Chapter VIII
Watershed Development

The watershed is a geohydrological unit draining at a common point by a system of streams. Watershed is all the land and water area, which contribute run-off to a common point. It is a land area that captures rainfall and conveys the overland flow and run-off to an outlet of the main flow channel. It is a topographical delineated area draining into a single channel. The watershed has a third dimension height or depth. The depth of watershed extends top of vegetation to confining geological strata beneath. Every watershed in the world is as unique as a fingerprint. The term watershed strictly refers to divide that separates one drainage basin to another. But, over the years, the watershed has been identified with drainage basin streams. A watershed may be neatly flat or may include hillocks, hills or mountains. Each and every water and land area is a part of one watershed and other. The peoples and animals are part of the watershed community.
The size of the watershed may vary from a few square meters to thousands of square kilometers. The size becomes important depending upon the objective of the project. The size of the watershed is also determined by afforestation, grassland development and cultivation. Many physiographical features like valley, undulating hillocks and logged hill tracks influenced the size of the watershed. The larger watersheds could be selected in plains or where afforestation and grassland development is the main objective of watershed. An average 5,000 hectares of land is an effective unit for watershed management and 500 hectares of micro watershed is a functional watershed unit.

Watershed is a biological, physical, economical and social system. It is a land mass bounded vertically by the area influenced by human activities and horizontally by the water that drains into point in the channel. With in this area we have a system consisting of a number of dynamic and inter related physical, social and economical factors.

In India, the concept of watershed as a small unit of management and development land and water resources was initiated by Shri (Late) V.P. Bali (1974), when Ministry of Agriculture, Government of India initiated programme of soil and
water conservation adopting watershed as a planning unit. The concept has gained momentum and presently watersheds form the basis of presenting natural resources for effective planning and optimum development of land and water resources. Watershed projects have been taken up under different programmes initiated by Government of India. The various programmes are the Drought Prone Area Programme in 1987, Desert Development Programme in 1987, Development of wasteland on a watershed basis adopted in 1989 by National Wasteland Development Board and National Wasteland Developmental Programme in rained area under the Ministry of Agriculture.

Watershed management is an integrated technological approach within the natural boundaries of a drainage area for optimum development of land, water and plant resources to meet the basic minimum needs of the people in a sustained manner. According to Soil Conservation Society of India, watershed management means harmonious development of land and water resources within the natural boundaries of a watershed, so as to promote or produce on a sustainable basis. Abundance of plants and animals and these products still deliver clean and controlled flow of water to the down streams. According to Food and Agriculture Organization, watershed management is the process of
the formulating and carrying out a course of action involving the manipulation of land and water resources in the watershed to provide goods and services without adversely affecting soils and water base.

Watershed management requires control of damage run-off, manage and utilize the run-off water for useful purposes, control of erosion, moderate floods in the down stream area, enhance groundwater storage, wherever applicable and appropriate use of land and water resources in the watershed for development of food, fodder and forest resources.

The basic data needed for watershed management are physical data, present land use, socio-economic and cultural conditions, land tenure systems, land facets and its problems, existing stage on development and infrastructural facilities, economic development activities and technology known-how. The important factors, which affect the behavior, are size and shape of the watershed, topography, soil and vegetation development. The selection of priority watershed area includes the location and determination of venerable watersheds, which are contributing high sediments and run-off in the reservoirs. The watershed which need to be treated on the priority basis can be determined using a
reconnaissance surveys, soil and land use survey, sediment yield
data, interpretation of aerial photographs or satellite data,
interpretation of topographic sheets and weight age to the socio-
economic factors. The major criteria for priority delineation of
watershed are soil conservation, identification of suitable
agricultural crops and contribution of more run-off and sediment
yield. The various soil moisture conservation measures to be
adopted in watershed are contour stone wall and contour
trenching on barren hill slopes, afforestation, bench terracing for
steep slopes contour and graded bunding on agricultural land,
gulley protection by check dams, construction of small ponds and
percolation ponds, stream bank erosion, control road-side
stabilization, pasture development, water spreading for ground
water recharge, control of land slides and mass wasting, in situ soil
moisture conservation method and vegetative barriers along contours. Mismanagement and over exploitation of natural
resources through over cultivation of agricultural land, over
grazing of grass land and over cutting of forests have resulted in
degradation of environment and drawing immediate awareness of
conservation of natural resources. About 16.2% of our country is
under wastelands, which are degraded lands. They include 4.3
million hectares of gullied ravines, 3.9 million hectares of saline
and alkaline lands and 0.88 million hectares of water logged land.
Every year about 16.55 thousands million cubic meters of soil, 6 millions tones of fertile soil along with 10 million tones of fertilizers and other plant nutrients are being lost. The progress of the country is linked with agricultural and biomass products, which depend on soil, water plant nutrient relationship of watershed. They are the basis for micro-level planning for optimum utilization of land, water and forest resources.

