maintenance of Borough-owned land	ADD TO: land-use ordinance	REF. ORDINANCE	REF. PAGE OF THIS PLAN
1. Design primary drainage systems to frequency standards of Pa. Dept. of Environmental Resources (1980). Run-off that overflows the primary drainage system must be conveyed without damage to homes, roads, and all other used facilities.	x	x	FP; S:VI.4; NR:VI.1	58
2. Locate all homes, roads, sewers, pump stations, lawns, other used facilities, and all clearing and grading, outside all <u>lowlands</u>, except at unavoidable road and utility crossings. Any road surface and the top of any manhole located in a <u>lowland</u> must be at least five feet above the <u>stream</u> line. A road that crosses a <u>stream</u> must convey water under the road by a culvert, and not onto the road's gutter. Where a cut slope intercepts a <u>stream</u>, the water must be conveyed down the slope by primary and secondary drainage structures.	x	x	FP; S:VI.4; NR:VI.1	58
3. Install subdrains around foundations of buildings, roads and other used facilities in all cut areas and anywhere else groundwater is encountered during excavation for foundations.	x	x	no precedent	59

FIGURE 70. Summary of recommended courses of action. Existing ordinances that cover aspects of these actions are listed. The recommendations were devised from mathematical relationships given on the listed pages of this Plan. Continued on following page. Referenced ordinances: FP = Floodplain; G = Grading; NR = Natural Resources; S = Subdivision; Z = Zoning.

RECOMMENDED COURSE OF ACTION	ADD TO: Construction & Maintenance of Borough-owned land	ADD TO: land-use ordinance	REF. ORDINANCE	REF. PAGE OF THIS PLAN
4. The following standards are applicable at any point along a construction area boundary: Peak runoff flow after development shall not exceed that before development at recurrence intervals of 10 to 50 years; runoff flow volume shall not exceed that before development at the 2-year recurrence interval. No sediment may be released from construction areas.	x	x	G; S:VI.3.2, 4.3, 4.6.B; NR:VI.2, f,g	59, 60
5. Locate lawns only in uplands. Minimize lawn area and rates of fertilization and spraying.	x		no precedent	61, 93
6. Maintain golf course ponds and Campbell's Lake as pollutant traps; dispose dredge spoils updrainage.		x	no precedent	61, 62
7. Minimize lengths of roads and sewers in site plans.		x	no precedent	61, 62
8. Seal existing sewers per Bankson report (1979).	x		Bankson (1979)	61, 62
9. Intercept pump station and treatment plants by gravity sewers. If warranted, purchase Ottawa treatment plant or contract for its operation.	x		no precedent	61, 62
10. Minimize rate of application of road salts.	x		no precedent	62

FIGURE 70. Continued from previous page.

RECOMMENDED COURSE OF ACTION	ADD TO: Construction & Maintenance of Borough-owned land	ADD TO: land-use ordinance	REF. ORDINANCE	REF. PAGE OF THIS PLAN
11. Follow latest BOCA building guidelines for energy conservation.	x	x	Borough building code.	92
12. Maximize location of buildings on warm southwest-facing slopes.	x		no precedent	92
13. Maximize shading of pavements by vegetative canopy.	x		Z:III-A. 305.2; 307; S:V.7	92
14. No new solid shade-making object may be placed in the solar "window" (Figure 44) of any point on another property at which the placement of a structure is permitted by the Borough Zoning Ordinance.	x	x	no precedent	93
15. Design and construct a system of public bikeways to reduce gas consumption.	x		no precedent	94
16. Areas of unique stands preserved in their entirety.	x	x	NR:VI.1.c.	128, 138
17. The terrestrial area left in successional vegetation after development on high site index land must be at least 50% of that before development.	x	x	NR:VI.2.c.	128

FIGURE ~~30~~ 70. Continued from previous page.

RECOMMENDED COURSE OF ACTION	ADD TO: Construction & Maintenance of Borough-owned land	ADD TO: land-use ordinance	REF. ORDINANCE	REF. PAGE OF THIS PLAN
18. The composite existing terrestrial productivity and diversity on a site after development must be at least 50% of that before development.	x	x	NR:VI.1.f., VI.2.c.	129, 130
19. The most mature ecological community on a site after development must be as mature as that before development.	x	x	NR:VI.2.c., d.	131
20. All identified unique trees must be preserved.	x		NR:II.1. 4.v.	131
21. The area of ponds and wetlands, the number of waterfalls, and the area of cliffs must not be reduced during development.	x	x	NR:VI.1.c; 2.c., d.,e.	136 - 139
22. Maximize the total area of forest canopy that is at least as high and dense as that of secondary forest.	x		NR:VI.1.c., 2.c.	138
23. For either foundation support or cut slope stability, the supporting slope gradient must be 25% or less when the hazard rating of the supporting rock formation is "moderate" or "high," unless an adequate engineering solution is documented by a soils engineer.	x	x	G; NR:VI.1.c., 2.c.	201 - 202

FIGURE 70. Continued from previous page.

RECOMMENDED COURSE OF ACTION	ADD TO: Construction & Maintenance of Borough-owned land	ADD TO: land-use ordinance	REF. ORDINANCE	REF. PAGE OF THIS PLAN
24. The detailed design of drainage conveyance and other land use components should be modified in certain ways given in the text.	x	x	G; S: NR:	48, 54

FIGURE 70. Continued from previous page.

Unused Borough road rights-of-way can be redesignated for uses that meet the recommended courses of action. Several such rights-of-way have been mapped, mostly in the older, dense parts of the Borough. Designating them as "Conservation Corridors", forbidding most access, and leaving them to natural succession would help to meet many of the Borough's ecological objectives. Before deciding on such redesignation, legal records should be checked for the necessity to give normal access to any surrounding properties.

Right-of-way redesignation brings up the possibility of a major Borough program to cut down on vehicular energy use (Figure 70). That is a Borough-wide system of bikeways to connect residential areas (where traffic is generated) to the recreational and commercial areas that are the destination of much of the traffic. Detailed planning of the bikeways should use the new property line map (Ferguson,July,1980) to locate routes, and should be coordinated with any similar efforts in O'Hara Township (such as to connect the Squaw Run valley to commercial areas and the Fox Chapel Mews to the south). Gentle gradients are critical for bike travel. In conceiving the system, the level parts of central Fox Chapel (where most of the recreation is at a middle elevation) can be visualized as a major "bicycling region", with the Squaw Run valley being a second "region" at a lower elevation, and with other parts of the Borough having to be reached somehow by major elevation changes. The components of the system could be:

1. Low-traffic through roads, with little special development except possibly signage at curves. Examples: Buckingham Road; Field Club Road between Squaw Run and old Hawthorne Road; Squaw Run Road East.

2. Unused Borough road rights-of-way, where necessary for low gradient or to bypass dangerous high-traffic roads, specially developed for bike travel. Examples: old Hawthorn Road (to bypass Squaw Run and Fox Chapel Roads from Field Club Road to Salamander Park); Shady Lane (to bypass Delafield Road).

3. Routes through Borough park lands, specially developed for bike travel. Examples: connecting Old Mill Road and Squaw Run Road East; from Salamander Park southward in Squaw Run valley.

4. All existing low-traffic local roads, without special development. These would be the feeders onto the specially developed bike routes.

5. Routes through private lands, designated for special bike development at the future time of the land's development. Example: private lands in the Squaw Run valley.

6. Routes through private lands with permanent uses, partly requiring special development, on easements granted by the owner. Example: Pittsburgh Field Club between Field Club Road and Squaw Run Road East.

A related possible program is a system of footpaths that replace the bikeways where the gradient is too steep (by including steps such as those at the entrance to Trillium Trail). An example (discussed further below) is a footpath from the parks along Hunt Road to the unused right-of-way off Longfellow Road. This path would shortcut the route now taken by cars, and would therefore invite valuable use.

For other specific actions on Borough-owned land, the current Green International stormwater study might produce recommendations for meeting hydrologic objectives. Also, it should be recognized that Laflure (1978) suggested check dams on Squaw Run just south of Glade Run. This suggestion is not pursued here because it seems to have been motivated more by the convenience of the location for check dams than by the value it would produce for downstream properties.

Privately-owned land is the majority of land in the Borough. There are about 5,600 private land owners.

The Borough's principal formal means of interacting with the landowners is its ordinances. If implemented through ordinances, the recommended courses of action will establish the Borough's substantive environmental program for the first time. All recommended courses of action should be added to the Borough's ordinances where they are not already covered. They will tend to control all future privately initiated land use changes and operations, whether intended to create something new or to repair something that has been subject to environmental hazards. The listed actions are substantive only; writing them into Borough ordinances will require restating them and coordinating them with other aspects of Borough ordinances and the Pennsylvania Municipalities Planning Code. Certain characteristics of the Borough's ordinances have been assumed in stating the recommended actions. For instance, the construction of land use components such as roads and sewers is specified in the existing ordinances. Also, the ability to comply with many listed actions depends on the freedom to do land use compression, which is permitted in Density Developments and Planned Residential Developments. At the time the listed actions are written into Borough ordinances, it would be worthwhile to review the ordinances as a whole to reduce conflicts.

The actions that are stated in terms such as "shall not exceed that before development" provide clear standards with which the developer must comply. The thresholds of adequacy listed in Figure 70 are intended to be reasonable standards based on an understanding of the relevant processes.

As a supplement to the Borough's police powers, members of the Borough staff may apply for status as local enforcers of Commonwealth laws. This has been done in the Turtle Creek Watershed, where the Executive Director of the Association is responsible for enforcing Commonwealth erosion and sedimentation laws. This has provided much closer control of erosion and sedimentation than the Commonwealth could have provided with its own staff.

In addition to ordinances that may result from this Plan, all the data in Section II-2 provide valuable advice to any creative, intelligent private person who wishes to use it. When a person uses these data, it will be to the Borough's benefit as well as his own. The data should be made freely accessible to the public.

The Borough can acquire properties to change the Borough's control over them from ordinance to overall Borough initiative. Two types of criteria for acquisition are suggested:

1. Undeveloped sites on extremely valuable (unique stands, waterfalls, etc.) or problematic (lowlands, landslides, etc.) land, where private development compatible with the Borough's objectives is very unfeasible. The feasibility of private development is determined largely by the proportion of the site occupied by critical resources, slope gradient, and the orientation of road access into the site. Two such sites are suggested for further investigation: a) the property southeast of the Fox Chapel Road-Guys Run Road intersection, and b) the property between Longfellow and Hunt Roads.

2. Developed sites subject to severe environmental hazards (floods, landslides) where saving the valuable structures by private means is very unfeasible. No such sites have been clearly identified in Fox Chapel. However, future experience with structures mapped as susceptible to environmental hazards may suggest Borough intervention.

