TokensFarm

TOKENSFARM

SMART CONTRACT AUDIT

zokyo

October 28th 2022 | v. 3.0

Security Audit Score

PASS

Zokyo Security has concluded that this smart contract passes security qualifications to be listed on digital asset exchanges.

SCORE

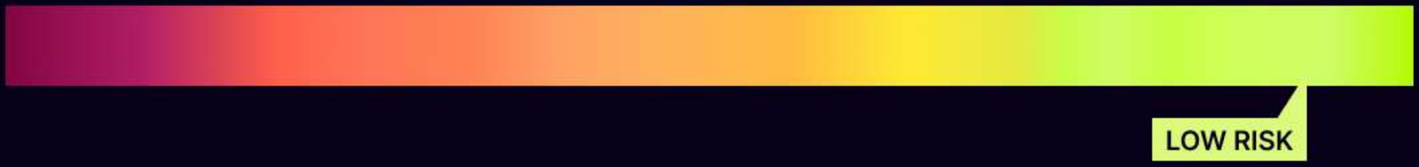
90

TECHNICAL SUMMARY

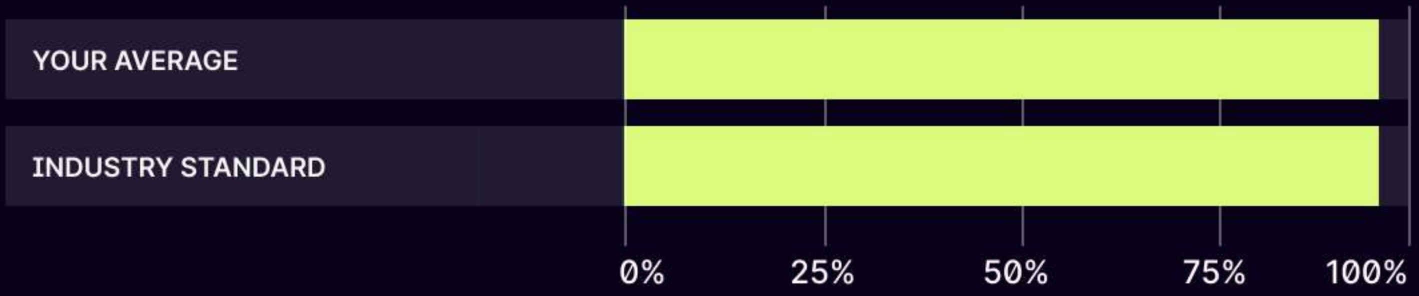
This document outlines the overall security of the TokensFarm smart contracts evaluated by the Zokyo Security team.

The scope of this audit was to analyze and document the TokensFarm smart contract codebase for quality, security, and correctness.

Contract Status



Testable Code



95% of the code is testable, which corresponds the standard of 95%.

It should be noted that this audit is not an endorsement of the reliability or effectiveness of the contract but rather limited to an assessment of the logic and implementation. In order to ensure a secure contract that can withstand the EVM network's fast-paced and rapidly changing environment, we recommend that the TokensFarm team put in place a bug bounty program to encourage further active analysis of the smart contract.

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AUDITING STRATEGY AND TECHNIQUES APPLIED

The source code of the smart contract was taken from the TokensFarm repository:
https://github.com/Tokensfarm/tokensfarm-contracts

Initial commit: 43e0e617143d209dacb6f8c71e31c53434a08ef4

Final commit: 59df44392e1b7b80d713b85b8f6a747a2a2f7cb9

Third iteration final commit: 944d561b63411241a49f25086858a9dab280c1c9

Within the scope of this audit, Zokyo auditors have reviewed the following contracts:

- PerpetualTokensFarmSDK.sol
- PerpetualTokensFarm.sol
- TokensFarmSDK.sol
- TokensFarm.sol
- TokensFarmFactory.sol
- TokensFarmSDKFactory.sol

During the audit, Zokyo Seurity ensured that the ontrat:

- Implements and adheres to the existing standards appropriately and effectively;
- The documentation and code comments match the logic and behavior;
- Distributes tokens in a manner that matches calculations;
- Follows best practices, efficiently using resources without unnecessary waste;
- Uses methods safe from reentrance attacks;
- Is not affected by the most resent vulnerabilities;
- Meets best practices in code readability, etc.

Zokyo Security has followed best practices and industry-standard techniques to verify the implementation of TokensFarm smart contracts. To do so, the code was reviewed line by line by our smart contract developers, who documented even minor issues as they were discovered. A part of this work included writing a unit test suite using the Truffle testing framework. In summary, our strategies consisted mostly of manual collaboration between multiple team members at each stage of the review:

01 Due diligence in assessing the overall code quality of the codebase.

02 Cross-comparison with other, similar smart contracts by industry leaders.

03 Testing contract logic against common and uncommon attack vectors.

04 Thorough manual review of the codebase line by line.

Executive Summary

During the audit, Zokyo Security audited the whole set of contracts within the scope. The contracts consist of staking farm contracts, SDK version of contracts, and factories for creating and managing instances of staking farm contracts.

The goal of the audit was to ensure the corectness of staking and reward mechanism, ensure safety of users' funds, validate the contract code against the list of common security vulnerabilities, check that the best Solidity practises are applied to reduce gas spendings.