Participatory Rural Appraisal in watershed programme is emphasized on the establishment of a more equitable relationship between facilitator and community. There is conscious effort made to empower the community. Empowerment through the creation of a participatory research process in which local people are viewed as active agents. The objective of participatory process is to facilitate local people doing their own analysis through own situations. Participatory rural appraisal is exploratory and helps in assessing needs and prioritizing problems. Planning formulation feasibility studies, monitoring and evaluation can be undertaken by using participatory rural appraisal techniques in the watersheds. The participatory development is a new economic force aiming at suitable development at the village level in the watersheds. There is a close link between resources and community. The community has a great deal of interaction among
individual user resources. Allocation of resources base on a community approach, rather than on an individualized one, adds elements of sustenance to the development process. Participatory development is a non-conventional approach. It is required to encompass the evaluation of non-market, non-government people organization, changes of system of property rights and methods of resource allocation.

The integrated watershed development aims at a sustainability, productivity and equity. It has been amply emphasized to ensure sustainability where there is a majority of people below poverty line, women are land less assistance and support to immergence and establishment local institution is crucial. Watershed Advisory Committee is an advisory body for watershed at development programmes in extensive areas. The Watershed Advisory Committee comprises of District Collector, Chief Executive Officer of ZillaParishad and Director of District Rural Development Authority, all MLAs of the district, all the project officers and one or two members from the relevant research and training institutes in districts. The Watershed Advisory Committee must meet regularly to advise and assist district rural development area for training, community mobilization for implementation of watershed development programme.
The Project Implementation Agency can normally be assigned 10 to 12 watersheds covering an area of about 5000 to 6000 hectares to motivate Gram Panchayat and pass necessary resolutions, to make public contribution, conduct participatory rural appraisal exercise, prepare the development plans for the watershed and undertake community organization and training for the village community. The project implementation agency should provide technical guidance and supervision of watershed development activity, inspect and authenticates project accounts; undertake action research to adopt low cost technology and validate and buildup indigenous technical knowledge. The project implementation agency should monitor and review the overall project implementation and setup institutional arrangements for post project operation. The project implementation agency shall carryout its duties to multi-disciplinary team designed as watershed development team. The project implementation agency shall constitute self-help group in the watershed area with the help of watershed development team. The project implementation agency shall constitute user groups in the watershed area with the help of watershed development team. Watershed associations are formed at village Panchayat level to implement watershed development plans, monitor and review the progress and approve the statement of account, formation of user groups and resolve
differences of disputes between different user groups, self-help groups are amongst members of user groups. Watershed community should be nominated by watershed association with 10 to 12 members, which constitute of user groups, self-help groups, Grampanchayat and watershed development team. The watershed community shall carry out day-to-day activities on the watershed development projects.

The watershed developments are:

1. Land development including insitu soil and moisture conservation measures like contour and graded bunds fortified by plantation, bench terracing in hilly terrain, nursery raising for fodder, timber, fuel wood, horticulture and non-timber forest product species.
2. Afforestation including block plantations, agro-forestry and horticultural development, shelterbelt plantations, sand dune stabilization, etc.
3. Drainage line treatment with a combination of vegetative and engineering structures.
4. Development of small water harvesting structures such as low cost farm ponds, nalla bunds, and check dams and percolation tanks and groundwater recharge measures.
5. Renovation and argumentation of water resources, desiltation of tanks for drinking water/irrigation.

6. Pasture development either by self or in conjunction with plantations.

7. Repair, restoration and up gradation of existing common property assets and structures in the watershed to obtain optimum and sustained benefits from previous public investments.

