Name of the Tool: Watershed Scorecard

Introduction

Conservation of natural resources on watershed basis is the most widely adopted technology in developed as well as developing countries due to its suitability across climatic conditions. The watershed approach enables planners to harmonize the use of soil, water and vegetation in a way that conserves these resources and maximize their productivity (Kerr, 2002). The first step in the development of a strategy for improving and protecting the condition of a watershed is its assessment. It is very important to assess a watershed in order to understand its current status and how it got there (Shilling et al, 2004). In order to tackle this situation, the society needs tools that cater to watershed management, that describes the current situation and trends, and deliver a simplistic approach to discuss natural resource stewardship in watersheds (Cornwall et al, 2010). A 'watershed scorecard' is a tool for prioritizing the need to monitor and inform and involve the local people, planners, decision makers, researchers and scientists (Cornwall et al, 2010). A watershed scorecard provides a snapshot of the current condition of the watershed and identifies changes that may have taken place over the past years (Mississippi Valley Conservation Authority, 2013). A scorecard not only reports the current status of natural resources but also helps to identify the drivers of change, major hotspots, emerging issues as well as measures trend (Maaskant & Quinlan, 2012).

Objectives of tool

Watershed Scorecard is an important management tool which works on the principle of 'what gets measured gets managed'. The scorecard will provide help to the regulatory and legislative decision makers, planners and watershed stakeholders to understand the condition of our forests, groundwater, surface water, soil, and agriculture in the watershed and to focus efforts where they are needed most. It also to identifies ecologically important areas that require protection or enhancement within the selected watersheds under the Neeranchal National Watershed Project.

Definitions and Concepts

- **Watershed Scorecard**
  A watershed scorecard is a tool which provides a snapshot of the current status of the natural resources of the watershed and identified the changes that may have taken place over the past few years.

- **Surface Runoff Losses**
  Portion of rainfall which is discharged in surface streams. When all losses are satisfied and if rain is still continued, with the rate greater than in filtration rate; at this stage the excess water makes a head over the ground surface (surface detention) which tends to move from one place to another, known as overland flow. As soon as the overland flow joins to the streams, channels or oceans, termed as surface runoff.

- **Natural Groundwater Recharge**
  The natural groundwater recharge occurs when it stems from the direct infiltration of rainfall or from the water percolation of adjacent water bodies.

- **Water Quality Index**
  Water Quality Index (WQI) is one of the most effective tools that helps to communicate the status on the quality of water to the local people and the decision makers. The WQI provides a comprehensive picture of the quality of surface/groundwater for most domestic uses. WQI is defined as a rating that reflects the composite influence of different water quality parameters.

- **Forest Cover**
  Forest cover is defined as an area more than 1 ha in extent and having tree canopy density of 10 percent and above

- **Crop Diversification Index**
  It means raising a variety of crops involving intensity of competition amongst field crops for arable land so as to expand production related activities on various crops and also to lessen risk.

- **Cropping Intensity**
  Cropping intensity refers to raising of a number of crops from the same field during one agriculture year. Thus, higher cropping intensity means that a higher portion of the net area is being cropped more than once during one agricultural year. This also implies higher productivity per unit of arable land during one agricultural year.

- **Soil Depth**
  Soil Depth determines the effective rooting depth for plants and in accordance with texture, mineralogy and gravel content, the capacity of the soil column to hold water.

- **Soil Irrigability**
  It is useful to make groupings of soils according to their suitability for sustained use under irrigation and also to predict the behaviour of soils when they are brought under irrigation.

- **Land Capability**
  Land capability classification is an interpretative grouping of soil mapping units mainly based on inherent soil characteristics, external land features and environmental factors that limit the use of land for agriculture, pasture, or other uses on a sustained basis.

Methods Used

This scorecard focuses on five wide areas of study: forest conditions, soil conditions, Water quantity, water quality and agricultural condition and uses a standard grading scheme. The indices and indicators selected for the study are given in Table 1. The detailed description of each indicator and the methodology used has been provided in subsequent section. The grades for the 5 theme areas are then converted into scores. Weights have been assigned to each theme which can vary from one watershed to another. An overall score for the watershed would finally be generated which will reflect the status of the watershed health.