There were several high and medium-severity issues found, as well as some informational ones. The issues were connected with the correctness of the work with Ether, creating and withdrawing stakes. Other issues were connected with the necessity of adding extra validations, gas optimization, and logic clarifications. Nevertheless, all the issues were successfully resolved or verified by the TokensFarm team. After all the fixes were implemented, the contracts have passed all security tests.

It should be mentioned that all the contracts are upgradable, which means that the admin of the contract can upgrade their logic at any time.

The overall security of the contracts is high enough. The TokensFarm team has prepared a solid set of tests to ensure the correctness of contract logic. Zokyo Security has prepared our own set of unit-tests as well to validate crucial bussiness logic scenarios. It should also be mentioned that due to the complexity and the size of the contracts, they lack readbility. We recommend TokensFarm to prepare a detailed documentation on the logic of the contracts.

During the second iteration of the audit, there were some additional fixes performed by the TokensFarm team. For example, a wrong address of user was verified in function finalizeDeposit(). The issue occured because variables have similar naming, such as `user` and `_user`. Nevertheless, the issue was fixed and the auditors verified its correctness.

On the third iteration of the audit, the TokensFarm team presented the migration functionality and some minor upgrades. Migration functionality allows protocol admins to migrate stakes from the previous epoch to the current epoch so that users continue to receive rewards. The team of auditors re-ran developed tests suite, added new tests to check the migration mechanism, and did an extensive review of both new functionality and all interactions with the original functionality. Auditors found several issues connected with extra gas spendings, incorrectly implemented epoch start checks, and a possible denial of service. It needs to be mentioned that the code has become a bit tangled after adding migrations and optimizing deposit functions. Yet, the main reason is keeping the contracts size acceptable for EVM, so there is no security influence. Auditors verified the migration and rewards update logic in conversations with TokensFarm team.

PROTOCOL OVERVIEW

The TokensFarm protocol is a staking protocol that allows users to lock staking tokens and receive reward tokens over time. The protocol consists of two versions of staking: original and SDK staking. Both original and SDK contracts are the composites of TokensFarm, PerpetualTokensFarm, and TokensFarmFactory contracts.

The main difference between original and SDK contracts is that SDK contracts don't actually store any staking tokens transferred from users to the contract's balance. Instead, all the crucial functions such as deposit(), makeDepositRequest(), finalizeDeposit(), noticeReducedStake(), and noticeReducedStakeWithoutStakeId() can be called only by the Contract Admin for users. This way, there is no risk of stealing staking tokens from the contract's balance.

The TokensFarm contract allows users to deposit their staking tokens and start earning rewards on their stakes. Each deposit is divided into stakes. In case there is a warmup period, the user has to make a deposit request and finalize it after the warmup period is finished. Users can withdraw their stake at any time in case early withdrawal is allowed. In this case, users still have to wait for minimal time to stake in order to receive the earned rewards. Otherwise, the rewards can be burnt or redistributed based on the contract's options. There is a single reward period, during which users can deposit and earn rewards. While the reward period is still on, it can be extended by funding or redistributing more rewards.

The PerpetualTokensFarm contract is similar to the TokensFarm contract. The only difference is that the reward period is separated into epochs. Users can deposit and earn rewards only in the current epoch. Once the epoch is over, the owner of the contract can create a new epoch.

The SDK version of the contracts also allows users to earn rewards based on their stakes. The reward period mechanism is similar to the original version of the contracts. The main difference is that users don't have to transfer their tokens to the staking contract. Instead, the admin creates and withdraws stakes for users.

The newly added migration functionality allows stakes migration from the finished epoch to the current epoch for all users.

STRUCTURE AND ORGANIZATION OF DOCUMENT

For the ease of navigation, document's sections are arranged from the most critical to the least critical. Issues are tagged "Resolved" or "Unresolved" depending on whether they have been fixed or addressed. Furthermore, the severity of each issue is written as assessed by the risk of exploitation or other unexpected or otherwise unsafe behavior:

● **Critical**

The issue affects the contract in such a way that funds may be lost, allocated incorrectly, or otherwise result in a significant loss.

● **High**

The issue affects the ability of the contract to compile or operate in a significant way.

● **Medium**

The issue affects the ability of the contract to operate in a way that doesn't significantly hinder its behavior.

● **Low**

The issue has minimal impact on the contract's ability to operate.

● **Informational**

The issue has no impact on the contract's ability to operate.

COMPLETE ANALYSIS

CRITICAL-1 | RESOLVED

New epoch can’t be started.

PerpetualTokensFarmSDK.sol

In order to start a new epoch, `allStakesAreMigrated` should be equal to true. (startNewEpoch(), line 576). However, in the initialize() function it is set as false (Line 282). Due to this, epoch 1 can’t be started. Also, during the execution of function startNewEpoch() `allStakesAreMigrated` should be set as false (Line 617).

The issue was found during the 3rd iteration of the audit in the newly added migration functionality.

Recommendation:

Set `allStakesAreMigrated` as true during initializing and as false during startNewEpoch() execution.

Post-audit:

The issue was found simultaneously with the TokensFarm team, thus by the time of the reporting the issue was meant to be resolved. Nevertheless, the team of auditors has checked the solution as well.