Before deciding to acquire an undeveloped property, the Borough should do the following: check the ownership of adjacent properties - if they are under the same beneficial ownership, it could influence overall feasibility of development. Prepare trial development site plans, to doublecheck whether 100% acquisition and conservation is the most feasible way to put the site to a permanent use while meeting Borough objectives. These site plans may disclose that the Borough needs to purchase only enough acreage to reduce the property to a size and topography where the number of dwellings permitted by zoning is feasibly buildable. Coordinate plans for acquisition with other Borough programs, such as bikeways, footpaths, and the redesignation of unused Borough road rights-of-way (for instance, the Longfellow-Hunt property could support a useful footpath from the parks along Hunt Road to the unused right-of-way off Longfellow Road).

THE PLANNING AND REVIEW PROCESSES

The form of our outcome equation is:

Outcome = f(Land, Land Use).

In this form, the equation can be used to evaluate proposed land uses in terms of their effects on our performance variables. This is the use assumed in the discussion (above) of Borough standards for private developments. That discussion does not address the question of how those proposals are generated. If they are merely generated at random, the process of review, revision, and re-review is one of uncontrolled trial and error, which would not produce a really good design except on lucky days. No matter how elaborate the process of evaluation - including environmental impact statements - it remains only evaluation, not design.

To try to control the process of design, let's change the form of the basic equation:

Land Use = f(Land, Outcome).

This new equation is a direct inference from our original equation. This one says that if we know what the land is like, and we know what outcome we want, then the best land use can be determined directly, with a minimum of trial and error. Our Plan has inventoried the relevant characteristics of land and established desired outcomes; hence, land use should be inferable. This is the "developmental" role of models, as opposed to the "evaluative".

Following our rewritten equation, an ideal site planning and review process for any Borough natural resource subproblem would consist of the following steps:

1. Inventory of site characteristics that are relevant to the Borough's objectives. This step can be recorded in one or more maps of the site showing geologic, hydrologic, and other variables. (An intelligent designer will also inventory other, non-Borough site characteristics, such as utility locations, in the same set of maps).

2. Inventory of Borough standards applying to the above land characteristics. This step can be recorded in another set of one or more site maps, showing areas to be protected, etc. These maps should be a direct inference from the previous maps, produced by overlaying. They shoud be thorough enough to produce the following step in compliance with all Borough standards. (An intelligent designer will also inventory other, non-environmental criteria, such as road access points, on the same set of maps).

3. Land use plan, showing on a map of the site the designer's conclusions as to construction areas, connecting road and utility alignments, etc., after taking all Borough and other considerations into account. This step should be a direct inference from the previous step, with the map produced by overlaying.

4. Site plan, showing the filling out of the designated construction areas with the desired roads, houses, utilities and other tangible facilities. Although this step is not as controlled as the previous steps and involves more of the designer's trial-and-error processes and ingenuity, the previous steps should have set up the problem's parameters sufficiently that this step can continue to meet the Borough's objectives. The plan should show construction area boundaries, primary and secondary drainage routes, and other land use components sufficiently to show that the Borough's objectives are being met when these components are applied to their designated locations.

5. Review of the maps by the Borough and other members of the LUDMS. Even the product of a developmental design process is subject to evaluation through the evaluative equation.

This process has three types of applications:

1. This Plan has followed the process thru Step 2 for the Borough as a whole. It has inventoried the Borough's relevant land characteristics, and specified land use standards with reference to those characteristics. It has not gone any further because the remaining steps are applied only one subproblem at a time, not for the Borough as a whole. However, this Plan does establish the rules that any subproblem, anywhere in the Borough, must follow.

2. For any subproblem on Borough-owned land, the Borough's designer can follow through the remaining steps straightforwardly. The Borough can select a designer who knows how to follow these steps to meet Borough objectives.

3. For any subproblem on privately-owned land, the Borough can require that the developer submit the mapped records of each of these steps as integral parts of the Environmental Report. It can strongly suggest that the developer's designer follow the developmental steps as a way of assuring that the resulting plan will meet the Borough's objectives. The developer's base data (step 1) may be either a reiteration of this Plan's findings, or the results of a more detailed survey of some kind, demonstrably more accurate or relevant than the results of this report. The Borough's impact analysis can then be a mere confirmation of compliance with Borough standards. Now that this Plan has been done, it should not be necessary for the Borough to search for more evaluative variables in open-ended Environmental Reports.

It has been contemplated that the Borough should produce a manual of design for compliance with this Plan's recommendations, since some designers working in Fox Chapel may not be familiar with the natural sciences, environmental technology, or developmental design processes. However, the emphasis of this Plan is on performance standards that allow the designer flexibility in how he solves his problem; a Borough design manual would unnecessarily stultify his approaches. Also, higher education is available and state registration is mandatory in architecture, landscape architecture and engineering. This Plan's recommendations should be a challenge to qualified designers, not a barrier.

There are two ways that the developmental design process and its applications could be modified in the future.

The process could be modified in step 4 with a technique that has been used in a few developments in other regions, and once in Fox Chapel. Two site plans would be produced in this step. The first one is preliminary - it is prepared with all due care, but it might be modified later. The locations of roads, buildings, utility lines, and disturbance boundaries that pass through critical forest, scenic or other areas are staked out accurately and completely on the site. Borough representatives can then review the locations and work out, with the developer, modifications of locations, tree-saving designs, aesthetic designs, etc., in consideration of the actual detailed site conditions. When a consensus is reached, the new locations are surveyed, a new, final site plan is produced incorporating them; and the process continues. In its ordinances the Borough could invite or even require this procedure, with the suggestion that it would probably expedite the review step in critical areas.

The applications of the developmental design process could be modified by an expansion of the Borough's role in residential development. This idea is currently being researched at the University of Maryland's School of Architecture (Murphy, 1978). The idea is that the Borough could make and adopt a physical plan for the development of the Borough showing precisely the streets, watercourses, public grounds, and possibly other features. The Borough itself could then construct the roads and install the utilities and other facilities. In other words, it could assume many responsibilities that are currently performed by private developers. The Borough's role could expand to any of the degrees listed in Figure 71.

The expansion of the Borough's role would be intended to fill the gap that tends to exist between the goals established in local plans and ordinances and the actual development that takes place. The problem stems from the inability of government to establish and implement a design for the future development of a community through the exercise of the traditional police power - that power of government to restrict or control the free exercise of liberty or property for the public welfare, on which land use ordinances are based.

Although this idea is a sharp departure from the existing system of land use planning and regulation which seeks primarily to control private developers, its basic concept originated in the strong tradition of governmental physical planning which was taken for granted in all communities until about 50 years ago, and is still practiced in many municipalities. All over Pennsylvania we can see examples of older boroughs and cities which originated through positive design and development by local governments. Governmental "official maps" - the equivalent of level 1 in Figure 71 - are still permitted and regulated by Article IV of the Pennsylvania Municipalities Planning Code. Today in the larger Pennsylvania cities, urban redevelopment authorities operate every day at about level 3. Fox Chapel Borough operates regularly at level 5 when it develops parks, firehalls or other public facilities.

The advantages of expanding the Borough's role could be many. The Borough would be able to decide the locations, types and arrangements of facilities, thus determining the actual shape of the new development. This would make the entire design and review process more straightforward and more directly expressive of Borough objectives. Private developers would be eliminated as a source of compromise. Since in the present system the developer who builds roads and utilities turns them over to the Borough for maintenance when they are completed, it is reasonable that the local government design and/or build the facilities in the first place. The Borough could hand the plans or facilities over to private developers, builders or individuals at low cost, because governments can obtain financing at cheaper interest rates than private developers. The cost to the Borough could be recouped by selling the project or by benefit assessments imposed upon the property.

The idea of the expansion of the Borough's role in development deserves further discussion. It is suggested that level 1 in Figure 71 - the making of official maps as permitted by the Pennsylvania Municipalities Planning Code, as a form of land regulation - would be a prudent, conservative, inexpensive and legal way for local governments to control the actual shape of developments as they have done in the past.

Borough Role	Passage to Private Role
1. Make preliminary/tentative plan.	Regulate land or sell project to developer for completion.
2. Make preliminary/tentative plan and final plan.	Regulate land or sell project to developer for completion.
3. Make preliminary/tentative plan and final plan and acquire land.	Sell project to developer for completion.
4. Make preliminary/tentative plan and final plan, acquire land, and construct site improvements.	Sell building sites to builders and individuals for home construction.
5. Make preliminary/tentative plan and final plan, acquire land, and construct site improvements and homes.	Sell homes to residents.

FIGURE 71. Possible Borough roles in residential development.

MANAGEMENT SUMMARY

The types of Borough actions that may be started as a result of this study are summarized here as a guide to those who may implement them.

1. The recommended development standards can be adopted in Borough ordinances. This can be integrated with an overall review and coordination of the Borough's suite of land use ordinances.

2. Land use proposals by private developers can be evaluated as they arise in the light of the recommended standards.

3. The recommended projects on Borough-owned land and of Borough acquisition can be started.

4. Further research on environmental science can be encouraged. Specific topics for research are suggested in Section III and are summarized in Figure 72.

5. Other types of Borough land use and fiscal planning can be pursued at their normal paces. Further planning should relate our recommended environmental actions to the broader considerations of zoning, subdivision and other Borough affairs in which many of the actions will be implemented. Expansion of the Borough's role in development can be investigated.

6. Progress in the state of the art of environmental science, planning, and land use activities should be welcomed. We have not had the benefit of a crystal ball in preparing this report. New issues will arise. To meet them, continued monitoring, research and planning will be necessary.

1. Empirical testing and improvement of models for runoff-producing zones, zones of saturated soil, and floodprone zones. These are now modeled mostly by lowland.

2. Empirical refinement of an accepted Q_p calculation method for use in small Fox Chapel watersheds. Tying such a refinement into the partial-areas theory, zonal models mentioned in 1., and the water-budget concept would help to unify our understanding of the natural environment.

3. Inventory of combined sanitary and storm sewers, with a view toward their separate reconstruction.

4. The quantitative extent of sunscreening by different species of northeastern trees.

5. The direct correlation of water-budget variables with Fox Chapel's ecosystem characteristics, and the detailed variation of water-budget variables over Fox Chapel's topography including the influence of downslope moisture variations.

6. Compare Auchmoody and Smith (1979) and Meentmeyer and Elton (1977) to Carmean's studies for applicability to natural resource problems in Fox Chapel.

7. Quantify ecological variables, in each community type, for use in the performance equations. These variables are: diversity, uniqueness as animal habitat, productivity, maturity, stability, degree of artificial maintenance, and canopy height and density.

FIGURE 72. Summary of topics for further research suggested in Section III.