Table 1: List of indices and indicators selected for the study

Themes	Indicators	How to measure?
Water Quantity	Runoff Losses from Watershed	Runoff to Rainfall Ratio (SCS CN Method)
	Natural Groundwater Recharge	Recharge to Area (Rainfall Infiltration Method)
Water Quality	Surface Water Quality Index	NSF Method (Modified by CPCB)
	Groundwater Quality Index	Weighted Arithmetic Index Method
Forest Conditions	% Forest Cover	NDVI Analysis
Soil Conditions	Soil Depth	GIS
	Soil Irrigability	GIS
	Land Capability	GIS
Agricultural Conditions	Crop Diversification Index	Gibbs and Martin's Method
	Cropping Intensity	(Gross Cropped Area/ Net Area Sown)*100

1. Water Quantity

1.1. Run off Losses

Ratio of runoff to rainfall has been used to estimate the runoff losses from the watershed. Runoff value used here is generated through the SCS- Curve Number method. The runoff /rainfall ratio for past 30 years' data has then analyzed and statistically classified on the basis of quartiles (Q1, Q2 and Q3). Lower value of the ratio indicates the that more water is retained in the watershed and not discharged much at the outlet at the downstream. The following table 1.1.1 provides the grading scheme for the classification of runoff/ rainfall ratio.

Table 1.1.1: Runoff Grading as per statistical classification

Quartiles	Grade
<Q1	A
Q1 - Q2	B
Q2 - Q3	C
>Q3	D

1.2. Natural Groundwater Recharge

Ratio of recharge to area has been used to estimate the natural groundwater recharge of the watershed. Recharge value used here is generated through the Rainfall infiltration method (GEC 1997). The following Table 1.2.1 provides the grading scheme for the classification of runoff/ rainfall ratio.

Table 1.2.1: (Recharge/ Area) Grade Classification

Grade	Class intervals	Condition
A	>50	Excellent
B	30 - 50	Very Good
C	10 – 30	Good
D	<10% and > 50%	Poor

2. <u>Water Quality</u>

2.1. Surface Water Quality

The National Sanitation Foundation, USA developed the Water Quality Index (NSFWQI), a standardized method for comparing the water quality of various water bodies. It is one of the most respected and utilized water quality index.

Given the parameters monitored in India under National Water Quality Monitoring Programme (NWMP) and to maintain the uniformity while comparing the WQI across the nation, the NSF WQI has been modified and relative weights have been assigned by CPCB (Abbasi, 2002, CPCB, 2001). Four parameters (pH, Dissolved Oxygen (% saturation), Biochemical Oxygen Demand, Fecal Coliform) are used for calculating WQI for surface water. Upon determining the Water Quality Index, the water quality is described for easy understanding and interpretation. The mathematical expression for NSF WQI is given by equation 2.1.1:

$$WQI = \sum_{i=1}^{n} QiWi \qquad \text{................ (2.1.1)}$$

Where,

Qi= sub-index for ith water quality parameter;

Wi= weight associated with ith water quality parameter;

n= number of water quality parameters.

The modified weights (Wi) and the sub-index/ quality value as per CPCB and Maharashtra Pollution Control Board, are given in Table 2.1.1 and 2.1.2, respectively. The range of the NSFWQI corresponding to various designated best use classification is given in table 2.1.3. The **NSF WQI** provides information on a rating scale from zero to hundred. Lower value of NSF WQI indicates poor quality of water and higher value shows excellent water quality.

Table 2.1.1: Original and Modified Weights for the computation of NSF WQI

Water Quality parameters	Original Weights from NSF WQI	Modified Weights by CPCB
Dissolved Oxygen (% saturation)	0.17	0.31
Fecal Coliform	0.15	0.28
pH	0.12	0.22
Biochemical Oxygen Demand	0.10	0.19
Total	0.54	1.00
Source: Central Pollution Control Board, Environmental Atlas of India (2001) New Delhi		

Table 2.1.2: Sub –Index Equations for Water Quality Parameters (NSF WQI)