8. Crop demonstration for popularizing new crops/varieties or innovative management practices.

9. Promotion and propagation of non-conjunctural energy saving devices and energy conservation measures.

The Pandameru and Tadakaleru river basin can be divided into 42 micro-watersheds. Each micro watershed consists of 500 hectares of land. Two micro-watersheds are selected in two different geological formations of the basin to study in depth the physical characteristics using IRS-1B Geo-coded data and Survey of India topographic sheets on 1:50,000 scale. They are Tumpera, which is located in northeastern parts of the basin in Proterozoic formations and Kanaganapalli, which is located southern part of the basin in Archean group of rocks.
**Tumpera Watershed:**

The Tumpera watershed covers an area of about 2,025 hectares. The watershed covers 7 villages. They are Narsapuram, Rangapuram, Jangamareddipalli, Ganganapalli, Harelisodanapalli, Mangapatnam and Tumpera. Physiographically the watershed varies in altitudes from 340 meters to a maximum of 472 meters above MSL (Fig: 8.1). The southern, southwestern and central parts of the watershed are less than 340 meters above the MSL. The altitude increases towards northeastern from 340 meters to 470 meters above MSL. (Fig: 8.1). The slope of Tumpera watershed has been worked out adopting Wentworth (1930) method (Fig: 8.2). The slope varies from 0° to 20°. They are classified into 5 categories of slope. They are less than 20° (gently sloping), 20° to 50° (moderately sloping), 50° to 100° (strongly sloping), and about 200° (steeply sloping). The Tumpera watershed possesses about 60% of the land under less than 20° slopes. The steep slopes are found in the hills and hillocks of Tumpera watershed. (Fig: 8.2). The moderate, strongly and very strongly sloping zones are found around steeply sloping zones of hills and hillocks. The type of drainage is sub-dentritic (Fig: 8.3). There are 37-first order streams, 9-second order streams, 2-third order streams and 1-fourth order streams in the watershed. All the streams are flowing to Tumpera tank. (Fig: 8.3). The Mid-Pennar south canal flow from
Relief
Tumpera Watershed - Anantapur Dt

Figure: 8.1
Figure 8.2

Slope
Tumpea Watershed - Anantapur Dt

Legend
- > 20°
- 10° to 20°
- 5° to 10°
- 2° to 5°
- < 2°
Drainage
Tumpera Watershed - Anantapur (Dt)
Andhra Pradesh

Figure: 8.3
western to northern. Geologically the Tumpera watershed is located in Proterozoic formations consisting of shales, dolomites and quartzites. The major landforms found in Tumpera watershed are shales and quartzitic hills and hillocks, pediment plains, valleyfills, creep built plains and wash plains. The pediment plains are found along the shales and quartzitic hills. The creep built plains are found at the foot of the hills and hillocks. The wash plains are found in less than 50 slope zones. The colluvial valley plains are found in the tank beds. (Fig: 8.4). The major types of soils found in Tumpera watershed are insitu soils, reddish stony pediment soils, silty soils and hilly terrains. The silts are accumulated in the Tumpera tank bed. (Fig: 8.5). The insitu soils are found in the shales and quartzitic hills and hillocks. Reddish stony pediment soils are found in pediment plains of the watershed. The black soils (silty) are located in northwestern parts of the watershed. The creep built soils are found at the foot of hills. In the Tumpera watershed the valleyfills and black soils and creep built soils are used for cultivation of sunflower, groundnut, paddy, sugarcane, banana, citrus, lemon and dry food crops under wet and dry conditions. The pediment plains of Tumpera watershed are used for cultivation of groundnut, red gram and sunflower under dry conditions. The shales and quartzitic hills and hillocks are barren lands without any vegetation. (Fig: 8.6).
Landforms
Tumpera Watershed - Anantapur Dt

Legend
- Sedimentary Hills
- Pediplains
- Creep Built Plains
- Wash Plains
- Colluvial Plains

Figure: 8.4
Hydrogeomorphology
Tumpura Watershed - Anantapur Dt

Figure: 8.5
Hydrogeomorphologically the Tumpera watershed is divided into 5 zones. The good zone of ground water resources is found in tank beds. In the wash plains ground water potential is very fair. In creep built plains ground water resources is fair. The pediment plains possess ground water resources is poor. The run-off zone is found on shales and quartzitic hills and hillocks. (Fig: 8.7). The intensity of erosion is high in shale and quartzitic hills. The intensity of erosion is moderate in pediment plains and wash plains. It is low in valleyfills and black/silty soils. (Fig:8.8).