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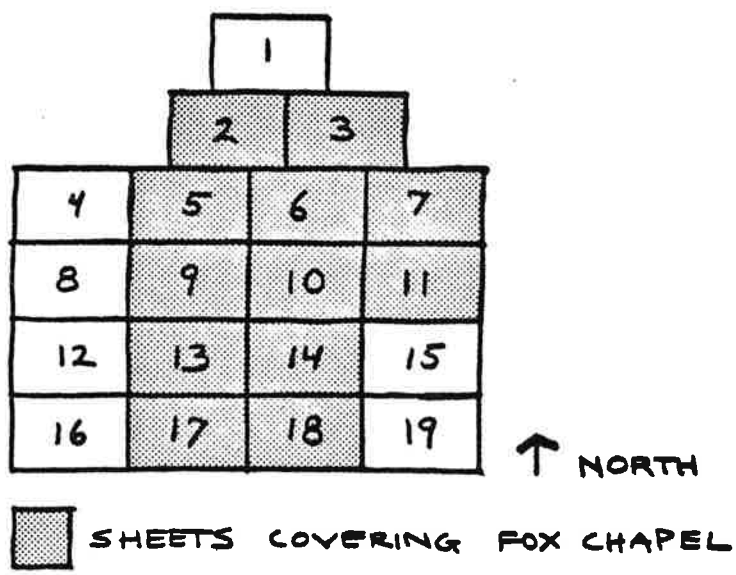
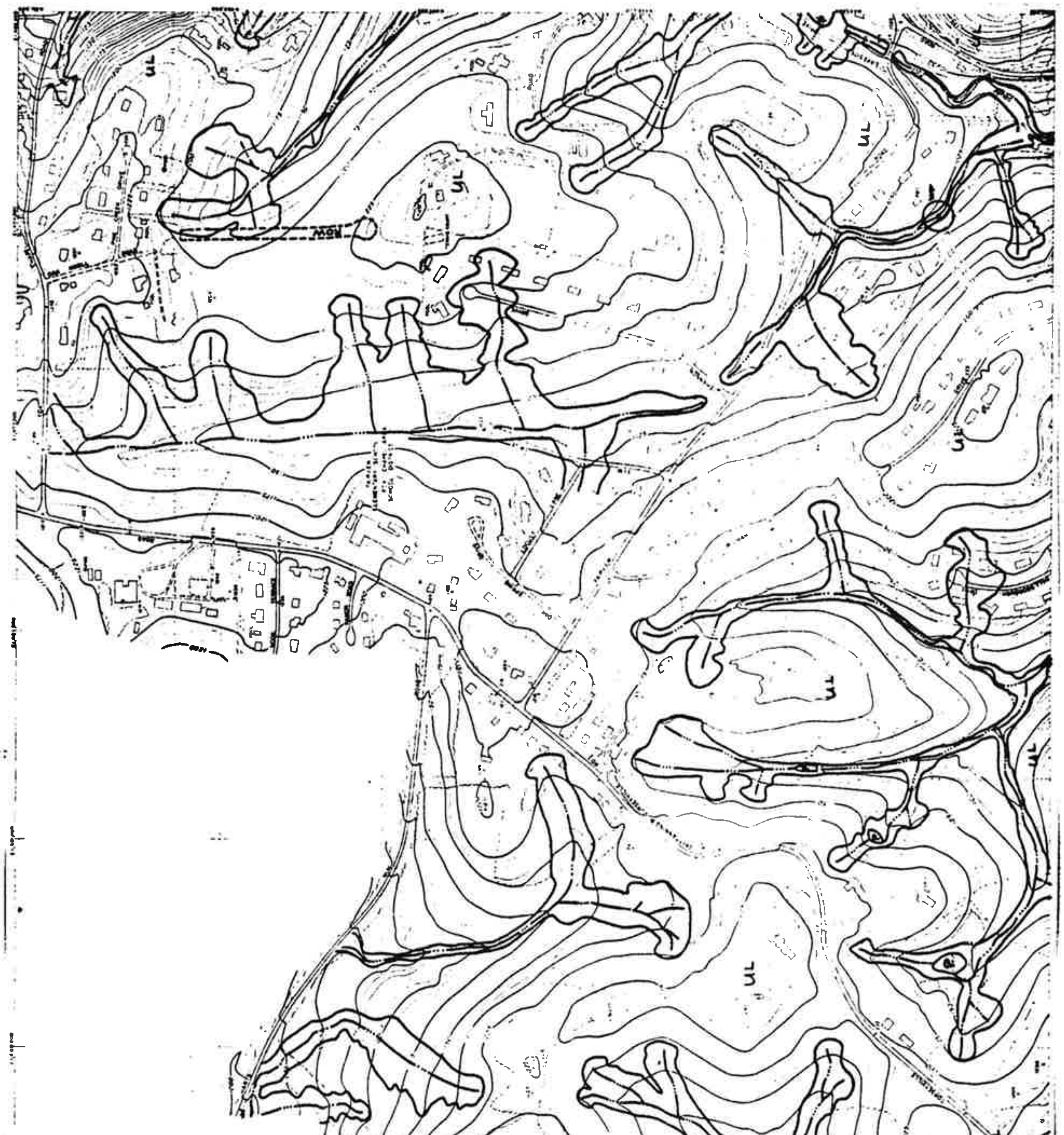
LIST OF FIGURES

MAP 1

WATER AND OWNERSHIP

- Stream
- Lowland
- Waterfall with 4'+ Vertical Drop
- Pond
- Wetland
- Upland
- Unused Right of Way
- Possible Acquisition Site
- U. S. Federal Insurance Administration (1975) Cross-Section Line, Cross Section Designation, and 100 Year Flood Depth





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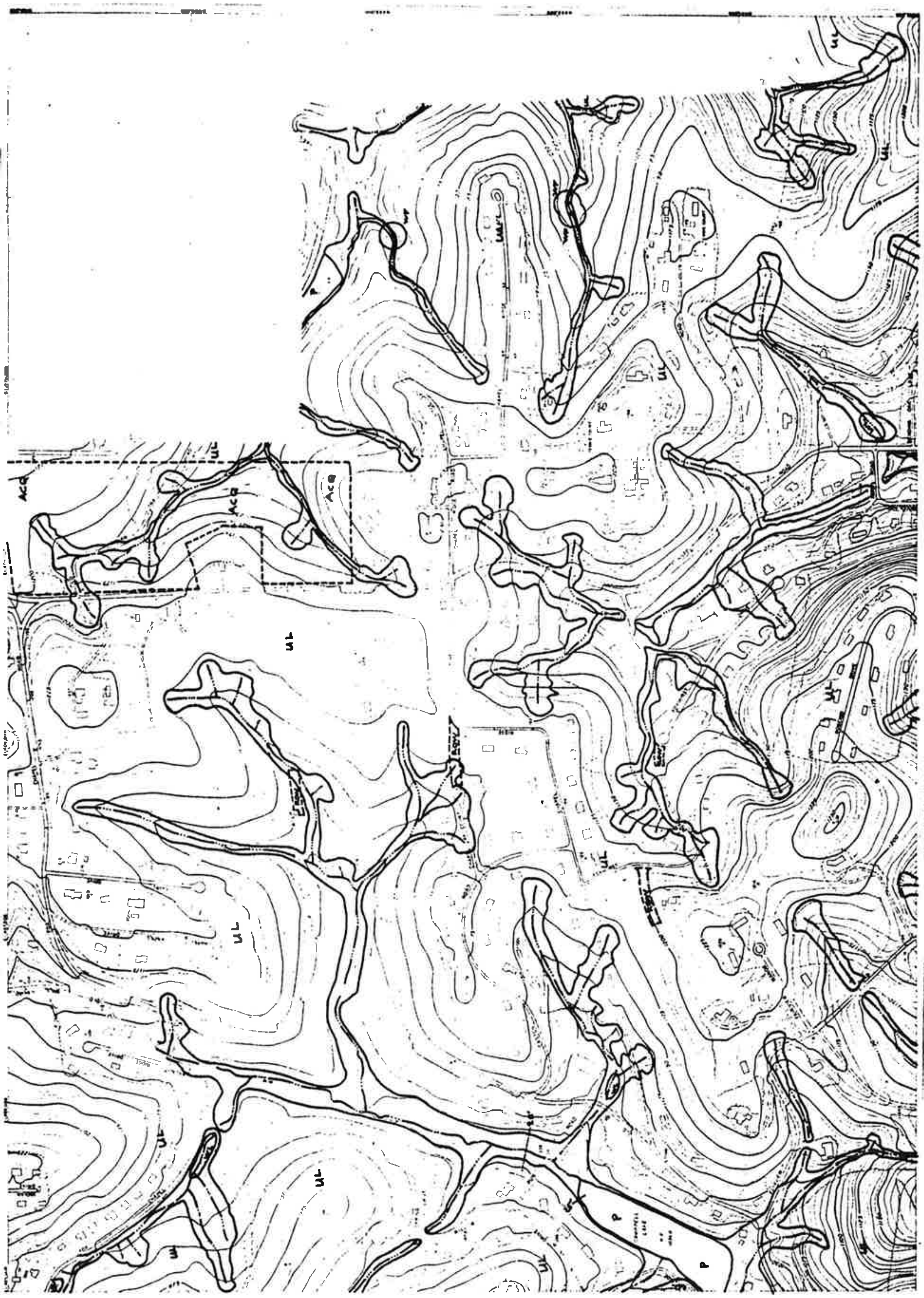
Map 1: Water and Ownership
Sheet 2