Water Quality parameters	Range Applicable	Equation
Dissolved Oxygen (percent saturation)	0-40% saturation 40-100% saturation 100-140% saturation	IDO = 0.18+0.66 x (% Saturation DO) IDO = -13.55+1.17 x (% Saturation DO) IDO = 163.34-0.62 x (% Saturation DO)
Fecal Coliform	1-10^3 10^3-10^5 >10^5	IFC = 97.2-26.6 x log(FC) IFC = 42.33 -7.75 x log(FC) IFC = 2
pH	2-5 5-7.3 7.3-10 10-12 <2,>12	IpH = 16.1+7.35 x (pH) IpH = -142.67+33.5 x (pH) IpH = 316.96-29.85 x (pH) IpH = 96.17-8.0 x(pH) IpH = 0
Biochemical Oxygen Demand	0-10 10-30 >10	IBOD = 96.67-7 (BOD) IBOD = 38.9-1.23 (BOD) IBOD = 2
Src: Abbasi, S.A. (2002) Water Quality Indices State-of-the-Art, Pondicherry University, Centre for Pollution Control & Energy Technology, Pondicherry.		

Table 2.1.3: NSF WQI for various designated best use

WQI	Quality Classification	Class by CPCB	Remarks	Colour code
63 –100	Good to Excellent	A	Non – Polluted	
50 – 63	Medium to Good	B	Non – Polluted	
38 – 50	Bad	C	Polluted	
38 and less	Bad to Very Bad	D, E	Heavily Polluted	
Source: Central Pollution Control Board, Environmental Atlas of India (2001) New Delhi				

<u>Conversion of DO to DO saturation (%):</u> Under the NSWQI, we take DO saturation % as a paremeter for calculating the overall WQI. Therefore, we need to convert the DO value to DO saturation %. This can be carried out using the give formula.

Step 1: Check the corresponding value of solubility with the given temperature conditions of water body from table 2.1.4.

Table 2.1.4: Solubility values corresponding to temperature

Temp. °C	100 % Solubility (mg/L)
0	14.60
1	14.20
2	13.80
3	13.50
4	13.10
5	12.80
6	12.50
7	12.20
8	11.90
9	11.60
10	11.30
11	11.10
12	10.90
13	10.60
14	10.40
15	10.20

Temp. °C	100 % Solubility (mg/L)
16	10.00
17	9.80
18	9.60
19	9.40
20	9.20
21	9.00
22	8.90
23	8.70
24	8.60
25	8.40
26	8.20
27	8.10
28	7.90
29	7.80
30	7.70

Step 2: Apply the Formula:

$$DO\ saturation\ \% = \frac{Observed\ DO\ Value}{100\%\ solubility\ value\ to\ the\ corresponding\ temp}\ X\ 100$$

2.2. Groundwater Quality

The groundwater quality index has been calculated using the weighted arithmetic index method. The method is based on 12 water quality parameters namely, pH, Electrical Conductivity (µS/cm), Total dissolved Solids (mg/l), Alkalinity (mg/l), Total Hardness (mg/l), Calcium (mg/l), Magnesium (mg/l), Chloride (mg/l), Iron (mg/l), Nitrate (mg/l), Sulphate (mg/l) and Fluoride (mg/l). Following steps have been adopted to estimate WQI:

Let there be n water quality parameters and **quality rating (qn)** corresponding to nth parameter is a number reflecting relative value of this parameter in the water sample with respect to its standard permissible value.

$$Qn = 100\ x\ \frac{(Vn-Vi)}{(Vs-Vi)} \qquad \text{................ (2.2.1)}$$

Where,

Qn = Quality Rating, Vs = Standard value, Vn = observed value Vi = ideal value

In most cases Vi= 0 except in certain parameters like pH, dissolved oxygen etc., Calculation of quality rating for pH:

$$Q\ pH = 100\ x\ \frac{(VpH - 7.0)}{(8.5 - 7.0)} \qquad \text{................ (2.2.2)}$$

Parameters Weightage:

Calculation of unit weight: The Unit weight (Wn) to various water Quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

$$Wn = \frac{k}{Sn} \qquad \text{................ (2.2.3)}$$

Where, Wn = unit weight for nth parameter; Sn = standard permissible value for nth parameter; k = proportionality constant.