Based on the physical characteristics, the Tumbera watershed has been divided into 5 classes of land. They are class-I valleyfills; the slope is less than 20\(^\circ\). The soil fertility is good. The ground water potential is good. The erosion susceptibility is low. The major crops cultivated are sunflower, groundnut and paddy. They are cultivated both under dry and wet conditions. The land development activities are land leveling, land grading and land mulching. The class-II land consists of 20\(^\circ\) to 50\(^\circ\) slopes. The soil fertility is moderate. The erosion susceptibility is moderate. The crops cultivated are groundnut, red gram and paddy. The land development activities are land leveling, land grading and land mulching. The class-III land consists of creep built soils with slope 20\(^\circ\) to 50\(^\circ\). The soil fertility is moderate, run-off is moderate and
Intensity of Erosion
Tumpera Watershed - Anantapur Dt
Landuse
Tumpera Watershed - Anantapur Dt

Legend
- Barren Lands
- Cultivable (Dry)
- Cultivable (Dry & Wet)
- Tank

Figure: 8.8
erosion is also moderate. The land development activities are land leveling, land grading and land bunding. The class-IV land consists of pediment plains. It is a low potential zone for ground water, infertile lands, run-off zone. The land development activities are land leveling, podoculture, rock bunding, terrace bunding, land grading and land mulching. The class-V possesses shales and quartzitic hills and hillocks with slope greater than 10° to 20° and more than 20°. The soils are insitu. It is a highly run-off zone. The intensity of erosion is high. The present land use on shale and quartzitic hills and hillocks are found scrubs and barren land. The land development activities are land bunding, construction of rockfill dams, peripheral bunding, trenching and check dams. Afforestation may be carried out. (Fig: 8.9).

**The Water Balance Elements of the Tumpera watershed:**

The water balance elements of the Tumpera watershed denote that the monthly precipitation varies from 2 mm to 128 mm (Table 8.1). The watershed receives an average rainfall of more than 100 mm in September and October months. The average rainfall ranges from 50 mm to 100 mm in July, August and November months. The average monthly rainfall is less than 50 mm in January, February, March, April and December month. The average potential evapotranspiration ranges from 90 mm to 200
Land Capability
Tumpera Watershed - Anantapur Dt

Legend
- Class I
- Class II
- Class III
- Class IV
- Class V

Figure: 8.9
mm. The average potential evapotranspiration is more than 150 mm in March, April, May, June, July and August months. The average potential evapotranspiration ranges from 90 mm to 150 mm in January, February, October, November and December months. The average actual evapotranspiration ranges from 23 mm to 149 mm. The average actual evapotranspiration varies from 50 mm to 150 mm in the months of June, July, August, September, October and November months. The actual evapotranspiration is less than 50 mm in the months of January, February, March and April months. The average water deficit of the basin varies from 1 mm to 146 mm. There is no water deficit in the months of September and October months. The water deficit exceeds 100 mm in March, April, May and June months. The average water deficit is 50 mm to 100 mm in January, February, September, October, November and December months. The water surplus is found in September months. There is no water surplus in all-remaining months in the year. The average monthly moisture adequacy varies from 14% to 99%. The moisture adequacy values vary from 41% to 99% in the months of July, September, October, November and December months. The Aridity Index varies from 1% to 86%. The 1% is noticed in September month. The Aridity Index is more than 50% in January, February, March, April, May, June, July and August months. Climatologically the watershed experiences dry
Water Balance Elements of Tumpera Watershed

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Table: 8.1
mm. The average potential evapotranspiration is more than 150 mm in March, April, May, June, July and August months. The average potential evapotranspiration ranges from 90 mm to 150 mm in January, February, October, November and December months. The average actual evapotranspiration ranges from 23 mm to 149 mm. The average actual evapotranspiration varies from 50 mm to 150 mm in the months of June, July, August, September, October and November months. The actual evapotranspiration is less than 50 mm in the months of January, February, March and April months. The average water deficit of the basin varies from 1 mm to 146 mm. There is no water deficit in the months of September and October months. The water deficit exceeds 100 mm in March, April, May and June months. The average water deficit is 50 mm to 100 mm in January, February, September, October, November and December months. The water surplus is found in September months. There is no water surplus in all-remaining months in the year. The average monthly moisture adequacy varies from 14% to 99%. The moisture adequacy values vary from 41% to 99% in the months of July, September, October, November and December months. The Aridity Index varies from 1% to 86%. The 1% is noticed in September month. The Aridity Index is more than 50% in January, February, March, April, May, June, July and August months. Climatologically the watershed experiences dry
sub-humid climate in August, September, October, November and December months. Semi arid climate is found in January, February, March, April, May, June and July months.