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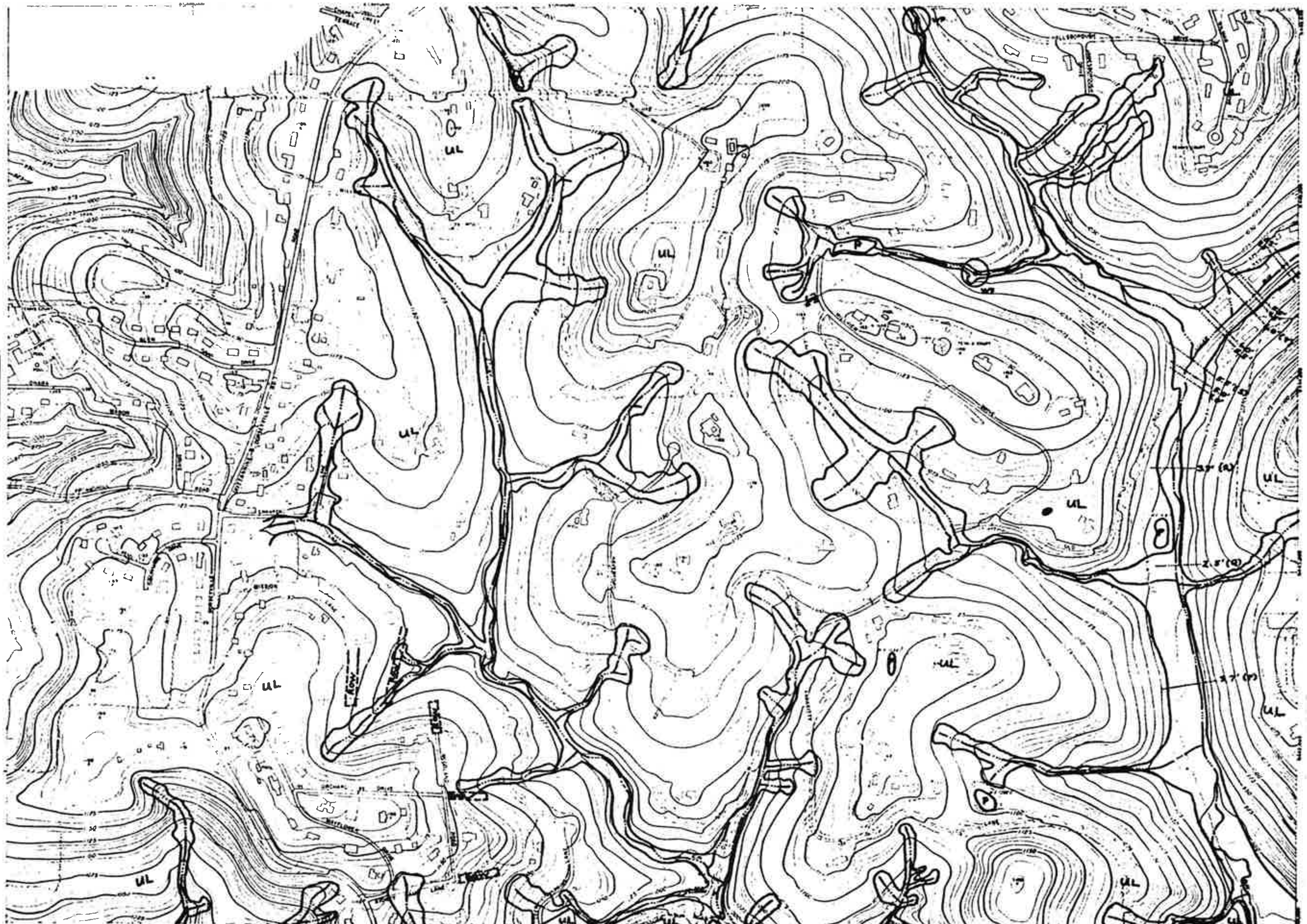

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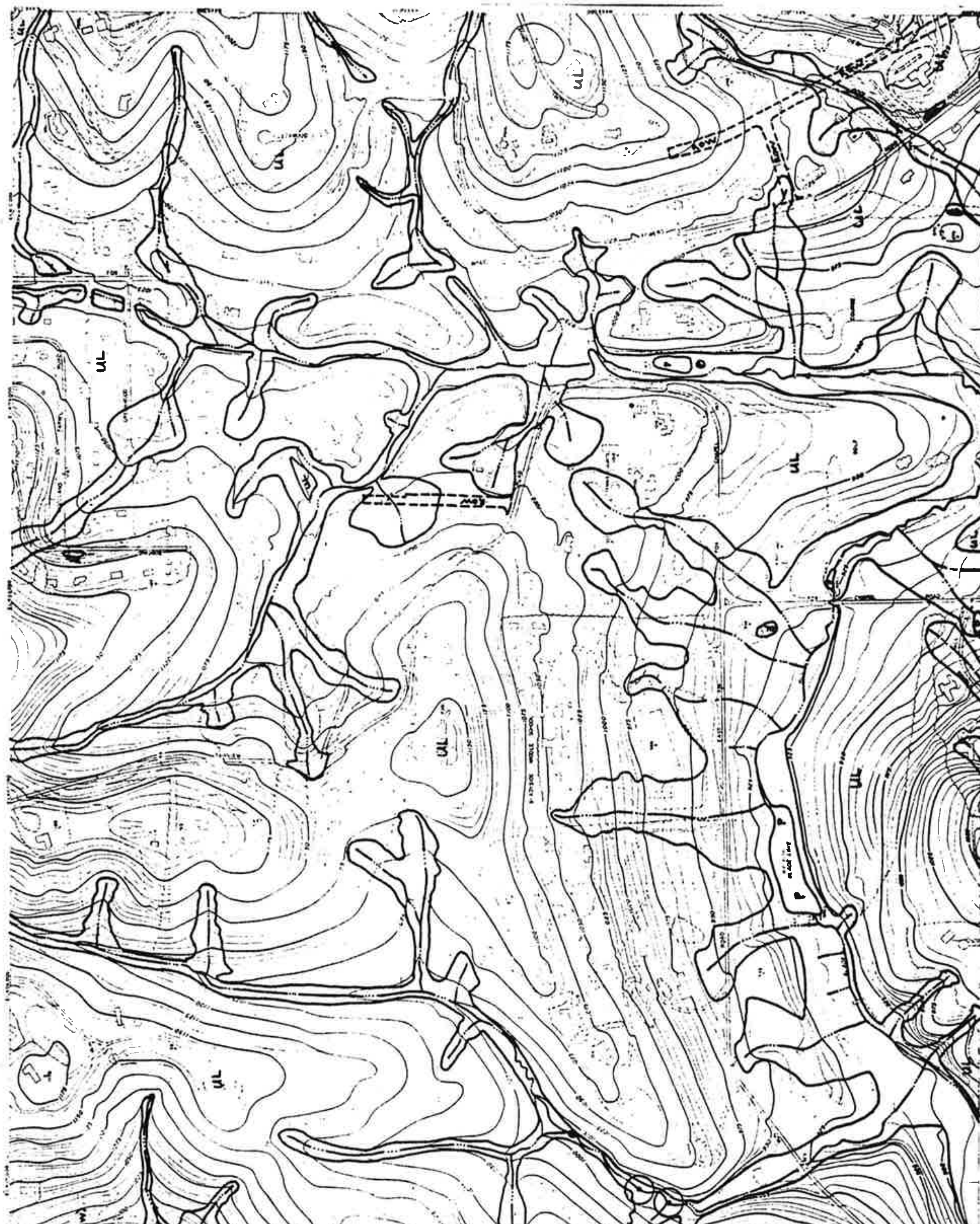

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Map 1: Water and Ownership
Sheet 6

Map 1: Water and Ownership
Sheet 7

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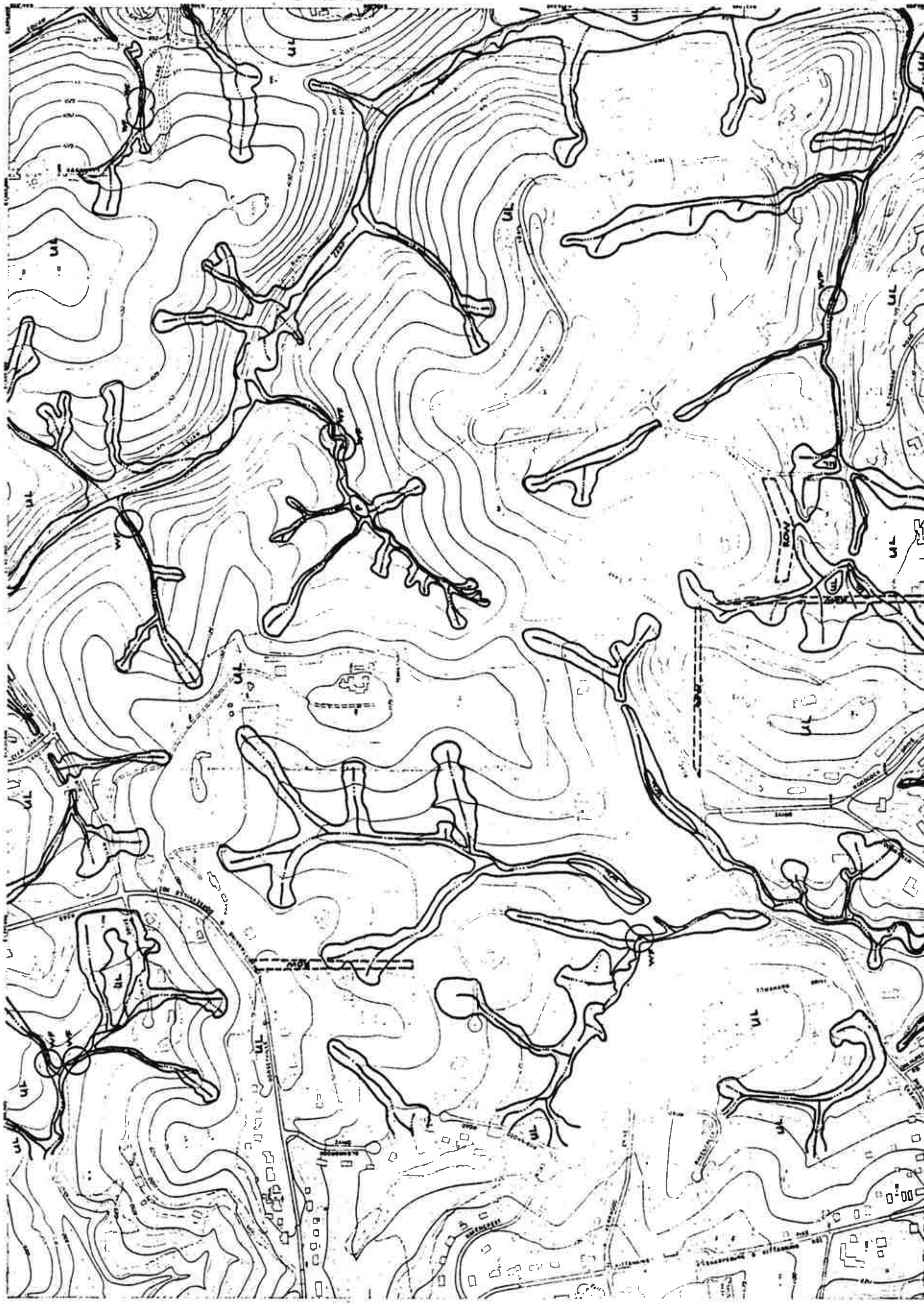