HIGH-1 | RESOLVED

Usage of msg.value in the loop.
PerpetualTokensFarmSDK.sol, function noticeReducedStakeWithoutStakeId(), line 1433.
TokensFarmSDK.sol, function noticeReducedStakeWithoutStakeId(), line 1451.
The _payoutRewardsAndUpdateState() function is executed multiple times in the loop. There is a call of the _erc20Transfer() function in this function, where msg.value is used and is added to the `totalFeeCollectedETH` storage variable. This way, the same msg.value is added multiple times. This can potentially prevent collecting ETH fees. Reference: https://github.com/crytic/slither/wiki/Detector-Documentation/#msgvalue-inside-a-loop

Recommendation:
Avoid using msg.value in the loop. Add msg.value only once to `totalFeeCollectedETH`.

HIGH-2 | RESOLVED

The value in the `idInList` mapping can be wrong.
TokensFarm.sol: function finaliseDeposit(), line 1103.
TokensFarmSDK.sol: function finaliseDeposit(), line 1061. PerpetualTokensFarmSDK.sol: function finaliseDeposit(), line 1114. PerpetualTokensFarm.sol: function finaliseDeposit(), line 1203. In case the user doesn't have any deposit requests, they get removed from the `waitingList`, and their ID in the waiting list is given to the last user in the `waitingList`. However, the value in the `idInList` mapping is not updated for `lastUserInWaitingListArray`. Due to this, the finalization of the request for `lastUserInWaitingListArray` can be blocked.

Recommendation:
Update the value in the `idInList` mapping for `lastUserInWaitingListArray` with `deletedUserId`. Delete the value from the `idInList` mapping for the user. Take into account that `lastUserInWaitingListArray` can be equal to `user` in case there is only one address in the waiting list.

HIGH-3 | RESOLVED

Users can withdraw the same stake more than once with the emergency withdrawal function.

TokensFarm.sol: function emergencyWithdraw().

PerpetualTokensFarm.sol: function emergencyWithdraw(). Users can execute the emergencyWithdraw() function with the same stake, even when the amount of the stake is 0. Due to this, the `participants` array is updated every time, deleting the first user from the array. This way, users can delete all users from the `participants` array and block all withdrawal functions to them.

Recommendation:

Do not let users conduct emergency withdrawal of the same stake more than once.

HIGH-4 | RESOLVED

The wrong stake amount is stored.

PerpetualTokensFarm.sol: function _deposit(), line 1083.

The `_amount` parameter is stored in `stake.amount`. In case there is a stake fee, a greater amount would be stored instead of the value after taking the fee.

Recommendation:

Store `stakedAmount` in `stake.amount`.

MEDIUM-1 | RESOLVED

User's stake can be reduced before stakes are finalized.
PerpetualTokensFarmSDK.sol
TokensFarmSDK.sol
During the execution of the makeDepositRequest() function, the value in the \`totalActiveStakeAmount[user]\` mapping is updated. This value is used in the noticeReducedStakeWithoutStakeId() function to verify that the user has sufficient stake amount. In case this function is called before the finalization of the stake, the user would be able to withdraw their non-finalized stake. Even though there is a validation that the stake is finalized (TokensFarmSDK.sol, line 1442), the issue still can occur when the user has only one stake that is not yet finalized. The issue is marked as medium since only the owner or the contract admin can execute these functions.

Post-audit:
The deposits that are not finalized can still be processed, potentially breaking the \`totalDeposits\` variable, and user's \`totalActiveStakeAmount\`.
Consider such a scenario:
1) The user has performed 3 different stakes with the following amounts:
   a) Stake \`0\` with amount = 1 token.
   b) Stake \`1\` with amount = 2 token.
   c) Stake \`2\` with amount = 3 token.
2) Stake \`0\` and \`2\` are finalized, leaving stake \`1\` unfinalized.
   a) \`totalDeposits\` is equal 1 + 3 = 4. (Since only stakes \`0\` and \`2\` are finalized.)
3) The user withdraws the amount of 3 tokens with the noticeReducedStakeWithoutStakeId() function. In this case:
   a) the amount of stake \`0\` will be equal 0.
   b) the amount of stake \`1\` (unfinalized) will also be equal 0.
   c) the amount of stake \`2\` will still be equal to 3.
   d) \`totalDeposits\` will be equal to 1 (Despite the fact that there is a finalized stake \`2\` with the amount of 3).

After this, the finalization of stake \`1\` will increase the \`totalDeposits\` despite the fact that the amount of stake \`1\` is equal to 0 (Because stakedAmount is also stored in the deposit request structure). And once \`totalDeposits\` is increased, the user will also be able to finalize stake \`2\`.

Post-audit 2:
A validation was added: in case `lastFinalisedStake[user]` > 0, stakeId to finalize should be equal to `lastFinalisedStake[user] + 1`. Yet, there is still a case, when the user can finalize the stake with the ID `0`, then stake with the ID `2` and won't be able to finalize stake with the ID `1`. Also, the user can finalize any stake at the very first time, thus not start with the stake `0`.

Post-audit 3:
Stakes can now be finalized only in the correct order.

MEDIUM-2 | RESOLVED

Possible Denial-of-Service
PerpetualTokensFarm.sol: function migrateUserStakes(), line 539.
PerpetualTokensFarmSDK.sol: function migrateUserStakes(), line 538.
There is a "require" statement which validates that the epoch ID of the user's stake strictly equals to `epochId` - 1. Yet, there might be a case when the user has a stake, whose epoch ID is lower than `epochId` - 1. Thus, migration would be blocked until the user withdraws such a stake.