**The Seasonal and Annual Analysis of Water Balance Elements of the Tumpera watershed:**

The seasonal and annual analysis of water balance elements of the Tumpera watershed indicates that the precipitation is low in winter. It is 5 mm. The average rainfall is high in southwestern monsoon period. The average precipitation during this period is 311 mm. During summer, the precipitation value is 76 mm. During northeastern monsoon period, the precipitation value is 136 mm (Table: 8.2). The average low potential evapotranspiration of 224 mm is found in winter period and the average high potential evapotranspiration of 625 mm is found in southwestern monsoon period. The actual evapotranspiration is low in winter period. It is about 67 mm. The actual evapotranspiration is high in southwestern monsoon period. The average water deficit is low in northeastern monsoon period. It is 68 mm. The water deficit is high during the summer period. It is 406 mm. The water deficit is 157 mm in winter, 284 mm in southwestern monsoon period. In all the seasons, there is no water surplus. The low moisture adequacy value of 22% is found in summer period and high moisture
### Water Balance Elements of Tumpera Watershed

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**Table: 8.2**
adequacy value is found in the northeastern monsoon period. In winter moisture adequacy value is 30% and in southwestern monsoon period it is 55%. The Aridity Index values range from 20% to 78%. It is 70% in winter, 45% in southwestern monsoon, 20% in northwestern monsoon and 78% in summer.

**Water balance of the Tumpera Watershed:**

1. Total surface water resources of Tumpera watershed = 10,692,000 m³.
2. Water resources stored in surface tanks = 1,069,200 m³ (10%).
3. Water resources recharged to the groundwater resources = 12,83,040 m³ (12%).
4. Water resources lost in the form of surface run-off = 21,38,400 m³ (20%).
5. Water resources lost in the form of evaporation and evapotranspiration = 62,01,360 m³ (58%).

**Kanaganapalli Watershed:**

Kanaganapalli watershed covers an area about 1900 hectares of land. It is a macro watershed. The villages covered are three. They are Kanaganapalli Konapuram, and Balepalyam. The relief in the watershed varies from 440 m to 508m above MSL
The relief is less than 450 in northern and northwestern parts of the watershed. The 460m contour is found in northeastern part. The 500m contour is found at southern part of the watershed [Fig: 8.10]. The slope ranges from $1^\circ$ to $>20^\circ$. They are classified into five categories of slope. They are less than $2^\circ$ (gently sloping), $2^\circ$ to $5^\circ$ (moderately sloping), $5$ to $10^\circ$ (strongly sloping), $10$ to $20^\circ$ (very strongly sloping) and $>20^\circ$ (steeply sloping) (Fig: 8.11). The gently sloping land is found in the northern and western parts of the watershed. The moderately sloping land is found in the central part of the watershed. The strongly sloping land is found in southern and northeastern parts of the watershed. The very strongly sloping land is found in the southeastern parts of the watershed (Fig: 8.11). The drainage of the Kanaganapalli watershed is dentritic (Fig: 8.12). There are about 157 streams in the watershed. Out of them 113 are first order streams, 33 are second order streams, 8 are third order streams, two are fourth order streams and one is found in fifth order stream. All the streams are empirically joined Peddavanka at Kanaganapalli village. The total length of the main stream is 10 km. The main stream originates at Konapuram. It flows from southern and southeastern to northern and northwestern directions for about 8 km (Fig: 8.12). The major landforms of the Kanaganapalli watershed are hilly soils, pediment plains, creep
Relief
Kanaganapalli Watershed - Anantapur Dt

Legend
(in Meters)
- < 400
- > 400 to < 450
- > 450 to < 500
- < 500

Figure: 8.10
Figure: 8.11

Legend

- > 20°
- 10° to 20°
- 5° to 10°
- 2° to 5°
- < 2°
Drainage
Kanaganapalli Watershed - Anantapur (Dt)
Andhra Pradesh

Figure: 8.12
built plains, colluvial soils, residual hills, pediplains and colluvial valleyfills (Fig: 8.13). The hilly terrain is found in southern and southeastern parts of the watershed. The pediment plain is found in southern part of the watershed. The residual hills are found in northeastern part of the watershed. Pediplains are found in northeastern and northwestern parts of the watershed. Creep built plains are found in western parts of the watershed. The residual hills are scattered in northeastern and southeastern parts of the watershed. The colluvial valleyfills are found in northern parts of the basin. There are 4 tanks out of which the Kanaganapalli tank is the major one.

Geologically the Kanaganapalli watershed is composed of mainly Archean rocks consisting of granitic gneisses. The Dharwar schists are traversed in northern, southern, northeastern and southeastern direction in the watershed. The major soils of the watershed are insitu soils, red sandy soils, moderately red sandy soils, colluvial sandy loam soils, silty soils and residual hills. The moderately red sandy soils are found in western parts of the watershed. The colluvial sandy loam soils are found in northern parts of the watershed. The shallow red sandy soils are found in northern parts of the watershed. The silty soils are found in tank beds of the watershed. The insitu soils are found in southeastern
and northeastern parts of the foot of the hills. The residual hills are found in northeastern and southeastern parts of the watershed (Fig: 8.14).