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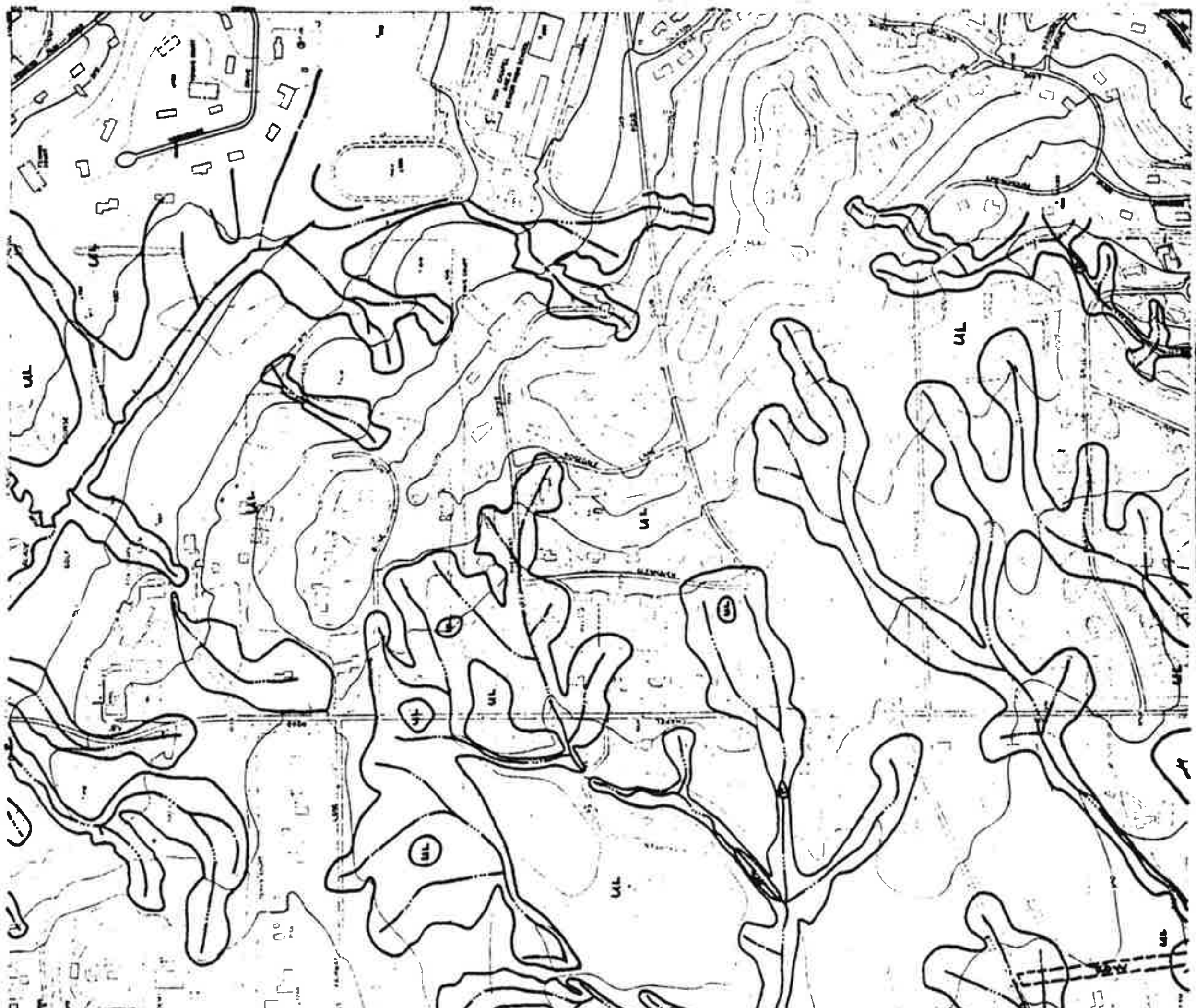

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Map 1: Water and Ownership
Sheet 10

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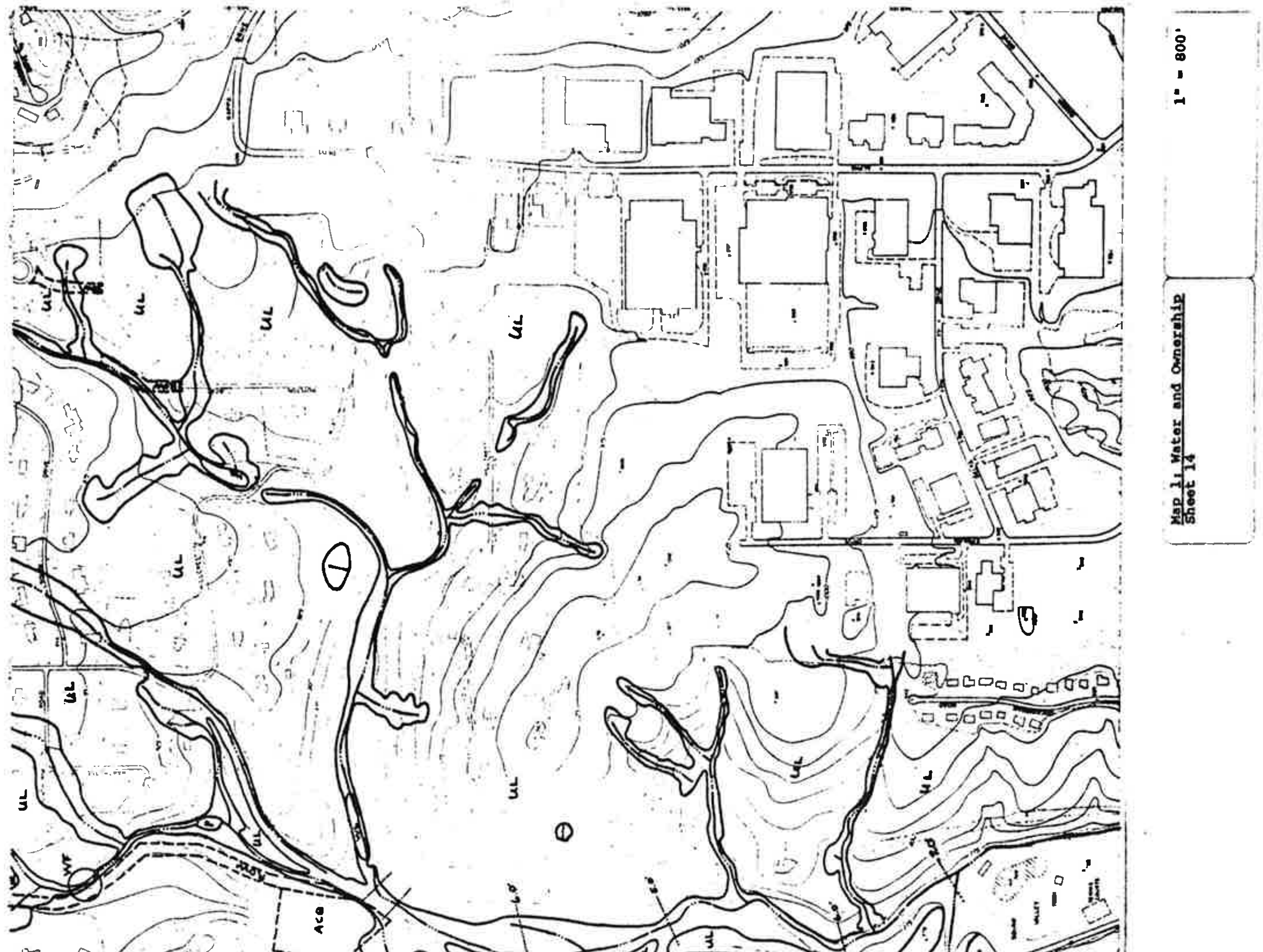
Map 1: Water and Ownership
Sheet 13



Map 1: Water and Ownership
Sheet 14
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UL
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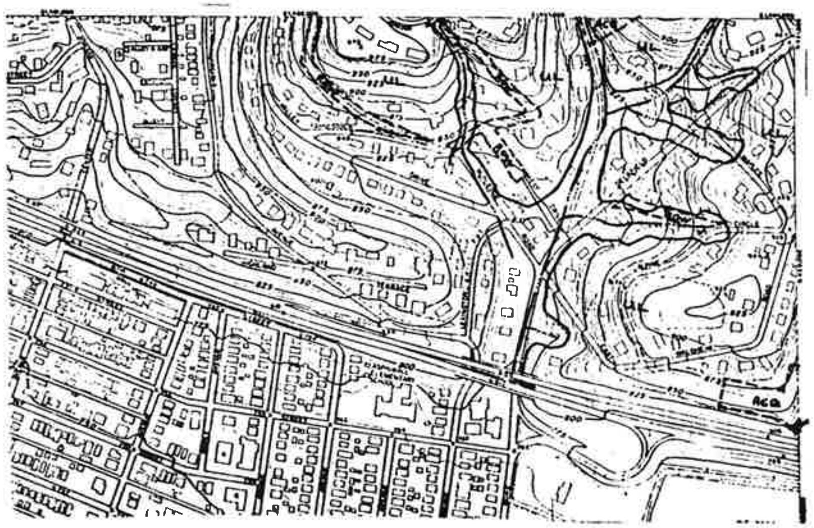

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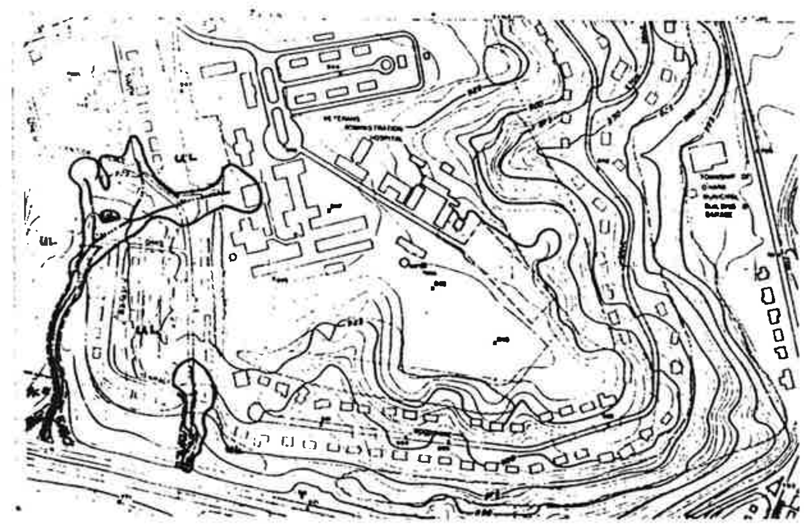


18

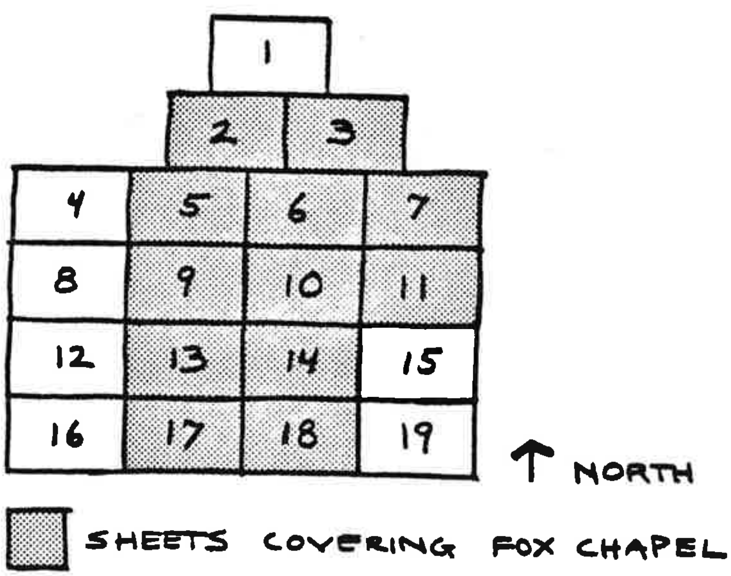
Map 1: Water and Ownership
Sheet 11, 17 and 18