The issue was found during the third iteration of the audit in the newly added migration functionality.

Recommendation:
Consider changing "require" to "if" so that migration is not blocked in such a scenario.

LOW-1 | RESOLVED

Unnecessary validation.
PerpetualTokensFarm.sol: function finaliseDeposit(), line 1156.
TokensFarm.sol: function finaliseDeposit(), line 1058.
PerpetualTokensFarmSDK.sol: function finaliseDeposit(), line 1076.

In PerpetualTokensFarm.sol and TokensFarm.sol, the `if` statement will never return false since if the caller is not the owner, the transaction will revert to the `onlyOwner` modifier. In the PerpetualTokensFarmSDK.sol contract, the function can be executed either by the owner or the contract admin. In case the function is called by the contract admin, the value of the local variable won't be assigned to the `_user` parameter and will be equal to msg.sender (which is the contract admin).

Recommendation:
Remove the unnecessary validation.

Post-audit:
In PerpetualTokensFarmSDK.sol, the validation was removed. In other contracts, functions can now be called by the user, so the validation is necessary now.

LOW-2 | VERIFIED

Internal functions are never used.
TokensFarmFactory.sol, TokensFarmSDKFactory.sol: functions _getFarmArray(), _getFarmImplementation().
Functions are internal and are not used within the contract. However, they increase the size of the contract.

Recommendation:
Remove unused functions.

Post-audit.
Functions will be used in the future updates of the contracts.

LOW-3 | RESOLVED

Reduce without stake ID might revert in case not the first stake was reduced with ID.
TokensFarmSDK.sol, PerpetualTokensFarmSDK.sol: function noticeReducedStakeWithoutStakeId().
In case the user has more than one stake and withdraws any stake but the first one, `lastStakeConsumed[_user]` will be equal to this stake. When the user decides to withdraw stakes using the noticeReducedStakeWithoutStakeId() function, it might revert in line 1463 since all the stakes before `lastStakeConsumed[_user]` will be skipped. The issue is marked as low since the user can still withdraw their stakes separately with the noticeReducedStake() function.

Recommendation:
Make sure that noticeReducedStakeWithoutStakeId() processes all actual stakes.

Post-audit.
The validation was added: `stakeId` is less or equal to `lastStakeConsumed[_user]` and greater or equal to `lastStakeConsumed[_user] + 1`. However, there are cases now when the user cannot withdraw all of their stake. For example:
1) The user has 4 stakes.
2) The user withdraws a part of stake `0`.
3) The user withdraws their stake `1`.
4) The user withdraws their stakes `2` and `3` without stake ID.
5) The user can't withdraw the rest of stake `0` due to "Must consume the next stake, can not skip".

Post-audit 2.
It is now verified that stakes can be reduced only in the correct order.

LOW-4 | RESOLVED

Enormous gas spendings
PerpetualTokensFarm.sol, PerpetualTokensFarmSDK.sol: function migrateUserStakes().
The lastStakeMigrated storage variable is written on every step of the double cycle, which provides enormous gas spendings.
Also, it is especially crucial since the variable is not used in the contracts at all.

The issue was found during the third iteration of the audit in the newly added migration functionality.

Recommendation:
Review the logic of the lastStakeMigrated usage, add conditions to provide storage updates just once for the last ID. E.g., consider adding a couple of conditions to write only the last ID in the double cycle, or consider moving the creation of the storage pointer for StakeInfo out of the cycle.

Post-audit.
The variable was removed from the contracts.

INFO-1 | RESOLVED

The visibility of the variables is not explicitly marked.
PerpetualTokensFarm.sol: `idInList`.
PerpetualTokensFarmSDK.sol: `idInList`.
TokensFarm.sol: `idInList`.
TokensFarmSDK.sol: `idInList`.
For better code readability, it is recommended to explicitly mark the visibility for all storage variables and constants.

Recommendation:
Mark the visibility of all variables and constants in the contracts.

INFO-2 | VERIFIED

Storage constants should be used.
PerpetualTokensFarm.sol: lines 244, 245, 535, 536, 637, 654, 1066, 1562.
PerpetualTokensFarmSDK.sol: lines 240, 535, 616, 1559, 1387.
TokensFarm.sol: lines 233, 234, 525, 545, 987, 1188, 1558.
TokensFarmSDK.sol: lines 243, 530, 1588, 1396.

Number 40 and 100 should be moved to a separate storage constant.

Recommendation:
Move the numbers used in the code to storage constants.

From the client:
In order not to exceed the contract size limit, constants won't be used.

INFO-3 | RESOLVED

Unnecessary adding of 0.
TokensFarm.sol: function deposit(), line 1214.
TokensFarmSDK.sol: function deposit(), line 1159.
Adding `warmupPeriod` in both cases has no effect since it was previously checked that `warmupPeriod` is equal to 0.

Recommendation:
Remove adding `warmupPeriod`.