The land use of Kanaganapalli watershed is divided into shrub forest, cultivated land (dry), cultivated land (dry & wet), wastelands, hills and tanks. The shrub forests are found in southeastern and eastern parts of the watershed. The cultivable (dry & wet) is found in northern part of the watershed. The cultivable (dry) land is found in central, western and northwestern parts of the watershed. The wastelands are found in the southwestern parts of the watershed. The barren hills are found in southern, eastern and northeastern parts of the watershed. There are 4 tanks located at 4 different parts of the entire watershed (Fig: 8.15). Hydrogeomorphologically the watershed is divided into 6 zones (Fig: 8.16). The excellent groundwater resources are found in tank beds. The good groundwater resources are found in colluvial sandy loam soils, located in northern part of the watershed. The very fair groundwater resources are found in the creep built plains. The fair groundwater resources are found in the pediment plains. The poor groundwater resources are found in weathered pediplains. The very poor (run-off) groundwater resources are found in residual hills.
Soils
Kanaganapalli Watershed - Anantapur Dt

Legend
- Residual Hills
- Shallow Red Sandy Soils
- Moderate Red Sandy Soils
- In situ Soils
- Silty Soils
- Colluvium Sandy Loam Soils

Figure: 8.15
Intensity of Erosion
Kanaganapalli Watershed - Anantapur Dt

Legend
- Very High
- High
- Moderate
- Low

Figure: 8.16
The intensity of erosion is very high in pediplains soils and hilly terrains above 20° of slope, located in southern and eastern parts of the watershed. The moderate intensity of erosion is noticed in pediment plains. The intensity of erosion is low in creep built plains and colluvial valleyfills (Fig: 8.17). Based on the physical characteristics of the watershed, the land is classified into six classes (Fig: 8.18). They are the class-I land consists of colluvial valleyfills. The slope is less than 20°. The soil fertility is good. The groundwater potential is good. Erosion susceptibility is low. The present land use is cultivated land under dry & wet conditions. The crops cultivated are groundnut, paddy, chillies, mangoes and vegetables. The land development activities that could be taken up are land leveling, land grading and land mulching. The class-II consists of creep built plains. The slope is varies from 20° to 50°. The soil fertility is moderate. The groundwater potential is good. The erosion susceptibility is low. The present land use is cultivated land under wet & dry conditions. The crops cultivated are groundnut, paddy and vegetables. The land development activities could be taken up are land leveling, land grading and land mulching. The class-III had consists of pediplains. The slope varies from 50° to 100°. The soil fertility is moderate. The groundwater potential is fair. The erosion susceptibility is moderate. The present land use is cultivated land under wet & dry conditions. The crops
Landuse
Kanaganapalli Watershed - Anantapur Dt

Legend
Cultiv#vabls, Dry)
Hills
Cultivable (Dry & Wet)
Waste Land
Tanks
Shrub Forest

Figure: 8.17
Figure: 8.18
cultivated are mangoes, mulberry, sunflower and groundnut. The land development activities that could be taken up are land leveling, land mulching and land bunding. The class-IV consists of pediment plains. The slope varies from 2° to 5° and 5° to 10°. The soil fertility is moderate. The erosion susceptibility is moderate. The present land use is cultivated land under dry conditions. The crops cultivated are groundnut, sunflower and dry food crops. The class-V consists of hilly terrain. The slope varies from 10° to 20°. The soil fertility is poor. The groundwater potential is poor. The erosion susceptibility is high. The present land use is barren. The land development activities that could be taken up are terrace bunding, rockfill dams, land leveling and afforestation. The class-VI consists of residual hills with greater than 20° slope. The soil fertility is very poor. It is a run-off zone. The erosion susceptibility is very high. The present land use is forest with shrubs and degraded forests. The land development activities that could be taken up are terrace bunding, afforestation.