1" = 800'

MAP 2

VEGETATION AND LAND COVER

MH	Mixed Hardwood
OF	Old Field
OH	Oak-Hickory
Or	Orchard
PP	Pine Plantation
SF	Secondary Forest
Un	Unique Stand
UR	Utility Right of Way
US	Urban Savanna
W	Water
■	Abiotic Cover



Map 2: Vegetation and Land Cover Sheet 2

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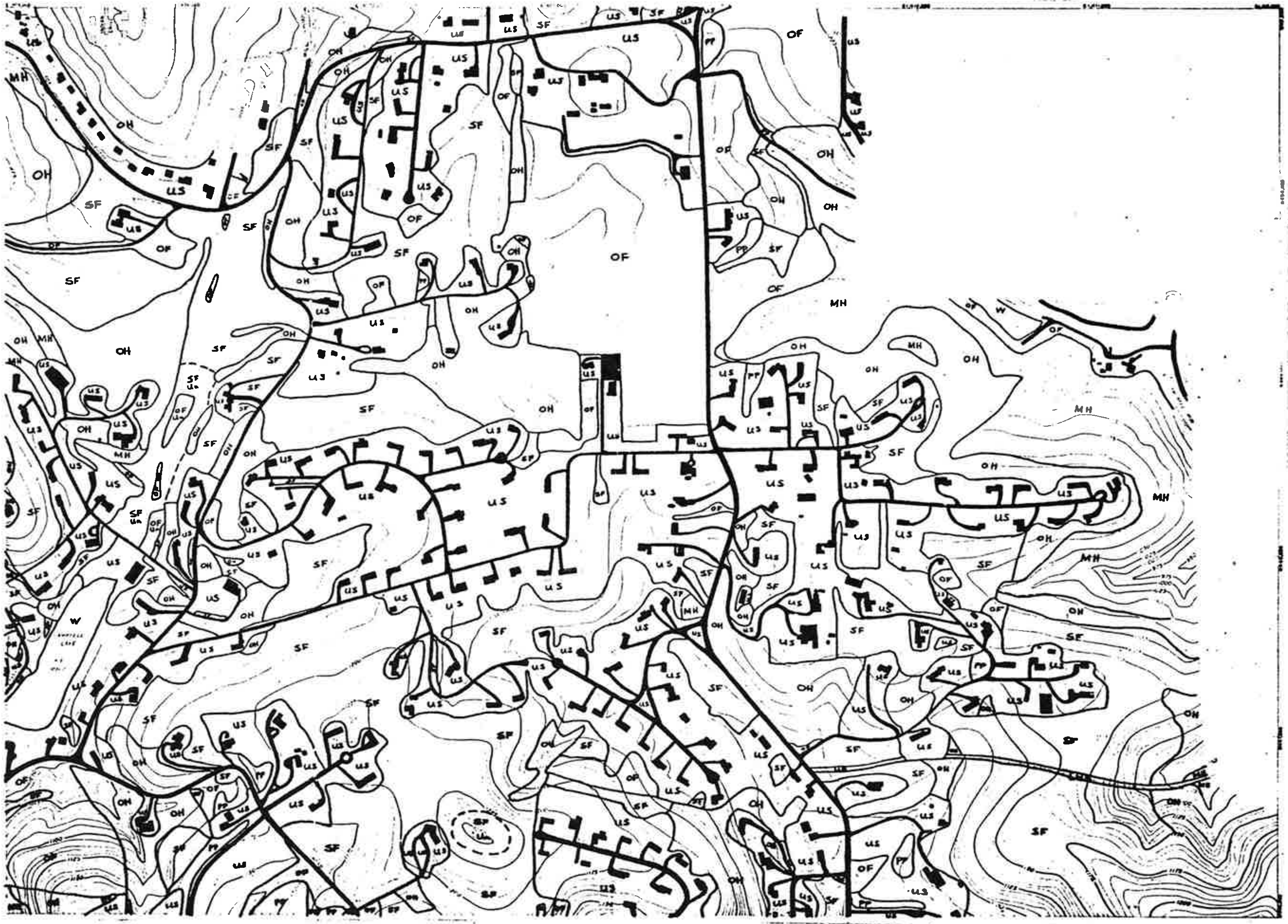

Map 2: Vegetation and Land Cover
Sheet 3

1" = 800'

Map 2: Vegetation and Land Cover
Sheet 5

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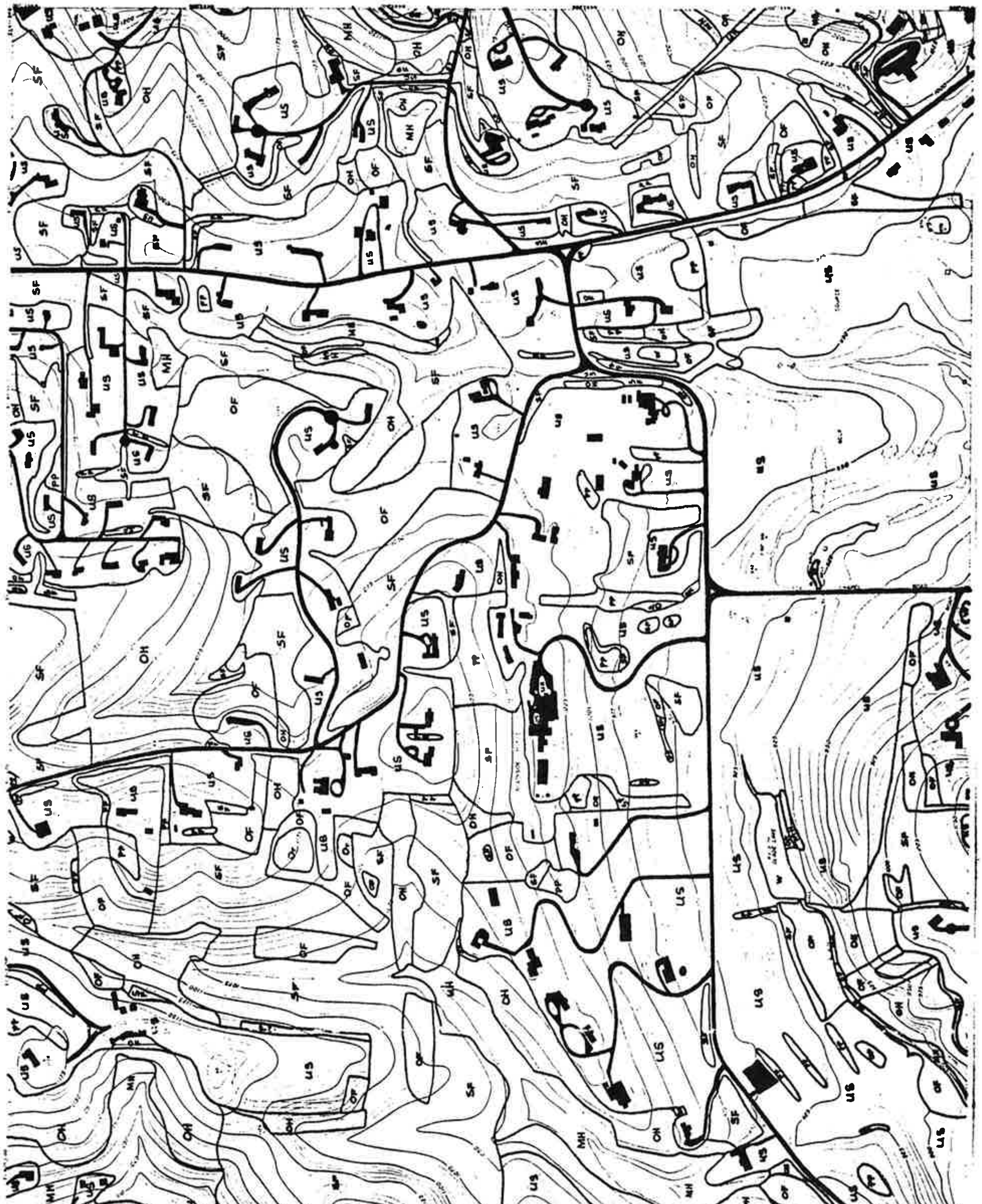

Map 2: Vegetation and Land Cover
Sheet 6

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Map 2: Vegetation and Land Cover
Sheet 7

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Map 2: Vegetation and Land Cover
Sheet 9

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Map 2: Vegetation and Land Cover
Sheet 10

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Map 2: Vegetation and Land Cover
Sheet 13

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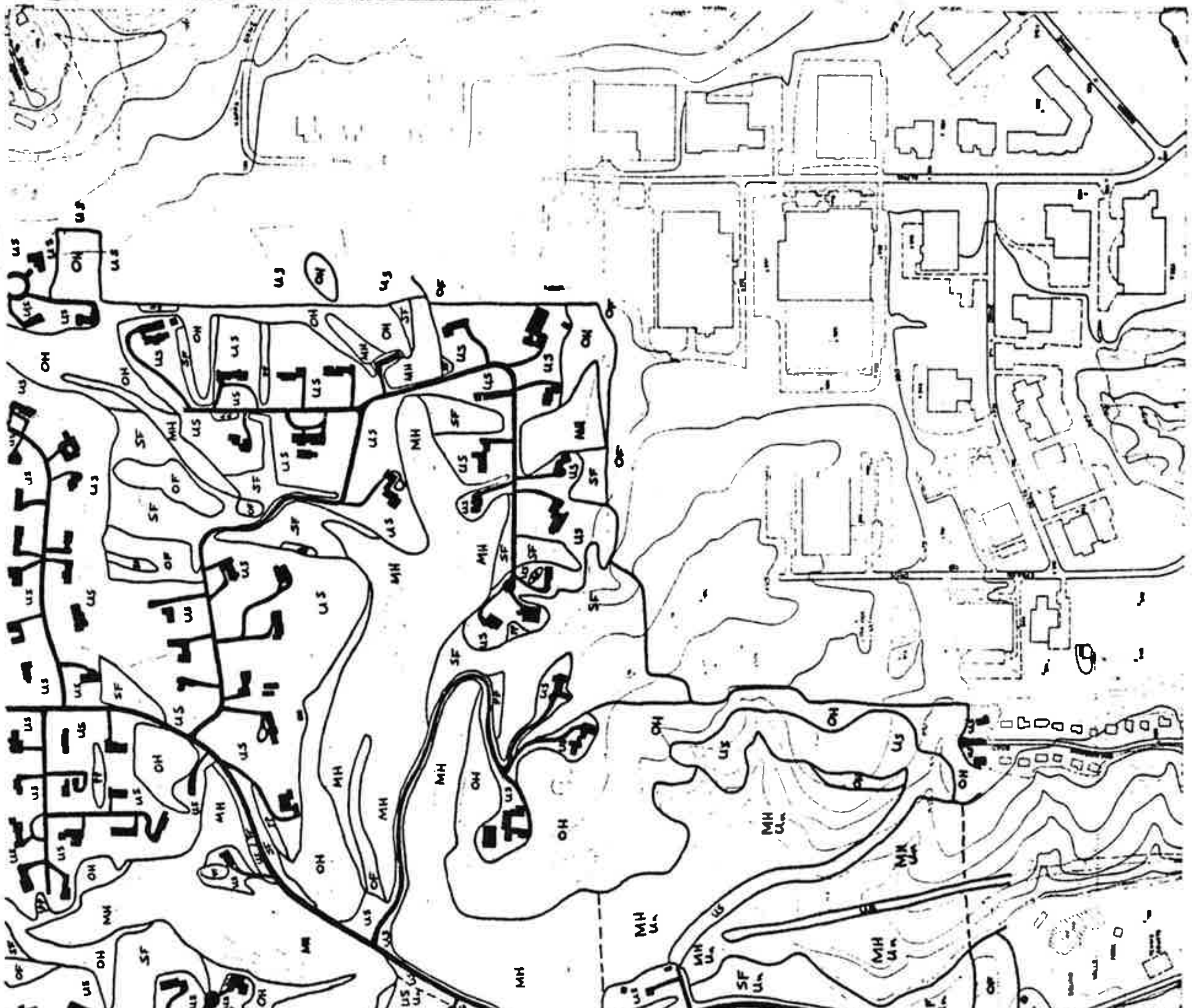