INFO-4 | RESOLVED

Finalizing pending deposit requests can be blocked.
TokensFarm.sol: function finaliseDeposit(), line 1063.
TokensFarmSDK.sol: function finaliseDeposit(), line 1026.
PerpetualTokensFarmSDK.sol: function finaliseDeposit(), line 1081.
PerpetualTokensFarm.sol: function finaliseDeposit(), line 1174.
There is a validation that `warmupPeriod` is not equal to 0 in these functions. However, in case the owner sets `warmupPeriod` as 0 with the setWarmup() function, all pending deposit requests will be blocked, preventing users from depositing and withdrawing their funds. The issue is marked as informational since only the owner can change `warmupPeriod`.

Recommendation:
Verify that users' funds can't get blocked due to the changes of the warmup period.

INFO-5 | RESOLVED

View function can be optimized.
TokensFarm.sol: function getAllPendingStakes(), line 690.
TokensFarmSDK.sol: function getAllPendingStakes(), line 649.
PerpetualTokensFarm.sol: function getAllPendingStakes(), line 777.
The function performs iteration through the whole participants array, which may consume more gas than allowed per transaction. In order to reduce gas spendings, the `waitingList` array can be used, which already contains all the users who have current deposit requests.

Recommendation:
Use the waitingList array instead of `participants`.

INFO-6 | VERIFIED

Redistributing rewards calculates more total rewards than there are on the contract's balance.

TokensFarm.sol: function withdraw(), line 1425.

TokensFarmSDK.sol: function _payoutRewardsAndUpdateState(), line 1246.

PerpetualTokensFarm.sol: function withdraw(), line 1437.

PerpetualTokensFarmSDK.sol: function _payoutRewardsAndUpdateState(), line 1245.

In case user's pending reward is to be redistributed, the _fundInternal() function is called, which increases the `totalRewards` storage variable. However, the actual reward balance doesn't increase since the same reward token is funded. This way, there can be a situation when there are not enough rewards to pay to users. The issue is marked as informational since it doesn't prevent the withdrawal of stakes but can prevent collecting rewards for users.

Recommendation:

Update `totalRewards` correctly in case of the redistribution of pending rewards.

From the client:

The `totalRewards` variable doesn't affect any calculations. It is an intended functionality to increase this variable during every redistribution.

INFO-7 | VERIFIED

The `start` parameter is unnecessary
PerpetualTokensFarm.sol, PerpetualTokensFarmSDK.sol: function migrateUserStakes().
Providing this parameter is unnecessary since it must always be equal to the storage variable `lastUserMigrated`. In order to simplify the execution of this function, it is recommended to remove this parameter.

The issue was found during the third iteration of the audit in the newly added migration functionality.

Recommendation:
Remove the `start` parameter and use `lastUserMigrated` instead.

From the client:
The Tokensfarm team prefers current functionality because the backend provides the start and end so it will be easier for BE to determine the failure in case that tx reverts.

INFO-8 | VERIFIED

The owner can withdraw reward tokens
PerpetualTokensFarm.sol, TokensFarm.sol: function withdrawTokensIfStuck().
There is no validation that provided `_erc20` is not equal to `erc20` (Reward token). Thus, in case the admin has withdrawn reward tokens, there might be not enough rewards for users to pay out. The issue is marked as informational since stakes can still be withdrawn with emergencyWithdraw() function, though the capability of the admin to withdraw rewards should still be mentioned in the report.
The issue was found during the third iteration of the audit in the newly added migration functionality.

Recommendation:
Restrict the admin from withdrawing reward tokens.

From the client:
This function is meant to be for the reward token also because there is a case where it can be funded more than needed, so it also stays like that.

INFO-9 | RESOLVED

New epoch can be started while the migration is in progress
PerpetualTokensFarm.sol, PerpetualTokensFarmSDK.sol. It is possible for the owner to start a new epoch while the migration is in progress. In this case, the previous migration won't be finished correctly and the new migration might not be started in the future. The issue is marked as informational since only the owner can execute these functions, and in this scenario, users will still be able to withdraw their stakes. The issue was found during the third iteration of the audit in the newly added migration functionality.

Recommendation:
Verify that a new epoch can't be started while there is a migration in progress.

INFO-10 | VERIFIED

The pool is updated twice and extra operations are performed
PerpetualTokensFarmSDK.sol, migrateUserStakes()
The pool is updated directly in the function and through the call of _payoutRewardsAndUpdateState() (with the _amount = 0 parameter). That is unnecessary gas spending.
The same applies to all math operations in _payoutRewardsAndUpdateState() (in the if(_unStake) statement), where a lot of operations are performed with re writing storage after the operations with 0 _amount.
The issue was found during the third iteration of the audit in the newly added migration functionality.

Recommendation:
Review the logic of the pool update if there is no side effects of double pool updates and if it is ok for additional gas spending.

Post-audit
1) It was confirmed with the TokensFarm team that the fix does not affect methods with _payoutRewardsAndUpdateState() calls.
2) The necessity of the updatePool() within the double migration cycle was confirmed.
3) The correctness of the logic was confirmed for the PerpetualTokensFarm.sol contract.