**The Water Balance Elements of the Kanaganapalli Watershed:**

The water balance elements of the Kanaganapalli watershed (Table: 8.3) denoted that the monthly precipitation varies from 3 mm to 140-mm. The watershed receives an average rainfall of more than 100 mm in the month of September. The average monthly
## Water Balance Elements of Kanaganapali Watershed

<table>
<thead>
<tr>
<th>Elements</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<td>4</td>
<td>19</td>
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<td>64</td>
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<td>99</td>
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<td>7</td>
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<td>154</td>
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<td>150</td>
<td>140</td>
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<td>75</td>
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<tr>
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<td>35</td>
<td>25</td>
<td>29</td>
<td>63</td>
<td>51</td>
<td>56</td>
<td>64</td>
<td>140</td>
<td>124</td>
<td>83</td>
<td>47</td>
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<tr>
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<td>85</td>
<td>129</td>
<td>143</td>
<td>116</td>
<td>111</td>
<td>95</td>
<td>86</td>
<td>0</td>
<td>0</td>
<td>12</td>
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<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
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<td>16</td>
<td>17</td>
<td>32</td>
<td>31</td>
<td>37</td>
<td>43</td>
<td>100</td>
<td>100</td>
<td>87</td>
<td>63</td>
</tr>
<tr>
<td>Ia (in %)</td>
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<td>71</td>
<td>84</td>
<td>83</td>
<td>65</td>
<td>69</td>
<td>63</td>
<td>57</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>37</td>
</tr>
<tr>
<td>Im (in %)</td>
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<td>-50.4</td>
<td>-49.8</td>
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<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>C1</td>
<td>C2</td>
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<td>C1</td>
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</tbody>
</table>

Table: 8.3
rainfall is less than 50 mm in January, February, March, April and June months. The average potential evapotranspiration ranges from 83 mm to 179 mm. The average potential evapotranspiration is more than 150 mm in March, April, May, June and July months. The average potential evapotranspiration ranges from 100 mm to 150 mm in the month of March, April, May, June and July. The average potential evapotranspiration is less than 100 mm in January, February, November and December months. The average actual evapotranspiration ranges from 25 mm to 140 mm. The average actual evapotranspiration is more than 100 mm in the month of September and October months. The average actual evapotranspiration values vary from 50 mm to 100 mm in the months of May, June, July, August, November and December months. The average actual evapotranspiration values are less than 50 mm in January, February, March and April months. The average water deficit in the watershed varies from 0 mm to 143 mm. There is no water deficit in the September and October months. The average water deficit exceeds 100 mm in March, April, May and June months. The average water deficit ranges from 50 mm to 100 mm in January, February, August, November and December months. There is no water surplus in all months of the year in the watershed. The average monthly moisture adequacy ranges from 16% to 100%. The moisture adequacy is 100% in
September and October months. The moisture adequacy values vary from 50% to 99% in November and December. The moisture adequacy is less than 50% in January, February, March, April, May, June, July and August months. The average actual Aridity Index value ranges from 0% to 84%. The 0% is noticed in September and October months. The Aridity Index is more than 50% in January, February, March, April, May, June, July and August months. The Aridity Index is less than 50% in November and December months. Climatologically the watershed experiences moist sub humid type of climate is found in September and October months. The dry sub-humid type of climate is found in January, August, November and December months. The semi-arid type of climate is noticed in February, March, April, May, June and July months. The seasonal analysis of the water balance elements of the Kanaganapalli watershed reveals during southwest monsoon the rainfall is high and the watershed receives 306 mm of rainfall. The potential evapotranspiration is high during southwest monsoon. The water deficit is high in summer period. The moisture adequacy is high during northeast monsoon and Aridity Index is high during summer period. The watershed experiences semi arid type of climate during winter and summer periods and dry sub humid type of climate during the southwest and northeast monsoon period (Table: 8.4). The watershed receives annual
## Water Balance Elements of Kanaganapalli Watershed

<table>
<thead>
<tr>
<th>Elements</th>
<th>Winter</th>
<th>Summer</th>
<th>Southwest Monsoon</th>
<th>Northeast Monsoon</th>
<th>Annual</th>
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<tbody>
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<tr>
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<td>505</td>
<td>603</td>
<td>294</td>
<td>1605</td>
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<tr>
<td>AE</td>
<td>70</td>
<td>117</td>
<td>311</td>
<td>254</td>
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<tr>
<td>WD</td>
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<td>388</td>
<td>292</td>
<td>40</td>
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<tr>
<td>WS</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ima (in %)</td>
<td>34</td>
<td>23</td>
<td>52</td>
<td>86</td>
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</tr>
<tr>
<td>Ia (in %)</td>
<td>66</td>
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<td>48</td>
<td>14</td>
<td>205</td>
</tr>
<tr>
<td>Im (in %)</td>
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<td>-8.4</td>
<td>-123</td>
</tr>
<tr>
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<td>D</td>
<td>D</td>
<td>C1</td>
<td>C1</td>
<td>C1</td>
</tr>
</tbody>
</table>

Table: 8.4
rainfall of 550 mm, annual potential evapotranspiration of 1605 mm, actual evapotranspiration of 885 mm. The annual water deficit is 720 mm. The Moisture Index is 55% and Aridity Index is 45%. Climatologically the watershed experiences dry sub humid type of climate.