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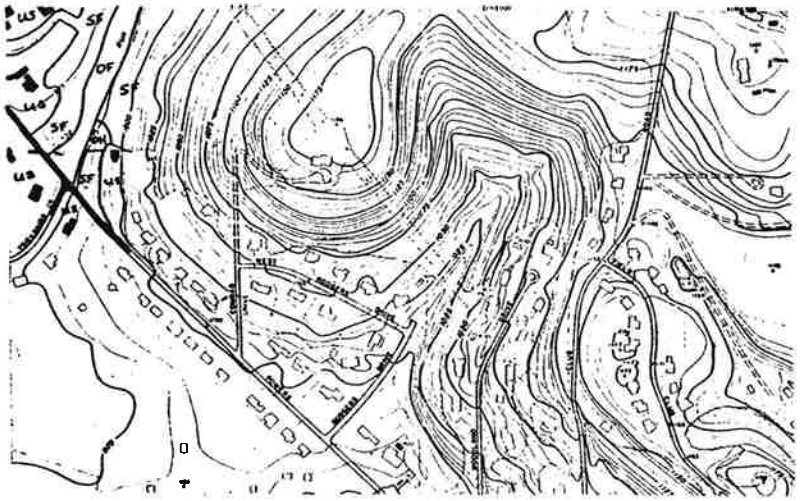

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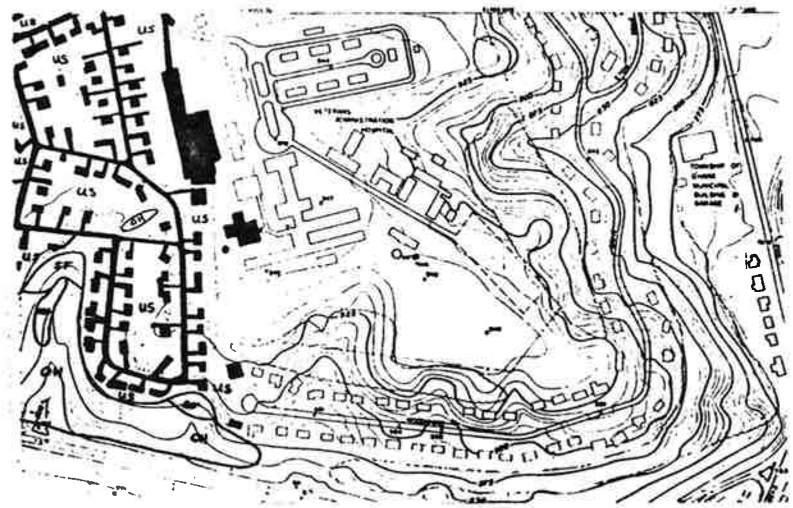


18

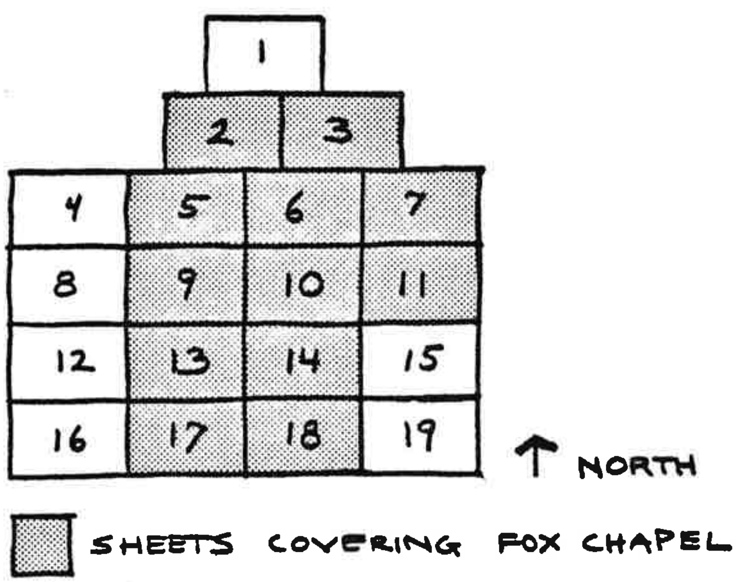
Map 2: Vegetation and Land Cover
Sheet 11, 17 and 18

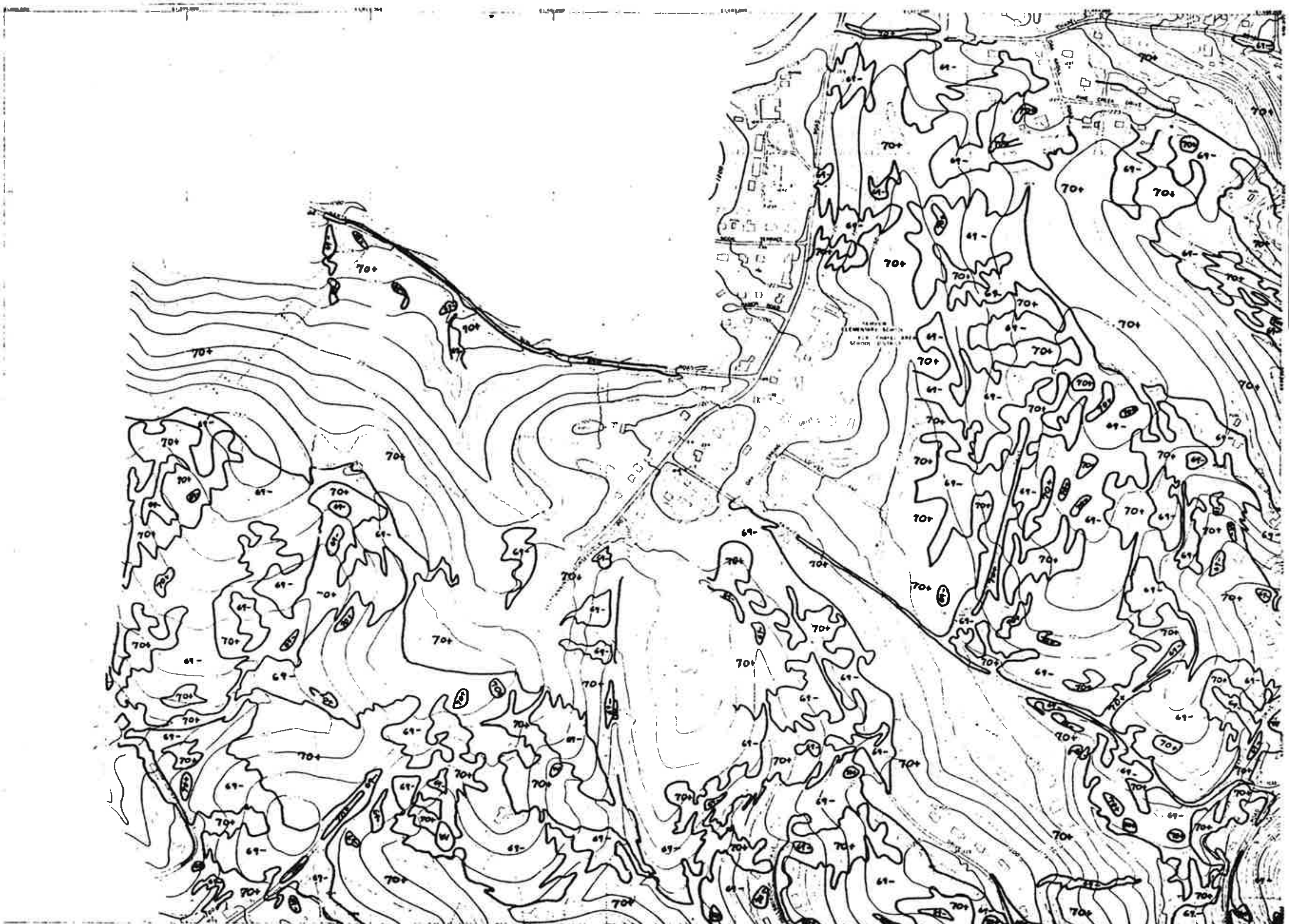
1" = 800'