	PerpetualTokensFarmSDK.sol	PerpetualTokensFarm.sol
Re-entrancy	Pass	Pass
Access Management Hierarchy	Pass	Pass
Arithmetic Over/Under Flows	Pass	Pass
Unexpected Ether	Pass	Pass
Delegatecall	Pass	Pass
Default Public Visibility	Pass	Pass
Hidden Malicious Code	Pass	Pass
Entropy Illusion (Lack of Randomness)	Pass	Pass
External Contract Referencing	Pass	Pass
Short Address/ Parameter Attack	Pass	Pass
Unchecked CALL Return Values	Pass	Pass
Race Conditions / Front Running	Pass	Pass
General Denial Of Service (DOS)	Pass	Pass
Uninitialized Storage Pointers	Pass	Pass
Floating Points and Precision	Pass	Pass
Tx.Origin Authentication	Pass	Pass
Signatures Replay	Pass	Pass
Pool Asset Security (backdoors in the underlying ERC-20)	Pass	Pass

	TokensFarmSDK.sol	TokensFarm.sol
Re-entrancy	Pass	Pass
Access Management Hierarchy	Pass	Pass
Arithmetic Over/Under Flows	Pass	Pass
Unexpected Ether	Pass	Pass
Delegatecall	Pass	Pass
Default Public Visibility	Pass	Pass
Hidden Malicious Code	Pass	Pass
Entropy Illusion (Lack of Randomness)	Pass	Pass
External Contract Referencing	Pass	Pass
Short Address/ Parameter Attack	Pass	Pass
Unchecked CALL Return Values	Pass	Pass
Race Conditions / Front Running	Pass	Pass
General Denial Of Service (DOS)	Pass	Pass
Uninitialized Storage Pointers	Pass	Pass
Floating Points and Precision	Pass	Pass
Tx.Origin Authentication	Pass	Pass
Signatures Replay	Pass	Pass
Pool Asset Security (backdoors in the underlying ERC-20)	Pass	Pass

	TokensFarmFactory.sol	TokensFarmSDKFactory.sol
Re-entrancy	Pass	Pass
Access Management Hierarchy	Pass	Pass
Arithmetic Over/Under Flows	Pass	Pass
Unexpected Ether	Pass	Pass
Delegatecall	Pass	Pass
Default Public Visibility	Pass	Pass
Hidden Malicious Code	Pass	Pass
Entropy Illusion (Lack of Randomness)	Pass	Pass
External Contract Referencing	Pass	Pass
Short Address/ Parameter Attack	Pass	Pass
Unchecked CALL Return Values	Pass	Pass
Race Conditions / Front Running	Pass	Pass
General Denial Of Service (DOS)	Pass	Pass
Uninitialized Storage Pointers	Pass	Pass
Floating Points and Precision	Pass	Pass
Tx.Origin Authentication	Pass	Pass
Signatures Replay	Pass	Pass
Pool Asset Security (backdoors in the underlying ERC-20)	Pass	Pass

CODE COVERAGE AND TEST RESULTS FOR ALL FILES

Tests written by Zokyo Security

As a part of our work assisting TokensFarm in verifying the correctness of their contract code, our team was responsible for writing integration tests using the Hardhat testing framework.

The tests were based on the functionality of the code, as well as the review of the TokensFarm contract requirements for details about issuance amounts and how the system handles these.

```
Contract: PerpetualTokensFarm
  Deposit/Request deposit/Finalize deposit request
  Deposit
  ✓ Should deposit tokens for user (136ms)
  ✓ Should revert deposit if warmup period is on (50ms)
  ✓ Should revert deposit if farm has ended (58ms)
  ✓ Should update firstDepositAt only at the first deposit (108ms)
  ✓ Should collect flat fee during depositing (62ms)
  ✓ Should revert deposit if msg.value != flatFeeAmountDeposit (53ms)
  ✓ Should collect stake fee (71ms)
  ✓ Should revert if amount == 0
  Make deposit request
  ✓ Should make deposit request (72ms)
  ✓ Should revert make deposit request if warmup is off
  ✓ Should revert make deposit request if reward will end after warmup
  ✓ Should update firstDepositAt only once during making a deposit request (78ms)
  ✓ Should collect flat fee during making a deposit request (47ms)
  ✓ Should revert make deposit request if msg.value != flatFeeAmountDeposit
  ✓ Should collect stake fee (48ms)
  ✓ Should revert if amount equals 0
  Finalize deposit
  ✓ Should finalize user s deposit request (78ms)
  ✓ Should revert finalizing deposit request if warmup period is 0 (47ms)
  ✓ Should revert finalizing deposit request if warmup period is not yet finished (41ms)
  ✓ Should finalize one of user s deposit requests (160ms)
  ✓ Should remove user from waiting list (198ms)
  ✓ Should revert finalizing if user has not deposit requests (45ms)
```

```
Withdraw/Make withdraw request/Emergency withdraw
Withdraw
✓ Should withdraw (107ms)
✓ Should revert if minimal time to stake is not respected (45ms)
✓ Should burn user's pending if minimal time to stake is not respected and penalty
should be burnt (92ms)
✓ Should redistribute user's pending if minimal time to stake is not respected and
penalty should be redistributed (79ms)
✓ Should burn user's pending if staking is ended and penalty should be redistributed (97ms)
✓ Should cover ETH commission if flat fee is allowed (71ms)
✓ Should revert if msg.value != flatFeeAmountWithdraw when flat fee is allowed (67ms)
✓ Should collect rewards without fee (73ms)
✓ Should revert withdraw if amount is greater than staked amount (41ms)
Make withdraw request
✓ Should make withdrawal request (82ms)
✓ Should revert make withdrawal request if whole stake amount is already withdrawn (69ms)
✓ Should revert make withdrawal request if cooldown is 0 (43ms)
✓ Should revert make withdrawal request if stake is not finalized (46ms)
✓ Should revert make withdrawal request if minimal time to stake was not respected (51ms)
✓ Should revert make withdrawal request if amount is greater than stake amount (51ms)
✓ Should make withdrawal request for different stakes (103ms)
✓ Should finalize withdrawal request (95ms)
✓ Should revert finalizing withdrawal request if request wasn't made for provided id (136ms)
✓ Should not finalize withdrawal request if cooldown has not passed yet (67ms)
Emergency withdraw
✓ Should withdraw in case of emergency (142ms)
✓ Should revert emergency withdraw if minimal time to stake is not respected (40ms)
Perpetual functionality
✓ Should deposit and claim rewards in correct epoch (197ms)
✓ Should revert start new epoch if current epoch is not ended
✓ Should revert start new epoch if start time is less than block.timestamp
✓ Should revert start new epoch if reward fee percent is greater than 100
```