**Water balance of Kanaganapalli Watershed:**

1. Total surface water resources of Kanaganapalli watershed = 3,45,57,050 m$^3$.

2. Water resources stored in surface tanks = 3455705 m$^3$ (10%).

3. Water resources recharged to the groundwater resources = 42,66,846 m$^3$ (12%).

4. Water resources lost in the form of surface run-off = 6911410 m$^3$ (20%).

5. Water resources lost in the form of evaporation and evapotranspiration = 20043089 m$^3$ (58%).

**Watershed management of Tumpera and Kanaganapalli Watersheds:**

A proper emphasis should be laid on land and water resources management to control soil erosion and conserve water resources. The soil erosion could be controlled by contour cultivation, contour bunding, graded bunding, bench terracing,
grass waterways, diversion of drains and land leveling and land grading. The soil erosion in the hills and hillocks of the Tumpera and Kanaganapalli watersheds could be controlled by contour trenching, gully control measures through vegetative barriers, diversion channels and ditches, rock fill dams, stone fill dams, check dams, brushwood check dams, boulder walls, embankments, spill way inlets, spill way conduits, spill way outlets and drop spill ways. The gullies could be reclaimed through construction of contour graded bunds, peripheral bunds, gully plugging, stabilization of peripheral bunds through grasses or vegetative cover, construction of composite check dams and construction of sediment retention structures.

The water resources could be conserved through border irrigation, furrow irrigation, corrugated irrigation, contour furrowing, small storage structures, earth embankments, spill ways, farm ponds, excavated ponds, nalla bunding, sand dams, small weirs, off-stream storage and water harvesting streams and scrubs.

The groundwater resources in the watershed can be managed by construction of artificial recharges, underground check dams, cementing the discharging faces, prevention of
leakages, pressure injunctions, droughting and construction of surface reservoirs.

The watersheds could be managed ecologically by large-scale plantation. The first step is to find out the preferences of beneficiaries in the watershed area. Information should be gathered regarding community plantation site, user groups, self-help groups, indigenous management systems, nursery location, nursery establishment, land use management and plantation operations. For successful development of plantation, the measures should be taken are land leveling, soil and water conservation, water harvesting structures, strip cultivation and weeding, seed selection, seed storage, seed treatment, nursery, use of fertilizers and irrigation.

The management of grasslands in the upper reaches of watershed is important as a constant and enriching biomass. It could help conserving soil moisture and create environment for the advanced tree species to regenerate. In watershed management the grasslands supply fodder and forage.

Afforestation is a sustainable land use system, which evolves to intermittent and interacting association of agriculture and
horticulture crops and woody perennials (trees, scrubs, plants and bamboos). The main objectives of agro-forestry are biomass production, soil conservation, soil improvement, promotion of agro-based industry, herbal drugs, poultry, piggery, dairy, honeybee keeping, sericulture and mushroom cultivation.

The major horticulture activities that could be taken up for development of watersheds are agro-horticultural system, home shed gardens and community hatcheries, fruit crops like sapota, pomegranate, custard apple, cashew, papaya, lemon, sweet orange, mango, mulberry, guava, jamen, bear and tamarind should be cultivated on the wastelands of watersheds.

The joint forest management and participatory forest management are alienated for the development of forest by local community groups from the different natural resources on which they have depended for generation. The local community gets increase access and rights over the degraded forest. Increasing biotech pressure, encroachments and development of forest based industries, scarcity of agriculture land, transfer of development activity and uncontrolled grazing has grossly depleted the natural resources of watersheds. The joint forest management system and participatory forest management system played a vital role in
development of watershed areas comprising of degraded forests. The joint forest management and participatory forest management are decentralized participatory and local need based forest management in the watersheds.

Common property resources management is formed for amalgamation of land, forest, water, soil and other natural resources. Common property resource management contributes for agricultural production, livestock management, non-farm activities and rural industry development. Management of common property resource management is an important priority sector in watershed development. The grasslands, the degraded forest, wastelands, water conservation and harvesting management are sources of the important areas of common property resource management. The above said watershed management activities could be implemented in Tumpera and Kanaganapalli watersheds with the financial support of central and state governments.