WQI is calculated by the following equation 2.2.4.

$$WQI = \frac{\sum_{n=1}^{n} q_n w_n}{\sum_{n=1}^{n} w_n} \qquad \text{................ (2.2.4)}$$

For this WQI method, the ratings of water quality have been defined by using Table 2.2.1

Table 2.2.1: NSF Water Quality Criteria and Grade Scheme

WQI	Class	Grades	Water Quality Status
<50	Excellent	A	Pristine Quality
51-100	Good	B	Good
101-150	Fair	C	Acceptable
151-200	Poor	D	Need Treatment
201-250	Very Poor	E	Need Treatment
>250	Unfit	F	Unsuitable for drinking

3. <u>Forest Conditions</u>

3.1. Percent Forest Cover

The normalized difference vegetation index (NDVI) is used for mapping the forest cover and changes. NDVI is an index based on spectral reflectance of the ground surface feature. Each feature has its own characteristic reflectance varying according to the wavelength. The NDVI analysis was carried out using Landsat 8 OLI/TIRS C1 Level – C1 (30 m resolution) satellite imagery and Spatial Analyst Tool in Arc Gis software. NDVI is calculated using the equation 3.1.1:

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad \text{................ (3.1.1)}$$

where RED is visible red reflectance, and NIR is near infrared reflectance. The wavelength range of NIR band is (0.845–0.885 µm) and Red band is (0.630–0.680 µm). NDVI value calculated, ranges between -1 to +1. Very low value of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow. Moderate values represent shrub and grassland (0.2 to 0.3), while high value indicates temperate and tropical rainforests (0.6 to 0.8). Bare soil is represented with NDVI values, which are closest to 0 and water bodies are represented with negative NDVI values.

NDVI image was re-classified to obtain forest coverage. Table 3.1.1 gives the classification

Table 3.1.1: Grades for percent forest cover, Source: Briggs et al, 2003

NDVI Range	Forest Classes
0.22 – 0.25	Land with or without Scrub
0.25 – 0.36	Scrub Forests
0.36 – 0.42	Dense Forests

With a view to maintain the environmental balance, the national forest policy envisages an average forest cover of 33% of the geographical area for the whole of the country (Ministry of Environment and Forests. 1988). As shown in Table 3.1.2, the per cent forest cover has been classified into 4 categories and then given a grade in reference to Conservation Ontario standardized guidelines (Briggs et al, 2003).

Table 3.1.2: Grades for percent forest cover, Source: Briggs et al, 2003

% Forest Cover	Our Grades	Grade Description
>30.1	A	Excellent
15.1-30.0	B	Good
5.0-15.0	C	Poor
<5.0	D	Very Poor

4. Agricultural Conditions

4.1. Crop Diversification Index

Gibbs and Martin’s Method for Demarcating Crop Diversification Regions (1962) is used to estimate the different variety of crops that can rise in a given area in one season. It is calculated by using the formula given in equation 4.1.1:

$$\textit{Crop Diversification Index} = 1 - \frac{\sum x^2}{(\sum x)^2} \quad \text{................ (4.1.1)}$$

Where, x represents percentage of total cropped area under an individual crop of the particular region The scores are classified into 4 classes which help us to assign grades as shown in Table 4.1.1

Table 4.1.1: Grades for crop diversification index (CDI), Source: Dutta, 2012

S.No.	Level of Diversification	Category	Our Grades
1	0.80-0.88	High	A
2	0.60-0.80	Medium	B
3	0.40-0.60	Low	C
4	Below 0.40	Very Low	D

4.2. Cropping Intensity

Cropping intensity refers to raising of a number of crops from the same field during one agriculture year. It can be computed using the formula given in equation 4.2.1

$$Cropping\ Intensity = \frac{Gross\ Cropped\ Area}{Net\ Sown\ Area}\ x\ 100 \qquad \ldots\ldots\ldots\ldots\ldots (4.2.1)$$

The scores are classified into 4 classes which help us to assign grades (Das and Mili, 2012) as shown in Table 4.2.1.