Contract: PerpetualTokensFarm

```
Deposit/Request deposit/finalize deposit
Deposit
✓ Should deposit tokens for user (53ms)
✓ Should revert deposit if warmup period is on
✓ Should revert deposit if farm has ended
✓ Should update firstDepositAt only at the first deposit (41ms)
✓ Should collect flat fee during depositing
✓ Should revert deposit if msg.value != flatFeeAmountDeposit
✓ Should not update ATH stake if deposited amount is less than ATH stake amount (43ms)
✓ Should revert if epoch hasn't started yet
Request deposit
✓ Should make deposit request
✓ Should revert make deposit request if warmup is off
✓ Should revert make deposit request if reward will end after warmup
✓ Should update firstDepositAt only once during making a deposit request
✓ Should collect flat fee during making a deposit request
✓ Should revert make deposit request if msg.value != flatFeeAmountDeposit
Finalize deposit
✓ Should finalize user's deposit request (50ms)
✓ Should revert finalizing deposit request if warmup period is 0
✓ Should revert finalizing deposit request if warmup period is not yet finished
✓ Should finalize one of user's deposit requests (104ms)
✓ Should remove user from waiting list (127ms)
✓ Should revert finalizing if user has not deposit requests
Notice reduced stake with stake id
✓ Should notice reduced amount (87ms)
✓ Should revert notice reduced stake if deposit request is not finalized
✓ Should revert notice reduced stake if withdraw amount > stake amount
✓ Should revert if minimal time to stake is not respected
✓ Should burn user's pending if minimal time to stake is not respected and penalty
should be burnt (78ms)
✓ Should redistribute user's pending if minimal time to stake is not respected and
penalty should be redistributed (62ms)
✓ Should burn user's pending if staking is ended and penalty should be redistributed (90ms)
✓ Should cover ETH commission if flat fee is allowed (52ms)
✓ Should revert if msg.value != flatFeeAmountWithdraw when flat fee is allowed (44ms)
Notice reduce stake without stake id
✓ Should reduce user's stakes amount (81ms)
✓ Should revert if user tries to withdraw more than he deposited
✓ Should reduce stake with id and then the rest of stake without id (161ms)
✓ Should not reduce stakes in not finalized stakes (161ms)
✓ Should revert if user has only one stake and it is not finalized yet
✓ Should withdraw a single user's stake (51ms)
Perpetual functionality
✓ Should deposit and claim rewards in correct epoch (142ms)
✓ Should revert start new epoch if current epoch is not ended
✓ Should revert start new epoch if start time is less than block.timestamp
✓ Should revert start new epoch if reward fee percent is greater than 100
```

```
Contract: TokensFarm
  Deposit/Request deposit/Finalize deposit request
  Deposit
  ✓ Should deposit tokens for user (71ms)
  ✓ Should revert deposit if warmup period is on
  ✓ Should revert deposit if farm has ended
  ✓ Should update firstDepositAt only at the first deposit (63ms)
  ✓ Should collect flat fee during depositing (46ms)
  ✓ Should revert deposit if msg.value != flatFeeAmountDeposit
  ✓ Should collect stake fee (45ms)
  ✓ Should revert if amount == 0
  Make deposit request
  ✓ Should make deposit request 53ms)
  ✓ Should revert make deposit request if warmup is off
  ✓ Should revert make deposit request if reward will end after warmup
  ✓ Should update firstDepositAt only once during making a deposit request (60ms)
  ✓ Should collect flat fee during making a deposit request (40ms)
  ✓ Should revert make deposit request if msg.value != flatFeeAmountDeposit
  ✓ Should collect stake fee (47ms)
  ✓ Should revert if amount equals 0
  Finalize deposit
  ✓ Should finalize user s deposit request (66ms)
  ✓ Should revert finalizing deposit request if warmup period is 0 (54ms)
  ✓ Should revert finalizing deposit request if warmup period is not yet finished (47ms)
  ✓ Should finalize one of user s deposit requests (149ms)
  ✓ Should remove user from waiting list (174ms)
  ✓ Should revert finalizing if user has not deposit requests (41ms)
  Withdraw/Make withdraw request/Emergency withdraw
  Withdraw
  ✓ Should withdraw (91ms)
  ✓ Should revert if minimal time to stake is not respected (39ms)
  ✓ Should burn user s pending if minimal time to stake is not respected and penalty
  should be burnt (81ms)
  ✓ Should redistribute user s pending if minimal time to stake is not respected and
  penalty should be redistributed (72ms)
  ✓ Should burn user s pending if staking is ended and penalty should be redistributed (102ms)
  ✓ Should not pay pendingReward if it is 0 (68ms)
  ✓ Should cover ETH commission if flat fee is allowed (67ms)
  ✓ Should revert if msg.value != flatFeeAmountWithdraw when flat fee is allowed (56ms)
  ✓ Should collect rewards without fee (69ms)
  ✓ Should revert withdraw if amount is greater than staked amount (38ms)
  Make withdraw request
  ✓ Should make withdrawal request (87ms)
  ✓ Should revert make withdrawal request if whole stake amount is already withdrawn (76ms)
  ✓ Should revert make withdrawal request if cooldown is 0 (47ms)
  ✓ Should revert make withdrawal request if stake is not finalized (49ms)
  ✓ Should revert make withdrawal request if minimal time to stake was not respected (43ms)
  ✓ Should revert make withdrawal request if amount is greater than stake amount (56ms)
  ✓ Should make withdrawal request for different stakes (118ms)
  ✓ Should finalize withdrawal request (102ms)
  ✓ Should revert finalizing withdrawal request if request wasn t made for provided id (123ms)
  ✓ Should not finalize withdrawal request if cooldown has not passed yet (80ms)
  Emergency withdraw
  ✓ Should withdraw in case of emergency (140ms)
  ✓ Should revert emergency withdraw if minimal time to stake is not respected (38ms)
```