MAP 3

SITE INDEX

70+	70+ feet of height at 50 years
69-	69- feet of height at 50 years





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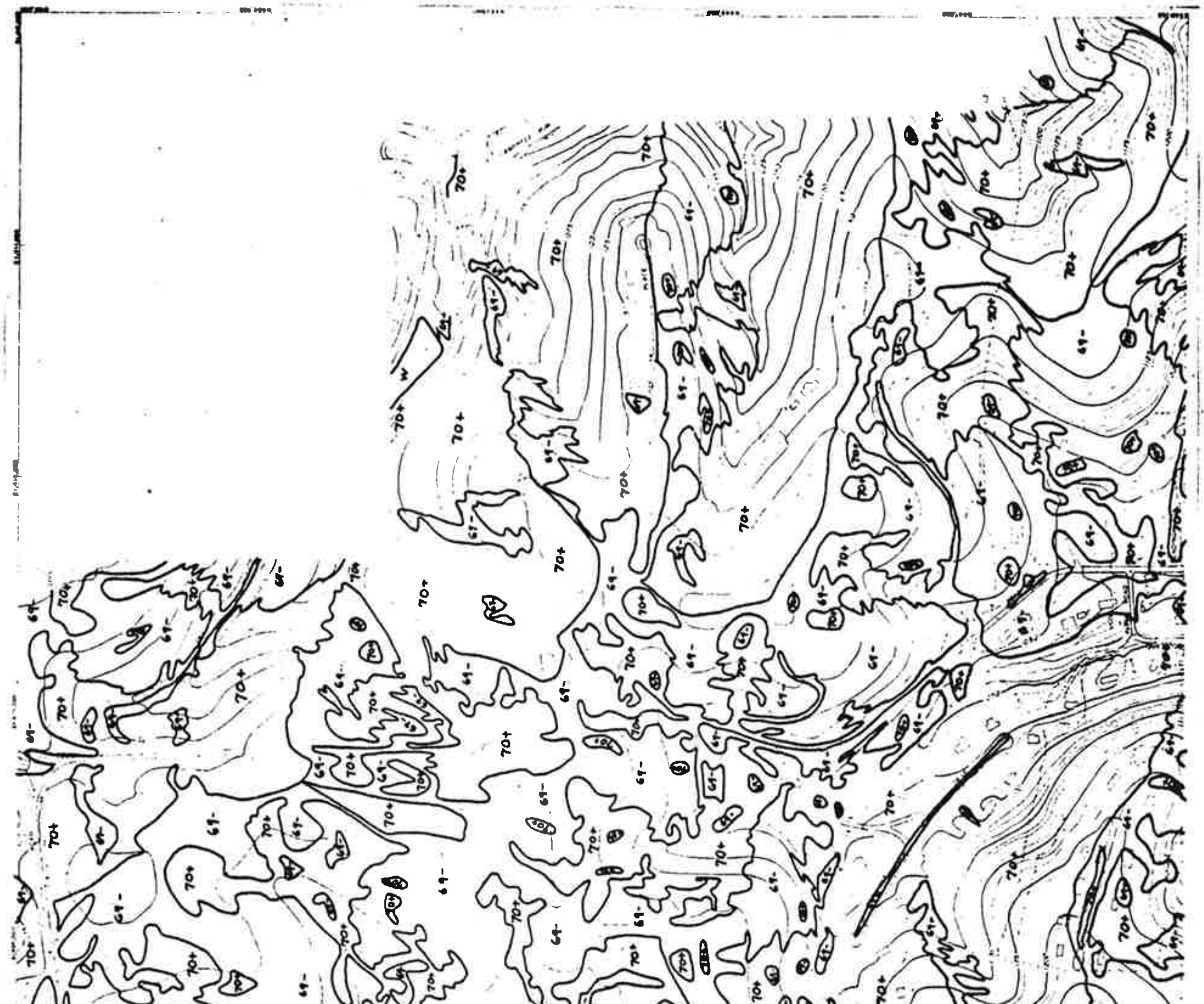

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Map 3: Site Index
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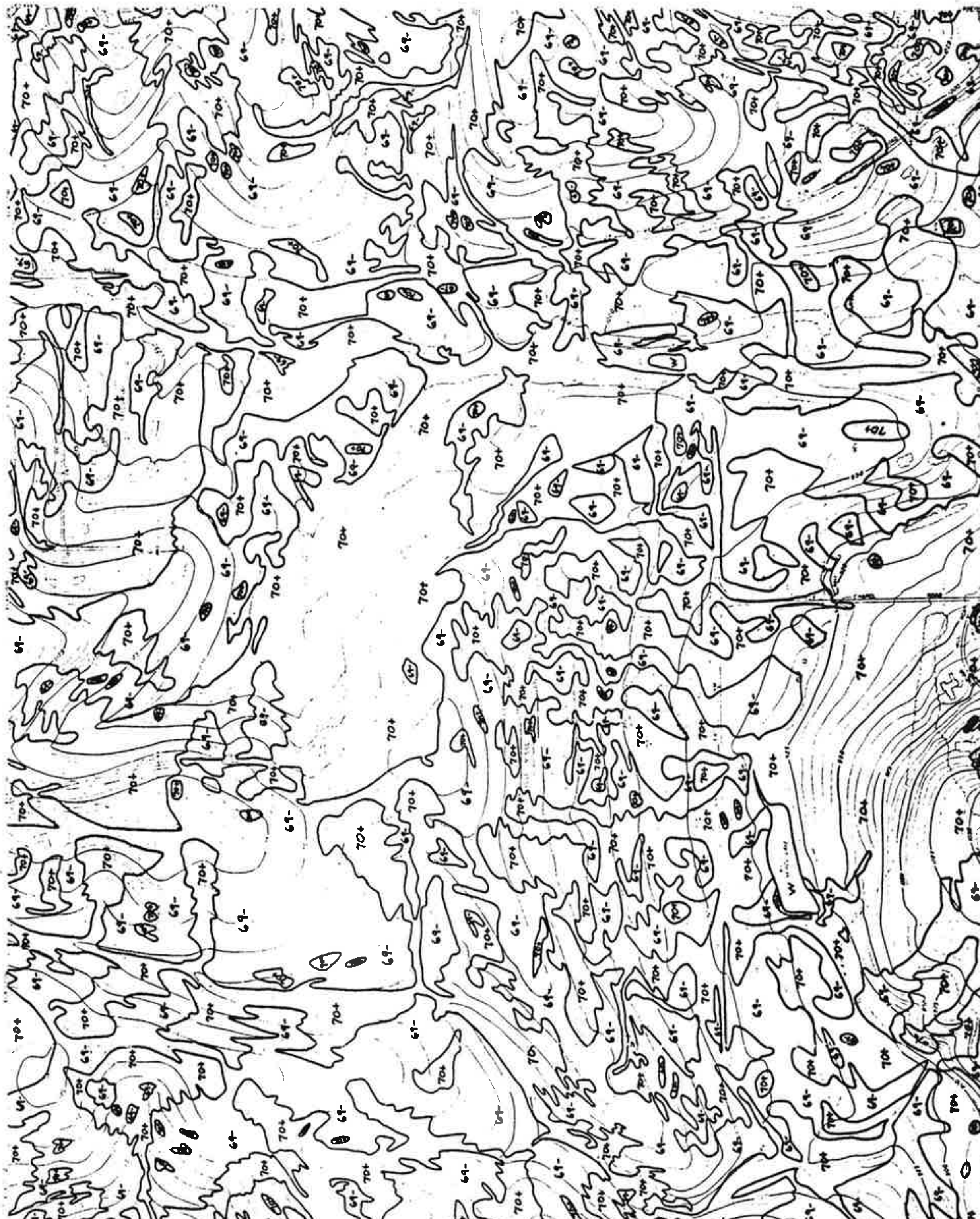

Map 3: Site Index
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Map 3: Site Index
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Map 3: Site Index
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Map 3: Site Index
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Map 3: Site Index
Sheet 14

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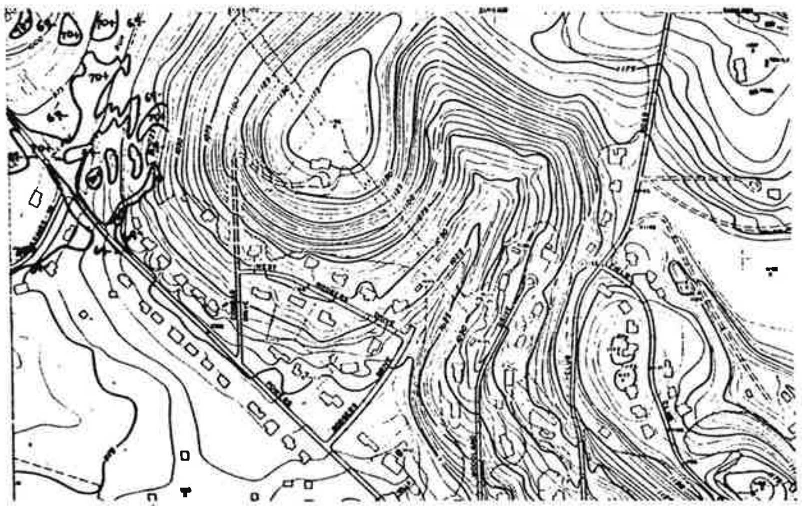

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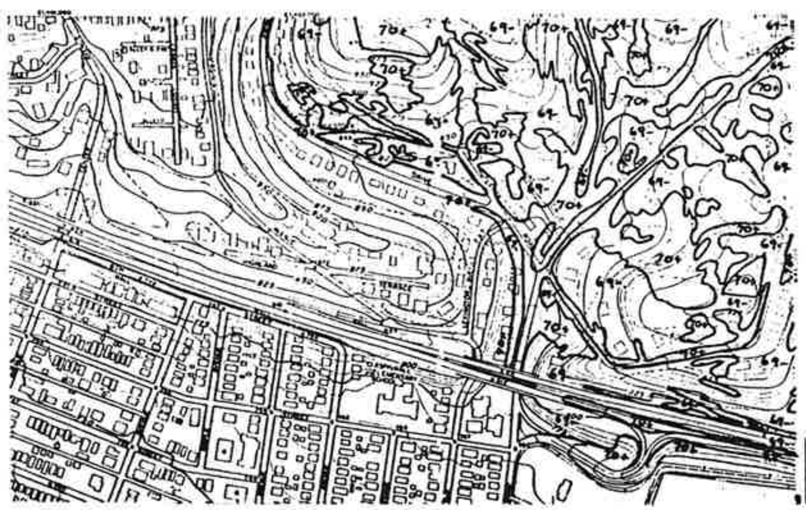

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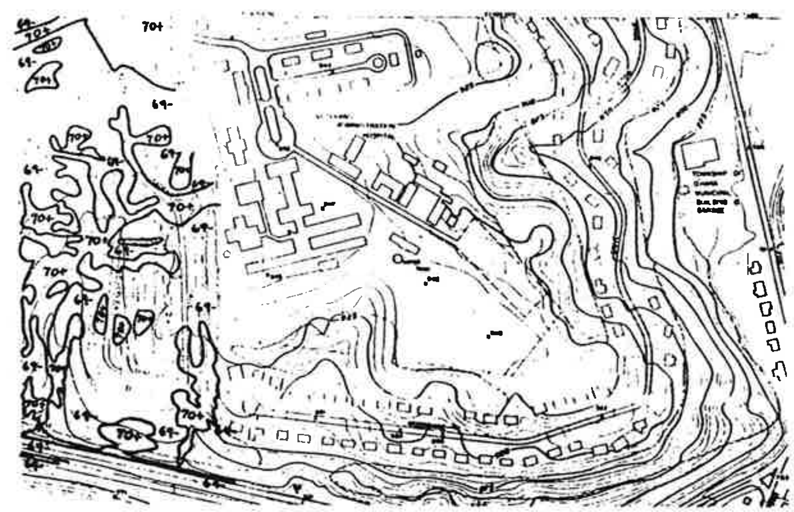

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Map 3: Site Index
Sheet 11, 17 and 18

1" = 800'

INDEX AND GLOSSARY