Table 4.2.1: Grades for cropping intensity index, Source: (Das and Mili, 2012)

S.No.	Levels for Cropping Intensity Index	Category	Our Grades
1	Above 140	High	A
2	130-140	Medium	B
3	120-130	Low	C
4	Below 120	Very Low	D

5. <u>Soil Conditions</u>

5.1. Soil Depth

The soil depth classification is done using the Soil Series - Criteria and Norms provided by the National Bureau of Soil Survey and Land Utilization Planning (Sehgal, 1992). The soil depth is categorised into 7 classes and grades are assigned accordingly as shown in Table 5.1.1.

Table 5.1.1: Grades for soil depth, Source: Sehgal, 1992

Soil Depth	Series	Our Grades
>150 cm	Very Deep	A
100 – 150 cm	Deep	B
75 – 100 cm	Moderately Deep	
50 – 75 cm	Moderately Shallow	C
25 – 50 cm	Shallow	D
10 – 25 cm	Very Shallow	
<10 cm	Extremely Shallow	E

5.2. Soil Irrigability Classification

The soil irrigability classification is done using the Soil Series - Criteria and Norms provided by the National Bureau of Soil Survey and Land Utilization Planning (Sehgal, 1992). The results fall under 5 classes with the help of which we have assigned a grade to each class as shown in Table 5.2.1.

Table 5.2.1: Grades for soil and land Irrigability, Source: Sehgal, 1992

Classes	Description	Our Grades
I	None or slight soil limitations for sustained use under irrigation	**A**
II	Moderate soil limitations for sustained use under irrigation	**B**
III	Severe soil limitations for sustained use under irrigation	**C**
IV	Very severe soil limitations for sustained use under irrigation	**D**
V	Not suited for irrigation or non-irrigable soil class	**E**
Misc.	Water bodies and built up	

5.3. Land Capability Classification

Land capability classification is an interpretative grouping of soil mapping units mainly based on inherent soil characteristics, external land features and environmental factors that limit the use of land for agriculture, pasture, or other uses on a sustained basis (All India Soil and Landuse Survey Organisation, 1971). The land capability has been classified under 8 capability classes using the United States Department of Agriculture (USDA) classification and we have assigned grades for the study accordingly as shown in Table 10 (Klingebiel & Montgomery, 1961).

Table 5.3.1: Grading scheme for land capability classification,
Source: Klingebiel and Montgomery, 1961

Classes	Description	Our Grades
1	Soils have slight limitations that reduce their use.	**A**
2	Soils have moderate limitations that reduce the choice of plants or that require moderate conservation practices.	**B**
3	Soils have severe limitations that reduce the choice of plants or that require special conservation practices, or both.	
4	Soils have very severe limitations that restrict the choice of plants or that require very careful management, or both.	**C**
5	Soils have little or no erosion hazard but have other limitations impractical to remove that limit their use largely to pasture, range, woodland, or wildlife food and cover.	
6	Soils have severe limitations that make them generally unsuitable for cultivation and limit their use largely to pasture, rangeland, forestland, or wildlife habitat.	**D**
7	Soils have very severe limitations that make them unsuitable for cultivation and that restrict their use mainly to grazing, forestland, or wildlife habitat.	
8	Soils and landforms have limitations that preclude their use for commercial plant production and restrict their use to recreational purposes, wildlife habitat, or water supply or aesthetic purposes.	**E**

6. Overall Score

The composite grades for the health of the overall watershed are based on average for water quantity, water quality, forest conditions, agricultural conditions and soil conditions are given in Table 6.1.

Table 6.1: Overall grades for the watershed

Overall Watershed Score	Grades	Description
80 – 100	A	Excellent ecosystem conditions.
60 – 80	B	Very Good ecosystem conditions. Some protection may be required
40 – 60	C	Good ecosystem conditions. Some areas may require enhancement.
20 – 40	D	Poor ecosystem conditions. Overall improvements necessary.
0 – 20	E	Very Poor ecosystem conditions. Considerable improvements required

Expected Inputs and Outputs

Expected Input:

- Values for the individual indicators and grades from the standards

Expected Output:

- Basis the performance of each indicator, the grades will be assigned to each indicator.
- Overall score of the watershed will be generated from the individual grades that have been generated.
- Grades and the final score reveals the current status of the watershed health.
- Trend can be established from the previous watershed scorecards

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Suggested Readings

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