Contract: TokensFarmSDK

```
  Deposit/Request deposit/Finalize deposit
  Deposit
  ✓ Should deposit tokens for user (53ms)
  ✓ Should revert deposit if warmup period is on
  ✓ Should revert deposit if farm has ended
  ✓ Should update firstDepositAt only at the first deposit (40ms)
  ✓ Should collect flat fee during depositing
  ✓ Should revert deposit if msg.value != flatFeeAmountDeposit
  ✓ Should not update ATH stake if deposited amount is less than ATH stake amount (41ms)
  Request deposit
  ✓ Should make deposit request
  ✓ Should revert make deposit request if warmup is off
  ✓ Should revert make deposit request if reward will end after warmup
  ✓ Should update firstDepositAt only once during making a deposit request
  ✓ Should collect flat fee during making a deposit request
  ✓ Should revert make deposit request if msg.value != flatFeeAmountDeposit
  Finalize deposit
  ✓ Should finalize user s deposit request (51ms)
  ✓ Should revert finalizing deposit request if warmup period is 0
  ✓ Should revert finalizing deposit request if warmup period is not yet finished
  ✓ Should finalize one of user s deposit requests (107ms)
  ✓ Should remove user from waiting list (167ms)
  ✓ Should revert finalizing if user has not deposit requests
```

```
    Notice reduced stake with stake id
    ✓ Should notice reduced amount (87ms)
    ✓ Should revert notice reduced stake if deposit request is not finalized
    ✓ Should revert notice reduced stake if withdraw amount > stake amount (40ms)
    ✓ Should revert if minimal time to stake is not respected
    ✓ Should burn user's pending if minimal time to stake is not respected and penalty
    should be burnt (83ms)
    ✓ Should redistribute user's pending if minimal time to stake is not respected and
    penalty should be redistributed (61ms)
    ✓ Should burn user's pending if staking is ended and penalty should be redistributed (81ms)
    ✓ Should not pay pendingReward if it is 0 (60ms)
    ✓ Should cover ETH commission if flat fee is allowed (47ms)
    ✓ Should revert if msg.value != flatFeeAmountWithdraw when flat fee is allowed (48ms)
    Notice reduce stake without stake id
    ✓ Should reduce user's stakes amount (91ms)
    ✓ Should revert if user tries to withdraw more than he deposited
    ✓ Should reduce stake with id and then the rest of stake without id (156ms)
    ✓ Should not reduce stakes in not finalized stakes (162ms)
    ✓ Should revert if user has only one stake and it is not finalized yet
    ✓ Should withdraw a single user's stake (54ms)

    165 passing (12s)
```

Tests prepared for the third audit iteration for migration logic testing:

```
  Contract: PerpetualTokensFarm
    Migration
    ✓ Should migrate from one epoch to another (126ms)
    ✓ Should migrate stakes for several users (480ms)

  Contract: PerpetualTokensFarmSDK
    Migration
    ✓ Should migrate from one epoch to another (126ms)
    ✓ Should migrate stakes for several users (480ms)

  Contract: TokensFarm
    Withdraw/Make withdraw request/Emergency withdraw
    ✓ Should withdraw rewards (137ms)

  Contract: TokensFarmSDK
    Notice reduced stake with stake id
    ✓ Should withdraw rewards (137ms)

  6 passing (3s)
```

We are grateful for the opportunity to work with the TokensFarm team.

The statements made in this document should not be interpreted as an investment or legal advice, nor should its authors be held accountable for the decisions made based on them.

Zokyo Security recommends the TokensFarm team put in place a bug bounty program to encourage further analysis of the smart contract by third parties.

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